



2020 Structures Construction Manual



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Department of Transportation

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INTRODUCTION

Purpose

As a Structure Inspector, your duties and responsibilities are large. They are part of the quality control process. The Department of Transportation depends on you to observe various operations involved in the satisfactory completion of a structure.

Quality structures are a result of good design and construction inspection.

The purpose of this Structures Construction Manual is to provide the following:

- 1** A field reference to be used on the construction project by the engineers and technicians responsible for the inspection of structures.
- 2** Assure statewide uniformity in the implementation of the plans and specifications for the construction of structures.
- 3** A training "aid" for the training of engineers and technicians in the inspection and testing responsibilities related to the construction of structures.
- 4** A desk reference for structure designers.

This manual is not intended as a substitute for the South Dakota Standard Specifications, nor does it cover all the phases of the specifications; it does, however, cover some sections of the specifications in considerable detail, primarily for the purpose of promoting more uniformity of interpretation and inspection.

Inspector Responsibilities

The inspector is responsible for seeing that the work is executed in full accordance with the Plans and Specifications. The inspector is responsible for having a thorough understanding of the Plans and Specifications and for exercising good judgment. Often the inspector's work is the deciding factor between a good job and an average or poor one.

A competent inspector is thoroughly conscious of the importance and scope of his or her work and is fully informed in regard to the design and Specifications. Armed with this knowledge and with sound judgment gained through experience, he or she will not only detect faulty construction but will also be in a position to prevent it by requiring proper construction procedures and materials.

Plans Review

The importance of comprehensive study and review of the Plans, Specifications, and Special Provisions cannot be overemphasized. Never assume that the requirements for this job are the same as for the last project. It is a good practice to highlight special requirements in colored pen particularly when they are new to the inspector or different than those normally used. Make certain that each point covered and each detail shown is fully understood. Those points and details which are not clear to you should be discussed with your coworkers or with the design engineer, until there is no longer any question regarding interpretation.

One of the best methods of becoming thoroughly familiar with the Plans is to check the quantities shown on the various material schedules. Since this is required for estimate purposes as well, it serves a dual purpose. In this way, errors in the Plans are sometimes discovered before it is too late to make changes conveniently. You will find that, in order to check the quantities for a structure, you will have to become quite familiar with the Plans

Preconstruction Meeting

In most cases a preconstruction meeting will be held to discuss the contractors proposed work schedule and traffic control and to obtain information on material suppliers, subcontractors, etc... In addition to this meeting, it is of considerable importance that the engineer or inspector view the site with the Contractor prior to starting work to make certain that the Contractor is fully aware of any special requirements which might later cause delays and hardships.

Structure Types

The term structure can have a variety of meanings. Within this manual the term refers to a bridge or box culvert. Bridges and box culverts differ in size and type. Generally, most bridges in South Dakota can be grouped into the following common types of bridges.

Concrete Slab Bridges

Cast-in-Place Concrete Bridges are bridges whose components have been built entirely on-site with reinforcement and poured cast-in-place concrete. These bridges are commonly known as slab bridges, continuous concrete bridges, or rigid concrete bridges. These bridges utilize a thick concrete slab to support the roadway, and therefore will not have any girders or beams underneath the slab itself. The pictures below show some typical concrete slab bridges.

Figure 1.1 Typical Concrete Slab Bridges



Girder Bridges

Girder bridges are those bridges that have steel or concrete girders (beams) supporting the roadway slab. The girders themselves may be built of a one piece "rolled" steel I-beam, a built-up "welded plate" steel I-beam, prestressed concrete, or precast concrete. These bridges are commonly referred to as steel girder bridges, I-beam bridges, steel girder viaduct bridges, continuous composite girder bridges, prestressed girder bridges, or concrete girder bridges. The roadway slab typically consists of a cast-in-place concrete "bridge deck" that is poured in place after the girders are set. Pictured below are several typical girder bridges commonly utilized here in South Dakota.

Figure 1.2 Typical Steel Girder Bridges



Figure 1.3 Typical Prestressed Girder Bridge



Other State Highway Bridges

By far and large, the most common bridges found on South Dakota state highways are either concrete slab or girder type structures. However, there are several other types of bridges that can be found throughout the state. These consist of steel truss bridges, wood glulam arch bridges, concrete box girder bridges, and others not mentioned. Shown below are just a few of the other types of bridges that you may one day encounter.

Figure 1.4 Steel Truss Bridge

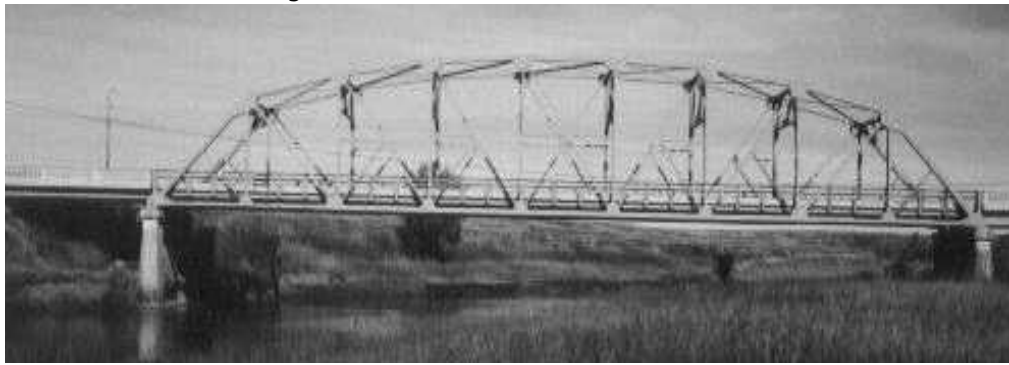


Figure 1.5 Timber Arch Bridge



Figure 1.6 Concrete Box Girder Bridge



Figure 1.7 Concrete Rigid frame



Other County Road Bridges

There are several additional types of bridges that are used predominantly on county secondary roads that should be noted. The SDDOT is typically responsible for the construction administration and inspection of most county bridges, you as an inspector should be familiar with some of these common county bridge types. County bridge types will vary from precast double tee bridges (a precast unit using prestressed concrete "stems" with monolithic concrete deck) and bulb-tee bridges to simple timber stringer bridges. Below are some typical county bridges.

Figure 1.8 Timber Stringer Bridge



Figure 1.9 Precast Double Tee Bridge



Figure 1.10 Bulb Tee Bridge



Box Culverts

Box Culverts are concrete structures that are typically buried within the roadway and are used to direct and carry the flow of a channel or stream underneath the driving surface. They essentially act the same as a small pipe or culvert, only on a larger scale, hence the name box culvert. Box culverts may consist of single or multiple rectangular openings called cells or barrels, and may be built on-site with cast-in place concrete or may be fabricated in a manufacturing yard as a precast unit. Retaining walls, again called wing walls, are located typically in all four corners of the culvert to retain the backfill placed around the culvert. Additionally, the ends of a culvert can often incorporate special items such as spillway chutes or energy dissipaters in an effort to reduce the velocity and slow the flow of the water passing through.

Figure 1.11 Typical Wing wall



Figure 1.12 Typical Precast box section



Figure 1.13 Typical Cast-in-Place Box Culvert



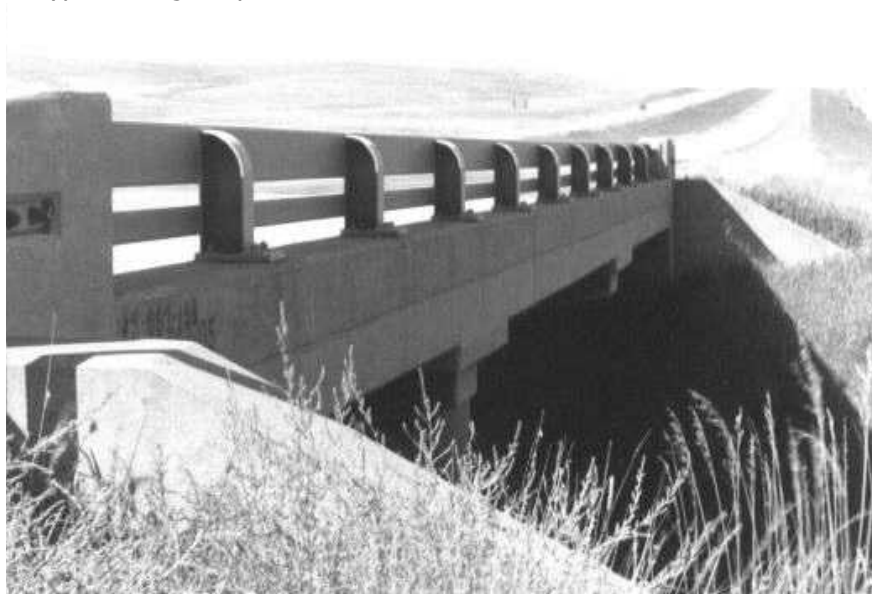
Bridge Components

You may have noticed in the previous pictures that bridges are actually comprised of several different components that work together to operate as a structure and support the roadway traffic. A basic breakdown of the bridge components is as follows.

Bridge Superstructures

The bridge superstructure can be thought of as the portion of the structure that directly carries the traffic load and transfers this load to the supporting foundation system. The superstructure would be comprised of the concrete slab or "bridge deck", barriers and/or rails, supporting girders, and any other items such as sidewalks.

Figure 1.14 Typical Bridge Superstructure



Bridge Substructures

The bridge substructure is the portion of the structure that supports the superstructure items. The substructure would be comprised of abutments (or sills) and their wing walls at each exterior end of the structure, as well as interior supporting units called bents or piers. The abutments (or sills) are located at each end of the structure. These foundation units serve a dual purpose; the first is to vertically support the superstructure loads, and the second is to laterally act as a retaining member to hold back the backfill at the end of the bridge. Extensions of

the abutments off each side of the bridge are called wing walls that act as retaining walls to hold back the fill and allow transition of the berm around the end of the bridge.

Figure 1.15 Typical Bridge Abutment and Wing wall



The bents or piers are the interior foundation units that support the superstructure loads. Several types of bents or piers exist, ranging from large single columns with cantilevered caps on each side (typically called hammerhead piers) to multiple columns with a concrete cap (acting as a beam) to even a full bridge width concrete wall (commonly called a pier wall). The following are examples of common bridge bents or piers.

Figure 1.16 Typical Hammerhead Pier



Figure 1.17 Typical Multi-Column Bent



Figure 1.18 Typical Pier Wall



STAKING

Checklist

Prior to Staking

- Check plans dimensions prior to staking
- Prepare field notes
- Discuss staking at preconstruction meeting

Staking

- Establish permanent points outside the construction limits
- Establish reference points
- Check the alignment and stationing of the structure center lines for general fit to the site
- Establish offset points for each reference point
- Check and recheck point locations by triangulation, traverse, or coordinates to verify accuracy of position
- Establish a minimum of two construction benchmarks
- Verify all benchmarks
- Install adequate guard stakes and flagging lathe for all points and benchmarks
- Record all distances, angles, benchmark elevations, and a sketch of the structure layout in a notebook for future reference

Follow-Up

- Review and explain staking and points established with the Contractor and inspection personnel

General

Staking a structure is a phase of the inspector's operations that should receive very careful attention. Serious and costly delays have resulted because of stakes placed out of line and because the work was not properly checked. The contractor should not be permitted to start work on a unit until the location and elevation of that unit has been accurately determined and verified.

A thorough review of plans should be done before work begins on a project. This helps in solving problems that may arise during construction. It is also beneficial in order to familiarize the inspector with the layout and details of the structure.

It is recommended that the inspector make notes during the plans review. These notes are helpful when staking the structure and during construction.

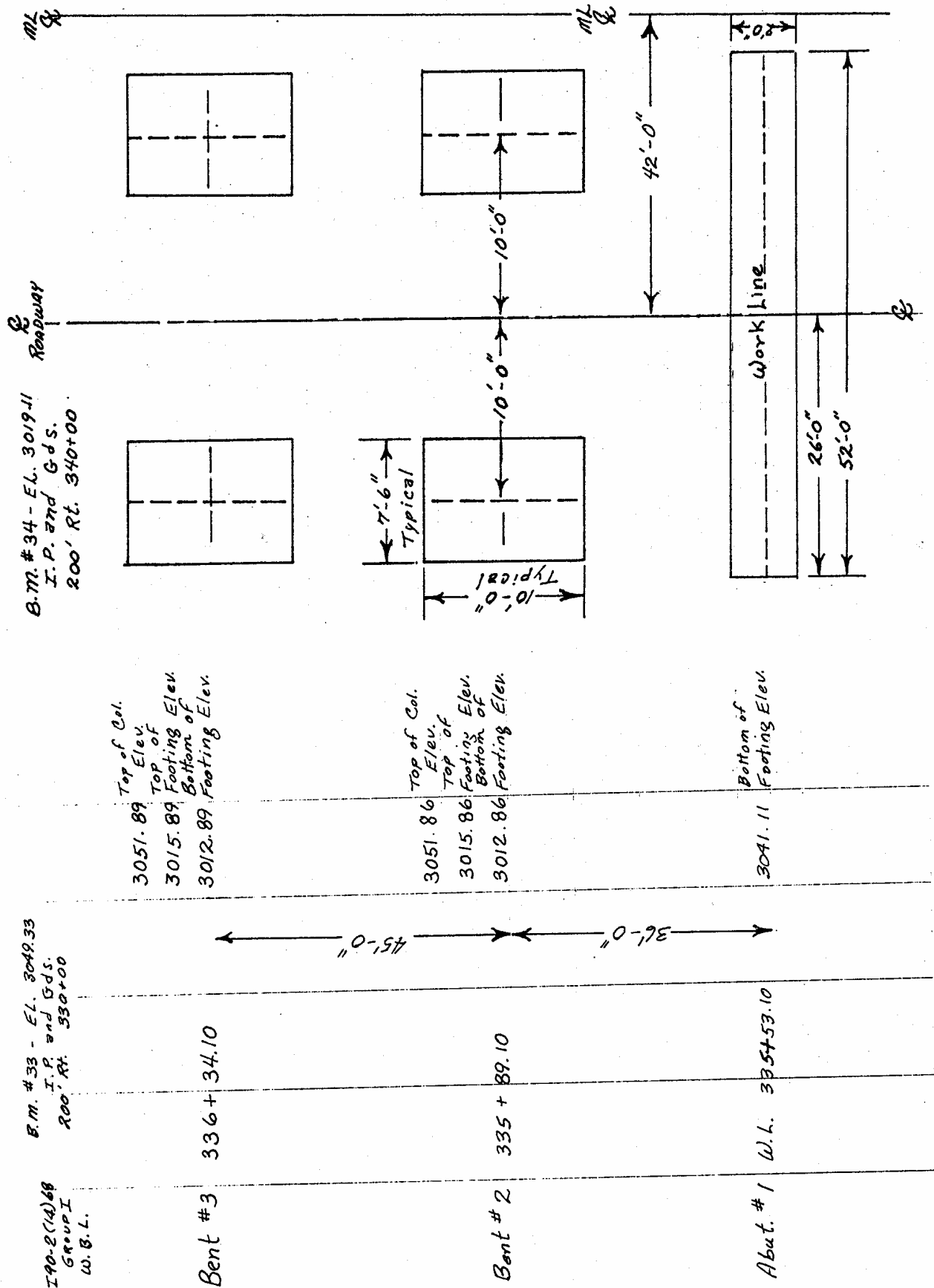
Notes should begin at abutment or sill no. 1 and proceed through each bent to the end abutment or sill. The information recorded for each foundation unit should include:

- Sketch of each unit
- Dimensions of each unit
- Distance from bridge center line to the center of each unit
- Stationing of each unit
- Skew angle
- Base of footing elevation
- Top of footing elevation
- Top of column elevation
- Distance from mainline center line to bridge center line (if applicable)
- Benchmark information (elevation and location)

Staking is done from the abutment center line or the work line on sills. If working lines or points are used, their location will be shown on the plans.

It is suggested that one abutment or sill and no more than two bents be placed on each sheet of notebook paper. This allows room for the sketches, elevations, stationing, and other information necessary to stake the structure. A typical page of notes is shown on the next page.

Figure 2.1 Typical Page of Field Notes for Structure Staking



Structure Staking

Normally a survey crew completes the structure staking, but you and a Contractor's representative should be with the survey crew during the staking process. This will familiarize you with stake locations and serves to double check your, and the survey crew chief's, interpretation of plan locations.

These staking practices should be used by the survey crew and the inspector:

- 1** Check all dimensions on the plans before staking. Both you and the survey crew chief should do this to double-check the plan locations. If discrepancies are found, you should notify the Office of Bridge Design to determine the controlling dimension.
- 2** Do the staking before construction operations begin. Whenever possible, the entire structure should be completely staked, checked, and referenced before construction operations are started.
- 3** Check alignment and stationing of the structure center line. Does the structure fit the proposed site of construction? For example, on crossovers, does structure stationing check out with the crossroad or railroad center line? On stream crossings, does the structure fit the existing or proposed channel? Have changes occurred at the site of construction (i.e. washouts, flooding, natural channel changes)? If the structure appears to not fit the site properly, notify the Office of Bridge Design for further instructions and possible adjustments.
- 4** Set an adequate number of reference points.
- 5** Check accuracy of staking by re-measurement and cross measurement (this is very important).

Minimum Staking Requirements

For bridges, the Department is responsible to provide stakes to establish elevation, location, and alignment for each abutment. The center line of each abutment in the longitudinal direction and in each transverse direction should be staked and referenced.

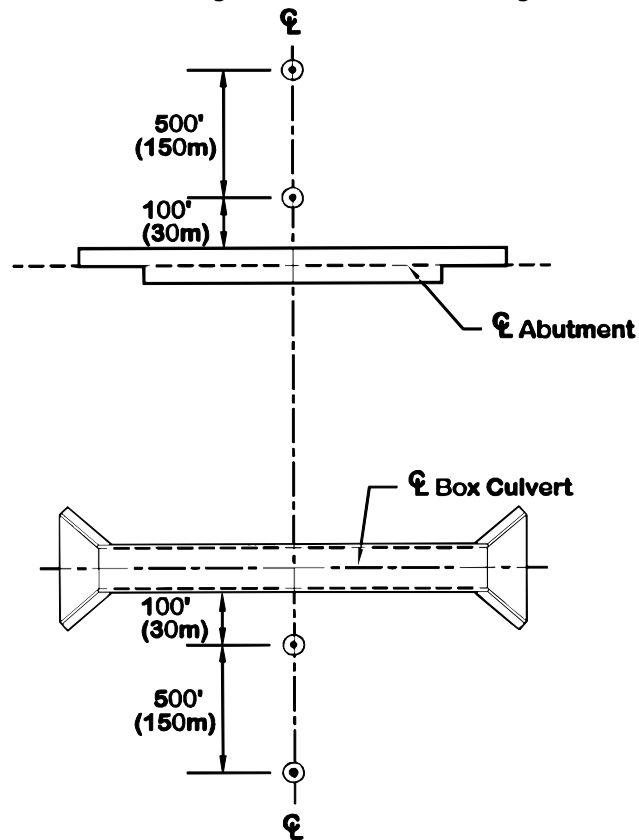
For box culverts, the Department is responsible to provide stakes to establish elevation, location, and alignment of both ends of the box culvert. The center line of each box culvert in the longitudinal and in each direction transversely should be staked as noted in the approved shop plans. If no staking instructions are given, then the precast box should be staked as described above.

On projects that include a bid item for Contractor Staking, the Contractor shall be responsible for providing all stakes for the structure. However, the inspector should still provide sufficient checks to minimize the potential for deviations and errors.

Reference Points

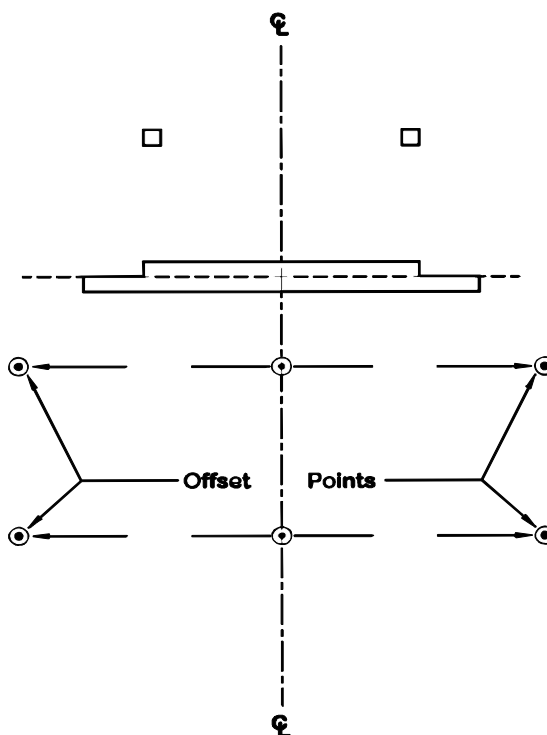
Two permanent points should be set beyond each abutment or four points beyond each box culvert (two in each direction). The first point should be at an even distance from the center line of an abutment or work line of a sill (100 feet). The second point should be about 500 feet beyond the first point. Normally this is far enough from the work area to remain undisturbed.

Figure 2.2 Permanent Points for Bridge and Box Culvert Staking



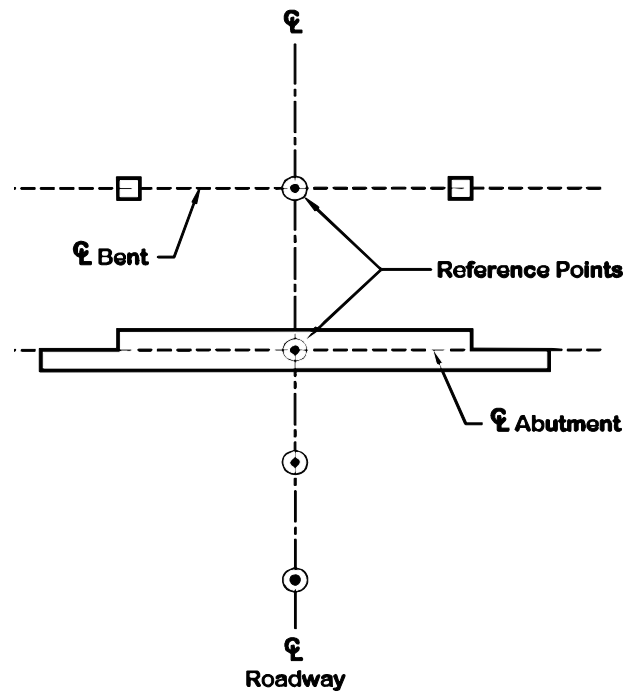
It is a good practice to set enough offset points so that should a reference point be lost or damaged, a sufficient number are available to reset the damaged point. Where a point may be disturbed by approaching fills, sufficient offset points should be set so the disturbed point can be replaced after the fill is completed. Be sure offset points are outside the work area.

Figure 2.3 Offset Points



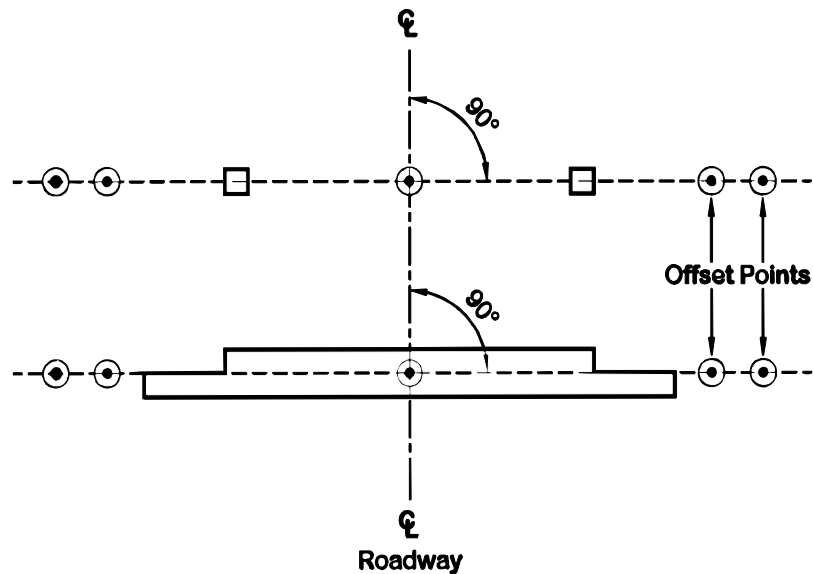
A reference point should be placed on the roadway center line at the point where center line of each bent and abutment or work line of a sill crosses. On stream crossings, this may not be possible due to water. On a dry-land structure, all of these points should be set.

Figure 2.4 Reference Points



A minimum of two offset points should be set left and right of each bent and abutment reference point. On straight bridges, these offset points should be set at right angles to the roadway center line.

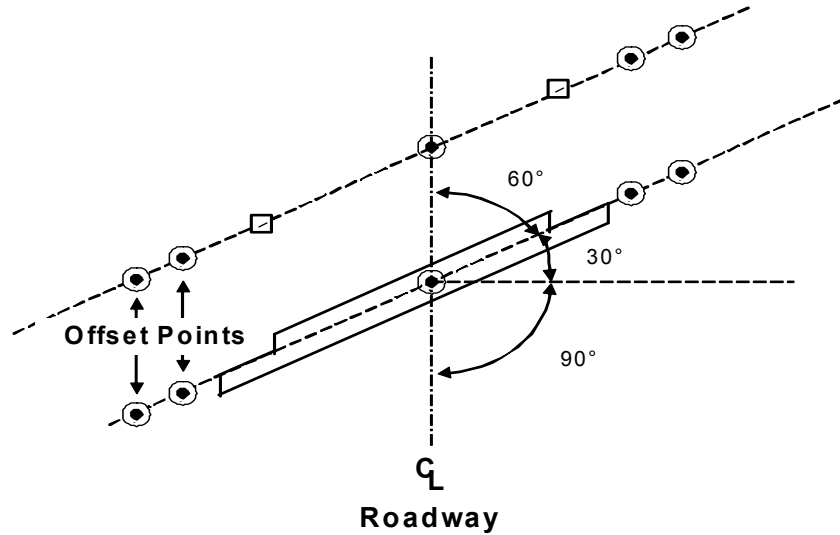
Figure 2.5 Offset Points on 0 Degree Skewed Bridge



Where the structure is to be built on a skew, offset points should be set in relation to the skew. These offset stakes are set by placing a transit on each reference point and the appropriate angles turned. The first stake on each side should be set far enough out so that it will not be in the work area.

Figure 2.6 Offset Points on Skewed Bridge

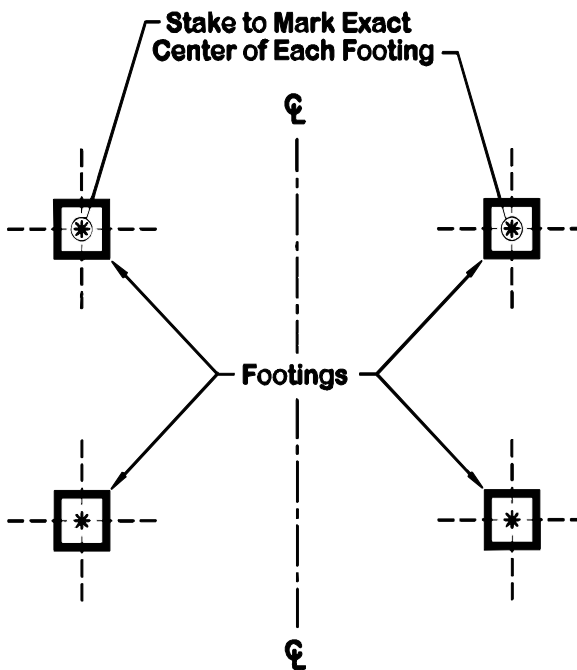
Structure on Skew 30° R.H.F



If landowner permission can be obtained, set the first stake on the right-of-way line and the second stake at least 100 feet out. This assures the stakes will be available when needed. While setting offset stakes on each bent, place a stake in the center of each footing, providing it is not underwater.

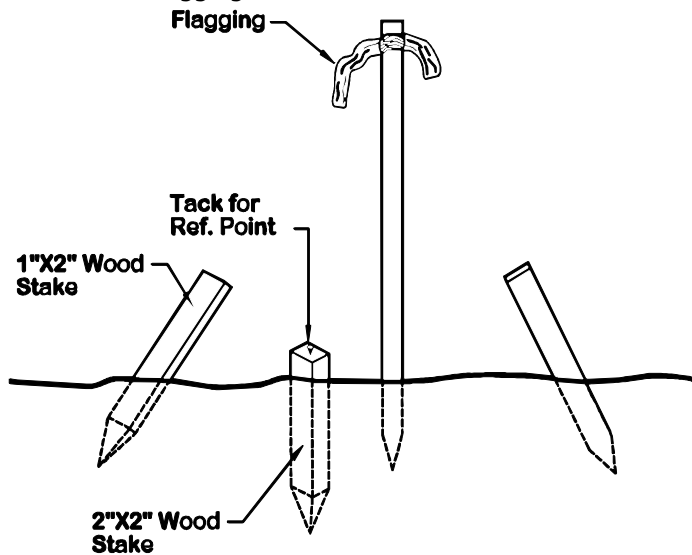
Reference points or offset stakes are usually 2"x2"x14" wood stakes driven flush with the ground surface. A tack or small nail can be driven into the top of the wood stake to mark the exact reference point. If the ground is unstable or if the reference points are to be used on a long-term basis, it will be necessary to use larger wooden stakes (4"x4"x6') or a long steel bar with the cap end punched.

Figure 2.7 Reference Points for Footings



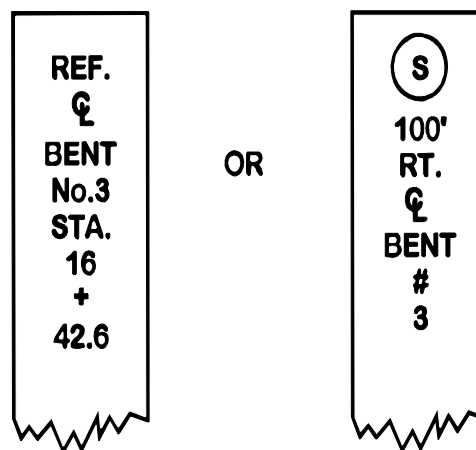
Guard stakes are usually 1"x2"x14" wooden stakes driven into the ground next to the hub or iron pin. A lath with colored flagging tied to the top or painted can also be set near the reference point to further mark the location.

Figure 2.8 Guard Stakes and Flagging Lathe



Each reference and offset stake should be identified. The description and location can be written on one or both of the guard stakes that are placed beside the point.

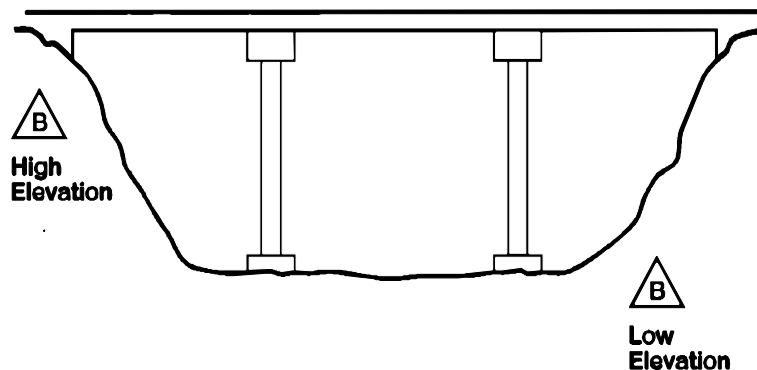
Figure 2.9 Typical Point Description and Location



Benchmarks

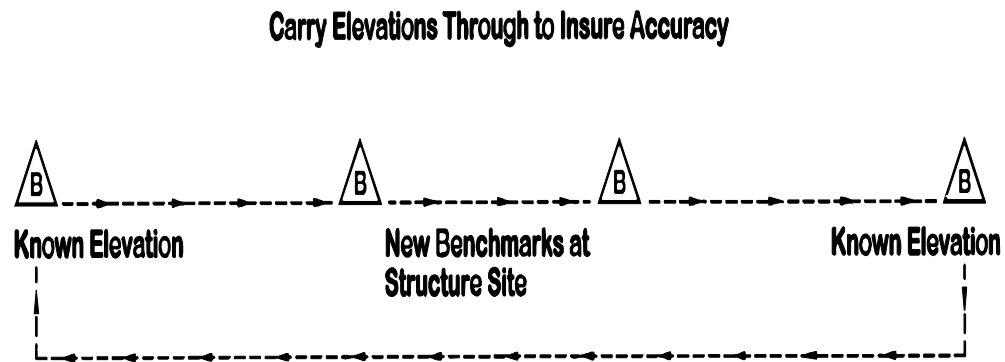
One or two benchmarks should be established near the structure site. It is desirable to have two, one placed at a higher elevation. This enables you to use the higher benchmark to check the work in the deck area and the other to check the lower elevations, footings, etc.

Figure 2.10 Bridge Benchmark Locations



The new benchmarks that are established at the structure site should be checked from two different previously established benchmarks. This will help reduce the possibility of error in the new benchmarks to be used to build the structure.

Figure 2.11 Checking/Tying Benchmarks



Common Staking Errors

The staking of a bridge or culvert is a highly responsible task and requires a thorough study of the layout of the structure. The utmost precision and care is necessary to avoid mistakes. The following are some common staking errors to avoid:

- Not checking all benchmarks immediately prior to start of construction
- Turning the wrong skew angle
- Errors in measuring from center line of piers to center line of abutments (this should be detected by an overall check from center line abutment to center line abutment)
- Inadvertently using the incorrect working line (example: measuring from the beginning bridge location rather than center line abutment)
- Center line of the bridge is not always on center line of road (this is quite common on interstate bridges)
- Never presume that staking and elevation controls have remained undisturbed since the last use. Always check control points against previously completed work before proceeding. This can eliminate the potential error resulting from incorrect instrument setup, incorrect instrument readings or the possibility that the bench control has been disturbed.
- Not tying in to a second benchmark when checking or setting elevations.

Contractor's Responsibilities

After initial staking of the abutments or box culvert center lines, it is the responsibility of the Contractor to provide all other stakes required to successfully complete the construction of the structure, unless additional staking due to difficult site conditions is requested by the Contractor and agreed to by the Engineer. Once staking and elevation control have been established in the field, the Contractor is responsible for preservation and correct use of the control points provided.

EXCAVATION AND BACKFILLING

Checklists

General Bridge Excavation

- Take preliminary cross-sections
- Take structure excavation elevation shots
- Check final excavation elevations for footings and units
- Are soils encountered adequate for bearing
- Take final berm and/or channel cross section
- Calculate unclassified excavation quantities
- Calculate structure excavation quantities

Box Culvert Excavation

- Take preliminary cross sections
- Are soils encountered adequate for bearing
- Take final cross sections
- Calculate unclassified excavation quantities
- Calculate structure excavation quantities
- Calculate undercut quantities

Cofferdams and cribs

- Verify sheet piling driven to adequate depth
- Verify adequate clearances for construction
- Check bracing to assure that there is no interference with piling or columns
- Check for any safety concerns
- Assure that no damage was done to the understructure during removal

Drilled Shaft Excavation

- Refer to 'Chapter 4 - Drilled Shafts'

Backfilling

- General

- Concrete attained minimum design compressive strength. Approval/permission given by Engineer prior to backfilling footings and columns
- General Bridge End Backfill Requirements
 - Concrete attained minimum design compressive strength
 - Minimum of 24 hours after deck pour prior to backfill
 - Base of backfill area properly prepared. Final top 6 inches scarified and re-compacted to 95% density
 - Under-drain system properly installed. Positive drainage verified. Screen or grate in place. Ends of pipe have sufficient length to stay uncovered even when loose material slides
- Select Granular Bridge End Backfill Requirements
 - Granular material meets Section 850 gradation requirements
 - Drainage fabric properly installed underneath and prepared to wrap the sides and top. Laps meet plans requirements
 - Lifts placed at maximum of 12 inches depth. Each lift properly compacted
- Bridge End Backfill Requirements
 - Granular material meets Section 430 gradation requirements
 - Geo-textile fabric certification sent in for approval and approved
 - Side limits of backfill kept 6 inches from outer edges of approach slab (unless otherwise shown in plans)
 - Bridge end embankment shall not exceed 8" loose lifts
 - Granular bridge end backfill shall not exceed 9" loose lifts.
 - Bridge and embankment compacted to 97% of maximum dry density.
 - Soil for bridge end embankment shall have optimum moisture of less than 25%.

General

Regardless of the specific structure type, there is always earth material that must be removed, or excavated, in order to make way for the structure and its foundations. For bridges, the Contractor is paid for removing this material under two different excavation categories: Unclassified Excavation and Structure Excavation. On box culverts, a special third category called undercut is added.

Unclassified Excavation covers material that must be removed to build the berms and channels. This work is usually performed by earth moving equipment. If you have responsibility for inspection of unclassified excavation you should complete the 'Earthwork Course'.

Structure Excavation covers the material that must be removed to make way for the structure foundation units or box culvert bottom slabs and cutoff walls. Most of this work will be in a confined area and is normally accomplished by a drag-line, clamshell, backhoe, or front-end loader.

Undercut is a combination pay item that covers the material that must be removed to adequately prepare the bedding grade of a box culvert or pipe. Payment for undercut includes backfilling the excavated area with a granular backfill material in addition to the excavation itself.

Excavation for Bridges

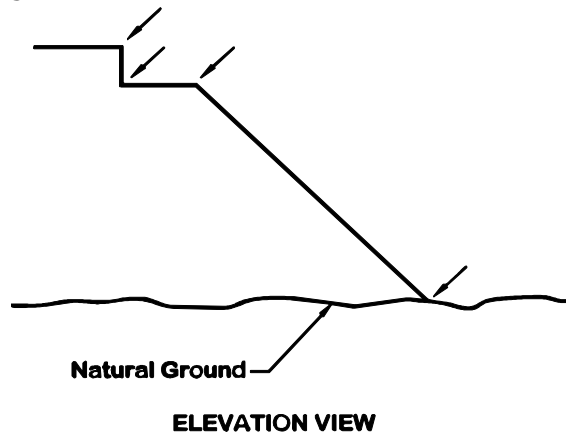
Cross Sections

If cross sections are needed the survey crew will take them. It is your responsibility to see that cross sections are taken at the proper time.

Unclassified Excavation

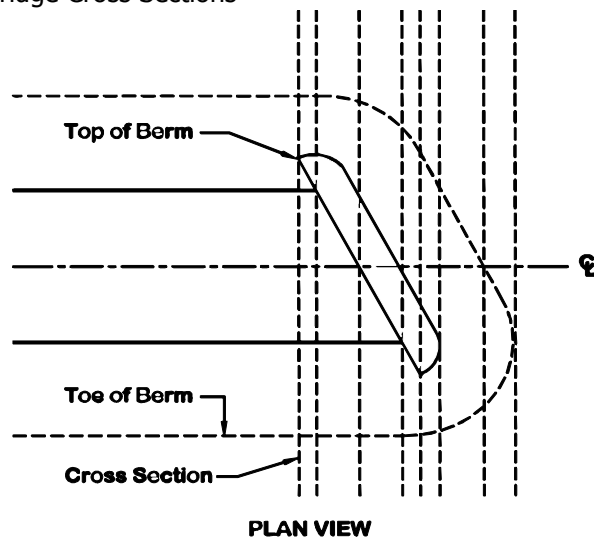
Before any excavation is started, or any embankments built, preliminary cross sections must be taken. These cross sections show the natural ground elevation before construction. They should show the breaks in the ground surface. After excavation and embankments are completed, you should take cross sections again at the same locations as the preliminary cross sections. By plotting these 2 sets of cross sections, you can determine how much excavation was moved. You will also know if the embankments were built according to the plans by comparing the final cross sections against the plan shown sections.

Figure 3.1 Typical Bridge Berm Break Points



Some consideration must be given to where the cross sections are needed. A comparison between the final cross section and what should have been built can be made only if you have picked certain cross section locations beforehand. Figure 3.1 shows a sketch of a berm as it looks from the side. The only way you are able to determine if it has been built correctly is by having the cross sections taken at the break points. The arrows show where they should be taken. You should figure the stationing of these locations and give them to the crew so they can take cross sections at these points.

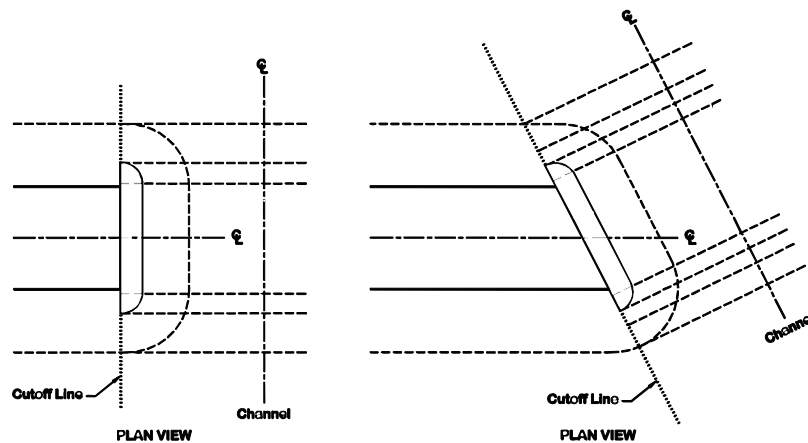
Figure 3.2 Skewed Bridge Cross Sections



When the structure is skewed, the procedure is similar. The difference is that you need more cross sections. Figure 3.2 gives you some idea of the cross sections needed. Visualize the completed berm and pick locations so the cross sections will show the different break points.

Where channel work is required, it is necessary to plan how the cross sections should be taken. The best way to get accurate quantities is to take the cross sections at right angles to the channel center line. In most cases, plans show a center line for the channel. If they do not, establish one. Channel work is generally designed to fit in with the berm face. This makes it fairly simple to use a cut-off line. The best place to put a cut-off line is at the back of the abutment. Then run the cross sections into the cut-off line as shown in Figure 3.3. Determining the location where cross sections hit the break points requires some calculations. This method does however produce accurate quantities that prevent under or over payments.

Figure 3.3 Channel Cross Sections



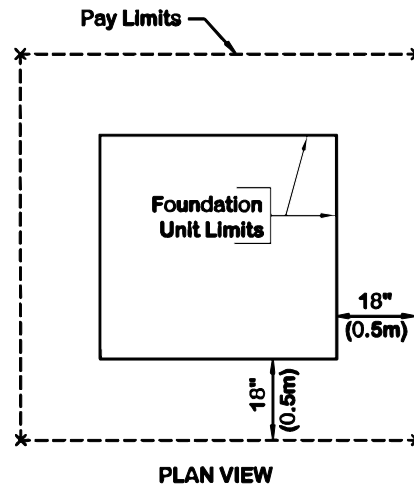
Structure Excavation

Standard Specifications state that under normal circumstances, structure excavation will be paid for at the plans shown quantity and thus field measurements are not necessary. However, if the Project Engineer feels that existing conditions warrant measurement, then the following criteria apply.

The structure excavation volume normally paid for is the volume bounded by vertical planes 18 inches outside the foundation unit. Since foundation units are quite large, you should take an original ground shot at each corner. If there are breaks in the

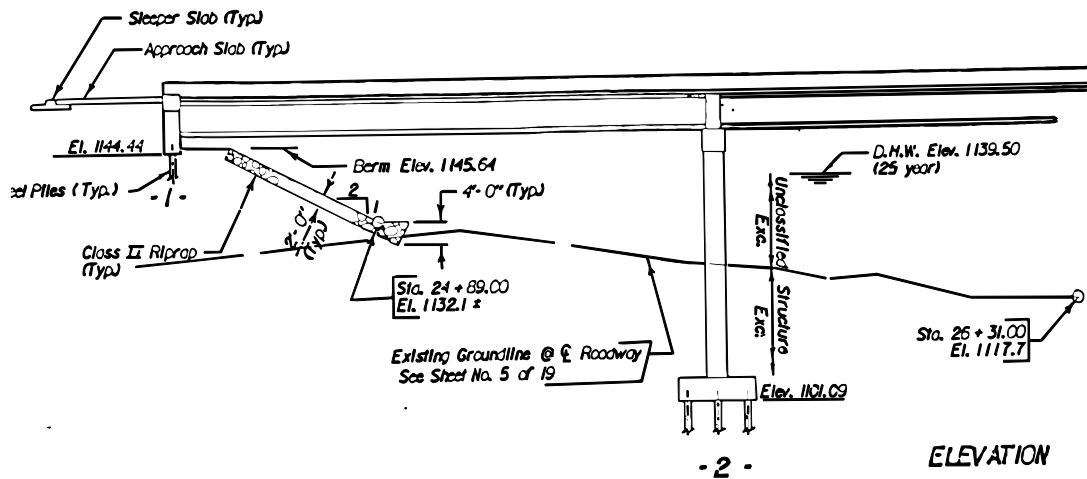
ground line between the corners, take additional shots to show these breaks. You can find the places to take these shots by getting the dimensions from the plans and using the offsets that the survey crew set when staking the structure.

Figure 3.4 Pay Limits of Typical Foundation



Some plans will show the dividing line between the unclassified and structure excavation. This is typically shown on the General Drawing sheet (refer to Figure 3.5 below)

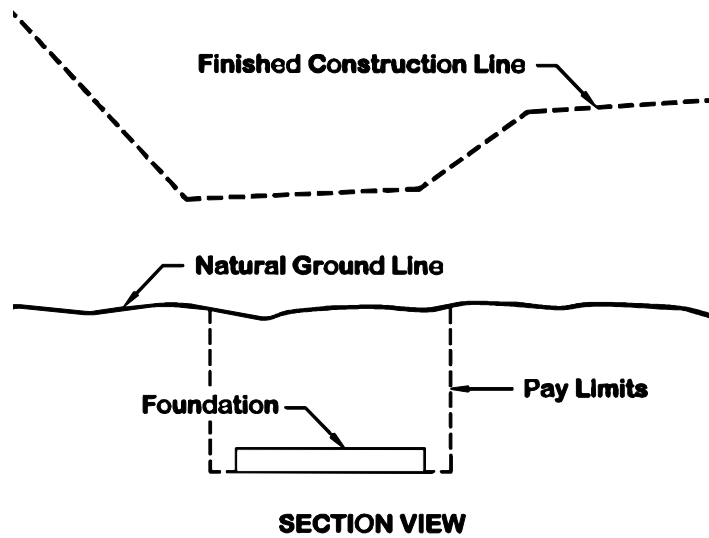
Figure 3.5 Partial General Drawing Showing Division between Unclassified and Structural Excavations



When this split is shown, be careful of what top elevation you use to figure the volume. There are three conditions that will affect which top elevation you use:

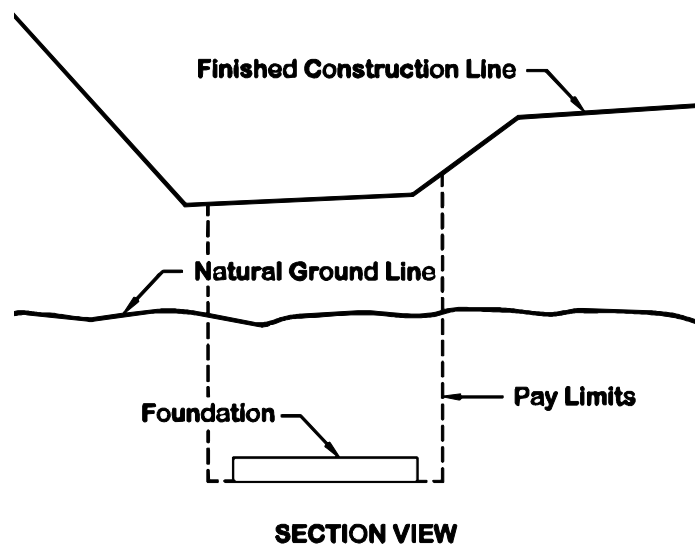
- 1 Assume the finished construction line is above the natural ground line but the construction of the fill has not begun. For this condition, the elevation of the natural ground is the top elevation to use. See Figure 3.6

Figure 3.6 Condition 1



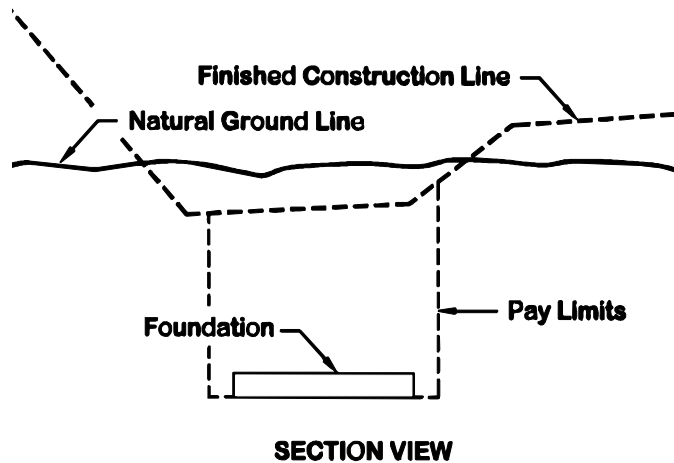
- 2 Suppose the finished construction line is above the natural ground line, and it has been built. In this case, the finished construction line becomes the top elevation you should use. See Figure 3.7

Figure 3.7 Condition 2



- 3 The finished construction line is below the natural ground line. It does not make any difference if the construction has been completed or not. The finished construction line must be used for the top elevation. The material between the natural ground line and the finished construction line will be paid for as unclassified excavation. See Figure 3.8

Figure 3.8 Condition 3



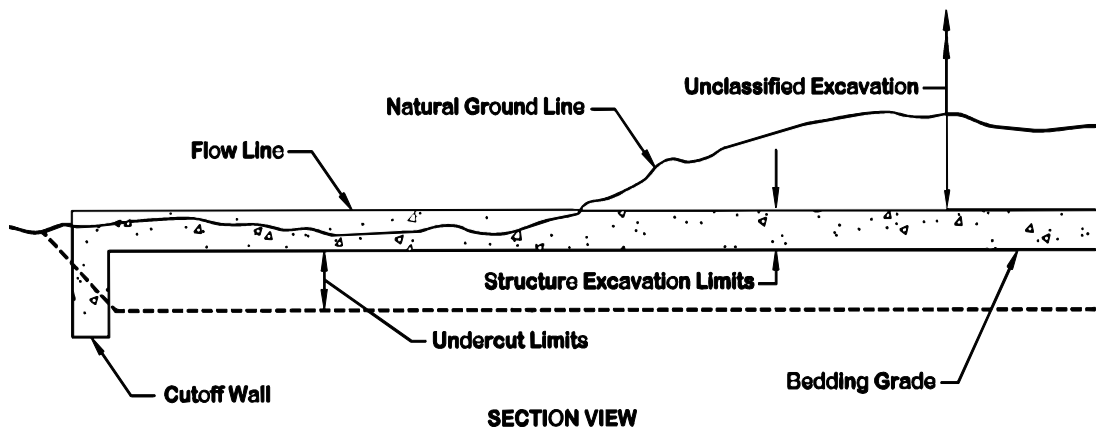
Be sure to make an entry in the field notebook on which elevation is to be used. Wherever you are using the finished construction line for the top elevation, it is the elevation called for by the plans. You still need to take shots to know if the work was over or under built. When the elevations taken are higher than called for, use the plan elevation. If the elevations taken are lower than called for, then use the lower elevations.

As the Contractor completes the excavation for each foundation unit, check it by using a level to see that it has been removed correctly. You only need to take the elevation to the nearest 0.1 foot. When you are satisfied with the removal, record the elevations in your field notebook.

Excavation for Box Culverts

For a box culvert, the split between unclassified and structure excavation is the flow line. The Contractor is paid structure excavation from the flow line down to the bedding grade only for a width equal to the outside dimension of the box culvert. The Contractor is always paid structure excavation for the cutoff walls. It makes no difference if they are in a cut or embankment. The Contractor is also paid for undercut from the bottom of the culvert's bottom slab to the depth as detailed on the plans. The diagram shown in Figure 3.9 demonstrates how the excavation limits for a box culvert are defined.

Figure 3.9 Excavation Limits for a Box Culvert



When the box culvert is built according to the plans (at the same stationing and elevations), the Contractor is paid plans quantities for both structure and

unclassified excavation. If changes are made, you need elevations taken for your records and to know where the natural ground line is in relationship to the flow line. Normally this should be done before any construction is started at the box culvert site. An exception is when part of an old structure to be removed falls across the new site. You then wait until it is removed, before required elevations can be obtained.

The Contractor is also paid plans quantities for undercut unless a significant change in depth or width is warranted. Should existing soil conditions require change, then you will need cross sections both before and after the undercut is performed in order to determine the volume of undercut.

The best way to obtain elevations is by taking cross sections at right angles to the center line of the box culvert. You need to take the cross sections so they will show all the break points in the ground line. You will also need to take additional cross sections for any breaks in the box culvert. Figure 3.10 shows the extra sections required.

Figure 3.10 Box Culvert Cross Section Locations

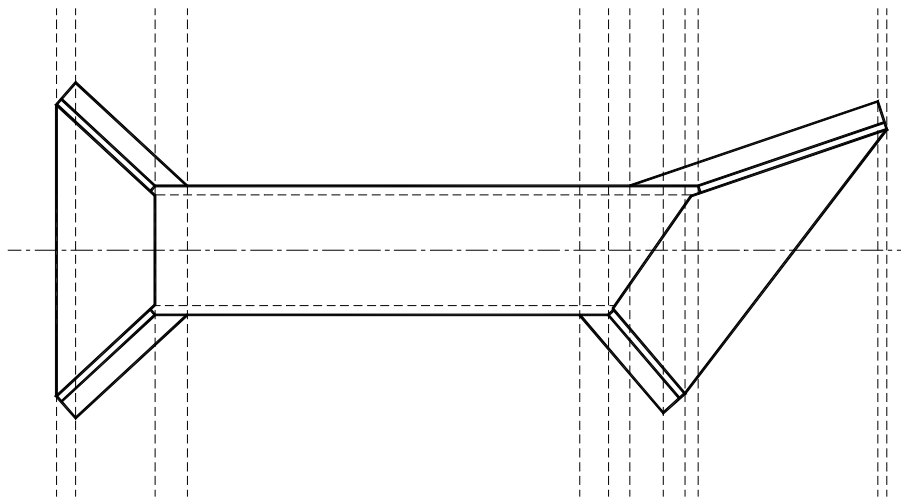


Figure the stationing of the extra cross section to the nearest 0.1 foot. Stationing on cross sections showing the ground line is figured to the nearest 1 foot. The exception is at the P.I. or P.C. where stationing is to the nearest 0.1 foot. While taking the cross sections, extend them beyond the box culvert sides and use them to figure the unclassified excavation. They should be taken wide enough to cover a 3:1 or 4:1 slope from the bedding elevation. After the Contractor has completed the excavation, check to see it is the correct depth. Once satisfied, have the final cross sections taken.

Foundation Bearing

Spread Footings

Special consideration needs to be given to the excavation for spread footings. A spread footing is essentially a large reinforced concrete pad that distributes the load of the structure uniformly over its area. The allowable resisting strength (or bearing strength) of the soil directly underneath the footing determines the size of the footing itself. It is critical that the soil underneath the footing meets or exceeds the assumed soil bearing strengths of the design. A thorough examination of the foundation soils should be made as soon as excavation operations have been completed. The types of soils encountered should be carefully compared to the

subsurface investigation sheet and any other pertinent notes provided in the plans. If conditions are different than shown or noted in the plans, the Office of Bridge Design should be notified in order to evaluate the adequacy of the footing size and design.

The plans may contain a note that says the footing must be cast to neat lines in undisturbed material. This means that the concrete must be placed directly against the earth material, and that forms cannot be used. If your plans have this note, make sure that the excavation for the footing is removed only to the dimensions of the footing.

When a spread footing is to be placed on material other than rock, the concrete should be placed shortly after the footing elevation is established. If it is not, the excavated surface may deteriorate and lose its bearing strength. Should this happen, the loose material must be removed as directed by the Geo-technical Engineer, and be replaced with concrete at the Contractor's expense.

Box Culverts

Like spread footings, box culverts need adequate soil bearing strength underneath the bottom slab to adequately support the weight of the box culvert and fill. This is done by properly preparing the undercut and backfill underneath the culvert.

Generally the depth of undercut as detailed in the plans will be enough to remove any unstable soil and provide an adequate bearing. When excavation for a box culvert reaches the bottom of undercut elevation, a decision needs to be made if the existing soil material has enough strength to support the structure. If the material is rock, gravel, or moist sand, checking the bearing is not required because all have bearing strengths greater than the minimum required. There is no simple method that can be used in the field for other materials. There are some rough indicators, but determining bearing strength is something you learn through experience.

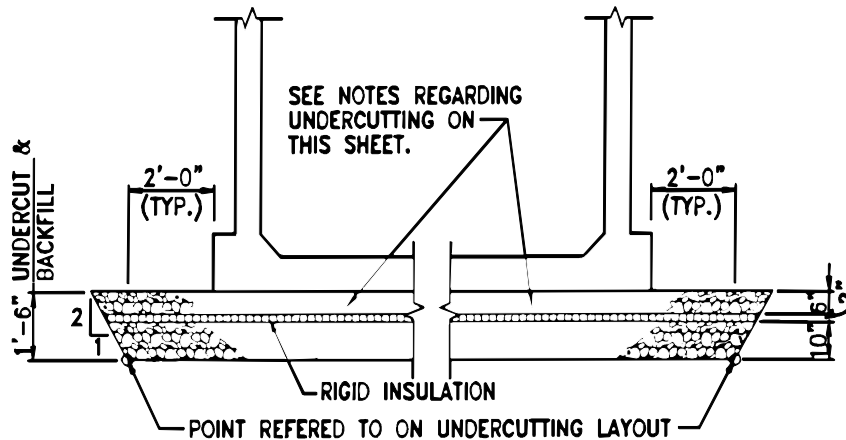
If the depth of excavation has not removed questionable soil, then the depth of undercut should be extended until it does. Usually a maximum depth of 3 feet is enough depth to permit the gravel backfill material to stabilize soft material. Occasionally deeper excavation and backfill with oversized material is required. If there is question as to the adequacy of the existing soils, contact the Office of Bridge Design or Geo-technical Engineer for further direction.

After excavation, have the survey crew take cross sections to determine the quantity removed. The Contractor may then start backfilling. The backfill material should conform to Section 421 of the Standard Specifications. Backfill should be placed in horizontal lifts not exceeding 6 inches in depth. Each lift should be compacted to 95% of maximum dry density. You should take periodic tests to verify that the backfill material has been adequately compacted.

Extruded Insulation Board

Plans will often require that a layer of extruded insulation board be placed within the depth of the undercut and backfill. The insulation board is used to help reduce the effects of potential frost heave that can occur in certain types of soil conditions. To avoid damage to the insulation board, make sure that equipment used to place and spread the top layer of backfill is not be operated on anything less than full depth of fill material.

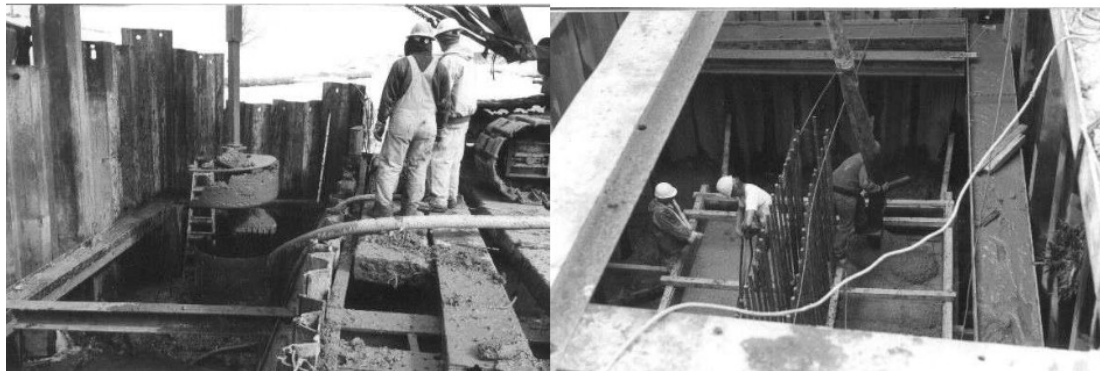
Figure 3.11 Typical Undercutting Section with Extruded Insulation Board



Cofferdams and Cribbs

Cofferdams are used where water and soil conditions make an open excavation impractical or unsafe. If excavation does not exceed 5 feet, this is not generally a problem as the hole can be widened and the sides sloped. This becomes impractical in excavation exceeding 5 feet. Preventing the sides of deeper excavations from caving is done by use of cofferdams or cribs.

Figure 3.12 Cofferdams



Cofferdams are generally built by driving sheet pile around the area to be excavated. After they are driven, material is removed from the inside. As the material is removed, bracing is placed inside the sheet pile to handle the outside pressure.

Cribs are built first, complete with bracing, then set over the area to be excavated. As the material is removed, the crib sinks or is driven down.

Excess water usually causes material to be unstable. Although cofferdams and cribs protect the work area, water may still seep. At times, water must be removed so the work can continue. Well points are driven into the material around the area. When pumping starts, the water is collected by the closely spread well points and is kept out of the work area.

The sheet piling should also be long enough so that water is not forced below the sheets and up through the bottom of the cofferdam as a 'blow-in' failure. Insufficient depth of sheeting creates conditions that could cause complete failure of the cofferdam when it is pumped out. To avoid failure due to water pressure often requires that the sheets be driven to a depth below the footing equal to $1/2$ the

distance (or as much as twice the distance in loose sandy soils) from the bottom of the footing to the ground surface water elevation.

When the bottom of the excavation is of sandy or porous material, and when the sheet piling cannot be driven deep enough so that the footing can be poured in the dry, then the excavation may need to be sealed with a foundation seal. A foundation seal is a large mass of concrete that is poured below the bottom of the footing at the base of the cofferdam or cribbing excavation, thereby 'sealing' the dam from water infiltration due to hydrostatic pressure. The Contractor should submit a request to use a foundation seal when necessary. Upon approval of the use of a foundation seal, the Contractor will be required to submit a foundation seal design and a concrete mix design to the Office of Bridge Design for approval.

When cofferdams and cribs are used, make sure they are large enough to contain the foundation unit being built. There should also be an allowance for working room around the foundation unit. Dimensions should be at least 2-3 feet greater than those of the foundation unit. Check the location to ensure the foundation unit they are supposed to protect is contained within. If they are improperly located they must be enlarged and relocated. Consideration as to the bracing locations within the cofferdam should also be noted, as their location should give adequate clearance for the driving of foundation piling when required.

Cofferdams and cribs are a tool of the Contractor, and the details are largely left to the Contractor's choice. Cofferdams and cribs must be constructed to protect the work and the workmen. If you suspect safety requirements are not being adhered to, discuss the situation with your Project Engineer. After construction of the substructure is complete, the Contractor is responsible to remove the cofferdam and shoring in a manner that does not damage the structure.

Backfilling

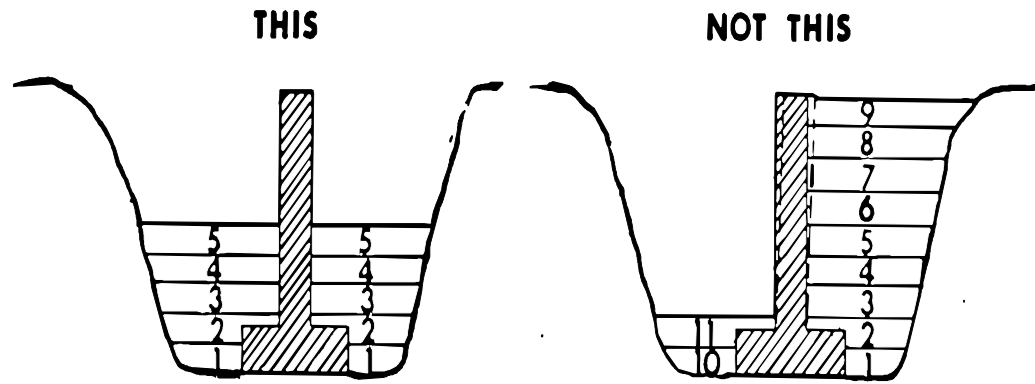
Backfill is the placing and compacting of material around structure units. This fills the excavated areas to the original ground line or plan's required finished line. The footings and columns cannot be backfilled until the concrete reaches full design strength, or until the Project or Area Engineer gives permission. All other units cannot be backfilled until the concrete reaches full design strength as noted in the plans.

With the exception of bridge end backfill (discussed later in this section), the backfill material is usually the same material that was removed. Be sure it is free of frozen lumps and other material such as wood, weeds, etc... The material is typically placed in layers or lifts that are 3-6 inches in depth. Unless specified otherwise, the lifts are generally compacted to about the same density as the surrounding material.

The Contractor can choose the method of compaction. This includes rollers and hand tampers, although pan type vibrating equipment works best. You need to be concerned about damage to the concrete. There should be no banging into or intense vibrating of the concrete.

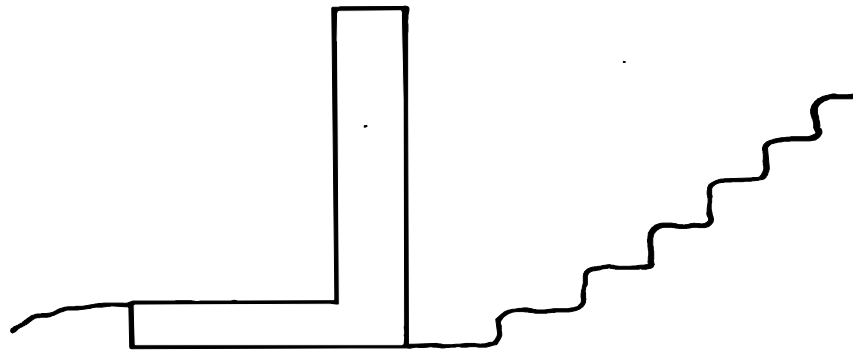
How the material is placed is also important. Where the backfill is placed on both sides of the unit, it must be brought up evenly on each side or the unit could be pushed out of position. In addition, many structural units like culverts are not designed to accommodate backfill loads on one side only. When loaded unevenly, damage to the structure itself could occur.

Figure 3.13 Backfill Placement



For structural items to be backfilled on one side only, such as retaining walls or abutments back walls, the backfill area should be stepped (benched) or at least roughened. This will help prevent the unit from being pushed out of place during backfilling operations.

Figure 3.14 Benching Backfill Area



Box Culverts and Large Pipes

The backfill of box culverts and large pipes, whether cast-in-place or precast, is generally the on-site excavated material. Occasionally, however, a special backfill material is required. Plan notes or special provisions should dictate what requirements to check if a special backfill material is to be used.

The fill for culverts should be placed in uniform lifts or layers not exceeding 6 inches in depth. Each lift should be thoroughly compacted by mechanical compactors to the specified density before the next successive layer is placed. Often hand-operated compactors are required in order to get proper compaction, particularly on multiple pipe or culvert installations where the distance between units is minimal.

Imperfect Trench Backfill

At times the plans may require that a pipe or arch be backfilled using the imperfect trench backfill method. In this method, the pipe is first backfilled to a depth at least equal to the outside diameter of the pipe plus 1 foot using normal backfill methods as described above. Following that, the compacted fill over the pipe is 're-excavated' back down to the top of the pipe. The width of the 're-excavated' trench is limited to not less than the outside diameter of the pipe, and not more than 8 inches above that. The trench is then filled with loose straw or sawdust to a depth of one outside

pipe diameter. The straw or sawdust must be reasonably dry and not decomposed or moldy. Following the placement of the straw or sawdust, the remainder of the fill and embankment is placed by normal backfill methods.

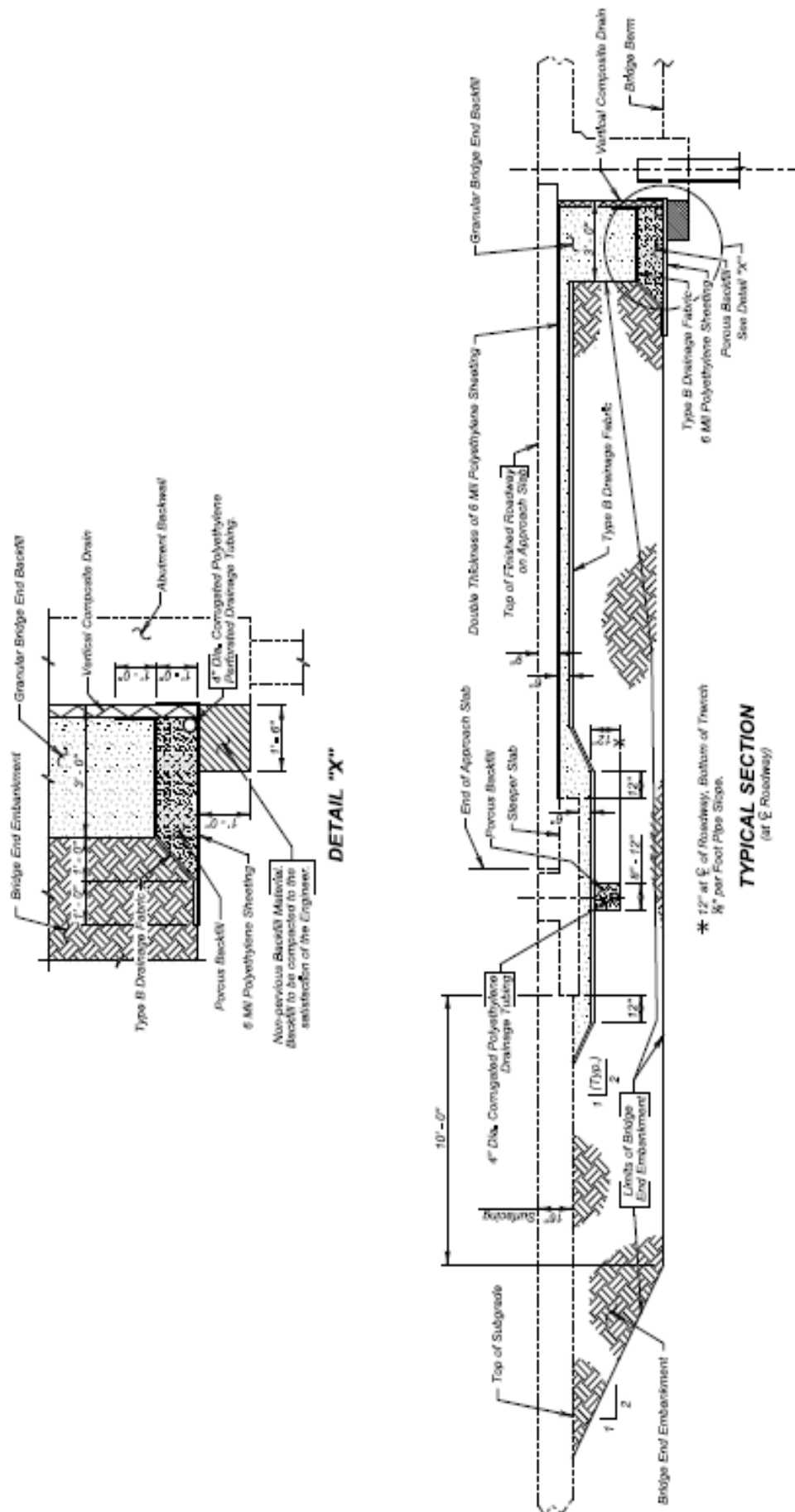
Flow-able Fill

When multiple culverts or pipes are placed so closely together that normal backfill and compaction methods are impractical, then a flow-able fill will often be used. Flow-able fill is a lightweight, low strength concrete mixture having a high slump. The concrete fill is typically placed only between adjacent pipe or culvert sections up to the top of the unit. Normal backfill methods are then used on the overall outside edges and top.

Bridge End Backfill

Shall be completed according to the typical sections in the end section 930 plans.

Figure 3.15 Typical Select Granular Backfill



4

DRILLED SHAFTS

Checklists

Prior to Construction

- Drilled Shaft Concrete Mix Design submitted and approved
- Drilled Shaft Installation Plan submitted and approved
- Drilled Shaft Preconstruction Meeting held
- Assure that all required equipment is on project
 - Tremie
 - Auger and T-Bar
 - Casing and dewatering pump
 - Clean-out bucket and pilot bit
 - Tape measure with a weight
- Verify staking of column/shaft location
- Verify that the drilling equipment is accurately centered on the shaft location
- Use mirror and weighted tape to evaluate shaft during drilling

Drilled Shaft Excavation

- Casing installed and set by twisting with T-Bar
- Check location and plumbness of kelly bar
- When caving, excessive sloughing, and/or water bearing soil layer encountered:
 - Drilling operations halted
 - Fill hole with water to prevent further cave in. Provide 10 feet of head where possible
 - Maintain head of water during remainder of drilling
- Assure that friction-bearing soil is encountered at or above the anticipated elevation specified in plans
- Assure that shaft construction can be completed within 24 hours
- Check the following upon completion of shaft excavation
 - Rate of water accumulation (less than 3 inches per hour may be considered a dry shaft)
 - Stability of sides of shaft

- Assure that loose material is removed from the bottom of the shaft
- Shaft to correct depth

Reinforcement Placement

- Check the following prior to inserting reinforcing steel cage:
 - Reinforcing steel bars are of correct size, number, and spacing
 - Spirals or hoops are the correct diameter
 - Spirals (if used) have at least 1.5 turns each end and at each lap
 - At least 3 vertical spacer bars provided
 - Cage adequately tied and stiffened to remain intact upon lifting and placing with crane
 - Centralizers are adequately placed
 - CSL tubes are in place
- Check the following when inserting and setting the reinforcing steel cage in the shaft
 - Six inches minimum clear provided at the bottom of the shaft
 - Cage centered within the shaft
 - Top of cage elevation checked
 - Cage adequately tied down to prevent floating
 - Tremie pipe or pump tube
 - CSL Tubes sealed and evenly spaced

Concrete Placement

- Dry Construction Method of concrete placement
 - Bottom of shaft clean and any standing water pumped out
 - Hopper and drop tube adequately cleaned
 - Hopper centered such that concrete will not hit against reinforcing or side of shaft during concrete placement
 - Temporary casing is removed prior to initial set of the concrete
- Recheck reinforcing steel cage location and elevation
 - Concrete adequately consolidated joint
 - Cured with wet burlap and polyethylene
- Concrete placement in a wet hole
 - Tremie pipe or concrete pump line is the proper size
 - Pipe or pump line is clean and smooth
 - Diversion trench cut to assure that water and contaminated concrete will flow at the end of the pour
 - Adequate seal or plug installed
 - Pipe placed at bottom of shaft prior to filling with concrete
 - After initial filling, pipe raised slowly about 6 inches to allow concrete to flow and displace water
 - Concrete flow continued until a minimum of 5 feet of head provided from top of concrete to bottom of pipe

- Both pipe and concrete level brought up uniformly and slowly maintaining 5 feet of concrete head above bottom of pipe
- Concrete supply is maintained until all water and contaminated concrete has been displaced
- Recheck reinforcing steel cage location and elevation
 - Cured with wet burlap and polyethylene
- Check construction tolerances throughout excavation and concrete placement

Follow-up

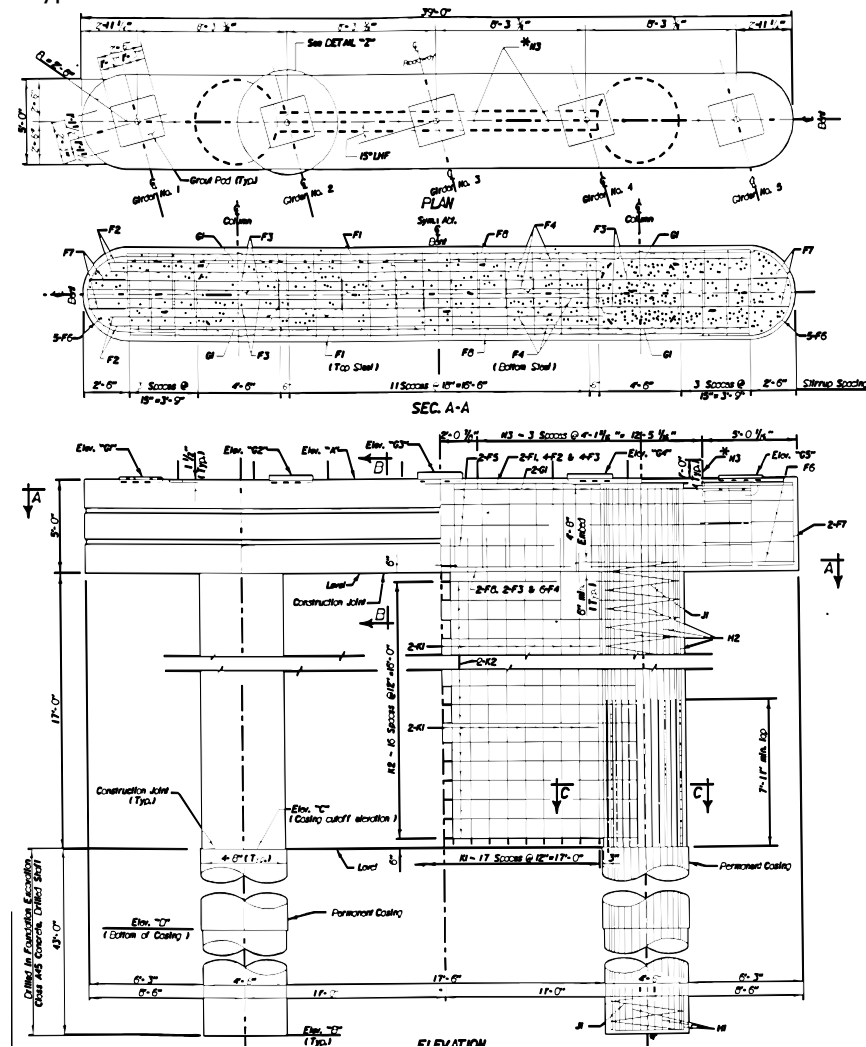
- Drilled Shaft Construction Report, DOT Form 297, completed for each shaft and sent in to the Office of Bridge Design

General

A drilled shaft is a type of substructure foundation where the bent or pier column is essentially extended underground without the use of footing. A cylindrical shaft is first excavated or drilled, then filled with concrete. The drilled shaft supports loads through a combination of skin friction between the shaft and adjacent soil, and end bearing. Typical sizes for drilled shafts vary from 30 inches to 72 inches and can extend 50 feet or more in depth. Figure 4.1 shows a typical drilled shaft substructure foundation unit found in bridge plans.

Drilled shafts require rigorous inspection. Initial structure plan review is a must. You should also thoroughly read through Section 465 of the Standard Specifications in order to have a clear understanding of the different types of shaft construction. Become familiar with the procedures set forth in the specifications in the event problems are encountered during construction.

Figure 4.1 Typical Drilled Shaft Substructure Unit



Types of Drilled Shaft Excavation

Casing

Most drilled shafts will require a steel casing to be used to facilitate the excavation of the shaft. A casing is a steel plate that is rolled and welded in a shop to form a large diameter pipe. The casing is placed in a shaft either before, during, or after excavation (depending on the method of excavation) to prevent caving or sloughing of the shaft's earth walls and to 'seal' off the walls from infiltrating ground water. The casing must be constructed of smooth steel having sufficient thickness to withstand the handling stresses, concrete pressure, and surrounding earth and fluid pressures that will arise during construction. The casing should be large enough in diameter to permit the drilling auger to pass through, and should have teeth cut into the bottom lip to allow anchoring or 'seating' the casing into the desired soil formation.

Excavation Methods

The specifications outline three different types of excavation methods for the drilling of the shaft. Depending on the application and use of the steel casing, one of the following methods will be required:

- **Dry Construction** - Consists of drilling the shaft without the use of a steel casing. This method is restricted to use in relatively stiff, stable soil formations in which infiltrating ground water is not a problem. Because most upper strata soil

conditions in South Dakota do not meet these conditions, this method is rarely used. Temporary Casing Construction - Consists of drilling the shaft with the use of steel casing that is extracted or removed during concrete placement. This method is prone to construction problems and requires a high degree of skill and experience by the Contractor for successful installation, hence it too is limited in its application.

- Permanent Casing Construction - Consists of drilling the shaft with the use of steel casing that is left permanently in place. This method has proven to yield the most consistent and quality shaft construction. Consequentially, it is the method most typically specified for construction.

Plans will typically require that the permanent casing construction method be used in the excavation and construction of the shaft. You should, however, be familiar with the requirements of the other two shaft construction methods (dry or temporary casing) in the event that a project utilizes one of these other methods. All three methods are summarized in detail in this chapter.

Preparing for Construction

Prior to Construction

Prior to the actual construction of a drilled shaft, several items and issues need to be addressed by the Contractor. At least 40 days before planned construction, the Contractor should submit a concrete design mix for the drilled shaft concrete for approval. Not less than 30 days before beginning construction the Contractor should submit a Drilled Shaft Installation Plan outlining the type of equipment to be used, overall shaft construction sequences, and detailed explanation of specific shaft construction methods, including plans on how to handle possible water and cave-in problems.

At a minimum of 5 working days prior to construction, a Drilled Shaft Preconstruction Meeting should be held. The purpose of this meeting is to review step-by-step the procedures and construction methods that will be used in construction of the shafts. Possible problem scenarios are reviewed and corrective construction procedures are discussed in an effort to best prepare all parties for actual construction operations.

Drilling Equipment

The Contractor needs to provide and use excavation and drilling equipment that has adequate capacity including power, torque, and downward force to effectively complete work within the specified time limits. A crane with a specialized drilling rig mounted on the front can be used providing mobility, auger shaft drilling, and casing handling capabilities. Alternately, the Contractor may choose to use heavy, rotary drilling equipment to drill the shaft while retaining the crane for lifting operations pertaining to casing or reinforcement and concrete placement.

Figure 4.2 Drilling Rig



Drilled Shaft Excavation

Dry Construction Excavation

The Dry Construction Method consists of drilling the shaft excavation, removing loose material from the bottom of the shaft, and placing the concrete in a relatively dry hole. After verifying the staking of the structure, a hole should be prepared at the center of the surveyed shaft. The auger extension will be placed in the hole to ensure that the shaft is in the correct location. This is followed by measurements from offset stakes and plumbing to ensure that the shaft is placed at the angle (or batter) specified in the plans. The figures below show the offset stake to center of shaft measuring and kelly bar plumbing checks which must be made or observed to ensure correct positioning and angle of the shaft.

Figure 4.3 Plumb Check of Kelly Bar



Figure 4.4 Measuring from Offset to Kelly Bar



The sides and bottom of the shaft must be inspected after excavation operations are complete. Generally flashlights are not adequate for this inspection as their light becomes quickly diffused in the deep shaft. The best method for quick visual observation is to use a mirror and deflect direct sunlight down the shaft. Alternately, a camcorder with an attached light can be lowered into the shaft for observation. A weighted tape measure can be used to verify the shaft depth. The dry construction method can be approved when the shaft excavation has a water accumulation rate of 3 inches or less per hour; the sides and bottom of the shaft remain stable without detrimental caving, sloughing, or swelling; and loose material and water can be removed prior to concrete placement.

Temporary Casing Construction Excavation

Shafts often may be drilled through a layer of granular material before penetrating into shale. While drilling through this granular layer, shaft squeeze, side wall caving, or water in-fall can result. The Temporary Casing Construction Method should be used when excavations, begun by the dry construction method, encounter these types of soil conditions, or if required by plans.

If during dry drilling operations, the Contractor encounters caving or water bearing soils, the Contractor should stop drilling and fill the hole with water to a point above the ground water elevation. If practical, a positive 10 foot head of water should be maintained above the natural ground water elevation.

Once measures to stop the caving or water infill are completed, the drilling operations can again resume. A sufficient head of water should be maintained until an impervious soil formation is reached. A temporary casing should then be placed into the impervious formation by use of a T-Bar and twisting the casing to produce a watertight seal. If the temporary casing can be sealed, the water can be removed and drilling can continue using the dry construction method. If the temporary casing cannot be sealed or if water infiltration occurs at an elevation below the bottom of the casing, the excavation must be continued in the wet.

Figure 4.5 Drilled Shaft Casing



Permanent Casing Construction Excavation

The Permanent Casing Construction Method, while being the predominant method specified, should be used only when specifically required by plans or as approved by the Office of Bridge Design. This method consists of placing a casing to a prescribed depth (usually to a known impervious formation layer) before excavation operations commence. If full penetration of the casing cannot be attained, the Engineer may require excavation of the material within the embedded portion of the casing, and/or excavation of a pilot hole ahead of the casing until the casing reaches the desired depth. Over reaming of the shaft diameter may be required prior to placing the casing itself.

As in the Temporary Construction Method, a T-bar should be used to twist the permanent casing into the specified formation in order to achieve a watertight seal at the bottom. After the casing is set into the impervious formation, drilling operations can continue as described in the Dry Construction Method. Should cave-ins or water in-fills occur below the casing, then corrective measures should be taken by filling the hole with water similar to that previously described under Temporary Casing Construction Methods.

Constructing and Placing Reinforcing Steel

After inspection and approval of the hole, and prior to concrete placement, the shaft's reinforcing steel cage (consisting of longitudinal bars, ties, cage stiffener bars, CSL Tubes, spacers, and centralizers) is placed as a unit. Generally the reinforcing cage is constructed and tied in advance on the construction site at some location off to the side of the shaft. You should check to ensure that the reinforcing

cage is tied and braced adequately so that it can be lifted into place without deformation and such that all bar locations and spacings remain true. Watch to ensure that the Contractor uses adequate support when lifting the cage so as not to damage or permanently deform the reinforcement. Once placed in the hole, the reinforcing cage should be supported, braced, and anchored in the shaft adequately so that it will remain within the specified tolerances during concrete placement.

The steel reinforcing cage should have approved centralizers located intermittently along its length to ensure that the proper concrete clear cover is provided along the entire depth of the shaft. The cage should also be constructed and tied in such a manner as to allow adequate clearance and placement of a tremie pipe.

Concrete Placement

Time Limitations

Once an excavation is completed, the resteel cage should be set and the concrete placed prior to starting excavation of another shaft. When possible, the drilled shaft concrete should be placed the same working day in which the excavation is done. If it is anticipated that the excavation, reinforcing placement, and concrete placement cannot be completed before the end of the working day, the excavation should not be started unless prior approval is obtained from the Engineer.

By specifications, it is required that the concrete be placed within 24 hours of the excavation reaching the friction bedrock elevation noted in the plans. If for some reason the 24 hour time limitation is exceeded, drilling operations should cease and the Office of Bridge Design should be notified immediately.

Concrete Placement in a Dry Shaft

If at all possible, the concrete should be placed in a dry shaft. Specifications permit concrete to be placed in shafts by the free-fall method provided that all of the following requirements are met:

- 1** The diameter of the shaft is 36 inches or greater. If the shaft is of a smaller diameter, then the concrete must be placed with a full height drop tube to control the fall of the concrete. Typically the tremie pipe is used as the drop tube.
- 2** The water accumulation rate in the hole is 3 inches or less per hour.
- 3** There is no caving or sloughing of the sides of the excavated shaft.
- 4** The excavation is dewatered immediately prior to concrete placement such that there is no more than 3 inches of standing water in the bottom of the shaft.
- 5** The concrete placement is directed through a hopper with a drop tube such that the concrete fall is vertical down the center of the shaft and the concrete is not allowed to hit the sides of the shaft or the reinforcing steel cage.

You should estimate the volume of concrete required per vertical height of the shaft prior to placement of the concrete. During the concrete pour, compare this estimate with the actual volume of concrete being placed. By doing so you can evaluate if any large cave-ins or sloughs have in fact occurred and at what approximate depth they are located.

If the Temporary Casing Construction Method has been used, then the temporary casing must be removed before the concrete has attained initial set. Before the casing is withdrawn, the level of fresh concrete in the casing should have sufficient head such that all water trapped behind the casing is displaced upward without contaminating or displacing the concrete.

After the temporary casing has been removed, the reinforcing steel cage location should be checked and rechecked and corrected for any movement or displacement. Should the temporary casing become lodged or bound in the excavation, construction operations should cease and the Office of Bridge Design should be notified immediately.

Concrete Placement Underwater

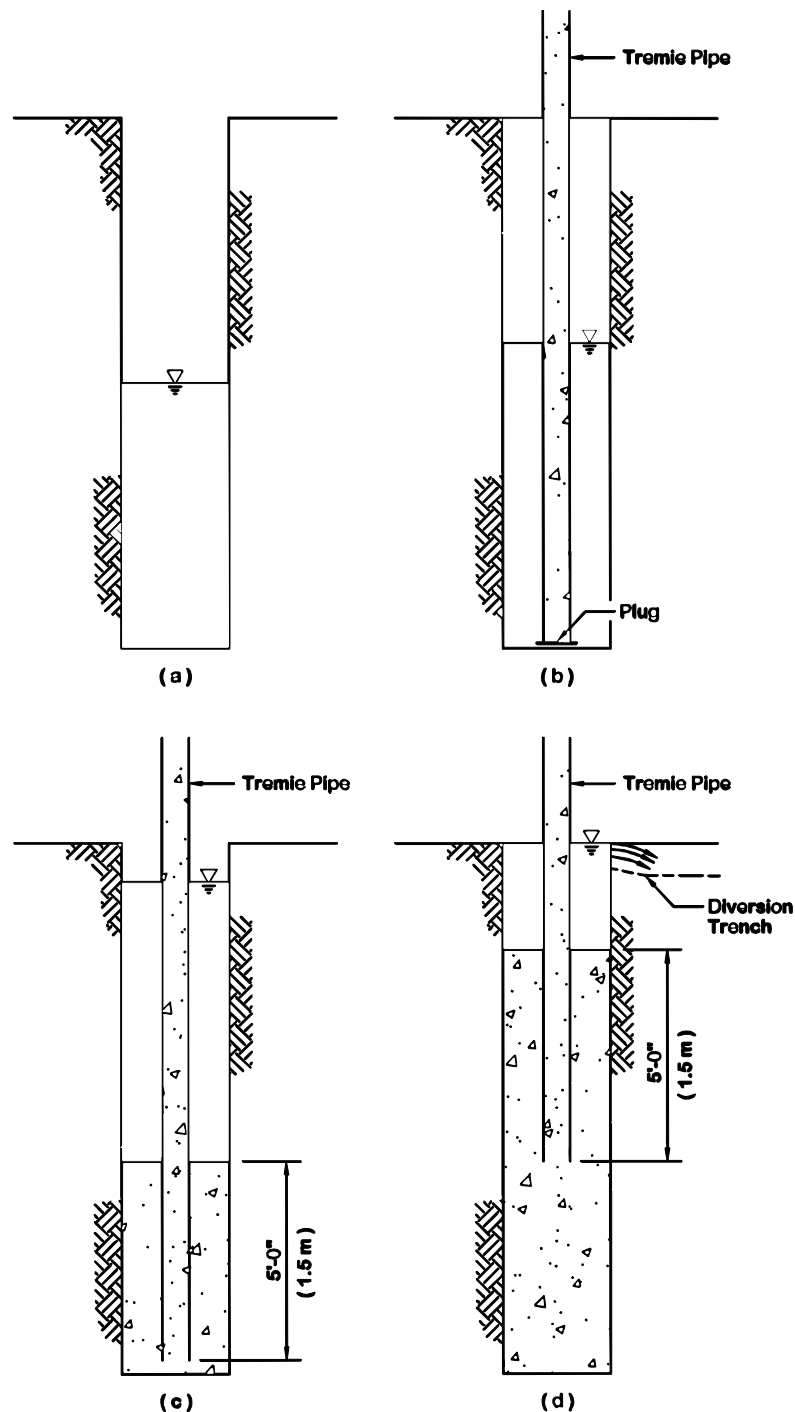
If the previously stated requirements for dry shaft concrete placement cannot be met, then the shaft should be considered a wet shaft and underwater placement construction practices should be used. Underwater concrete placement can be done with either a tremie pipe or by a concrete pump.

Tremie Concrete Placement

Specifications require that the tremie pipe have a minimum inside diameter of 7-3/4 inches and a minimum thickness of 1/4 inch. The pipe should be checked for smoothness particularly at joints, and should be clean of any hardened concrete, rust, or other contaminants. The tremie should be marked at uniform intervals to allow determination of the depth of the bottom of the tremie relative to the level of concrete.

Figure 4.6 illustrates the basic procedure for placing concrete underwater. Essentially the procedure is a matter of displacing the water with sound, uncontaminated concrete until the shaft is completely filled.

Figure 4.6 Concrete Placement Underwater with a Tremie



The process begins with a shaft that is partially filled or fully filled with water as shown in Figure 4.6(a). A plugged, empty tremie pipe is lowered into the hole then filled with concrete as illustrated in Figure 4.6(b). As the tremie is lifted slightly off the bottom of the shaft, the plug will be dislodged and the concrete will begin to flow into the shaft. The tremie is kept at the bottom of the shaft until a head of concrete develops over the bottom of the pipe as shown in Figure 4.6(c). The tremie is then slowly lifted out of the hole as the concrete fills and displaces the water above as illustrated in Figure 4.6(d).

It is important to keep the tremie pipe buried a minimum of 5 feet within the concrete in order to ensure that the concrete remains sound and is not contaminated by the water above. Placement of the concrete should be performed in one continuous operation. If an interruption occurs lasting longer than 30 minutes,

the tremie should be removed from the concrete and concrete placement should be restarted as described below.

Starting/restarting of the concrete placement should begin by sealing the end of the tremie with a watertight seal prior to placing the tremie into the water. The seal should be constructed such that water is prevented from entering the tremie pipe, yet will become dislodged when the concrete flow is initiated. The tremie should be sealed and lowered to the bottom of the shaft, then completely filled with concrete. Begin by slowly lifting the tremie 6 inches off the bottom of the shaft to start concrete flow. The concrete supply should continue until soundings or depth measurements confirm that the concrete has attained sufficient head above the bottom of the tremie, at which point both the tremie and concrete should be brought vertically upwards together in a slow and controlled manner.

The mouth of the tremie should always be embedded in the fresh concrete at a minimum depth of 5 feet. Should the bottom of the tremie ever be lifted such that the embedment of the tremie into the concrete is less than 5 feet or if a delay of more than 30 minutes occurs, the concrete pour should be halted and restarted as described below.

Restarting of the concrete placement should begin by sealing the end of the tremie with a watertight seal. The tremie is then pushed down into the concrete to a level at least 5 feet below the level that the tremie was at before concrete placement was halted. The tremie is filled with concrete and concrete placement is continued.

A diversion trench should be cut and consideration be given to where the water in the hole will drain during displacement from the top of the shaft. At the end of the pour, an adequate supply of fresh concrete should be continued until all water and contaminated concrete is displaced and only fresh sound concrete remains at the top of the shaft.

Concrete Pump Placement

Concrete pumps can be used for underwater concrete placement provided surging of the pump line can be controlled and the pump line can be sufficiently kept embedded in the fresh concrete. The pump line should not be less than 4 inches in diameter, and the portion of the line that is in the resteel cage must be a rigid steel pipe.

Placement of concrete is the same as described for the tremie except that an approved plug should be inserted in the pump line near the pump rather than using a seal at the bottom of the pump line.

If concrete placement becomes interrupted for more than 30 minutes, or if the bottom of the pipe comes out of the concrete, then it will be necessary to stop procedures and restart the concrete placement. A stand alone tremie pipe must be used to restart the concrete placement. Restarting using the pump tube shall not be allowed. Restarting concrete placement shall be as previously described for tremie concrete placement.

Work Activity Adjacent to Freshly Poured Concrete

Vibrations caused by near-by work activities can be detrimental to freshly placed concrete. You will need to monitor a freshly poured shaft to evaluate if work activities, such as drilling operations or free-fall concrete placement in an adjacent shaft, are causing excessive vibrations. Place a 2"x4" stake driven solidly in the ground adjacent to the freshly poured shaft. Then place a small container of water on top of the stake. If the water surface remains calm during near-by construction work, then no excessive vibrations are reaching the concrete and drilling operations can continue. However, if the water surface shows any movement, then vibrations

are reaching the concrete and the construction activities should be halted or altered in such a manner as to eliminate the induced vibration. Work activities that induce excessive vibrations to adjacent freshly poured concrete cannot resume until at least 72 hours after placement or until the concrete has attained a minimum compressive strength of 1600 psi.

Drilled Shaft Construction Tolerances

The following construction tolerances should be maintained and checked:

- 1** The drilled shaft shall be within 1/12 of the shaft diameter or 3 inches, whichever is less, of the plan shown horizontal position at the top of the shaft
- 2** The bottom of the shaft shall be drilled to the plan shown elevations, within a tolerance of plus or minus 6 inches.
- 3** The vertical alignment of the shaft excavation shall not vary from the plan alignment by more than 1/4 inch per foot of depth or 3 inches total, whichever is less.
- 4** After all concrete is placed, the top of the reinforcing steel cage shall be no more than 6 inches above nor more than 3 inches below plan position.
- 5** The diameter of the completed shaft shall be the plan diameter with a tolerance of minus 0 or plus 2 inches.
- 6** The top of the shaft shall be built to plan elevation with a tolerance of plus or minus 1 inch. The plan shown elevation of the top of the shaft shall not be changed without prior approval or permission from the Office of Bridge Design.
- 7** Excavation equipment and methods shall complete the shaft excavation with a relatively flat or level bottom.

Drilled Shaft Construction Report

DOT Form 297 should be completed and filled out during the construction of each individual shaft. The Drilled Shaft Construction Report becomes a permanent record of the drilled shaft in place. In addition, the dimensions and elevations recorded are later needed for figuring pay quantities. Figure 4.7 is an example of a completed report.

CSL Testing

Cross Hole Sonic Log (CSL) Testing tubes will be placed on all drilled shafts and testing will be done on all Single Shaft Bents and when problems occur during concrete placement. CSL Tubes shall be filled with water prior to concrete placement. After testing or before column placement the pipes need to be cut off and filled with grout using a tremie pipe to ensure they are filled from bottom to top.

Figure 4.7 Drilled Shaft Construction Report

DOT 297

DRILLED SHAFT CONSTRUCTION REPORT

PROJECT NO. P-BRF 3661 (02) COUNTY DaVison

STRUCTURE NO. 18-160-099

DRILLED SHAFT CONTRACTOR Industrial Builders

INSPECTOR John Smith

FOUNDATION UNIT Bent #2 STATION 8+56

DRILLING OPERATIONS : DATE 4/17/99

TIME : START 7:15 am FINISH 10:00 am
(Shale encountered @ 8:00 am)

SHAFT DIAMETER	PLAN	ACTUAL
	4'-0"	4'-0"
GROUND ELEV.	1263.86	1263.1
TOP OF SHAFT (Top of casing)	1264.86	1264.8
SHALE ELEV.	1248	1249.5
BOTTOM OF SHAFT	1221.0	1221.4

CONCRETE PLACEMENT : DATE 4/17/99

TIME : START 12:15 pm FINISH 2:00 pm

CONCRETE QUANTITY :

PLANS QUANTITY 20.3 ACTUAL 20.6 ±

DRILLING METHOD Permanent Casing

Casing was twisted down approximately 10' ± prior to excavation, then began excavation, last 5' ± of casing was twisted down periodically along with shaft excavation. When chalk/shale was encountered, casing was twisted to set.

WATER CONDITIONS (DRY HOLE, WATER FLOWING INTO HOLE, ETC.)

Had ground water problems and infiltration from 1'-0" ± depth until the permanent casing could be set @ approx. EL 1249 ±. Casing effectively sealed the hole but still had trickling water (less than 3" in one hour). Water was pumped out w/ a sump prior to placing concrete.

CONCRETE PLACEMENT (CONCRETE PUMP, TREMIE PIPE, ETC.)

Since water could be sealed & pumped out, poured concrete by free-fall using a hopper & drop tube @ the top.

DISTRIBUTION: PROJECT FILE
OFFICE OF BRIDGE DESIGN

The following describes where information may be found, or what information should be entered in the report:

- Project Number, County and Structure Number - Obtained from the plans.
- Drilled Shaft Contractor - List the Contractor (Primary or Subcontractor) who is responsible for the construction of the bridge. You should also list the subcontractor who is operating the drilling equipment.
- Inspector - Your signature after completing the report. It is also helpful to print your name underneath for clarity.
- Foundation Unit and Station - Obtained from the plans, list the number and station for the substructure that is being drilled.
- Drilling Operations: Date - The date or dates the drilled shaft is excavated.
- Drilling Operations: Time (start to finish) - Note the times that excavation operations began and ended. It is also helpful to note the time that competent shale was encountered, as this controls the 24 time restriction for pouring concrete.
- Shaft Diameter - List the plans shown diameter, and actual diameter that was drilled.

- Ground Elevation - List the plans shown top of ground elevation (if any), and the actual top of ground elevation during the excavation operations.
- Top of Shaft - List the plans shown top of shaft elevation, and the actual top of shaft elevation after construction.
- Shale Elevation - List the plans shown approximate shale elevation (taken from plan notes underneath 'bents' or 'piers'), and the actual elevation at which competent shale was encountered.
- Bottom of Shaft - List the plans shown bottom of shaft elevation, and the actual bottom of shaft elevation after excavation is complete.
- Concrete Placement: Date - Note the date the shaft was poured with concrete.
- Concrete Placement: Time (start to finish) - Note the times that concrete pouring operations commenced and ended.
- Concrete Quantity: Plans Quantity and Actual - Record the plans shown quantity of concrete, and the actual volume of concrete placed in shaft.
- Drilling Method - Record the method of construction (dry, temporary casing, or permanent casing) that was used to excavate the shaft. Record any changes of method during operations and note any deviations from what was shown on the plans.
- Water Conditions - Record the water conditions encountered during the excavation. It is also helpful to note at what elevations (or depths) certain water conditions were encountered, particularly when documenting switching from the dry construction method to the temporary casing method. Record the condition of water prior to start of concrete placement.
- Concrete Placement - Record the method used for placement of concrete. Record any deviations or circumstances that may have occurred (for instance: break in pouring operations lasting longer than 30 minutes, etc...).

A finished and signed copy of the report should be submitted to the Office of Bridge Design and the Foundations Office as soon as possible after construction. You should also place a copy of the report in the Project Construction File.

PILE DRIVING

Checklists

Prior to Driving

Timber Piling

- Certificate of Compliance received. Certificate clearly documents number of piles of each length, length of each pile, and tab number assigned to pile. Certificate specifically states that material meets the latest South Dakota Specifications.
- All piles have tab number matching certificate
- Each pile checked for circumference and diameter requirements. Pile lengths correct
- Piles checked for straightness requirements
- Pile tips, if used, meet plans requirements. Piles coated with creosote after trimming to fit tip

Steel Piling

- Certificate of Compliance received. Heat numbers of shipment match heat number on certificate
- Pile size and lengths verified
- Piles checked for twisting or bends
- Pile tips (if required) correctly welded and installed on piles

Concrete Piling

- Piles checked for cracks and chips
- Pile size and length verified

Pile Driving Equipment

- Pile hammer is of adequate weight (mass) and minimum energy requirements. All necessary data to determine bearing is obtained.
- Pile cap is of adequate size and fits piles being driven adequately. All necessary data to determine bearing is obtained.
- Pile driving leads are adequate. Markings provided to measure gravity hammer vertical drop (where applicable). Guy lines required.

- Hammer cushion suitable to prevent damage to piles
- Water jetting equipment (if used) capable of delivering 100 psi at 2 jet nozzles

General

- Excavation completed to near bottom of footing. Elevation verified
- Pile locations staked and verified (rechecked)
- Piles clearly numbered and marked for easy identification. Pile weight logged in diary for use in determining bearing
- Piles clearly marked at intermittent intervals to identify depth during driving
- Required penetration per blow determined for each pile prior to start of driving
- Plans' subsurface investigation sheet reviewed for aid in determining approximate depth of bearing. Sheet readily available during driving for reference
- Preboring performed (where applicable). Prebore hole size meets minimum requirements
- Pile cutoff elevation known in the event set-up or splicing will be required
- Splicing material available in the event a pile splice is required

Driving

General

- Leads securely held in place. Batter accounted for and correct
- Leads for gravity hammer are well greased (where applicable)
- Location and batter of pile checked several times and corrected if necessary during first few feet of driving
- Gravity hammer fall limited to 10 feet maximum (where applicable)
- Single-acting or double-acting hammer running smoothly and operating well. If not, operations should be stopped until Contractor can get the hammer up and running in a uniform and consistent manner
- Ambient temperature cold. If so, timber piles should be driven slowly at first until the pile can be 'warmed' up to prevent cracking or possible shatter
- Driving near freshly poured concrete. If so, concrete should be monitored for vibration influence from driving operations. If vibrations are noted, driving operations should be stopped or moved to alternate location

Test Piling

- Penetration measurements and bearings determined at 5 foot increments after first third is driven
- Penetration measurements and bearings determined at 1 foot increments after 75% bearing obtained
- Pile driven to a bearing between 10% and 20% more than plans required bearing
- Unusual items or pick-ups noted at specified depths

Bearing Piling

- Test pile driven. Test Pile Report completed and bearing pile order length determined
- Pile driven to at least the bearing required in the plans, but no more than 10% more than plans required bearing

Pile Set-Up

- Driving stopped if bearing is not obtained with only 2 feet of piling remaining above cutoff elevation
- Pile is allowed a 24 hour set-up time prior to retapping
- Power hammer warmed up on separate pile to operating energy prior to retap
- Cap securely set after first couple of taps
- Penetration measurements taken
- Bearing obtained. If so, then driving operations can be stopped. If not, then pile splicing required

Pile Splicing

- Timber pile shaft trimmed to fit snugly into splice. Affected surfaces of pile coated with creosote after trimming
- Welds on steel pile good. All welds provided
- Location of splice more than 10 feet into the ground

Following Driving

Pile Cutoff

- Cutoff elevation established with a level
- Cutoffs are cut according to plans, horizontal or in plane of pile. All damaged pile material removed
- Timber pile ends coated with creosote or Copper Napthenate after cutoff
- Cutoff lengths measured and recorded in diary and on pile reports

Pile Reports

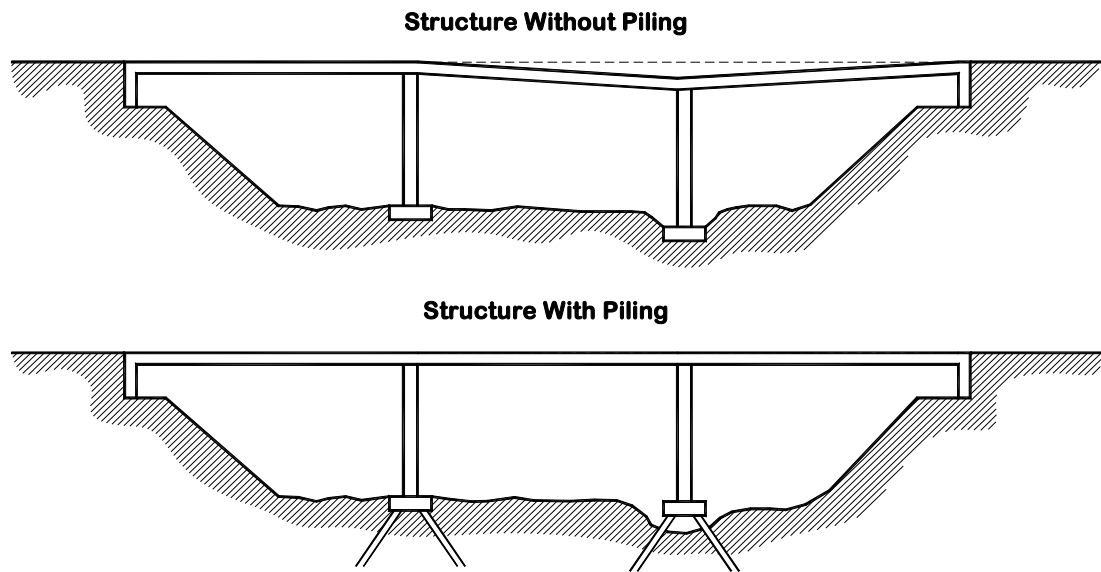
- Test Pile Report completed for each test pile and sent in to the Office of Bridge Design
- Pile Inspector's Report (Bearing Pile Report) completed and logged in project files

General

Piles are long slender members usually made of timber, steel, or reinforced or prestressed concrete that are driven into the ground to carry a vertical load as well as resist a lateral force. Piles are used when the soil investigation indicates that the soils at and below the elevation of the bottom of the structure footings are too weak or too compressible to provide a stable foundation without possible settlement of the structure. In addition, piles may be used for a footing when there is danger of erosion or scour that would undermine the soil underneath the footing, such as in streams or rivers.

Generally pile-driving inspections involve the use of sound judgment which can only be attained through training and experience. The inspector must determine the acceptability of the pile before it is placed in the leads, must observe the performance of the hammer, must determine when damage or breakage has occurred or is likely to occur, and must make a judgment regarding acceptable penetration and bearing capacity.

Figure 5.1 Piling Support



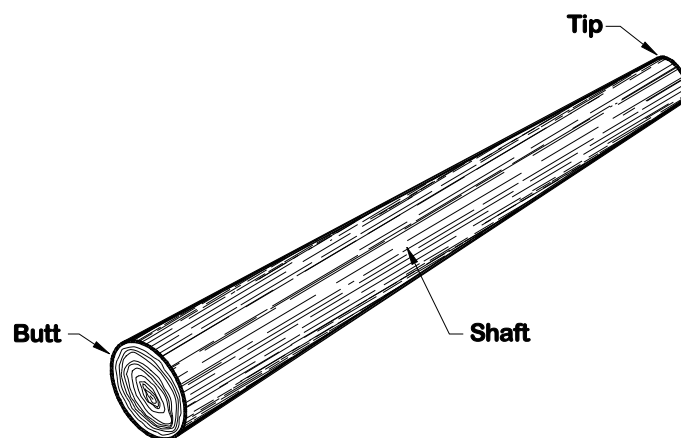
Pile Types

There are three basic types of pile that may be used in a structure:

- Timber Pile
- Steel Pile
- Concrete Pile

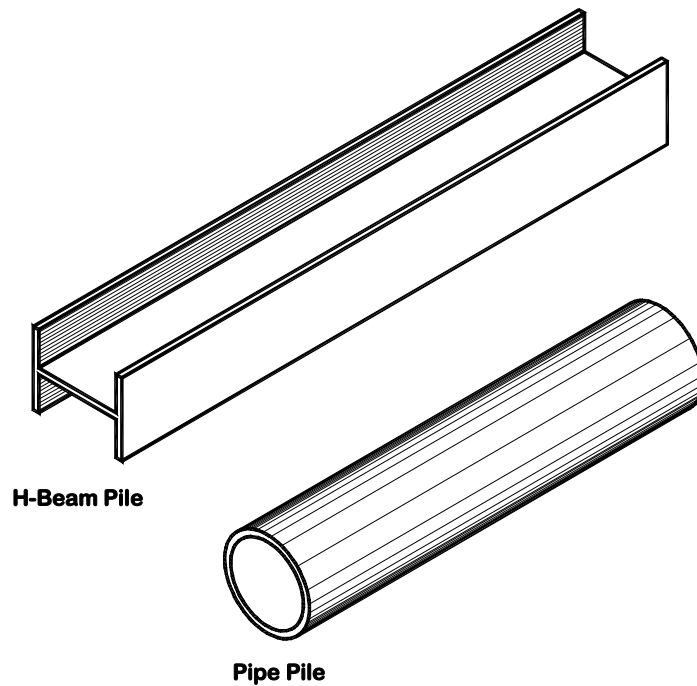
Timber Piles are made from trees having branches and bark removed. The principle parts of a timber pile are the tip, shaft, and butt. The tip is the small end that enters the ground first. The butt is the large end of the pile that is pounded on to drive the shaft into the ground.

Figure 5.2 Timber Pile



Steel Piles are made from round pipe or standard structural shapes called "H-Beams". The term "H-Beam" comes from the fact that when viewed from the end, the beam looks like an "H". Steel pile can be obtained in a variety of sizes and weights. The kind specified for a particular project is determined from design needs.

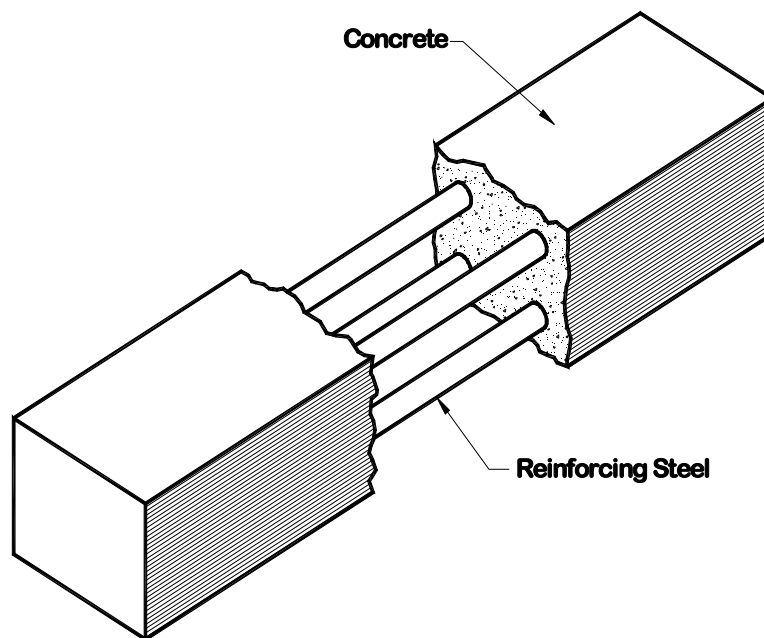
Figure 5.3 Steel Pile



Concrete Piles are constructed using standard reinforcing bars, prestressed strands, or a combination of both. Typically they are cast in forms in a fabrication yard, where they are cured to attain the desired strength and then shipped to the site to be driven into the ground. On occasion, holes are drilled into the ground first and then filled with the concrete.

The Cross-sectional shape of concrete pile will vary depending on what the designer feels is needed to meet the design requirements. The most commonly used shapes for concrete pile are round, square, hexagonal, or octagonal.

Figure 5.4 Concrete Pile



Pre-Driving Pile Inspection

Before a pile is used, an inspection is needed to ensure that it meets project specifications. The best time to make this inspection is when the material is delivered, resulting in little or no work stoppage.

Timber Pile

The timber that the DOT accepts includes Douglas Fir, Hemlock, Spruce, Tamarack, Oak, Cedar, Pine, Cypress, and other hard woods. Other kinds of timber have some negative characteristics.

Timber pile is generally treated with a preservative to prevent rotting. For identification, each group being treated is given identical numbers stamped on a metal tag attached to the pile. The manufacturer maintains a record of preservatives used to treat the timber, the kind of tree, the number treated, and the tag number assigned to each group. A copy of these records is sent to the Central Testing Laboratory to insure the treatment meets specifications.

It is difficult to check the pile treatment without considerable testing. As it is impractical to hold up pile use until tests are run, the supplier is allowed to submit a document with each pile shipment certifying the pile meets specifications. This is a Certificate of Compliance and should be similar to the one shown in Figure 5.5

Figure 5.5 Example Certificate of Compliance on Timber Piling

No.	Truck Ticket No.	Pcs.	Length	Tag No.
41-3499	24795	3	35'	#10362
I, James H. Mills, Huron Manager of the Wheeler Lumber Bridge and Supply Co., Box 1434, Huron, S. D., hereby certify that the material delivered to _____		9	35'	#10356
Sioux Falls Construction Company				
on Project No. F053-2(8) - Turner County				
will meet the latest South Dakota State Highway Specifications, and upon completion of the above project, a summary certificate will be furnished. However, the central Testing Laboratory at Pierre has been furnished proper treatment certification on each shipment to us, showing tag identification numbers included hereon.				
Date: August 22, 1968	Inspector _____			
Notarization	Resident (2) _____			
My commission expires June 16, 1972	Contractor _____			
Wheeler Lumber Bridge & Supply Co. By <u>James H. Mills</u> James H. Mills, Huron Manager				

A Certificate of Compliance must accompany each pile shipment to the job site. The truck driver should have the certificate, and you need to obtain it when the piles are unloaded. Three things that must appear on the certificate are:

- The number of piles of each length
- The length of the pile
- The tag numbers assigned to the pile

In addition the Certificate of Compliance will state "The material delivered will meet the latest South Dakota Specifications." This statement means the pile meets

requirements for treatment and soundness (knots, cracks, checks, etc...). Upon delivery, check whether the certificate actually covers the pile in the shipment.

If any pile is missing a tag number, reject it. If any pile has a tag number different from what is shown on the certificate, place the pile aside and have the Contractor obtain a new certificate. However, if any is of a length different than shown, or if the quantity is more or less than shown, the shipment can be accepted for use. Put a note on the Certificate of Compliance specifying the difference.

Once you have documented the shipment, the Certificate of Compliance becomes your authorization to accept the pile for use. Make an entry in your diary that certificate number "xxxx" was received and checked with the shipment. Also note any changes that you made on the Certificate. Then give it to the Project or Area Engineer so it can be forwarded to the Testing Engineer.

Check the circumference and diameter of the pile at both the tip and butt for the following:

- To see that the circumference and diameters meet the requirements
- For use later in figuring the weight of the pile

Figure 5.6 Circumferences and Diameters of Timber Piles

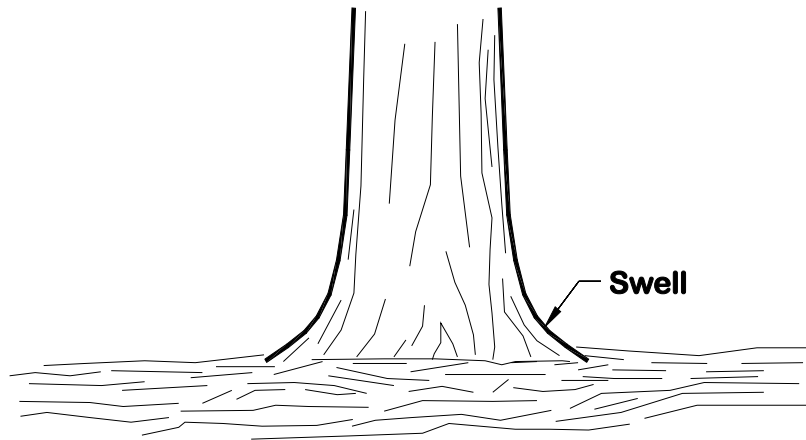
(US Customary)						
Length in Feet	<i>3 Feet from Butt</i>				<i>Tip</i>	
	Minimum		Maximum		Minimum	
	Circumference	Diameter (approximate)	Circumference	Diameter (approximate)	Circumference	Diameter (approximate)
	(Inches)	(Inches)	(Inches)	(Inches)	(Inches)	(Inches)
Douglas Fir, Hemlock, Pine, Spruce or Tamarack						
Under 40	35	11	63	20	25	8
40-50 incl.	38	12	63	20	22	7
51-70 incl.	41	13	63	20	22	7
71-90 incl.	41	13	63	20	19	6
Oak and Other Hardwoods, Cypress						
Under 30	35	11	57	18	25	8
30-40 incl.	41	13	63	20	22	7
Over 40	41	13	63	20	19	6
Cedar						
Under 30	35	11	69	22	25	8
30-40 incl.	41	13	69	22	25	8
Over 40	41	13	69	22	22	7

Figure 5.6 above lists circumference requirements of the pile before it can be accepted. The Specifications permit piling less than 30 feet in length to have a minimum butt circumference of 35 inches and a minimum tip diameter of approximately 11 inches. The balance of the table applies to all piling.

The tip circumference is measured at the tip of the pile. The butt circumference is measured 3 feet from the butt of the pile. This is done because a tree cut near the ground line will be somewhat flared. This flaring is called "ground swell". Finding the circumference at the butt of a pile with this ground swell would give you a larger circumference than the pile actually has.

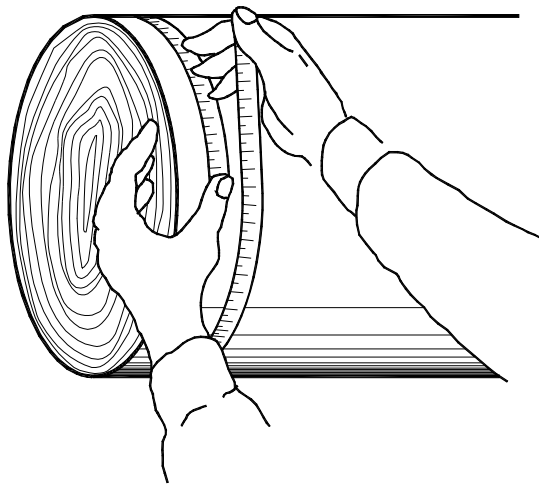
Remember: The butt circumference is always measured 3 feet from the butt end of the pile.

Figure 5.7 Ground Swell of Tree Trunk



Use a steel tape to measure the circumference of the tip and butt. Measure to the nearest whole inch. Since most pile are not perfectly round, the ratio of the maximum butt diameter divided by the minimum diameter of the butt or tip is required to be less than 1.2. You can get these diameters by holding the tape across the pile and "eyeballing" the measurements. Take the diameter measurements to the nearest 1/2 inch.

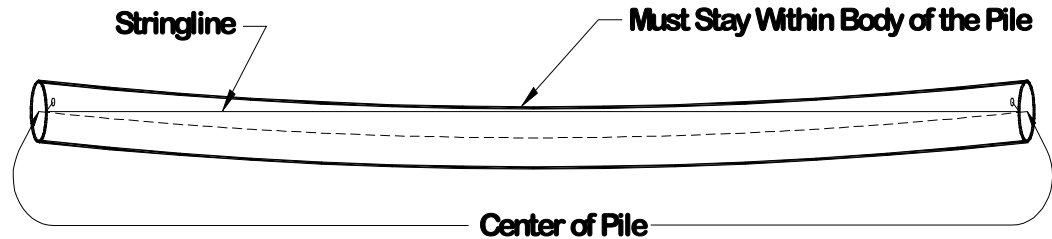
Figure 5.8 Measuring Circumference with Tape



You should also measure the length of each pile. This information is used later to find the weight of each pile and for payment purposes. Measure the length to the nearest 0.1 foot. Record circumference, diameters, and length of each pile in your diary. So you will know what dimensions belong to which pile, number each pile while you are inspecting it with yellow keel or paint. You also need to know what length is in the ground when driving the pile. Start at the tip and put marks every 5 feet for 3/4 of the length and mark each foot from there to the butt.

You also need to check the straightness of the pile shaft. If the shaft is curved, it will follow a curved path when driven into the ground and will not be in the desired location. To meet the straightness requirement, a string line stretched from the tip to the butt must stay within the body of the pile. Check this by turning the pile until you locate the most curvature. Drive nails into the tip and the butt at locations that are at right angles to the curvature. Then stretch a string line between the nails, and "eyeball" to see if the string line is inside or outside of the body of the pile. You need to check only those which appear to not meet requirements.

Figure 5.9 Checking Straightness of Timber Pile



Steel Pile

The material in steel pile must meet specifications. Specification testing is impractical. Therefore, we rely on tests made during the production of the steel. As steel is produced, the manufacturer gives it a heat number. Both chemical and physical tests are made on the material of each heat number. The test results are sent to the suppliers and the Testing Engineer.

Similar to timber pile, the supplier sends a Certificate of Compliance along with each shipment. The certificate should be similar to the one shown in Figure 5.10. Once delivered, check the heat numbers of the shipment against those on the Certificate of Compliance. The heat numbers (circled in Figure 5.10) should be either stamped on each pile or on a tag attached to each pile. If the heat number is not with each pile, or if a pile has a heat number different than those on the certificate, inform the Contractor that the pile cannot be accepted until there are heat numbers, or until a Certificate of Compliance is received.

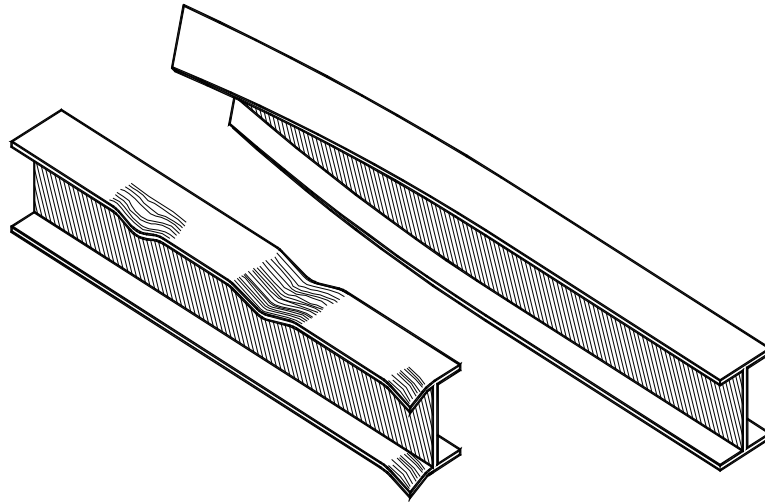
Figure 5.10 Example Steel Pile Certificate of Compliance

PRODUCTION DEPARTMENT - METALLURGICAL United States Steel Corporation		JO		PAGE 01 OF 01														
TEST REPORT OF <u>IL R CARB H PILES</u> WORKS <u>SOUTH</u> U.S. ORDER NO. <u>HM 60113</u> INVOICE NO. <u>187-0-79247</u> CUSTOMER ORDER NO. <u>1895 2/22/65</u> CAR OR TRUCK NO. <u>RT 852</u> SHIPPER NO. & DATE <u>002764 05/23/65</u>				STATE OF ILLINOIS COUNTY OF COOK SUBSCRIBED AND SWORN TO BEFORE ME THIS <u>4TH</u> DAY OF JUNE 1965 NOTARY PUBLIC MY COMMISSION EXPIRES <u>7/1/66</u>														
EGGER STEEL CO 909 SOUTH SEVENTH STREET P O BOX 1495 SIOUX FALLS SOUTH DAKOTA		EGGER STEEL CO 909 SOUTH SEVENTH STREET SIOUX FALLS SOUTH DAKOTA		BEING DULY SWORN ACCORDING TO LAW, DEPOSES AND SAYS THAT THE CHEMICAL ANALYSIS AND/OR TESTS SHOWN IN THIS REPORT ARE CORRECT AS CON- TAINED IN THE RECORDS OF THE COMPANY. <u>KIENKER</u>														
H PILES OR ASTM A-36-62T MILL 5 SW T/R TO CHG TO				E. C. RUDOLPH, CHIEF METALLURGIST DATE <u>6/1/65</u>														
ITEM NO.	HEAT NO.	PIECE IDENTITY NO.	NO. PCS.	THICKNESS OR SECTION	WIDTH DIA. OR FT. WT.	LENGTH	WEIGHT	YIELD ST. PSI.	TENSILE STR. PSI.	ELONGATION % IN 8"	% RED. OF AREA	REMARKS						
	121234			C8P 103	1/2"	60 FT	25200	41950	68420	29.0								
	111303			C8P 103	1/2"	60 FT		39440	65600	29.0								
	211243			C8P 103	1/2"	60 FT		43450	69300	28.2								
	151248			C8P 103	1/2"	60 FT		42990	67240	30.2								
	151249			C8P 103	1/2"	60 FT		44430	65860	28.0								
	181282			C8P 103	1/2"	60 FT		39620	66240	30.0								
SPECIMEN SIZE TESTED ACCORDING TO COMPANY RECORDS CONFORMS TO THE REQUIREMENTS OF THE SPECIFICATION LISTED ABOVE.																		
HEAT NO.	TYPE	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	Al	N	V	B	Bi	Cb	Co
121234	L	21	63	012	027													
111303	L	22	62	011	025													
211243	L	22	70	010	021													
151248	L	22	66	011	032													
151249	L	23	71	010	024													
181282	L	22	61	011	020													

When satisfied that the certificate covers the pile delivered, make an entry in your diary. Give the certificate to your Project or Area Engineer for forwarding to the Testing Engineer where chemical and physical test results for these particular heat numbers will be compared with original test reports.

The only inspection needed for steel pile is a visual inspection. Rust does not hurt the pile, unless it has started to make "pits" in the steel. Of primary concern with steel pile is twisting and bending during handling. If you find a pile that is twisted or bent, it needs to be rejected.

Figure 5.11 Damaged Steel Piling



Steel pile is generally about 60 feet long. If the defect is where it can be cut off and still give you the length of pile needed, you need not reject the whole pile. Advise the Contractor that they are allowed to use the pile, after the damaged portion has been cut off. Note your discussion in your diary along with the reason for rejecting a portion of the pile.

Concrete Pile

Concrete pile is generally precast and/or prestressed. An inspector will be sent to the plant and will check dimensions, materials specifications, and fabrication. Your responsibility is inspecting for visual damage such as cracks and chips. If a pile has a crack that extends through the pile, or where the concrete is chipped out to a depth of 10% of the pile width, reject the pile.

Improper handling may cause damage. The plans will show how the concrete piles are to be picked up in order to be moved. If the Contractor does not handle them by the methods shown, reject the pile.

Pile Drivers

A pile driver is used to drive the pile into the ground. There are 3 basic parts to all pile drivers: the hammer, the cap, and the lead.

- The hammer is a large heavy block or piston used to actually drive the pile. The hammer (or piston within the hammer) is raised above the pile and the force of its falling pushes the pile into the ground.
- The cap is a small metal block that fits over the butt end of the pile. Its purpose is to hold the pile in position and to protect it from being damaged by the hammer blows.

- The lead is the framework used to guide the hammer. There is a guide that the hammer slides up and down on. This keeps the hammer lined up, so it strikes the pile squarely each time. During the driving operation, the top of the lead is attached to the crane. If the lead is long, the bottom will rest on the ground. When a short lead is used, it should be stabilized in some way so the pile can be held in its proper position. Generally, this is done by use of guy lines.

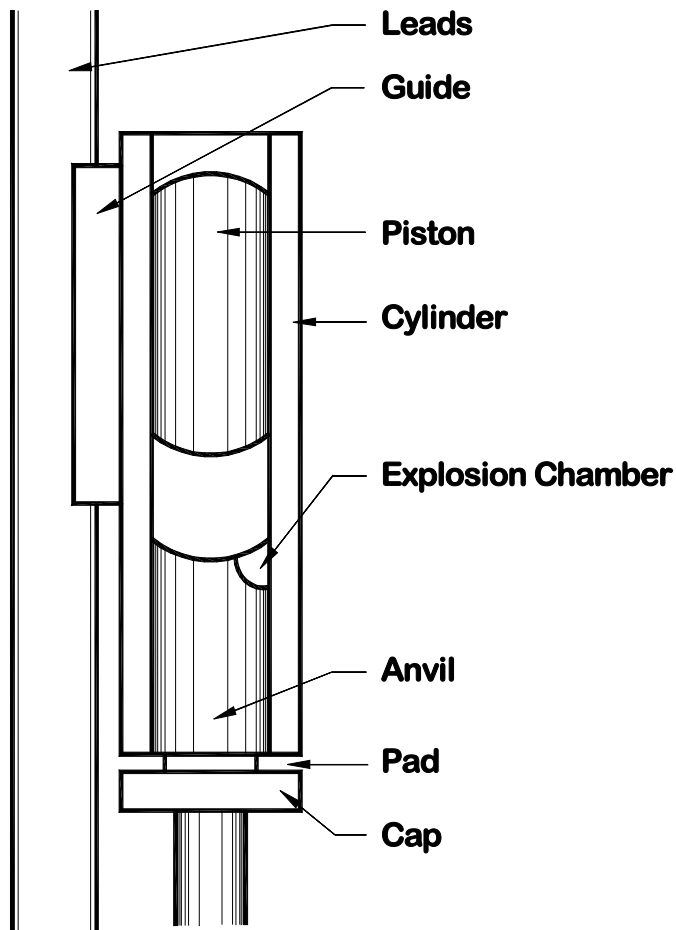
To drive pile into the ground, the falling hammer must transfer its energy to the pile. The energy being delivered to the pile varies with the hammer and its use. The 2 types of hammers commonly used to drive pile are: Single-acting and Double-acting hammers.

Single-Acting Hammer

A single-acting hammer is a large weight that delivers a blow by free falling. It differs from the gravity hammer in that its hammer is a piston inside a cylinder. Instead of using a cable to raise the piston, it is raised by compressed air, steam, or diesel explosion.

Figure 5.12 shows a typical single-acting pile driver. Notice that the leads are an I-beam that has an attached driver. The cut away shows the inside of the cylinder. The bottom part of the cylinder is called the "anvil" and contains the "explosion chamber". This is where the compressed air, steam, or diesel fuel is introduced. It works like a car engine; the explosion chamber fires and the piston is forced upward. After the piston drops there is another explosion and the process is repeated.

Figure 5.12 Single-Acting Hammer

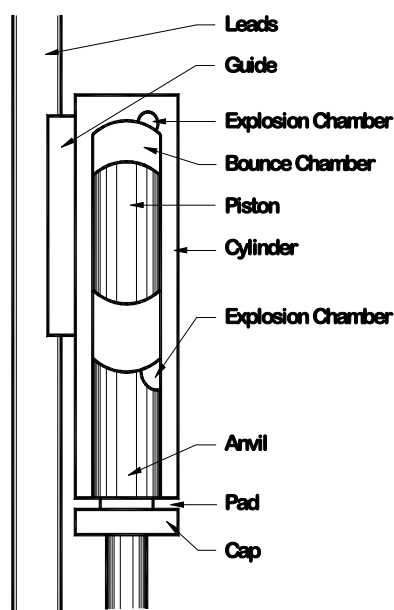


A single-acting hammer should develop sufficient energy so that the pile penetration is about 10 blows per inch at the design bearing. Often there will be a plan note specifying a minimum energy rating. Energy should never be less than specified in Standard Specifications Section 510.3 B.2. The energy of the hammer is equal to the weight of the piston times its free fall distance.

Double-Acting Hammer

A double-acting hammer is a modification of the single-acting hammer. The top of the cylinder is enclosed. Some hammers have a "bounce chamber". Others have a bounce chamber as well as another explosion chamber. As the piston is forced upward, the air is compressed in the bounce chamber. When the piston starts down, the compressed air expands and gives the piston an additional push. This increases the force with which the piston hits the anvil. By having another explosion chamber at the top of the cylinder, more force can be applied to the downward movement of the piston. Charts are necessary to determine the energy delivered to the pile, because of the extra force that is applied to the piston of a double-acting hammer. The manufacturers have prepared charts and graphs for the different hammer models to determine energy. The Contractor must furnish you the chart or graph for the particular hammer in use.

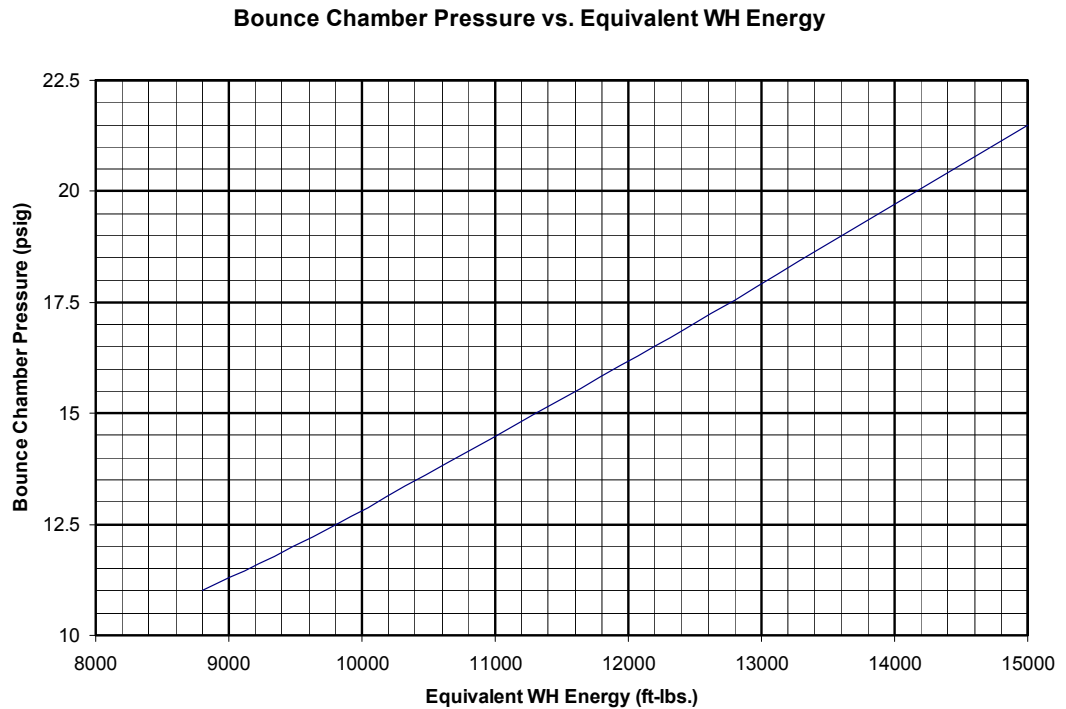
Figure 5.13 Double-Acting Hammer



Bounce Chambers

The energy generated by a hammer with a bounce chamber is found by using the pressure in the chamber. As the pile is being driven, look at the pressure gauge to find the pressure of the operating hammer. After noting the pressure gauge reading, use the chart to find the energy being applied. Figure 5.14 shows a typical chart that is used to convert pressure to energy.

Figure 5.14 Typical Pressure to Energy Conversion Chart



The left hand side of the chart lists operating pressures. Read horizontally from this point to the calibration line, then down to the bottom to obtain the foot-pounds of energy.

Example: A Link-Belt Speed Hammer Model 312 is operating at a pressure of 16.8 pounds per square inch (psi). Based on the chart shown in Figure 5.15, how much energy is the hammer delivering per blow? At 16.8 psi, the hammer would be providing an equivalent energy of roughly 12,400 ft-lbs.

Explosion Chamber

When the hammer has another explosion chamber at the top of the cylinder, the energy is based on the blows delivered per minute. The blows delivered per minute vary with the pressure applied to the explosion chamber. Determine blows per minute at a certain pressure in order to find the energy being delivered per blow. This is accomplished by counting between 50 and 100 blows, depending on the hammer being used. Use a stopwatch to do the timing. Don't watch both the hammer and the stopwatch while you are counting the blows. Count the blows until you have the number desired and stop the watch. A blow is counted each time the hammer strikes the anvil. Divide the "time" into the number of blows counted to determine blows per minute. To find the energy delivered, you will need a table or chart similar to the one shown in Figure 5.15.

To utilize the table in Figure 5.15, first locate the type of hammer being used. Find the blows per minute previously determined and read the foot-pounds of energy per blow. If the blows you figured are not shown, you need to set up a ratio to find the energy delivered.

Important

The hammer must be operated so the blows per minute fall within the limits given for each hammer. Pressure must be held constant during the driving so the blows per minute remain constant.

Figure 5.15 McKiernan-Terry Corporation Double-Acting Hammer Speeds and Ft.-Lb. Per Blow

Hammer	Strokes per Minute	Ft.-Lb. Blows
6	275	2,500
	230	2,160
	200	1,680
7	225	4,150
	195	3,720
	170	3,280
9B3	145	8,750
	140	8,100
	135	7,500
	130	6,800
10B3	105	13,100
	100	12,000
	95	10,900
	90	9,550
11B3	95	19,150
	90	18,300
	85	17,500
	80	16,700

Example: A McKiernan-Terry Model 9B3 is being used for pile driving. Eighty-Two blows were counted during a period of 36 seconds. What energy is being delivered per blow?

- 1 Convert to blows per minute: $\frac{82}{36} \times 60 = 137$ blows per minute.
- 2 Interpolate for Energy: From Figure 5.16, at 137 blows per minute for hammer 9B3, the energy would be approximately 7,700 ft.-lbs.

Minimum Energy Requirements

Mechanically powered hammers need to be able to develop a minimum energy level in order to successfully drive piling. Standard Specifications Section 510.3.B.2 requires that the minimum energy as per the hammer manufacturer's rating shall not be less than that required to achieve design bearing when the penetration is 0.1 inch per blow. In addition, plan notes will often define or set a minimum energy rating that the hammer must be capable of developing or a list of Approved Hammers. You should check and verify that the hammer to be used is capable of meeting the minimum energy levels required or on the list of hammers. If the hammer to be used is not on the Plan's list, then it must be approved by BCE prior to allowing pile driving to commence.

Water Jetting

Occasionally a Contractor may choose to use water jetting as an aid in driving the production piling. Jet nozzles are located near the tip of the pile. During driving, the jet nozzles erode the soil material adjacent to the pile in such a manner that often penetration is accomplished merely by the weight of the pile and hammer themselves. Jetting is particularly effective when piles are to be driven through dense fine sand to desired penetration in firmer soils below.

A pumping plant is required to supply pressure through piping to the jet nozzles at the tip of the pile. Specifications require that the pumping plant supplying water to the jet nozzles be capable of maintaining at least 100 psi hydraulic pressure at 2 jet nozzles. Before desired penetration is reached, the jets should be withdrawn and the piles should be driven with the hammer to firmly secure the piling and provide final

bearing. The final penetration driving should be at a minimum depth of 5 feet or to refusal of the pile.

Note that jetting is not recommended for driving the test piling, but should only be used on the production or bearing piling. The reason is that the driving of the test pile provides a 'bearing log' that gives actual bearings for various depths of the pile. If jetting were utilized for the test pile then this 'log' would not be generated, and only the final portion of the driving would be recorded. Test piles are covered in more depth later in this chapter.

Vibratory or Sonic Power-Driven Hammers

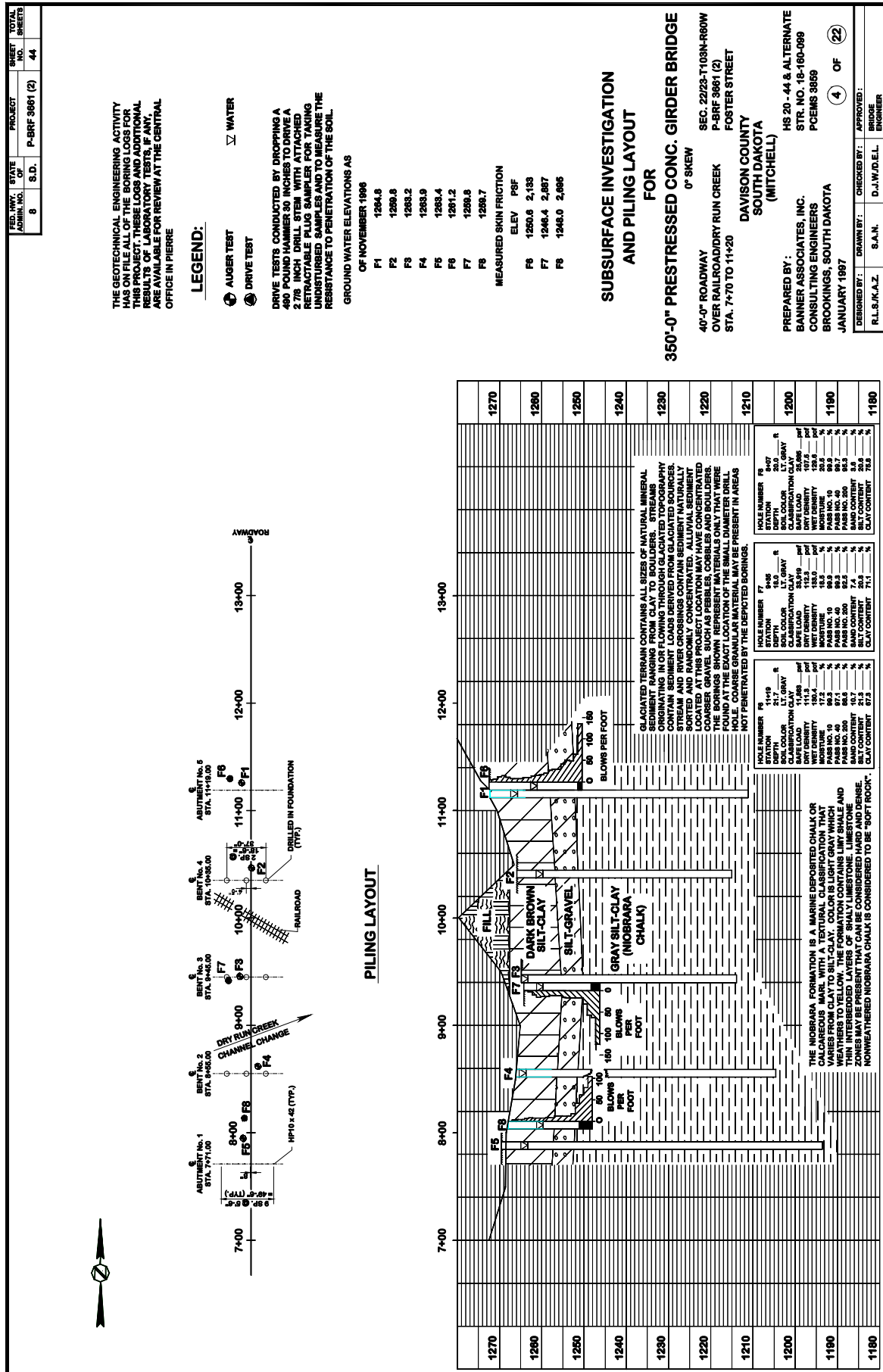
Occasionally you may hear of vibratory or sonic power-driven hammers. Vibratory hammers vibrate the pile at a frequencies and amplitudes which tend to break the bond between the pile surfaces and the adjacent soils, thus delivering more of the developed energy to the tip of the pile while decreasing the resisting skin friction. A sonic hammer operates at higher frequencies than vibratory hammers, and is tuned to the natural resonant frequency of the pile. At this frequency, the pile changes minutely in dimension and length with each cycle, thus alternately enlarging the cavity then shortening the pile.

Because many of the piles driven in South Dakota are skin friction developed piles, and because these driving methods tend to compromise or destroy this friction, vibratory or sonic hammers and driving methods are not allowed or utilized. Should the Contractor inquire as to using these types of hammers, you should advise them that they are not allowed. The Office of Bridge Design can be contacted for more information.

Subsurface Investigation

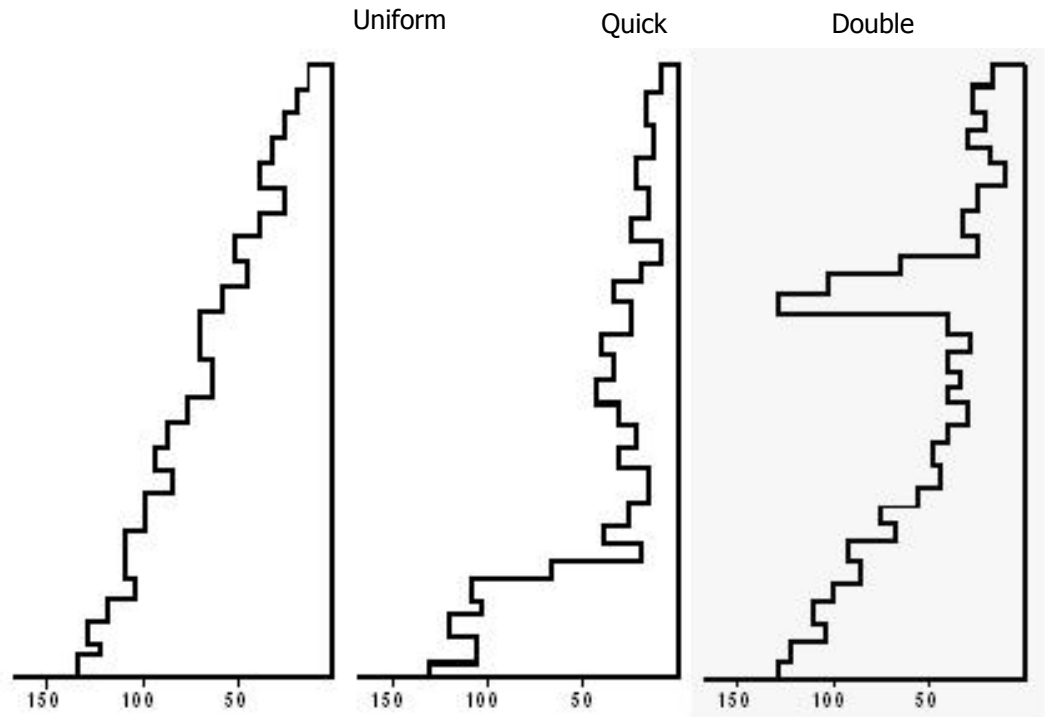
Bridge plans include a page on subsurface site investigation. Figure 5.16 is a typical subsurface investigation and piling layout sheet. The upper portion is a layout with the location of the structure, project center line, piling layout, and test holes. The bottom half is a geographical profile of the area showing the natural ground profile along with the types and depths of materials below the area. The main item here is the blow per foot graph.

Figure 5.16 Typical Subsurface Investigation and Piling Layout Sheet



The graph of blows per foot depicts information obtained from the drive test during the foundation investigation. The graph depicts the blows it takes to push a test driver through each foot of material. The fewer the blows required to drive the test driver through a foot of material the less bearing support available. Knowledge of the materials at the site gives you an idea of how your pile will pick up bearing. The bearing of a pile will generally increase in about the same fashion as the blow count graph. The shape of the blow count graphs fall into 3 general types: uniform, quick, and double buildup.

Figure 5.17 Uniform, quick, and double buildup graphs



A uniform buildup graph looks something like that shown above, indicating that the soil is fairly consistent and will exert a uniform pressure on the pile during driving. You can expect the bearing of a pile to increase uniformly when driven in this type of area. The bearing will be almost entirely picked up by the friction between the pile and the soil.

The upper part of the quick buildup graph shows the soil has little supporting power. The pile will pick up only a small amount of bearing in this zone. The bottom of the graph shows a rapid pickup of blow counts, which indicates a hard layer. You can expect the pile to pick up bearing quickly near the end and be mostly point bearing.

The double buildup graph tells you that there is hard material overlaying softer material. This graph always shows two distinct areas of high blow counts. The graph shape leading up to these two areas may be either uniform or a quick buildup.

The normal procedure is to investigate the site prior to designing the structure. Several problems may develop. First, the test holes seldom fall where the sills and bents are to be built. Because materials may change in a few feet, the blow count graph may not be exact for where the pile will be driven. Second, the water table at construction time might be higher or lower than when investigated, causing an inaccurate blow count graph. Test piles are used to check these variables.

Pile Reports

You should complete the current pile report forms when driving pile. The Test Pile Report is shown in Figure 5.18 and a Pile Inspector's Report (Bearing Pile Report) in Figure 5.19. The forms become a permanent record of the pile length in place and the bearing obtained. The length of pile in place and cut off are needed for figuring pay quantities.

Complete a Test Pile Report for each test pile driven. All the bearing pile for a particular unit of the structure (Abutment #1, Bent #2, etc...) should be entered on one Bearing Pile Report. Use a separate report for each unit of the structure.

Figure 5.18 Example Test Pile Report - DOT 203

**SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION
INSPECTOR'S TEST PILE REPORT**

PROJECT NO. BRF 6599(03) PCEMS 6086 COUNTY Brown STR. # 07-110-356
 CONTRACTOR IBI
 STR. TYPE 85' -0" Bulb Tee FOUNDATION UNIT Abutment #1
 TYPE OF PILE HP 10X 42 ON HWY OVER Footh Creek
 TYPE AND NO. OF HAMMER Single Acting Diesel INSPECTOR STATION
 WEIGHT OF STRIKING PART 3,300 lbs
 WEIGHT OF CAP 1450 lbs CAP # A 146 WT OF ANVIL 1140 lbs
 REQ'D BEARING 192

REMARKS:

TEST PILE NO.	PILE SIZE			ELEVATIONS						PILE LENGTH			PAY QUANTITIES		
	TIP (FT.)	BUTT (FT.)	WT. PER FOOT (LBS.)	LENGTH (FT.)	TOTAL WT. (LBS.)	FINAL TIP	PLAN CUTOFF	GROUND	WATER	PLAN DRIVEN (FT.)	DRIVE (FT.)	PREBORE (FT.)	SPACE (FT.)		
1C			42	60.0	2520	1343.87	1285.87	1285.87	1291.00	57.0	59.0		6.0		

AVE. OF LAST 10 BLOWS				AVE. OF LAST 10 BLOWS				AVE. OF LAST 10 BLOWS			
BLN PLCE	TR402	TR402	TR402	BLN PLCE	TR402	TR402	TR402	BLN PLCE	TR402	TR402	TR402
LENGTH (FT.)	0.0000	0.0000	0.0000	LENGTH (FT.)	0.0000	0.0000	0.0000	LENGTH (FT.)	0.0000	0.0000	0.0000
20.0	4.57	4.4	3.50	0.35	66.5	52.5	52.2	5.2	0.75	0.08	302.0
30.0	5.00	4.3	4.00	0.40	58.5	53.0	52.3	5.4	0.75	0.08	309.8
35.0	5.02	4.2	2.50	0.25	81.6	53.0	52.4	5.3	0.63	0.06	221.7
36.5	5.04	4.6	1.50	0.15	125.1	53.2	52.4	5.4	0.63	0.06	223.9
38.0	5.05	4.5	3.00	0.30	76.5						
39.5	5.06	4.7	2.75	0.28	85.2						
41.0	5.07	4.2	2.75	0.28	76.1						
43.0	5.08	4.6	2.62	0.26	86.4						
45.0	5.10	4.9	2.12	0.21	106.8						
47.0	5.12	4.8	1.75	0.18	118.7						
48.0	5.14	4.9	1.63	0.16	126.9						
49.0	5.16	5.1	1.50	0.15	138.7						
50.0	5.18	5.0	1.13	0.11	160.0						
50.5	5.19	5.1	1.13	0.11	163.2						
51.0	5.20	5.2	1.13	0.11	166.4						
51.5	5.21	5.2	1.00	0.10	176.8						
52.0	5.21	5.2	1.00	0.10	176.8						

NOTE: Sketch footing on reverse side and indicate position of this pile. Where pre-boring is required, use bottom of preboring as ground elevation.

Remarks: Sketch need not be to scale. Show plan view of footing with position of test pile in relation to other piling, centerline of roadway, centerline of substructure unit and north arrow.

Drive test pile as near to the center of piling group as practical. Record time at start of test pile driving and when each bearing check is taken. Take at least one bearing check each five (feet) during driving and at approximately one (1) foot intervals after bearing is reached.

Figure 5.19 Example Pile Inspector's Report

cc-Bridge Design
Foundations

General Information

The tops of these reports are similar and you can complete most of this area prior to driving the pile. A majority of information required is from the plans and items inspected. The following describes where information may be found.

- Project No., PCN, County, Structure No.- Obtained from the plans. When there are two or more structure groups in a project also give the group number.
- Contractor - Use the name of the Contractor awarded the contract. If a Subcontractor is building the structure, list their name also.
- Structure - This is the description of the structure being built and is on the plans (80 feet Continuous Concrete, 276 feet 2 1/2 inches I-beam, etc...).
- Type and Material of Pile - This is a description of pile being used (treated timber, HP10X42 steel, etc...)
- Type and No. of Hammer - This is a full description of the pile driver being used (Link Belt 180 Double-Acting, Vulcan #3 Single-Acting, etc...). For gravity hammers, also give the number assigned by the State if available. If it does not have one, a Pile Driver Data Sheet will need to be filled out and submitted to the Office of Bridge Design.
- Weight of Striking Part - This is the weight that you found in the Weight File, you weighed yourself, or from the manufacturers specifications.
- Weight of Cap and Cap No. - Cap weight from the Weight File or the weight you obtained. Also give the number assigned by the State if available. If no number is available a Pile Driver Data Sheet will need to be completed and submitted to the Office of Bridge Design.
- Anvil weight - Some energy hammers have an anvil weight that must be included with cap and pile weights in "M".
- Bearing Required (Tons) - It is the amount specified for bearing pile on the plans.
- Foundation Unit (Test Pile Report) - On the plans, this identifies the location of particular pile in the structure (Abutment #1, Bent #3, etc...).
- Date - The date pile are driven.
- Inspector - Your signature after completing the report. Don't print your name.
- Station - Location of pile being driven with respect to the survey center line.

Test Pile Information

The remainder of the form is completed using information from your initial inspection of the pile and during the Driving Operation. Beginning with the Test Pile Report, the following is necessary.

- Test Pile No. - The number you placed on the pile during preliminary inspection.
- Pile Size - Taken from your Diary recorded during the preliminary inspection. The tip and butt diameters are filled in only when using timber pile. Give the actual length of the pile even if it is greater than what was ordered.
- Elevations
 - Tip Final - This is the pile tip elevation after pile is in place. It is obtained by subtracting the length of the pile in place from the cutoff elevation.
 - Ground - This is the elevation of the ground line through which the pile is being driven. Use the bottom of the footing elevation for this except where you prebore, then use the bottom of hole elevation.

- Water - Fill this in when driving pile in a location surrounded by water. It is the elevation of the surrounding water.
- Plan Cut Off - This elevation to the nearest 0.1 foot is from the plans.
- Length Bearing Pile (refers to the bearing pile length, fill in after the test pile is driven)
 - Plan - The estimated length of bearing pile listed on the plans.
 - Length Driven - Plan cut off elevation minus final tip elevation.
- Pay Quantities
 - Drive - Linear feet of pile, to the nearest foot, remaining in the structure.
 - Prebore - If preboring was performed; indicate linear feet of preboring.
 - Splice - Number of splices to be paid. Splices that qualify for payment are those required due to the specified length being insufficient.

The bottom portion of the Test Pile Report is a log of the driving operation. These following are items in the log.

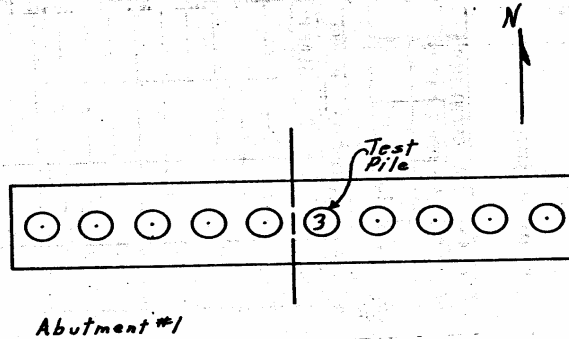
- Pile in Place
 - Length - This is the pile that has been driven into the ground and measured from the cutoff elevation. You record the length to the nearest 0.5 foot every time you measure the penetration for a bearing calculation.
 - Time - Record the hour and minute you measured the penetration for a bearing calculation.
- Average of Blows
 - Filled in by inspector: (10 blows for energy hammer)
 - "H" or "E" - This is the free fall distance ("H") of a gravity or single-acting hammer recorded to the nearest 0.1 foot. When a double-acting hammer is being used, fill in with the energy ("E") being applied.
 - Total Penetration - This is the penetration of the pile in the specified number of blows.
 - "S" - This is penetration ("S") per blow. Convert the distance to the nearest 0.01 inch and divide by the number of blows.
 - Bearing - The bearing calculated for the various depths while the pile was being driven. Record this to the nearest 0.1 ton.
- Remarks - Record here anything that effects the pile including breakdowns, splicing, batters, and the factor used to figure the bearing.

The backside of the report has a place to sketch the unit where the test pile was driven. This sketch does not have to be to scale or dimension. Show the approximate location of the pile in the unit and identify the one driven as the test pile. Show a North arrow.

Figure 5.20 Example Backside of a Test Pile Report

REMARKS:- SKETCH NEED NOT BE TO SCALE. SHOW PLAN VIEW OF FOOTING WITH POSITION OF TEST PILE IN RELATION TO OTHER PILING, CENTERLINE OF ROADWAY, CENTERLINE OF SUBSTRUCTURE UNIT AND NORTH ARROW.
 DRIVE TEST PILE AS NEAR TO THE CENTER OF PILING GROUP AS PRACTICAL RECORD TIME AT START OF TEST PILE DRIVING AND WHEN EACH BEARING CHECK IS TAKEN, TAKE AT LEAST ONE BEARING CHECK EACH FIVE (5) FEET DURING DRIVING AND AT APPROXIMATELY ONE (1) FOOT INTERVALS AFTER BEARING IS REACHED.

PENCIL SKETCH



SUBMIT THIS REPORT TO THE
 OFFICE OF BRIDGE DESIGN
 IMMEDIATELY AFTER DRIVING FOR
 THEIR FURTHER DISTRIBUTION.

APPROVAL DATE 8-20-
 APPROVED BY Howe Price
 LENGTH OF PILING ORDERED 25'

Pile Inspector's Report (Bearing Pile) Information

These items are to be completed for the bottom of the Bearing Pile Report.

- Location of Pile
 - Substructure Unit - The unit where this group of piling are being driven. The unit name is on the plans.
 - Number - The number assigned each pile during preliminary inspection.
- Pile Size - Recorded from you diary during the preliminary inspection. The tip and butt diameters are filled in only when timber pile is used. The "begin" column is for the pile length. The "total" column is used when a splice is made. (The begin length plus that added). The weight column is for the weight of the pile.
- Elevation
 - Tip - Record the elevation of the tip after the pile is in place. Figure this elevation by subtracting the length of the pile in place from the cut off elevation.

- Cut Off - The elevation where the tops of the pile are cut off. This is obtained from the plans and recorded to the nearest 0.1 foot.
- Ground - The ground elevation line through which the pile is being driven. Use the bottom of footing elevation except when you prebore, then use the bottom of hole elevation.
- Water - For data obtained when driving pile in a location surrounded by water. It is the elevation of the surrounding water.
- Average of Last Blows
 - Drop or "E" - This is the free fall distance ("H") of a gravity or single-acting hammer recorded to the nearest 0.1 foot. When a double-acting hammer is being used, fill in with the energy ("E") being applied
 - Total Penetration - This is the penetration of the pile in the specified number of blows.
 - Pent. "S" - The penetration per blow at the point you measured to the nearest 0.01 inch and divide by the number of blows before recording.
 - Brg. "Q" - This is the bearing calculated when you stopped driving. Record this to the nearest 0.1 ton.

The original length placed in the leads was 35.0 feet and is shown in the "Begin" column. The 6.4 feet of cutoff was ordered spliced on by the Engineer when bearing could not be reached. Of this 6.4 feet, 6.2 has already been paid under the furnish item recorded in the "previous furnish" column under the "Length Added" heading. The remaining 0.2 foot is in the "New Furnish" column and added to the original 35.0 feet of this pile as the pay quantity furnish. This makes 35.2 feet of furnish for Pile No. 50. The pile length is recorded as 41.4 (35.0+6.4) feet under the "Pile Size" heading and the weight is the original 35 foot of pile plus the added 6.4 feet. The "Drive" in the pay quantities heading is computed by subtracting the 3.6 feet of cut off from the 41.4 feet of total length. A notation indicates where the 6.4 feet of "Length Added" came from. The pay quantities show one splice.

- Length Cut Off - The length of the piling cut off.
- Pay Quantities
 - Drive - The linear feet of pile, to the nearest foot, remaining in the structure.
 - Prebore - Indicate the number of linear feet of preboring.
 - Splice - Splices used on that pile (if any)
- Drive Date - The date piling was driven.

Both reports are source documents of the driving operation. Enter all the information requested. A reproducible copy of the Test Pile Report should be submitted to the Office of Bridge Design and the Foundations Office as soon as possible. It is not necessary to submit copies of the Bearing Pile Reports.

Pile Driving

The plans indicate where the piles are needed. Before you can drive pile for a footing, all excavation must be completed. Often while driving a group of piles that are fairly near each other, as is a column footing, the ground level can become heaved and displaced. To accommodate this, and to allow for removal of displaced ground to form the bottom of footing elevation, the excavation may be left up to one foot high and removed later after pile driving operations are concluded.

Test Piles vs. Bearing Piles

There are two categories of piling that are generally driven on a bridge project, test piles and bearing piles.

Test piles are the first piles to be driven on a project. They are, as their name indicates, an initial test of the actual bearing conditions. Generally one test pile is required for each substructure location (i.e. - abutment and bent).

The remaining piles to be driven are the bearing or production piles. Test piles and bearing piles are covered in greater depth in other sections of this chapter.

Preboring Piling

Preboring will often be required by plans when piling is to be driven in an embankment area. If piling is being driven in an embankment area and preboring is not on the plans, check and ask an Engineer to determine whether preboring should be required. Preboring, as the word implies, is merely drilling or boring holes through a layer of soils (typically an embankment) prior to driving piling. Regardless of how well an embankment is constructed it always seems to settle. If a pile was driven without preboring, the pile may possibly pick up most of its bearing in the embankment layer rather than the intended supporting soil stratum. Additionally, the potential settlement of the embankment material could cause the pile to move downward. This would put additional stresses into the structure that may cause a failure of the structure. By preboring the pile is inserted through the embankment layer. The pile can then pick up its full bearing in the intended original ground.

When preboring is required, the hole is determined by the size of the pile as follows:

- 1 For timber pile, the hole diameter must be at least 2 inches larger than the diameter of the pile, 3 feet from the butt.
- 2 For steel piles, the holes cannot be less than the following diameters:
 - HP8 Piles (HP200) 12 inches
 - HP10 Piles (HP250) 15 inches
 - HP12 Piles (HP310) 18 inches
 - HP14 Piles (HP360) 21 inches

After the piles are driven, backfill the holes with coarse dry sand. The sand shall be loosely compacted; however, compaction should be sufficient to prevent bridging.

Location and Position

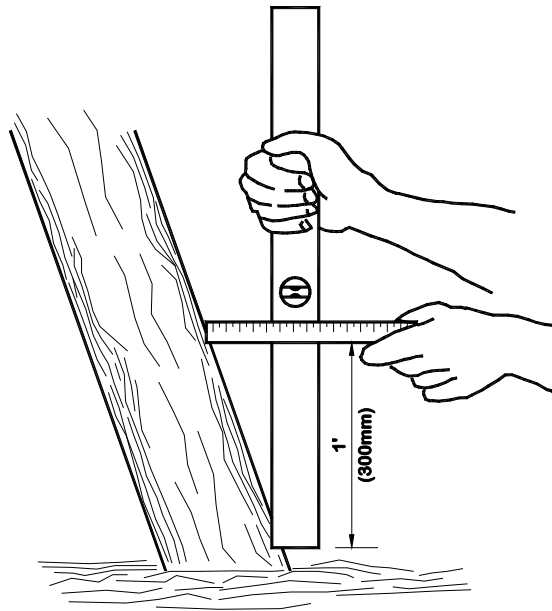
Plans also give location and position for pile. It is the Contractor's responsibility to drive the pile in the correct location and position, but you need to check them.

The two positions for driving pile are vertical or battered. Battered means the piles are driven into the ground at an angle. Batters are shown as 1 to 12, 2 to 12, etc. This means they are to be inclined from a vertical axis by 1 inch, 2 inches, etc., in a 12 inch length. It is not always possible to get this exact position. A deviation of $\pm 1/4$ inch per foot is allowed. This deviation is also allowed for pile driven vertically.

Check the position of the pile near the ground line several times as it is being driven. Place the end of a carpenter's level against the pile and move the top back and forth until the bubble shows it is vertical. Measure between the level and the piles at a point 1 foot up on the level. If the distance does not meet requirements the Contractor will have to reposition the pile. When the pile is only a few feet in the ground, this can be done simply by shifting the leads to push it into the correct

position. If the pile has more than a quarter of its length driven, it may need to be pulled and re-started.

Figure 5.21 Checking Batter Alignment

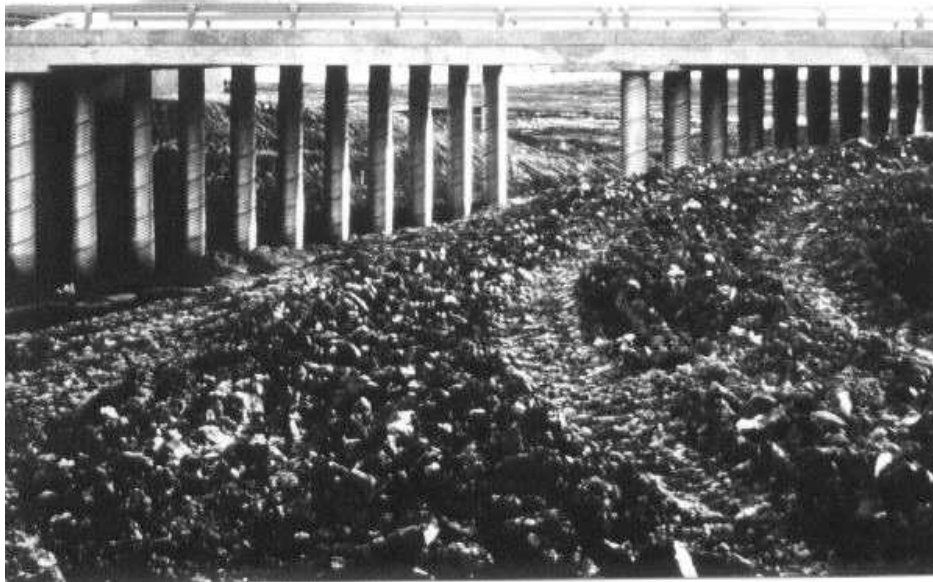


The location of each pile is important. The design takes into account that every pile may not be driven in the exact location specified. It is typically allowable for the center of each pile's top to be as much as 6 inches away from the designated location; however, the plans may specify closer tolerances for some applications. Driving piling through a template may be required to keep pile within tolerances. You can check the location after the pile is driven by using the reference points set by the survey crew. Should you end up with a pile driven out of position or location by more than the allowed tolerances, or such that they affect reinforcing steel placement, the Office of Bridge Design should be contacted to determine correction action.

Pile Bents

Plans may call for a Pile Bent. This is where the piles are left sticking out of the ground and used for columns. For protection they may be encased with concrete inside a corrugated metal pipe or protected by some other armoring. Since the columns are inside the bent cap, the pile must be driven accurately.

Figure 5.22 Pile Bent



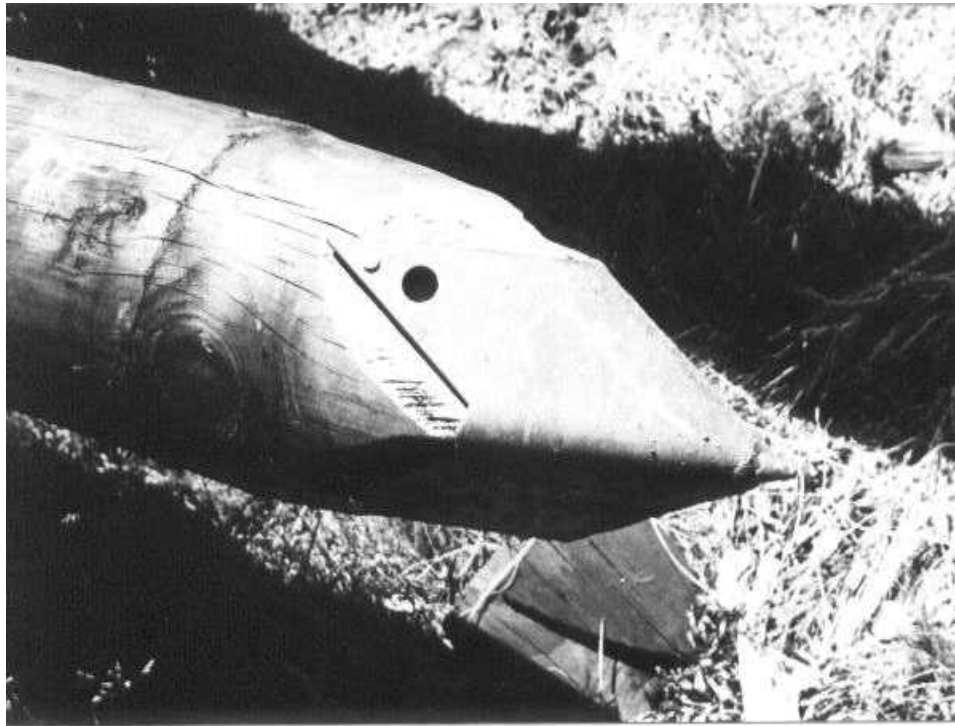
Usually there is no problem when the piles are driven within the specification limits for position and vertical alignment. Occasionally the pile cannot be driven accurately. Following these guidelines during driving can reduce the difficulty of keeping these columns lined up:

- 1** Be certain the pile is started in the position and to the vertical alignment shown on the plans.
- 2** Begin driving with low energy (maximum of 5 foot drop) and continue easy driving until a major portion of the pile is driven.
- 3** Check the position and vertical alignment regularly during this early driving. Correct any straying of the pile immediately. This can usually be done by shifting the leads.
- 4** The driving energy can be increased after about 2/3 of the pile length (exclude the column length) is in the ground or when it appears the pile is well committed to the driving line.
- 5** Use a template to drive pile through.

Steel Pile Tips

Normally timber pile will drive straight when the tip is blunt. As the pile is driven, the material ahead of the tip forms its own point. Layers of hard material in the first 10 feet, or rocky material, are exceptions where pointing is needed. If the material is hard or has large rock in it, you should order metal pile shoes. When you require pile shoes to be used, the pile must be trimmed so the shoes fit "snugly". The size requirements for pile shoes are given in the plans.

Figure 5.23 Trimmed Timber Pile with Metal Shoe



Note: The trimmed portion of the pile must be given three brush coats of hot creosote before it is driven.

When rocks are encountered while driving steel piles, reinforced pile tips may have to be added.

The butt of any pile must be cut at right angles to the shaft center line. If not, the blow delivered by the hammer will exert all its force on one side of the pile and result in pile damage.

The butt of a timber pile also needs to be “fitted” to the cap. Trim the butt slightly larger than the opening in the cap. The first few blows of the hammer will compress the timber fibers and give the cap a snug fit. However, if the butt starts to crush and mash out, stop the driving and have the damaged area cut off.

Driving the Pile

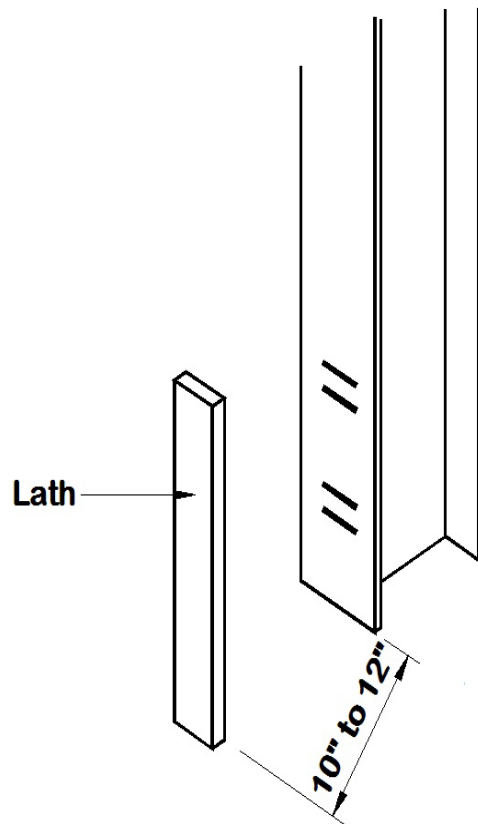
A bearing pile should not be driven much beyond the required bearing. About 10% above the plans required bearing is sufficient. You should figure the penetration for this increase when determining the required bearing. In most cases, stop driving when the penetration falls between that penetration required to achieve the plans specified bearing and that penetration required to achieve 10% more than the plans specified bearing. To find the bearing of the pile, figure it using the last penetration you measured.

You find the penetration during driving by placing a mark on the pile, drive the required number of blows, place another mark on the pile and measure the distance between the marks. The points are usually close, so a solid reference plane to mark from is necessary. If the reference is not solid, your mark will be in error and you will not be able to figure an exact bearing value.

There are two common methods for establishing marks. The first is when leads are anchored solidly; you can lay a board across the bracing and mark. Another way is to drive a lath into the ground 10 to 12 inches away from the pile. When making a

bearing check, bend the lath over to make your first mark on the pile. Release the lath while waiting to make the second mark.

Figure 5.24 Measuring Penetration



The way a pile is driven has a major effect on the calculated bearing value. The energy applied by the driver should be relatively constant. The pile will move at a fairly uniform rate while a particular amount of energy is being applied. Should the driving energy be increased, allow time for a new rate to be established. If you took a penetration measurement while the new rate was being established, it would probably show a higher bearing than you actually had. This is because the pile is not moving at the full rate for the increased energy being applied.

Timber pile driven in cold weather requires special care. When the driving starts, lower energy should be applied. The pile is cold and a heavy blow can crack or shatter it. After the pile has been "warmed" by blows, energy can be increased.

Figure 5.25 Driving Pile



Hammer Fall

The fall height of a single-acting diesel hammer is not as easy to gauge or measure. The fall height is not constant throughout the driving of the pile. As the pile begins to pick up bearing and offer more resistance to the pile, the rebound of the piston is increased. In addition, the pistons of these type hammers are not usually marked well; making accurate visual measurement difficult.

The Department has purchased some instruments called "Saximeters". This instrument, through the use of a sound recognition circuit, automatically counts the number of hammer blows and determines the blows per minute. It also calculates the stroke "fall height" for all open-end diesel hammers. Through the use of this instrument, an accurate fall height can be determined with ease without having to mark the hammer or leads. This instrument has a memory function that records and stores much of the data necessary to determine bearing and to fill out a pile report. You should contact the Region Office to obtain the instrument for use during the pile driving.

Bearing Determination

Bearing is how much load a driven pile can hold without settling. The plan notes for each structure give the bearing required. You need to determine the bearing of a pile while it is being driven, so driving can be stopped at the design bearing. The bearing is found using the formulas found in Figure 5.26.

Figure 5.26 Determining Bearing Values of Piles

(US Customary)	
Hammer Type	Bearing Equation
Single-Action Steam or Air Hammers and Open Cylinder Top Diesel Hammers	$Q = \frac{10.5WH}{S + 0.1} \times \frac{W}{W + M}$
Double-Action Steam or Air Hammers and Closed Cylinder Top Diesel Hammers	$Q = \frac{10.5E}{S + 0.1} \times \frac{W}{W + M}$
<p>The formula terms are defined as follows:</p> <p>Q = the nominal pile bearing resistance to the nearest 0.1 tons.</p> <p>W = the weight (mass) of the hammer or piston to the nearest 0.01 tons. <i>NOTE: W must be greater than M for Gravity Hammers.</i></p> <p>H = the free fall distance of the hammer or piston to the nearest 0.1 foot.</p> <p>M = the combined weight (mass) of the cap and the pile to the nearest 0.01 tons. <i>NOTE: When using some energy hammers the weight of the anvil must be included when determining M.</i></p> <p>E = the energy per blow to the nearest 0.01 foot-tons.</p> <p>S = the average penetration per blow to the nearest 0.01 inches.</p>	

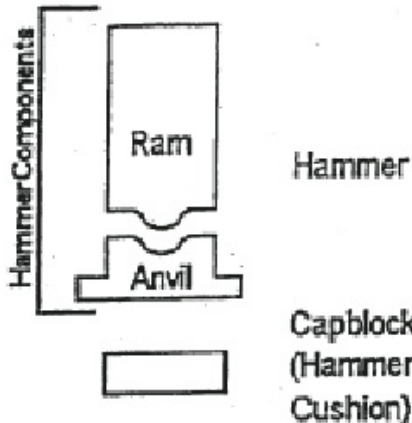
Hammer or cap weights are easy to determine. Most caps have been weighed and stamped with an identification number. A data sheet with weight data has been sent to the Office of Bridge Design. Copies of this information are distributed to each Region. Figures 5.27 and 5.28 are typical data sheets. Using the identification number you should be able to check the files for the hammer and cap weight. If it appears like they have been modified or repaired, check the file for a revised data sheet. If you find a hammer or cap without identification numbers, have the Region Materials Office weigh it or weigh it yourself on a certified scale. If you weigh it, fill out a data sheet and send it to the Office of Bridge Design, also record the data in your diary.

It is not practical to weigh the pistons of single or double-acting hammers nor the anvil when present, because the hammer would have to be taken apart. Have the Contractor supply the manufacturer's specifications for the hammer. The weight of the piston and anvil is listed in them.

Figure 5.27 Example Drop Hammer Data Sheet

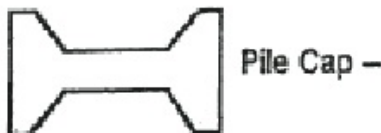
SPI D-30--ENGLISH

Contract No.: _____ Structure Name and/or No.: _____
 Project: _____ File Driving Contractor or Subcontractor: _____
 County: _____ (Piles driven by)



Manufacturer: SPI Model: D-30
 Type: DIESEL S/A Serial No.: _____
 Rated Energy: 69,937 FT LB @ 10.58 FT Length of Stroke
 29,502 FT LB @ 4.46 FT
 RAM WEIGHT: 6,610 LBS.
 Modifications: _____

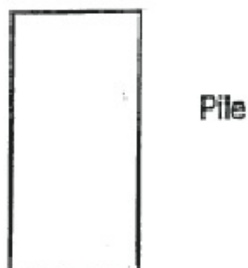
 ANVIL WEIGHT--1,363 LBS.
 Material: NYLON
 Thickness: 2" Area: 397.6 SQ IN
 Module of Elasticity - E 175 KSI (P.S.I.)
 Coefficient of Restitution-e .92



Helmet
 Bonnet
 Anvil Block - Weight: 2,200 LBS--24" SQUARE
 Drivehead 1,335 LBS--UNIVERSAL



Cushion Material: _____
 Thickness: _____ Area: _____
 Module of Elasticity - E _____ (P.S.I.)
 Coefficient of Restitution-e _____



Pile Type: _____
 Length (in Leads) - _____
 Weight/ft. _____
 Wall Thickness: _____ Taper: _____
 Cross Sectional Area _____ in²
 Design Pile Capacity: _____ (Tons)
 Description of Splice: _____
 Tip Treatment Description: _____

Note: If mandrel is used to drive the pile, attach separate manufacturer's detail sheet(s) including weight and dimensions.

Submitted By: _____ Date: _____

PILE AND DRIVING EQUIPMENT DATA

Figure 5.28 Example Timber Pile Cap Data Sheet

DOT 221 (7-1-74)

PILE DRIVER DATA

CONTRACTOR DAVE GUSTAFSON & Co. Inc.

TYPE OF EQUIPMENT
(Underline Part Applicable)

S.D.D.H. EQUIPMENT NO. 308

WEIGHT 790 lbs.

Drop Hammer ☒ Timber Pile Driving Cap ☐ Steel Pile Driving Cap

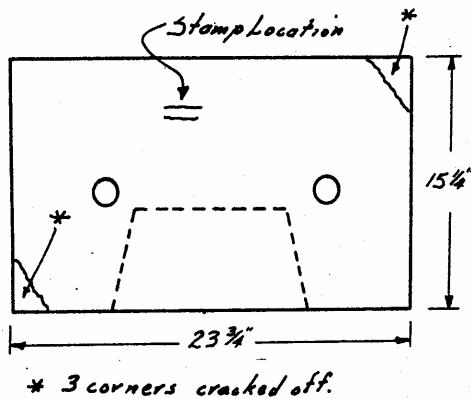
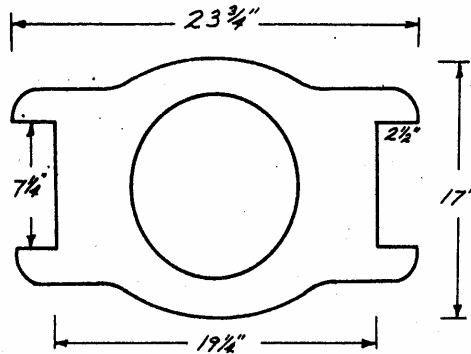
TRADE NAME & NUMBER (if any) LOFTUS EQUIPMENT CO, LEO0109E

LOCATION OF STAMP SEE SKETCH

DATE STAMPED 8-9-89 BY: James Mc Anders
(Signature)

SKETCHES

Show approximate typical cross section(s), height, width between leads, etc.



DOT-75
(1-84)

SOUTH DAKOTA

MATERIALS AND WEIGHT TICKETS

PROJECT DAVE GUSTAFSON
MATERIAL TIMBER PILE CAP # 308

DATE 8-9, 1989 SAMPLE NO. _____

TANK OR CAR NO. _____ M. GALS. _____

TRUCK NO. _____ LANE _____

GROSS WT. 8570 SECTION _____

TARE WT. 7780 STATION _____

NET WT. 790 SPREAD _____

TONS _____ END STA. _____

WEIGHER J. Mc Anders CHECKER _____

CONCRETE MIX (TREATED MAT'LS) WATER: MAX _____ ACTUAL _____

TIME START MIX _____ BATCH _____

DISCHARGED _____ SIZE _____

REVOLUTIONS: RATE _____ INSPECTORS: _____

FINAL _____ PLANT _____

INITIAL _____ PLACING _____

NET _____

REMARKS: WEIGHED ON PATROL SCALE

No. D 623252

BOOK QUANTITY

PREV. TICKET _____

THIS TICKET _____

TOTAL _____

LEAVE THIS SLIP IN BOOK

Figure 5.29 Timber Pile Weight in Lbs per Linear Foot

Tip Butt	7	8	9	10	11	12	13	14	15	16
7	13.36	15.36	17.54	19.91	22.46	25.18	28.08	31.18	34.46	37.89
8	15.36	17.46	19.73	22.18	23.84	27.64	30.63	33.82	37.19	40.72
9	17.54	19.73	22.09	24.64	27.36	30.29	33.36	36.64	40.09	43.74
10	19.91	22.18	24.64	27.27	30.09	33.10	36.27	39.62	43.18	46.91
11	22.46	24.84	27.36	30.09	33.00	36.09	39.36	42.82	46.45	50.27
12	25.18	27.64	30.29	33.10	36.09	39.27	42.63	46.18	49.89	53.82
13	28.08	30.63	33.36	36.27	39.36	42.63	46.09	49.71	53.54	57.54
14	31.18	33.82	36.64	39.62	42.82	46.18	49.71	53.45	57.35	61.46
15	34.46	37.19	40.09	43.18	46.45	49.89	53.54	57.35	61.36	65.53
16	37.89	40.72	43.74	46.91	50.27	53.82	57.54	61.46	65.53	69.82
17	41.54	44.45	47.54	50.81	54.27	57.91	61.72	65.72	69.90	74.27
18	45.36	48.35	51.54	54.90	58.45	62.18	66.08	70.17	74.45	78.90
19	49.35	52.54	55.72	59.17	62.81	66.63	70.63	74.81	79.17	83.72
20	53.54	56.72	60.08	63.63	67.36	71.27	75.36	79.63	84.08	88.72
Tip and butt diameters in inches. Pile weight in pounds per linear foot; based on unit weight of 50 lb. / ft ³ . Obtain total pile weight by multiplying total pile length by factor obtained above.										

To find the weight of a timber pile you need the tip and butt diameters and the charts shown in Figure 5.29. There are two ways to get the diameters:

- 1 Use a diameter tape, or
- 2 Divide the circumference by 3.1416.

In either case, round the diameter to the nearest whole inch.

The tip diameters are shown across the top of the table, and the butt diameters run down the side. Read across the top to the tip diameter of your pile, then down until you are across from its butt diameter. The figure you see is the weight per foot of the pile. To find the pile's total weight, multiply its length times its weight per foot. Record the weight of each pile in your diary to the nearest 10 pounds.

Example: Douglas Fir piles are being used and pile #7 is 20.6 feet long. The tip circumference is 27 inches and the butt circumference is 39 inches. The diameters of the tip are 8 1/4 and 9 1/2. The diameters of the butt are 12 and 13 1/2 inches. Does this pile meet DOT requirements? If so, what is its total weight?

Solution:

- 1 First check the circumference of the pile against Figure 5.6. The minimum and maximum butt circumferences for a Douglas Fir pile less than 40 feet are 35 and 63 inches. Pile #7's is 39 inches, therefore the butt circumference meets

specifications. The minimum tip circumference from Figure 5.6 is 25 inches. Pile #7's tip circumference at 27 inches is greater than the minimum, therefore the tip circumference is acceptable.

- 2 Next check the ratio of the tip and butt diameters. The ratio of the largest diameter to smallest diameter should be less than 1.2. For the tip, $9.5 \div 8.25 = 1.15$. For the butt, $13.5 \div 12 = 1.13$. Both are less than 1.2, so the pile meets the tip and butt diameter ratio requirements.
 - 3 Finally, obtain the total weight of the pile. Use the butt and tip circumferences to obtain the average end diameters of the pile. Then use the average end diameters in Figure 5.29 to obtain the weight per length.
- Average butt diameter: $\frac{39}{3.1416} = 12.4$ or 12 inches.

- Average tip diameter: $\frac{27}{3.1416} = 8.6$ or 9 inches.
- From Figure 5.29, the pile weight per foot is 30.29 lb/ft. Therefore that total pile weight is $30.29 \text{ lb/ft} \times 20.6 \text{ ft} = 624 \text{ lbs.}$ or 620 lbs. rounded.

The steel pile weight is determined from its description. Suppose plans call for the pile to be HP8x36. The 8 tells you the flanges are 8 inches wide and that the distance between the outsides of the flange is also 8 inches. The other number is the weight per foot of the pile. In this case it is 36 pounds per foot. To determine total weight of the pile, multiply its length times the weight per foot. Record in your diary the weights to the nearest 10 pounds for each pile.

The item still unknown is the penetration per blow. This is measured during the actual driving. Measuring penetration will be covered later. Specifications recommend measuring penetration for 5 blows when using a gravity hammer and 10 blows when using a single or double-acting hammer. These are not exact values. There are times when you may want to use more. For example, when penetration is so slight that measurement is difficult or when a double-acting hammer is being used, because it strikes so many times per minute. Divide the number of blows you use, into the total penetration measured to determine the penetration per blow.

Example: A Link Belt Model 312 double-acting pile driver was used to drive some HP12x53 piles that were 45 feet long. The piston weighs 3,860 pounds; the cap - 910 pounds; and the anvil - 550 pounds. During driving a penetration of 0.88 inches was measured for 10 blows with the hammer operating pressure of 17 psi. Using the Pressure to Energy Conversion Chart shown in Figure 5.15, what was the bearing at this point?

- Use the formula found in Figure 5.26, the terms are as follows:

$$Q = \frac{10.5E}{S + 0.1} \times \frac{W}{W + M} \text{ where:}$$

- E= From Figure 5.15, at 17 psi operating pressure, the energy is approximately equal to 12,500 ft/lbs. or $12500 \div 2000 = 6.25 \text{ ft/ton.}$
 - W = 3,860 lbs., or $3860 \div 2000 = 1.93 \text{ tons.}$
 - M = 910 lbs. (cap) + 550 lbs. (anvil) + 53 lbs/ft x 45 ft (pile) = 3,845 lbs., or $3845 \div 2000 = 1.92 \text{ tons.}$
 - S = 0.88 inches over 10 blows, or 0.09 inches per blow.
- Putting the above values into the formula, the bearing at this point equals:

$$Q = \frac{10.5(6.25)}{(0.09) + 0.1} \times \frac{(1.93)}{(1.93) + (1.92)} = 173.1 \text{ tons.}$$

Determining Penetration Required

When pile are driven with a batter, the hammer does not deliver the same energy that it does to a pile driven vertically. To compensate for this, you have to multiply the bearing computed by the formulas times a factor. The factor you should use is (cosine a) minus (f sine a).

Figure 5.30 shows the factors for the common batters. The "a" is the angle between the leads and a vertical line. The "f" is the coefficient of friction between the hammer or piston and the surface on which it slides. For all practical purposes, "f" can be assumed to be equal to 0.1.

Figure 5.30 Batter Factors

*BATTER FACTORS cosine a - f sine a	
1 on 12	0.988
2 on 12	0.970
3 on 12	0.946
4 on 12	0.917
5 on 12	0.885
6 on 12	0.850

* for f = 0.1

Once pile driving starts, it moves quickly. To figure bearing for each penetration would require fast action. You already know what bearing you want. It simplifies the process if you figure what penetration will give you that bearing. Figure 5.31 gives you the bearing formulas transposed so you can solve for penetration.

Figure 5.31 Determining Penetration Required for Specific Bearing

Hammer Type	Penetration Equation
Single-Action Steam or Air Hammers and Open Cylinder Top Diesel Hammers	$S = \frac{10.5WH}{Q} \times \frac{W}{W + M} - 0.10$
Double-Action Steam or Air Hammers and Closed Cylinder Top Diesel Hammers	$S = \frac{10.5E}{Q} \times \frac{W}{W + M} - 0.10$
<p>The formula terms are defined as follows:</p> <p>Q = the nominal pile bearing resistance to the nearest 0.1 tons.</p> <p>W = the weight of the hammer or piston to the nearest 0.01 tons. <i>NOTE: W must be greater than M for Gravity Hammers.</i></p> <p>H = the free fall distance of the hammer or piston to the nearest 0.1 foot.</p> <p>M = the combined weight of the cap and the pile to the nearest 0.01 tons. <i>NOTE: When using some energy hammers the weight of the anvil must be included when determining M.</i></p> <p>E = the energy per blow to the nearest 0.01 foot-tons.</p> <p>S = the average penetration per blow to the nearest 0.01 inches.</p>	

Example: The plans call for an HP8x36 steel pile to be driven on a 2 to 12 batter. From the test pile log you ordered a 60 foot pile. The pile driver is a McKiernan - Terry double-acting 9B3, operating at 142 blows per minute. The piston weighs 5,000 pounds and the cap weighs 860 pounds. What is the penetration required per blow, to obtain a bearing of 157.5 tons?

Solution:

- Use the formula found in Figure 5.31, the terms are as follows:

$$S = \frac{10.5e}{Q} \times \frac{W}{W + M} - 0.10 \text{ where:}$$

- e = From Figure 5.15, at 142 blows per minute for a 9B3 hammer, the energy is approximately equal to 8,360 ft/lbs., or $8360 \div 2000 = 4.18$ ft/ton.
- W = 5000 lbs., or $5000 \div 2000 = 2.5$ tons.
- M = 860 lbs. (cap) + 36 lbs/ft x 60 ft (pile) = 3,020 lbs., or $3020 \div 2000 = 1.51$ tons.
- Q = 157.5 tons divided by 0.97 batter factor, $157.5 \div 0.97 = 162.4$ tons.
- Putting the above values into the formula, the penetration at this point equals:

$$S = \frac{10.5(4.18)}{162.4} \times \frac{(2.5)}{(2.5) + (1.51)} - 0.10 = 0.07 \text{ inches per blow}$$

Remember: The value you calculate is for only one blow. To determine distance you will actually be measuring, multiply this value times the number of blows.

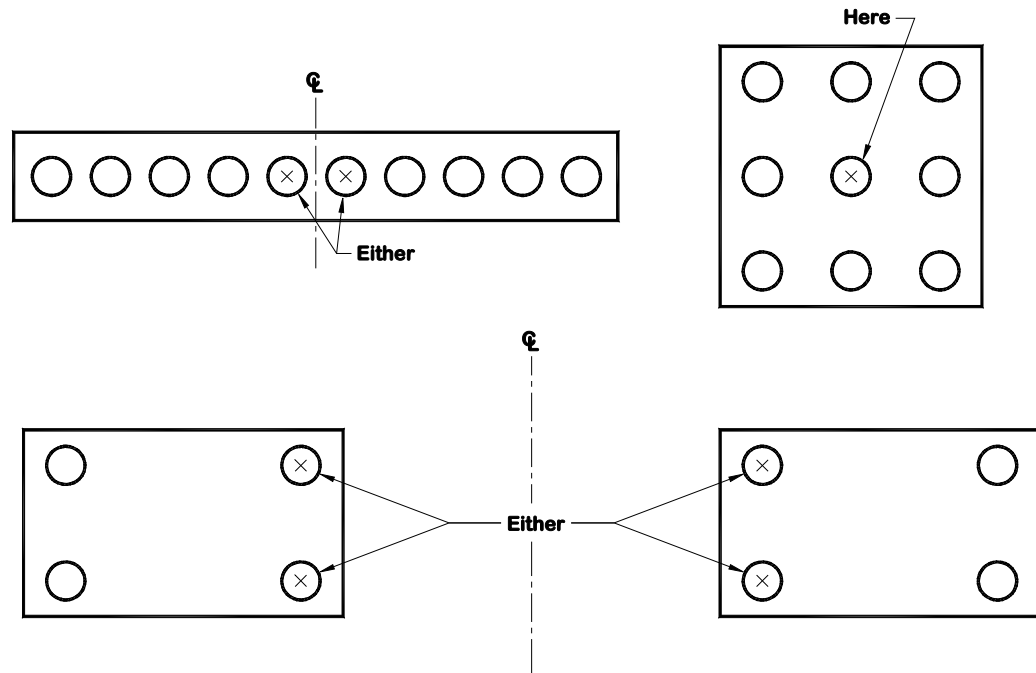
Test Pile

Although the subsurface investigation data gives site information, you must determine the length of pile needed to obtain the required bearing. Drive a test pile in each foundation unit. The length of test pile is given on the plans in the estimated quantities for the various substructure units.

- The test pile needs to be driven to a greater bearing than plans require for regular bearing pile. This is done to determine what is beneath the site. In most cases, a test pile driven to a bearing from 10%-20% more than the required bearing should give you the necessary information. Specifications state that you shall not exceed 20% over plans bearing, particularly with timber, because the heavy pounding can damage the pile.
- Test pile must be driven to required bearing. Delayed bearing shall not be allowed.

The test pile is used for an actual "bearing log" of the site. This means you calculate the bearings for various depths as the test pile is driven. Usually, the first third of the pile length drives easily and picks up very little bearing. In this instance, you need not make a bearing calculation for this part of the driving. From that point on, checking and recording the bearing at each 5 foot increment is required. When the bearing is about 75% completed, start checking and recording the bearings at every 1 foot increment. Continue taking these 1 foot readings until you stop driving the test pile. The plans show where each pile is to be driven. The best place to drive a test pile is near the center.

Figure 5.32 Test Pile Locations



Some footings only call for pile in corners. In these footings, drive the test pile on one of the inside corners of the structure. Occasionally a test pile is driven to its length and you still don't have enough information about the location. In this case, order the Contractor to drive a longer test pile. Have the Project or Area Engineer determine the length. The second test pile location should be determined in the same manner as the first one.

Bearing Pile

After the test pile has been satisfactorily driven, the Contractor may begin driving the bearing pile. The driving log for the test pile and the subsurface investigation sheet in the plans should be used as a guide when driving the bearing pile. This is especially true in the case in which the bearing pile drives to a significantly different depth than the test pile.

Example:

A bearing pile is driven to the plans specified bearing of 55 tons at a depth of 52 feet, but the test pile had been driven to a depth of 80 feet. The question becomes, should the bearing pile continue to be driven deeper or will the pile function as intended as is.

Assume that in reviewing the driving log for the test pile, it is noted that the specified 55 ton bearing was attained at a depth of 50 feet. However, when driving to the 10%-20% over the specified bearing, as is done for the test pile, the bearing at 52 feet of depth was 61 tons. The bearing remained at 61 tons and then suddenly dropped off at a depth of 56 feet and driving was continued until a bearing of 66 tons (20% over the specified bearing) was attained at a depth of 80 feet. In addition, assume that upon reviewing the subsurface investigation sheet, the blow count graph indicates that a double buildup condition exists with the upper buildup occurring at a depth from 48 feet to 54 feet.

A question becomes, should the bearing pile continue to be driven deeper or will the pile function as intended as is. This decision requires some experience and engineering judgment. As a general rule for this condition, the answer is that the pile will function as intended if you can answer 'yes' to the following questions:

- Was the bearing 5-10 tons more than the required bearing before it dropped off?
- Did the pile have more than the required bearing for a depth of at least 3 feet?
- In this example, the bearing of the test pile was 61 tons, which is 6 tons more than required; thus the answer to the first question is 'yes'. The answer to the second question is also 'yes' as the test pile had more than plans bearing for the depths between 52 feet and 56 feet, which is more than 3 feet. Therefore, driving of this particular bearing pile should be stopped.

Obviously, there are many other scenarios that could be encountered. The point, however, is that the inspector should utilize the test pile report and the subsurface investigation sheet as a guide as to what to expect. If something unexpected happens, experience and engineering judgment are required to assess the situation. If there are any doubts as to what should be done, contact your Project Engineer, the Office of Bridge Design, or the Foundations Office for assistance.

Figure 5.33 Driving a Steel Pile



Using Set-Up to Obtain Bearing

Despite using a test pile log to obtain a length for the bearing pile, you may have a pile that is not picking up bearing as the other pile. If it appears that required bearing will not be obtained when it is fully driven, stop driving when the pile is still 2 feet above the cutoff elevation and delay any further driving for 24 hours. Then try to drive the pile again and take a penetration measurement. For single-action or double-action hammers, it is critical that the hammer be warmed up on another pile until it is operating at the same energy level as it was prior to the set-up time before placing it on the pile to be retapped. The first couple of blows on the 'retap' should not be measured as they will be necessary to effectively reset the cap. Following this, the penetration should be measured over the next 10 blows. For gravity hammers, as warm up and energy levels are not required, the penetration can be taken on the next 1 or 2 blows delivered after setting the cap. In most cases, the bearing will have increased. This results from a "setting up" effect caused by friction between the soil and pile. If the bearing determined after set-up meets or exceeds plans required bearing, then the pile can be accepted and no further driving is required. If the bearing determined does not meet the plans required bearing, then a pile splice will be required.

If this happens to another pile in the same group, you may not have to stop. Provided that the driving has progressed similar to the other pile, determine if the pile has as much or more bearing than the other pile had at approximately the same elevation before the "setting up" effect was checked. If this is the case, add the

increase you found for the other pile, due to the “setting up”. Should this result in a greater than minimum bearing required, keep driving the pile to the cutoff elevation and figure its final bearing value. When the pile has a bearing that is less than the other pile had before checking the “setting up” effect, the Contractor will have to stop driving it for 24 hours and then check it for its own “setting up”. If anything unusual occurs during driving that may make the setting up effect suspect, have the Contractor check the setting up after 24 hours.

Driving Near Fresh Concrete

There are times when the Contractor will want to drive pile near some freshly placed concrete. If possible, do not allow pile driving for at least 24 hours after the concrete has been placed. Vibrations can adversely affect the concrete during the early stages of its gaining strength. Should the Contractor want to drive pile before the 24 hour period is over, determine if vibrations are reaching the fresh concrete. Drive a 2"x4" stake solidly into the ground near the concrete and set a glass of water on it. If the water surface remains calm, driving can continue. If the water surface shows any movement, vibrations are reaching the concrete and the pile driving must be stopped until the end of the 24 hour period.

Pile Splicing

Figure 5.34 Steel Pile Splice



When set-up procedures don't provide the bearing needed, a pile splice is required. Be sure the contractor has the materials to make splices before driving pile.

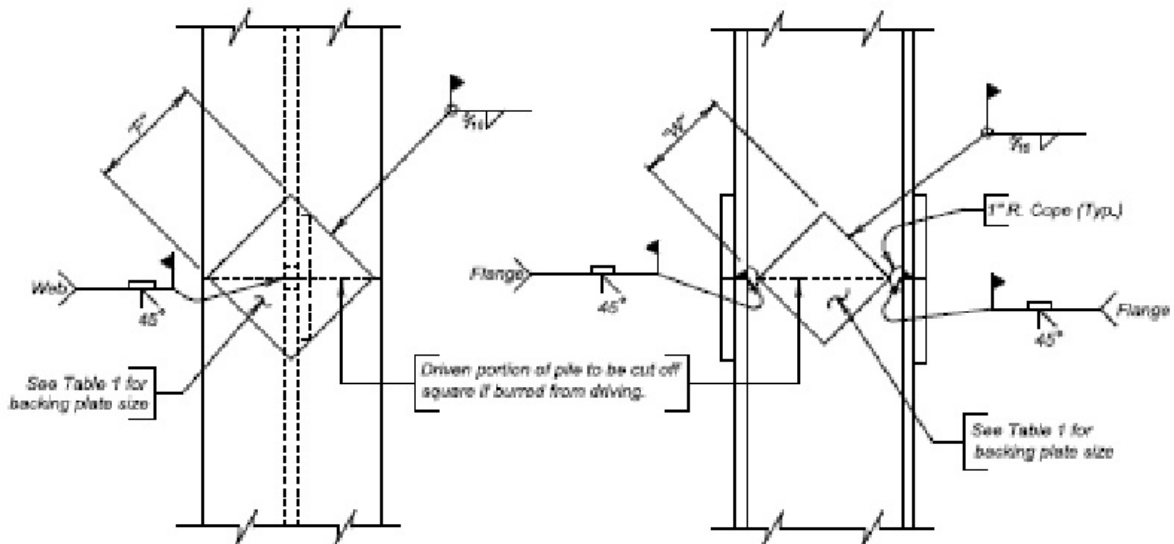
Generally pile splices should not be permitted if the final elevation of the pile splice remains at a point less than 10 feet below ground line. In these locations, the piles are subject to bending in addition to axial loads. Consequently, a full moment pile splice would be required rather than the standard splice as detailed in the plans. If a

splice is required to be left in place in this zone, contact the Office of Bridge Design for further assistance and direction.

Check the workmanship of all splices:

- On a timber splice, the pile is to be trimmed so the splice barrel will fit snugly.
 - The trimmed portion of the timber pile must be given 3 brush coats of Copper Napthenate before it is driven.and
- Check the welds on a steel splice are completed according to the Standard Plate. A Certified Welder registered with the SDDOT must be used. All welding must be done according to AWS D1.5 Bridge Welding code.

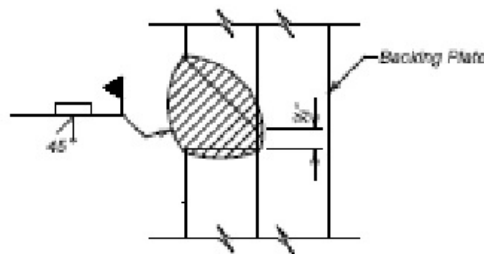
Figure 5.35 Standard Plate 510.40



NOTE:

Prepare joint surfaces lower end of upper section on the ground and weld on backing plates; then place upper section on lower section and weld.

COMPLETE JOINT PENETRATION WELD DETAIL



GENERAL NOTES:

1. Steel for backing plates shall conform to ASTM A709 Grade 50.
2. Welding and weld inspection shall be in conformance with AWS D1.5 (Current Year) Bridge Welding Code - Steel.
3. Welder must be certified and registered with the SDDOT.
4. Backing plate shall at a minimum be as thick as the web of the pile being spliced.
5. Web must be coped with 1 inch radius.
6. Submit Welding Procedure Specification (WPS) to Bridge Construction Engineer for approval prior to pile driving.

TABLE 1 (BACKING PLATES)			
PILE	10"	12"	14"
"F" FLANGE	6 1/2"	8"	10"
"W" WEB	4 1/2"	6 1/2"	7 1/2"

<p><i>Published Date: 3rd Qtr. 2013</i></p>	<p>S D D O T</p>	<p>STEEL PILE SPLICE DETAILS</p>	<p>December 23, 2012</p>
			<p>PLATE NUMBER</p> <p>510.40</p>
			<p>Sheet 1 of 1</p>

Pile Cut-Off

After the piles are driven to the required bearing and in the correct position, they must be cut to the elevation shown on the plans. Establish this cutoff elevation with a level, using the benchmark set by the survey crew.

After establishing cutoff elevation, measure from it to one of the marks you put along the length of the pile. Make this measurement to the nearest 0.1 foot. From this you can determine the length of the pile that is in place below the cutoff line.

There is no payment to the Contractor for the pile cutoff, except when the Engineer orders the Contractor to drive the cutoff material in another location. Cutoff that is not ordered driven becomes the property of the Contractor. Undamaged cutoff material with a length greater than 5 feet may be spliced to satisfy a minimum pile length requirement.

When the Contractor cuts pile tops, check to see they are cut according to plans. This may be in a horizontal plane or perpendicular to the pile center line. They should be cut to a uniform plane. If the pile is driven to a point very near the cutoff elevation, all "broomed", splintered, or otherwise injured material must be removed. After cutoff, the tops of timber pile are to be given 3 brush coats of hot creosote or Copper Napthenate.

Figure 5.36 Cutting Off Timber Pile



Payment

Steel and timber piles are paid as "furnish and drive" items.

- **Test Piles:** These will be paid for at the contract unit price per linear foot. If the plans quantity is greater than the actual quantity driven, the plans quantity will be used for payment. This payment will be full compensation for all labor, equipment, and incidentals necessary for furnishing and driving the test pile.
- **Bearing Piles:** The furnishing and driving of bearing pile will be paid for at the respective contract unit price per linear foot. This payment will be full compensation for all labor, equipment, and incidentals necessary for furnishing and satisfactorily driving the bearing pile. When the final in-place quantity of each size of bearing pile driven and accepted for payment varies from the plans quantity, the Contractor will be compensated for the difference as follows:
 - When the final quantity of each size under-runs the total contract quantity by more than 5 feet times the number of piles, the Contractor will receive 20% of the contract unit price for the entire difference in quantity.
 - When the final quantity of each size overruns the plans quantity, the Contractor will receive the contract unit price plus 10% for the excess over plans quantity.

TEMPORARY WORKS

Checklist

Falsework checks

Prior to Erection

- Falsework plans for bridge superstructure submitted and approved
- Falsework plans thoroughly reviewed

Falsepile

- Falsepile driven to required bearing as witnessed by an SDDOT Inspector
- Adequate cross bracing installed

Mudsills

- Soil conditions will provide adequate bearing strength
- Soil is properly compacted prior to setting/constructing mudsill
- Any reinforcing steel required is adequately supported
- Uniform bearing provided across entire area of mudsill
- Mudsill is constructed in accordance with falsework plans

Tubular Steel Scaffolding

- Frames installed match those approved on falsework plans
- Frames are free from kinks, bends, or other defects that could compromise strength
- Base plates have bearing on full contact area
- Diagonal bracing and lock clamps installed
- All connections rigid and tight
- Jacks are not overextended

Friction Collars

- Collar fits tight against the concrete for the entire circumference
- Bolts installed and tightened
- Direct support (posts) installed vertically between collar and footing or ground line

Bolted Brackets

- Bracket fits tight against supporting member
- Bolts long enough such that threaded portion is not in the contact plane

Timber Beams, Stringers, and Joists

- Lumber is of good quality and is free from large shakes, cracks or knots, splits, or warping that could compromise strength
- Sizes, locations, span length, and spacing matches those approved in the falsework plans
- Adequate bracing provided
- Connections are well nailed or bolted

Structural Steel Beams, Stringers, and Joists

- Sections are in good condition. Check for section loss from previous welds, holes, or openings
- Sizes, locations, and span length matches those approved in falsework plans

Manufactured Steel Joists

- Joists are in good condition. Check for bends or other damage that would compromise strength
- Joist type, length, and spacing match that indicated in falsework plans
- Residual Camber accounted for in setting elevations

Hangers

- Make and model number or type matches that approved in falsework plans
- Hangers held securely in place such that they will be loaded evenly
- Hanger brackets are in good condition and match the type specified in the approved falsework plans
- Hangers are not welded to top flange of steel beam

Overhang Brackets

- Brackets are in good condition. Check for bends or other damage that would compromise strength
- Type, spacing, and cantilever length matches those approved in falsework plans
- Bracing of bridge girder installed (where required)
- Bottom of bracket padded or protected to prevent damage to girder
- Deflections accounted for in setting formwork

Bracing and Connections

- Bracing adequate to prevent rotation or movement when loaded
- Uplift at stringer ends accounted for and prevented with adequate hold downs and restraints in place
- All connections tightened and checked
- Wedges and spacers nailed or clamped to prevent movement

Formwork Checklist

General Material

- Material is in good condition
- Plywood sheathing laid with grain perpendicular to supports unless otherwise stated in Falsework Plans
- Quality material used on exposed faces
- Sap areas removed or covered to prevent concrete contamination
- Metal forms have smooth surface that is free from rust, grease, and contaminants
- Plastic, fiberglass, or paper forms clean and in good condition

Construction

- All joints in formwork are mortar tight
- Adequate ties used to resist fluid pressure of concrete
- Rustication strip, drip strip, and/or chamfers are installed
- Take slab form elevations for girder bridges. Haunch depths determined and slab forms set accordingly
- Form camber accounted for in formwork for slab bridges
- Timber crushing accounted for in setting formwork elevations
- General tolerances are adhered to

Removal Checklist

- Concrete strength verified prior to removal
- Care taken during removal to prevent damage to structure
- Supports removed slowly and uniformly this includes box culverts

General

False works and forms are temporary structures erected to support the concrete until it has gained enough strength to support itself. Forms are those members that are required to maintain the plastic (or fluid) concrete in its desired shape until the concrete has set up. Forms resist the fluid pressure of the concrete, the additional fluid pressure generated by mechanical vibration of the concrete, and the impact of placing the concrete in the forms

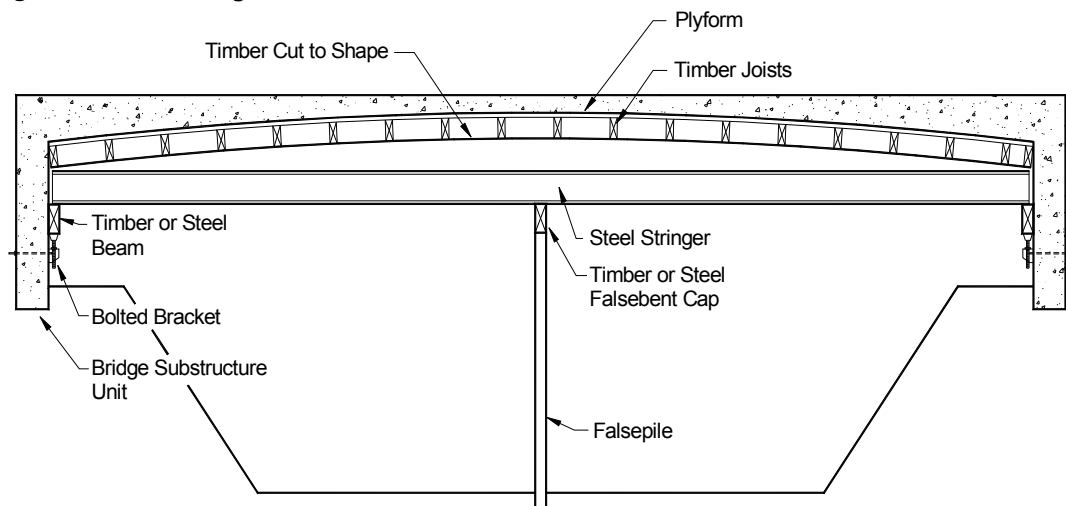
Figure 6.1 Typical Slab Bridge Falsework



Falsework is the framework supporting the forms required to maintain the concrete in the desired position until the concrete is strong enough to carry its own dead weight. Falsework must be strong enough to carry its own dead weight, the dead weight of the forms and concrete, and the live load of the construction crews and their equipment. The Contractor is responsible to have a PE design safe and adequate falsework. Standard Specifications require that the Contractors' Engineer design all falsework and forms in accordance with the latest edition of the AASHTO "Guide Design Specification for Bridge Temporary Works." In addition, Standard Specifications require that all superstructure falsework for bridges be submitted to the Office of Bridge Design for review and approval.

The Contractor must submit stamped superstructure falsework plans, which include all details and material specifications necessary to determine the structural adequacy of the falsework. Included on falsework plans is the anticipated date of the deck pour and the make and model of the finish machine being used. The plans should be sent to the Office of Bridge Design for review and analysis a minimum of 30 days prior to the erection of the superstructure falsework. Under no circumstances should the Contractor be permitted to begin erecting superstructure falsework without approval of the falsework plans by the Office of Bridge Design.

Figure 6.2 Slab Bridge Falsework

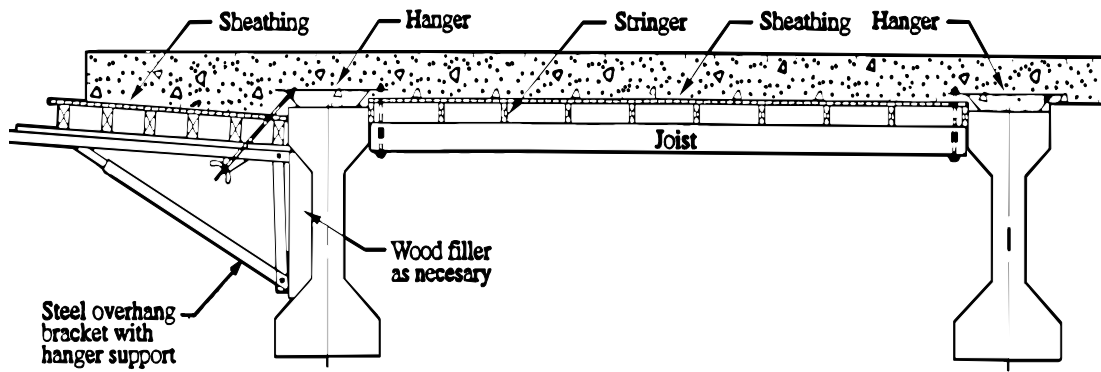


The Office of Bridge Design reviews the falsework plans for the structural adequacy and potential unstable details. When necessary, their review comments will include recommendations on changing member size, strength, and/or spacing. When the Contractor chooses not to follow these recommendations, record that fact in your diary and advise the Office of Bridge Design of the situation. Be familiar with the falsework plans. If you find the falsework is not being built according to plan, ask why. If necessary, send a revised falsework plan to the Office of Bridge Design for analysis.

Falsework

The type of structure determines, to a large extent, what the falsework arrangement will be like. For slab bridges and box culvert top slabs, the falsework configuration is such that the bridge deck or top slab is supported with framework from the ground line up, utilizing substructure units where practical. For girder bridges, the falsework configuration is such that the bridge deck is supported with framework spanning or cantilevering off the superstructure girders themselves. Falsework can be built using a variety of construction methods and materials.

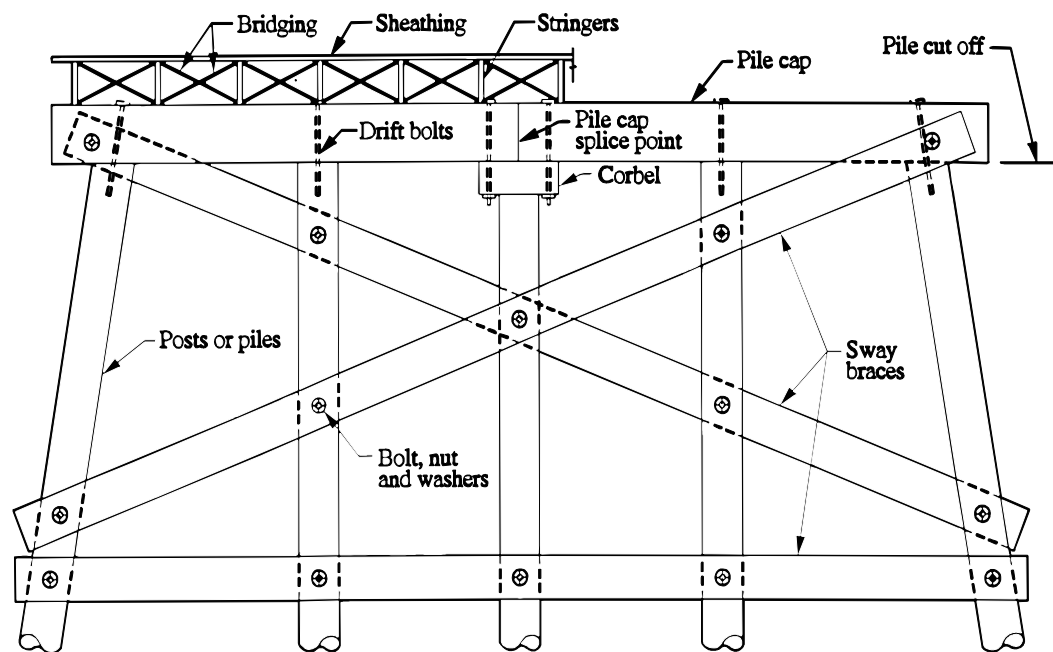
Figure 6.3 Girder Bridge Falsework



False Piles

Bridge falsework must be constructed on a solid base to provide adequate support with negligible settlement. The structure can be severely damaged, and lives can be endangered, if the falsework settles during the concrete pour or during the curing period. If the bearing strength of the soil is not adequate for mudsill applications, then temporary piling or false piles are typically installed. The falsework piling must be driven to sufficient bearing capacity to support the imposed loads. The Office of Bridge Design will check the location and bearing of the falsework pile and determine if they provide adequate support. You should check the driving of these pile, so that they are driven in the proper location and to the correct bearing in accordance with the approved falsework plans. When any items differ from that proposed, consult your Project or Area Engineer and the Office of Bridge Design. Record all findings and decisions in your diary. When the falsework is no longer needed, the temporary piling must be removed. If they are sawed or broken off, the top of the pile remaining must be at least one foot below the finished ground line or a depth your Engineer specifies.

Figure 6.4 Typical Falsework Pile Bent



Mudsills

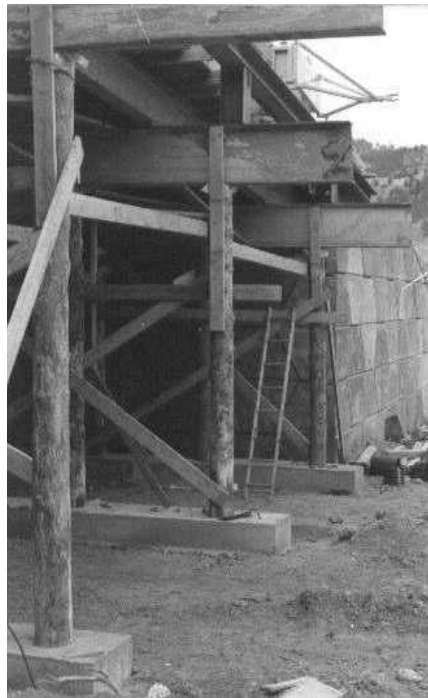
Mudsills can be used only where soil conditions provide adequate bearing strength. Areas on which mudsills are placed must be thoroughly compacted. The Office of Bridge Design and Foundation Office should be notified and consulted if there is any question as to the supporting bearing capacity of the soil.

There are two types of mudsills commonly used, timber or concrete.

- Timber mudsills consist of laying a large timber member flat on the ground. If the timber mudsill is allowed to bear on uneven ground, and thus is supported by high spots, there will be settlement when the concrete is placed in the forms. If necessary to obtain uniform bearing, a thin layer of sand may be used to fill in surface irregularities.
- Concrete mudsills consist of filling a trench or pad area with concrete. The concrete strength and pad depth must have sufficient thickness to resist any punching shear loads that may result from the loaded framework.

Details of proposed mudsills should be submitted in the falsework plans to the Office of Bridge Design for review. These details should show all dimensions and sizes of the mudsills. In addition, the details should note the size and spacing of reinforcing steel, if any, that is going to be used in a concrete mudsill. You should check that the sizes of the mudsills have been included and approved along with the falsework plans.

Figure 6.5 Typical Mudsill



Tubular Steel Scaffolding

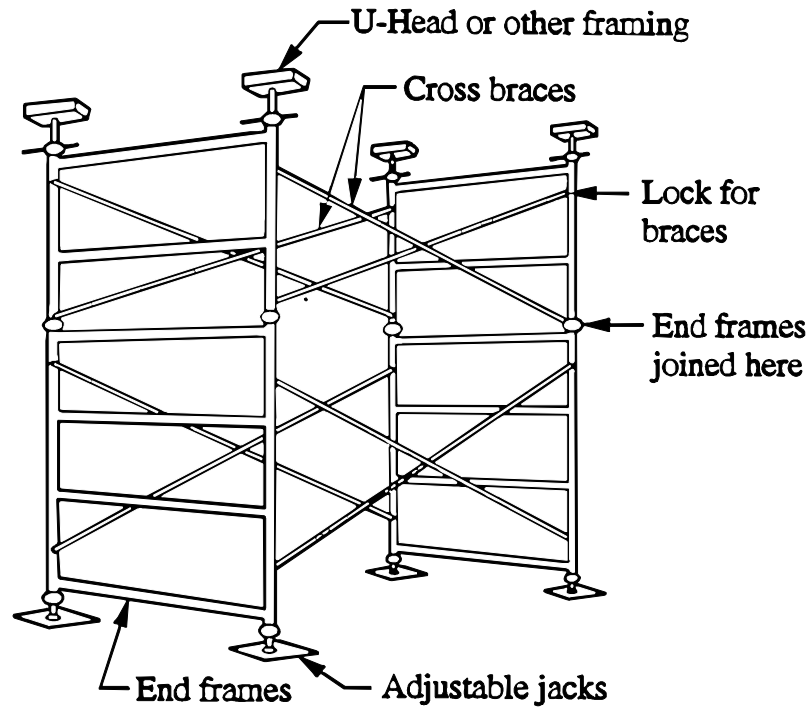
The basic components of tubular steel scaffolding are end frames of various designs and dimensions which are assembled with diagonal bracing and lock clamps. Vertical adjustments are made by adjustable jacks either at the top or bottom of the frames. Frames are normally fitted either with flat tops or U-heads for supporting the above falsework and forms.

Manufacturer's data should be included with the falsework plans detailing the size of the frames and the allowable loads per leg or frame (two legs). You should check to verify that the frames being used match those approved in the falsework plans, and

that they are free from bends, kinks, or any other defects that could compromise their strength. Any members that appear damaged should be rejected and not allowed as part of the falsework.

Adequate rigid bracing is a must with this type of support. All the braces should be rigid, and connections should be adequately tightened prior to any concrete pour. Full bearing for the base plates should be provided on top of the mudsills.

Figure 6.6 Tubular Steel Scaffolding



Strickland Bracket

Strickland brackets are steel brackets with threaded adjustment for height. Threaded rod is placed through the column in holes formed before concrete placement. Contractor will normally place two brackets in each column. Attention to placement location is necessary especially on skewed bridges if the bracket gets too far around the column it will not fully support the beam.

Figure 6.7

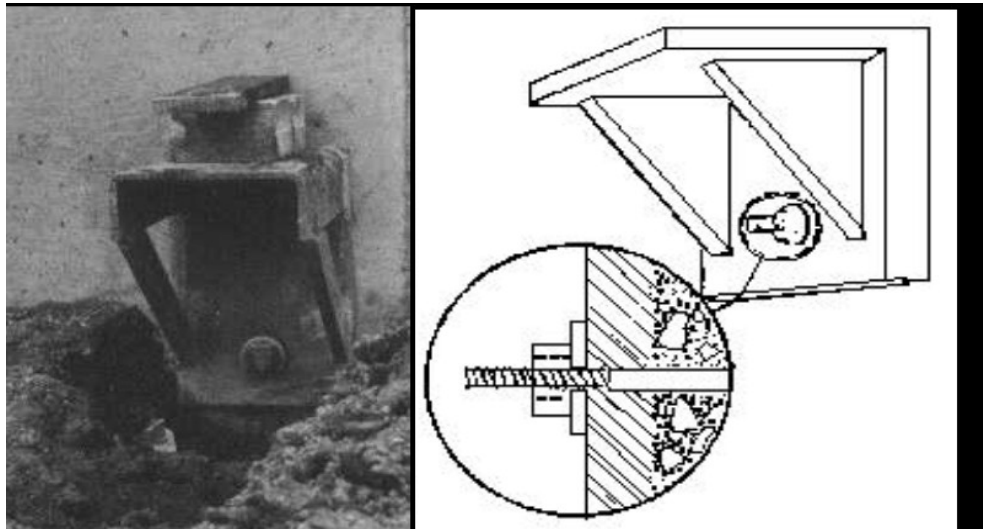


Bolted Brackets

These are metal brackets attached to beams, columns, or abutments with a bolt. The falsework plans show the size and location of the brackets, and they must meet specifications. The bolts must be long enough so none of the threaded portion is in the contact plane between the bracket and supporting unit.

When the bracket is attached to concrete, the bolt hole is made by placing a pipe sleeve between the forms. When the bracket is no longer needed, the hole should be filled with grout. Bolt holes for brackets on steel beams are made by drilling a hole in the beam. Before drilling any holes in steel, check with the Office of Bridge Design. After the bracket is removed, high strength bolts must be placed in the holes. Have the bolt installed so the head is to the outside of the structure on the exterior beams.

Figure 6.8 Bolted Bracket



Beams, Stringers, and Joists

The bridge deck is directly supported by a framework system of joists, stringers, and beams. These members can be either timber, steel, or manufactured products that are specifically designed for falsework applications.

Timber

Timber members are the most common members directly supporting plywood formwork. Although occasionally all new lumber may be used for the falsework, more often than not, the lumber is old and has been used over and over. Timber, no matter what quality or grade, always loses strength with age and repetitive use. You should always bear this in mind when inspecting the lumber used in the falsework framing.

You should check the quality of the timber as well as critical dimensions and spacing. Timber having large shakes, checks or knots, or which are warped and split should not be used at critical locations. Check to see that the proper sized members are used at the locations, span lengths, and spacing as approved in the falsework plans. If there are deviations that are not being corrected, notify the Office of Bridge Design immediately.

Structural Steel

Used beams, particularly beams salvaged from a previous commercial use, should be examined carefully for loss of section due to welding, rivet or bolt holes, or other openings which may adversely affect the ability of the beam to safely carry the load imposed by the falsework. Like timber, steel beams that have large openings, bends or warped flanges, or other questionable damage should not be used at critical locations. Again, verify that the same beam size and span length is being used as was approved in the falsework plans.

Manufactured Steel Joists

There are several versions of manufactured joists that provide the Contractor greater flexibility because they can be adjusted to a variety of span lengths. The joist's load capacity, allowable spacing, and deflection data are available from the manufacturer's literature that should be included with the falsework plans submittal and approval. As the capacity of the joist is controlled by the adjusted length, it is critical that the spacing and span lengths as approved in the falsework plans are not exceeded or deviated.

Another unique aspect of adjustable steel joists is the residual camber that is built into the joist. Most manufactured joists have a camber built into the member. Since the member is designed to accommodate several span lengths, there is always some camber that remains in the joist (residual camber) even after the joist is fully loaded. The Contractor should have a good feel for the amount of residual camber anticipated after placement of the concrete. Adequate allowance should be made when setting the joist bearing height so that the specified minimum slab thickness is maintained.

It is important that extreme care is taken in setting slab forms to assure that the specified surface profile of the finished bridge deck is achieved.

Hangers

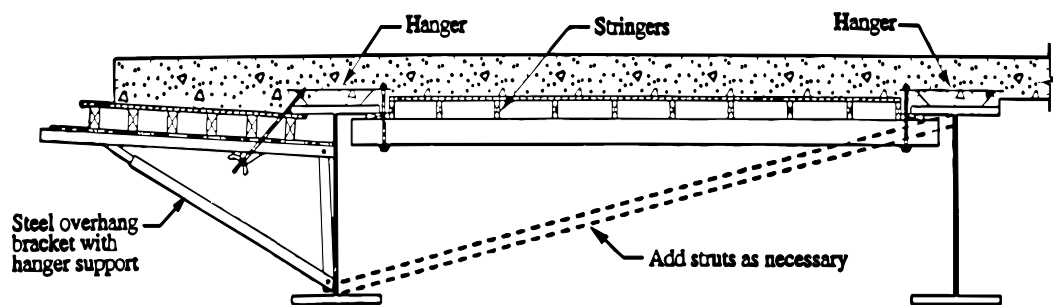
Falsework for girder bridges typically relies heavily on manufactured hangers that support a system of joists and timber framing. The hanger is essentially a hardware item that is laid transversely across the top flange of the beam to receive a vertical or diagonal bolt on either side of the flange. The bolt in turn supports the main falsework member.

These hangers are specifically designed for use in bridge falsework construction. Manufacturer's data on the hangers should be included with the falsework plans. This data should note the hanger model number, type, allowable loads, and specific installation requirements. It is critical that the hangers be installed as per manufacturer's instructions. You should verify that the hangers used in the falsework match those approved in the falsework plans.

Balanced loading of the two sides of the hanger (simultaneous loading of both bolts) is important in the early stage of falsework unless measures are taken to hold the hanger in place.

Occasionally a Contractor will request to weld these hangers directly to the top flange of a steel girder. Welding of falsework components to any part of a steel girder is not allowed. Welding to reinforcing steel is also not permitted.

Figure 6.9 Hangers and Overhang Bracket on a Steel Girder Bridge



Overhang Brackets

The cantilevered slab edge of a girder bridge is usually supported with an overhang bracket. Most often, this bracket is a manufactured item designed specifically for this application. Occasionally the bracket may be a 'home-made' item built by the Contractor. Again, manufacturer's literature and data on the bracket should be included with the falsework plans. You should verify that the brackets used in construction match those approved in the falsework plans.

It is critical that the Contractor have a working knowledge for how much deflection the bracket will undergo when fully loaded during construction (including formwork weight, concrete weight, and finish machine weight). Allowance should be made for

this deflection when setting the formwork as well as the rail height for the finish machine.

Cantilever brackets can tend to rotate or push the bottom flange of the exterior bridge girder inward. Occasionally, special bracing is required to prevent this rotation. You should check the approved falsework plans for bracing requirements. In order to prevent damage to the bridge girder, the bottom of the bracket should also have blocking or carpet padding installed between it and the supporting bridge girder.

Bracing and Connections

Every effort should be made during falsework erection to ensure that all connections are structurally stable and that adequate bracing is installed. Inadequate attention to bracing and connections is often the most common cause of falsework failures.

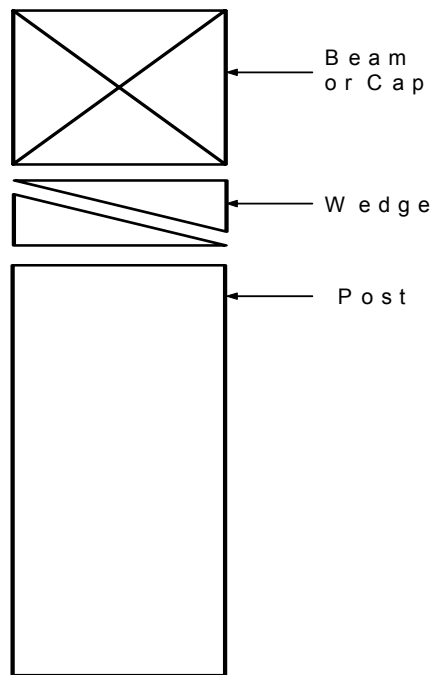
Timber members, in particular, rely on heavy bracing to prevent rotation or movement. Often the strength of the member can be greatly reduced if adequate bracing is not in place. If cable bracing is used, pay particular attention to the clamping or fastening of the cables at the ends. Improperly installed clamps can reduce the safe working load of the cable by as much as 90%.

Check all connections to ensure that they are adequate. Make sure that all bolts have been tightened and are not loose. Check field welds to make sure that they are free from cracks or other defects that could compromise their strength.

Blocking and wedges should be kept to a minimum. It is poor workmanship to extend a short post by piling up blocks and wedges. When using wedges, it is a good practice to use wedges inserted from both sides rather than deeply setting a single wedge. Using only one wedge increases the twisting effect on the member. It is also good practice to install the wedges parallel to and with the flat (non-tapered) side against the main member. This improves the contact with the main member and decreases the change of a wedge "backing out" from vibration. The wedge should be nailed or clamped in place after installation and final elevations are set.

The Contractor is responsible for the structural stability of the falsework, however, you as an inspector should not allow areas to be built that are, in your opinion, questionable as to stability and adequacy. If in your opinion the falsework system is unstable, and the Contractor fails to make corrective measures to alleviate the problem, then notify the Office of Bridge Design immediately.

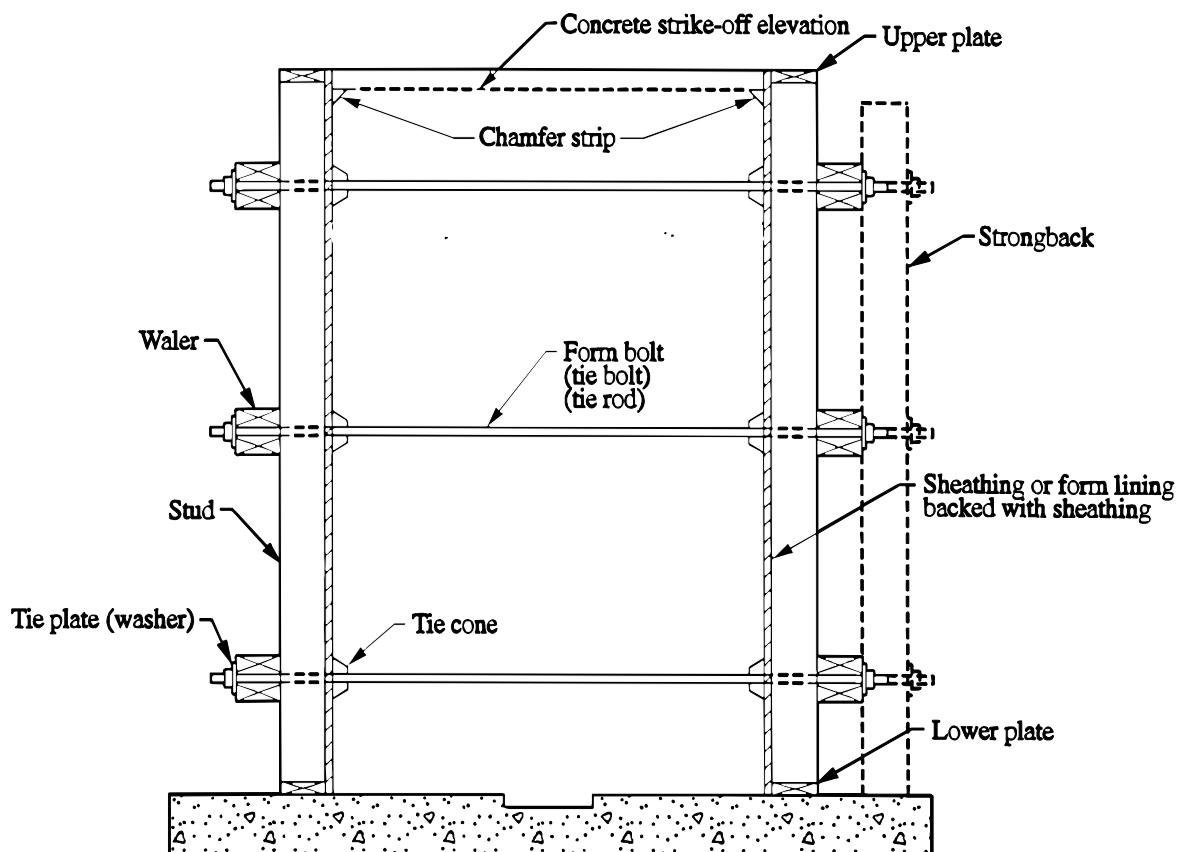
Figure 6.10 Wedge Placement



Forms

Forms hold the plastic concrete in place until it gains strength to hold its own shape. The form material condition and how it is assembled determines the finished structure.

Figure 6.11 Typical Formwork



Material

Forms can be of a variety of material: wood, metal, plastic, fiberglass, or even paper. Wood, generally plywood (or plyform), is the most commonly used form material. Wood has more strength and a greater resistance to bending when its grain runs perpendicular to the supporting member. Plywood is made by laminating thin sheets of wood, the grain of each sheet being perpendicular to the previous sheet. Plywood is stronger when the grain on the face plies run across or perpendicular to the supports.

Figure 6.12 Plywood in Weak Direction

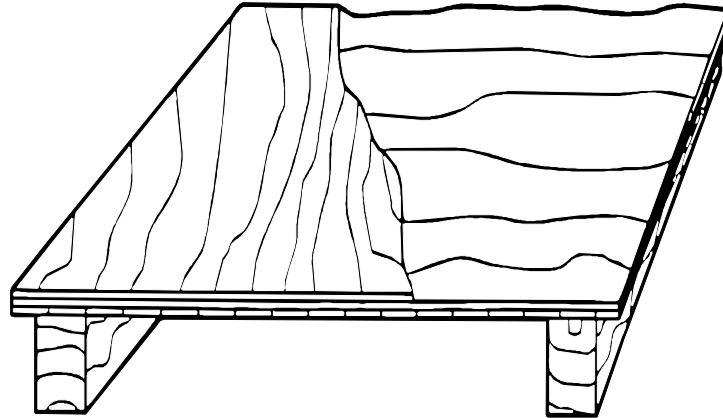
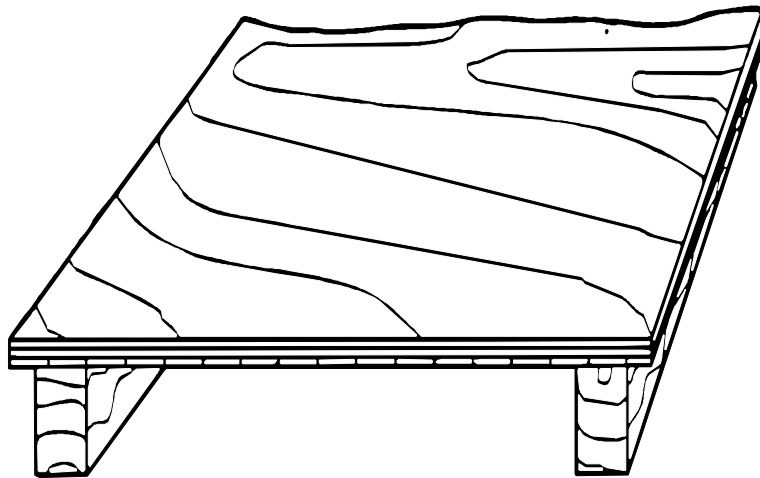


Figure 6.13 Plywood in Strong Direction



The falsework plans are reviewed with the assumption the forms will be placed with the grain perpendicular to the supports. Inspect the construction work to make sure lumber is being properly placed. If you observe two or more sheets incorrectly placed, advise the Contractor.

If form lumber is reused, inspect it for condition. Lumber that is split, warped, marred, or has a defect that could produce inferior work should not be used. Concrete surfaces not exposed after the structure is complete do not require as good a material as those surfaces exposed. The material must be structurally sound however.

Lesser quality of material can be allowed when forming: footings, backs of abutments, or barrels of box culverts.

Good material should be used when forming: columns, decks, or wing walls.

Any form lumber that contains a sappy area needs to be covered with shellac, white wash, or a plastic coat. Sap is a source of tannic acid and causes concrete to remain soft.

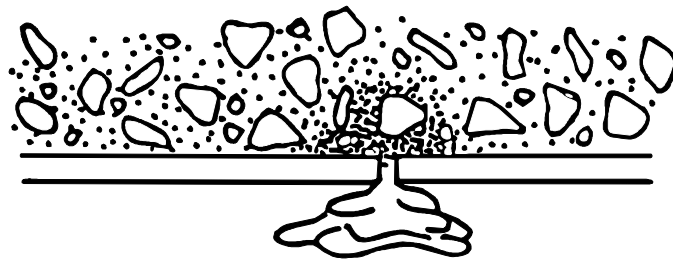
There are two types of metal forms: all metal, and metal frame with wooden panels. Check to see they have a smooth surface. Reject any that have bolts, rivets, or pins protruding or are bent, twisted, or dented. When these forms are used where finished concrete will be exposed, they must be free of rust, grease, or anything that may discolor the concrete.

Plastic, fiberglass, and paper forms are used for fancy designs and occasionally as column forms. They must be clean and in good condition.

Construction

The manner in which forms are constructed determines the appearance of the finished product. Observe the form building and make sure they are built to correct dimensions, elevations, and line. The form joints must be tight, or mortar from the concrete will leak through, leaving a sand streak in the concrete surface or a rock pocket. All joints of the form material should meet at a support. If not, the plastic concrete may blow them out. This will create an uneven surface and possibly a sand streak or rock pocket.

Figure 6.14 Results from Forms not Tight

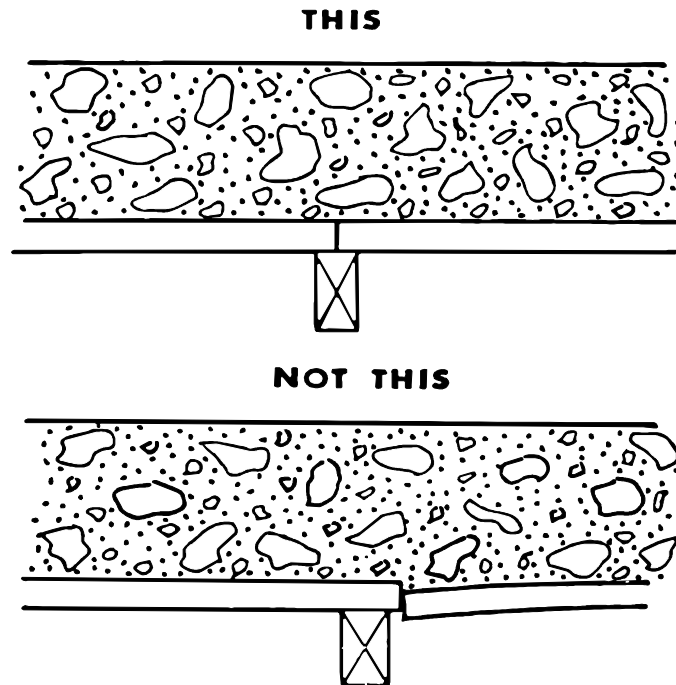


Sand streak



Rock pocket

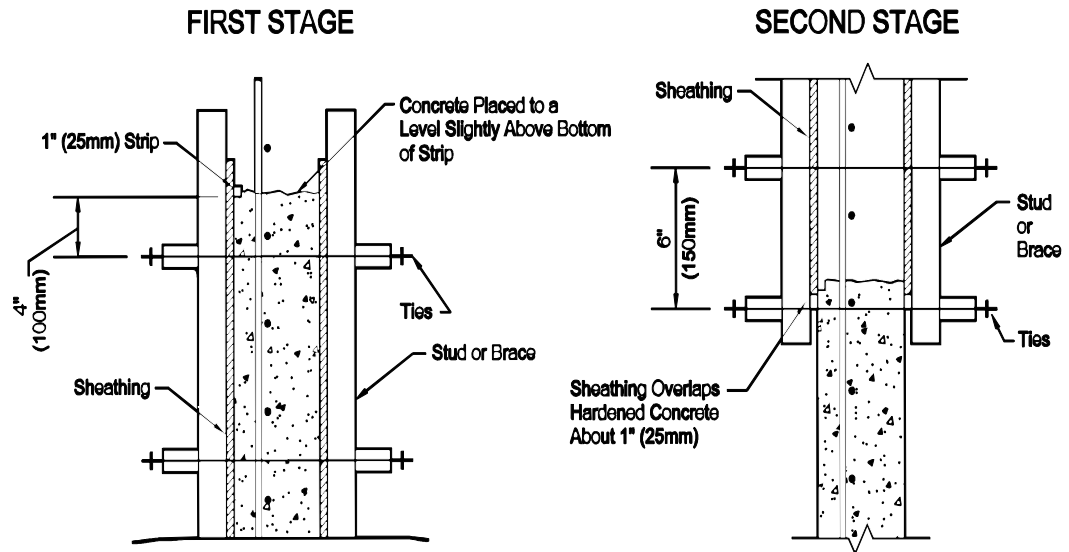
Figure 6.15 Form Joints



Form oil must be placed on the formwork prior to placement of reinforcing steel in order to permit easy removal of the form after the concrete has cured. The oil should be an approved commercially available product intended for use with concrete formwork. Motor oil, grease, or other contaminants are not acceptable.

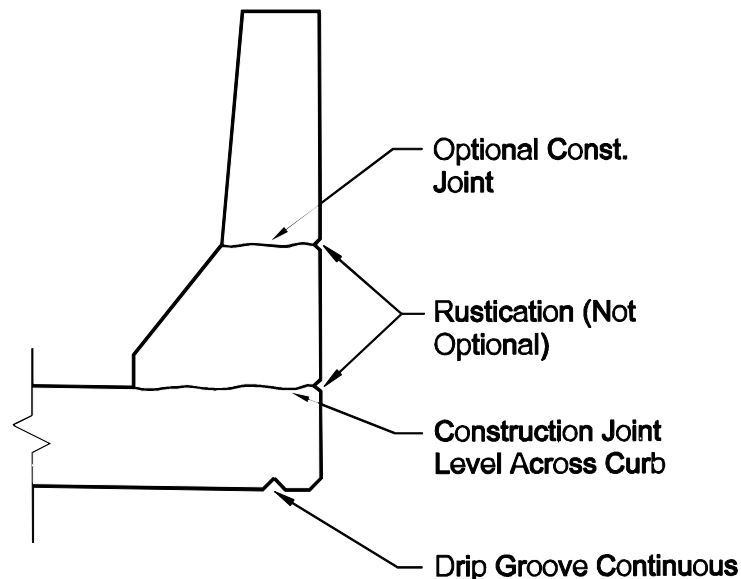
Occasionally forms will be set so additional concrete can be extended smoothly from a section already in place. This occurs when high walls are poured in several lifts or when another part is added to previously placed concrete (curb to deck, back wall to abutment footing, another barrel section of a box culvert, etc.). Bracing forms on "in place" concrete and achieving a smooth surface is difficult. The form placement diagrams in Figure 6.16 illustrate form construction to ensure a smooth surface match.

Figure 6.16 Multiple Pours on a Wall Section



There are instances where forms cannot be tied as shown in Figure 6.16. When these can be seen, the plans provide a way of covering the joint with a rustication strip. Figure 6.17 shows a rustication strip between the deck and barrier curb. A rustication strip is occasionally used for decoration as may be typical in a pier or bent cap. Figure 6.17 also shows detail for the drip groove and chamfer. The drip groove is a collecting point where the water must drop off the deck. A chamfer is a bevel used to round corners of exposed concrete. This keeps the edges from chipping and becoming unsightly.

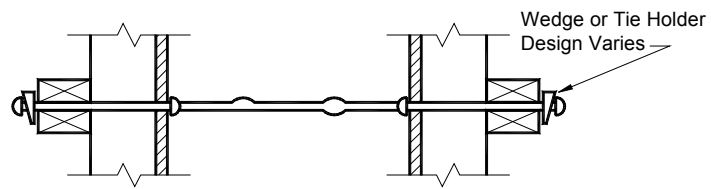
Figure 6.17 Rustication, Drip Groove, and Chamfer



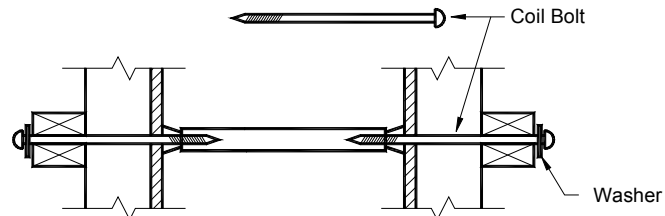
Forms of wall sections are held together with ties. There are several types of ties, and ordinary wire can be used. When removing forms, ties must be cut back at least 1/4 inch from the concrete face. Check the dimensions between the forms to see that the ties are the correct length for the wall being built.

Figure 6.18 Typical Form Ties

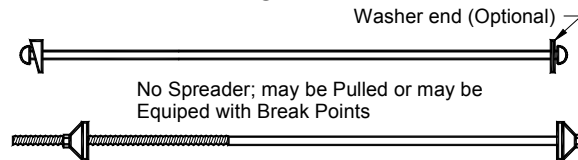
SNAP TIE WITH SMALL CONE SPREADER



COIL TYPE TIE WITH CONE SPREADER

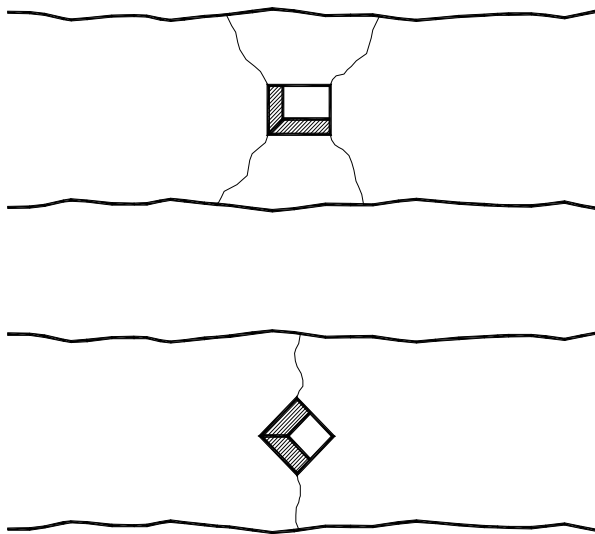


TAPER TIE TO BE WITHDRAWN



Often plans call for an area in the concrete to be blocked out. The blocking out will usually be a rectangle. If possible, set them so they appear as a diamond - this reduces cracking. It is also good to taper the blockout, as removal is easier and reduces the chance of spalling out a chunk of concrete.

Figure 6.19 Blockouts



Dimensions, Tolerances, and Deflection

General Tolerances

The Contractor is responsible for building forms of proper dimension and elevation. Check them before any concrete is placed and again after to assure that nothing moved during concrete placement. Specifications required that the construction tolerances be in accordance with the latest edition of ACI 117. A detailed, tailored

summary of the specification has been included in the Appendix. You should refer to this specification for specific construction tolerances for each formed item (i.e. - walls, columns, slabs, etc.).

Take form elevations to the nearest 0.01 foot. It should be close to specifications or there will be difficulty in fitting structure parts. You should be able to check the elevation within ± 0.02 feet. If a dimension or elevation variance is greater than the allowable, the Contractor must make corrections.

Girder Bridges

Before constructing the deck of a steel beam or prestressed concrete girder structure, the Contractor must have elevations for the plywood decking. After the beams are in position, take elevations along the tops of the girders at the locations given on the Erection Data Sheet of the plans (Figures 6.20 and 6.21).

With these elevations, you can determine where to set the form by using the Table of Slab Form Elevations and Computations on the Erection Data Sheet (Figure 6.21). The elevations "M" already shown in this table are for the top of slab and contain an allowance for camber. By subtracting the elevation for the top of beam and the deck thickness from "M" elevation for that location, you have the "h" distance the form needs to be from the beam top. Usually the forms will be between 1/2 inch and three inches above the beam. Occasionally, the "h" may have a minus value. This means the form will be lower than the top of the beam. Anytime "h" values exceed three inches or is less than 1/2 inch, contact your Project or Area Engineer and the Office of Bridge Design. The grade line of the deck may require change, because the shear connectors will not function as designed, if these values are not maintained.

After figuring the "h" distance, convert it into increments of 1/8 inch and paint them on the beam. When the forms are built, measure the forms at each of these points along the beams to check accuracy of their construction. A copy of the slab form elevations (Figure 6.21) should be sent to the Office of Bridge Design. Final elevations on top of the slab for matching points should also be submitted. This information gives a basis for comparing actual dead load deflection to the theoretical, actual camber of the beams, etc.

Example: The top of Girder #2 elevation for point #4 in Fig. 6.20 & 6.21 is 1305.60. What is the "h" distance for this point?

Solution

- 1 Determine distance "d": $1306.391 - 1305.60 = 0.791$ feet.
- 2 Determine distance "h": $0.791 - 0.7083 = 0.0827$ feet or 1 inch

Form Camber and Crushing

Checking form elevations of a continuous concrete structure is more difficult. While adjusting for the dead load deflection camber, an allowance must also be made for lumber crush and form camber. The dead load deflection camber is the distance the top of the slab must be above the profile grade when the forms are in place. When form support is removed, the deck becomes self-supporting, and this camber is flattened due to its own weight.

Form camber is similar. The forms are "humped up" so when they flatten due to the weight of concrete, they can support the deck at its camber elevation. Regardless of the type of form used (commercial truss system, a series of steel beams, or timbers) to support the forms, some form camber is necessary. If not shown on the falsework plans, ask the Contractor what they plan to use.

Figure 6.20 Typical Girder Layout and Camber Diagram Plans Sheet

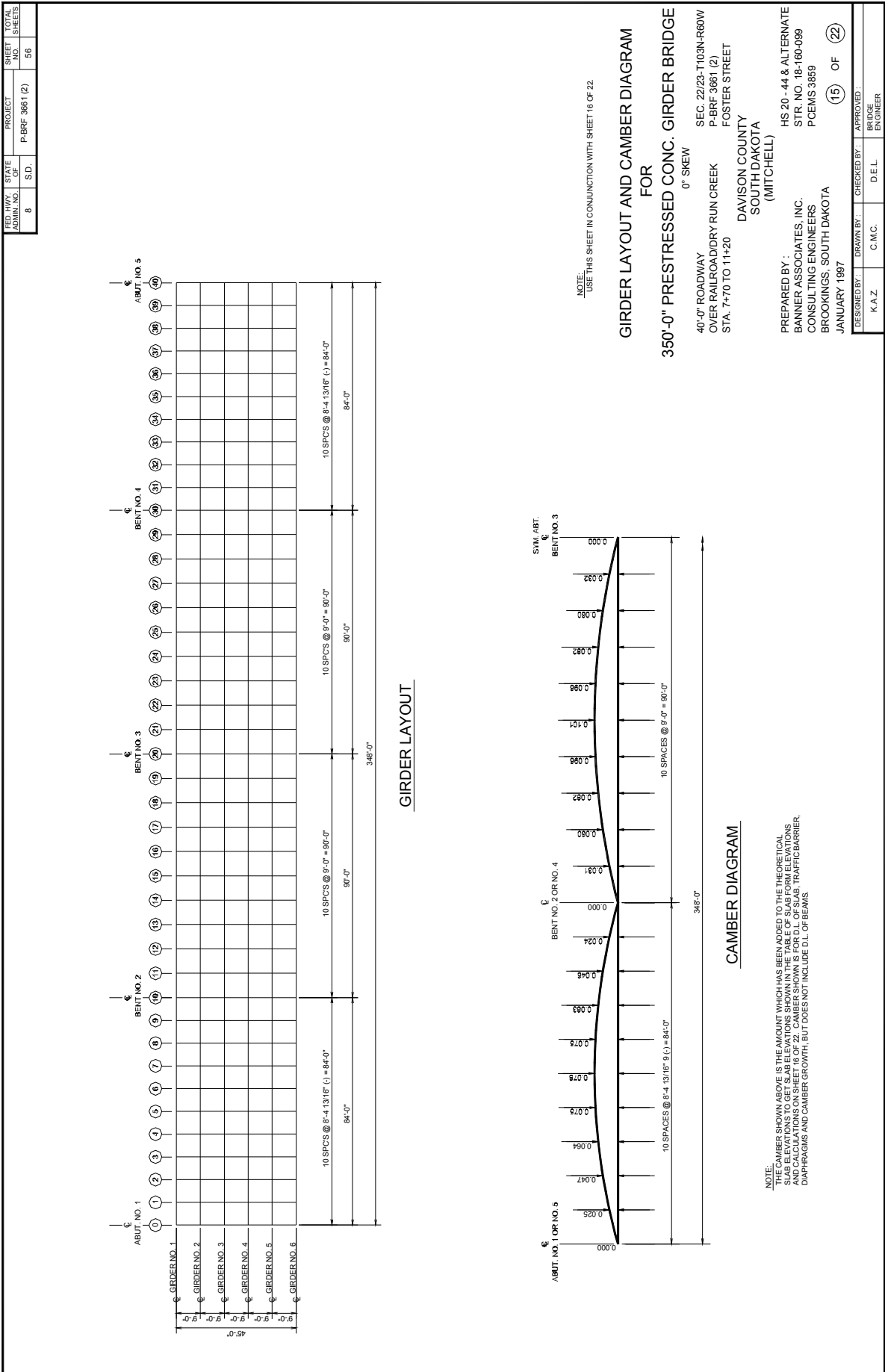


Figure 6.21 Typical Slab Form Elevations Plans Sheet

		FED. HWY. STATE		PROJECT		TOTAL	
		ADMIN. NO.		NO. OF SHEETS		NO. SHEETS	
		8		S.D.		P-BRF 3661 (2)	
						57	

TABLE OF SLAB FORM ELEVATIONS AND CALCULATIONS

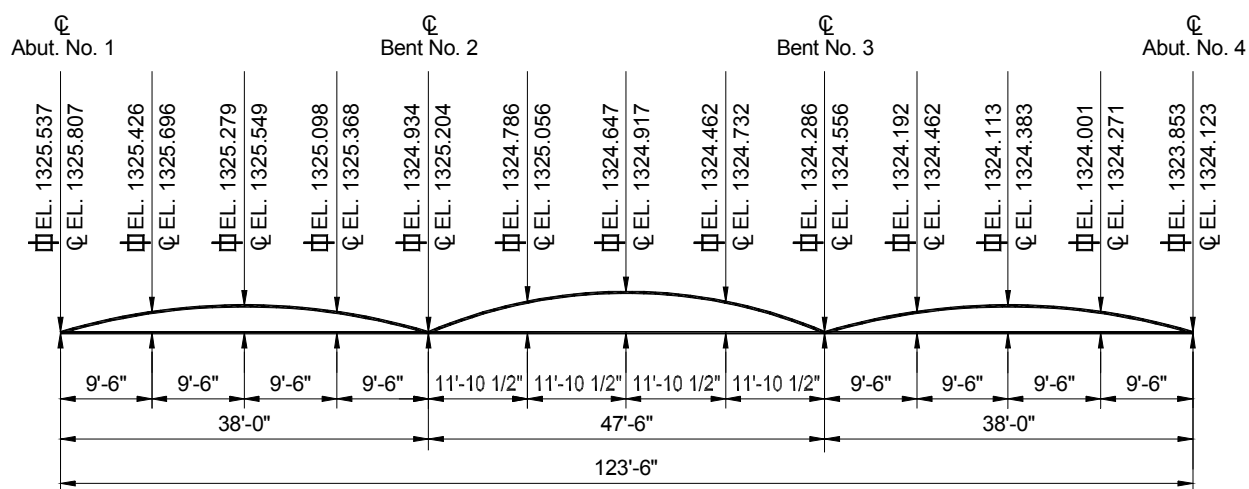
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
GIRDER NO. 1	ELEV. "M"	1305.144	1305.431	1305.705	1305.966	1306.211	1306.440	1306.653	1306.850	1307.031	1307.199	1307.366	1307.572	1307.774	1307.960	1308.127	1308.275	1308.403	1308.511	1308.601	1308.673	1308.735	1308.848	1308.948	1309.031	1309.096	1309.141	1309.167	1309.172	1309.160
	(-) ELEV. "N"																													
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GIRDER NO. 2	ELEV. "M"	1305.324	1305.611	1305.885	1306.146	1306.391	1306.620	1306.833	1307.030	1307.211	1307.379	1307.536	1307.752	1307.954	1308.140	1308.307	1308.455	1308.583	1308.691	1308.781	1308.853	1308.915	1309.028	1309.128	1309.211	1309.276	1309.321	1309.347	1309.352	1309.340
	(-) ELEV. "N"																													
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GIRDER NO. 3	ELEV. "M"	1305.504	1305.791	1306.065	1306.326	1306.571	1306.800	1307.013	1307.210	1307.391	1307.559	1307.716	1307.932	1308.134	1308.320	1308.487	1308.635	1308.763	1308.871	1308.961	1309.035	1309.095	1309.208	1309.308	1309.391	1309.456	1309.501	1309.527	1309.532	1309.520
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GIRDER NO. 4	ELEV. "M"	1305.684	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
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GIRDER NO. 5	ELEV. "M"	1305.804	1305.791	1306.065	1306.326	1306.571	1306.800	1307.013	1307.210	1307.391	1307.559	1307.716	1307.932	1308.134	1308.320	1308.487	1308.635	1308.763	1308.871	1308.961	1309.035	1309.095	1309.208	1309.308	1309.391	1309.456	1309.501	1309.527	1309.532	1309.520
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GIRDER NO. 6	ELEV. "M"	1305.924	1305.611	1305.885	1306.146	1306.391	1306.620	1306.833	1307.030	1307.211	1307.379	1307.536	1307.752	1307.954	1308.140	1308.307	1308.455	1308.583	1308.691	1308.781	1308.853	1308.915	1309.028	1309.128	1309.211	1309.276	1309.321	1309.347	1309.352	1309.340
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GIRDER NO. 7	ELEV. "M"	1306.044	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
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GIRDER NO. 8	ELEV. "M"	1306.164	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
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GIRDER NO. 9	ELEV. "M"	1306.284	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
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	(-) ELEV. "N"																													
GIRDER NO. 10	ELEV. "M"	1306.404	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
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	(-) ELEV. "M"																													
	(-) ELEV. "N"																													
GIRDER NO. 11	ELEV. "M"	1306.524	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
	(-) ELEV. "N"																													
	(-) ELEV. "M"																													
	(-) ELEV. "N"																													
GIRDER NO. 12	ELEV. "M"	1306.644	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
	(-) ELEV. "N"																													
	(-) ELEV. "M"																													
	(-) ELEV. "N"																													
GIRDER NO. 13	ELEV. "M"	1306.764	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
	(-) ELEV. "N"																													
	(-) ELEV. "M"																													
	(-) ELEV. "N"																													
GIRDER NO. 14	ELEV. "M"	1306.884	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
	(-) ELEV. "N"																													
	(-) ELEV. "M"																													
	(-) ELEV. "N"																													
GIRDER NO. 15	ELEV. "M"	1307.004	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193	1307.390	1307.571	1307.739	1307.896	1308.112	1308.314	1308.500	1308.667	1308.815	1308.943	1309.051	1309.141	1309.215	1309.275	1309.388	1309.488	1309.571	1309.636	1309.681	1309.707	1309.712	1309.700
	(-) ELEV. "N"																													
	(-) ELEV. "M"																													
	(-) ELEV. "N"																													
GIRDER NO. 16	ELEV. "M"	1307.124	1305.971	1306.245	1306.506	1306.751	1306.980	1307.193																						

Lumber crush is settlement that takes place when the joints are squeezed due to the weight of the concrete in the forms. The general rule is 1/16 inch of settlement for each place where a support rests on another. A 1/4 inch is the maximum allowance to use for this crush. Ask the Contractor for the amount they plan to allow.

Once values for form curb elevation, center line elevation, and lumber crush have been obtained, check the form elevations. Form elevations are figured as follows:

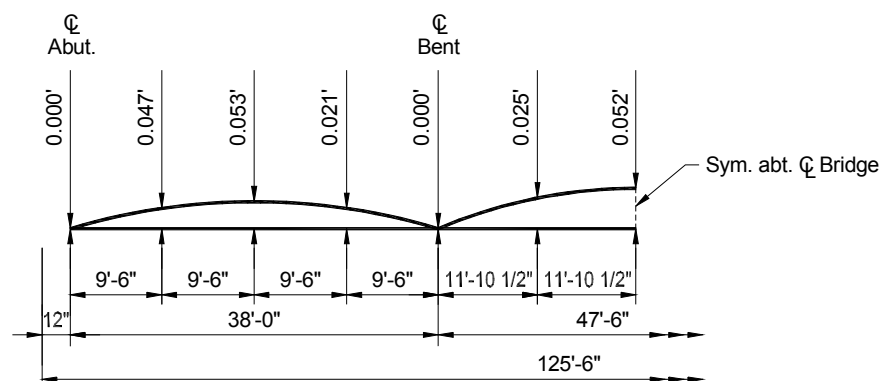
- 1 Use the top of slab elevation from the Curb and Center line Elevation Diagram (Figure 6.22) and subtract the thickness of the deck.
- 2 Add the lumber crush being allowed to each of the elevations from above.
- 3 Add the form camber to each elevation in #2. There should be no form camber to add at the supporting substructure units or false bents.

Figure 6.22 Typical Slab Form Elevation and Camber Diagrams on a Slab Bridge



CURB & CL ELEVATION

Elevations indicated with $\overline{\text{C}}$ are Top of Finished Slab at Curbs; with $\overline{\text{CL}}$ are Top of Finished Slab at Center Line of Roadway. Camber for Dead Load Deflection PLUS Plastic Flow, shown below, have been included in the elevations shown above.



CAMBER DIAGRAM

Camber is calculated for dead load deflection plus plastic flow and shall be added to the proposed grade elevations at the respective stations to establish the elevations of the finished roadway slab.

Example: The Contractor has a false bent in the center of each span of a continuous concrete bridge. He is allowing 7/8 inch for form camber between supports, and 3/16 inch for lumber crush. Using the camber diagram in Figure 6.22, what should the form elevation be at the center line quarter point between Bents #2 and #3? The thickness of the deck at the quarter point is 15 inches.

Solution

- 1 Obtain bottom of deck elevation prior to crushing or form camber:

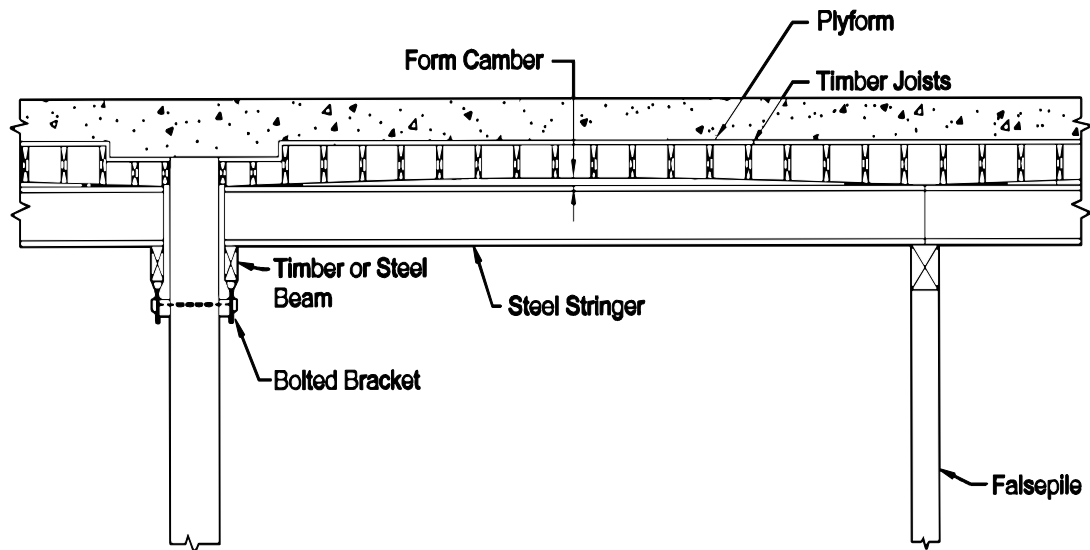
$$\text{El. } 1325.056 - \frac{15}{12} = 1323.81 \text{ (to the nearest 0.01 feet)}$$

- 2 Add lumber crushing: $1323.806 + .016 \text{ (3/16 inch)} = 1323.82$

- 3 Add form camber: $1323.82 + \frac{7.8}{12} = 1323.89$

Therefore the form elevation at the center line quarter point between Bents 2 & 3 should be El. 1323.89.

Figure 6.23 Form Camber



Removal

Concrete must be self supporting before forms and false work are removed. Usually the concrete strength will be obtained from concrete cylinders that are taken at the time of the concrete pour. These cylinders need to be cured as close as possible to the condition of the concrete that the cylinders represent. Should the need arise, an approximate concrete strength can also be checked using a Swiss Hammer. Both the procedures for taking the concrete cylinders as well as performing the Swiss Hammer tests are included in the SD Materials Manual and are discussed in more detail in 'Chapter 8 - Concrete'. If when determination of concrete strength is not possible, formwork may be removed when the concrete cure time exceeds a specified amount of time. The table shown in Section 460.3.K of the Standard Specifications shows the strength or time requirements that must be met prior to removal of forms.

When the forms and falsework are removed, you should be present when the falsework and forms are removed. See that care is taken not to jar, pry, or bang the forms. Remove supports from under the concrete slowly and uniformly. This allows concrete to pick up its own dead load, without causing any possible impact damage to the newly poured concrete. In addition, this allows you to observe the condition of the concrete surfaces and any possible defects that may exist before the Contractor begins grouting and finishing operations.

REINFORCING STEEL

Checklists

Acceptance Requirements

Certified Fabricator, Uncoated or Plain Bars

- Check steel delivered to site against shipping record
- Inspect bars for excessive rust and other signs of mishandling or damage
- Shipping record must be dated and signed for the project file

Non-Certified Fabricator, Uncoated Bars or Plain Bars

- Weather and wear resistant tags with heat numbers, size, length, etc. are attached to the bundles
- Check steel delivered to site against the mill test or certification report
- Inspect bars for excessive rust and other signs of mishandling or damage
- Shipping record must be dated and signed for project file

Epoxy-Coated Reinforcement

- Weather and wear resistant tags with heat numbers, size, length, etc. are attached to bundles. Check steel delivered to site against the mill test or certification report.
- Inspect bars for voids, holes, cracks, or other damage to coating and other signs of mishandling or damage
- Sample of 2 - 24 inch bars received and sent in to Central Laboratory for approval

Storage and Handling

General

- Bars stored on wood blocking to keep off the ground
- Long bars supported at several points
- Bars are carried not dragged along the ground or across forms with oil applied
- Damaged bars clearly marked "rejected" and removed from the site to prevent possible use in project

Epoxy-Coated Reinforcement

- Padded or non-metallic slings and straps used for movement of bundles
- Bars to be stored longer than 30 days covered with a waterproof opaque covering

Inspection Prior to Placement

- Check bars against reinforcing schedules for proper number, size, shape, and lengths
- Check bends for proper radii

Inspection During and After Placement

- Check bars placed against number required in plans
- Check that bars placed are at required locations and at proper spacing
- Splices and laps are tied correctly with the proper lap length provided
- Bars are free from dirt, oil, grease, mortar, or other contaminants

Wire Ties

- Ties are 16 gauge minimum
- Ties are plastic or epoxy coated when used for epoxy-coated reinforcement
- Bars are tied securely at required intervals
- Top mats tied as per special requirements
- Ties are bent inward or away from face of concrete or formwork

Clear Cover

- Proper clear cover maintained and within allowable tolerances
- Metal chairs or bolsters are spaced as per specifications
- Chairs and bolsters are plastic or epoxy coated when epoxy-coated reinforcement is used
- Concrete blocks used for reinforcing steel supports are of material stronger than concrete to be poured

Field Touch-up of Epoxy Reinforcement

- Touch-up coating material compatible with epoxy coating on reinforcement
- Touch-up coating material is used before pot life is exceeded
- All damaged areas are repaired
- Bars that have greater than 2% surface area damaged within a 1 foot length should be rejected
- The touch-up coating must be applied a minimum of 24 hours prior to concrete placement

General

Reinforcing steel is placed in concrete to increase its ability to resist bending and tension. Reinforcing steel for structures will be in two forms:

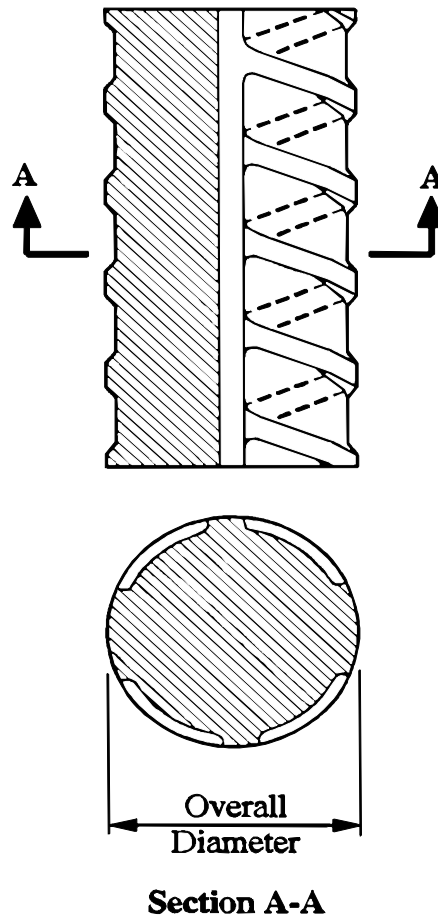
- 1 Smooth or plain bars

2 Deformed bars (epoxy coated or plain)

Smooth bars are used only for the spiral steel placed in the columns. This steel is fabricated in a spiral form before it is brought to the project.

Deformed bars have an irregular surface so the concrete can “grip the bar”. This utilizes the strength of the steel when placed in the concrete. Each steel manufacturer has individual design for the irregular surface. Bars are either straight or bent to some specific shape. Unless the plans state otherwise, all bending is done by the fabricator, prior to delivery.

Figure 7.1 Deformed Bar



Acceptance Requirements

When steel is delivered, you will first have to check who the supplier is. Certification and testing of the bars depends on whether the supplier is a Certified Fabricator (a list of these is in each Area Office) or a Non-Certified Fabricator.

Certification Requirements for reinforcing steel are as follows:

- From Certified Fabricator, Uncoated Bars: A record (bar list, shipping or bill of loading) of the lengths, shapes, and sizes to the Engineer for each shipment. Note that if the required information is contained on a single (master) list for all re-steel to be supplied to the project, then a record for each shipment will not be required.
- From Non-Certified Fabricator and for all Epoxy Coated Bars: A certified copy of the mill test report of chemical analysis and physical properties for each heat number or lot shall be forwarded to the Engineer. Deliveries to the project shall be identified by heat numbers, using metal or weather resistant tags wired to the bundles. Heat numbers may be referenced to the appropriate steel through a job

or shipping number, provided that the number is on both the certified copy of the mill test and the steel it represents.

- A Certificate of Compliance stating that the epoxy coating and the coating process conform to specifications.

NOTE The reinforcing steel shall not be placed in the work until records or certifications have been received or tests made.

Acceptance Requirements for reinforcing steel are as follows:

- From Certified Fabricator, Uncoated Bars: Use shipping record (bar lists, packing list, or bill of lading) to check shipment for lengths, shapes, and sizes. Visually inspect for rust scales, proper grade markings, and signs of mishandling. The Inspector shall include remarks and date and sign the shipping document for the project file.
- From Non-Certified Fabricator and for all Epoxy Coated Bars: A visual inspection on delivery to the project to note heat numbers, size, length, shape, and condition of shipment shall be recorded, dated, and signed by the Inspector on the certified copy of the mill test. The heat numbers shall be metal or weather and wear resistant tags secured to the appropriate bundles. Alternately, the heat number may be referenced to the appropriate steel through a job or shipping number, providing that number is on both the certified copy of the mill test and the steel it represents.
- On Epoxy Coated Bars check for voids, holes, cracks, and handling and shipping damage to epoxy coatings.
- One sample, 2 - 24 inch lengths per project, per source, from a randomly selected size, representing not more than three sizes or three heat numbers to be tested for physical properties at the Central Laboratory.

Storage and Handling

Reasonable care should be exercised by the Contractor when unloading or handling reinforcing bars to avoid kinking or otherwise damaging them. Long bars should be supported at several points when being handled or stored, and should not be dragged on the ground or across forms that have had form oil applied.

Reinforcing steel should not be stockpiled on the ground or where it is likely to be damaged or bent by equipment. Wood blocks should be used to elevate steel off the ground. Non-coated steel bars which are to be stored for a long period of time should be protected to minimize rusting. Rust, itself, should not be cause for rejection; but rusting to the extent that the bar becomes pitted or heavily scaled is definitely cause for rejection due to loss of strength and bonding ability.

Reinforcement bars which have become irreparably damaged due to improper handling, storage, bending, excessively rusted or pitted, or for any other reason should be rejected and removed from the site. When placed in the work, the reinforcement should be free from dirt, detrimental scale (rust), paint, oil, or other foreign substances that could hinder the bond between the bar and the concrete.

Figure 7.2 Reinforcing Steel Storage on Site



Epoxy-coated Reinforcement

Epoxy-coated reinforcing steel needs to be handled very carefully in an effort not to damage the coating. The following requirements should also be adhered to when handling epoxy coated reinforcement:

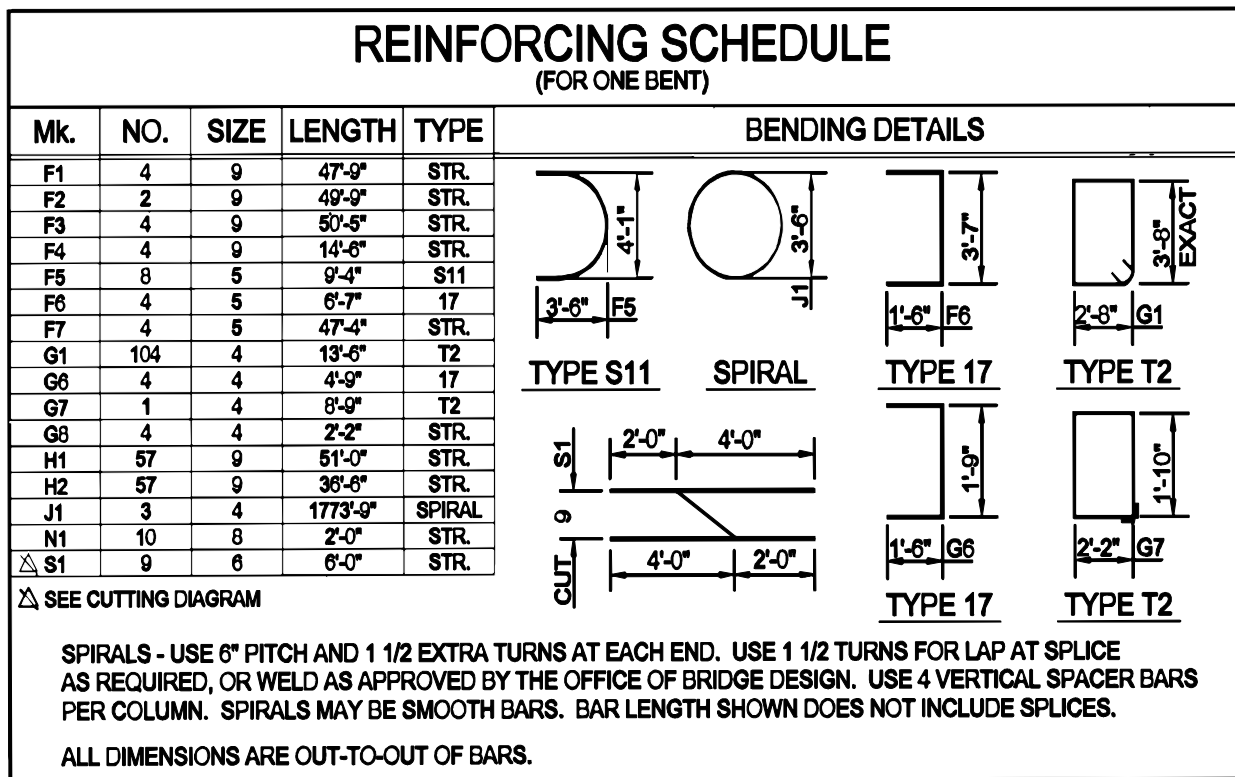
- Use padded or non-metallic slings or straps to load, unload, or move epoxy-coated reinforcement
- Bundled bars should be handled in a manner to prevent excessive sagging of the bars
- Care shall be taken during placement handling to assure that the bars are not dropped or dragged
- Bars should be covered with a heavy-duty waterproof opaque covering to protect the epoxy coating from dirt and debris and from the effects of ultraviolet rays if stored more than 30 days
- Damaged areas of bars should be field touched-up prior to concrete placement. This will be covered in greater detail later in this chapter

Checking Reinforcing Steel Prior to Placement

Reinforcing Schedule

The inspector should check size, grade, length, and bending of the reinforcing steel before it is placed in the structure. The reinforcing schedule on the plans describes size, length, number of pieces, and bending details for all steel used.

Figure 7.3 Typical Reinforcing Schedule

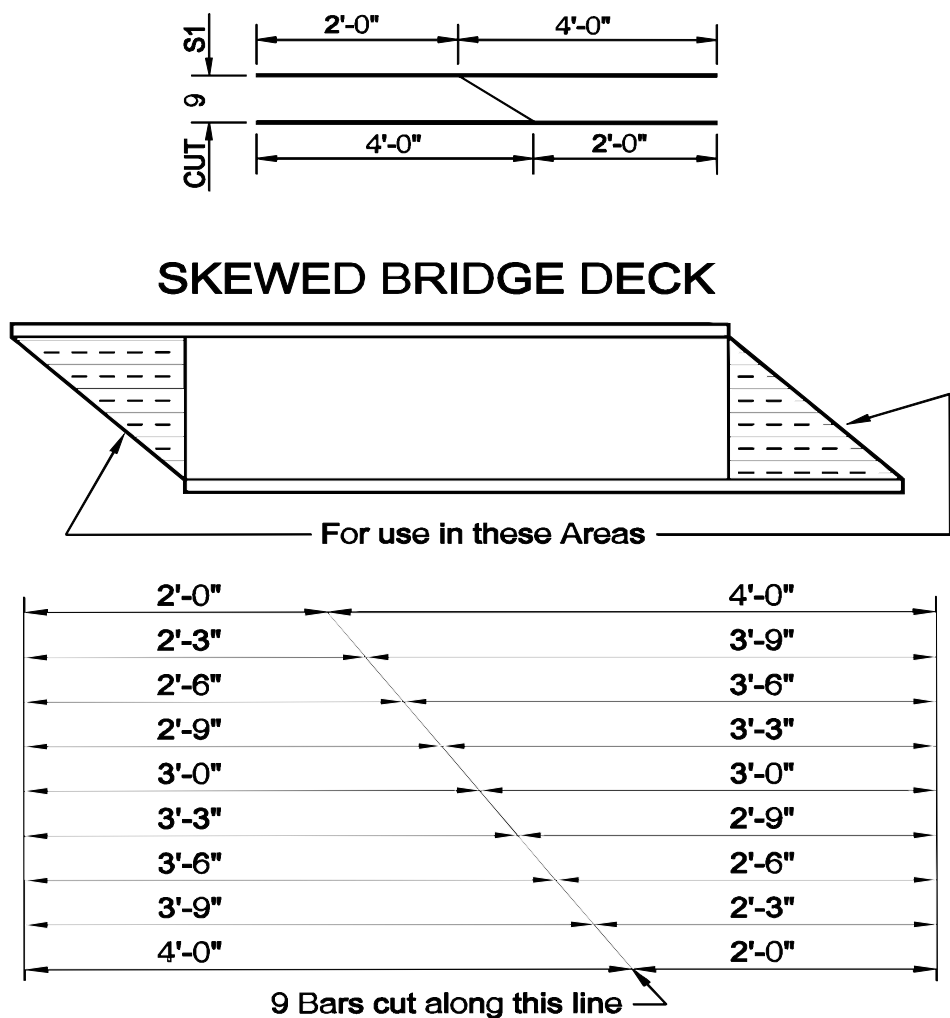


The reinforcing schedule shown above gives these items:

- Column 1 - Mk.: Shows an identification **mark** or bar name
- Column 2 - No.: Lists the **number** of pieces needed
- Column 3 - Size: Shows the bar **size**
- Column 4 - length: Lists the overall **length** of each bar
- Column 5 - Type: Designates the **type**, straight (str.) or bent. If bent, the designation indicates the shape or type of bend with reference to the bending details on the right side of the reinforcing schedule
- The Bending Details provide the dimensions and **shape** of bent bars as well as detail the cutting diagrams for cut bars
- The reinforcing schedule also has **notes** on the reinforcing steel

The bending details show the shape of bent bars. Straight bars are not detailed except when cut bars are needed. The following symbolizes a series of bars that will need to be increased in length in an equal amount from 2 feet to 4 feet. These bars are cut to these varied lengths for use in skewed decks, wing walls, etc. The 'S1' bar shown in this Figure illustrates how this bar would be detailed in the reinforcing schedule.

Figure 7.4 Example of Cutting Diagram Bars



To determine the length of the bars, divide the number of spaces into the length increase. The sketch calls for nine bars that are from 2 feet to 4 feet. This means eight spaces are between the bars, and the length increase is 2 feet. So, 24 inches divided by eight spaces equals a 3 inch increase per bar.

Bar Numbers and Symbols

Numbers are used when referring to bar sizes and are stamped on all bars. The chart shown in Figure 7.5 shows bar numbers and their respective weight and nominal dimensions. You can check sizes by referring to the reinforcing schedule, then reading the number stamped on the bar.

Figure 7.5 Properties of Standard Reinforcing Bars

Inch-Pound Bar Size	Nominal Weight Lb./Ft.	Nominal Dimensions – Round Sections		
		Diameter In.	Cross Sectional Area In. ²	Perimeter In.
#3	0.376	0.375	0.11	1.178
#4	0.668	0.500	0.20	1.571
#5	1.043	0.625	0.31	1.963
#6	1.502	0.750	0.44	2.356
#7	2.044	0.875	0.60	2.749
#8	2.670	1.000	0.79	3.142
#9	3.400	1.128	1.00	3.544
#10	4.303	1.270	1.27	3.990
#11	5.313	1.410	1.56	4.430
#14	7.650	1.693	2.25	5.320
#18	13.60	2.257	4.00	7.090

Concrete reinforcing bars are made from several different material sources; Billet, Rail, Axle, or Low Alloy Steel. A letter or symbol will be stamped on the bar indicating the source of the material, or steel type, as follows:

- The letter N indicates the bar is new process billet steel
- The letter S indicates that the bar is billet steel meeting supplemental requirements of ASTM A615 (S615M)
- A railroad 'rail' symbol or the letter R indicates the bar is melted down railroad track
- The letter A indicates the bar is from carbon steel railroad car axles
- The letter W indicates the bar is low alloy steel

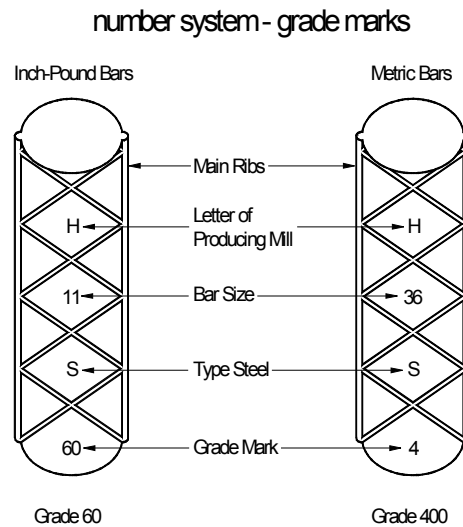
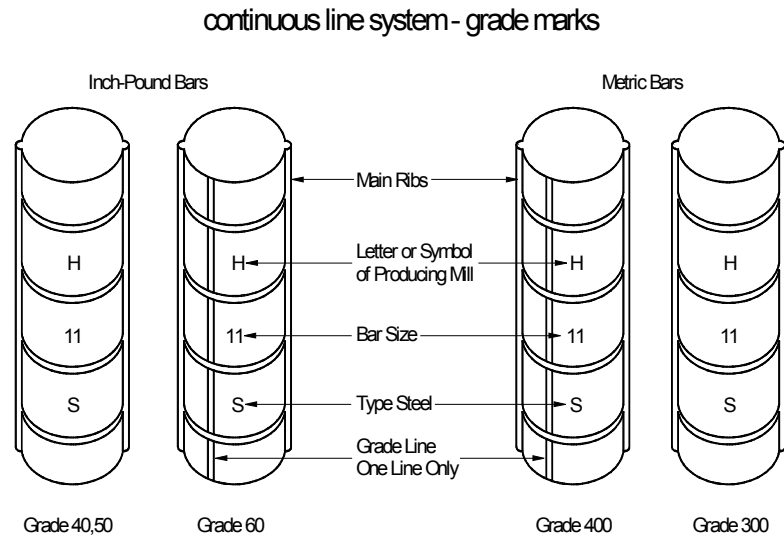
Each are produced in various grades of strength. The grade will be noted on the bar in the form of an additional line called a grade line indicating Grade 60 (Grade 400), or it will be stamped on the bar in numerical form. Grade mark lines are smaller and between two main ribs which are on opposite sides of all American produced bars. The above steel types are available in the following grades:

- Billet Steel - Grade 40 (Grade 300) or Grade 60 (Grade 400)
- Rail Steel - Grade 50 (Grade 350) or Grade 60 (Grade 400)
- Axle Steel - Grade 40 (Grade 300) or Grade 60 (Grade 400)
- Low Alloy Steel - Grade 60 (Grade 400)

In addition to the size, type, and grade of the bar, a symbol will typically be stamped on the bar indicating the manufacturer. Typically this will appear above or to the left of the bar size while the steel type and grade will appear below or to the right of the size.

The plans specify the steel and the grade of reinforcing bars to be used. South Dakota bridge plans normally specify ASTM A615 Grade 60 (A615M Grade 400), which is new billet steel. If the plans call for Intermediate Grade or Grade 40 (Grade 300), you may accept Intermediate Grade, Grade 40 (grade 300), or Grade 60 (Grade 400). If the plans call for Grade 60 (Grade 400), you must receive Grade 60 (Grade 400). Note that Grade 60 (Grade 400) is used almost exclusively on South Dakota structures today.

Figure 7.6 Typical Bar Identification Marks



Dimensions and Bends

When checking reinforcing bar length and bending dimensions, give consideration to the fabrication tolerances. Each bar shape has certain fabrication tolerances (plus or minus a given amount) that it must comply with according to specifications. A copy of the acceptable bending and length tolerances for most bar shapes is included in Figure 2.1(a) of Appendix A.

Straight reinforcing bars are cut to length by shearing with a tolerance of 1 inch more or less than the specified length. Use the reinforcing schedule to find out what the specified lengths for the straight bars are, then measure the pieces with a steel measuring tape. If the steel is bundled, measure several pieces and "eyeball" the remainder.

Bent bars are harder to check. The bending details in the reinforcing schedule specify a dimension for each important part of the bar. Each dimension and the overall length should be measured. Generally longer dimensions for bar sizes #3 - #11 are plus or minus 1 inch. Smaller dimensions are generally allowed a tolerance of plus or minus 1/2 inch. Dimensions and tolerances are always in reference to the extreme, or out-to-out dimension of the bar.

Use the same procedure for checking dimensions on bent bars and straight bars. The reinforcing schedule and bending details provide specified dimensions and overall length. Measure a few of each type of bent bar and “eyeball” the rest. If any are out of the tolerance, reject the bar and check the rest of the shipment.

Also check for conformity to bending requirements. There are three angles to which reinforcing steel is bent, 90 degrees, 135 degrees, or 180 degrees. Check a few bars in each bundle to see if the bend diameter meets the standards. Figure 7.10 gives the dimensions and diameters to which bars are to be bent in standard English units.

To determine which of the 90 degree bends apply, look at the type column in the plans reinforcing schedule. If the bar has a “T” or “S” designation, the tie and stirrup hook diameters apply. All other 90 degree bends must meet the standard hook dimensions.

Figure 7.7 Stirrup Dimensions

Inch-Pound Bar Size	D	90° Bends	135° Bends	
		A or G	A or G	H
#3	1 ½”	4”	4”	2 ½”
#4	2”	4 ½”	4 ½”	3”
#5	2 ½”	6”	5 ½”	3 ¾”
#6	4 ½”	1’-0”	7 ¾”	4 ½”
#7	5 ¼”	1’-2”	9”	5 ¼”
#8	6”	1’-4”	10 ¼”	6”

Figure 7.8 Standard Hook Dimensions

Inch-Pound Bar Size	D	180° Hooks		90° Hooks
		A or G	J	A or G
#3	2 ¼”	5”	3”	6”
#4	3”	6”	4”	8”
#5	3 ¾”	7”	5”	10”
#6	4 ½”	8”	6”	1’-0”
#7	5 ¼”	10”	7”	1’-2”
#8	6”	11”	8”	1’-4”
#9	9 ½”	1’-3”	11 ¾”	1’-7”
#10	10 ¾”	1’-5”	1’-1 ¼”	1’-10”
#11	12”	1’-7”	1’-2 ¾”	2’-0”
#14	18 ¼”	2’-3”	1’-9 ¾”	2’-7”
#18	24”	3’-0”	2’-4 ½”	3’-5”

A steel tape and template should be used to check the bend diameters. Make your own template of stiff material, like cardboard, with various circles drawn on it. Remember that bends are measured on the inside of the bar.

Figure 7.9 Example Bend Diameter Template

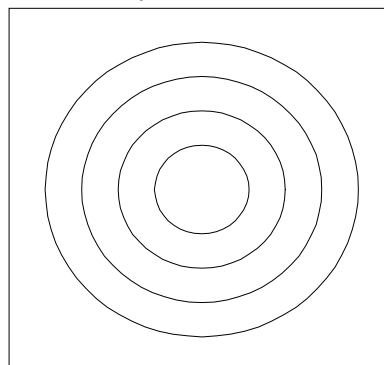
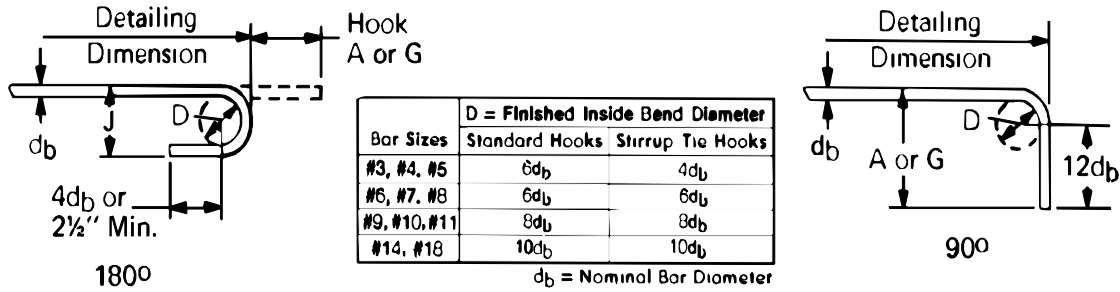


Figure 7.10 Standard Bending Dimensions

STANDARD HOOK DETAILS

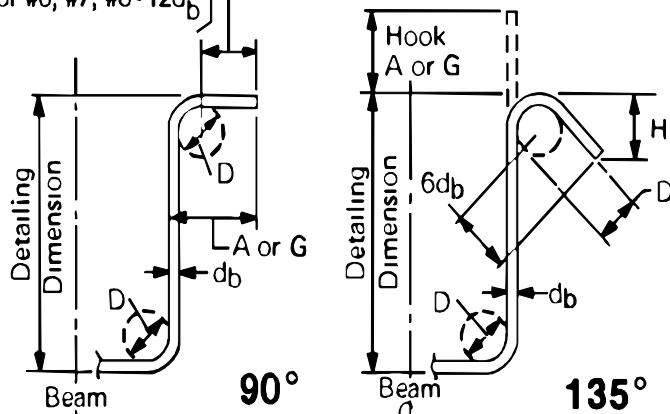


Bar Size	Dimensions of standard 180-deg hooks, all grades			Dimensions of standard 90-deg hooks, all grades	
	A or G	J	D	A or G	D
#3	5"	3"	2 1/4"	6"	2 1/4"
#4	6"	4"	3"	8"	3"
#5	7"	5"	3 3/4"	10"	3 3/4"
#6	8"	6"	4 1/2"	1'-0"	4 1/2"
#7	10"	7"	5 1/4"	1'-2"	5 1/4"
#8	11"	8"	6"	1'-4"	6"
#9	1'-3"	11 3/4"	9 1/2"	1'-7"	9 1/2"
#10	1'-5"	1'-11 1/4"	10 3/4"	1'-10"	10 3/4"
#11	1'-7"	1'-2 3/4"	12"	2'-0"	12"
#14	2'-3"	1'-9 3/4"	18 1/4"	2'-7"	18 1/4"
#18	3'-0"	2'-4 1/2"	24"	3'-5"	24"

For #3, #4, #5 - 6 db

For #6, #7, #8 - 12 db

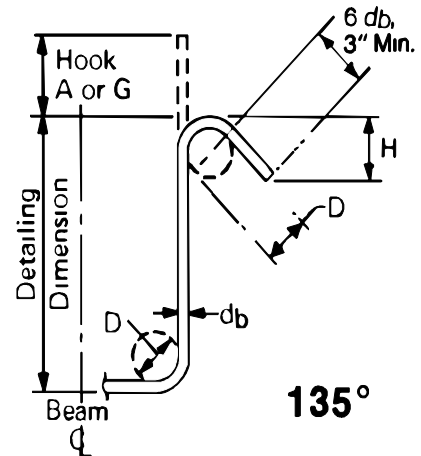
D = Bend diameter



Stirrup Hooks

(Tie Bends Similar)

Bar Size	D	90°	135°	
		A or G	A or G	Approx. H
#3	1 1/2"	4"	4"	2 1/2"
#4	2"	4 1/2"	4 1/2"	3"
#5	2 1/2"	6"	5 1/2"	3 3/4"
#6	4 1/2"	1'-0"	7 3/4"	4 1/2"
#7	5 1/4"	1'-2"	9"	5 1/4"
#8	6"	1'-4"	10 1/4"	6"



Seismic Stirrup/Tie

135° Seismic Hook			
Size	D	A or G	Approx. H
#3	1 1/2"	4 1/4"	3"
#4	2"	4 1/2"	3"
#5	2 1/2"	5 1/2"	3 3/4"
#6	4 1/2"	7 3/4"	4 1/2"
#7	5 1/4"	9"	5 1/4"
#8	6"	10 1/4"	6"

Placement

It is critical that reinforcing steel be placed in the locations and positions shown in the plans. If bar locations are changed, the load carrying capacity of the concrete section or slab can be adversely affected. Proper clear cover and spacing must be maintained by supporting devices.

- Clear Cover is the distance between the finished surface of concrete and the nearest surface of the reinforcing steel.
- Spacing is the distance between centers of reinforcing bars.

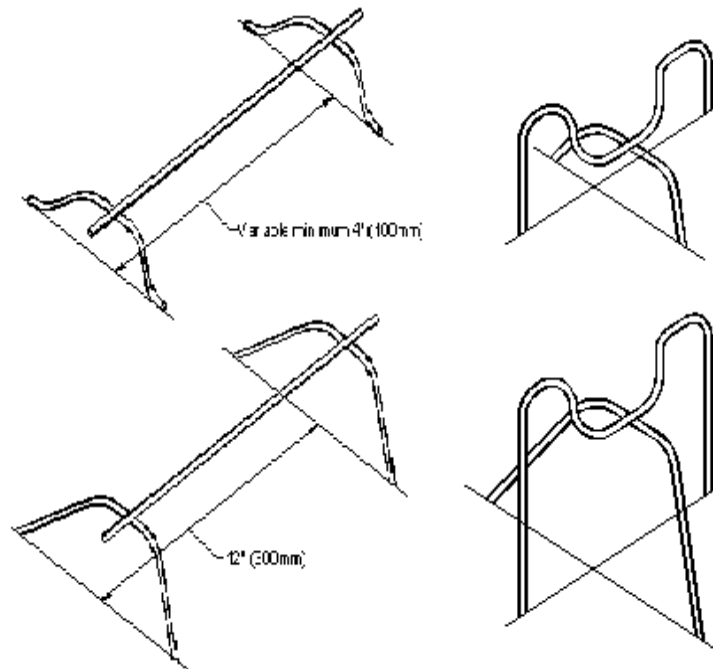
Several manufactured items are used to maintain proper cover and spacing. The most common are metal chairs and bolsters, precast mortar blocks, wire hangers, and ties, or wood. With the exception of wood, most items become cast in the concrete itself. Therefore it is critical that the devices used to support reinforcing meet certain requirements in order to not compromise the strength of the concrete.

Supporting Devices

Metal Chairs and Bolsters

Metal chairs and bolsters are pre manufactured items typically made of light to heavy gauge wire. They support the reinforcing steel directly from the bottom of the slab, or directly from the lower mat of reinforcement (for top mat steel support). Metal chairs used with epoxy-coated bars must be coated with plastic or epoxy. Chairs or bolsters made exclusively of plastic are not allowed.

Figure 7.11 Metal Chairs and Bolsters



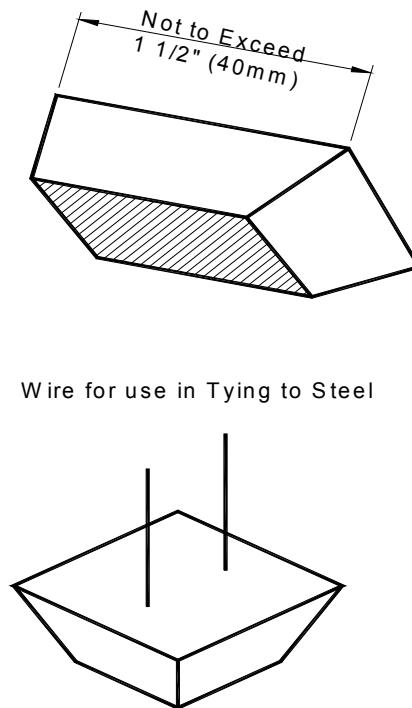
Precast Mortar Blocks

Rather than using metal chairs, precast concrete or mortar blocks are often used to support the reinforcement, particularly in footings and box culvert bottom slabs. These blocks are typically cast in a tapered trapezoidal shape much like a pyramid with the top cut off. Their height should be equal to the required concrete cover. The smaller face should rest on or against the forms to prevent their falling when the forms are removed.

NOTE Blocks should be made of the same or higher strength concrete than that being placed.

Blocks may be precast with a wire embedded for tying to the reinforcing steel. By tying the blocks to the rebar, they maintain the required cover in all structure parts.

Figure 7.12 Precast Blocks



Wire Hangars and Ties

Wire is used to fasten bars where two bars cross. This wire should be 16 gauge or larger (bare wire thickness without any coating). The wires used for epoxy-coated bars must be plastic coated. When using wire ties, the twisted ends should project away from any exterior surfaces. This is done to maintain the minimum cover from the edge of the concrete.

Wood

Wood is often used to hold reinforcement in a particular pattern or spacing until the concrete has set up enough to support the steel. This occurs most often to hold the circular pattern of reinforcement in place for columns when pouring the concrete footing. The wood spacers should always be placed outside the poured concrete, and should always be removed after the concrete has attained enough strength to directly support the reinforcement.

Support Devices Not Allowed

Occasionally, a Contractor will try to use an item for support that is not permitted by the Department. The following summarizes the most common items that Contractors attempt to use, and the reasons they should not be allowed for reinforcement supports:

- Pebbles - they tend to tip
- Broken stone or brick - they leave an undesirable appearance when the forms are removed
- Metal pipe - mortar does not flow into the pipe, it remains hollow

- Embedded wooden blocks - wood tends to rot and does not have the same strength as concrete
- Metal devices which expose a large amount of metal at the surface, the exposed metal rusts
- Individual chairs or high chairs - can tip over and are not strong enough

Placement Methods

The Contractor can place reinforcing steel either by piece or by the section. On parts of the structure, he may place each piece of steel individually or assemble the steel into a large mat or cage before placing it in the forms.

Figure 7.13 Bridge Deck Mat Reinforcement

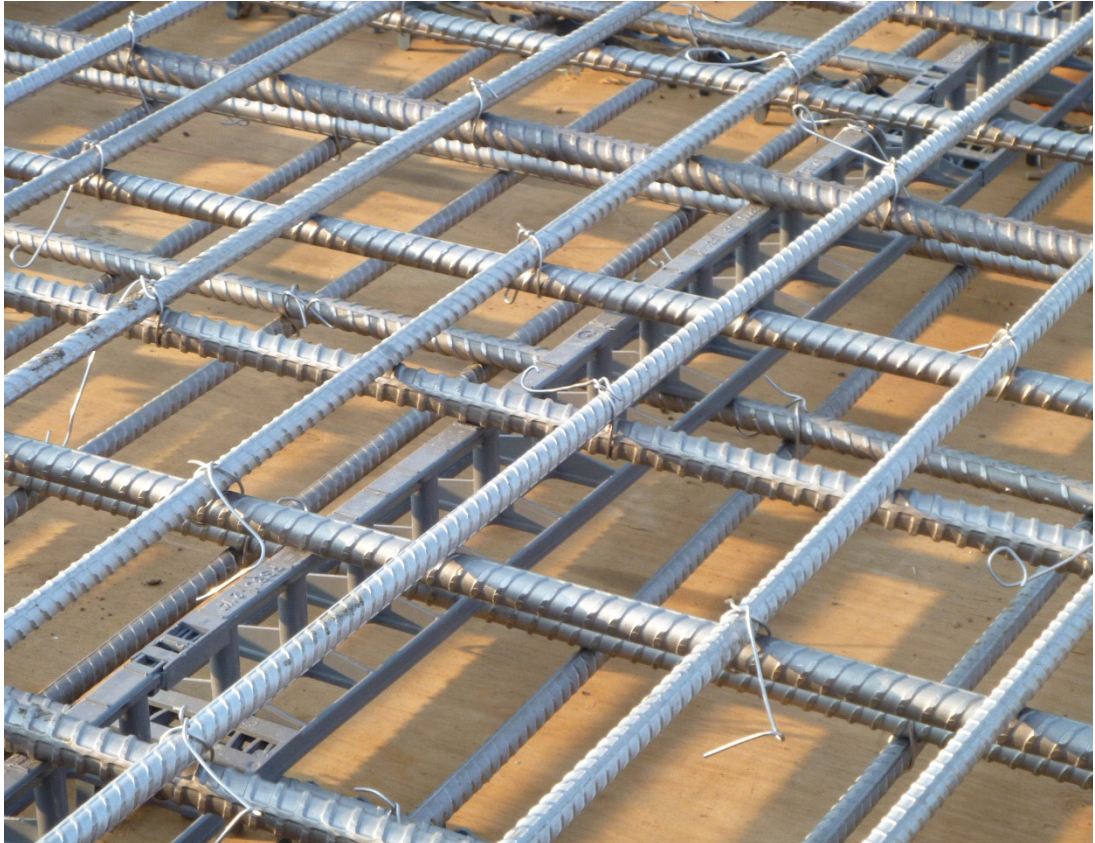
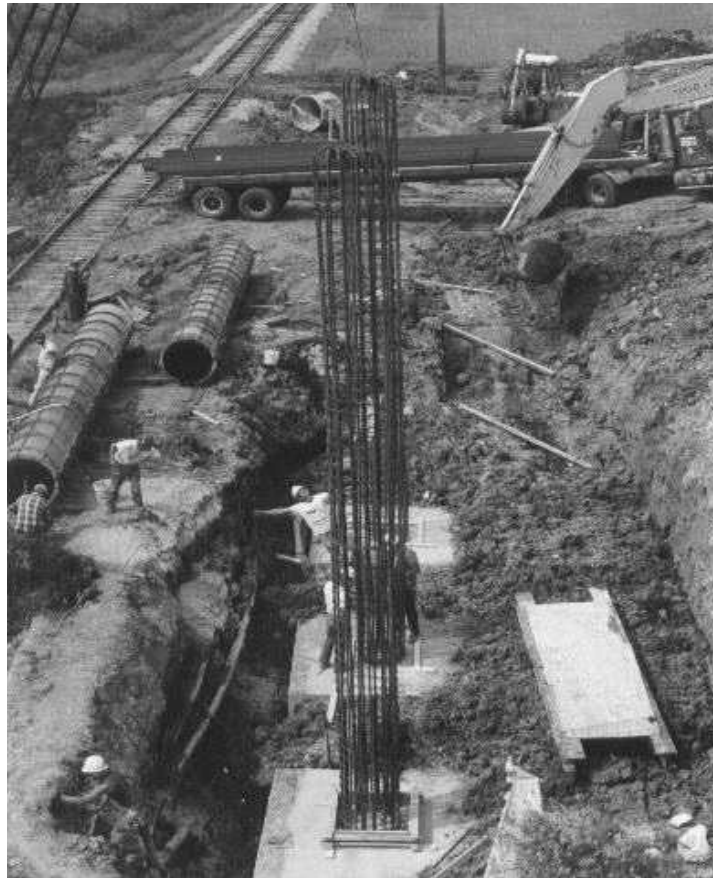


Figure 7.14 Column Reinforcement Cage



Inspection

Your job is to see that the proper bars are in the proper place and remain in position during concrete placement. The following should be completed before concrete placement.

- Count bars used, it should equal the number called for on the plans.
- The proper size bars should be used in the proper locations. The size number is stamped on all bars. Substitution of bar sizes and quantity is not permitted without authorization from the Office of Bridge Design.
- Make sure the bars are tied securely. They must be tied where two bars cross, unless the spacing is less than 1 foot, then tie alternate intersections. Bridge deck and box culvert top mat reinforcing steel has additional tying requirements. The top mat of the reinforcement must be fastened down to a lower supporting member to prevent the mat from 'floating' up during concrete placement. On girder bridges, the top mat should be tied down every 8 feet along the length of each girder. The tie can be fastened to the shear stud or stirrup of the girder, or to the bottom mat of reinforcement where no stirrups are used. On slab bridges and box culverts, the top mat should be tied down every 12 feet in both directions. The ties should be securely fastened either to the bottom mat or to the lower formwork. Reinforcing bars should be firmly held in place during the placing of concrete. The supports must be adequate to hold the weight of the steel plus the weight of the workmen who will be walking on top of them.

Figure 7.15 Tie pattern at >12 inches either direction

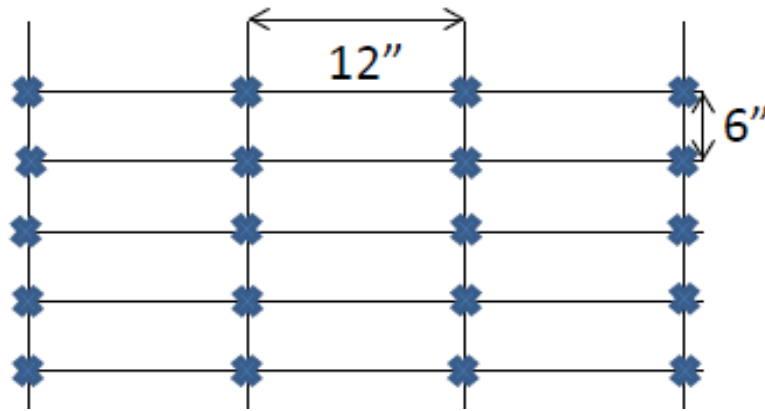
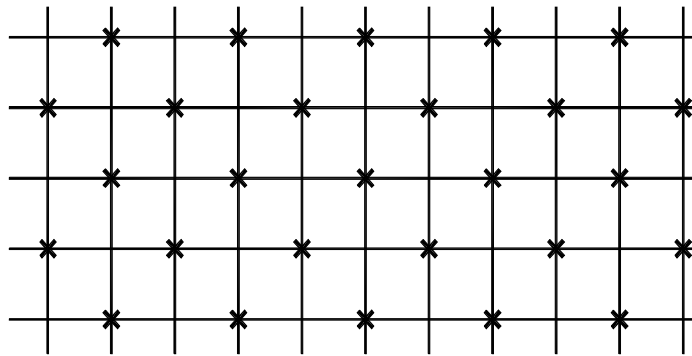
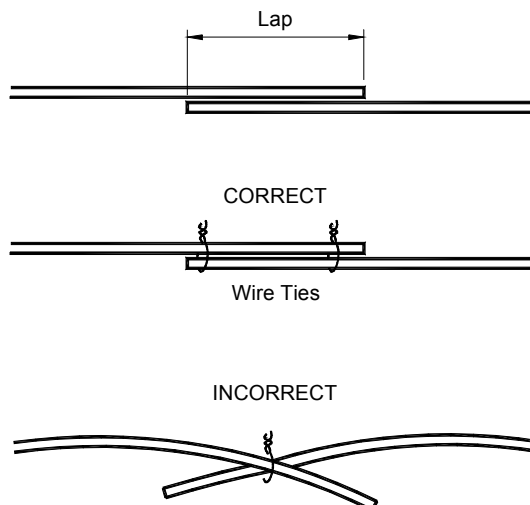


Figure 7.16 Tie pattern at <12 inches



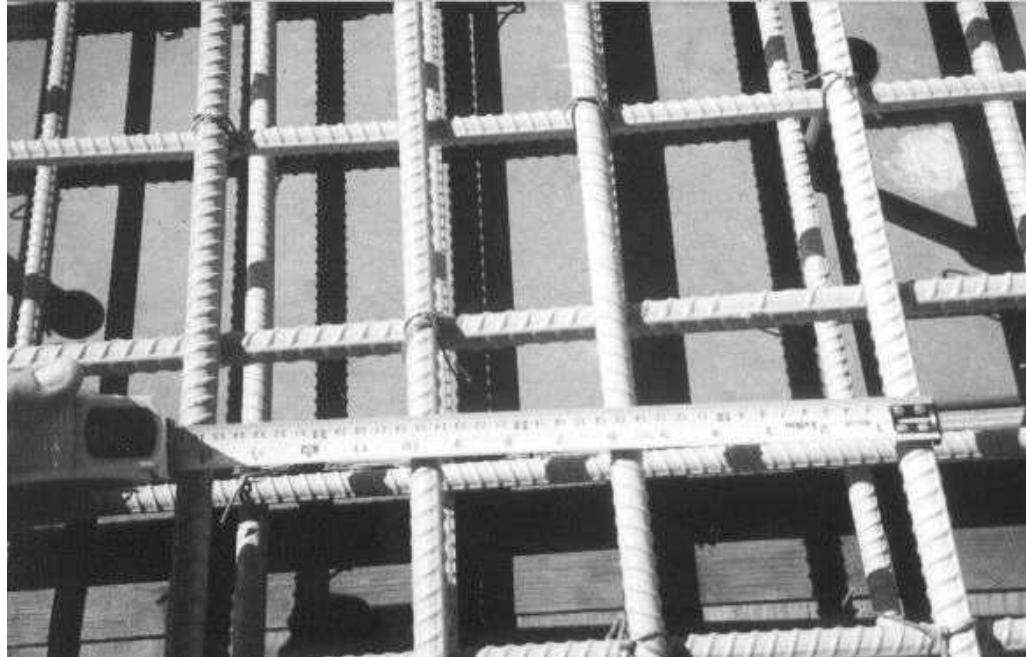
- Check splices - Reinforcing bars can only be spliced as shown on the plans unless there is approval from the Office of Bridge Design. Splices are made away from points of maximum stress and are lapped a distance sufficient to transfer the capacity of the bars. The plans usually specify a minimum length for the bars to be lapped. Lap lengths of splices are governed by design specifications, and may vary due to splice location, number, and size of bars being spliced, etc. If a lap length is inadvertently omitted on the plans, or additional splices are required, contact the Office of Bridge Design. The overlap should be wired in two places, not welded. Welding of reinforcing bars is not allowed without approval of the Office of Bridge Design (see Welding Reinforcing Steel at the end of this Chapter).

Figure 7.17 Tying Splices



- Determine if bars have been placed with the proper spacing. The plans will call for " " bars at " " inch centers. They will also show beginning and ending locations, which must be measured. The bars need to be placed close to the location specified in the plans or there is a possibility of being overstressed. Bar placement as shown in the plans can be difficult to attain at times. You may accept the reinforcements if it falls within acceptable construction tolerances as follows. The reinforcement spacing should be within $\pm 1/2$ inch of the plan location. The tolerance ensures a reasonable distribution of the reinforcing steel throughout the concrete. Equal distribution allows each rebar to carry its proportionate share. Uneven distribution of the steel may cause cracking of the concrete. Check bar spacing, if bars are more than $1/2$ inch off specified location, the Contractor must move them to the proper location.

Figure 7.18 Checking Spacing of Reinforcement



- Check to see that the proper cover is being maintained. The plans call for a specific cover which places the layers of bars in the correct position for strength purposes. Proper cover also prevents the following problems:
 - Buckling under certain conditions of compressive load
 - Rusting under exposure of the concrete to corrosive liquids or vapors
 - Scaling of the concrete caused by reinforcing steel being too close to the surface

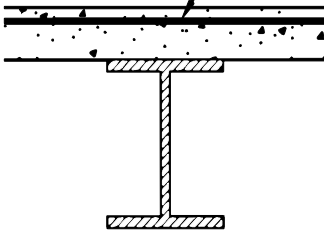
Figure 7.19 Scaling of Concrete due to Improper Clear Cover of Reinforcement



The designers assume that the proper cover will be maintained, although at times this may be impossible. Therefore, accept the work as meeting the cover requirements if the following construction tolerances are maintained: The cover should be maintained within $\pm 1/4$ inch of the plan specified amount. Check the cover distance with a measuring tape, and if the cover that is needed is not being maintained, have the Contractor place additional devices to properly support the bars.

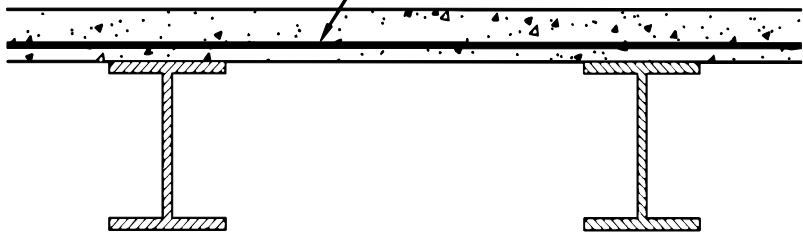
Figure 7.20 Results of Misplaced Clear Cover on Girder Type Bridges

If steel at top of slab is placed too high, strength of slab is increased but rebar does not have enough cover, which encourages concrete to crack and accelerated rebar corrosion. If placed too low, strength of slab is decreased.



AT BEAMS

If steel at bottom of slab is placed too high strength of slab is reduced. If placed too low, strength of slab is increased but steel does not have enough cover, encouraging concrete to crack.



BETWEEN BEAMS

- The plans call for a beginning and ending point for the steel bars. Measure to make sure these are correct.
- The dimensions and positioning of bent bars should not be altered from that on the plans. If you encounter a bar with a bad kink or bend not on the plans, the bar should be rejected. If the bar has a minor kink or bend, a hammer or other straightening tool will generally straighten it. A bar that is bent repeatedly or is bent severely will crack and be weakened. Reinforcement bars are generally bent around a pin of specific diameter. This eliminates too sharp a bend. Heating

reinforcement bars for bending should be avoided. Heating can change the characteristics of the steel. If necessary, the metal must not exceed a dull red heat.

- All reinforcement must be in place prior to the concrete pour.
- Check the condition of the bars. Bars should be free from objectionable coatings such as dirt, oil, grease, or mortar from a previous pour that would reduce or destroy the concrete to steel bond. A thin film of rust or mill scale that firmly sticks to the steel is not considered objectionable. Reinforcing bars can be cleaned of the objectionable material by the following methods:
 - Remove dirt by rubbing with burlap or washing with water
 - Oil or grease can be removed by washing with Methyl Ethyl Ketone (MEK). MEK is a solvent used to clean oil and grease from steel and is available from paint suppliers.
 - Weak, dried mortar on the bars can be removed with a wire bristle brush. Care must be taken not to break the concrete-steel bond in the section already placed.

Figure 7.21 Typical Contaminated Reinforcement



Field Touch-up of Epoxy Coated Reinforcement

Damage caused during shipment or installation of epoxy-coated reinforcing steel must be repaired prior to concrete placement. All damaged areas shall be repaired. All bars with handling and installation damage greater than 2% of the bar surface area per foot, shall be rejected and removed. The total damage, including any previously repaired damage due to fabrication and handling plus the damage caused during shipment and installation, shall not exceed 5% of the bar surface area per foot. Where it does exceed 5%, the bar should also be rejected and removed. One area of epoxy-coated bars that typically requires field touch-up is the sheared ends of the bars. Particular attention to these areas is required.

Touch-up of damaged areas should be repaired by removing all rust and contaminants from the area and applying an epoxy coating. The touch-up epoxy coating material must be inert to concrete and compatible with the epoxy coating already on the reinforcement. This coating material should be supplied by an epoxy

coating manufacturer who supplies the epoxy coating originally placed on the reinforcement. Generally, the compound usually consists of a two part epoxy material that must be field mixed. Touch-up epoxy coatings from spray cans should not be permitted. (The coatings in aerosol cans are thinned to allow them to be sprayed. When sprayed onto the bar, the coating runs to the bottom of the bar and leaves insufficient coating on the top of the bar.)

NOTE The touch-up coating should be allowed to cure for 24 hours or as per manufacturer's recommendation (whichever is more stringent) before concrete is placed.

Welding Reinforcing Steel

The carbon content of reinforcing steel is beyond what is considered weldable by ordinary procedures. When steel with a high carbon content is welded, it becomes brittle and has less resistance to impact. Even spot-welding or tack welding of high carbon rebar may produce these undesirable results.

There are cases when welding a reinforcing bar is necessary. It will not be allowed unless it is on the plans or written approval is obtained from the Office of Bridge Design. A Contractor's written request for approval must include:

- Bars to be welded
- Welding procedure to be followed
- Type of electrode to be used
- Detail of the joint
- Mill certificate of the reinforcing bars to be welded

Mechanical Reinforcement Splices

There are times when splicing of rebar in a manner other than direct lapping is necessary. This can occur in retrofit projects where an existing rebar is not long enough to develop strength required by lapping. Manufactured devices or couplers are sometimes specified to mechanically splice the rebar.

NOTE Mechanical splicers must be specified on the plans or have prior approval by the Office of Bridge Design prior to use. The Contractor should submit the type of coupler to be used along with the location and sizes of reinforcement proposed to be spliced.

Mechanical splice devices or couplers must be capable of developing 125% of the reinforcing bar's yield strength. There are currently several manufactured couplers that are commercially available for both plain and epoxy-coated reinforcement. Couplers for epoxy-coated rebar should be pre coated with fusion-bonded epoxy coating. Repair of the coating as described earlier is required after installation.

Checklist

List of Equipment Required for Inspection

General

- Wheelbarrow and/or concrete buckets for sampling concrete
- Shovel and scoops
- Rod and rubber mallet
- Water bottles
- Opaque plastic to cover samples
- Watch
- Tape measure

Testing Equipment

- Slump cone and plywood or other rigid base platform
- Glass Thermometer and High/Low Thermometers
- Air Entrainment Testing Apparatus
- Cylinder Forms
- Scale

General Checks Prior to Concrete Placement

Joints at correct locations; Keyways

Strike-off elevations verified; Chamfer Strips

Forms and Reinforcement

- Falsework and formwork checked in accordance with Chapter 6
- Reinforcement checked in accordance with Chapter 7
- All dirt, chips, sawdust, and other debris or foreign material removed from formwork
- Wood forms thoroughly moistened with water prior to concrete placement

- All items to be embedded in concrete (e.g. conduits, drains, blockouts, anchor bolts, etc.) adequately secured and locations verified.

Infiltrating Water

- Water infiltration or seepage accounted for and properly addressed
- If placing underwater, follow underwater concrete placement procedure specified in Section 460 of the Standard Specifications.

Placement Equipment

General

- Equipment generally clean and mortar tight
- Minimum dimensions of tubes and tremies maintained
- Concrete pumps properly primed or flushed prior to commencing pumping operations. Grout used for priming discharged outside of forms
- Adequate number of vibrators provided (a minimum of two recommended)

General Concrete Placement

Immediate Inspection at Delivery

- Concrete discharged and screeded within specified time limits
- Number of revolutions recorded, minimum revolutions obtained
- Sample for concrete testing taken, mixed uniformly
- Slump
- Air Content
- Temperature
 - If any of the above requirements are not met, then the load should be rejected or remedial measures taken. If water, cement, or air entrainment is added on site, make sure that the minimum number of revolutions (30) at mixing speed is undertaken. Following mixing, the concrete should be retested prior to allowing its placement within the structure
- Concrete Cylinders
- Concrete haul or weight ticket completed for project records

Time Requirements

- Discharge time maintained
- Interval between concrete deliveries limited to 30 minutes
- Specified rate of pour maintained

Placement and Finishing

- Vibrators operated correctly
- Surface texture (brooming, etc.) applied

Cold Weather Requirements

Temperature Requirements

- The temperature of concrete immediately after placing shall not be less than 50 degrees F

- The temperature of concrete shall be maintained above 50 degrees F for the first 72 hours after placement. It shall be maintained above 40 degrees F for the next 48 hour period. If low temperatures are recorded during this protection period, one extra day of protection time above 40 degrees F shall be added to the original five days of protection time
- If high early strength concrete or additional cement is used, then the concrete temperature for the first period is limited to 60 degrees F rather than 50 degrees F. If the temperature falls less than this during the first period, then the second period low temperature requirements of the above paragraph shall apply.

Preparation

- Forms and ground to receive concrete above freezing temperature
- High-low thermometers ready
- Measures taken by the Contractor to protect placed concrete; blankets, straw, etc. are adequate for temperature requirements
- Heat enclosures reasonably airtight, proper clearance to forms provided, and heating equipment acceptable (open flames or salamanders not allowed)

Diary/Log

- Cold weather concrete form or log maintained
- During the protection period, the maximum temperature of concrete protected shall not exceed 100 degrees F

Hot Weather Requirements

Temperature Requirements

- The temperature of concrete immediately after placing shall not be more than 90 degrees F, except that the maximum temperature for bridge deck concrete shall not exceed 80 degrees F (see Bridge Deck Checklist on next page)

Preparation

- If high ambient temperatures are expected during the day, consider placing the concrete at times that the ambient temperature is cooler (i.e. early morning)
- Other measures to reduce concrete temperature taken; Aggregate piles flushed with water, Efforts made to cool water prior to use with ice, etc.
- Wet material or white polyethylene sheeting available to be applied as soon as possible

General Curing

Exposed concrete surfaces shall be kept continuously wet by ponding, spraying, or covering with materials that are kept continuously and thoroughly wet

Materials used to cover concrete shall consist of burlap or other materials that do not discolor or damage the concrete

- Care taken when placing material to not leave marks on concrete surface
- Materials monitored and kept continuously wet
- Paper or plastic sheets inspected for holes and patched prior to use

In lieu of the materials or wetting above, a membrane curing compound may be applied

- Sample taken and sent in for approval, and approved

- Uniform coating applied, if second coat is required it must be applied within 30 minutes of the first coat

Bridge Deck Preparation

Finish Machine Set-up

- Adequate support of rails established to prevent sagging of rails under machine weight
- Machine set to match skew of bridge
- Machine set to provide proper crown and slopes
- Dry run made verifying slab depth and clearances to top mat of reinforcement

Pre-pour Inspection Preparation

- Office of Bridge Design notified at least 24 hours prior to meeting time
- Falsework and formwork checked as per the checklist in Chapter 6; mortar tight; adequate walkways and railings in place to provide access for finishing slab edges
- Reinforcing checked as per checklist in Chapter 7; top mat tied down at proper spacing
- Screed rails for finish machine set up and adjusted
- Finish machine set up and dry runs made verifying slab depths and reinforcement clearances
- Contractor employee designated to represent Contractor during pre-pour inspection

Bridge Deck Concrete Placement

Monitoring Finish Machine and Slab Finish

- Concrete kept in front of machine screeds/augers sufficiently to prevent low spots
- Rollers on finish machine giving smooth finish, forcing coarse aggregate below surface
- Machine operating correctly; engine fluids (gas, oil, grease, etc.) not dripping or leaking from machine
- Spot checks of slab depths and clear cover taken as soon as machine gets to 1/2 or 3/4 point of first span, depths and cover correct. If not, take remedial measures immediately to adjust for remaining spans
- Excess material from rollers at sides properly removed and wasted and not incorporated into slab and curb finish. Watch carefully to ensure worker do not use this material to fill low spots
- Carpet drag operating correctly, leaving micro texture without leaving large depressions or gouges
- Transverse metal-tine finish placed correctly
- Immediately after concrete finishing, a fog shall be applied to the exposed concrete surfaces until such time that wet burlap is in place in such a way as to prevent drying of the concrete surface.
- A single layer of wet burlap shall be placed as soon as possible. Caution shall be used when placing wet burlap so that no damage occurs to the surface.
- cover material shall be kept continuously wet by misting with water until the concrete can support soaker hoses without causing deformation to the concrete.

After the soaker hoses are in place, the burlap and soaker hoses shall be covered with polyethylene sheeting.

- In lieu of the above, the contractor is allowed to immediately cover the wet material with polyethylene sheeting and wait until the concrete can be walked on before putting down the soaker hoses.
- Water shall be run through the soaker hoses periodically as to keep the burlap continuously wet, but at a minimum of once per day. These wet cure procedures shall be continued for a period of 7 days after completion of the deck pour.

Hot Weather Requirements for Bridge Deck Concrete

- Maximum concrete temperature may be allowed to be raised to 85 degrees F by the Engineer provided the following actions are taken
 - Aggregate pile flushed with water
 - Minimum pour rate of 40 cubic yards per hour, or plans specified rate if more than 40 cubic yards per hour, maintained
 - Wet burlap or white polyethylene sheeting applied as soon as possible
 - Continuous fogging required if the ambient temperature exceeds 80 degrees F

Emergency Construction Joint

- Office of Bridge Design contacted immediately

Cast-in-Place Box Culverts

- Working points carefully established and checked
- Bottom slab joints have drainage fabric installed prior to concrete pour
- Drainage fabric attached with adhesive to hold in place during backfill operations

Precast Box Culverts and Large Pipes/Arches

- Shop Plans sent in to the Office of Bridge Design for approval, approved

Backfilling

General

- Concrete attained minimum design compressive strength. Approved/permission given by Engineer prior to backfilling footings or columns

General Bridge End Backfill Requirements

- Concrete attained minimum design compressive strength
- Minimum of 24 hours after deck pour prior to backfill
- Base of backfill area properly prepared. Final top 6 inches scarified and re-compacted to 97% density
- Under-drain system properly installed; positive drainage verified; screen or grate in place. Ends of pipe have sufficient length to stay uncovered even when loose material slides

Select Granular Bridge End Backfill Requirements

- Granular material meets Sec. 850 gradation requirements
- Drainage fabric properly installed underneath and prepared to wrap the sides and top, laps meet plans requirements

- Lifts placed at maximum of 12 inch depth, each lift properly compacted

General

Concrete is one of the most widely used construction materials in the world. Concrete's versatility and durability have made it a common material for a variety of structures, ranging from as simple as sidewalks to as complicated and intricate as skyscrapers and dams. Nearly every structure constructed in South Dakota highways will incorporate concrete in one form or another.

While concrete on the surface has a simple appearance, it has in reality a very complex internal nature. Plain concrete is formed from a hardened mixture of cement, water, fine aggregate (sand), coarse aggregate (crushed stone or gravel), air, and often other admixtures. Reinforcement is typically added to concrete to give concrete flexural and tensile strength in addition to help in controlling cracking.

This chapter will cover concrete from the point it is delivered to the construction site in its plastic state. The actual mixing of the concrete from its raw ingredients can be performed in a variety of mixing operations or plants. Usually concrete is obtained from a stationary batch plant that is a permanently established production facility. Occasionally, especially in more remote locations, the Contractor may choose to produce the concrete from a portable concrete plant or mobile concrete mixer. Regardless of where the concrete is produced, a Plant Inspector representing the Department must be present. The duties and inspection requirements of a plant inspector are thoroughly covered in the 'Concrete Plants Manual' and will not be covered in this manual. Mobile concrete mixers are units that are commonly used in bridge deck overlay projects. Inspection and operation of these units is covered in detail in Chapter 16 - Bridge Rehabilitation in this manual.

Inspection at Delivery

Your inspection of the concrete begins when it reaches the structure. Your inspection focuses on items that can affect the strength and durability of the concrete. It is best if you have a technician perform the concrete testing during the pour so that you, as an inspector, can closely monitor and watch the operations of the pour itself. However, you too should be intimately familiar with all the testing procedures required, in the event that the technician needs assistance or in the event that you need to perform the testing yourself. The following notes the key items during the delivery and concrete pour that you will need to test and monitor:

- Time limits
- Amount of mixing
- Slump
- Air Content
- Temperature
- Concrete cylinders
- Unit weight

Material and Weight Ticket

When concrete is produced or batched, the Plant Inspector issues a haul ticket for every load produced. Usually this ticket will be the DOT-75 Form as illustrated below. In some cases, the plant may be a computerized batch plant. In this case, the ticket will be a computer printout containing the same key information as shown below.

Figure 8.1 Material and Weight Ticket

DOT-75
(1-84)

SOUTH DAKOTA

MATERIALS AND WEIGHT TICKETS

PROJECT S 6490 (1)
 MATERIAL CLASS A
 DATE 6-10, 1989 SAMPLE NO. _____
 TANK OR CAR NO. 3 M. GALS. _____
 TRUCK NO. _____ LANE _____
 GROSS WT. _____ SECTION _____
 TARE WT. _____ STATION _____
 NET WT. _____ SPREAD _____
 TONS _____ END STA. _____
 WEIGHER _____ CHECKER _____

CONCRETE MIX (TREATED MAT'LS) WATER: MAX 794 ACTUAL 750
 TIME START MIX 2:16 P BATCH SIZE 3 C.Y.
 DISCHARGED _____
 REVOLUTIONS: RATE _____ INSPECTORS: _____
 FINAL _____ PLANT ROB
 INITIAL 761 PLACING _____
 NET _____

REMARKS: _____

No. D **623255**

BOOK QUANTITY
 PREV. TICKET _____
 THIS TICKET _____
 TOTAL _____

LEAVE THIS SLIP IN BOOK

The following items should be filled in and noted by the Plant Inspector:

- Project - The project number. If the concrete is being produced for more than one project, you need to fill in the number
- Material - This is the class of concrete being used
- Date - Day, Month, and Year the concrete was mixed
- Truck Number- Number of the truck hauling
- Water: Max. - The Plant Inspector indicates the maximum water the load of concrete can contain either in pounds or gallons
- Water: Actual - The Plant Inspector lists the water placed into the concrete at the plant in pounds or gallons
- Batch Size - The amount of concrete in the load
- Time Start Mix - Mixing starting time
- Inspector: Plant - Script initials of the Plant Inspector
- Revolutions Rate - Mixer speed (only if needed)

- Revolutions Initial - The Plant Inspector indicates the revolution counter reading when mixing started and is used only for concrete mixed in transit

NOTE Computer tickets generally have printed information only for the original batch. If the plant operator adds additional material (usually water) after the initial batch, the added material will not be reflected on the computer batch ticket. The Plant Inspector should monitor and record any additional added material onto the computer printed ticket.

Time Limit

The time between when the cement comes in contact with the water and when it is placed in the forms determines the quality of concrete produced. For a short time the cement is being dispersed throughout the mix. Then a chemical reaction called hydration takes place, and the cement takes on water to form a plastic paste that slowly hardens around the aggregates. There is a "set point" where the paste will no longer bond to the aggregates if disturbed. If concrete is mixed too long, it will "set" before it can be used. To keep this from happening, limits have been set for the maximum time between when the mixing is started and when the concrete is placed and screeded.

For concrete agitated or mixed in hauling units, the discharge and screeded time limits are:

- Discharged within 90 minutes, and screeded within 105 minutes, for concrete with a temperature below 80 degrees F.
- Discharged within 45 minutes, and screeded within 60 minutes, for concrete with a temperature above 80 degrees F.

For concrete not agitated or mixed in hauling units, the discharge and screeded time limits are:

- Discharged within 45 minutes, and screeded within 60 minutes, for concrete with a temperature below 80 degrees F.
- Discharged within 30 minutes, and screeded within 45 minutes, for concrete with a temperature above 80 degrees F.

The haul ticket received from the truck driver shows the time the mixing started. If the limit is exceeded, reject the load. If the time limit has not been exceeded, use the concrete and enter the time the last of it was placed on the Discharge blank of the ticket.

Amount of Mixing

Along with the time, the amount of mixing determines quality. Concrete that is under mixed can result in the following defects:

- The materials will not be thoroughly combined and segregation will exist
- The coarse aggregate will not be fully coated with cement paste
- The ultimate strength of the concrete will be low

Conversely, concrete that is over mixed can produce the following defects:

- A grinding action produces fines that in turn reduces slump, increases water demand, and reduces the cement paste coating on the aggregates
- The percent of entrained air is reduced
- The temperature of the concrete is raised
- The ultimate strength of the concrete will be low

The Plant Inspector should ensure that the concrete is properly mixed at the concrete plant. You must check the amount of mixing done in the haul units. For transit mixed concrete (completely mixed in the truck), the mixing limits are a minimum of 70 and a maximum of 100 revolutions at mixing speed.

Each truck used for transit mixing must have a counter to register the revolutions of the drum or blades at mixing speeds. The Plant Inspector writes the reading of the revolution counter when mixing begins on the haul ticket. When the truck is ready to unload, you record the revolution counter reading. If the concrete has not been mixed the minimum number of revolutions, continue the mixing until the minimum requirement is reached. If the maximum requirement has been exceeded, reject the concrete load. Enter the counter readings on the haul ticket

Figure 8.2 Revolutions Counter



Sampling Concrete

All tests require a concrete sample. The following pages describe the method of sampling fresh concrete, and briefly review the tests required. The specific tests and the testing procedures are in the SD Materials Manual.

It is important that you obtain a representative sample of the fresh concrete or the test results can be misleading. The procedures for sampling concrete are outlined in the Materials Manual under SD402 - "Method of Sampling Fresh Concrete". The sample can come from stationary or volumetric mixers, revolving truck mixers, concrete pumps, or after the concrete is placed in the forms.

Figure 8.3 Sampling Concrete



The concrete is placed in a wheelbarrow or mortar-tight box for transporting to the test site. Obtain at least 1 cubic foot of concrete for each test. After transporting to

the test site, be sure to remix the sample with a shovel to insure uniformity. The following concrete sample requirements must be followed:

- 1 Remixing of the concrete be kept at a minimum, shovel it only enough to make sure that the sample is uniformly mixed.
- 2 The sample must be tested within 15 minutes from the time taken.
- 3 Protect the sample from wind and sun until used, this can be done by covering the sample container with wet burlap or canvas.
- 4 Do not use concrete that has been previously used in the air test for any other test.
- 5 Samples of concrete taken from a mobile mixer shall be left in a covered container for 5 minutes immediately after discharge before testing for slump and air content.

Slump

Slump is a test that shows concrete consistency. The procedure for a slump test is in the SD Materials Manual, SD404. You need a slump test for each concrete sample used for making concrete cylinders. Additional tests are needed when the mix is difficult to work or when ordered by the Project Engineer.

Figure 8.4 Slump Test



Specifications generally require that concrete have a slump between 2 to 4 inches at the time of placement. The slump for concrete used in bridge decks must be between 2 to 4 inches at the time of placement. You should review the plans and specifications to verify the slump requirements. To achieve uniform concrete, hold the slump at some constant value. For most parts of the structure, the best results are obtained with a slump between 3 and 4 inches. In hot weather, a slump of up to 4 1/2 inches may be needed to get the concrete placed and finished.

You should check the slump of the first load of concrete and a load once every two hours thereafter. For bridge deck concrete, the frequency is once an hour. On small pours, check the slump every few loads to catch any variation. You should also check the slump anytime the visual appearance of the concrete indicates that slump has changed.

If the slump is too low, the Contractor may add water to the mixer. Water can only be added to full batches before any concrete is discharged. Adding water to a partial load after some portion of the concrete has been discharged should not be allowed. It is the Contractor's responsibility to determine how much water to add provided the maximum water content is not exceeded. The Plant Inspector has listed the maximum water that the load can contain and the total amount in the load on the weight ticket. The Contractor is allowed to add water to the load in the amount not to exceed the difference between these values. Enter the total water added by the Contractor in the Net Wt. blank. After water is added, the load must be re-mixed for 30 revolutions at mixing speed.

Rule of thumb One gallon of water will increase slump of 1 cubic yard of concrete 1 inch.

If an occasional load has slump higher than the limit allows, the Contractor may be allowed to add cement to lower it. It is the Contractor's responsibility to determine how much cement to add to bring high slump concrete back to within the specifications limits. The following can be used as a guide.

Reducing Slump by Adding Cement

Amount out of Specifications	Cement Addition per Cubic Yard.
0 to +1"	0.5 bag
Over 1" to +2"	1.0 bag

Like water, cement can only be added to a full batch. The cement should be added slowly so it will distribute throughout the load. Otherwise there is a possibility of forming cement balls that cause non-uniform concrete. After adding cement, re-mix the concrete for 30 revolutions at mixing speed. Note this on the weight ticket. In case of low or high slump, contact the Plant Inspector immediately so they can monitor any adjustments made in the plant.

Air Content

The term air content refers to the air that is captured or entrained in the concrete. It is billions of tiny bubbles (the largest is about the size of a pinpoint) that increase the durability of concrete. Without the entrained air, any moisture that has soaked in and freezes will crack the concrete. The bubbles act as a cushion, letting moisture freeze without causing concrete damage.

Specifications require that structural concrete, except bridge deck concrete, shall have an air content of 5% to 7.5% entrained air. Bridge deck concrete shall have an air content of 5.5% to 7.5% entrained air. Air shall be entrained by an approved air entraining admixture.

Figure 8.5 Air Test



You need to determine the air content of the concrete sample used to make cylinders. Check the air content of the first load each time concrete is placed, and once every two hours thereafter. For bridge deck concrete, the frequency is once an hour. The same is true with slump. At the start of every pour, run tests until you are sure proper air content will be maintained. If air content is above the allowed limits, reject the concrete. If air content is below the allowed limit, additional air entraining admixture may be added to full loads at the site. It is, however, a practice that should not be encouraged with any degree of regularity.

Adding water to increase the slump will also generally increase the air content of the concrete. Likewise, adding admixture to increase air content will also generally increase the slump. Keep both slump and air values in mind when making adjustments for either condition.

The following guide should be used when adding air entraining admixture to bring low air content concrete back to within specification limits. It is the Contractor's responsibility to determine how much admixture to add.

- It is extremely important that any adjustment be made in such a way as to ensure that the air-entraining admixture is evenly distributed throughout the batch. Usually admixtures are added to a gallon of water, then placed in the truck.
- Add slowly and mix and additional 40 revolutions at mixing speed to obtain a uniform mixture.
- To raise the air content, use additional air-entraining admixture as needed. When additional water is used to assure mixing, it should not exceed 3% of the design batch water. The total amount of water (include water added) should not exceed the specified water/cement ratio.
- Following these adjustments, both air content and slump should be checked to determine specification compliance.
- Contact the Plant Inspector to monitor any corrective action taken by the Contractor and plant.

Temperature

Record the temperature of the concrete you are using to establish time limits and for future reference. Take the temperature of the first load when you place concrete, and thereafter, as needed. Use a glass thermometer for the most accurate readings. Temperature is normally taken in conjunction with slump and air tests.

Temperature plays a big role in the quality of concrete and how quickly it must be placed. Extremely high temperatures can adversely affect the concrete as much or more than low or cold temperatures. When high temperature concrete is placed during hot weather, the following defects can occur:

- The ultimate strength will be low
- Durability will be lessened
- Resistance to repeated freeze/thaw cycles is reduced
- Shrinkage cracking will increase

Specifications require that the temperature of mixed concrete always be less than 90 degrees F. When concrete is used for a bridge deck, it must be kept below 80 degrees F. Should you start getting temperatures in this area, discuss the situation with the Contractor. Have them cool the materials at the plant so the temperature of the mixed concrete can be lowered. There is no minimum temperature requirement for the concrete during hot weather.

Low temperatures can also adversely affect the final properties of concrete. In cold weather, low concrete temperature at placement produces concrete that can have the following defects:

- Low ultimate strength
- A reduced durability
- Less resistance to repeated freeze/thaw cycles

Concrete during placement must be higher than 50 degrees F. If you encounter low concrete temperatures during cold weather, talk to the Contractor. The Contractor may heat the material to within the following limits before mixing:

- Mixing water shall not be heated above 160 degrees F
- Aggregates shall not be heated above 100 degrees F and shall be free of frozen lumps, ice, and snow

Handling concrete placed at extreme temperatures, whether hot or cold, is discussed in greater detail under "Placement" later in this chapter.

Concrete Cylinders

Concrete cylinders are molded and immediately placed in a storage box or covered with wet burlap or plastic and protected so a temperature of 60 to 80 degrees F is maintained. Cylinders should not be moved for 20 hours after the set occurs. They should not be subjected to vibration during the first 24 hours.

After 24 hours, cylinders should be removed from the forms and stored in lime saturated water which is 70 to 76 degrees F. One teaspoon of lime per gallon of water is required. Special care should be taken when handling the cylinders. Cylinders for 28 day strengths may be transported to Central Testing Lab anytime after seven days. Cylinders should not be removed from the storage water until just before breaking.

Figure 8.6 Concrete Cylinder



Requirements

You must make at least one set of four cylinders per day for each 150 cubic yards of each class of concrete from each plant. Additional cylinders are needed only when ordered by the Project Engineer for control of backfilling, removal of forms, permitting traffic use, etc. One cylinder from each set of cylinders made will be tested for 28 day strength in the Central Testing Laboratory (a backup cylinder will be broken when requested). The other cylinders are tested at the age and laboratory designated by the Project Engineer.

Figure 8.7 Sample Data Sheet - Front

SAMPLE DATA SHEET

DOT 1
(1-82)

File No. _____ Laboratory Test No. _____

① SUBMITTED BY _____

② SEND RESULTS TO _____

③ CONTRACTOR & SUBCONTRACTOR ④ _____

⑥ PROJECT _____ COUNTY ⑤ _____

⑦ CHARGE TO (If not above project) _____

This is a () PRELIMINARY PIT (add. data on back) () PROCESS CONTROL () ACCEPTANCE
() INDEPENDENT ASSURANCE () CORRECTIVE ACTION () COMPARATIVE () MIX DESIGN
() _____ sample. () SUBMITTED SPECIFICALLY FOR QUALITY TESTS

FIELD SAMPLE NO. _____ DATE SAMPLED ⑧ _____, 19 _____

THIS SAMPLE REPRESENTS _____ (quantity & unit of measurement)

Please identify as: () Sta. _____ () Lift ____ / ____ () Windrow
() Bin () Plant () Stockpile () Composite () Belt () _____ (other)

FOR CONCRETE	Type	Lot No.	FOR SURFACE COURSES	MISCELLANEOUS	Type	Lot No.
() cement, _____			() gravel _____ %	() beads, _____		
() admixture, _____			() crushed rock _____ %	() paint, _____		
⑧ () latex modifier, _____			() sand _____ %	() asphalt, _____		
() curing compound, _____			() clay _____ %	() sampling method _____		
() coarse aggr., size _____			() filler _____ %	() fencing material (list under remarks)		
() fine aggr. _____			() coated aggregate _____	() _____		
() cylinders (add. data on back)			() lime _____ %			

If material is to be used for CONCRETE, check its use as follows: () Class _____
() On Grading () On Bridge () Paving () _____

If material is to be used for SURFACE COURSES, check use as follows: () Subbase, Type _____
() Base Course, Type _____ () _____ Treated _____ () Gravel Surfacing
() Asph. Conc., Class _____, Type _____ () Asph. Surf. Treatment, Type _____ () Shoulders
() Maintenance Stockpile () Miscellaneous _____

FOR SHIPPED IN MATERIAL: Producer's Name & Address _____
Brand, Trade Name or Quarry _____

FOR LOCAL MATERIAL: Location of Pit or Quarry _____ & Sec. _____
Twsp., _____ Range, _____ County Owner & Address _____

Shipping Ticket No. _____ Truck or Car No. _____ Unloaded At _____

REMARKS:

(over)

Figure 8.8 Sample Data Sheet - Back

CONCRETE TEST CYLINDER DATA

CONCRETE TEST CYLINDER DATA						
LAB TEST NO.						
Cylinder Number	(10)					
Station	(11)					
Identity	(12)					
Quantity Represented	Yd ³ m ³ (13)					
Date Made	(14)					
Breaking Age	(15)					
Breaking Date	(16)					
Percent Entrained Air	(17)					
Slump	in. mm (18)					
Cylinder Wt.	lbq. kg (19)					
DESIGN MIX NO.	(20)					

PRELIMINARY GRAVEL SAMPLES

[illegible]

Sample Data Sheets

The concrete cylinders made at the structure site must be sent to the Region Laboratory or the Central Testing Laboratory. You need to fill out a sample data sheet (shown previously) to accompany the cylinders. At least the items indicated below must be filled in on the form:

- 1** Submitted By - Name, title, and address of person who took the concrete sample and made the cylinder.
- 2** Send Results To - Person to whom the test results should be sent - if different than item #1 (usually the Area Engineer).
- 3** Contractor - Use the name of the Contractor awarded the contract.
- 4** Subcontractor - List the Subcontractor building the structure if different than the prime.
- 5** County - List the county in which the structure is located.
- 6** Project Number -
- 7** Charge To - Project number to which the lab personnel should charge their time to if different from item #6.
- 8** Cylinders - Put an 'X' in the parenthesis to indicate this information for cylinders.
- 9** Date Sampled - Date sample was taken and the cylinder molded.
- 10** Cylinder Number - Cylinder identification number (number put on cylinder).
- 11** Station - Stationing of the structure.
- 12** Identity - Place where the pour was being made when you made the sample (deck, abutment, etc.).
- 13** Quantity Represented - Number of cubic yards represented by the sample.
- 14** Date Made - Date the cylinder was molded.
- 15** Breakage Age - Age at which your Project Engineer wants the cylinder tested.
- 16** Breakage Date - Date at which the cylinder is to be tested.
- 17** Percent Entrained Air - Percent of entrained air in the sample used to make this cylinder (results of your air test).
- 18** Slump - Slump of the concrete used to make this cylinder.
- 19** Cylinder Wt. - Weight of the actual cylinder to the nearest 0.01 pound.
- 20** Design Mix Number - The identification number of the design mix used.

NOTE If you are sending more than one cylinder in at a time, you can use the same data sheet for up to six different cylinders sent in the same shipment.

Completing the Material and Weight Ticket

After the concrete has been unloaded, complete your portion of the haul ticket. The figure below shows a completed ticket and the items you might have to fill in.

Figure 8.9 Completed Ticket

DOT-75
(1-84)

SOUTH DAKOTA

MATERIALS AND WEIGHT TICKETS

PROJECT S 6490 (1)

MATERIAL CLASS A

DATE 9-11, 1989 SAMPLE NO. _____

TANK OR CAR NO. _____ M. GALS. _____

TRUCK NO. 7 LANE _____

GROSS WT. _____ SECTION _____

TARE WT. _____ STATION 167+40

NET WT. _____ FOOTING BENT #3

SPREAD _____

TONS _____ END STA. _____

WEIGHER _____ CHECKER _____

CONCRETE MIX WATER:
(TREATED MAT'LS) MAX 1305 ACTUAL 1247

TIME START MIX 10:40A BATCH _____

DISCHARGED 11:10A SIZE 5 C.Y.

REVOLUTIONS: RATE _____

FINAL 768 INSPECTORS: _____

INITIAL 78 PLANT _____

NET 77 PLACING J.F.

REMARKS: 5 gal. WATER ADDED

No. D 623257

BOOK QUANTITY

PREV. TICKET _____

THIS TICKET _____

TOTAL _____

LEAVE THIS SLIP IN BOOK

- Project - If not entered by the Plant Inspector
- Station - The stationing and unit where the concrete was placed
- Discharge - The time when the last of the concrete was discharged from the truck
- Inspector: Placing - Your initials in script
- Revolutions: Final - Enter the revolution counter reading after mixing is completed
- Revolutions: Net - The total mixing revolutions of the load
- Remarks - The water in pounds or gallons added to increase slump or the amount of cement or air entrainment that was added. (if any)

Concrete Placement Equipment

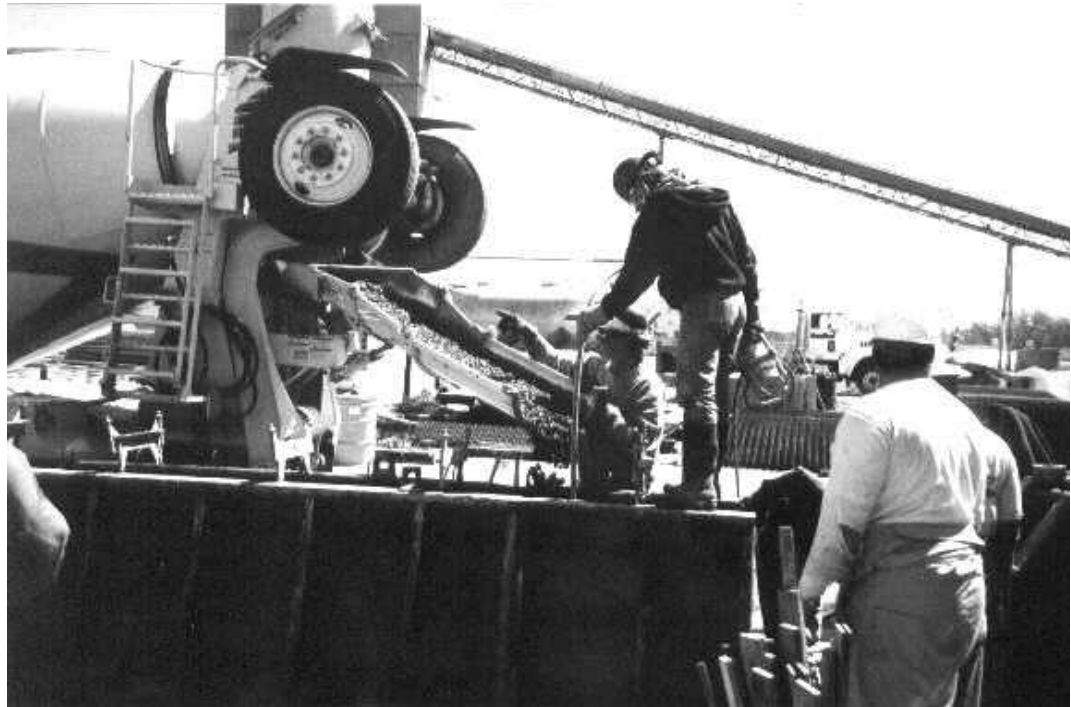
There is a large variety of equipment and options for a Contractor to use when placing the concrete. The most common methods used to place concrete are:

chutes, concrete buckets, concrete buggies, hoppers and drop tubes, tremie pipes, concrete pumps, and conveyor belts.

Chutes

Chutes are constructed of metal in a semicircular shape. Aluminum chutes should never be permitted since the coarse aggregate will wear off particles of aluminum and cause gassing in the concrete mix. Chutes must be clean and mortar tight. Dirt or dried mortar in the concrete being placed produces weak spots. The Contractor should wash the chute after each time it is used, and should give it a thin coating of water just prior to use. This coating prevents the mortar from the first part of the load sticking to the chute. If a long or extension chute is used, it could reduce the uniformity of some of the concrete.

Figure 8.10 Concrete Chute



Concrete Buckets

Concrete buckets are used as a crane attachment to transport concrete from one location or level to another. The size commonly used on bridge projects varies from a 3/4 cubic yard to a 2 cubic yard bucket. They are constructed with manually operated gates. The rate of discharge may be varied by manually varying the gate opening. Concrete buckets also must be clean and dampened before use. Often, mortar builds up near the top of the bucket. If this gets into the concrete, the Contractor must clean the bucket. Check the gates at the bottom of the bucket for proper operation. They must close tightly and be of a type where the opening can be controlled. This is necessary so a layer can be held to a uniform depth.

Figure 8.11 Concrete Bucket



It is necessary to rest the bucket on a sheet of plywood or other material when it is being filled to prevent contamination with dirt. The concrete bucket should be filled by dropping concrete directly over the gate opening. Dropping concrete on the sloping sides of the bucket can cause segregation of the aggregate while filling.

Figure 8.12 Filling the Concrete Bucket



CORRECT
Dropping of
concrete directly
over gate opening.



INCORRECT
Dropping of
concrete on
sloping sides of
bucket.

Concrete Buggies

There are two types of buggies used for placing concrete. They are commonly referred to as hand buggies or power buggies.

Figure 8.13 Power Buggy



Hand buggies are two wheeled with rubber tires and have capacities of approximately 1/4 yard of concrete. They are pushed and dumped manually like a common wheelbarrow.

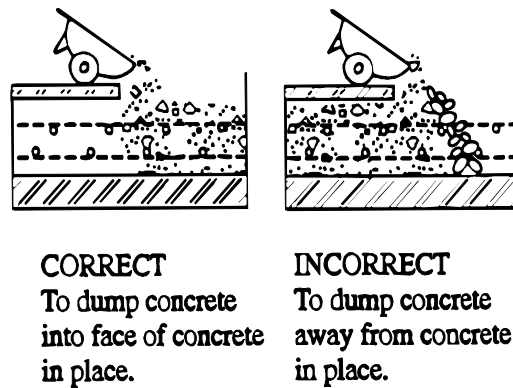
Power buggies are usually three or four wheeled, with rubber tires, and have a capacity varying from 3/8 to 1 cubic yard of concrete. They are self-propelled and the rate of discharge may or may not be controlled.

Concrete buggies require runways when they cannot operate on previously placed concrete. Buggies are most commonly used for placing concrete on low volume deck pours, particularly on low slump dense concrete bridge deck overlays. When used to place concrete on bridge decks, they must be driven on runways that are directly supported from the falsework. Laying plywood on the reinforcing steel and using the chairs or bolsters for runway support should not be allowed. The runways are constructed in sections and must be removed as the pour progresses.

Often the buggy will be driven on adjacent concrete decks that were just recently poured. As per Sec. 460.3.L, any construction equipment weighing less than 4,000 pounds may be used on finished slabs provided the most recent concrete placed has attained a compressive strength of 2,400 psi. This weight should include the weight of the buggy and the concrete it is hauling. One cubic yard of concrete in and of itself weighs close to 4,000 pounds. Any equipment that weighs more than this should not be allowed on the deck until the most recently poured concrete has attained a compressive strength of 4,000 psi. When allowed, the speed of power driven buggies should be limited to prevent impact and springing action that could damage or crack the recently poured slab. Any damage to the curing compound membrane should be repaired and maintained during the curing period.

When placing concrete from buggies, the concrete should be dumped into the face, rather than away, of the concrete in place. This will prevent separation of the coarse aggregate and mortar.

Figure 8.14 Placing Concrete from Buggies



Hoppers and Drop Tubes

When placing concrete in columns or walls, a hopper and drop tube is usually used. Hopper and drop tubes are required when the height of fall exceeds 5 feet. The hopper funnels the concrete down a tube attached in the middle at its base. The tube can be made of metal or rubber, and is commonly referred to as an elephant trunk when made of rubber. The hopper and tube (if metal) is typically steel or sheet metal type construction. Aluminum should not be allowed as the concrete aggregate can wear off particles of aluminum and cause gassing in the concrete mix.

The hopper can be directly supported on top of framework above the section to be poured, or is often hung directly from a concrete bucket when supported by a crane.

Figure 8.15 Concrete Hopper and Tube



Tremie Pipes

A tremie pipe is often required when placing concrete in underwater applications (see underwater placement later in the chapter). The steel pipe must have a minimum 1/4 inch thick wall, with a minimum inside diameter of 7 3/4 inches. The tremie should be smooth and thoroughly cleaned of any hardened concrete, rust, or other contaminants. Usually the tremie is a series of pipes connected by joints. The joints should be gasketed and bolted to be watertight, welded joints are acceptable if the smooth finish can be maintained on the inside diameter of the pipes.

Concrete Pumps

The modern mobile concrete pump utilizing a hydraulic placing boom can be an economical means for placing both large and small quantities of concrete. The pumping operation consists of a truck-mounted rig that the concrete is dumped into, and a pipeline that carries the concrete to where it will be placed. When metal pipe is used to transport the concrete, it must be steel and not aluminum.

Figure 8.16 Concrete Pump



Typically pumps are initially flushed with a thin water/cement paste mixture to coat the lines. The grout lubricates and dampens the pipe walls, eliminating the loss of grout or water when the concrete is pumped. Do not allow this grout to be used for the concrete - waste it!

The friction between the concrete and the pipe walls can generate heat. If necessary to hold the temperature down, keep the pipe covered with wet burlap.

Take samples for testing from the discharge end of the pipe. It is necessary to determine temperature, slump, air content, and strength of the concrete. Traveling through the pipe usually causes all of these to change. You must watch the slump closely; since the concrete pumps easier when the slump is high, Contractor's routinely try to place concrete at the high end of the slump range.

Figure 8.17 Discharge End of Pump Line



Conveyor Belts

Conveyor belts provide an easy way to transport concrete long distances, particularly on long bridge decks. The belt must be clean and dampened. Segregation will usually result at the discharge end of the belt unless a suitable hopper with a vertical downspout is used. Do not allow the operator of the belt to 'shoot' the concrete to hard to reach areas, as this can also cause segregation of the concrete. The belts should be set up to easily reach all areas of the section to be poured. If it cannot, then manual transportation by wheelbarrow or bucket should be done to get the concrete to the hard to reach areas. A scraper in good working condition should be installed on the underneath side of the assembly at the discharge point to remove mortar that tends to stick to the belt.

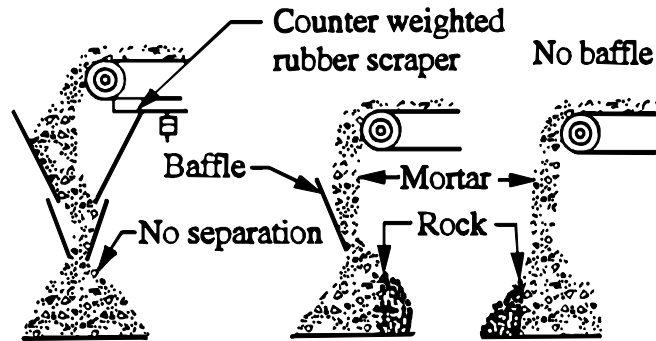
Figure 8.18 Conveyor Belt



Typically, small amounts of loose mortar or concrete will spill from the sides of the conveyor belt, plastic or burlap should be placed directly underneath the conveyor

for the full length to prevent this from falling on the deck yet to be poured. Efforts should be made to keep the number and distance of drops between belts to an absolute minimum.

Figure 8.19 Placing Concrete with Belt



CORRECT

The above arrangement prevents segregation of concrete whether it is being discharged into hoppers, buckets, trucks, or forms.

INCORRECT

Improper or lack of control at end of any belt. Usually a baffle or shallow hopper merely changes the direction of segregation.

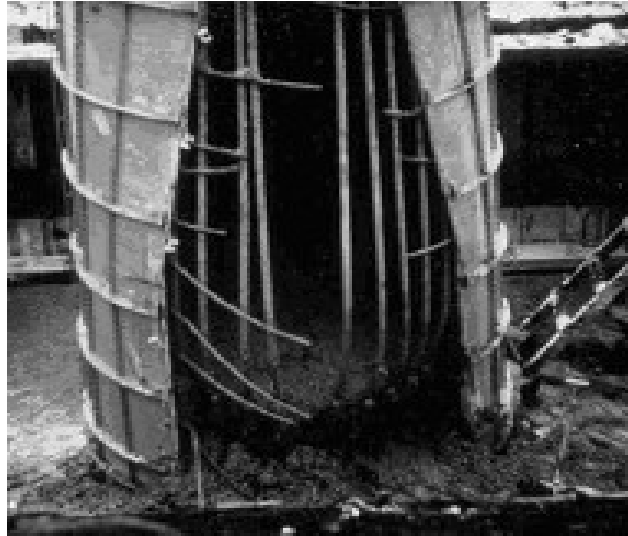
General Concrete Placement

The methods and equipment used to place concrete determine the finished product. Improper handling during placement can result in a poor quality product. Pay particular attention to the methods used by the Contractor and advise him of improper procedures.

Time Requirements

To obtain uniform concrete, the placement rate must be timed so a layer does not "set up" before the next layer is placed. If this occurs, the bond between the layers will be poor. It results in a plane of weakness that could cause structural failure. The Contractor is to regulate operations so the interval between deliveries of concrete does not exceed 30 minutes. If the Contractor is unable to meet this criterion, advise your Project Engineer. The Engineer may stop the placement until the Contractor adjusts his operations. Occasionally, there is a reason to extend the 30 minute time limit. Placing concrete in a column is one instance. Placing the concrete too fast does not allow time for concrete at the bottom to start setting up and the concrete stays plastic. As depth increases, pressure increases to a point that it can split the forms. On hot, dry, and windy days, 30 minutes may be too long and 15 minutes should be used. On cool days, 45 minutes may be proper. Check with the Project Engineer when in doubt.

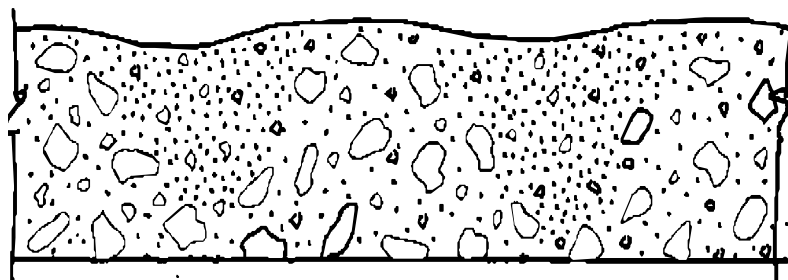
Figure 8.20 Column Form Failure



Placement Pattern

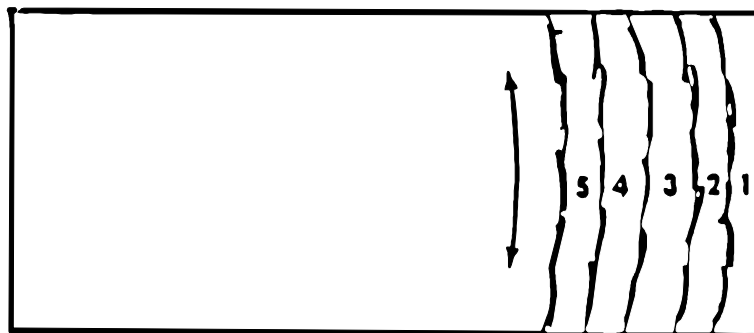
Concrete should not be dumped in piles. While being moved from piles, the concrete will segregate. Usually the rock will tend to stay where it was dumped and the mortar and fine material will be moved. Also, concrete dumped in a pile will be somewhat consolidated. The concrete used to fill between the piles will have very little consolidation. Regardless of how you work and vibrate the concrete, there will be two degrees of consolidation. As concrete cures, it shrinks. Areas with the least consolidation shrink the most. Figure 8.21 shows how a slab appears after curing if the concrete is placed in piles.

Figure 8.21 Improperly Placed Slab



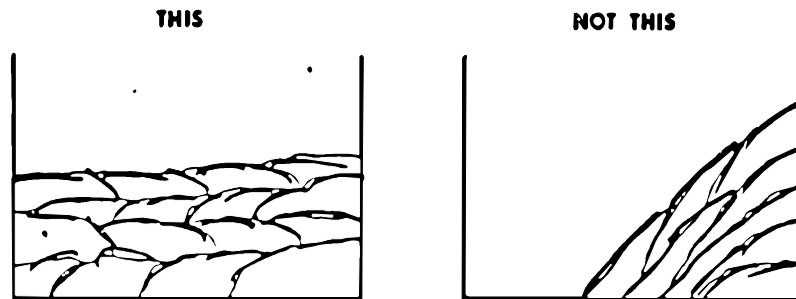
Not only does the concrete shown in Figure 8.21 have a rough surface and segregation, but it also has less strength. Problems can be eliminated by placing the concrete in continuous layers of uniform depth. For floors, decks, and other large areas, the placing should start at one end and move toward the other. Spread the concrete evenly over the entire width.

Figure 8.22 Placement in Slabs



When placing concrete in walls or along narrow sections, make sure a uniform depth is maintained and that the layers are not more than 12 inches deep. Layers 6 to 12 inches in depth make for easy handling. Concrete layers that are allowed to slope can become segregated, mortar flowing down hill and rock remaining stationary.

Figure 8.23 Placement in Walls



Consolidation

As concrete is placed, it is in a loose condition and has areas containing voids. If struck off and left this way, you would have concrete with a rough surface and questionable strength. To eliminate voids and settling, concrete must be of uniform density. Uniform density is achieved by using vibrators.

The most common vibrators are the portable spud vibrators. To obtain good uniform consolidation, the vibrators should be inserted into the concrete at intervals of 12 to 18 inches and a pattern followed. In a large pour like a bridge deck, the pattern can be like a grid. You must watch that they don't insert the vibrators in the same location of each lift in walls and columns.

There is no set time that the vibrator needs to be in the concrete. We do know that too little time does not fully consolidate the concrete, while long periods in one place segregates concrete. The length of time the vibrator needs to be in the concrete then varies with the slump and depth of the layers.

Figure 8.24 Spud Vibrator

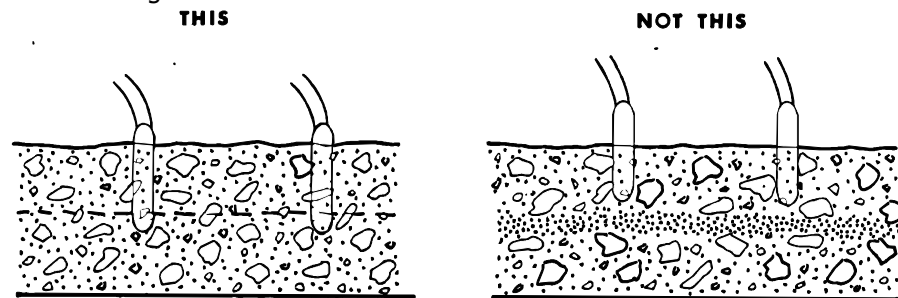


Rule of Thumb Let the vibrator penetrate the concrete to the desired depth under its own weight. Pull it out of the concrete at the same rate as it entered.

If possible, vibrators should enter the concrete vertically. This does away with segregation that might occur when pulling angled vibrators out of the concrete. Where concrete is placed in lifts, vibrators need to penetrate through the lift being placed and into the previous lift an inch or two. This is needed to get uniform

concrete for the full depth of the section. If lifts are not tied together, there is a possibility of getting planes of weakness.

Figure 8.25 Vibrating Lifts



Do not allow the workmen to use the vibrators to move the concrete from one place to another. As vibrators are pulled through the concrete, they only move mortar and fine material. The rock stays in place, which can result in segregated concrete.

Water Infiltration

At times, water will be in the foundation excavations. Seeping water can greatly affect the quality of concrete. If it is allowed to flow through the fresh concrete, it will wash out the fines and cement. This leaves poor quality concrete with little strength. There are three methods to handle this situation:

- 1 Pump the water out.
- 2 Place a foundation seal.
- 3 Place the concrete underwater.

Unless otherwise specified in the plans or specifications, water should be pumped out of the excavation. Additional measures such as cofferdams or cribs may be required to help facilitate the dewatering (refer to 'Chapter 3 - Excavation', for more information). Foundation seals or underwater concrete placement should only be permitted when approved by the Office of Bridge Design or when specified in the plans.

When water enters the excavation through the sides, it can usually be removed by pumping. The Contractor should dig a low spot called a sump, outside the footing forms, for a collecting point for water to be pumped out. Be sure that the water flows around and not through the footing to reach the sump. The pumping must continue until the placed concrete has taken a set.

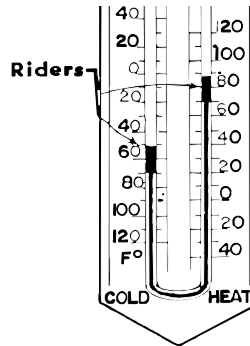
Typically when the water is entering from the bottom of the excavation, driving the cofferdam to a greater depth or seating a crib deeper will stop or slow down the water infiltration. Well points may also be used. If these countermeasures are not effective, contact the Office of Bridge Design for advice. If a foundation seal is recommended, the Contractor will be required to provide a foundation seal design for approval. The approved design will give the depth, type of concrete mix, and procedures to use for placing the seal. The area can be de-watered when the concrete in the seal or footing has enough strength to withstand the water pressure. Before additional concrete can be placed, the face must be cleaned. All unsatisfactory concrete must be removed so sound concrete is exposed. This can be done by chipping, scraping, or abrasive blasting.

If the concrete is to be placed underwater, follow Section 460.I in the Standard Specifications. Placing underwater concrete in a drilled shaft is discussed in great detail in 'Chapter 3 - Excavation' in this manual.

Cold Weather Requirements

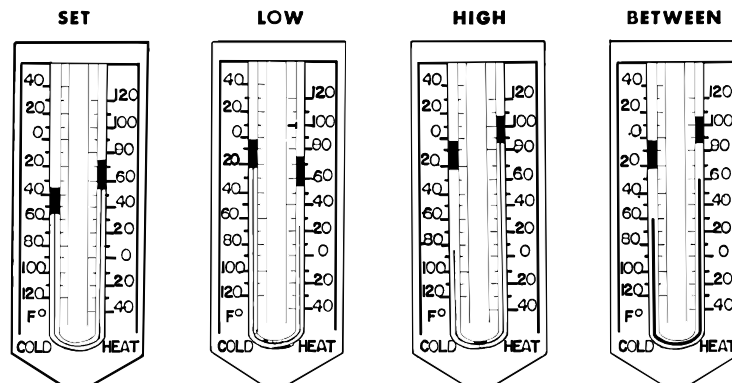
Placement of concrete for bridge decks is not permitted from November 1 to April 1, without written authorization from the Engineer. If parts of the structure are built during cold weather, the concrete must be at least 50 degrees F and not more than 90 degrees F when placed. The ground must not be frozen, and there cannot be frost on either the reinforcement or forms at the time of placement. The placed concrete must be maintained at certain temperatures during the curing period. When the ambient temperature nears 45 degrees F, check the Contractor's protective material and procedures. It is also time to take temperature readings of the concrete in place. You need both the high and low temperature. Use a high-low thermometer such as shown below.

Figure 8.26 High/low Thermometer



The temperature tube is "U" shaped and has readings on both sides. The right side records the "high" and the left side the "low". The recording is done by the "riders" that are on the ends of the mercury column. The temperature is read at the bottom of the riders.

Figure 8.27 Using High/Low Thermometers



The high-low thermometer has to be reset each time temperatures are recorded. This is done using a magnet to move the riders until they touch the mercury. As the temperature rises, the mercury pushes the right rider up. When the temperature falls, the right rider stays at the high reading as the mercury moves away. While the temperature is not the high or low for the day, the mercury will not be touching the riders. When engaged in cold weather procedures, place a high/low thermometer near the structure. You may use one daily, giving you the high and low temperatures for your diary.

When following cold weather procedures, place some high-low thermometers on the concrete. The concrete must be maintained between 50 and 100 degrees F for the first 72 hours after placement. During the next 48 hours it must be kept between 40 and 100 degrees F. After this, there are no temperature requirements. If the temperature does fall below the specified temperature for this 5-day period, one extra day of protection above 40 degrees F must be added for each day the temperature falls below the specified temperature.

Figure 8.28 Cold Weather Concrete Temperature Record (front)

DOT-227 · SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION
(10/85) COLD WEATHER CONCRETE TEMPERATURE RECORD

PROJECT NO. S 7080 (2) COUNTY HUGHES DATE OF POUR 10-11 —
CONTRACTOR JONES CONSTR. CO. INC. STA. 56+ REPORT NO. 1
STRUCTURE 124'-0" CONTINUOUS CONCRETE BRIDGE
UNIT DECK - APPROX. 250 CY INSPECTOR Tom Nierx

(2)

D A Y S	DATE	(1) ATMOSPHERIC TEMPERATURE		— CONCRETE TEMPERATURES —						(3) STRENGTH		
		HIGH	LOW							PSI	GAIN %	ACC. %
				"A"	"B"	"C"	"D"	"E"	"F"			
0	10-11	45°	28°	(See Reverse Side for Fresh Concrete Temp. Record)								
1	12	46°	29°	52°	56°	57°	56°	48°	45°	760	19	19
2	13	50°	33°	58°	60°	62°	61°	56°	55°	1300	13	32
3	14	58°	38°	60°	60°	63°	63°	61°	62°	1960	17	49
4	15	72°	36°	62°	64°	65°	64°	65°	64°	2520	14	63
5	16	50°	38°	43°	46°	47°	46°	46°	45°	3010	12	75
6	17	44°	26°							3200	5	80
7	18									—	—	
8	19									—	—	
9	20									—	—	
10	21									3560	—	89
11	22									—	—	
12	23									—	—	
13	24									—	—	
14										4050	—	100 (+)

REMARKS: (1) HIGHS & LOWS RECORDED BY "HI-LO" THERMOMETER LOCATED AT JOB SITE.
(2) CONCRETE TEMPERATURES RECORDED BY THERMOMETERS "A" THRU "F" LOCATED AS SHOWN ON SKETCH ON REVERSE SIDE OF THIS FORM. THESE THERMOMETERS, ALONG WITH THE "HI-LO" THERMOMETER, WERE READ AT APPROX. 9:30 AM EACH DAY. ANY TIME OTHER THAN THIS WAS SHOWN TO THE LEFT OF THE "DAYS" COLUMN ABOVE.

(3) STRENGTH RECORDS ARE THE RESULTS OF IMPACT HAMMER READINGS TAKEN AS AN INFORMATIONAL CHECK AND THEY ARE INDEPENDENT OF CYLINDER BREAKS USED FOR CONTROL. STRENGTH SHOWN IS AVERAGE OF SEVERAL READINGS ALONG DECK.

NOTE: 5% EXTRA CEMENT ADDED TO MIX TO OBTAIN A HIGH RATE OF STRENGTH GAIN AT AN EARLY AGE.

EXPLAIN ALL DEVIATIONS FROM SPECIFICATIONS:

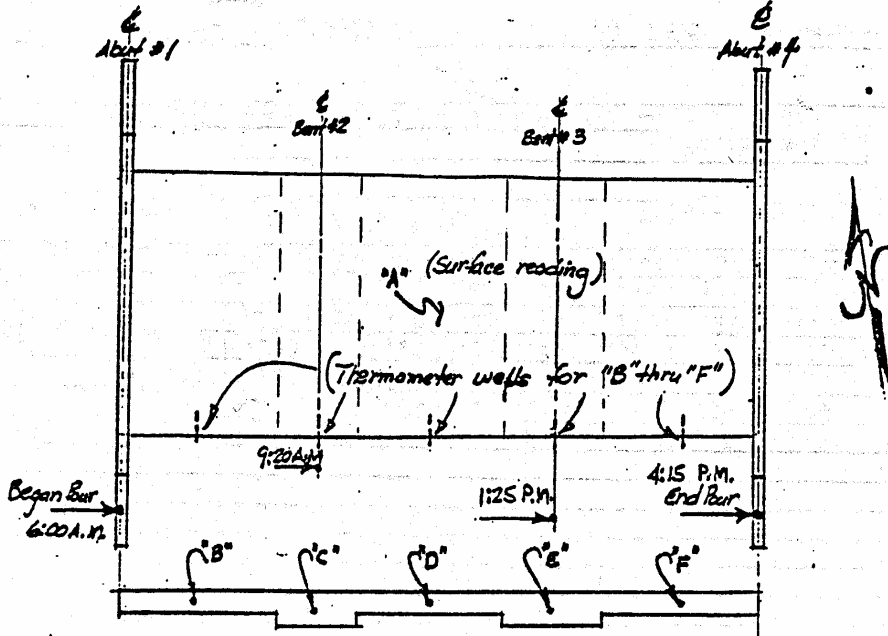
AREA ENGINEER

ON THE 1ST DAY AFTER THE POUR, THE CONCRETE TEMPS. AT CERTAIN LOCATIONS ARE SHOWN TO BE BELOW THE SPECIFIED 50°F. IT IS BELIEVED THAT THIS WAS A RESULT OF NOT BEING ABLE TO GET THE PLASTIC COVERING AND 12" OF STRAW COVER ON THE FRESH DECK UNTIL IT HAD SET UP SUFFICIENTLY SO THAT THE COVERING OPERATION WOULD NOT DISTURB THE FRESHLY FINISHED SURFACE.

Figure 8.29 Cold Weather Concrete Temperature Record (back)

MARKS: Sketch need not be to scale. Show locations of all thermometers, in relation to centerline of roadway, centerline of structure unit and north arrow.

PENCIL SKETCH



RECORD OF CONCRETE TEMPERATURE AT TIME OF PLACEMENT

[illegible]

If the Contractor has written permission to add an additional bag of cement, or if high early strength cement is allowed, then the concrete should be maintained at a temperature of 60 degrees F or above for 72 hours. If a temperature less than 60

degrees F is recorded during this period, then you should revert back to the requirements of the previous paragraph.

If the Contractor uses protection to maintain temperatures, then the concrete temperature shall not be permitted to fall more than 40 degrees F for each 24 hour period when the protection is removed. The maximum concrete temperature when using protection is 100 degrees F.

Unit 1 of the protection periods has been satisfied, cold weather protection shall continue, falsework shall remain in place, live loads shall not be applied, and the concrete temperature shall be maintained above 35 degrees F.

Placement of the high-low thermometer should be planned. Usually the lowest temperature will be at the edge or corners. The highest temperature is normally in the middle of the mass or where the concrete is the thickest. Set at least one thermometer in each area.

When the Contractor places insulation directly on and around the concrete, place the thermometer between insulation and the concrete. When the unit being built is completely "housed in", place plastic over the thermometer. This is done to record the concrete temperature and not the air temperature.

Several items may be used to insulate concrete during cold weather. They range from straw to insulated blankets. Figure 8.32 has two tables showing insulation materials ability to protect units at various temperatures. Some, like insulated blankets, are easily damaged. Check the Contractor's insulating material to see if it is in good condition and dry. Make sure measures have been taken to keep the insulation in contact with the forms and concrete. Make sure the Contractor has someone available to monitor the protective covering during nights, weekends, and other non-working periods.

Figure 8.30 Insulating Blankets



Heated enclosures keep the workmen out of bad weather. Check to make sure they are reasonably airtight so cold air does not reach the concrete. You should also see that the enclosure is big enough to maintain at least one foot of clearance between it and the forms. This is needed so the warm air is free to circulate around the unit.

Figure 8.31 Heating Enclosure



Figure 8.32 Insulating Properties

**TABLE 2b—INSULATION REQUIREMENTS FOR CONCRETE SLABS
PLACED ON THE GROUND**
Concrete at 50 F placed on ground at 35 F—
No ground temperature gradient assumed

Slab thickness, ft	Minimum air temperature allowable for these thicknesses of commercial blanket or bat insulation, deg F				
	0.5 in.	1.0 in.	1.5 in.	2.0 in.	2.0 in.
Cement content—300 lb per cu yd					
0.333	•	•	•	•	•
0.667	47	42	36	35	29
1.0	37	19	—1	—1	—21
1.5	26	—5	—57	—72	—70
2.0	16	—27			
2.5	6	—51			
3.0					
Cement content—400 lb per cu yd					
0.333	•	•	•	•	•
0.667	50	49	47	46	46
1.0	42	30	17	17	5
1.5	29	1	—27	—58	—117
2.0	16	—28	—72		
2.5	3	—53			
3.0	—10	—66			
Cement content—500 lb per cu yd					
0.333	•	•	•	•	•
0.667	47	42	35	30	30
1.0	37	19	0	—19	—92
1.5	21	—16	—54		
2.0	6	—51			
2.5	—13				
3.0	—26				
Cement content—600 lb per cu yd					
0.333	•	•	•	•	•
0.667	43	34	24	14	14
1.0	31	7	—18	—42	—127
1.5	18	—33	—60		
2.0	—6	—74			
2.5	—22				
3.0	—42				

*See explanation, Table 2c.

Notes: The tables are calculated for the stated thicknesses of blanket-type insulation with an assumed conductivity of 0.26 Btu per hr per sq ft for a thermal gradient of 1 deg F per in. The values given are for still air conditions and will not be realized where air infiltration due to wind occurs. Close-packed straw under canvas may be considered a loose-fill type if wind is kept out of the straw. The insulating value of a dead-air space greater than about 1/4 in. thick does not change greatly with increasing thickness. Textbooks or manufacturers' test data should be consulted for more detailed data on insulations. See insulation equivalents, Table 2a.

**TABLE 2a—INSULATION REQUIREMENTS FOR CONCRETE WALLS AND
FLOOR SLABS ABOVE GROUND**
Concrete placed at 50 F

Wall thickness, ft	Minimum air temperature allowable for these thicknesses of commercial blanket or bat insulation, deg F				
	0.5 in.	1.0 in.	1.5 in.	2.0 in.	2.0 in.
Cement content—300 lb per cu yd					
0.5	47	41	33	28	28
1.0	41	29	17	6	6
1.5	35	19	0	—17	—17
2.0	34	14	—9	—29	—35
3.0	31	8	—15	—35	—39
4.0	30	6	—18	—39	—43
5.0	30	5	—21		
Cement content—400 lb per cu yd					
0.5	46	38	28	21	21
1.0	38	22	6	—11	—11
1.5	31	8	—16	—89	—89
2.0	28	2	—26	—63	—63
3.0	25	—6	—36		
4.0	23	—8	—41		
5.0	23	—10	—45		
Cement content—500 lb per cu yd					
0.5	45	35	22	14	14
1.0	35	15	—5	—26	—26
1.5	27	3	—33	—65	—65
2.0	23	—10	—50		
3.0	18	—20			
4.0	17	—23			
5.0	16	—25			
Cement content—600 lb per cu yd					
0.5	44	32	16	6	6
1.0	32	8	—16	—41	—41
1.5	21	—14	—50	—89	—89
2.0	18	—22			
3.0	12	—34			
4.0	11	—38			
5.0	10	—40			
Insulation equivalents*					
Insulating material					Equivalent thickness, in.
1 in. of commercial blanket or bat insulation					1.000
1 in. of loose fill insulation of fibrous type					1.000
1 in. of insulating board					0.768
1 in. of sawdust					0.610
1 in. (nominal) of lumber					0.333
1 in. of dead-air space (vertical)					0.234
1 in. of damp sand					0.023

*See notes, Table 2b.

Most heating systems, except salamanders and open flames, can be used if a uniform temperature is maintained. The heating unit must have a shield so exposed metal is not in contact with flames. Steam heat is the best due to moisture. Other heating units usually produce a dry heat and sometimes carbon dioxide, pulling moisture out of the concrete and resulting in surface cracking and low strengths. Carbon dioxide is a health hazard and also combines with cement to form calcium carbonate. A layer of calcium carbonate has little strength and wears off quickly, exposing the aggregate. You must make sure that the curing material is kept in place and in good condition. Before any concrete is placed in cold weather, the forms and any surfaces it will come in contact with must be raised above 32 degrees F.

It is permissible to flood concrete to a minimum depth of 1 foot for 10 days after the concrete is placed maintaining a water temperature which prevents freezing of the water in contact with the concrete.

Keep an accurate record during cold weather concreting, including a description of the protection used, temperature conditions, and anything else that may effect the concrete. A form has been devised for recording the information. An example completed in form is shown in Figure 8.29; this form does not replace your diary.

Hot Weather Requirements

During periods of extreme and sustained hot weather, it may become extremely difficult to maintain the 80 degree F, maximum concrete temperature, for bridge deck concrete. When such conditions exist, the Engineer may authorize the maximum concrete temperature to be raised to 85 degrees F provided the following actions are taken:

- 1 The aggregate piles are flushed with water for a minimum of 24 hours.
- 2 A minimum rate of pour of 40 cubic yards per hour, or the plans specified rate (whichever is greater), can be maintained by the Contractor.
- 3 Wet burlap and white polyethylene sheeting can be placed as soon as the concrete has stiffened sufficiently such that the surface will not be damaged.
- 4 If the ambient temperature is 80 degrees F or less, the concrete shall be cured with a linseed oil base emulsion curing compound as specified in Section 460.3.N of the Standard Specifications.

Whenever the ambient temperature exceeds 80 degrees F, in addition to the linseed oil base emulsion curing compound, a continuous fogging should be applied from the time of initial strike-off until the wet burlap is in place.

Fogging equipment shall be capable of applying a fine mist, not a spray, under pressure through an atomizing nozzle. The fogging option will not be allowed when wind conditions preclude complete coverage.

Joints

Structure parts are held together by joints so the structure will act as a unit. There are two major types of joints:

- 1 Construction Joints - used in the structure because there is no way to place all of the concrete at one time; and
- 2 Contraction/expansion joints - provide a "connection" for different units of the structure but do not create a solid bond between them.

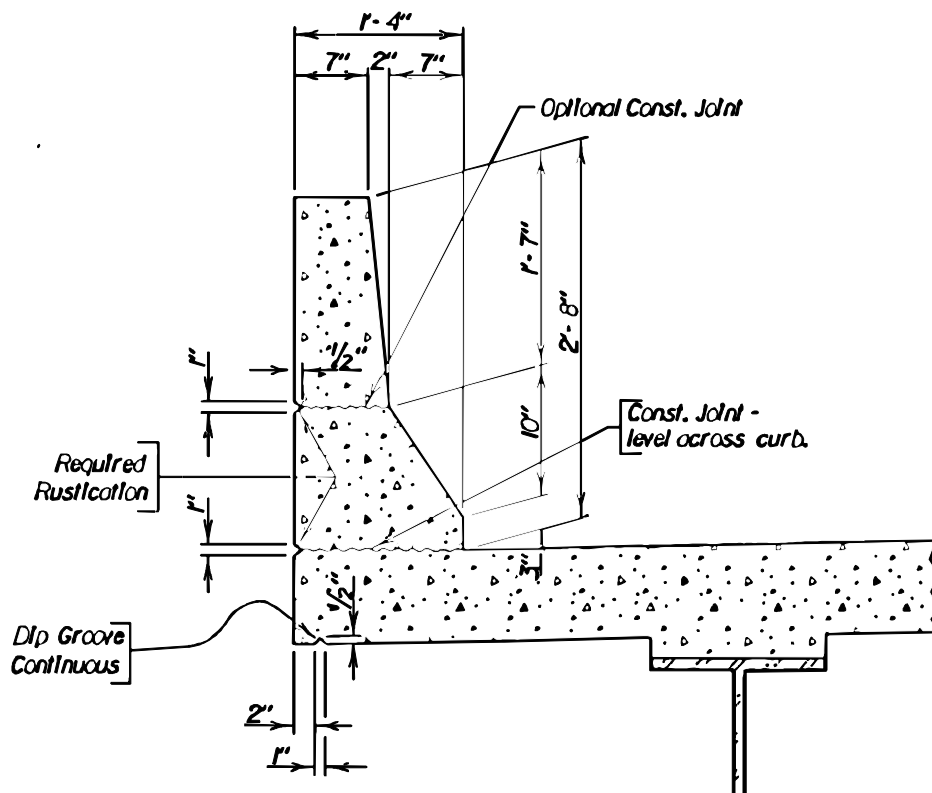
Construction Joints

Because of size and shape, structures are built piece by piece. This results in fresh concrete being placed against previously placed concrete. The joint must be properly prepared. In most cases, the plans designate where joints must be or can be located (i.e. - required or optional). There are two types of construction joints, the roughened and the formed joint.

Roughened Joints

A roughened joint is made by roughening the concrete surface. This is accomplished by placing the concrete a little high and then rough floating the concrete to the desired height to sufficiently consolidate the surface. This gives the Contractor an opportunity to remove grout. Grout left on the surface gives a plane of weakness. As the grout is removed, the concrete surface will be somewhat rough, with aggregate showing. Most roughened joints are located where reinforcement is through the joint. Workers should smooth between and outside the reinforcement.

Figure 8.33 Roughened Joints



Roughened joints generally fall in a horizontal plane, between the deck and curb (as shown in the figure above), footing and column, cap and deck, etc. Although the plans may not call for a joint to be roughened, it should be unless a formed joint is specified. Roughened joints should be protected from curing compound and should be cleaned of all loose laitance or other foreign material prior to subsequent concrete placement.

Formed Joint

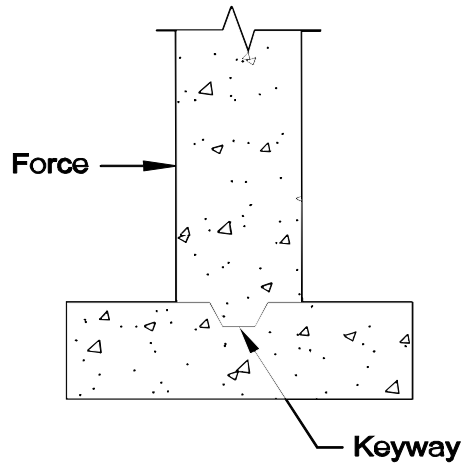
Formed joints are made by placing a form where the concrete placement is to be stopped. Concrete must be well consolidated at the joint. Check so that voids are not left near the form face.

Keyways

A keyway is an indentation in the concrete at a joint, providing load transfer. In Figure 8.34, if a force were pushing on one side of the top concrete, the only way it could move is by shearing the lip of concrete that fits into the keyway. The plans show the width, depth, and where keyways are required. Keyways may be used in either a roughened or a formed joint. See that keyways are placed properly and of the dimensions shown. Discuss this prior to placement of concrete.

Keyways must always be formed. Footprints, gouged holes, etc. are not an acceptable form of a keyway.

Figure 8.34 Keyway

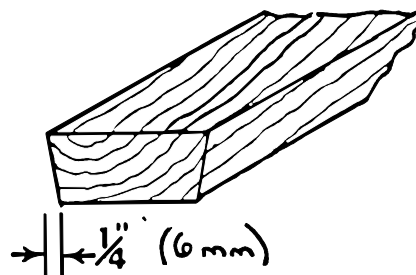


The keyway form should be a trapezoid with a 1/4 inch bevel to ensure that the concrete edges do not crack when removing the keyway. As most keyways are made of wood, the form must be oiled before being placed or concrete will stick to it, and it will expand absorbing moisture. Both can cause concrete damage.

Keyways should be continuous along the length of the construction joint. There are two exceptions:

- 1 The keyway need not be continuous where reinforcement falls in the keyway location. It can be stopped and started again.
- 2 The keyway is to be stopped about three inches from the end of the joint at any location where it can be seen after the structure is completed. This will happen on caps and in certain places on a box culvert.

Figure 8.35 Wood Keyway Form



Emergency Construction Joints

You may encounter a situation where the Contractor is unable to supply the concrete required to complete the placement due to time or equipment breakdown. Action must be taken before the concrete sets up. In most cases, (walls, columns, floors, etc.) the Contractor can place a construction joint where the concrete stops. The concrete should have a fairly straight or level surface. The same joint that was specified for the completed placement should also be made.

If work has to be stopped when placing a bridge deck, consideration needs to be given as to the location of the emergency construction joint. Dependent upon the bridge type, certain locations for emergency construction joints are the least detrimental to the bridge. For continuous concrete bridges, it is preferable to place emergency construction joints at the nearest $1/4$ or $3/4$ points of the span as shown in Figure 8.36. For continuous composite steel girder and prestressed girder bridges, it is preferable to place emergency construction joints such that concrete has been placed on $3/4$ of the span as shown in Figure 8.37. For simple span bridges, emergency construction joints can usually be placed as necessary without significant detriment to the structure.

Figure 8.36 Emergency Construction Joint Locations for Continuous Concrete Bridge Slabs

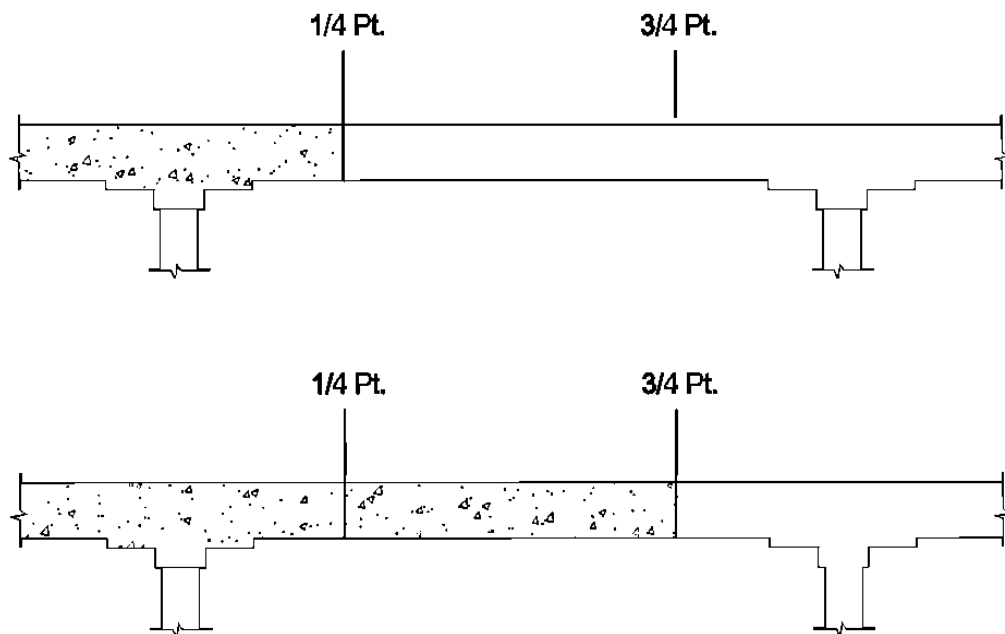
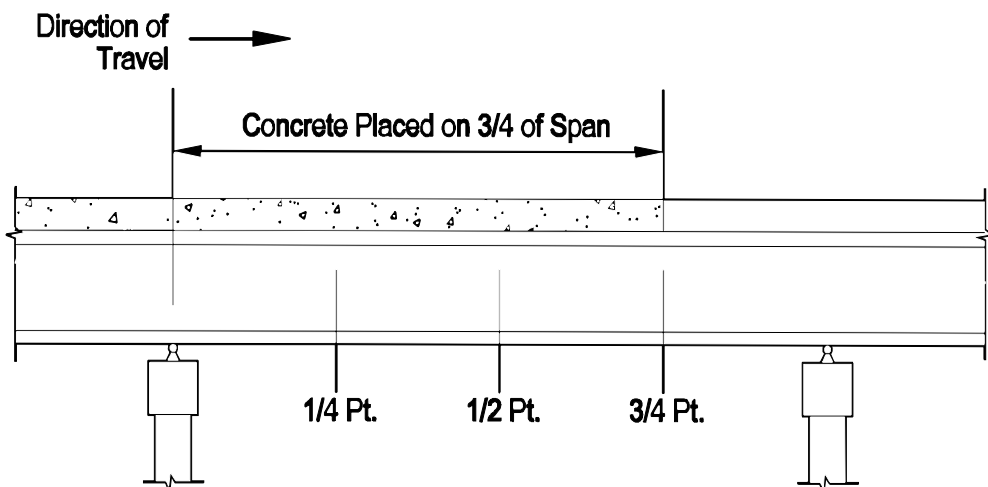


Figure 8.37 Emergency Construction Joint Locations for Continuous Composite Girder Bridge Slabs



The foregoing describes the most desirable locations for emergency construction joints for some of the more common bridge types. If an emergency construction joint is required, it should be placed at or near these locations whenever practical. There may be times, however, where conditions are such that it is simply not practical or possible to place an emergency construction joint at these locations. Unless otherwise specified on the plans, an emergency construction joint can usually be placed wherever needed without serious detriment to the structure. The emergency construction joint should be vertical and should have a keyway, unless a specified emergency construction joint detail is provided in the plans.

After making the emergency construction joint, discontinue any concrete placement and immediately contact the Office of Bridge Design. The Office of Bridge Design will analyze the conditions and determine if any special procedures for subsequent concrete placement are required.

Contraction/Expansion Joints

Concrete, like steel, expands and contracts with thermal temperature changes. Contraction and expansion joints are specifically designed to accommodate this movement.

In simple structures like retaining walls, contraction joints may simply be a groove (formed or saw-cut) that creates a weak point in the wall. When shrinking or contracting, the concrete will usually crack at the weakest location, thus cracking at the preformed contraction joint rather than in another undesired location. The reinforcement is usually run through the joint to keep the joint from growing too large, and to provide lateral resistance perpendicular to the wall. Expansion joints are typically formed using a compressible filler material between the planes of concrete. The expansion joint material provides room for the concrete to enlarge or expand. Dowels are typically placed in the joint to provide lateral resistance perpendicular to the wall. Figure 8.38 shows the contraction and expansion joints that are typically used in these applications.

The superstructures of bridges also expand and contract with thermal temperature changes. With the exception of some steel girder bridges, most all bridges constructed in South Dakota utilize integral abutments. The superstructure and bridge deck are directly connected to the abutment. This means that when the deck contracts or expands due to temperature, the movement is transmitted to the abutments - which must move back and forth by a like amount. The ends of the structure must be designed to accommodate this movement. On South Dakota roadways, bridges are typically designed with an approach slab and sleeper slab that have a joint between them allowing the superstructure to expand and contract. In addition, very long structures may also have intermediate joints placed within the length of the bridge itself that accommodate this movement. There are several versions of these joints, and depending on the application and degree of movement or opening required, different joints are selected.

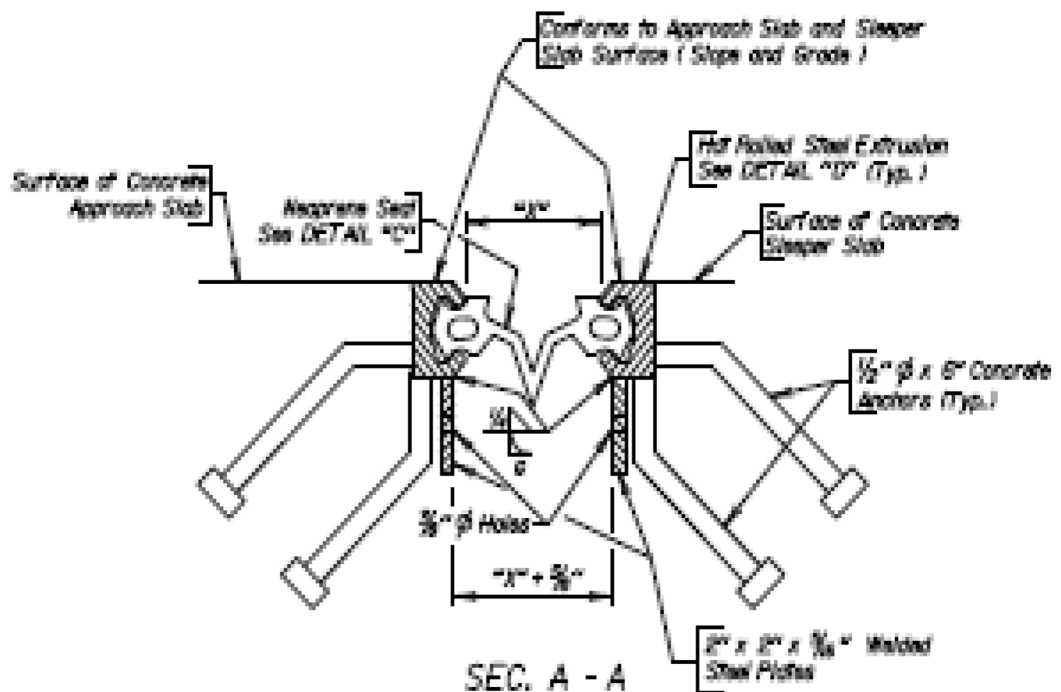
Figure 8.38 Typical Membrane Sealant Expansion Joints



A Membrane Sealant Expansion Joint is used for most bridge expansion joints. The approved manufacturers are listed on the approved product list found on the DOT website. The pavement slot can be saw cut after approach slab and sleeper slab hat concrete is cured, or formed while placing the approach slab and the sleeper slab hat. The joint shall be installed according to manufacturer's recommendations. After the concrete is cured, Styrofoam is placed in the slot to allow proper height for the foam expansion joint. The joint is placed with a 1/2" top recess and glued using a manufacturer approved epoxy.

Strip Seal Expansion Joints

Figure 8.39 Strip Seal Expansion Joint



In the past the most common bridge joint is the strip seal expansion joint. These joints may appear within the length of the bridge itself on long bridges, and are used almost exclusively as the joint that is placed at the end of the approach slab. A strip seal expansion joint is constructed using a hot rolled steel extrusion that is formed to hold a neoprene (rubber) gland, referred to as the seal.

The plans, shop plans, and manufacturer's product data sheets will give installation instructions for the joint. These instructions must be followed. During installation, pay particular attention to the following:

- The neoprene strip shall be installed after the steel extrusions are concreted in the approach slabs or bridge deck. Assure both parts of the steel extrusion are at the proper height and set to the proper grade.
- The steel extrusions are galvanized in the shop. If a field weld is used, the weld affected area shall be repaired by the method specified in the shop plans. No welds shall be permitted in the internal section of the extrusions where neoprene seal is located.
- Advise the Contractor to put protective material in the extrusions prior to concrete pour. This ensures extrusions are free of concrete that would be very difficult to remove.
- The neoprene seal is installed and bonded to the steel extrusions with a high-solids lubricant adhesive. The neoprene surfaces shall be roughened with a wire brush before application of the lubricant adhesive. The lubricant adhesive acts first as a lubricant, then upon curing, bonds the neoprene seal to the steel extrusion. Assure the Contractor uses a sufficient amount of lubricant adhesive and the proper tools for installing the neoprene seal. This seal should not be damaged.

Strike Off

After the concrete has been placed and consolidated, it needs to be cut off to the proper elevation by using a strike off operation. The method the Contractor uses depends on what is being built. Small areas (top of walls, caps, etc.) are done with a wood float. Usually a chamfer strip is in place, and it is the guide to obtain the desired elevation. Larger areas (tops of footings, box culvert floors and tops, etc.) may be struck off with a board screeded back and forth on the top of the forms. Large areas of concrete (bridge decks) must be struck off with a finish machine. Bridge deck strike off and finishing is discussed in more detail later in this chapter. The Contractor is responsible for the actual strike off. You need to verify the proper elevation.

Cast-in-Place Box Culverts

Cast-in place box culverts, while relatively simple in function and design, can be quite involved and complicated in construction. Often there are more reinforcing details and reinforcing bars to be placed in a box culvert than there are in a bridge itself. Careful attention to plan notes and details is a must during construction.

Placement Sequence

Work on the box culvert progresses from the ground line up. Generally, the bottom slabs of the barrel sections and the cutoff wall/heel portions of the wing walls are poured first. Following that, the wing walls and barrel walls are poured. The last pours usually involve the top slab or aprons.

Prior to pouring the bottom slabs, you should ensure that the undercut and backfill operations have been performed in accordance with plans and specifications. The backfill should be placed at the correct elevations that take the flowline or slope of the culvert into consideration. In addition, the backfill should be smooth and even, with no depressions or high points.

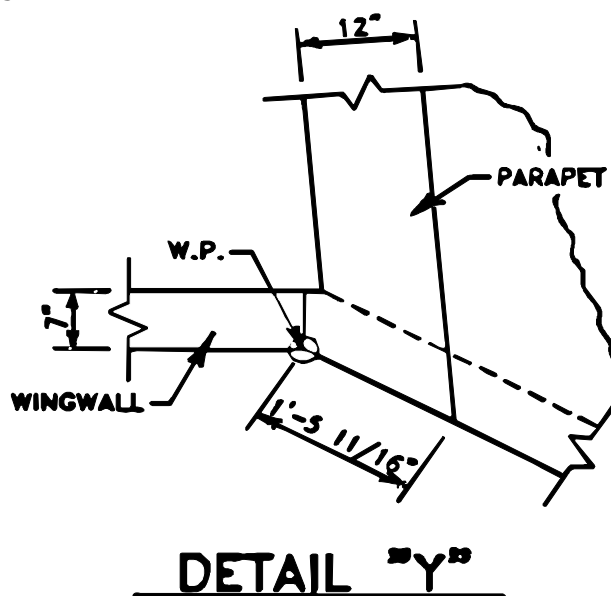
The joints between the bottom and top slabs and the walls have triangular corner shapes, called fillets, that improve the hydraulic capacity of the culvert. At the option of the Contractor, the fillets at the bottom slab may be constructed in a square fashion rather than triangular. Any additional concrete for this option is to be paid by the Contractor, and should not be included in pay quantities for concrete.

The walls of the box culvert are generally poured separate from the top slab. Occasionally, a Contractor will want to pour the walls and top slab together in one sequence. This is permissible except on large multi-cell box culverts where the size or volume of the pour can often become quite large. The concrete in the culvert walls must be in a plastic or fluid state when pouring the top slab. If they are not in a plastic state, and initial set has taken place, then cold joints detrimental to the integrity of the culvert can occur. There will usually be a plan note prohibiting a combined pour where applicable. You should be comfortable that the Contractor has the equipment and manpower available to adequately handle the pour, keeping the walls in plastic form while pouring the top slab, before allowing both walls and top slab to be poured in one stage. When in doubt, or if you question the size of the pour, you should contact the Office of Bridge Design for recommendations and approval.

Working Points

Perhaps the most common error made when constructing box culverts is that of mislocating the working points (W.P.) at the transition from barrel walls to flared wing walls. Figure 8.40 shows a typical working point detail for a flared wing wall on a box culvert. Most all dimensions pertaining to the wingless's geometry and reinforcement will be referenced from the established working point. Careful attention should be paid to these details to assure that the transition point, or working point, is placed in the correct location.

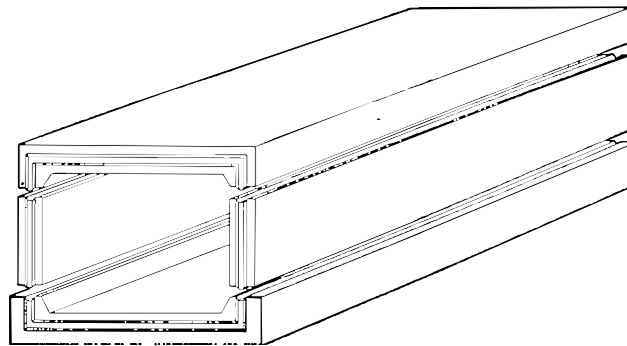
Figure 8.40 Working Point



Joints

Figure 8.41 demonstrates how the joints of a box culvert should be placed when built in sections.

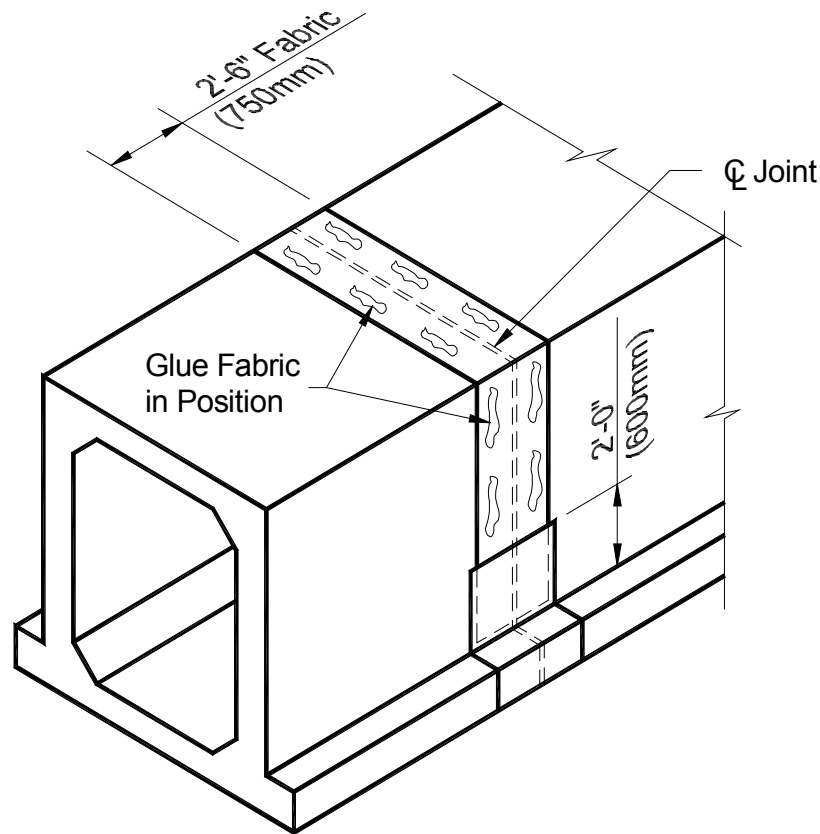
Figure 8.41 Box Culvert Joints



Plans will show keyways in most all box culvert construction joints. However, plan notes state that horizontal joints in box culverts may be made as roughened joints rather than keyways. Vertical joints must always be made with keyways. In addition, the joints between barrel sections must always be formed with keyways.

The joints between barrels of a box culvert have dowel bars that are lapped with the horizontal steel of the walls and slabs. In addition, the entire joint between barrels is wrapped with drainage fabric as per Section 422 of the Standard Specifications. This is done to prevent fine soil material from migrating through the joint resulting in a void in the backfill. The fabric must be a minimum of 2 feet, 6 inches in width, and must have 2 foot minimum overlaps (where required). The fabric is placed prior to concrete pours at bottom slab joints, and following concrete pours on the top slab and walls. The fabric should be glued down to the box culvert sufficiently such that it will remain in place during backfilling operations.

Figure 8.42 Wrapping Box Culvert Joints



The Contractor may want to pour the bottom slabs of two barrel sections at one time. This is permissible if they install a metal keyway between the two sections. This keyway must have a width that extends through the concrete at all places. The dowel bars and drainage fabric are still required at the joint location.

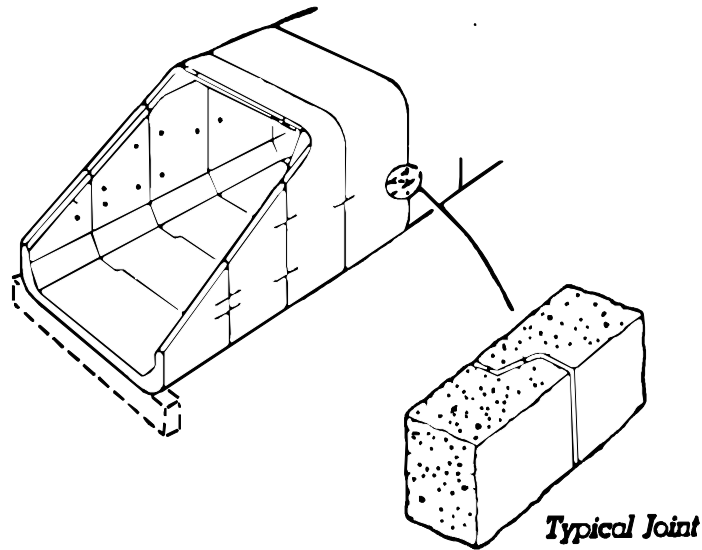
Precast Box Culverts and Large Pipes and Arches

Fabrication

Precast box culverts and large pipes or arches are usually cast in the fabrication yard of a precast concrete products supplier. The Contractor will need to supply the Office of Bridge Design a set of shop drawings (or shop plans) and a copy of design computations for review and approval at least 30 days prior to start of fabrication. Shop Drawings are working plans that function as the following:

- They specifically detail how the supplier will construct or fabricate the precast units; and
- They function as additional construction plans that provide erection or placement sequencing as well as additional specific required details

Figure 8.43 Precast Box Culvert



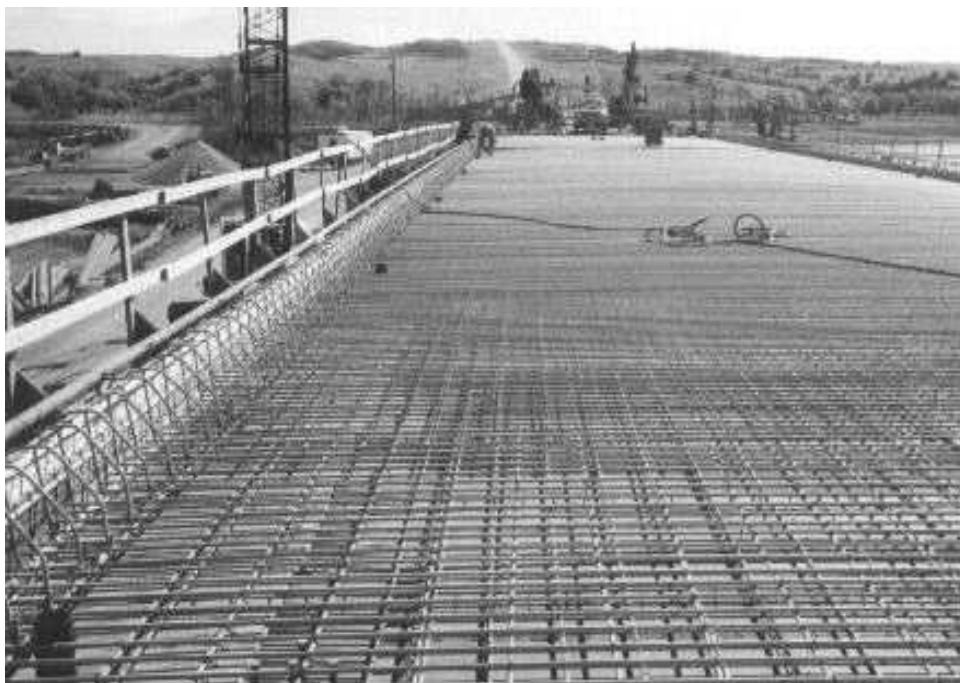
Shop plans are covered in greater detail in 'Chapter 13 - Shop Plans and Fabricated Items' of this manual.

Bridge Deck Concrete Placement

Pre-Pour Inspection Requirements

Specifications require that a pre-pour inspection be conducted for all new concrete bridge decks. The Contractor should advise the Engineer a minimum of 24 hours prior to the time when the bridge deck will be complete and ready for inspection. Once notified, the Engineer should inform the Office of Bridge Design immediately of the inspection. Most often, a representative from the Office of Bridge Design will be present for the pre-pour inspection.

Figure 8.44 Bridge Deck Ready for Pre-Pour Inspection



The primary focus of the pre-pour inspection is to verify that all items are in place and that all formwork and equipment is ready to pour the bridge slab to correct plans shown dimensions and elevations. For this reason, all items should be in a 'ready-to-pour' condition prior to the pre-pour inspection. The following items should be ready and complete before the time of inspection:

- Formwork - Formwork and decking should be complete and all joints mortar tight.
- Reinforcing Steel - All reinforcing steel should be placed, secured, and tied in accordance with plans and specifications.
- Screed Rails - Screed rails for the finish machine should be set and adjusted for the final grade.
- Finish Machine - The finish machine should be set up on the screed rails, and should be adjusted to the proper crown and depth of slab.
- Safety - Walkways and safety railing should be installed on each side of the bridge deck to allow access for edge finishing.
- Contractor Representative - A responsible Contractor employee should be designated to represent the Contractor and to accompany the Engineer during the pre-pour inspection.

Any corrective measures that must be taken as a result of the pre-pour inspection should take place during normal work shift hours and not during extended late evening hours. This is done to ensure that the adjustments and corrective work is done correctly and with thought, rather than hastily and possibly incorrect. By specifications, the Engineer can postpone the schedule of the bridge deck placement should this provision not be followed.

Bridge Deck Finish Machines

Specifications require that the concrete deck of a bridge be placed with the use of an approved bridge deck finish machine. Bridge deck finish machines are specialized equipment manufactured primarily for use in trimming and finishing the bridge slab surface during the concrete pour.

Basically there are only two manufacturers of bridge deck finish machines currently used in industry today, Gomaco or Bidwell. Both kinds of finish machines operate in a similar manner. The machines mount on a paving carriage that travels on screed rails set on each side of the concrete pour. The finish machines utilize augers to strike off and rollers to finish the concrete surface.

The screed rails and finish machine should be set up and adjusted for correct grade, crown and slab depth prior to the pre-pour inspection. The Contractor should have a good working knowledge of how to set the rails and finish machine. As the inspector, you should monitor and check the Contractor's set-up methods to ensure that everything is set to pour the bridge deck slab to the correct plans shown dimensions and elevations. The following gives a brief explanation of the basic procedures required to correctly set up the finish machine and screed rails.

Setting Up the Finish Machine

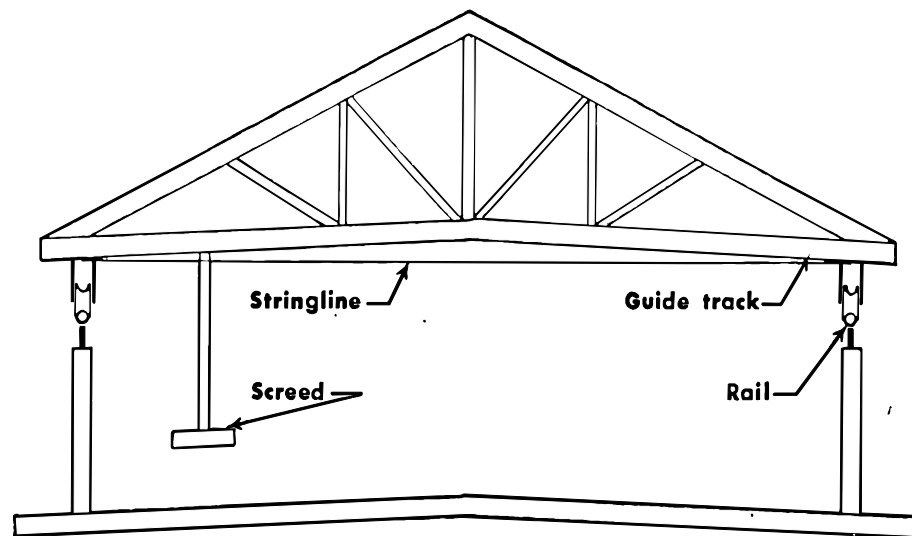
The finish machine should be set to match the skew of the bridge. On very large skews, it may be necessary to have the finish machine set a skew that is less than the skew of the bridge. This is usually discouraged, and is only approved when absolutely necessary as deflections and rail elevations are more difficult to establish and set.

After setting on the rails, first check to see that the machine is adjusted to strike off concrete to the required cross-section. This is done by stretching a string line between points on the screed guide track that are directly over the rails. Note that

on square bridges, the screed rails should be verified to be at the same elevation on each side of the machine before making adjustments to the finish machine for crown slope. For skewed decks, the difference in elevations at the point of support along the rails should be accounted for when making crown adjustments.

If the machine is jointed in the center, have the workers lower the guide track until it touches the string line. Any spots along the guide track that are high or low must be adjusted so as to just touch the string line. As soon as the guide tracks are straight, raise the center of the machine so you can check the crown distance. When the crown point of the deck is midway between the rails, the crown distance is equal to $1/2$ the distance between rails, times the crown slope. This is the distance the guide track must be set above the string line. The easiest way to check the crown when it does not fall midway between the rails is to use a level and rod. Take a shot at the bottom of the guide track over the rail and at crown point. The difference in elevations must be equal to the crown slope times the distance between shots. If the difference in elevation is not equal to crown slope times distance, adjustments are required.

Figure 8.45 Setting Up the Finish Machine



For machines not hinged in the middle, check the straightness of the guide track by stretching a string line from the rail point to the crown point. The total crown can be checked just like it is for the other machines.

Setting the Screed Rails

For a continuous concrete structure, you need to find the distance the rail is above the bottom of the finish machine's screed. Have the Contractor move the screed next to the curb. Then take a shot on top of the rail and at the bottom of the screed. The difference provides the constant distance the rail should be set above the top of concrete elevation. Now figure railing elevations by adding the amount allowed for lumber crush and form curb and center line elevation to the constant the railing is above the top of the concrete. Add this sum to the elevations on the curb and center line elevation diagram to get the elevations for the rail.

The rail usually has more support points than given by the curb and center line elevation diagram. You must interpolate to get the extra points. To check the rail elevations, have the finish machine run up to each point. This puts the dead load of the machine on the forming and also forces the rail to fit tightly in the saddles. The rail elevations can be adjusted to what is required with the bolts that are connected to the saddles.

After the rails are set, run the machine the length of the deck. Run the screed back and forth at the same time and check the distance between it and the reinforcing steel and also check slab depth. This extra check may disclose mistakes in reinforcement placement or the rail elevation.

Figure 8.46 Checking Elevations on Screed Rail

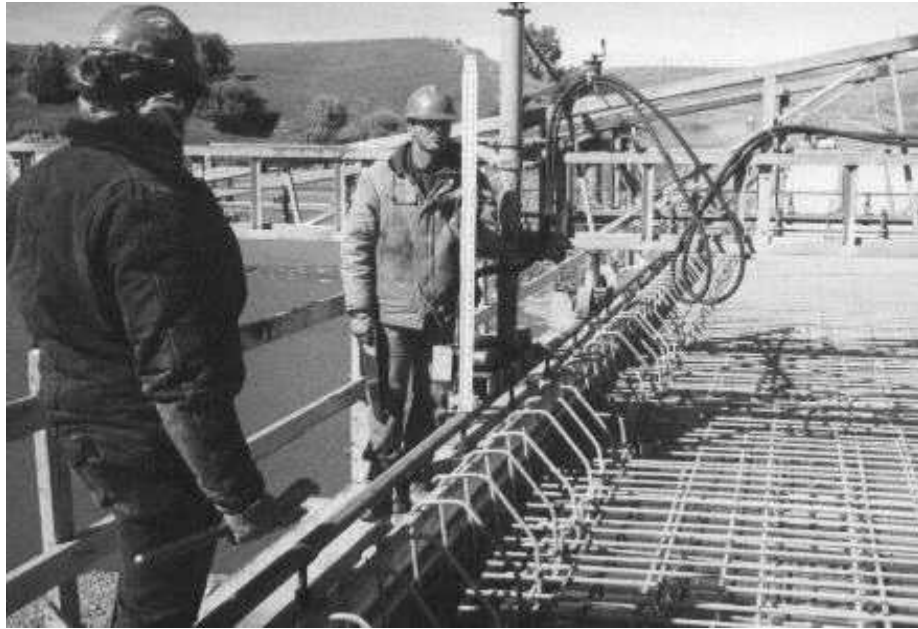
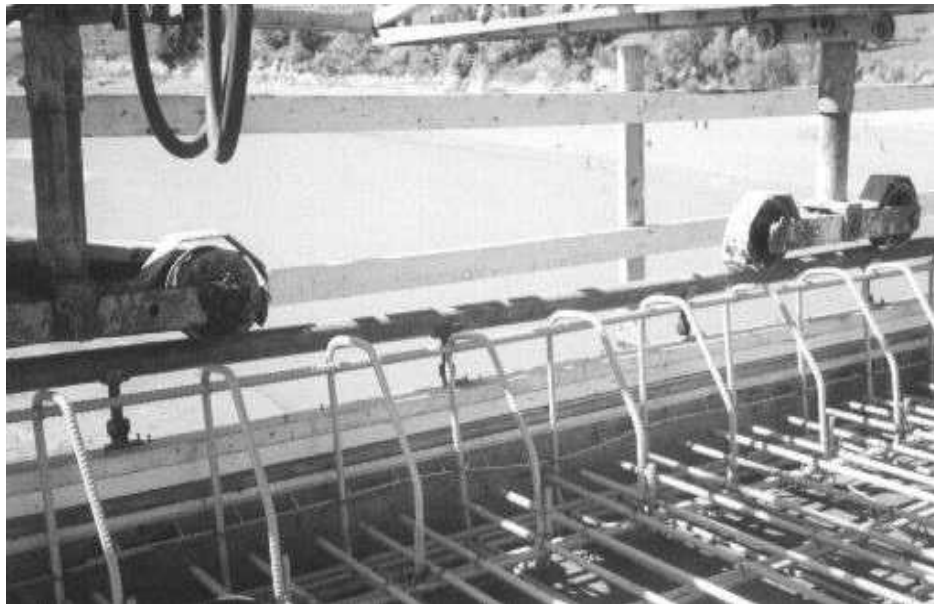


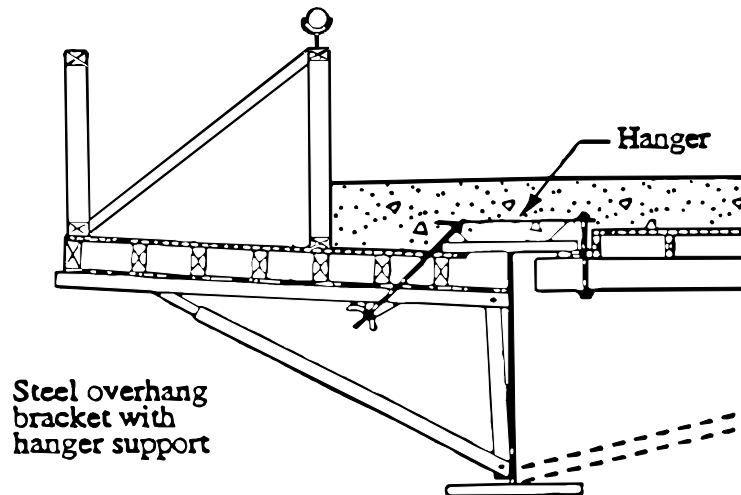
Figure 8.47 Finish Machine on Screed Rails



For steel or concrete girder structures, the procedure is different to establish the rail elevations. First, find the constant distance between the bottom of the screed and the rail top. This is done by moving the screed until it is directly over the outside girder. Take a shot on the bottom of the screed and one on the top of the rail. The difference between these shots is the constant that should be used.

The outside forms of a girder structure are supported with overhang brackets. the concrete weight on this part of the form causes it to sag. Generally, sag runs about 3/8 inches. Ask the Contractor for his figures, you will need the value to determine the railing elevation.

Figure 8.48 Screed Rail on Overhang Bracket



The rail elevation is found by adding the constant distance and the sag to the slab form elevations of the exterior girder. The elevations are set at each point on the rail the same as for a continuous concrete structure.

Checking the Screed Rails During Concrete Placement

During placement of deck concrete, check the rails again. On continuous concrete bridges, wait until the Contractor has placed about $1/2$ to $3/4$ of the concrete needed for the span. Then check the rail elevations for the first part of the placement since settlement due to lumber crush and form camber should have occurred. If all goes as planned, the rail elevation should be equal to the camber elevation plus the constant above the concrete surface.

If your checks show rail elevations are off more than $+0.02$ feet, there is a problem. First, take depth checks to see what depth you are actually getting across the deck. The deck should not be more than $1/8$ inch thin or $1/4$ inch thick. If the corrections required exceed these limits, split the difference. This gives a camber somewhat different than desired, but the deck will not be too thin or thick.

Remember

Keep your rail checks about $1/2$ to $3/4$ the span length behind the concrete placement. This allows time for the settlement to come out of the forms.

Once the Contractor starts to place concrete for decks on girder bridges, checking rail elevations is not practical. The best procedure is to take depth checks across the deck, between the exterior girders. If they show an incorrect depth, the overhead brackets are not settling as planned. The rail can be adjusted up or down, based on your depth checks. Because of the design of these thin decks, attempt to keep the depth within $+1/4$ inch and $-1/8$ inch.

Monitoring Finish Machine During Concrete Placement

To obtain the best strike off, the finish machine must have a little concrete to cut off. Be sure that the workmen keep a little concrete overfill in front of the screed, or a low spot will be filled with grout causing weak or undesirable sections.

Each pass of the finish machine should overlap the previous pass. The screed can cut off any excess that might have rolled under it on the last pass. Usually the overlap is such that the roller is only advancing on a few inches of new concrete during each pass.

For girder bridges, it is important that the concrete be placed on the bridge deck matching approximately the same skew angle as the bridge itself. This is done to

keep the deflections due to the concrete weight uniform across the girders (i.e. - at the same span point locations for each girder). Usually this is easily accomplished because the finish machine itself is generally set to the skew of the bridge. However, for skewed bridges where the finish machine has been set square or at a different skew than the skew of the bridge, this needs to be closely monitored. Pay special attention to the progress rate of the machine, as it is undesirable to have the concrete sit on the deck for too long prior to being leveled and screeded by the machine.

The finish machine will leave a roll of concrete on each side of the deck after each pass of the drum. This material consists mostly of fines or mortar, and should never be used to fill in low spots along the curb area or elsewhere, but should rather be removed and wasted.

Finishing

Finishing gives concrete a surface texture. The finish required depends on the surface location. Surfaces in view of the traveling public need to have a uniform texture and pleasing appearance. If the surface is not easily seen by the traveling public, as shown in the following pictures, no special finish is needed.

Figure 8.49 Girder Bridge

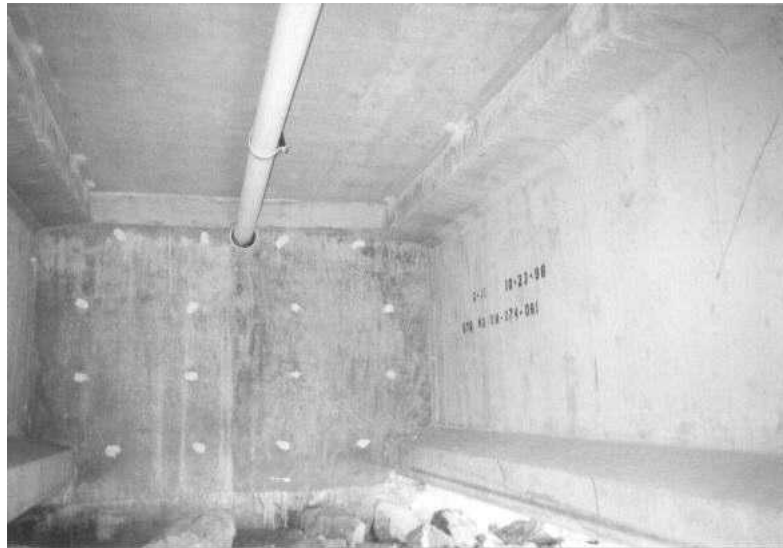


Figure 8.50 Box Culvert



Concrete in forms will generally have a smooth surface when the forms are removed. When the surfaces are not in view of the traveling public, the only finishing required is what is necessary to fill holes left by ties or honeycombing. Honeycombing is similar to a rock pocket. It occurs when concrete is not vibrated thoroughly, resulting in rock not surrounded with fines and grout.

Figure 8.51 Large Honeycombed Area

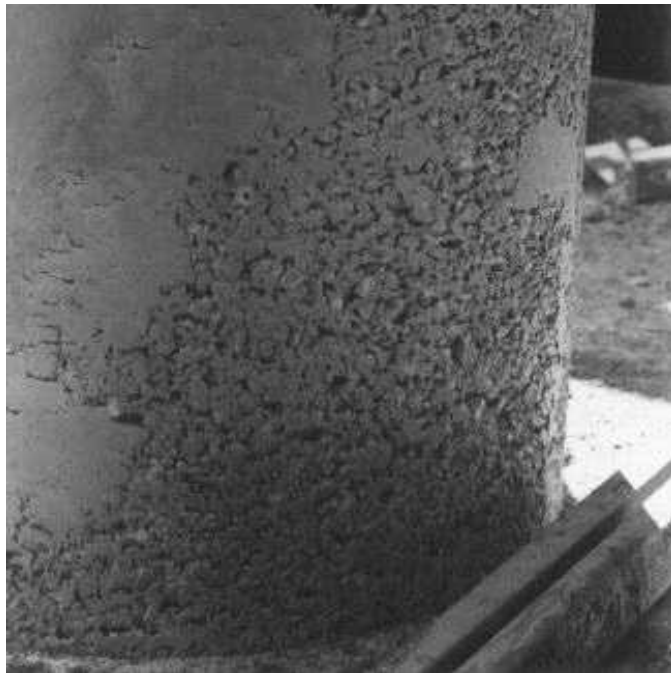
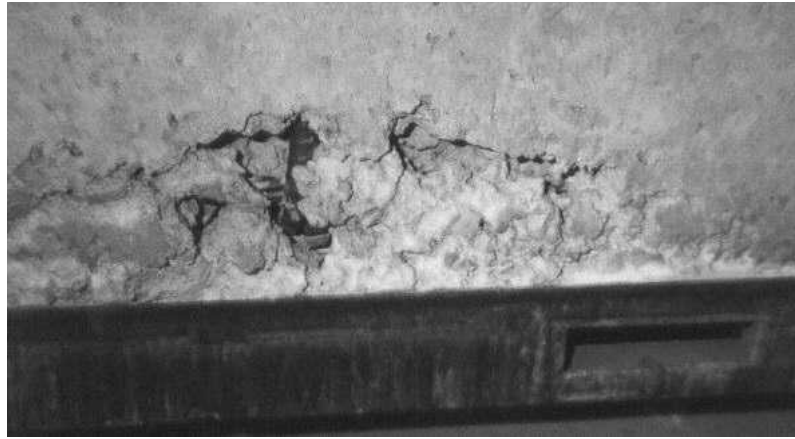


Figure 8.52 Small Honeycomb Area



Small areas of honeycomb must be chipped out until solid concrete is exposed before being repaired. Several areas of honeycomb indicate poor procedures were used during placement. If severe enough the entire segment may require removal and replacement. Discuss this with your Project or Area Engineer before starting repairs.

Important Be present when the forms are removed so you can observe the condition of the concrete.

Before tie holes or honeycomb areas are filled, make sure that loose material is removed, the hole is clean, and exposed concrete is damp. This is the only way to assure the patch remains in place. The repair needs to be done with a grout consisting of 30% cement and 70% sand by weight, and enough water to give it a mushy consistency. Trowels or floats can be used to repair these areas. The grout must be thoroughly worked into the hole and the surface finished to blend with the other concrete. For deeper repairs, the grout may have to be placed in several applications. Thick layers of grout tend to shrink and crack. Do not allow a plaster patch over the hole.

Surface Finish

The surfaces of all concrete masonry shall be worked during placement. The working shall force all coarse aggregate from the surface and thoroughly work the mortar against the forms to produce a smooth finish relatively free of water, air pockets, and honeycombing.

As soon as the concrete has set sufficiently, the forms on all exposed surfaces shall be carefully removed and all depressions resulting from the removal of metal ties or other causes shall be carefully pointed with a mortar of sand and cement in the same proportions as the concrete treated. All fins and rough corners on the surfaces shall be removed to present a neat and uniform appearance.

Additional finishing will be required as follows:

- **Rubbed, Brushed, and Commercial Texture Finishes:** One of these three finishes will be required for all railing, curbs, parapets, wings, and other surfaces not subject to wear which are visible to the traveling public unless otherwise designated in the plans. The selected finish shall be used throughout the entire structure, except the finish for the top and inside of the curb may be different than that used for the other parts of the structure. These finishes will not be required on wing walls and parapets of box culverts, and wing walls and backsides of curbs on bridges, which do not have traffic passing beneath them, provided the forms result in a smooth unblemished surface.
- **Rubbed Finish** - As soon as the pointing has set sufficiently, the surfaces to receive a rubbed finish shall be thoroughly wetted with a brush and rubbed with

a medium coarse carborundum stone or an abrasive of equal quality using a small amount of mortar on stone face. The rubbing shall be continued until all form marks and projections are removed, producing a relatively smooth clean surface free from pits or irregularities. The final finish shall be obtained by rubbing with a fine carborundum stone or an abrasive of equal quality. This rubbing shall continue until the entire surface has a smooth texture and uniform color.

- Brushed Finish - This finish will be permitted only if it is accomplished within 12 hours of concrete placement. The forms shall be removed as soon as the concrete is able to stand firm without slumping. The surface shall be worked with a rubber float which may be dipped in a very wet 3:1 fine sand and cement grout mixture. Immediately after the surface is worked into a lather, a soft bristle brush shall be used to smooth the surface, leaving a fine grained, smooth, but sanded texture. A "plastering" job resulting from the use of an excess of grout on the surface will not be permitted.

Note Commercial Texture Finish and Special Surface Finish are now combined under a new title 'Commercial Texture Finish Class B'. In this manual they are still listed separately since the Special Surface Finish is still used on existing bridges.

- Commercial Texture Finish - This finish shall consist of an application of a textured latex paint. The Department will maintain a list of approved materials and mixes for use. The mixture shall be applied in sufficient thickness to completely cover the original surface with a one coat application, but shall not be so thick as to cause runs, sags, or a plastered effect. The final dried surface shall be uniform in color and texture, with no evidence of laps or breaks in continuity. Corrective work, at the expense of the Contractor, will be required on areas that have not been satisfactorily finished, including as much adjacent area as necessary to provide a uniform appearance. Application of the commercial texture finish shall not be started until other work which might mar the finish has been completed. If the Contractor elects to commence with the finishing operation prior to completion of any work that might damage the surface, provisions shall be taken to protect the finished surface. The finishing operation shall be carried on continuously from beginning to completion on any one surface.
- Special Surface Finish: A special surface finish will be required on the concrete surfaces designated in the plans. The objective is to obtain a surface that is reasonably uniform in texture and appearance. Repairing surface blemishes to prevent "show through" prior to application of the special finish is required. The surface finishing shall be performed using an approved mixture of commercial textured latex paint. The materials used for the mixture shall be compatible with each other, and shall produce a mixture suitable for the purpose intended. The Department maintains a list of approved materials and mixes for Contractor use. The work in conjunction with the special surface finish shall not start until the material and mixture have been approved. The same materials and application method shall be used for all surfaces specified on any one structure.
- The special surface finish shall be mixed and applied according to manufacturer recommendations. A copy of the manufacturer recommendations shall be provided to the Engineer. The surfaces to receive the finish shall be abrasive blasted or power washed to break the surface film and to remove all laitance, form release agent, and all other foreign matter. All surfaces shall be thoroughly flushed with clean water not more than 24 hours before applying the finish. The concrete surfaces shall not be wet or damp when the special surface finish is applied. The mixture shall be applied by spraying or rolling. The mixture shall cover the original surface with a one coat application. The one coat application shall not be too thick to cause runs, sags, or a plastered effect. After drying, the final surface shall be uniform in color and texture, with no laps or breaks in continuity. The finished surface shall be lighter in color than the

original concrete, but not white, unless otherwise specified in the plans notes. The application of the special surface finish shall not be started until all other work that could damage the surface has been completed. The finishing operations shall be carried on continuously from beginning to completion on any one surface. Corrective work, at the Contractor's expense, will be required over any areas which have not been satisfactorily finished, including as much adjacent area as may be necessary to achieve uniform appearance.

- Float Finish: Unformed surfaces, except bridge decks, shall be given a float finish. After the concrete has been struck off, the surface shall be thoroughly worked and floated with a suitable floating tool. Before the finish has set, the surface cement film shall be removed with a fine brush in order to have a fine grained, smooth but sanded texture.
- Bridge Deck and Approach Slab Finish: The concrete shall be placed slightly higher than the finished surface of the deck or approach slab. Immediately after the concrete has been placed and consolidated, the surface shall be struck off and finished with an approved finishing machine. For bridge decks the finishing machine shall meet the following minimum requirements:
 - The finishing machine shall be a self-propelled rotating cylinder type, with one or more rotating steel cylinders and augers. The machine shall span the concrete placement width. The cylinders and augers shall spread and consolidate the concrete to the established profile by traversing the placement width, transverse to the roadway center line. The machine shall be capable of forward and reverse motion under positive control, and be capable of raising all cylinders and augers to clear the surface when traveling in reverse. Any modifications to the factory product will require approval by the Engineer. The portion of the deck adjacent to curbs shall be neatly finished to a true surface with a wooden hand float.
 - Before the concrete has attained its initial set it shall be given a final finish by transverse brooming or carpet drag to provide a surface micro texture.
 - The surface of the concrete bridge deck and approach slab shall be given a transverse metal-tine finish. The metal-tine finish shall provide a groove depth of $\frac{3}{16}$ inch $\pm \frac{1}{8}$ inch. The spacing between the individual grooves shall be randomly spaced and shall vary between $\frac{5}{8}$ inch to $1 \frac{5}{8}$ inches with 50% of the spaces being 1 inch or less. The repeating random pattern on the tining device shall be avoided. Successive passes of the tining shall not overlap. The 12 inch width of the deck next to the curb shall be left ungrooved.
 - After the concrete has hardened, the surface and joints shall be tested with a 10 foot straightedge. The permissible longitudinal and transverse deviation shall be $\frac{1}{8}$ inch in 10 feet. Any portion of the deck and approach slab showing variation from the template of more than $\frac{1}{8}$ inch shall be either ground to an elevation that will be within the permissible deviation or be accepted under the provisions of Section 5.3. Necessary grinding shall be accomplished with specially prepared circular diamond blades mounted on a horizontal shaft. Areas that have been ground shall not be left smooth or polished, but shall have a uniform texture equal in roughness to the surrounding unground concrete.

After the concrete has cured and the forms are removed, check the surface. The surface has to have a degree of smoothness such that no areas show a bump over $\frac{1}{8}$ inch. The best check is to use a Hi-Low Machine. This is usually done by the Region Materials personnel. However, if you do it, run the machine the length of the deck where the wheels of the traffic will run. This means a minimum of four passes on most decks. Then mark any spot that is over $\frac{1}{8}$ inch high with marking dye, keel, or paint.

Figure 8.53 Hi-Low Machine



The Contractor may, at the discretion of the Engineer, correct these high spots by grinding or accept with a price adjustment. A grinder may be used as long as it does not damage the concrete. If the grinder tears rock loose, its use should be discontinued. One of the best grinders has a diamond cutting edge mounted on a horizontal tube. It cuts rather than tears the surface.

Figure 8.54 Grinding



After high spots are ground, check to see that the area meets the 1/8 inch tolerance. The easiest way is to use a 10 foot straightedge. The main disadvantage to removing bumps after the concrete has cured is poor concrete appearance.

Curing

Concrete gains strength from the chemical action between cement and water. This means water must be kept inside the concrete so a reaction can occur. If concrete dries, it stops gaining strength and hairline cracks develop. To prevent this, make sure the concrete is cured in a manner that produces sound, strong, durable concrete. There are several ways of curing concrete:

- Membrane Curing Compound
- Cotton or Burlap Blankets
- Paper or Plastic Sheets
- Wetted Earth, Sand, or Straw
- Continuous Wetting
- Leaving Forms in Place

Note Check your Plan Notes and Special Provisions for special curing procedures.

Membrane Curing Compound

Application of the membrane curing compound should begin as soon as the bleed water sheen leaves the concrete surface, but before the surface dries. If for some reason application of the membrane curing is delayed, the surface moisture should be kept from evaporating by the use of fogging. It is important that the surface be damp when the membrane material is placed. Curing compound is a liquid that forms a watertight seal on the concrete surface and thus retards evaporation of the surface moisture. It must be applied uniformly as a fog spray at the specified rate. The compound must contain a white pigment to observe uniform application. The pigment tends to settle so stir the liquid before applying. It can be applied all at one time or in two coats. If two coats are applied, the second coat must be placed no later than 30 minutes after the first coat.

If the membrane film is broken during the 7-day curing period, the damaged area must be given another application of curing compound. The second treatment has the same requirements as the first. In some instances, the Contractor needs men, material, and equipment on the surface before the curing is complete. This is allowed if the film is protected with a fine sand (about 1/2 inch deep) or some other protective material. None of these shall be placed until at least 8 hours after the compound is placed.

Do not allow curing compound on any construction joint surface, any exposed reinforcement, or any surface that is to receive special surface finish, because the concrete will not bond properly. Also, do not allow curing compound on surfaces that are to be rubbed or brushed until the rubbing or brushing is done. In the interim some other method of curing must be used. Before using curing compound, have it tested. Stir or agitate the compound thoroughly, taking a sample of at least one pint per batch or shipment. Send it to the Central Testing Laboratory. A Certificate of Compliance can be submitted by the Contractor to allow use of the curing compound prior to obtaining test results.

Cotton or Burlap Blankets

Care must be exercised when placing blankets on the concrete or marks will be left in the surface. Blankets need to be lapped so the surface stays covered and the blankets remain in contact with the surface. When they are hung on the sides of a unit, the Contractor will need something to hold them against the surface. The blankets must be kept wet during the curing period.

Figure 8.55 Burlap Blankets



Paper or Plastic Sheets

Like blankets, paper or plastic must be placed with care to prevent surface marking. Before placing sheets, spray the surface with a fine fog of water. You must also inspect the sheets for holes each time used. All holes must be repaired or sheets replaced. Holes allow water to evaporate.

Figure 8.56 Plastic Covering



Wetted Earth, Sand, or Straw

These make good curing material if kept in place and wet. It is preferred to have them placed several inches thick. If placed too thinly, it may appear wet, but may in fact be drawing water out of the concrete rather than retaining water in the concrete.

Continuous Wetting

This can be accomplished by several methods: soaker hoses, lawn sprinklers, or fog spraying. Check to make sure the surface stays wet during the curing period. If the Contractor fails to keep the surface wet, require him to use another method. Continuous wetting can also be done by flooding the concrete with water. During cold weather, the water must have a depth of at least 1 foot above the concrete, be left for 10 days of curing, and watched so it does not freeze to the concrete.

Leaving Forms in Place

Combined with most of the above procedures, leaving forms in place is an added form of protection that helps to retain moisture within the concrete for proper curing. The specifications dictate a minimum amount of time that forms must remain prior to removal.

Note Be sure to enter the method and duration of curing in your diary.

Application of Live Load

It is critical that the concrete has attained full design strength and all falsework be removed prior to backfilling and applying highway live loads. The only exceptions are that footings and columns cannot be backfilled until specific permission has been given by the Engineer.

Box Culverts and Pipes

Plans will specifically note the type of live load the structure was designed to carry. Generally culverts are only designed for legal highway loads with the full depth of fill over the culvert in place. The depth of fill directly impacts the live load capacity of the culvert. The greater the depth of fill, the more the vehicle load is evenly distributed over a larger surface area. The less the depth of fill, the more the vehicle's weight becomes a concentrated load over a particular smaller area. Often a Contractor will request to drive scrapers over the top of a box culvert at fill depths less than the final depth. This should not be allowed unless prior approval has been obtained from the Office of Bridge Design or unless plan notes already accommodate the scraper load.

Bridge Decks

Specifications allow construction vehicles, material, and equipment weighing less than 4,000 pounds in total to be allowed on bridge spans, provided the most recently placed concrete has attained a compressive strength of 2,400 psi. Loads over 4,000 pounds are not allowed until the concrete has attained full design strength and falsework has been removed.

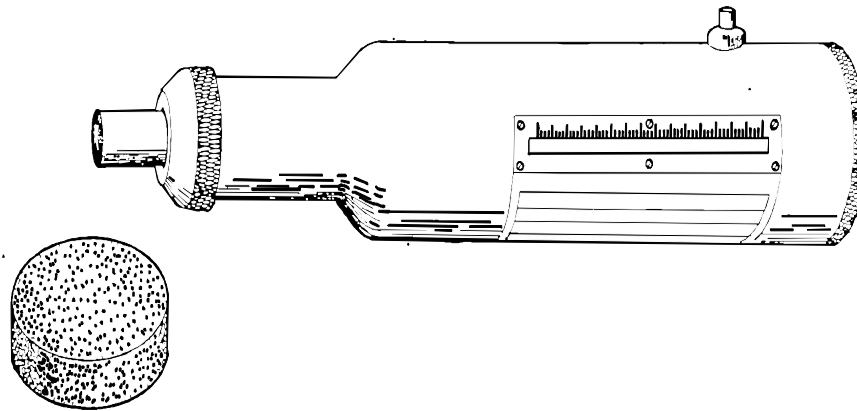
Swiss Hammer Testing

The Swiss Hammer can be used to make a quick determination of the approximate compressive strength of concrete in place. It can be used to determine the compressive strength of concrete for these purposes:

- Removing forms
- Opening the structure to traffic

- Comparative tests

Figure 8.57 Swiss Hammer and Carborundum Stone



The Project Engineer will advise you which method to use to check compressive strength of the concrete (Swiss Hammer or extra cylinders).

Equipment

All that is needed for this test is a Swiss Test Hammer and Carborundum Stone. Both are included in the carrying case. When you take the hammer out of the carrying case, it will look something like the one in Figure 8.58. To make the plunger release, press the plunger against something solid. After release, the Swiss Hammer should look similar to the bottom hammer shown in Figure 8.59. The hammer is now ready for operation.

Figure 8.58 Hammer Plunger Position in

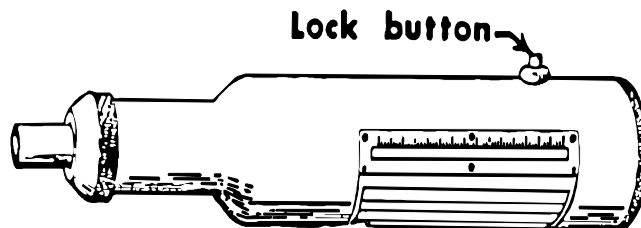
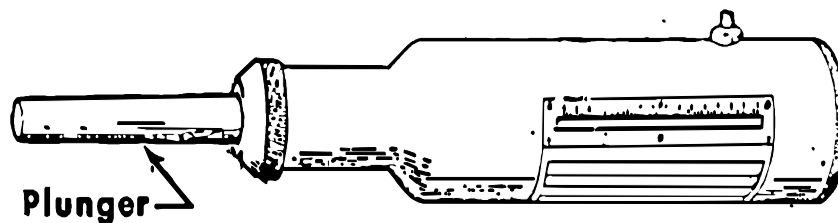


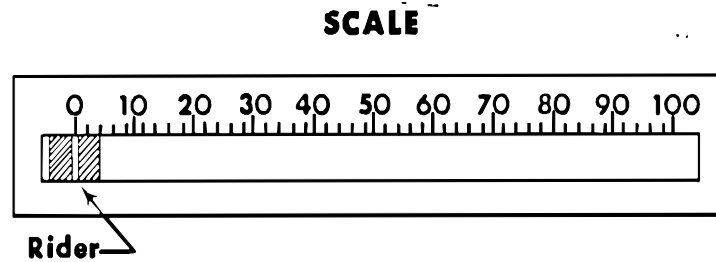
Figure 8.59 Hammer Plunger Position out



When placing the hammer in the case, put the plunger against something solid and push it all the way in. Then press the lock button on the side.

On the side of the hammer is a scale marked 0 to 100. In the center of this scale is a small rider with a line in the center. When the hammer releases, the reading is taken where the line points.

Figure 8.60 Hammer Scale

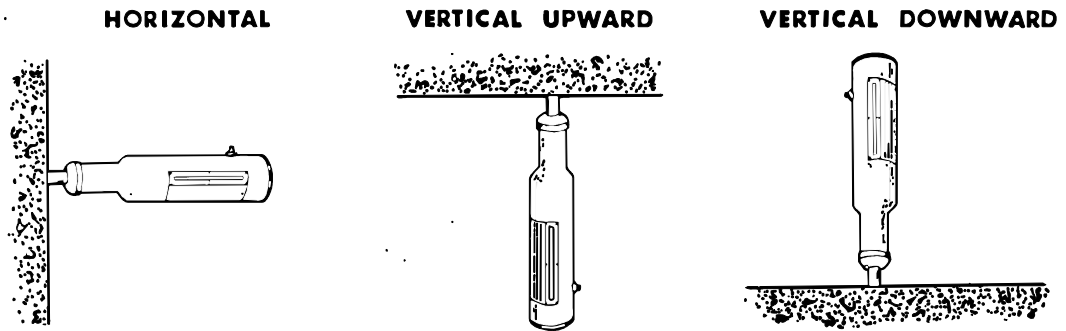


In the horizontal position, you can read the number directly as displayed.

In the vertical upward position, subtract 500 pounds per square inch.

In the vertical downward position, add 500 pounds per square inch.

Figure 8.61 Swiss Hammer Testing Positions



Procedures

- If the concrete surface is rough, use the carborundum stone to grind the spots where you want to test.
- Operate the hammer in a horizontal position whenever possible.
- Place the plunger at right angles to the concrete being tested. Press the plunger slowly until you hear a 'clunk'. Hold the hammer at that position. The 'clunk' is the sound of the plunger release. When the plunger releases, the rider will slide up the scale. Record the reading where the rider stopped. There are two ways to get this reading:
 - Take your reading in the exact position where the plunger released.
 - If you are testing a post where the scale is in an awkward position to read; press the lock button after the plunger has been released. The rider will remain at the place where it stopped. Then you move the hammer from the test spot and take your reading.
- Test about 15 different places. Take only one reading at any one spot. Average the readings after discarding those obviously in error. Very high readings may be caused by rock or steel near the surface. Very low readings may be caused by trapped air pockets near the surface.

Cleaning and Re-calibration

Annually and after about 2,000 impacts, the hammer should be sent to the Central Laboratory for cleaning and re-calibration.

BRIDGE RAILING

Checklists

Concrete Barriers - General

- Formwork and Reinforcement
 - Reinforcing steel protruding from deck is cleaned of dried mortar, curing compound, etc.
 - Reinforcement meets required sizes and spacing. Tied adequately. Proper clear covers to forms maintained.
 - Joint between deck and barrier blown clean prior to placing formwork.
 - Formwork dimensions in accordance with plan dimensions. Erected such that the barrier will be normal to grade. Snap ties epoxy coated.
- Deck Strength Requirements
 - Deck allowed to cure for a minimum of 48 hours or to a strength of 1200 psi, whichever comes first, prior to placing the concrete in the barrier.
- Finishing and Curing
 - Finishing and curing should be completed in accordance with Section 460 and 'Chapter 8 - Concrete'.

Concrete Barriers - Slip Form Paving

- Concrete Mix
 - Special concrete mix approved by Concrete Engineer prior to placement of concrete.
- Slip Form Paver
 - Weight over 4,000 lb. If so, or if concrete trucks are to be driven on the deck, then the deck must be at full strength prior to permitting equipment on deck.
 - Machine equipped with tracks. Special rubber mats or other approved material placed under tracks to prevent damage to deck.
 - Guide controls adequate (wire, string line, etc.). Elevations of guide control checked.
 - Dimensions of the slip form paver's 'mule' checked.
- Special Reinforcing Requirements

- Reinforcing fastened to be securely held in place during concrete placement. Diagonal bracing installed.
- Inspection During Concrete Placement
 - Fit of 'mule' over reinforcement cage spot checked periodically for clearances.
 - Overlap shape and finish of barrier acceptable. Plumb. Top of barrier checked with a straightedge for depressions or sagging.
 - Shadowing of reinforcement noted
 - If shadowing or excessive sagging of barrier is noted, operations should be stopped and corrections made prior to allowing continuation of pour.

Secondary Roads (County) Bridge Rails

- Fabrication, Delivery, and Handling
 - Shop Plans sent in to the Office of Bridge Design for approval. Approved.
 - Pieces spot checked for conformance to plans and approved shop plans at time of delivery.
 - General condition of paint checked. Dry Film Thickness measured if not previously checked at the fabrication shop. Handled in a manner to prevent nicking and damage to paint.
 - Materials stored on wood blocking.
- Erection
 - Posts set to string line where possible. Adjusted for smoothness and alignment.
 - Nuts on all bolts adequately tightened after loose fit-up.
 - Thrie-beam laps oriented correctly for direction of traffic.
 - Touch-up painting done on all damaged areas following erection.

Bridge Sidewalk Railing

- Fabrication, Delivery, and Handling
 - See checklist above
- Erection
 - Posts set to string line where possible. Adjusted for smoothness and alignment.
 - Field welds adequate. Ground smooth (where applicable).
 - Nuts on all bolts adequately tightened after loose fit-up.
 - Touch-up painting done on all damaged areas following erection.

General

All bridges require railing of one type or another. Typical bridge railing has a two-fold purpose:

- 1 To serve as a visual guide or aid in identifying the edge of the bridge to traffic; and
- 2 To prevent vehicular traffic or pedestrians from falling off the bridge.

Bridge railing may also serve a third role by acting as a divider between vehicular and pedestrian traffic. This occurs on any structure that has a pedestrian sidewalk or bike path immediately adjacent to the lane of traffic.

There are several different versions of railings used on South Dakota structures. Bridges for state highways primarily use cast-in-place concrete for the construction of the bridge railing. County structures are typically constructed utilizing steel posts with rails constructed of steel tube, guardrail thrie-beam, or a combination of both. Pedestrian railings are generally constructed of steel tube posts and rails along with chain link fence.

Crash Testing Requirements

Federal regulations require that all railing used for vehicular traffic loading be crash tested in order to verify its safety and adequacy of design. This process of getting a bridge rail type designed, crash tested, and approved by the Federal Government is very involved and quite extensive. Once approved, the bridge railing cannot be modified in any manner without requiring re-testing and approval. For this reason, bridge rail systems and details cannot be modified in any manner.

Concrete Bridge Railing

Cast-in-place concrete sections called barriers are almost used exclusively as the bridge railing for structures on state highways. The barrier is really a monolithic section consisting of a lower curb and an upper railing section. The ends of the barrier, called end blocks, are special shaped to allow installation and transition from the concrete barrier to a guardrail thrie-beam.

Figure 9.1 Barrier Section

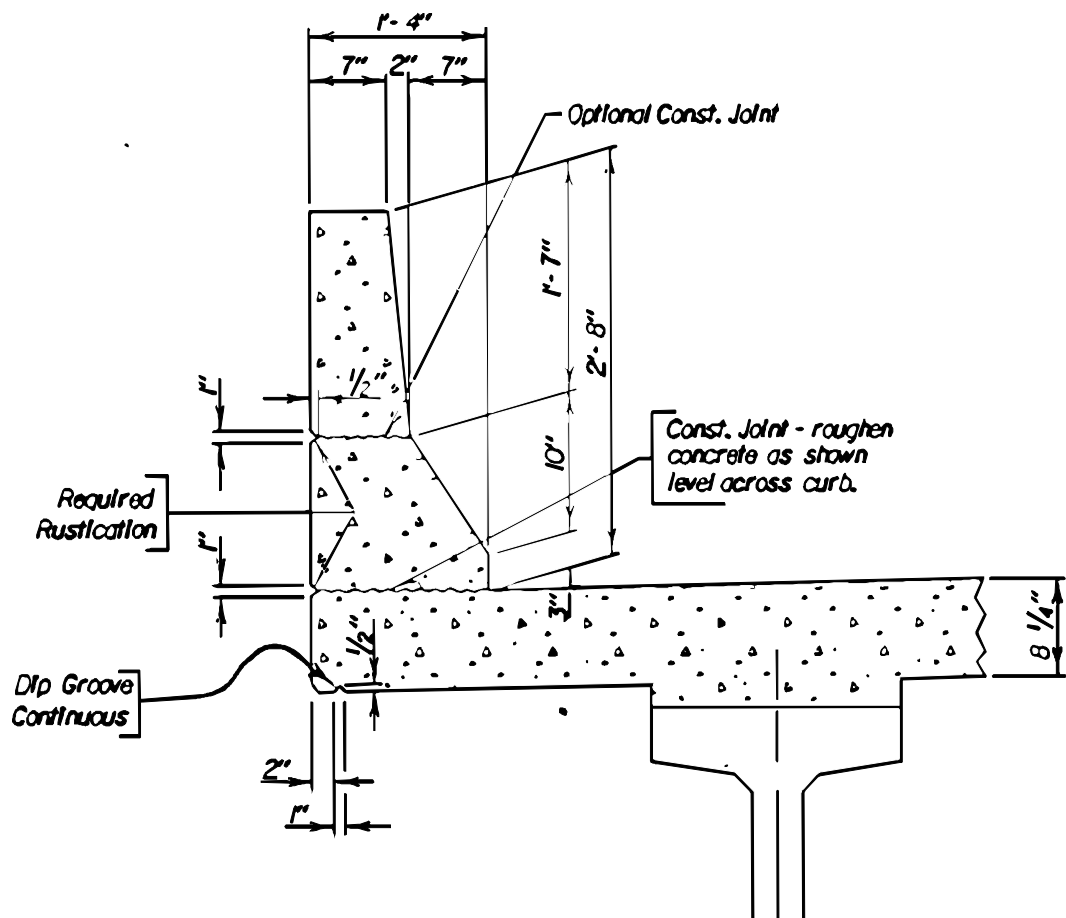
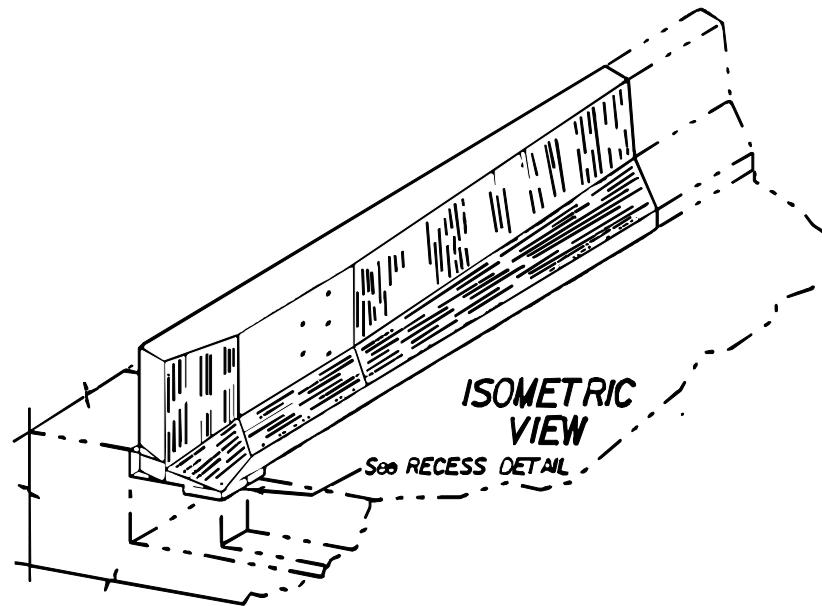


Figure 9.2 Barrier End Block



Placement

Barriers cannot be poured until after the concrete in the bridge deck has attained a compressive strength of 1200 psi, or until the bridge deck has cured for 48 hours at temperatures above 40 degrees F, whichever comes first. The concrete barriers are formed much the same as all other cast-in-place concrete, utilizing in place formwork and pouring the concrete in the forms by hand.

The barrier should be constructed normal to grade and not perpendicular to the deck. The joint between the deck and curb should be a clean, relatively level, roughened construction joint. Check to be sure that the reinforcement steel protruding from the deck is clean of all dried mortar, curing compound, mud, or other contaminants.

Like all other cast-in-place concrete, you should check the size, spacing, and tying of the reinforcing steel to be sure that it is in compliance with the plans. Make sure that the reinforcement is constructed normal to grade with the proper clear cover. Note that there are three different clear covers within the concrete barrier, depending on location. For state highways, all reinforcement within the barrier should be epoxy coated. Snap ties, if used for formwork support, must also be epoxy coated and should be compatible with the epoxy used on the reinforcement. Refer to 'Chapter 8 - Concrete' for further details on inspecting cast-in-place concrete.

Finishing and Curing

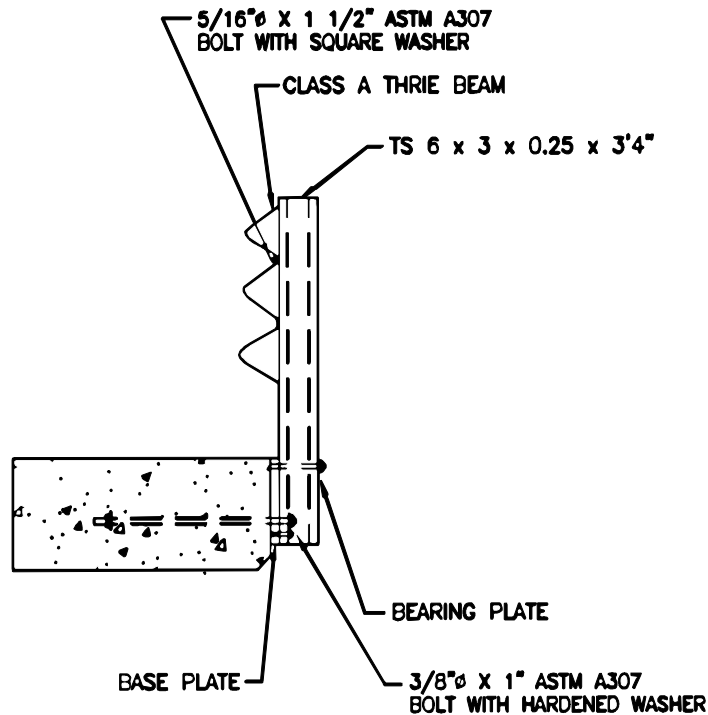
Following the placement of the concrete, the barrier should be finished and cured in accordance with Section 460 of the Standard Specifications. Refer to 'Chapter 8 - Concrete' for more details on concrete finish and curing requirements.

Secondary Roads (County) Bridge Rails

Most county bridges are constructed using some type of steel railing rather than the concrete barrier. This is done for a variety of reasons, mainly having to do with economy and snow drift considerations. Three types of railings are currently used on secondary road projects:

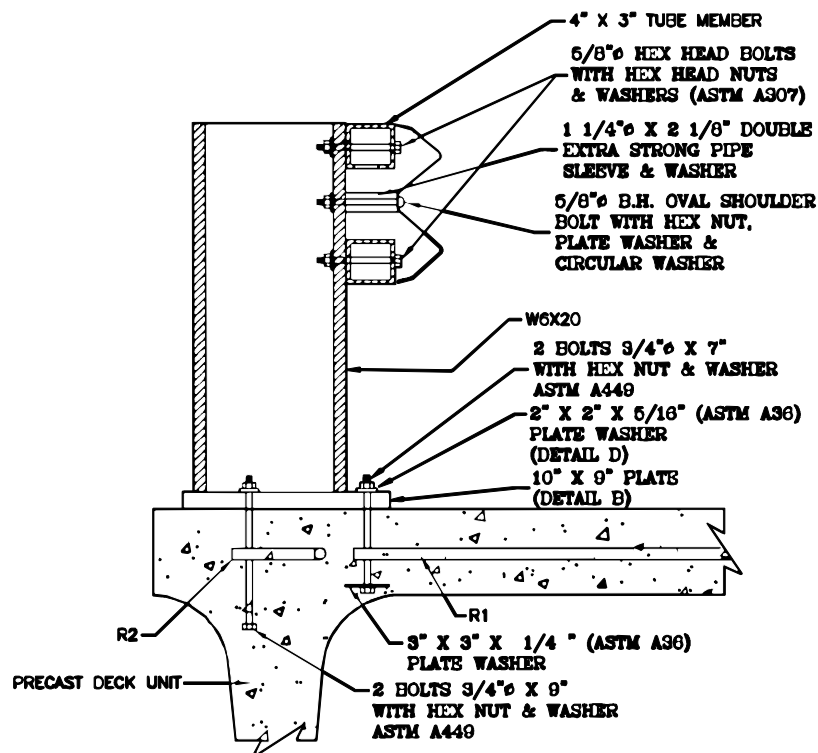
- 1 SL-1 Bridge Rail - Uses a steel breakaway post fastened to the edge of the bridge deck along with a thrie-beam guardrail that is continuous across the length of the bridge.

Figure 9.3 SL-1 Bridge Rail



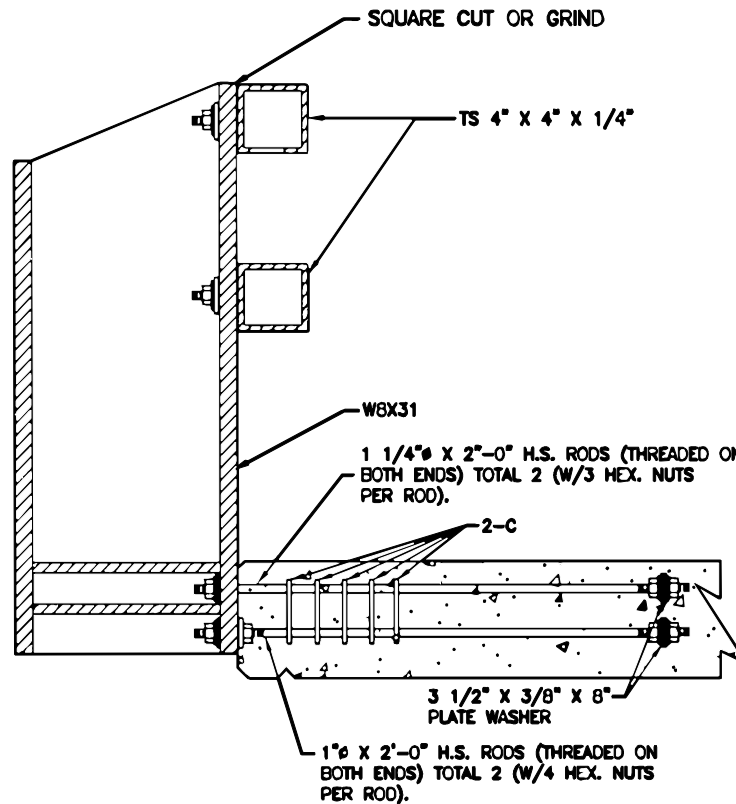
- 2 Type T101 Bridge Rail - Using a rigid steel post anchored to the top of the bridge deck along with a rail that is comprised of steel tubes backing a W-beam guardrail.

Figure 9.4 Type T101 Rail on a Precast Bridge Deck



- 3** Type T115 Bridge Rail - Uses a rigid steel post anchored to the edge of the bridge deck along with continuous steel tube railing.

Figure 9.5 Type T115 Bridge Rail



Fabrication, Delivery, and Handling

Steel rail posts and rails are built at a steel fabrication shop. The fabrication of the bridge rails will follow a shop plans review and approval process as explained in 'Chapter 12 - Shop Plans'.

When delivered to the job site, you should check the rail components for any damage that may have occurred during transportation or improper handling at the shop. Many bridge rails are fabricated in shops that do not have a DOT representative present. Consequently, you may be the first Department personnel to inspect and accept the condition of the work on the railing. You should spot check general dimensions for conformance to the plans and approved shop plans. In addition, inspect the condition of the paint coating. If possible, obtain a Dry Film Thickness gauge and spot check the total thickness of coating material. You should notify your Project Engineer of any major defects or discrepancies that are found.

Erection

Dimensions are given on the plans for establishing the elevation of the railings. Occasionally a post needs adjustment to get a smooth looking rail. The posts should be set normal to the grade line. This eliminates shimming and twisting to set them vertical. The best way to set the alignment on a straight bridge is as follows:

- 1** Set the end posts in proper position.
- 2** Stretch a string line across the tops of the end posts.

- 3 Set the remaining posts to this string line. Should the structure be on a horizontal or vertical curve, you will have to sight them in a smooth line.

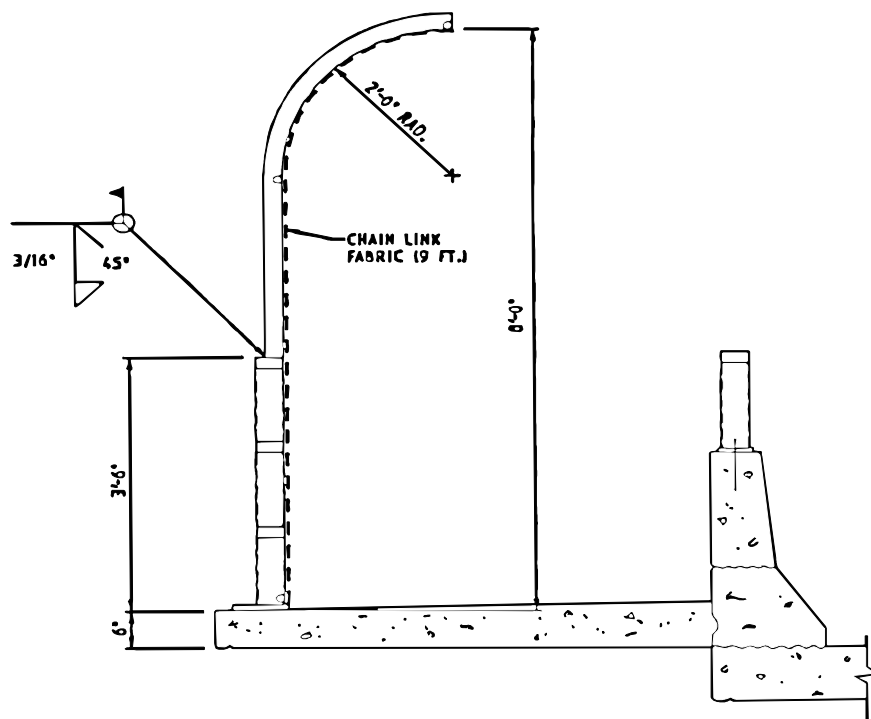
Once the posts are bolted in place, set the rails according to the dimensions on the plans. It may be necessary to get good rail alignment to shim between the rail and post or post and deck. Often bolts will be left loose until all the pieces are fitted together. You should make sure that all nuts and bolts are fully tightened after final fit-up and installation.

Three-beam guardrail pieces for SL-1 and Type T101 railing generally require several laps throughout the length of the structure. The laps should be oriented such that there is always a smooth transition for the direction of traffic. This means that the direction of laps should be opposite for each side of the bridge. Check to ensure that the laps have been oriented correctly.

Bridge Sidewalk Railing

Railing is always provided when a bridge has a sidewalk on one or both of its sides. A concrete barrier is used between the lane of traffic and sidewalk to protect the pedestrians from vehicular traffic. A short steel rail is placed on top of the barrier to provide further protection and to help keep pedestrians from leaning into the path of traffic.

Figure 9.6 Bridge Sidewalk Railing and Chain Link Fence



Steel railing is also placed on the outer edge of the sidewalk. Typically the railing will be used in conjunction with chain link fence material. When the bridge is over the top of a roadway, the chain link fence will usually be detailed to wrap radially over the sidewalk to protect the traffic below from falling or thrown objects.

Fabrication, Delivery, and Handling

Like vehicular bridge railing, bridge sidewalk railing is usually fabricated in a steel shop and then transported to the site. Generally the sidewalk railing is fabricated in sections or units of posts and rails already welded together. These sections are then erected and field welded together at splice points along the rails.

Like all steel fabricated items, you should check the rail components for any damage that may have occurred during transportation or improper handling at the shop when the railing is delivered to the job site. Spot check general dimensions for conformance to the plans and approved shop plans. As with vehicular bridge railing, inspect the condition of paint coating. If possible, obtain a Dry Film Thickness gauge and spot check the total thickness of coating material. You should notify your Project Engineer of any major defects or discrepancies that are found.

Erection

Sidewalk rail posts should be set normal to the grade line (plumb). Cavities or recesses are left in the concrete sidewalk and curb that give room for the posts to be adjusted with leveling nuts during installation. Some adjustments will probably be necessary to produce a railing that is smooth in appearance. After adjusting and leveling the railing, the recesses underneath the base plates should be thoroughly filled and packed with a non-shrink grout as noted in the plans. You should observe the grouting operations to ensure that no voids or air pockets are left that could collect water.

Plans will detail a welded field splice for the railings. You should make sure that the welder is a 'green' card certified welder qualified for the 3G (vertical) weld position. See 'Chapter 10 - Welding' for further details.

After the field splice locations have been welded and ground smooth, all splices and any other damaged areas of the railing should be touch-up painted. Make sure that the paint used for touch-up is the same paint system used in the original shop applied paint coats. See 'Chapter 14 - Painting' for more details.

WELDING**Checklist**

- Prior to Welding, ensure that:
 - Welder certified and approved for position and weld type.
 - Electrodes have proper Certificate of Compliance or approved Test Report
 - Welder has proper equipment including oven for heating rod
 - Base metals cleaned and prepared for weld.
 - Base metals have proper preheat temperatures.
- After Welding, Check the Weld Size:
 - On groove welds, check the reinforcement dimensions.
 - On fillet welds, check the size of weld based on throat dimensions for concave welds, and leg dimensions for convex welds.
- After Welding, Check the Weld Condition:
 - Undercut
 - Overlap
 - Porosity
 - Cracks
 - Spatter
- Sign the back of the Green Card for each welder that worked on your project.

Important

Never watch the welding operation without a welding helmet. Watching the welder strike an arc can burn your eyes severely. Borrow a welding helmet from the Contractor or get one from your supervisor to use.

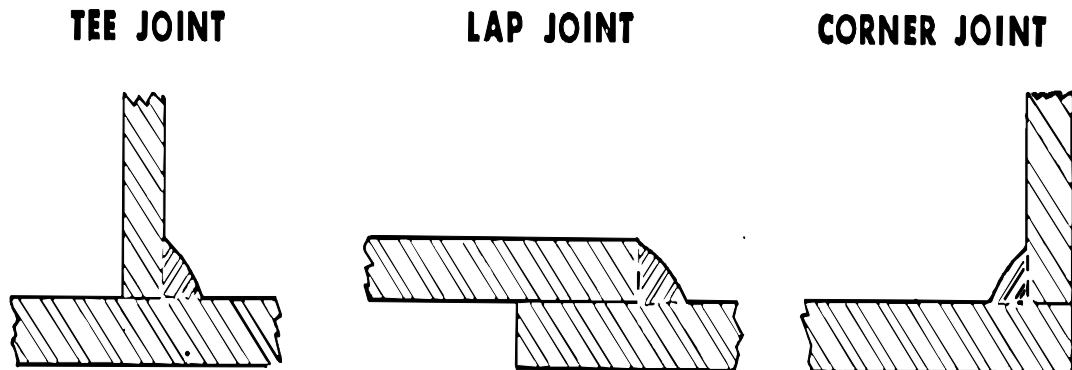
Weld Types

The following pertains to welding operations performed in the field. Before welding, study the plans to determine what connections are to be made. There are primarily only two types of welds that will be performed in the field, fillet or groove welds. The remaining more complicated welds are generally performed in the shop during the fabrication process. Plan notes and symbols explain the two types of welds used in the field.

Fillet Welds

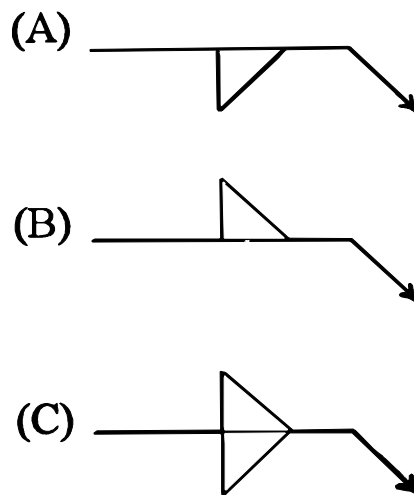
The first type of field weld is a fillet weld. Fillet welds are used to join surfaces that are at approximately right angles to each other.

Figure 10.1 Typical Fillet Weld Locations



The typical symbols for fillet welds are shown in the figure below. The symbol shown for weld 'A', with the triangle below the line, means that the weld is to be placed on the side which the arrow points. The fillet weld 'B', with the triangle above the line, means the weld is to be placed on the opposite side of the joint where the arrow is pointing. Weld 'C' has triangles on both sides of the line. This means the weld is to be placed on both side of the joint.

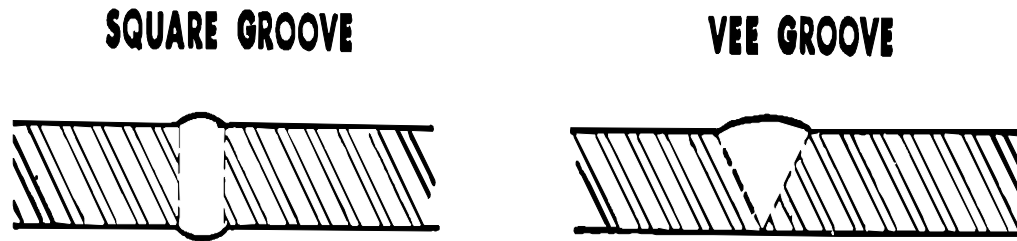
Figure 10.2 Typical Fillet Weld Symbols



Groove Welds

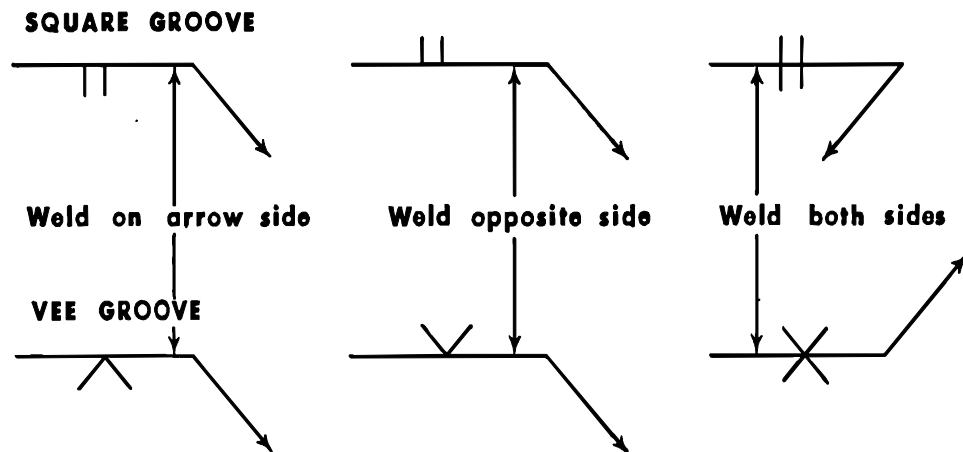
The second type of weld is a butt or groove weld. It is made in the groove between pieces that are to be connected.

Figure 10.3 Typical Groove Weld Locations



Typical symbols used for groove welds are shown below.

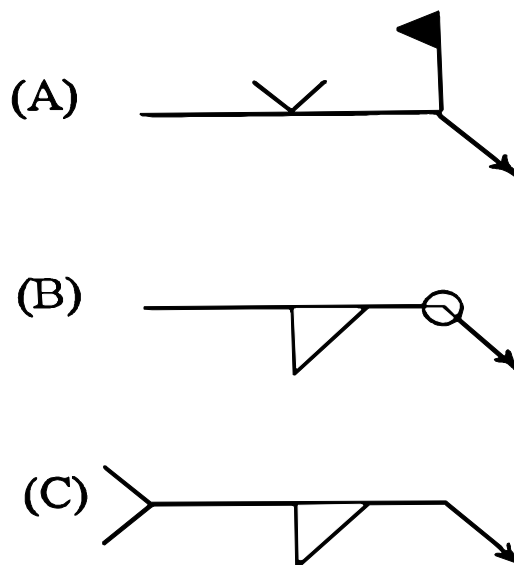
Figure 10.4 Typical Groove Weld Symbols



Additional Weld Markings

There are times when other markings are shown on the weld symbols. The most common markings are shown below. Each marking indicates the procedure for a given welded connection.

Figure 10.5 Other Common Weld Symbol Markings

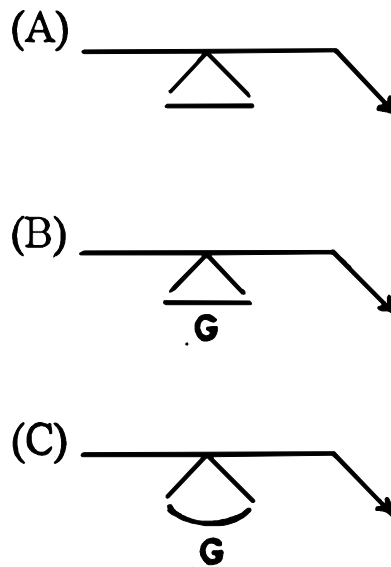


- A shaded flag on weld 'A' means that the welding will be done in the field at the structure site. If the symbol does not have a flag, the welding will usually be done at the fabrication shop before delivery to the project. Shop welds are usually, but not always, inspected prior to project delivery. You should visually inspect these welds for conformance to shop plans.
- A circle drawn on weld 'B' means that the weld is to be placed all around the joint.
- The tail on weld 'C' means something special has to be done to the weld. This will be written by the symbol or you will be directed to a note on the sheet.

In some locations, the weld surface must have a certain shape. These contours can be obtained by welding to a specific contour or by grinding after welding. The markings for the desired surface contour are:

- A straight line indicates the face of the weld must be flush with the metal being joined.
- An arched line means the face of the weld must be slightly convex. The weld metal will protrude above the surface of the metal being joined.
- A large 'G' means the face of the weld should be ground to the desired surface contour.

Figure 10.6 Weld Surface Symbols



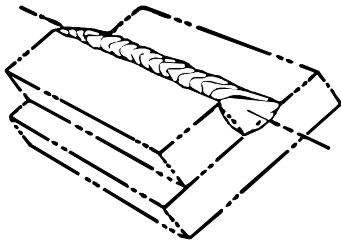
- Weld 'A' indicates a Vee groove weld that is to be welded flush without additional grinding.
- Weld 'B' is to be made flush with the adjoining metal through grinding.
- Weld 'C' indicates the weld face will be ground to a convex face.

Weld Positions

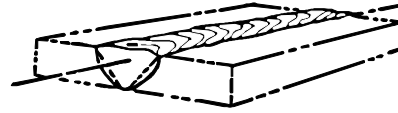
Welded connections can require welding be done in four different positions: flat, horizontal, vertical, and overhead. The four positions for each weld and the position designation (1F, 1G, etc.) are illustrated below.

Figure 10.7 Welding Positions

FLAT POSITION

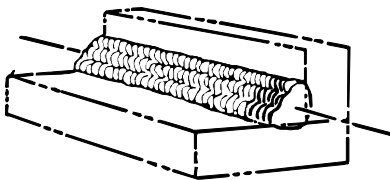


**FILLET WELD
(1 F)**

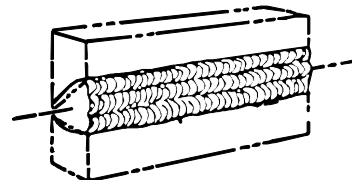


**GROOVE WELD
(1 G)**

HORIZONTAL POSITION

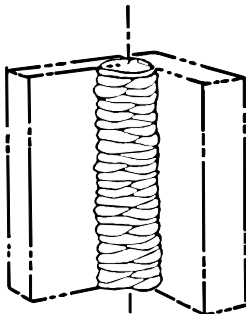


**FILLET WELD
(2 F)**

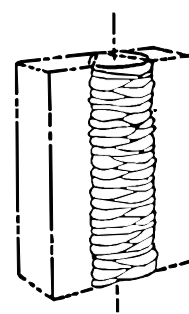


**GROOVE WELD
(2 G)**

VERTICAL POSITION

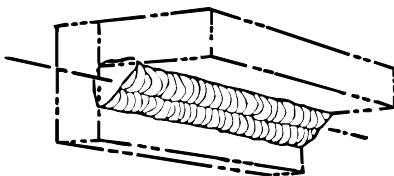


**FILLET WELD
(3 F)**

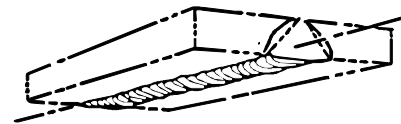


**GROOVE WELD
(3 G)**

OVERHEAD POSITION



**FILLET WELD
(4 F)**



**GROOVE WELD
(4 G)**

Determining which of the four positions a given weld falls under is sometimes difficult. You must look from two different views, the end view and the side view. The end view is the rotation of the weld face around a circle viewed from the 'end'. The side view is the incline of the weld between a horizontal and vertical plane. Each of the four weld positions is given a certain range within these two views.

Figure 10.8 End View

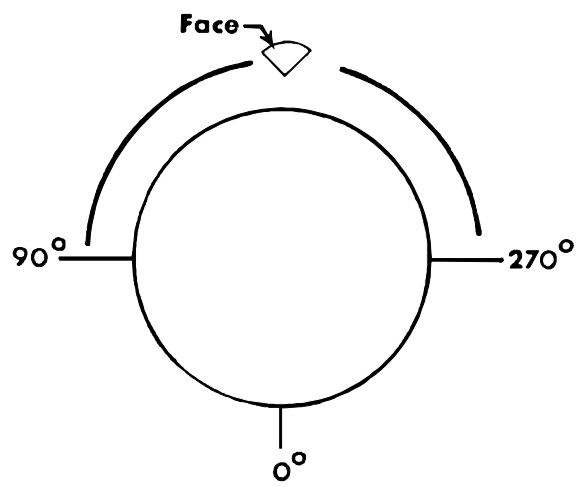


Figure 10.9 Side View

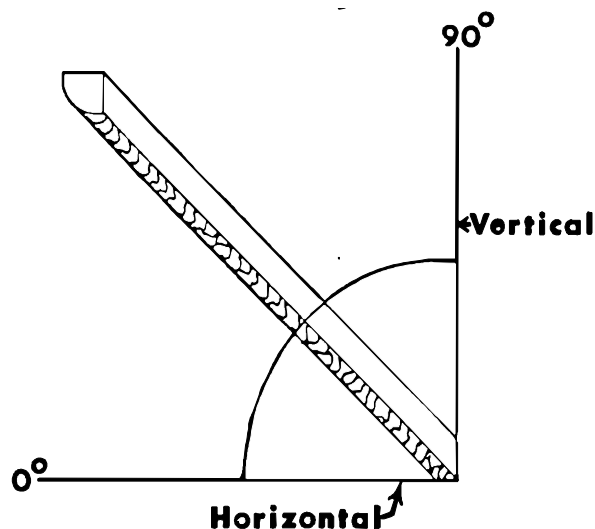


Figure 10.10 Position Locations from End View

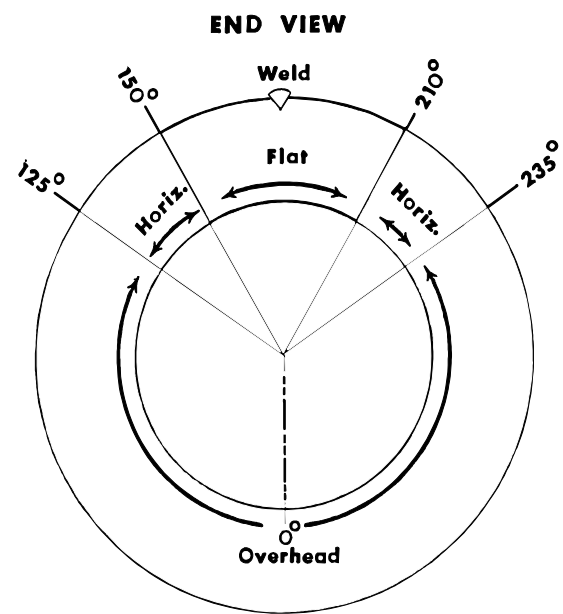
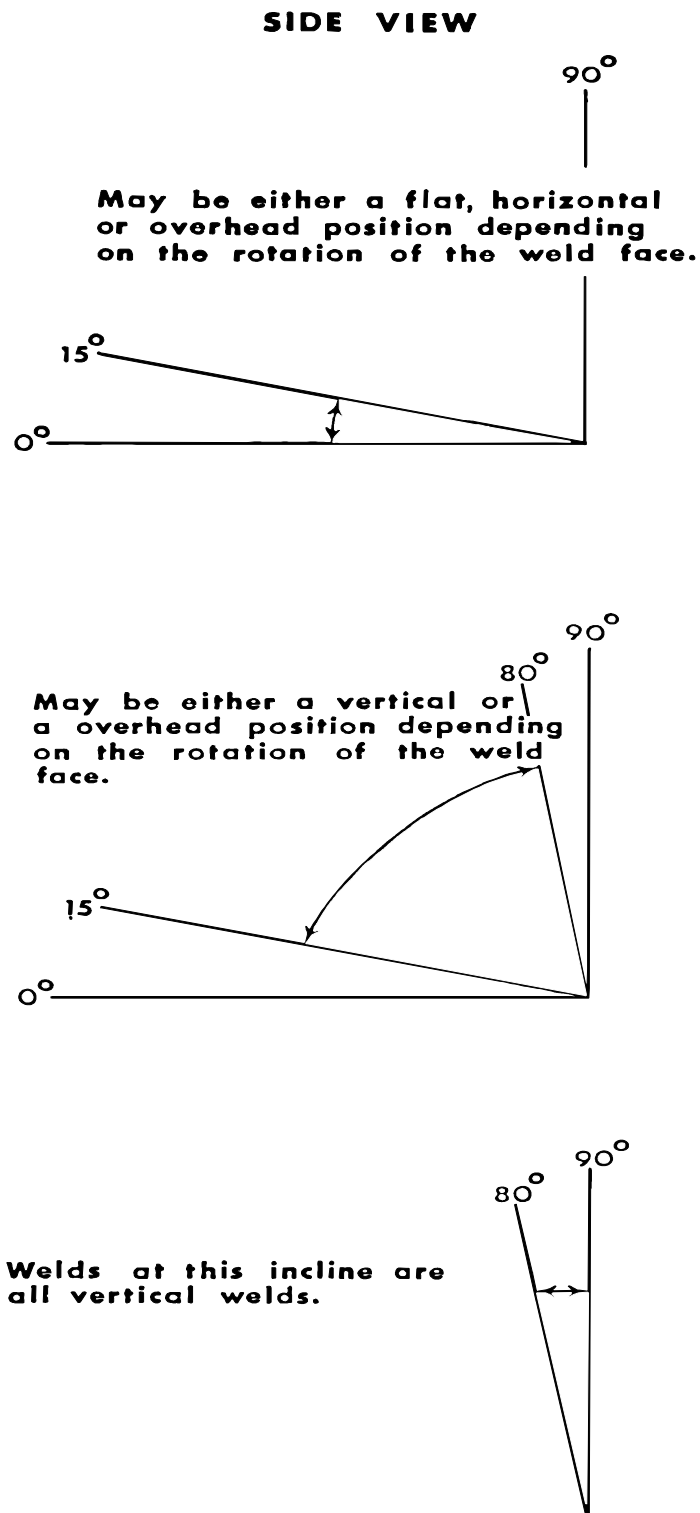


Figure 10.11 Position Locations from Side View



Welder Qualification

All welding on a structure, including pile splicing, must be done by a qualified welder. The welder must present a "green card" signed by the Bridge Construction Engineer prior to welding. After the welder furnishes evidence of a satisfactory welder qualification test, they are issued a welder qualification card (green card) as shown in Figure 10.12.

Figure 10.12 Welder Qualification Card

DOT-231A	SOUTH DAKOTA
DEPARTMENT OF TRANSPORTATION	
CERTIFICATION OF WELDER QUALIFICATIONS	
AND	
WELDING RECORD	
NAME	<u>JOHN DOE</u>
SOCIAL SECURITY NO.	<u>504-46-0663</u>
	<u>John Doe</u> (Welder's Signature)
	<u>James Wartz</u> (Inspector's Signature)
DATE	<u>APRIL 16, 1989</u>
TYPE OF BASE METAL	<u>A 36 STEEL</u>
ELECTRODE CLASSIFICATION	<u>E7018</u>
TEST POSITION QUALIFIED FOR:	
(Cross Out Those Not Applicable)	
Fillet Welds: 1F 2F 3F 4F	
Groove Welds:	
3/8" Metal: 1G 2G 3G 4G	
<u>3/4" MAXI</u> Metal: 1G 2G 3G 4G	
WELDING RECORD: (See Reverse Side)	

Even if a welder has a qualification card and proves they have done arc welding in the last six months, their welds and weld preparation must meet DOT requirements. If the size and appearance or metal preparation of the welds are not satisfactory, the welder can be told to stop and re-qualify before continuing to weld on your project. The size and appearance requirements are given later in this chapter. If a person is not qualified in all positions, allow them to weld only those positions in which they are qualified. The Contractor will need to get someone else qualified to perform the welds in the other positions.

In addition, be sure to check the metal thickness that is to be welded against the metal thickness the welder has been certified to weld. Current specifications require welders to qualify for unlimited base metal thickness; however, previous qualified welders may only be permitted to weld on a maximum plate thickness as specified on the green card. Do not allow a welder to weld a joint that has a metal thickness greater than that noted on the green card.

Once a welder has passed the qualifications test, they need not requalify provided:

- They have done arc welding within the past six months; and
- The size and appearance of their weld meets our requirements.

To weld on a DOT project, the qualification card must show that the welder has welded on a South Dakota project within the past six months. If the welder does not meet this requirement but has done other welding, and can furnish evidence of such welding, contact the Bridge Construction Engineer for possible authorization to allow them to weld on your project.

Be sure to sign the back of the "green card" anytime a welder works on you project.

Electrodes

Field welding is done with a covered electrode. This is a metal wire with a protective covering. Current passes from the welding machine through the electrode to the work, causing metals to melt and fuse. Electrodes are identified by an American Welding Society (AWS) classification number on the container. Check the container to determine if the correct electrodes are being used. Only low hydrogen electrodes may be used. They must be AWS A5.1 or A5.5 electrode numbers E7016, E7018, or E7028.

If the welder does not have an oven that will store rods over 250° and will not be welding on the project for more than 4 hours, they should not be allowed to weld. When electrodes are exposed to the atmosphere, they may absorb moisture. When the Contractor uses electrodes that are brought to your job in the original container, not damaged or opened, they can be used directly from the package. Electrodes not used within 4 hours, or not stored in a 250° oven, after opening the package or electrodes brought to the job in a damaged or open package must be dried as follows:

- AWS A5.1 electrodes must be dried for at least two hours at temperatures between 450-500 degrees F before use. AWS A5.5 electrodes must be dried for at least one hour at temperatures between 700-800 degrees F before use.
- After drying, the electrodes can be stored in a storage oven held at a temperature of at least 250 degrees F.
- The welder has four hours to use the electrodes after taking them from the drying or storage oven. After four hours, they must be re-dried.
- Electrodes that have been wet must not be used.

Certificate of Compliance

Electrodes are accepted on the basis of a Certificate of Compliance. Some manufacturers or suppliers send this certificate with the electrodes, while others send it to the Test Engineer in Pierre. Before the electrodes can be used, you must receive the Certificate or have someone check with the Test Engineer for the Test Report from the manufacturer.

If you receive the Certificate of Compliance from the Contractor, make sure the electrodes classification number on the certificate is the same as the one the Contractor will be using on your job. If it matches, the Contractor can use the electrodes. Then give the certificate to the Project Engineer to forward to the Test Engineer for review and filing.

Weather and Temperature Requirements

The temperature of steel to be welded is subject to these requirements:

- When the Contractor is welding A36 (A36M) steel 3/4 inch to 1 1/2 inches thick, the steel must be preheated to at least 70 degrees F.
- For welding A36 (A36M) steel less than 3/4 inch thick, the steel must be preheated to at least 50 degrees F.
- For welding A36 (A36M) steel greater than 1 1/2 inches thick, the steel must be preheated to at least 150 degrees F.
- For welding A36 (A36M) steel greater than 2 1/2 inches thick, the steel must be preheated to 225 degrees F.

Several methods can be used to check compliance. Determine the steel thickness where the welded connections are to be made. Normally the temperature of the steel will be close to the existing air temperature. If you are to be concerned with either the 50 degree F or the 70 degree F requirements, ask the Contractor to furnish a thermo-melt stick or obtain a surface thermometer from you Region Materials Engineer. Thermo-melt is a chalk-like stick that will liquefy at a stated temperature. The welder will touch or stroke the pre-heated steel with the stick. If the steel is too cold, only a faint mark results on the steel. If the steel is at least at the rated temperature, the stick melts leaving a visible mark. Surface thermometers are small dial thermometers that attach to the steel with magnets. After allowing time for the needle to rise, the temperature of the steel is read on the dial.

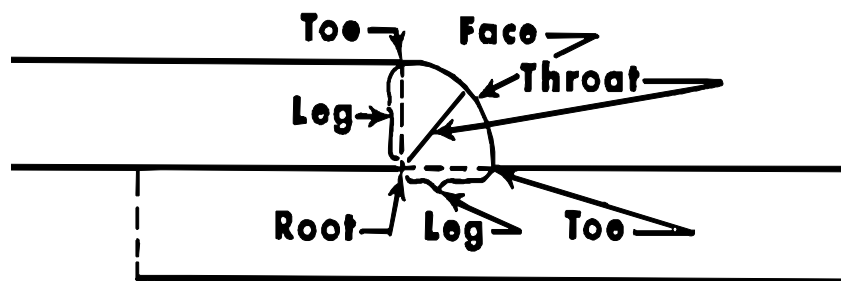
Preheating is usually accomplished with a gas torch to heat the area for the connection. Normally the welder will experiment with the first connection to determine the heat that must be applied to raise the steel temperature. From this you can tell if they are applying the same to each connection. Make periodic checks with the thermometer or thermo-melt. The surface to be welded should not be wet or exposed to rain, snow, or high wind. The Contractor can overcome weather problems by building windbreaks or shelters.

Welding shall not be done in rain or snow.

Field Welding

The parts of a weld are labeled below, these names will be used frequently throughout this next section.

Figure 10.13Parts of a Weld



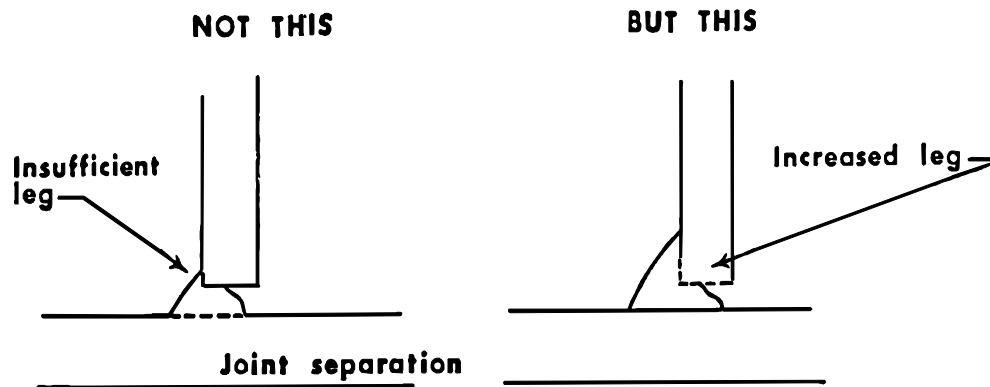
Preparation of Materials

Check the weld connection area. It must be clean and free of defects that could affect the strength of the weld. The surfaces to be welded need to be:

- Free from loose mill scale, rust, grease, or moisture which would prevent a proper weld. A wire brushing will remove most of these materials.
- The surface within 2 inches of a weld location must be free from paint or other materials that would interfere or produce objectionable fumes.

The parts to be joined by a fillet weld must be brought together. If the separation is more than 1/16 inch, the leg of the weld should be increased by the same amount of separation, up to 3/16 inch. The parts to be joined must not be separated more than 3/16 inch, if they are, the Contractor must correct the situation.

Figure 10.14 Joint Separation



The correct alignment of the parts to be welded can be held by:

- Erection Bolts
- Tack Welds
- Clamps, jacks, etc.

Erection bolts are often used to make preliminary connections and for holding the pieces for welding. These bolts usually remain after the welding is completed, but the welds must carry all the stress as designed.

Tack welds are short welds on the connection to temporarily hold the pieces for the final weld. Tack welds are subject to the same quality requirements as the final welds and must be made by a qualified tack welder. You can allow a person to make tack welds that has passed the tacker qualification test or allow the regular qualified welders to tack weld in the same positions in which they are qualified to perform fillet welding. Tack welds must be incorporated into the final weld.

Procedures

A qualified welder generally knows the procedures. However, you should observe when they begin and then occasionally as they are welding.

Important Never watch the welding operation without a welding helmet. Watching the welder strike an arc can burn your eyes severely. Borrow a welding helmet from the Contractor or get one from your supervisor to use.

These procedures should be followed:

- Work should be positioned for flat welding whenever possible.
- When welding in the vertical position, the passes should be from the bottom up.
- Before welding over previously deposited metal, remove slag by chipping with a pointed hammer and then brushing.
- The arc must be struck in the immediate weld area, not on the base metal outside the weld area. A scar in the metal results wherever the arc is struck.

Quality Weld Inspection

This section on weld quality pertains only to welds made in the field on the structures' low stress areas. These welds are on strip seal steel extrusions, rail element to rail posts, and bearing plate to bottom flange.

Figure 10.15 Rail to Post Welds

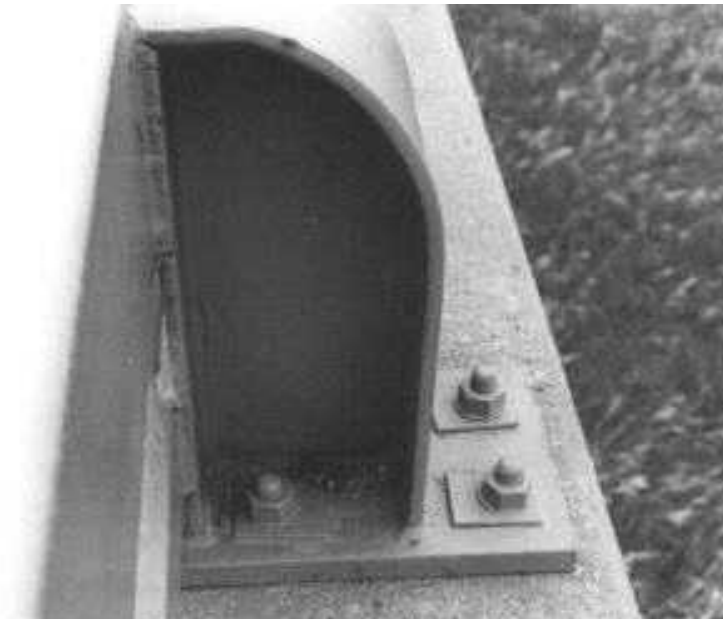


Figure 10.16 Bottom Flange to Bearing Plate Welds



These are generally the only welds made in the field because most high stress connections are bolted. Welds made in high stress areas must meet rigid requirements, including tests for weld subsurface quality as determined by Magnetic Particle Testing, Ultrasonic Testing, or X-rays. Welding in high stress areas, unless specified in the plans, is not allowed without prior approval of the Bridge Construction Engineer.

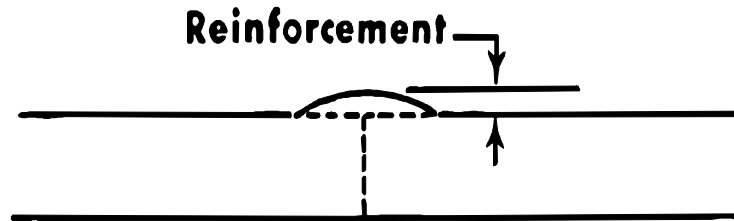
Subsurface quality tests are performed only on welded splices in high stress areas. Strip seal extrusions, bridge railing, and bearing plates are not high stress connections and do not require testing.

Most serious weld defects are apparent through visual examination. Various weld samples and sketches have been prepared to show good and bad welds. Refer to these sketches as you read this section. Additional information is available in the "Bridge Welding Code", an American Association of State Highway and Transportation Officials (AASHTO), and the American Welding Society Joint Publication.

Reinforcement

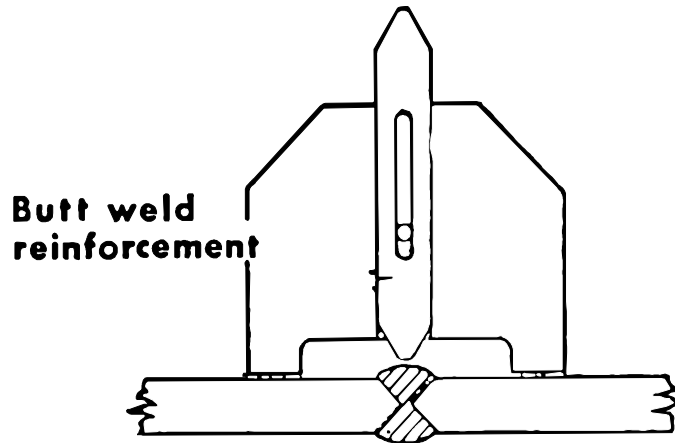
This applies only on a butt or groove weld. The top of the finished weld should be $\frac{1}{32}$ to $\frac{1}{8}$ inch above the metal surface being jointed except when the weld is a flush weld.

Figure 10.17 Reinforcement



The reinforcement can be measured with a weld gauge. Place the legs of the gauge over the reinforcement and slide the pointer until it touches the weld as shown.

Figure 10.18 Measuring Reinforcement with a Weld Gauge

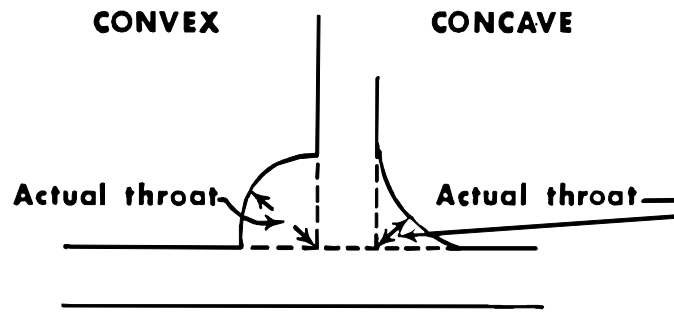


The line on the slide bar must fall between the $\frac{1}{8}$ inch maximum and the $\frac{1}{32}$ inch minimum marks on the weld gauge. If the $\frac{1}{32}$ inch minimum reinforcement dimension is not met, additional weld metal must be added. Whenever the $\frac{1}{8}$ inch maximum is exceeded, the excess material must be ground off.

Concave Welds

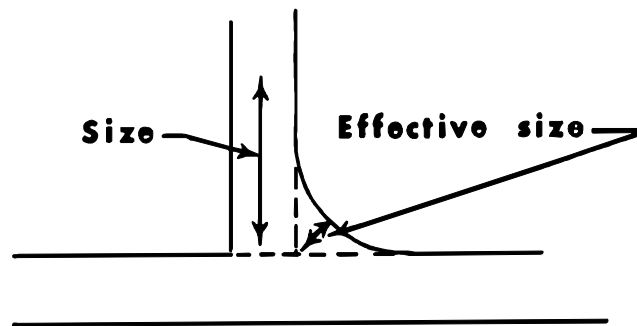
The fillet weld face is seldom flat, but rather is usually either concave or convex. It is desirable to have the weld face nearly flat to obtain full weld strength.

Figure 10.19Fillet Welds



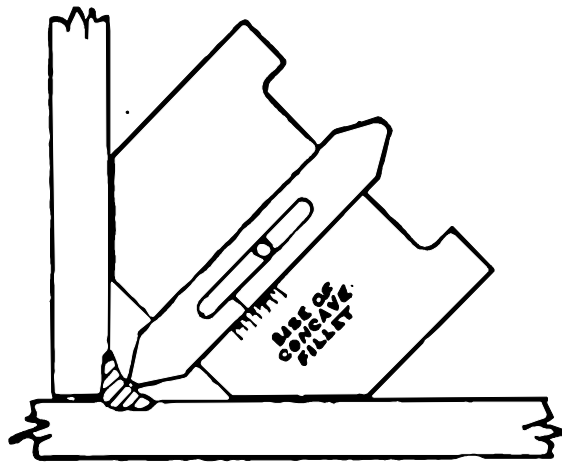
The effective size of a concave weld is reduced when the throat size is reduced. The effective size should be at least the weld size listed on the plans.

Figure 10.20Effective Size of Fillet Weld



The concave fillet weld can be measured with a weld gauge. Place the gauge against the base metal and slide the pointer until it touches the weld as shown below. The reading on the "of concave fillet" must be at least the weld called for on the plans. If it is not, another layer of weld metal must be added.

Figure 10.21Measuring Concave Fillet Welds

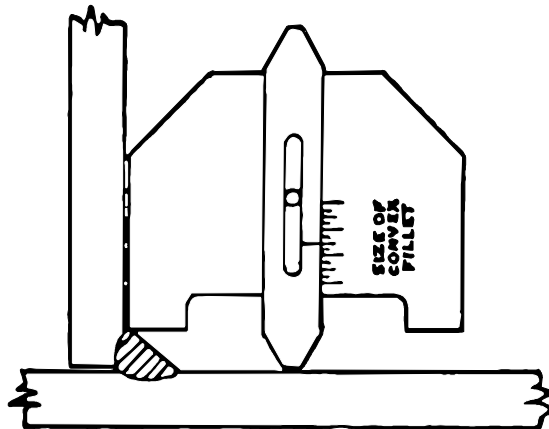


Convex Welds

The primary problem with a convex weld is that weld metal has been wasted, provided the shortest leg on the weld is the size listed on the plans. Place the gauge against the toe of the weld's shortest leg and slide the pointer until it touches base metal as shown below. Read "size of convex fillet" on the gauge. This dimension

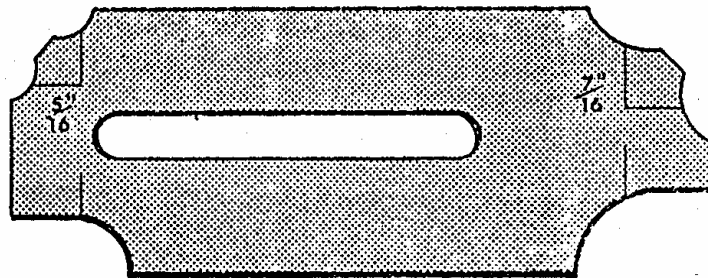
must be at least the size weld listed by plans, such as 5/16 inch. If not, additional weld material must be added.

Figure 10.22 Measuring Convex Fillet Welds



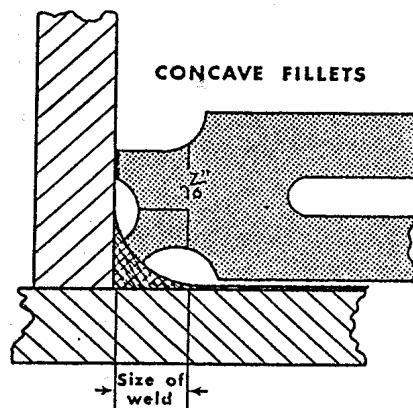
The Department gauge for measuring concave and convex fillet welds consists of seven blades that measure weld sizes 1/8 inch through 1 inch.

Figure 10.23 Department Fillet Weld Gauge



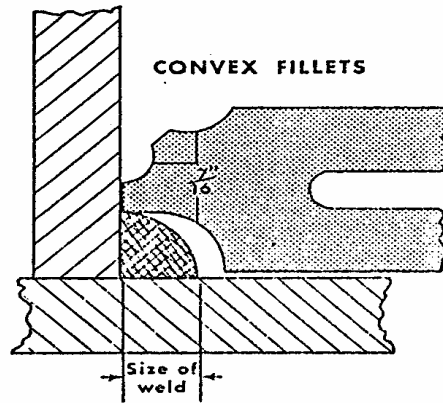
To measure a concave fillet weld, select the proper size blade with a double curve. Place the lower edge of the blade on the base plate with the tip just touching the upright. The projection formed by the double curve should touch the center of the weld.

Figure 10.24 Measuring Concave Fillet Welds with Department gauge



To measure a convex fillet weld, select the proper blade with a full curve. Place the lower edge of the blade on the base plate, with the tip of the blade moved to the upright. A weld of proper size will just touch the blade tip, as the blade tip touches the upright. All other weld defects can be determined by visual inspection.

Figure 10.25 Measuring Convex Fillet Welds with Department gauge



Undercut

This is a reduction in thickness of base metal alongside the weld deposit, causing a weak spot. When the undercutting is severe, correction must be made.

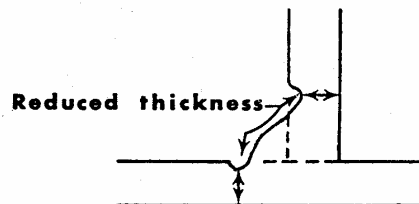
Causes:

- Excessive welding current
- Too rapid a welding speed
- Excessive electrode manipulation
- Electrode held at the wrong angle

Correction:

This defect can be repaired by adding weld material at the undercutting. It should conform to the shape of the desired weld. Remember, remove the slag before adding new weld material

Figure 10.26 Undercut



Overlap

This is an overflow of weld material onto the base metal without fusing to it.

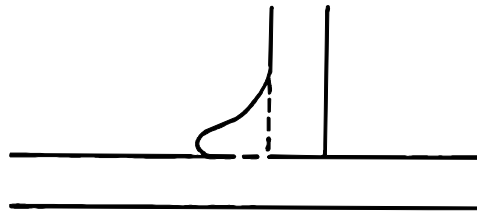
Causes:

- Electrode held at the wrong angle
- Too large an electrode
- Welding speed too slow
- Incorrect welding current

Correction:

Remove the excess or defective weld material with a grinder or gas cutting torch. The Contractor needs to be careful so the remaining weld or base metal is not gouged or undercut. After removing the bad weld metal, re-weld the joint to the correct size.

Figure 10.27Overlap



Porosity

These are cavities in the weld metal caused by trapped gas. This defect results in a very weak weld. If there are a lot of cavities or they are larger than 1/8 inch, corrections should be made.

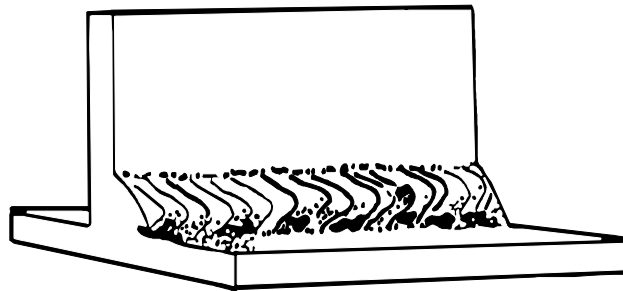
Causes:

- Excessive moisture in the electrode covering
- Low welding current
- The arc length is too long or too short

Correction:

Remove the defective portion of the weld by grinding or by air carbon arc. Be sure the surface is thoroughly cleaned by chipping and wire brushing, then re-weld.

Figure 10.28Porosity



Cracks

This is a separation in the weld metal or adjacent base metal. Cracks are the most serious weld defect. All cracks must be repaired.

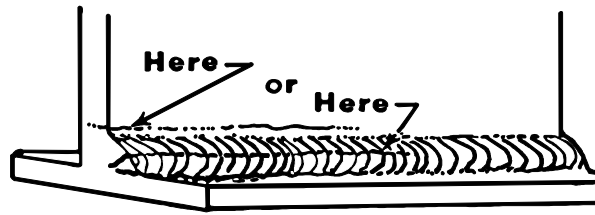
Causes:

- Shrinkage of the weld metal and the resistance to movement of the parts being joined.
- Excessive welding current and then rapid cooling.
- Cracks are more prevalent when the air temperature is low.

Correction:

Remove the defective area and re-weld. Make sure the cracked portions are removed at least 2 inches beyond the cracks visual extremes.

Figure 10.29Cracks



Spatter

These are small pieces of metal from the electrode that are scattered over the weld's surface and adjacent base metal. They have no effect on weld strength but are undesirable due to appearance and the poor surface for painting.

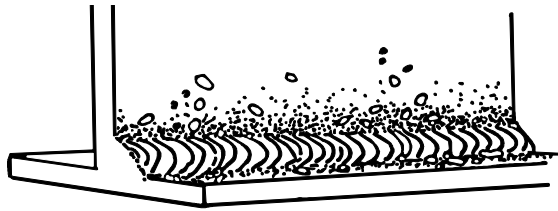
Causes:

- Excessive welding current.
- Too long an arc.

Correction:

These globs can be removed by wire brushing and chipping with a pointed hammer.

Figure 10.30Spatter



When the welder finishes welding, they must remove all slag so that you can examine the weld. All defects seen by visual examination must be corrected.

Seal Weld

Occasionally a note on your plans call for a seal weld. This is weld material placed to seal a joint and prevent moisture from entering where the two pieces of metal come in contact. The term seal weld is used only by our Office of Bridge Design. At present we do not have specific requirements for size or strength on seal welds. You must visually inspect seal welds.

Safety

Arc welding radiation is harmful to the eyes. If you intend to watch any welding, borrow an arc welder's helmet from the Contractor. This helmet will limit your vision, so be careful when moving around. Also be aware of electrical shock and high welding temperatures. Severe burns will result if a fresh weld is touched.

11

BOLTING

Checklist

Prior to Erection, ensure that:

- Bolts, nuts, and washers checked after delivery to site for general condition
- Markings match the grade of bolt required
- Bolt lengths match those required for the connections as per plans or approved shop plans
- Certificate of Compliance received and sent to Central Office and approved prior to use
- Direct Tension Indicators (DTI's) tested in calibration device. A minimum of three must be field tested
- Steel plates to be connected clean and free of materials that could compromise frictional strength.

During Erection, ensure that:

- Drift pins or temporary splice bolts used to hold connection secure until adequate number of bolts are installed
- Holes align properly
- Nuts properly lubricated
- All bolts placed within connection and snug tightened in a systematic pattern radiating from the center outward
- Bolts finish tightened in systematic pattern radiating from the center outward
- Hardened washer is watched during tightening to ensure that it does not rotate
- Impact wrench has adequate pressure and air supply to tighten bolts

Following Erection

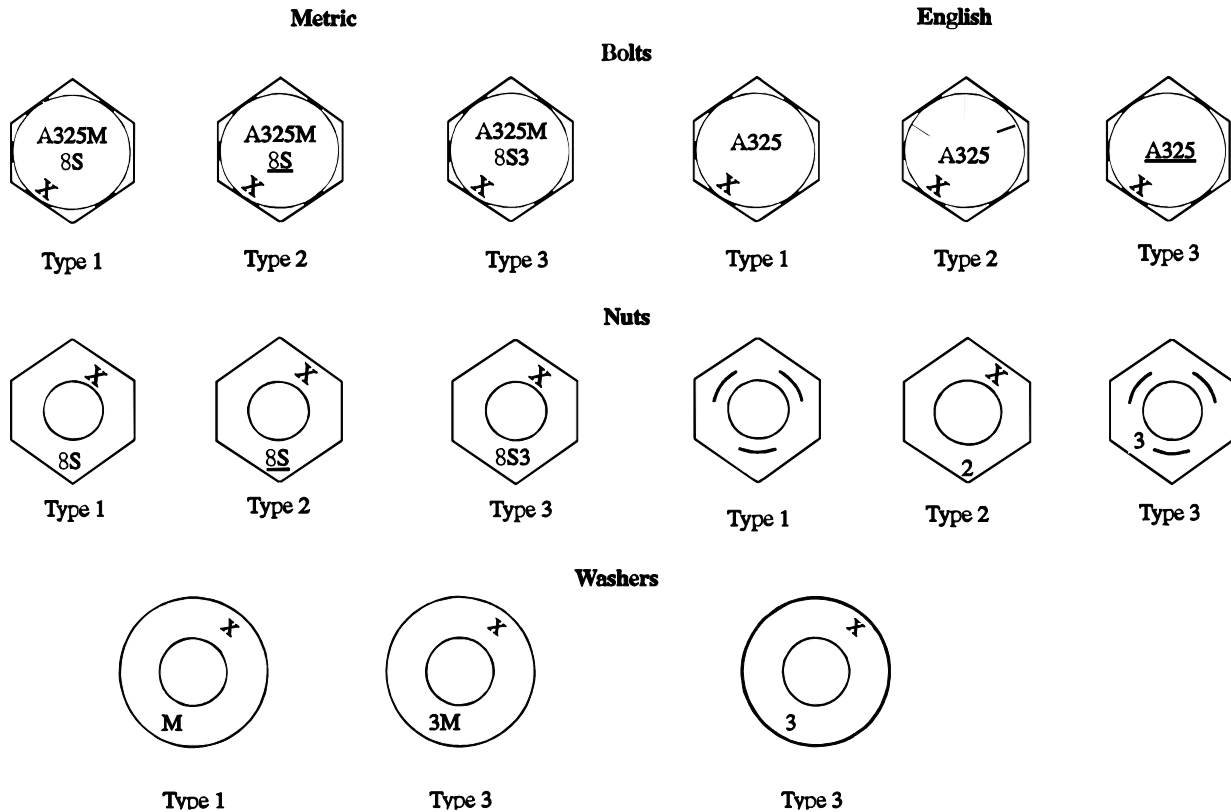
- Minimum of 20% of bolts (not less than 4) checked with metal feeler gauge
- Bolts retightened as necessary after checking with gauge

General

High strength bolts have virtually replaced welding for splicing beams and girders. The plans specify the bolts to be used. At present, the DOT uses A.S.T.M.

Specifications A325 or A490 Heavy Hex Bolts. Each item has the manufacturer's markings on them, indicating the type and grade of the piece. Figure 11.1 shows the typical markings that can be found for A325 or A325M type bolts, nuts, and washers.

Figure 11.1 Example Markings on Bolts, Nuts, and Washers



Occasionally you may find that some bolts that are not required to be high strength, and may be called out as A307 or some other specification. These are generally limited to applications where the strength of the bolt is not critical.

Certification Requirements

You must receive a Certificate of Compliance for all bolts, nuts, and washers used in the field. By specifications, the high strength bolts must undergo rotational-capacity testing in order to be approved. The certification should indicate where the testing was done, and should include certified mill test reports providing test results in accordance with the following requirements:

- When bolts conforming to ASTM A325, A449, A307, or A687 are designated for use in the plans and/or shop drawings, a Certified Mill Test Report for each type designated shall be submitted for approval to the Certification Engineer a minimum of 14 days prior to incorporating these bolts into the work (Including certified mill test reports for all nuts, washers, and other required hardware).
- The Certified Mill Test Reports for the bolts shall include test results (tested in accordance with the applicable ASTM Specifications) as listed below.

Figure 11.2 Certified Mill Test Report Requirements

Test	A325	A449	A307	A687	Others
Chemical Analysis	X	X	X	X	X
Hardness Test	X	X	X		X
Tensile Strength (* by Wedge Test Method)	X	X	X	X	X
#Proof Load Test	X	X	X	X	X
@Rotational Capacity Test	X				
Charpy V-Notch				X	X

*Certified Mill Test Report shall state that Wedge Test Method was used (For ASTM A307 and A449 bolts the Wedge Test Method is required only for square and hexagon head bolts. Wedge Test Method not required for ASTM A687. See appropriate specifications).

#Proof Load Test and/or Yield Test as allowed or specified by the applicable ASTM Specification.

@ This test shall be conducted using the actual nuts that are used on the project.

~The requirements set forth in this table are to alert the Contractor to the requirements for testing and certification as specified in the applicable ASTM Specifications and are not intended to alter the requirements of the specification.

Method of Connection

All high strength bolted connections on South Dakota projects are friction type connections. The principle is that the bolts are tightened to a high tension, producing clamping forces that enable the connecting steel surfaces to carry loads by friction. The clamping force or bolt tension is the key to the integrity of the connection. The mere physical presence of the bolt itself does not mean that the connection is adequate.

Bolt, Washer, and Nut Requirements

Adequate bolt tension is created by properly tightening the bolt. This relies on several factors: bolt length, location of hardened washer, use of beveled washers (where required), and proper treatment of the bolt and nut threaded surfaces.

Bolt Length

Generally the bolt length will be determined by the steel fabricator, and will be approved through the shop plans review process. You should check the lengths of bolts against the plans and approved shop plans to ensure that the proper bolt length is used in the proper location. When in doubt or if not shown, you can determine the required bolt length as follows:

- 1 Determine the total thickness of the material to be connected, exclusive of washers. This dimension is called the grip.
- 2 Add the dimension found in the table below for the respective bolt diameter.

Figure 11.3 Bolt Length

Bolt Diameter Size	*Length to Add
5/8"	7/8"
3/4"	1"
7/8"	1 1/8"
1"	1 1/4"
*Add to the grip to determine total bolt length required.	

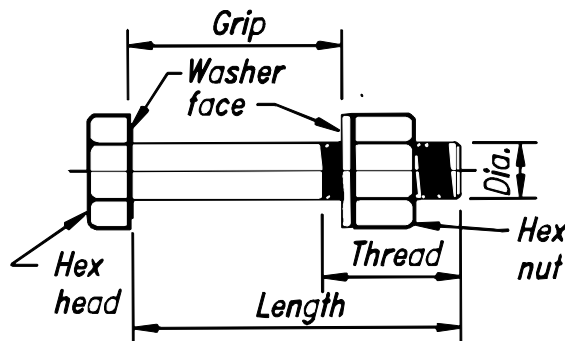
3 Add the thickness of the washers as found in the table below.

Figure 11.4 Thickness of Washers

Washer Type	*Thickness
Flat Washer	3/16"
Beveled Washer	5/16"
Direct Tension Indicator (DTI)	1/8"
*Add to the grip to determine total bolt length required.	

4 The total length calculated is the minimum length the bolt must be from the base of the head to the tip of the shaft. You should round up to the nearest 1/4 inch.

Figure 11.5 Bolt Length

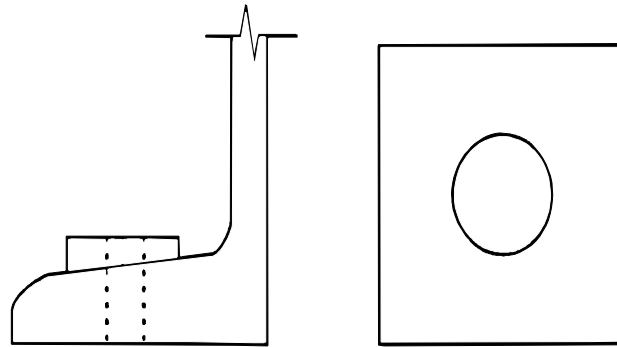


Hardened Washers

A hardened washer must be furnished for the end of the bolt that will be turned when tightening. This is very important. If they are tightening the bolt by turning the nut, the washer must be under the nut. If they plan to tighten the bolt by turning the head of the bolt and holding the nut, the washer must be under the head. The plans may specify which specific tightening configuration should be used.

In some cases the flange of the beam will be sloped rather than level. When the outer face of the bolted part has a slope more than 1:20 with respect to the normal plane to the bolt axis, a smooth hardened beveled washer is required.

Figure 11.6 Beveled Washer



Bolt and Nut Threaded Surfaces

Bolts, nuts, and washers should be free from rust, dirt, or other foreign material that could have adverse influence on the tightening of the bolt. It is important to visually inspect the bolts and nuts when they are first delivered to the site and each day during bolting operations. Bolt and nut threads should be inspected to determine whether or not they have been damaged, and that the threads are properly formed. Nuts should be tested to see that they can easily be hand threaded on the bolt.

For galvanized bolts and nuts, the nut thread must contain a dyed lubricant. If the lubricant is missing or the nut cannot be hand-threaded onto the bolt, stop the bolting operations until the situation is corrected. Insufficient lubrication can result in inadequate tightening of the bolt and can make it difficult to reach the required tension. If insufficient lubrication occurs, the Contractor should be directed to lubricate threads with a stick wax specifically designed for lubricating high strength bolts.

Note Do not allow oil or grease to be used to lubricate bolts and nuts.

Connected Plates

It is critical that the connected steel plates are clean and free of any materials that could compromise the friction resistance of the connection. Make sure the joint surfaces and area in contact with washer are free of:

- Dirt and loose scale
- Burrs
- Oil
- Paint and lacquer (except shop applied primer)
- Galvanizing
- Or anything that prevents a tight joint

Bolt Placement

All bolts in the flange splice must be placed with the head down. Bolts in the web splice on exterior girders must be placed with the heads on the exterior surface. A bolting sequence must be followed that will progress from the joint center outward in all directions. The splice plates may have small wrinkles, and if the outer edges are tightened first, these wrinkles would be trapped in the center and you will not get complete surface contact. A suggested bolting sequence is shown below.

Figure 11.7 Bolt Sequence

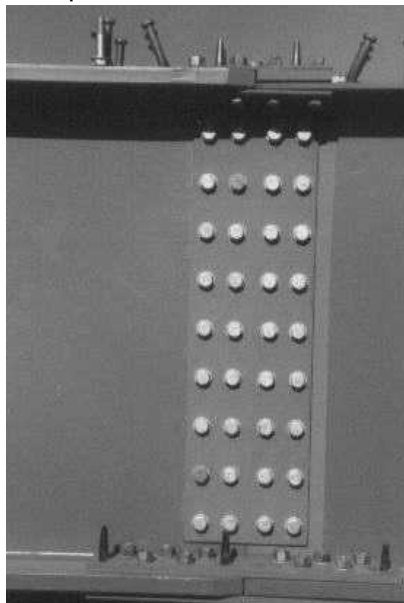
● 20	● 9	● 10	● 15
● 19	● 8	● 7	● 14
● 18	● 5	● 6	● 13
● 17	● 4	● 3	● 12
● 16	● 1	● 2	● 11
● 29	● 21	● 22	● 33
● 30	● 24	● 23	● 34
● 31	● 25	● 26	● 35
● 32	● 28	● 27	● 36

The fabricator shop drills the holes for the splice bolts to insure proper fit in the field. The Contractor must use drift pins placed on both sides in several holes to line up the holes for placement of the bolts. If bolts cannot be placed in the hole with no resistance, contact your Project Engineer. Do not allow reaming or re-drilling of the bolt holes without approval by the Office of Bridge Design.

The Contractor can use erection bolts to hold the splice temporarily. Then splice bolts are placed and tightened permanently. If the erection bolts are the same as the splice bolts, they can re-use them as splice bolts provided that a hardened washer is used in lieu of the Direct Tension Indicator (DTI) during erection, and provided that the bolts are not fully tightened. Temporary use of bolts as erection bolts will not damage them.

A sufficient number of bolts shall first be placed in the joint and “snugged” to insure that all faying surfaces are in firm contact prior to tightening. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary wrench. Bolts shall be placed in any remaining holes and snugged tight as erection bolts or pins are removed. All bolts in the joint shall then be fully tightened progressing from the center outward towards the free edges as described previously. It will be necessary to go back and re-tighten the center bolts after the perimeter bolts have been fully tightened. Support of the girders shall not be removed until all bolts in the joint are brought to full tension.

Figure 11.8 Fitting up of a Bolted Splice



Once a bolt has been tightened to full tension capacity, it cannot be released and then reused. If it becomes necessary to unbolt some portions of a connection because of erection problems, and the bolts that are released were previously tightened to full capacity, then new bolts should be used to re-bolt the connection.

Figure 11.9 Bolted Splices



Turn-of-Nut Installation Method

When the turn-of-nut installation method is specified, hardened washers are not required.

The nut shall be snug tightened. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary wrench. The nut shall then be rotated to amount given in the table below, depending on bolt length. During tightening there shall be no rotation of the part not turned by wrench.

Nut Rotation from Snugged Condition (a,b)

Bolt Length Measured From Underside of Head to End of Bolt	Geometry of Outer Faces of Bolted Parts		
	Both Faces Normal to Bolt Axis	One Face Normal to Bolt Axis and Other Face Sloped Not More Than 1:20, Bevel Washer Not Used	Both Faces Sloped Not More Than 1:20 From Normal to Bolt Axis, Bevel Washers Not Used
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters (c)	2/3 turn	5/6 turn	1 turn

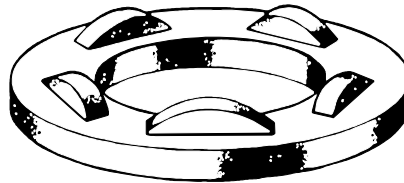
a Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance should be plus or minus 30 degrees; for bolts installed by 2/3 turn and more, the tolerance should be plus or minus 45 degrees.

- b Applicable only to connections in which all material within grip of the bolt is steel.
- c No research work has been performed by the Research Council Riveted and Bolted Structural Joints to establish the turn-of-nut procedure when bolt lengths exceed 12 diameters. Therefore, the required rotation must be determined by actual tests in a suitable tension device simulating the actual conditions.

Direct Tension Indicators

The Direct Tension Indicator (DTI) is a specially hardened washer with protrusions on one face.

Figure 11.10 Direct Tension Indicator



The DTI, or load indicator, is usually placed under the bolt head, and the protrusions create a gap. As the bolt is tightened, the clamping force flattens the protrusions, reducing the gap.

Direct Tension Indicators are marked for use on A325 or A490 bolts. They are different, so carefully check that the Direct Tension Indicator is correct for the bolt strength.

Figure 11.11 Prior to Tightening Bolt

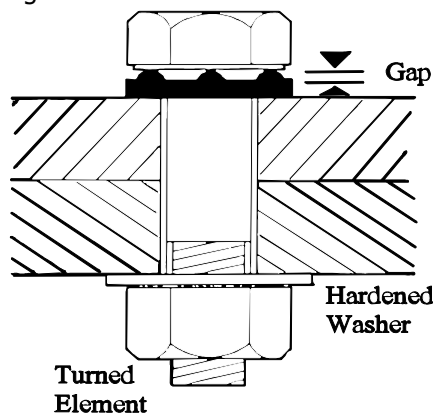
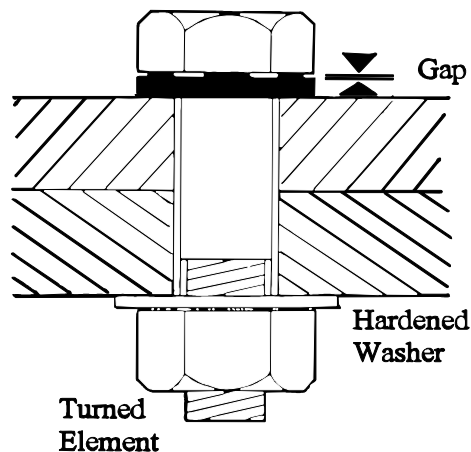


Figure 11.12 After Tightening Bolt



If there is a problem operating wrenches, the bolt may be the turned element. Two hardened washers would be needed, one under the head and one under the nut. The Direct Tension Indicator would be placed with the protrusions bearing against the hardened washer under the head. If the head is inaccessible, the nut may be the turned element with the Direct Tension Indicator protrusions bearing against the hardened washer under the nut. In all cases, the Direct Tension Indicator washer protrusions shall bear against a hardened surface and this surface should not turn or turn very slightly.

Testing

High strength bolts should be tested in accordance with the South Dakota Materials Manual Test #SD507.

Inspection

Observe the bolting to make sure a proper sequence is followed.

After tightening a few bolts in a joint, the Contractor should re-tighten the first bolts. He should continue to re-tighten bolts in the splice until they are at the required tension. You should check a minimum of 20%, but not less than four bolts in each joint, with a metal feeler gauge. If all gaps checked are within the allowable range the joint shall be accepted. If some gaps are in excess, the Contractor shall reinspect and re-tighten each bolt in the joint. Recheck after this procedure is completed in the joints.

The 0.005" metal feeler gauge shall be used as a "no go" inspection tool by inserting the tapered nose into the openings between protrusions. If half of the openings refuse the gauge, and there is a gap, then the bolt is at tension. If there is no gap on all protrusions, then the bolt needs to be replaced.

Points to Remember

- Make sure bolt certifications have been approved
- Make sure bolt has proper coatings shown in Spec Book or Plans
- Use a new bolt each time. Once a bolt has been tightened and needs to be loosened for some reason, the bolt should be discarded and a new bolt, Direct Tension Indicator, hardened washer, and nut should be used.
- Make sure the washer does not turn as the nut is being tightened. Roughen the washer if it tends to turn.
- Bolts shall be tightened in one continuous action and in less than 10 seconds.
- Make sure the Contractor checks a sufficient number of load indicators.
- Make sure the nuts are lubricated.

Anchor Nut Tightening

Proper installation of anchor nuts is critical to the performance of traffic signal poles, roadway lighting poles, cantilever sign poles and sign bridge poles. Due to the high loads and large size of anchor bolts, specialized equipment and inspection is required for proper anchor nut tension to be achieved. The anchor rods are tensioned using the turn-of-nut method covered earlier in this chapter.

The leveling nuts on the bottom of the base plate shall be brought to full bearing and cannot be more than one diameter of the anchor rod above the concrete.

If any part of the top or bottom nut is not in full contact with base plate a beveled washer must be placed.

A wax based lubricant shall be applied to the threads and the bearing surface of the top nut

The top nut needs to be snugged tight in a minimum of two passes and the nuts shall be tightened in the order shown in figure 11-13.

Adjustable wrenches shall not be used in the snug tight or final tightening process.

Snug tightening of the top and bottom nut shall be witnessed by SDDOT personal and checked by applying 20% to 30% of the verification torque shown in table 1 in section 635 of the standard spec.

The final nut rotation shall be achieved with a minimum of two passes and in the order shown in figure 11-13.

Refer to table 1 & 2 of section 635 of the standard spec for verification torque and the final rotation for the top nut.

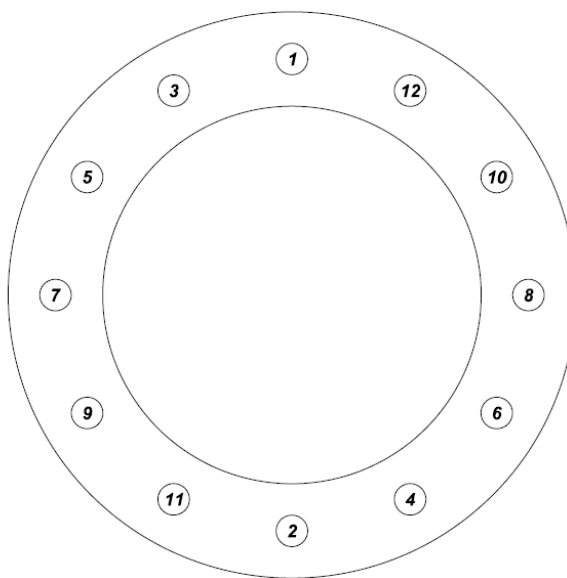
Final tightening of the nuts shall be witnessed by SDDOT personal and checked by applying verification torque. The anchor nuts shall be checked again 48 to 96 hours by applying verification torque.

Bolt shall protrude above the top nut or jam nut as applicable and at a minimum shall be flush with top of the nut.

If verification torque cannot be achieved during final tightening or when checking 48 hours after final tightening then contact the Office of Bridge Design.

After verification Torque has been applied to the top nut, jam nuts shall be lubricated and torqued to 100 ft-lb. Jam nuts shall be placed on anchor rods for sign bridges, cantilever signs and high mast light towers.

Figure 11.13 Anchor nut tightening sequence



SHOP PLANS AND FABRICATED ITEMS

Checklist

- If you receive shop plans directly from the Contractor, make sure that they have been reviewed and approved by the Office of Bridge Design. If they are an initial submittal, send them to the Office of Bridge Design or designing consultant as noted in plans.
- Received Final Shop Plans and Fabricated Items have been Delivered
 - Check to see that final shop plans have been stamped and approved by the Office of Bridge Design
 - Review shop plans for erection notes, sequence, and piece markings
 - Check fabricated items carefully for conformance to plans and approved shop plans
 - Check fabricated items for evidence of damage that may have occurred in handling and transportation
 - Notify the Project Engineer or Office of Bridge Design of any damage

General

Many structural members or pieces are not built on site, but are rather pre-manufactured or constructed in a fabrication yard or shop. After fabrication, these items are transported to the job site and then erected and incorporated into the construction of the bridge. This is true of a wide variety of fabricated items, whether they are steel, concrete, wood, or other material.

Generally speaking, most of these items are built at the fabrication shop from working drawings called shop plans or shop drawings. Shop plans are detailed drawings created by the fabricator. The plans serve a multi-purpose role as follows:

- They provide specific details for the fabricator's use in constructing or fabricating the item
- They provide quality control through a review and approval process by those involved in the actual design of the item
- They provide erection and construction details for the Contractor to follow during the erection process

The following is a partial list of typical items that required shop plans review and approval to be incorporated into construction on DOT projects:

- Precast concrete box culverts
- Prestressed concrete girders
- Steel diaphragms
- Steel girders
- Bearings (fixed, rocker, pot, elastomer, etc.)
- Expansion joints (finger, sliding, strip seal, etc.)
- Armor angle assemblies
- Steel railings (on box culverts, bridge barriers, bridge sidewalks, etc.)
- Light and sign tower posts and masts
- Timber beams and rails
- Pre-manufactured pedestrian bridges

Many shop manufactured items are designed by the fabricator themselves. Where required, plan notes and/or specifications will also required that structural computations stamped by an Engineer registered in the State of South Dakota be included with the shop plans submittal.

Submittal for Review and Approval

Content

Shop plans should give full detailed dimensions and sizes of all fabricated items. They should identify the material type used for each component. In addition, they should give all other details and information as may be necessary for erection of the items at the job site. For steel items they should include all miscellaneous parts such as pins, nuts, bolts, drains, weld details, paint system, etc. For prestressed items they should include reinforcement, embedded items, as well as the method and sequencing of the stressing.

It is critical that the shop plans include all information, as it is necessary for both the fabrication and erection of shop built items.

Format

Specifications do not require shop plans to adhere to a particular format (i.e. paper size, title blocks, numbering, etc.) However, they should be prepared in a neat and legible form and on media that is easily reproducible.

Shop plans should contain critical data that is important for the identification of the item and the structure that it pertains to, such as project number, structure number, county, fabricated item description, etc. In addition, the drawings should include the name, address, and phone number of the fabricator that is responsible for the production of the item.

Submittal for Review and Approval

Section 410.3.E of the Standard Specifications requires that shop plans for steel fabricated items be submitted a minimum of 15 days prior to the start of fabrication. Sections 490.3.A and 560.3.A.2 require that shop plan for prestressed girders and precast box culverts be submitted a minimum of 30 days prior to the start of fabrication.

Plan notes will define how the shop plans should be submitted for review and approval. On State designed projects, the note will typically read as follows:

- Shop Plans shall be submitted in PDF format and sent via email to the Bridge Construction Engineer.

On consultant designed projects, the note will typically read like this:

- The fabricator shall initially submit in .pdf format shop plans to [consultant name and address] for review. One reviewed copy will be sent back to the fabricator who will then make the necessary changes, if any, and then send seven final copies to [consultant name]. After review, the .pdf will be forwarded by [consultant name] to the Office of Bridge Design, SDDOT, who will then review them, authorize fabrication, and distribute the final copies.

During the review process it may be necessary to require re-submittal for approval. This would occur when the changes or comments are so numerous or critical that final approval cannot be given without further review of the changes. The final approved shop plans will be stamped by the Office of Bridge Design and consultant (where applicable). Note that only the Office of Bridge Design can give final authorization and approval for fabrication.

You should receive a copy of the final approved shop plans directly from the Office of Bridge Design. If you get shop plans through the Contractor, check to make sure the Office of Bridge Design has approved them.

Inspection of Fabricated Items at Time of Delivery

Although the DOT generally has an inspector at the major steel and precast concrete producers within the State, there are often times where no inspection of the item has taken place prior to delivery at the job site. For this reason, you should carefully check the fabricated items when delivered for conformance to the final approved shop plans. In addition, look for damage that may have occurred during handling and transportation. You should notify the Project Engineer of any items or damage that appear questionable or inconsistent with the approved shop plans.

BEAMS AND GIRDERS

Checklist

Steel Girders

Fabrication, Delivery, and General Handling

- Final shop plans received and approved
- Check girders for damage when they arrive at job site
- Steel handled in a manner to prevent damage to girders, particularly damage to the paint
- Steel stored on blocking to keep it off the ground and supported to prevent tipping
- Notify the Project Engineer or Office of Bridge Design of any damage

Bearings

- Construct grout pads level and to proper elevation
- Grout pads must attain 2,000 psi compressive strength prior to setting girders
- Check bearings for conformance to plans and approved shop plans
- Locations of bolts or angle of bearings adjusted for proper temperature requirements
- Anchor Bolt Nuts spot welded, punched, or locked by other measures as noted in plans. Adequate gap left to allow movement/rotation of bearing

Erection

- Final shop plans received and approved
- Check girders for damage when they arrive at job site
- Girders handled in a manner to prevent damage
- Girders picked up only at designated points
- Girders stored on blocking to keep them off the ground
- Notify the Project Engineer or Office of Bridge Design of any damage

Prestressed Concrete Girders

Fabrication, Delivery, and General Handling

- Final shop plans received and approved
- Check girders for damage when they arrive at job site
- Girders handled in a manner to prevent damage
- Girders picked up only at designated points
- Girders stored on blocking to keep them off the ground
- Notify the Project Engineer or the Office of Bridge Design of any damage

Bearings

- Construct grout pads level and to proper elevation
- Grout pads must attain 2,000 psi compressive strength prior to setting girders
- Ensure that elastomeric pads are placed at correct locations relative to the center line of bearing

Erection

- Set girders according to piece markings noted on shop plans
- Girders aligned and held rigidly in place during placement of cast-in-place intermediate diaphragms
- All girders must be cast within an eight day period or greater than six weeks old prior to pouring the deck
- Integral diaphragms poured such that top of diaphragm is just filled when finish machine arrives

Precast Concrete Deck Units (Double T's/Channels or Bulb T's)

Fabrication, Delivery, and General Handling

- Final shop plans received and approved
- Check units for damage when they arrive at job site
- Units handled in a manner to prevent damage
- Units stored on blocking to keep it off the ground
- Notify the Project Engineer or Office of Bridge Design of any damage

Bearings

- Top of substructure units must be checked for proper elevation
- Neoprene pad should be placed between unit and support (where applicable)
- Ensure that the ends of units are attached to substructure as per plans and shop plans

Erection

- Set units according to piece markings noted on shop plans
- Weld units or fasten together as per plans and approved shop plans
- Fill joints with non-shrink grout as noted in the plans

General

Girder bridges are those bridges that have several longitudinal beams or girders supporting the roadway slab. As explained in 'Chapter 1 - Introduction', the girders can range from steel rolled I-beams or welded plate steel girders, to prestressed concrete girders or cast-in-place concrete beams. This chapter will summarize the process and inspection necessary to construct steel and prestressed girder bridges. Cast-in-place concrete beams should be built in accordance with 'Chapter 8 - Concrete'.

Figure 13.1 Prestressed Girder Bridge



Figure 13.2 Steel Girder Bridge



Steel Girders

Fabrication

Steel girders are built specifically for the structure at a steel fabrication shop. The fabrication of the girders will follow a shop plans review and approval process as explained in 'Chapter 12 - Shop Plans'. Generally, a DOT representative is present at the steel shop while the parts are being fabricated, checking procedures, dimensions, welds, and material. For the most part you can assume that the parts conform to project plans and specifications.

Transportation, Handling, and Storage

When delivered to the job site, you should check the girders for any damage that may have occurred during transportation or improper handling at the shop. Check all surfaces for damage. Carefully check where the paint is scratched or cracked. This is an indication of possible damage, some defects to watch for are:

- Bends - Usually found on the flange, and normally result from being struck or improper lifting
- Kinks - Result when metal has lost its strength from excessive stretching or metal separation
- Cracks - Result of severe bending or over-stressing when using excessive heat for straightening purposes
- Warpage - Usually the result of dropping or tipping over a girder. The girder is no longer straight. This can be seen by sighting down the girder.

When you find a defect, report it to your Project Engineer. The Office of Bridge Design should be contacted for a determination of whether or not the defect can be repaired. If repairable, the Office of Bridge Design will suggest a repair procedure.

It is the Contractor's responsibility to handle and store steel carefully. Large girders are cumbersome and can be damaged if dropped, bumped, or tipped over. The structural steel is usually delivered to the job prior to the time it is needed. The Contractor should store it in a manner to keep it clean and damage free. All steel should be kept off the ground. Girders should be stored upright on planks or 4"x4"s and braced to prevent tipping. They should be firmly supported to prevent damage from deflection. Bolts should be stored in a building or in a manner that will prevent rusting.

Bearings

Plans will designate the bearings as either fixed or expansion (F or E). A fixed bearing prevents movement of the joint longitudinally, but allows the girder to rotate about the joint. An expansion bearing allows the girder to move longitudinally as well as rotate. Generally both types of bearings prevent movement of the bridge in the transverse direction in order to resist wind loads.

Grout Pads

Grout pads are placed on the cap to provide a smooth, level surface for the bearing plates and to assure the bearing plate will be at the correct elevation. You must check the Contractor's work to make sure the pads serve both purposes. The Contractor should make the top surface smooth enough to allow uniform contact with the bearing plate. Also make sure the Contractor considers the exact depth of the girder because of fabrication tolerances. Measure the girder at each point and

compare this with the plans. If the size is more or less than the plans specified, consider this on the grout pad elevations.

Example: The plans call for the depth of the girder to be 4 feet- 8 3/4 inches at Bent #2. While measuring the girder that is to be placed over Bent #2, you find that it is 4 feet-8 5/8 inches. Determine the adjustments needed when setting the grout pad elevation.

Solution: You would need to raise the grout pad 1/8 inch from the plan shown grout pad elevation for that particular girder.

The grout to make these pads is specified in Section 460.3.R of the Standard Specifications. It should be a mixture of 5 1/2 gallons of water and 285 pound of sand to each bag of cement, or a commercially available non-metallic non-shrink grout.

Before the superstructure is erected, the pads must have a minimum strength of 2,000 psi; determined by making cylinders or using the Swiss Hammer. These procedures are covered in the South Dakota Materials Manual.

Anchor Bolts

Most bearings are held in position by anchor bolts. The anchor bolts can be set by two different methods:

- 1 Set the anchor bolt directly in the plastic concrete; or
- 2 Block out a 4 inch hole for each bolt, then grout the anchor in at a later time.

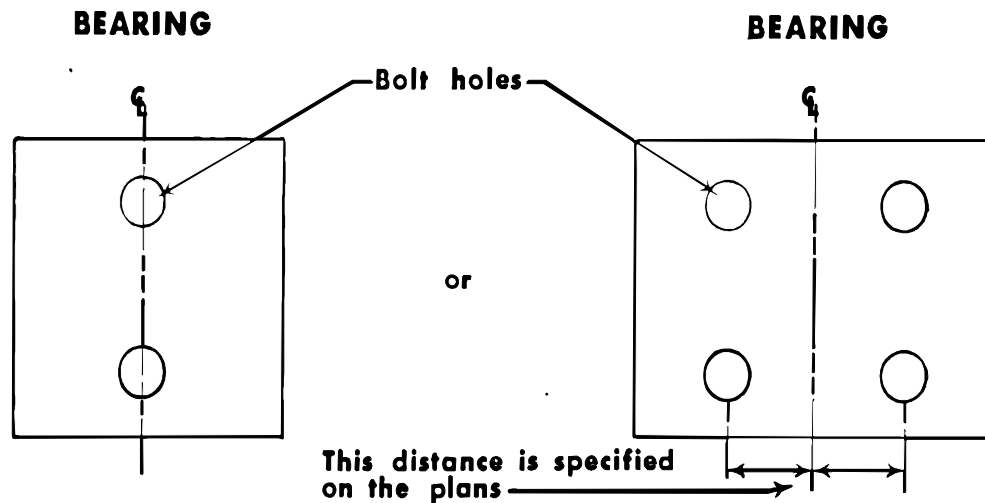
The Contractor determines the method used. You must check their measurements to make sure the bolts will fit the plans shown girder length between bearing points. Make sure the reinforcing bars in the cap do not interfere with the placement of the anchor bolts. When there is a conflict, move the reinforcement to allow proper location of the anchor bolts. A template should be used to hold the anchor bolts rigidly in position when cast directly into the concrete.

Note Extreme caution must be taken to make sure that water is not trapped when placing grout in blockouts during installation of anchor bolts. If water is trapped, subsequent freezing and thawing can result in extensive damage.

Grout the anchor bolts in blockouts only when air temperatures are favorable. The anchor bolts should first be inserted into the dry holes to check proper embedment depth and projection height. If there is inadequate embedment depth, then the hole should be field drilled to the depth required and cleaned out. After checking that the anchor embedment and projection lengths are correct, fill the hole about 2/3 full of grout. The bolt should be immediately inserted and forced down until the top of the bolt is at the correct projection height. The hole should then be filled with grout flush to the top of the grout pad. All excess grout which may have been forced out should be removed.

Steel shrinks in cold weather and expands in hot weather. The fabricating shop builds the girders, and drills the holes, so that the girder meets the plan dimensions at a specified temperature. Usually it will be 45 degrees F, but the plans may state 50 degrees F or even 70 degrees F. Temperature also affects the steel measuring tape. If you are using a steel tape to check the Contractor's measurements for setting the anchor bolts, you must correct the tape for temperature changes as well. The length correction is 0.0000065 feet per foot from the fixed bearing, per degree of temperature change from the plan stated temperature. Check your plans to see where the bolts are to be set in relation to the center of bearing (see Figure below)

Figure 13.3 Anchor Bolts in Relation to Center line of Bearing



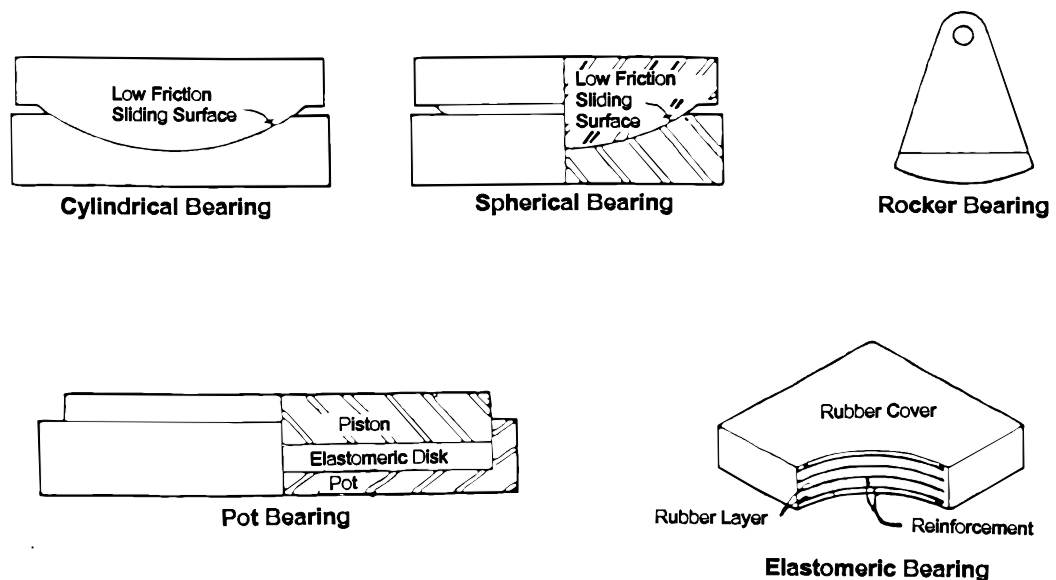
Example: The plans show 65 feet from the center of the fixed bearing on the sill to the center of an expansion bearing on the bent. If the temperature that day was 15 degrees F and the plan stated temperature you are to correct to is 45 degrees F, determine the adjustments needed when setting the anchor bolt location.

Solution: Multiply 0.0000065 by 65 times 30. So you should set the anchor bolt in the expansion bearing $0.0000065 \times 65 \times 30 = 0.0127$ feet (approximately 1/8 inch) less than the plans shown dimension.

Types of Bearings

There are many different types of bearings that can be used on steel girder bridges. Some of the more common bearings as recognized by AASHTO are shown in the Figure below. The most typical bearings used in South Dakota on steel bridges are sliding plate or rockers.

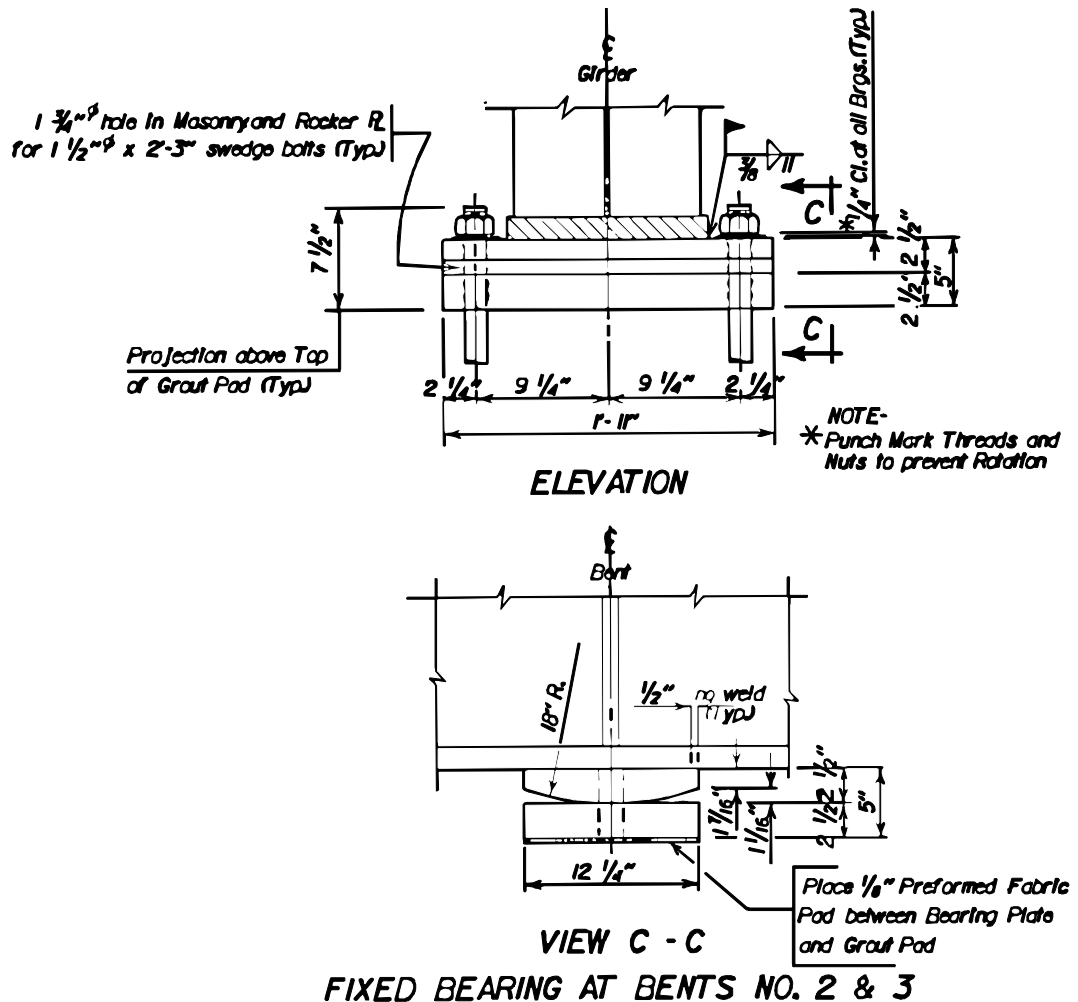
Figure 13.4 Common Types of Bearings



Sliding bearings are usually steel plates that have a low friction surface made of Teflon or other material sandwiched between them. However, sliding bearings can also be constructed using components like the pot bearings or elastomeric bearings shown in the previous Figure. The key is that the bearing must be free to slide with little resistance.

Rocker bearings are typically always constructed of steel, but may come in many different forms ranging from that shown in Figure 13.5 to bearings utilizing large diameter pins that the beam rotates on. The key is that the bearing must be free to rotate with little resistance. Rockers can be used for both fixed or expansion bearings. When fixed, the rocker is used to only allow the girder to rotate, but not move laterally. When expansion, the rocker is used such that lateral movement is provided.

Figure 13.5 Typical Fixed Rocker Bearing



The expansion bearing shown on the next page is a combination sliding plate and rocker bearing. Notice the dimensions that give the erection dimensions required at various temperatures.

TEMP.	"A"	"B"
30° F	10 1/8"	10 1/8"
40° F	10 1/16"	10 1/16"
50° F	10 1/4"	10 3/8"
60° F	10 3/8"	10 1/2"
70° F	10 1/2"	10 1/2"
80° F	10 5/8"	10 3/4"
90° F	10 3/4"	10 1/4"
100° F	10 11/16"	10 3/5"

Pier Brng

INCREASING STATIONS →

30° F	10 ¹ / ₁₆ "	10 ¹ / ₁₆ "
40° F	10 ¹ / ₁₆ "	10 ¹ / ₁₆ "
50° F	10 ¹ / ₄ "	10 ¹ / ₄ "
60° F	10 ³ / ₈ "	10 ³ / ₈ "
70° F	10 ¹ / ₂ "	10 ¹ / ₂ "
80° F	10 ⁵ / ₈ "	10 ⁵ / ₈ "
90° F	10 ³ / ₄ "	10 ¹ / ₄ "
100° F	10 ¹ / ₂ "	10 ³ / ₈ "

Pier No. 2

Pier No. 4

Hex Cap Screw Spacing

vortex ⚡

**10 Ga. Stainless Steel IR
1'-2" x 1'-9" Welded
to Sole Plate**

See DETAIL "X"

3 1/4" x 1'-4" x 2'-2" Rocker Plate

3" x 1'-4" x 2'-2" Masonry Plate

**Place 1/8" Preformed Fabric
Pad between Masonry Plate
and Grout Pad**

VIEW B - B

**EXPANSION BEARING
PIER NO. 2 & 4**

Figure 13.8 Rocker Bearing with nut over tightened



The anchor bolts on the sliding plate type or the fixed device can be tightened. The sliding plate has a self lubricating plate below the flange that allows movement. The fixed device remains stationary.

Girders

The girders or beams are then set on the bearing device. All pieces of the beam or girder are match-marked. These marks are painted on or punched into the steel. Each piece must be put in its proper place in the structure with no interchange of sections. The sections that fit over a bearing device are placed first. On a fixed bearing device and the sliding expansion type, inspection is minimal. When bolts are to be used for fastening the flange to the bearing device, the holes in the bearing plate will be slotted to allow for fabrication tolerances. The device can be slid to match the holes in the flange and still remain vertical.

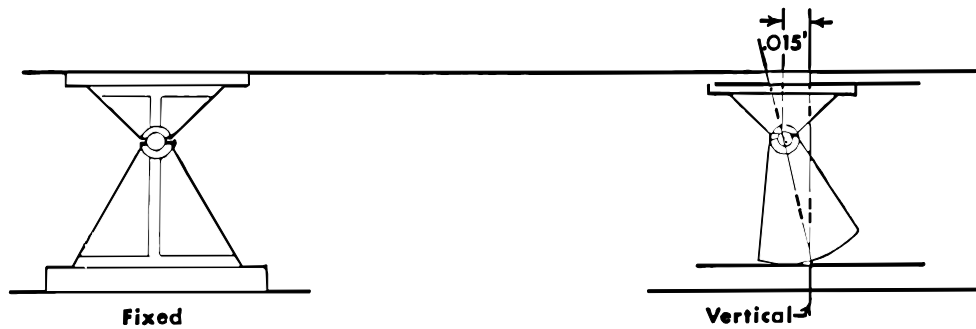
The rocker type expansion device permits the steel to expand and contract by rotating on its base. Most structures are designed assuming the rocker will be vertical when the temperature is at 45 degrees F. Therefore, make sure the rocker is positioned for the temperature at the time of erection. You can determine the direction and the rotation by making the temperature correction to 45 degrees F based on the span and the temperature of the steel at erection. To obtain the steel temperature, place a thermometer on the flange of the girder or beam. Be sure the sun is not shining directly on the thermometer. It is best to put the thermometer on the shady side of the beam or girder.

Example: The distance between the fixed device and the rocker is 80 feet and the temperature of the steel at the time of erection is 15 degrees F. The plans state that you should correct to a temperature of 45 degrees F.

Solution: The distance you should adjust for is: $0.0000065 \times 80 \times 30 = 0.015$ feet.

Adjust the rocker so that it would be positioned 0.015 feet from the vertical. It should be positioned like that shown in Figure 13.9.

Figure 13.9 Adjusting Rocker Bearing for Temperature at Erection

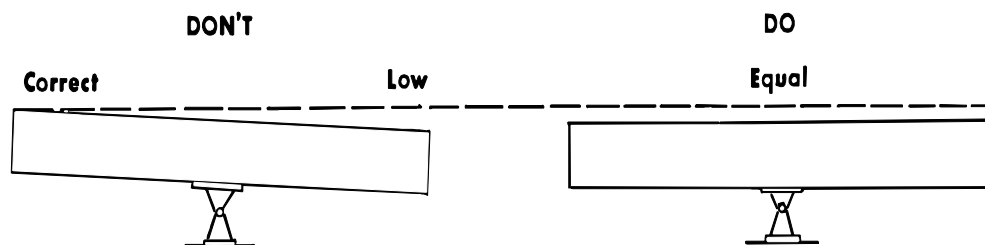


Remember The rocker would be rotated in the opposite direction if the temperature of the steel was above 45 degrees F.

The bolt holes in these bearing plates are slotted, allowing for fabrication tolerances and the correct positioning of the rocker. If the rocker device does not fit the holes in the girder flange or you cannot obtain the correct positioning of the rocker, advise your Project Engineer. Never allow the Contractor to slot the holes in the flange.

Elevations are given for the top of the girder in its erected position. No consideration is given to fabrication tolerance or deflection. When the girder is fastened to the bearing device, it will be held by supports or fastened to the bent. Take elevation shots at the girder ends and compare them with the plan shown elevation. If these points are high or low, make adjustments at the splice points. Both points should vary from the plan location by the same amount and in the same direction (see Figure below). The center is then put into position and bolted.

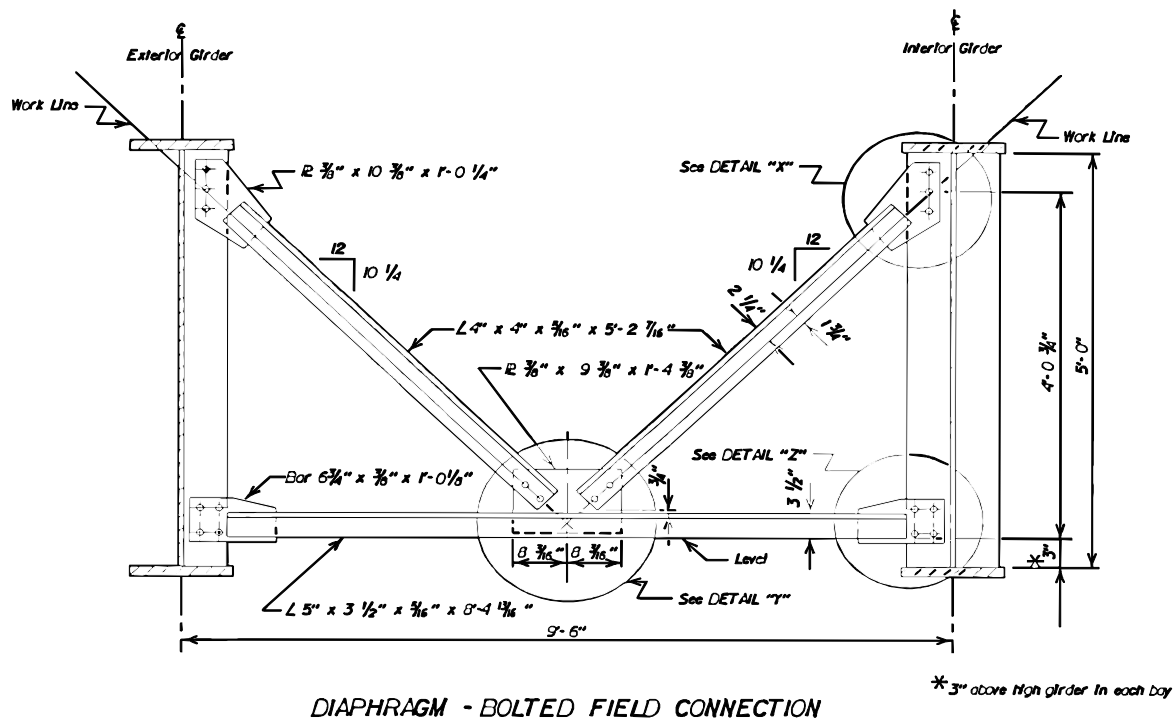
Figure 13.10 Correcting for Elevations



Diaphragms

Steel girders, particularly deep welded plate girders, are very wobbly and unstable when free standing by themselves. The girders should be held in position with temporary bracing until the girder diaphragms or cross frames are installed. The diaphragms at the supports should be the first to be installed. Following that, the intermediate cross frames should be placed. The girders should not be considered stable until all diaphragms are in place.

Figure 13.11 Typical Diaphragm for Steel Girders



Prestressed Concrete Girders

Fabrication

Like steel girders, prestressed girders (or beams) are usually not cast at the structure site, but are rather built at a precast concrete supplier's fabrication yard. Usually a DOT shop inspector will make sure the beam is fabricated in accordance with plans and specifications.

Transportation, Handling, and Storage

Inspection

When the beam arrives at the structure site, check it for damage that may have resulted in storage or shipment. Typical items to look for include:

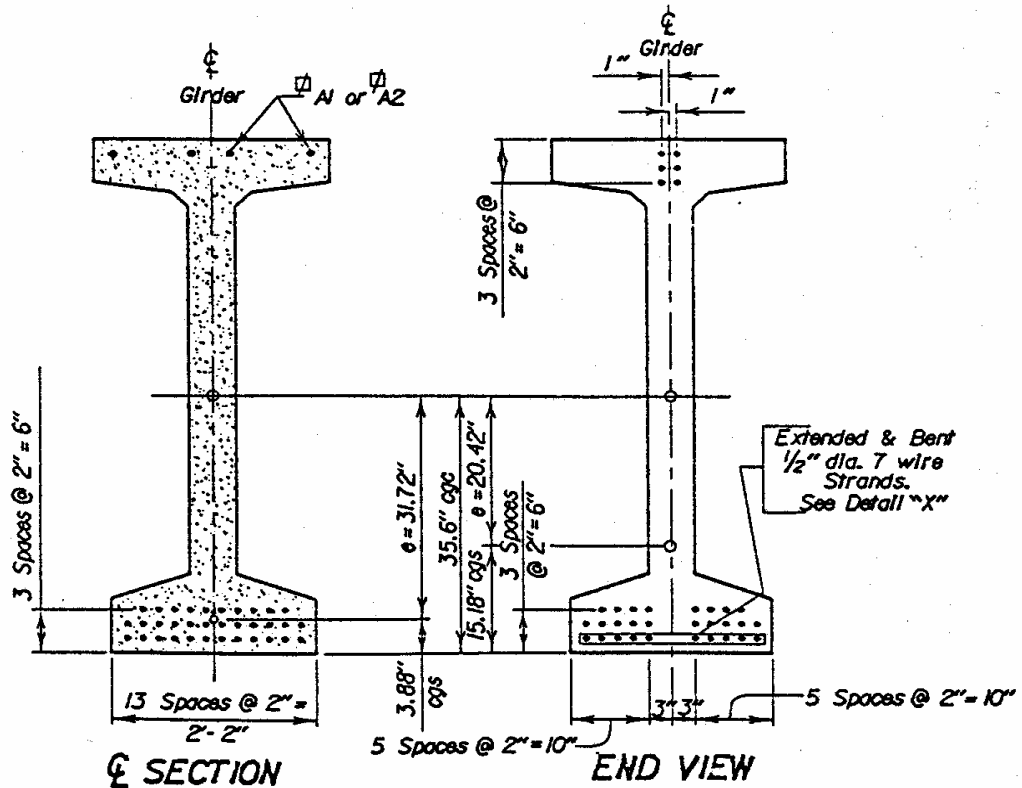
- Cracks - These can be anywhere on the beam but especially around the 1/3 points. Small ones are usually just tension cracks and may not be too damaging. Larger cracks are an indication the beam has been mishandled.
- Pieces Broken Off - The beam was probably dropped or something was dropped on it.
- Bent Steel - Reinforcing steel protruding from top of beams should not be broken or bent more than 45 degrees from plan shape. The connecting strands should be bent according to plans and should not be broken.

If you find any beam damage, contact your supervisor. Major damage should also be brought to the attention of the Office of Bridge Design. If no damage is found, assume it is ready for placement.

Handling and Supports

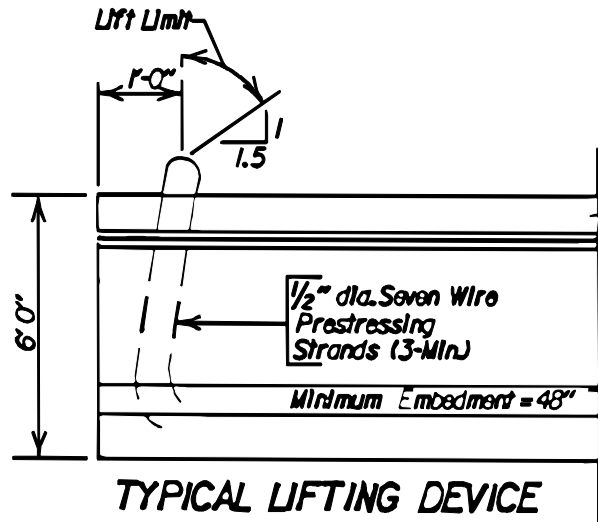
Prestressed concrete girders must be upright at all times. The placement of pretensioned cables (called prestressed strands) at the bottom of the beam puts it into compression, while the beam top has little compression. In the upright position, the weight of the concrete is working against this action. If the beam is tipped, the concrete weight would cause the top of the beam to go into tension. Cracking or collapsing may result. If it is necessary to store the beams, they must be kept upright. The support points should be approximately the same as the beam is in its final structure position. They should be no farther from the end than $\frac{1}{3}$ the depth of the beam. If the beams are 6 feet deep, the supports could be no farther than 2 feet from the ends.

Figure 13.12 Prestressed Girder



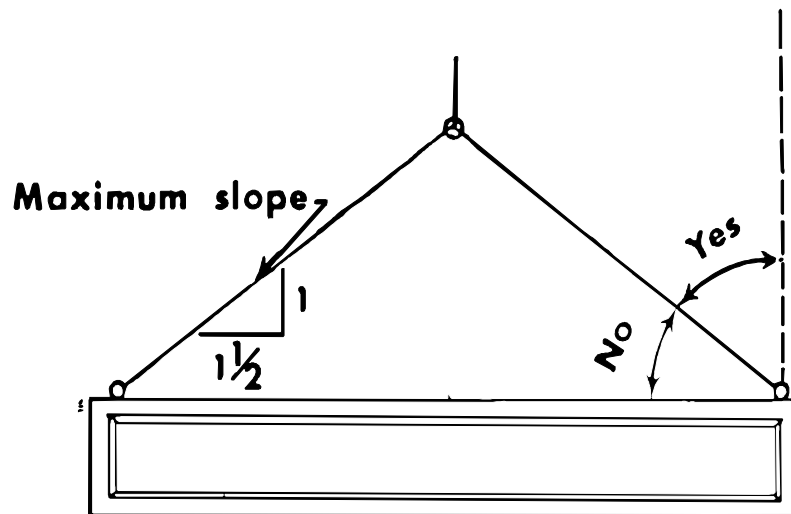
Beams should be picked up and supported only at the designated points unless the plans state otherwise. These pickup points are loops protruding from the beams (one near each end).

Figure 13.13 Lifting Device



Shop plans will specify a maximum slope for the pickup cable, usually 1 1/2 to 1. If a flatter slope is used, the beam can be damaged. Normally the Contractor will use two cranes, one at each end of the beam. If they only use one crane, make sure the cables are long enough to have 1 1/2 to 1 or more slope.

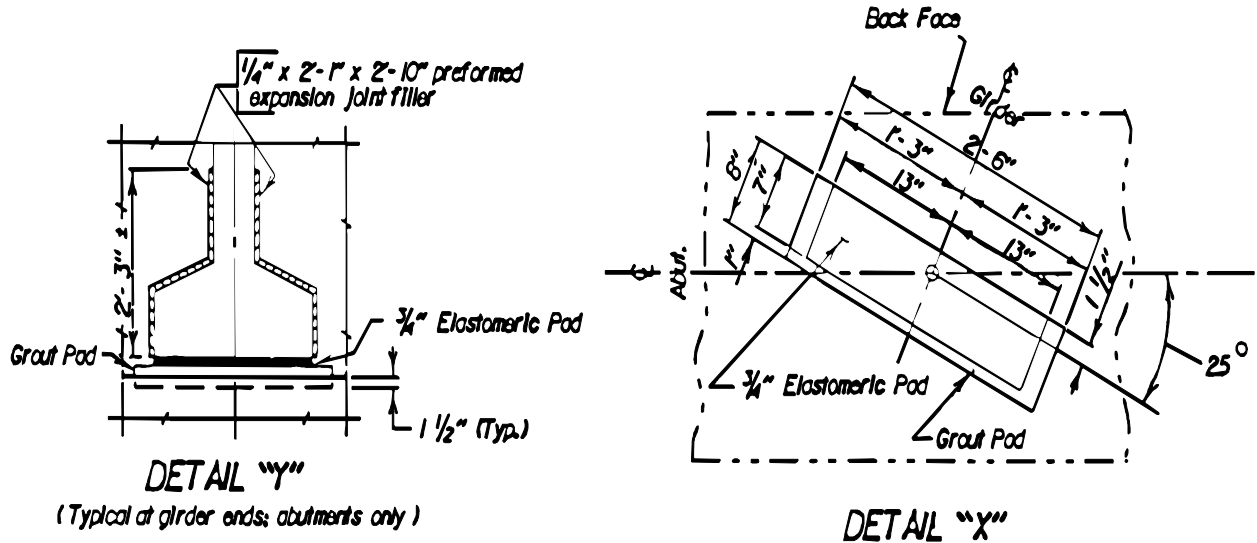
Figure 13.14 Picking Up Beams



Bearings

Prestressed girders are typically set on elastomeric bearing pads that rest on top of grout pads. The grout pads should be constructed the same as described for steel girders. Plans will show where to set the elastomeric pads relative to the center line of bearing. For abutments the pads are generally set 1 1/2 inch past the center line, for piers the pads are generally set 4 1/2 inches or 5 inches from the center line.

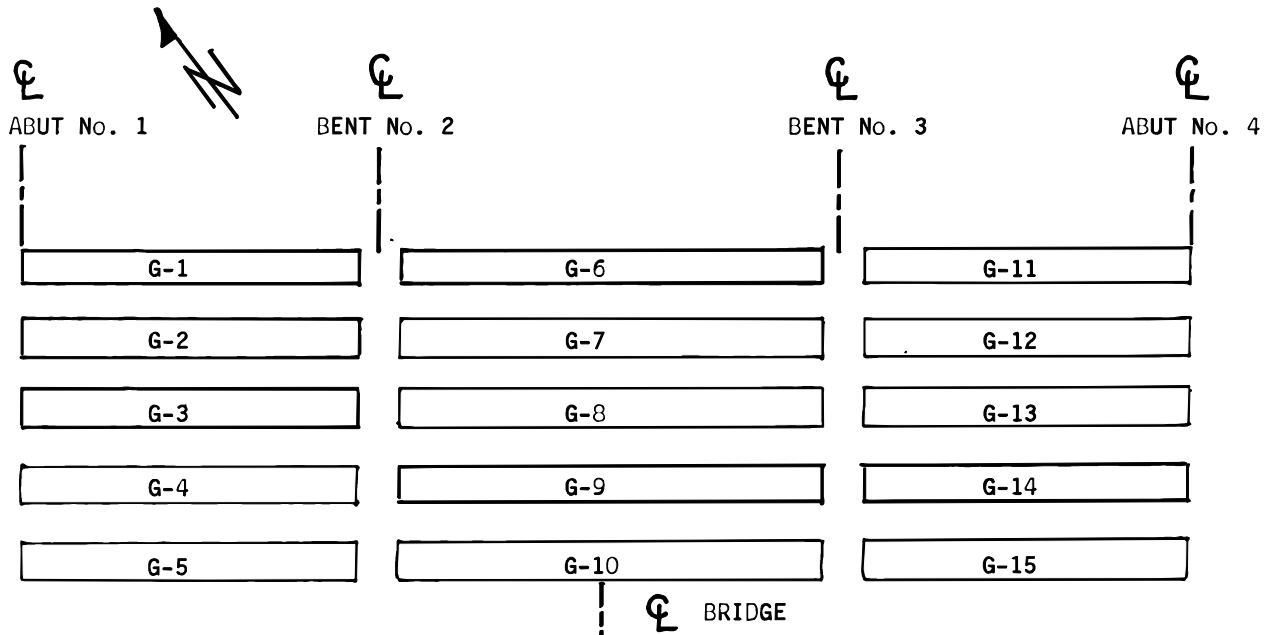
Figure 13.15 Typical Prestressed Girder Bearing at Abutment



Girder Erection

The shop plans will designate an 'ID' marking for each beam that provides its respective location within the bridge. Each beam will be marked by paint or stamp. Pay careful attention when placing the girders to ensure that they go in their correct locations.

Figure 13.16 Example Girder Erection Layout



Diaphragms

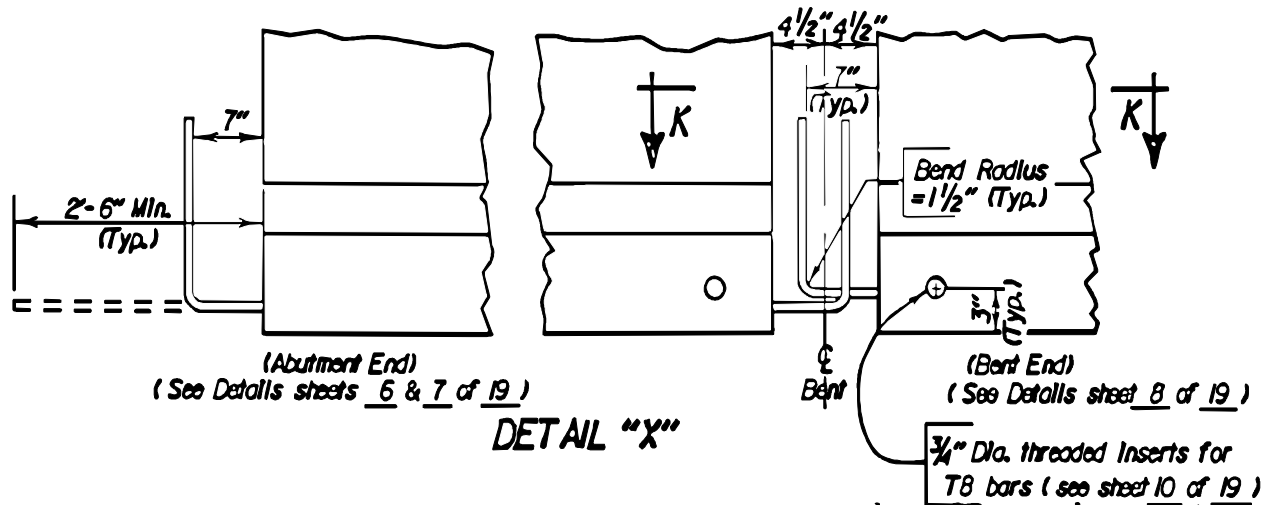
Two types of diaphragms are used for prestressed girder bridges:

- 1 Bent Diaphragms (and Abutment Back walls) at girder ends; and
- 2 Intermediate Diaphragms and girder centers.

Bent diaphragms are concrete diaphragms that are poured integrally with the deck slab. The bottom end strands of the girders are cut 2 feet - 6 inches from the ends of

the beams. They are then bent upwards and serve to help anchor the girder into the diaphragm. See Figure below.

Figure 13.17 Bottom Strands at Bents and Abutments



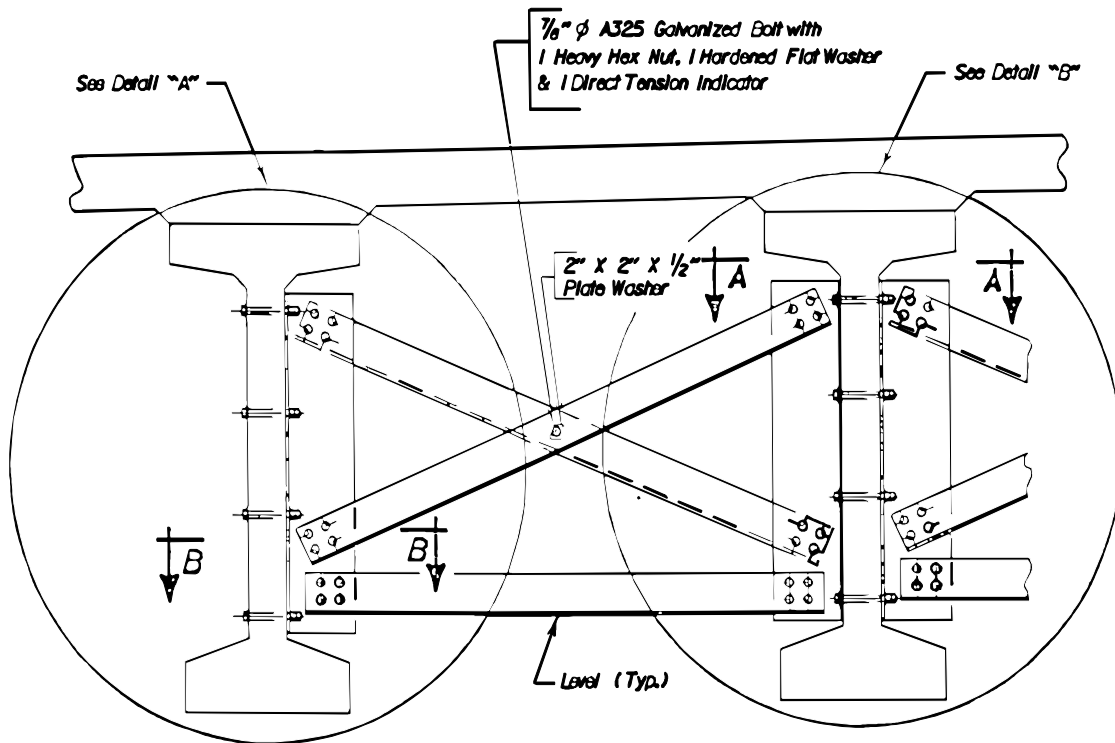
At the Contractor's option, the abutment back wall (which acts as the diaphragm) can be poured separately or integrally with the deck slab. Like the bents, the bottom strands are extended and bent to anchor the girder into the back wall. The lower portion of the girder in the abutment has preformed expansion joint filler applied to each side of the beam for the length of girder embedment. This allows the girder to rotate slightly within the abutment without cracking the abutment back wall.

During the deck slab pour, it is critical to watch for the following in relation to the concrete diaphragms (or back walls):

- Prior to concrete placement, watch to make sure that the diaphragms are clean of loose material and trash that tends to collect in the bottom. It can be difficult to remove debris from the bottom of the diaphragm formwork, especially on deep girders. Often workers will neglect cleaning them out.
- During the deck pour, placement of the concrete in the diaphragms and abutment back walls should not slow down the rate of concrete placement or finishing. The Contractor should time the filling of the diaphragm such that it is filled to bottom of deck level just as the finish machined arrives to finish the deck itself.
- Watch to ensure that the diaphragms are vibrated properly. This could mean not vibrated enough or vibrated excessively. If possible, view the formwork from underneath the bridge at some point during concrete placement. Proper placement should have a small amount of mortar showing through the formwork joints. Excessive bowing or bulging of joints can indicate that the diaphragm was vibrated too much.

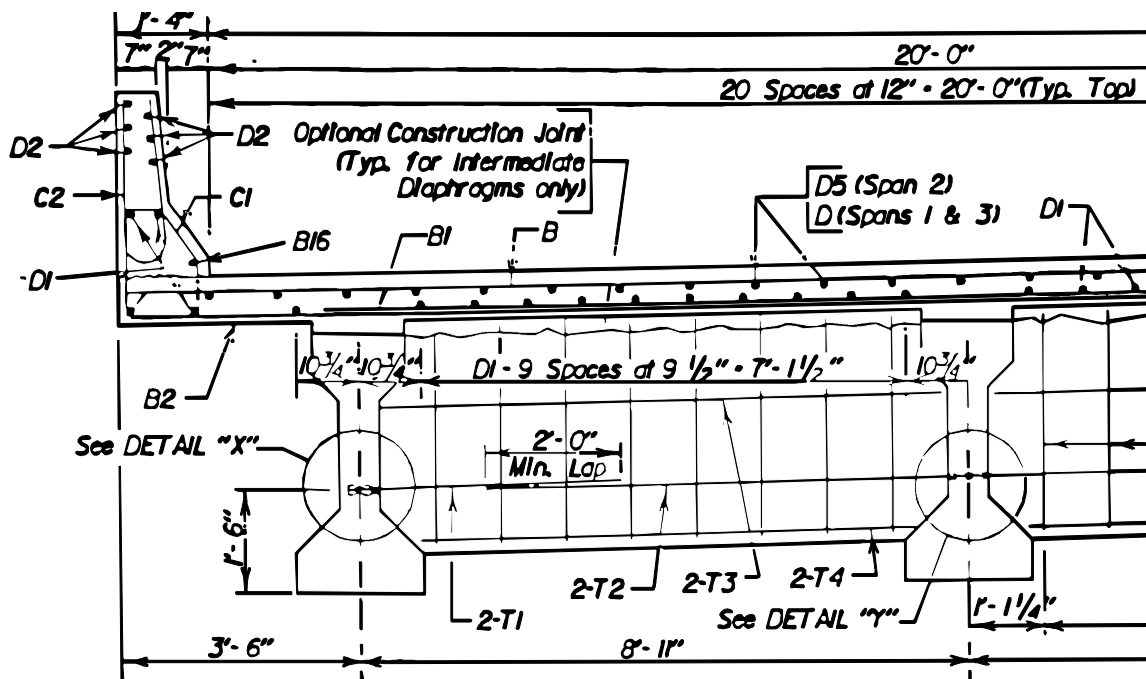
Intermediate diaphragms can either be made of steel or cast-in-place concrete. Steel diaphragms are bolted to the prestressed girders through pipe sleeves that are precast into the beam.

Figure 13.18 Typical Steel Diaphragm for Prestressed Girder



If cast-in-place concrete diaphragms are used, they may be poured prior to or during the deck pour. If poured before the deck, the diaphragms should be allowed to set at least 48 hours before the deck placement. The beams need to be aligned and rigidly held in place until the cast-in-place intermediate diaphragms are set.

Figure 13.19 Typical Cast-In-Place Diaphragm



Girder Age

Prestressed girders continue to gain camber with age. Before the deck can be placed, make sure all beams in the unit were made within an eight day period or at least six weeks old. The manufacturer date is painted on the beam.

Exterior Girder Finish

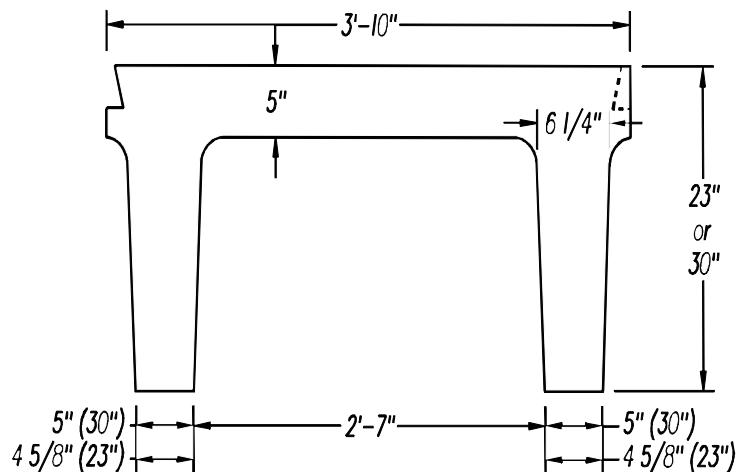
The outer surface of exterior beams must have smooth appearance. While placing the slab, mortar will leak through forms and adhere to the surface. This must be removed. Water and burlap will remove this if done soon after the pouring operation. Rust can be removed with a muriatic acid. Have the Contractor try it on a small patch. He may adjust the strength if necessary.

The plans may call for the exterior girders to receive a commercial texture finish or a special surface finish.

Precast Concrete Deck Structures

The county secondary road systems use a precast deck structure which consists of a number of prestressed channels, sometimes called Double T's. These precast units consist of legs that contain prestressed strands like that described earlier for prestressed girders. The top of the unit is a precast deck segment tying the two legs together.

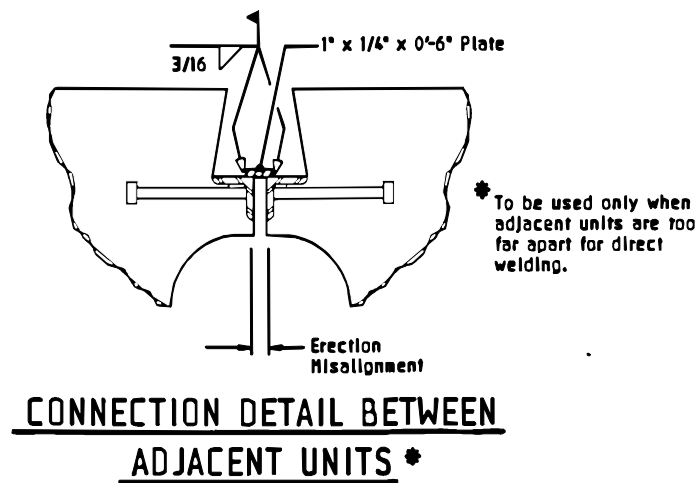
Figure 13.20 Precast Channel



The channels have angles and plates cast into them so they can be welded together. After welding, the gap in the joint (called the key) is grouted shut with a non-shrink grout. Combined together, the top of the channels form the bridge deck surface that carries traffic. In order to create a smooth driving surface, the units must have approximately the same relative camber. You should check to ensure that adjacent precast units do not have a differential camber greater than 1/4 inch in 10 feet or 3/4 inch maximum.

Usually these structures are single span with abutments consisting of wood or steel piling, and wood or prestressed planks fastened to the outside of the piling to retain the earth fill. The channels rest upon wood or steel caps supported by the piling. There may be, however, bridges that are multiple span or channel bridges that rest on concrete abutments similar to those used for typical state highways. Usually a neoprene pad will be placed between the channel and the supporting substructure unit.

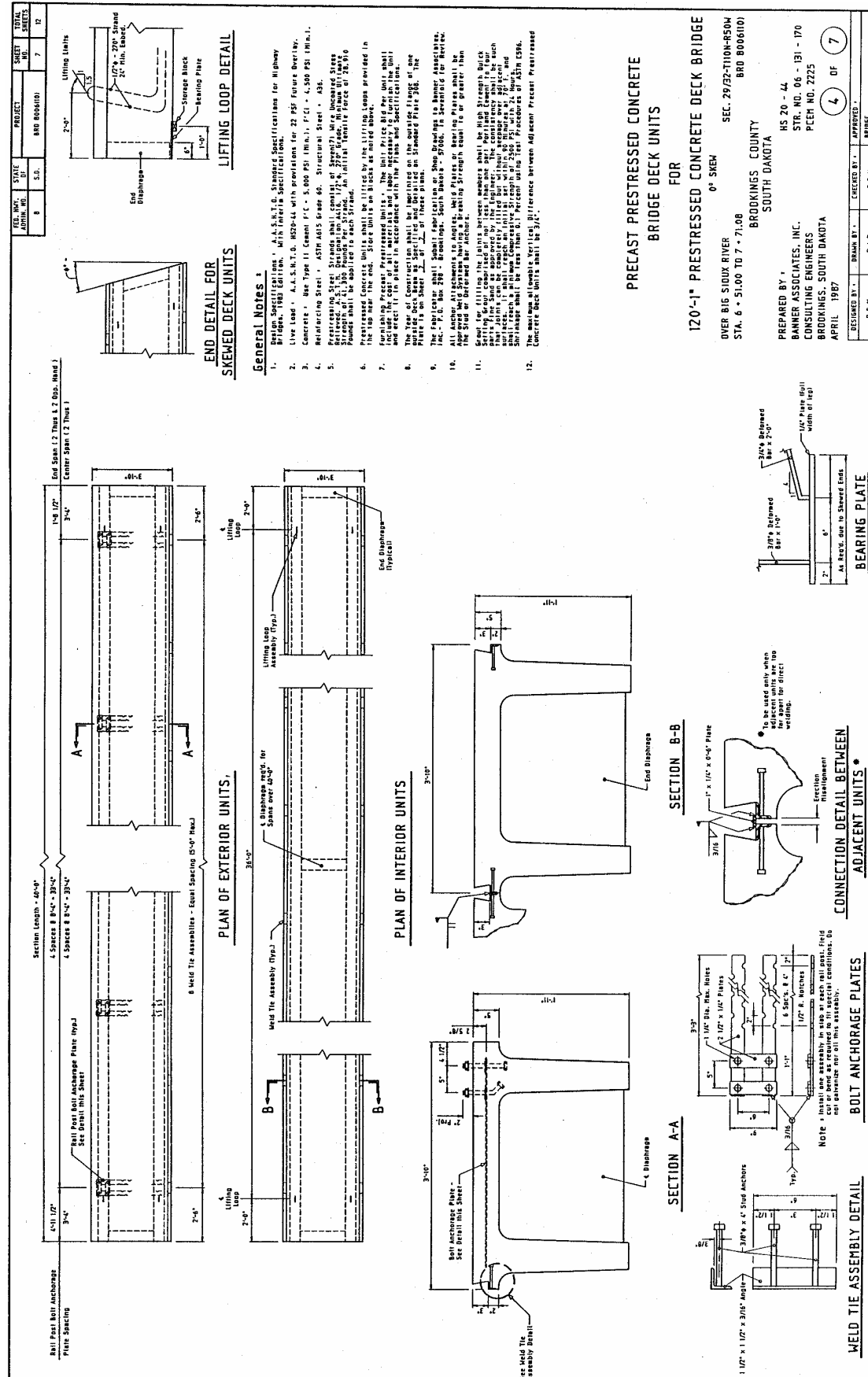
Figure 13.21 Connection Detail



Channels are designed by the fabricator to carry the loads indicated on the plans. As a result, usually a copy of the structural design computations stamped by a registered Engineer as well as shop plans are required to be submitted for approval prior to constructing the units. See 'Chapter 12 - Shop Plans and Fabricated Items' for more details on the shop plans approval process. Usually the depth of the unit will be specified on the plans. However, because the fabricator designs the channels, there may be an option available for the fabricator to adjust the depth as required. You should check to make sure the abutment caps, and if it is a multiple span structure also the bent caps, are at the correct elevation to accommodate the unit depth.

Usually a layout of the channels is given on the shop plans for skewed and multiple span structures. Particular attention should be given to this so the channels are placed in the proper location. The exterior channels will usually have anchor bolts or steel plates embedded so that rail posts can be attached to them. The railing may not fit if the exterior channels are not placed in their correct location. Handling of the channels is similar to that for the beams, and when stored, must be supported approximately 1 foot from the ends.

Figure 13.22 Typical Plans Sheet for Precast Channel Details



PAINTING AND REPAINTING

Checklist

Inspection at Delivery

- Overall condition. Inspect for general overall condition, evenness and appearance
- Damaged areas. Nicks, scratches, or other evidence of mishandling and damage
- Missed Areas
- Runs or Sags
- Dry Film Thickness (DFT)
- Notify the Project Engineer or Office of Bridge Design of any damage

Handling

- Equipment and falsework padded to prevent damage
- Steel stored off ground on padded supports

Field Touch-Up and Repair

- Deck poured and falsework removed prior to field repair
- Steel given a thorough inspection to identify all areas needing repair or touch-up
- Protection of pedestrians, traffic, or other parts of the structure considered and installed
- Temperature and weather conditions favorable for time of application and cure time required
- Coating materials from Approved Products List for field painting

Bridge Repainting

- Pre-Surface Preparation Inspection
 - Containment plan approved by Bridge Office
 - Coating materials (paint/thinner) from Approved Products List and received in good condition
 - Shelf life or pot life not exceeded
 - Abrasive material able to provide surface profile required (manufacturer's product data should give approximate indication of ability)
 - Blastox added to abrasive in the amount of 15% by weight

- Moisture traps and oil separators installed in supply air
- Air purifiers and monitors installed in breathing air supply
- Bridge repainting testing and inspection kit obtained
- Existing bridge reviewed for trouble area
- Ambient conditions monitored
- Class I Removal - Power tool cleaning
 - All areas of visible grease, oil, dirt, or other soluble contaminants removed by solvent cleaning
 - Power tools shrouded at cleaning head and equipped with a vacuum collection system
 - All detrimental loose material removed in accordance with SSPC SP-3
 - All residue placed in a 55 gallon drum after collection. Marked Hazardous Waste and for date filled
 - Residue weighed to verify that it is less than 220 pounds
 - Contractor is responsible to collect and temporarily store residue. Department is responsible for disposal.
- Class II - Abrasive Blasting
 - All areas of visible grease, oil, dirt, or other soluble contaminants removed by solvent cleaning
 - Collection and containment system in place
 - Wind conditions favorable for removal
 - Blotter test on compressed air performed to verify that it is free of oil and moisture
 - Blasting pressure verified
 - Mock-up test panel established
 - Removal to 'commercial blast cleaned surface' in accordance with SSPC SP-6
 - Surface profile or anchor pattern verified
 - Hard to reach areas verified
 - All residue placed in 55 gallon drum(s) after collection
 - Sample of residue submitted to Office of Bridge Design after first drum is filled
 - Collector emptied at end of workday
- Paint Application
 - Ambient conditions acceptable
 - Within 24 hour time limit from abrasive blasting
 - Paint mixed as per manufacturer's instructions
 - Thinning (if required) done strictly as per manufacturer's instructions
 - All edges and corners, rivet heads, bolts and nuts, and small individual members given a brush coating in advance of spraying coating
 - Spray being applied in correct pattern and technique
 - Brushes, rollers, and/or mitts clean and well maintained
 - Wet film thickness spot checked frequently

- Dry film thickness checked between coats and after final coat
- If painting and blasting operations are performed at same time (i.e. opposite ends of girder, etc.), monitor over blast
- Over-spray, drips, and other application defects corrected while coating is still wet.
- Final Inspection and Repairs
 - Final condition of coating acceptable. The items below verified/corrected:
 - Dry Film Thickness correct
 - No dry spray
 - No mud-cracking
 - No runs or sags
 - No delamination

General

Painting serves primarily to protect steel against corrosion (rusting) and, secondarily, to improve its appearance. Rust can weaken the metal and cause a failure. The items that normally require painting are steel beams and girders, bracing, bridge rails, and some expansion and fixed devices. Occasionally, other items may require painting as noted on the plans.

By specifications, all new structural steel will have both prime and finish coats applied in the shop prior to shipment. Painting in the fabrication shop typically consists of abrasive blasting to a near white finish then applying an inorganic Zinc prime coat. After the prime coat has cured properly, a polyurethane finish coat is applied. With the exception of bolted field splice areas, the prime coat should be 3-6 mils and the finish coat should be 3-5 mils when completely dried and cured. For bolted splice areas, only a primer coat of 1-2.5 mils should be applied.

Your responsibility starts when the product is delivered to the job site. Major structural items such as steel girders will generally have a DOT inspector at the shop monitoring and approving the application of the paint system. However, several miscellaneous smaller items, including at times steel bridge railing, may not have any inspector at the shop. You may be the first Department representative to inspect and accept the condition of the shop applied paint.

Inspection at Delivery

After a painted structural steel item has been delivered to the site, you should inspect the condition of the painted surface. Some general items to look for are:

- Overall Condition - Inspect the overall general condition of the coated surfaces for evenness, mud-cracking, blistering, peeling, soft to the touch, or any other signs that may indicate that the surface and application was not applied and cured correctly.
- Damaged Areas - Look for nicks, scratches, or other damage that may have occurred during handling and transportation.
- Missed Areas - Pay particular attention to inaccessible areas that are difficult to blast or paint such as behind brackets, inside edges of channels, or other hard to reach areas.

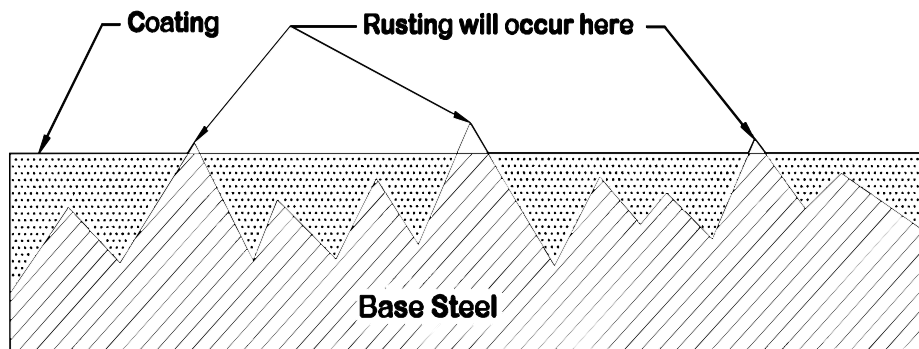
- **Runs or Sags** - Check for areas that may have excessive running or sagging. Small isolated cases of sagging are acceptable. However, large areas of sags indicate that the coating was applied improperly and may need to be corrected.
- **Dry Film Thickness (DFT)** - Verify with the Central Office whether or not the item was inspected in the shop. If not, you should check the finish thickness of the paint system with the testing apparatus as described below.

Dry Film Thickness (DFT)

The DFT is simply a measurement of the thickness of the paint coat after it has completely cured. When measuring in the field, the film thickness is actually the combined thickness of both the prime and finish coats. This combined coat thickness should be 6-11 mils - a 'mil' is 1/1000 of an inch. A typical piece of writing paper is about 3 mils thick, a typical dollar bill is about 4 mils thick.

Measurement is actually an average reading of the film thickness over a given area. Steel, although smooth to the touch, is still a 'rough' surface when blown up under a microscope. The paint actually fills in the valleys and should cover the peaks. When coatings are too thin the failure begins by pinpoint rusting where the anchor pattern of the base steel extends through the coating system. In later stages, it appears as general rusting of that area.

Figure 14.1 Pinpoint Rusting



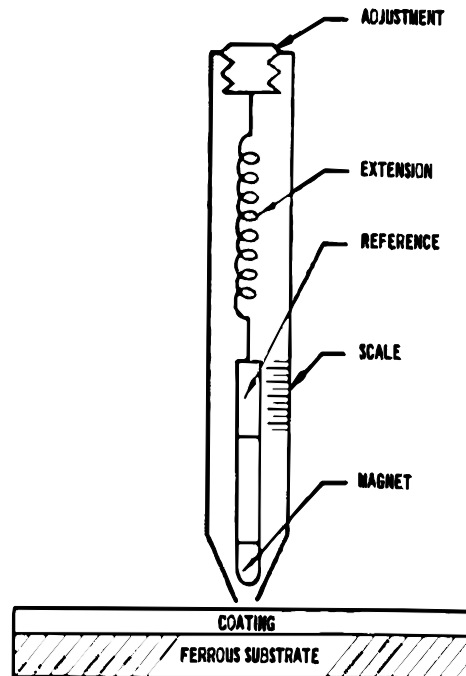
There are many different gauges that measure DFT. These gauges range from a spring loaded magnetic pencil gauge to highly complex electronic instruments. The most common DFT gauges are the magnetic pull off variety, and the digital thickness gauges. The Department has on hand, a paint testing kit that includes instruments that can measure the film thickness as well as instructions on how to properly use them. The thickness should be measured in accordance with the Structural Steel Painting Council (SSPC) Specification PA 2. Each type of gauge should be calibrated both before and after testing to ensure the accuracy of the film thickness testing.

Figure 14.2 Paint Inspection Kit



Thickness readings are taken to provide reasonable assurance that the specified or desired dry film thickness has been achieved. However, it is not possible to measure every square inch of the surface. SSPC PA 2 states that five separate spot measurements should be made over every 100 square feet in area. Each spot measurement consists of an average three gauge readings next to one another. The average of the five spot measurements must be within the specified thickness, while single spot measurements are permitted to be 80% of the specified thickness. The single gauge readings making up the spot measurements, however, can under-run by a slightly greater amount.

Figure 14.3 Operating Principle of Pencil Pull-Off Gauge



Example: Assume a specification calls for 10-12 mil of dry film thickness. The five spot measurements (each a cluster of three readings) are as follows:

Spot 1 - Readings are 10, 11, and 12 for an averages of 11 mils.

Spot 2 - Readings are 7, 8, and 9 for an averages of 8 mils.

Spot 3 - Readings are 12, 12, and 12 for an averages of 12 mils.

Spot 4 - Readings are 7, 8, and 9 for an averages of 8 mils.

Spot 5 - Readings are 12, 13, and 11 for an averages of 12 mils.

Solution: This measured area would be acceptable because the average of the five spots is 10.6 mils and thus within specification. The 8 mil spot measurement would be acceptable because it is not less than 80% of the required thickness (8 mils is exactly 80% of the 10 mil minimum). The 7 mil single gauge reading is acceptable because single gauge readings may under-run by a greater amount.

Be careful what areas you choose to test. Specifications Section 411.3.B.3 requires that the areas to be measured are the top of the bottom flange, top of horizontal stiffeners, and top surfaces of diaphragms. You should also check the thickness along the edges of members. The surface tension of paint as it cures tends to pull the paint away from sharp edges, so the edges should be closely looked at.

Handling and Care of Painted Items

Extreme care must be exercised in handling the painted steel during shipping and erection and then during subsequent construction of the bridge. Overhang brackets shall be padded where they bear against the web. Deck formwork shall be mortar tight to prevent leakage onto the girders. The steel shall be stored off the ground on padded supports.

Field Touch-Up and Repair

Although construction practices should use care when handling painted steel as explained above, there may still be need for touch-up and repair of painted surfaces. The shop applied primer, inorganic zinc, requires a high degree of skill and careful control of surrounding environment to properly cure. For this reason, the primer coat used in the field is an epoxy mastic primer rather than an inorganic zinc. The finish coat, however, is still the same shop applied polyurethane coating. Both field coats may be applied by spraying, brushing, or rolling as determined by the manufacturer's recommendations. In inaccessible areas, sheepskin daupers may be used.

The field touch-up painting should follow the same procedures as outlined in Specifications Section 412 under bridge repainting. Bridge repainting procedures are covered in depth later in this chapter.

Field repair shall not be performed until after the deck is poured and falsework removed. All damaged areas should then be repaired. Note that bolted connections and field splices will most always need to have field touch-up to paint the galvanized bolts and any surfaces that may be exposed having only a primer coat.

The temperature and weather conditions have a big affect on painting. Paint cannot be applied when the temperature is below 40 degrees F or above 90 degrees F, when surfaces are damp, or when the humidity exceeds 85%.

It is important to watch that the paint is applied uniformly. If the paint does not look uniform, advise your supervisor. If the work is unsatisfactory, they may order the Contractor to remove the paint, clean the metal, and completely repaint the area.

The Contractor shall protect pedestrian, vehicular, and other traffic upon or underneath the bridge and also other parts of the structure. Do not allow painting without such protection.

Bridge Repainting

A great many of the existing steel girder bridges built in South Dakota have weathered and deteriorated paint systems that require repair. Years ago repainting a structure was not much different than giving your house another coat of paint. Today, however, repainting a structure is a complex issue. Increased emphasis on the enforcement of environmental regulations has made repainting a bridge a major task. While the emphasis for many of these regulations has come from the Federal Government, it is the State and other local government agencies that must set the limits and enforce the regulations. The regulations that have most greatly affected field painting activities recently are those concerned with solid waste, air quality, paint formulation, and water quality.

The largest impact on South Dakota projects is the classification of lead as a hazardous material. Lead had been used as a pigment in paint coatings for over 100 years prior to its hazardous classification. It is estimated that as much as 80% of the bridges in the United States may be coated with lead based paints. Any material used in the removal process, such as blast cleaning debris, must be collected and tested for leaching characteristics to determine if it will be classified as hazardous or non-hazardous material. South Dakota has recently begun using a blasting media additive that has the ability to absorb and lock the lead particles and prevent them from leaching. These measures have helped to reduce the quantity of hazardous material generated from a bridge repainting project. However, until the media can be tested, it must be treated as a hazardous material. The rule of paint residue when it pertains to hazardous classification is "guilty until proven innocent".

In addition, the coating systems used for painting structures today require a greater degree of inspection as compared with bridge repainting coatings of the past. These new 'high-tec' coating systems are much more sensitive to ambient and environment conditions, surface preparation, and application procedures.

Paint Removal and Bridge Repainting Classifications

The Standard Specifications divide existing bridges to be repainted into two separate categories, dependent on the amount of work and surrounding environment involved. These categories are as follows:

- Bridge Repainting, Class I - Work consists of the removal of existing paint, preparing the surface, and repainting only in the work affected areas.
- Bridge Repainting, Class II - Work consists of the complete removal of the existing paint, preparing the surface, and repainting the entire existing structural steel.

Because of the environmental issues and more sophisticated 'high-tech' coatings now associated with bridge repainting, the role of the inspector has changed greatly. The inspector's role will cover these four key issues:

- 1 Pre-surface preparation inspection
- 2 Surface preparation inspection
- 3 Application inspection
- 4 Final inspection and acceptance

Pre-Surface Preparation Inspection

Inspection is required to assure that the materials the Contractor will use and the conditions under which he/she works are correct. Allowing work to proceed with out-dated material, incorrect abrasive, contaminated air or in the wrong ambient conditions can lead to premature failure of the paint system. Anticipating problems before hand is much preferred to reporting and correcting problems after the fact. Pre-surface preparation inspection involves the following items:

- Inspection of equipment, coating materials, cleaning solvents, abrasives, and their storage conditions
- Familiarization with ambient conditions
- Familiarization with the bridge
- Verification that inspection instruments are on site and calibrated

Coatings Material Inspection

The initial inspection of coating materials should assure the following:

- That the material storage area is capable of complying with the specification and safety requirements.
- That the right coatings and thinners have been purchased.
- That the coating materials have been received in good condition and in sufficient quantity.
- That the shelf life will not be exceeded prior to the material application.

Specifications require that the paint system be one of the systems on the Approved Products List for 'Paint for Repainting Bridges'. You should verify and document that the paint materials match those on the list for each specific coat (primer, midcoat-where applicable, and topcoat). Check to make sure that the final coat color matches

that required by plans. When only spot painting work affected areas, the Contractor should obtain a paint chip sample from the existing bridge and submit it along with a proposed color chip sample for the new paint to the Office of Bridge Design for approval.

Material storage areas should have the capability of maintaining storage temperature within the specified limits. The storage temperature can be easily verified with a High/Low Thermometer or with two surface thermometers with built-in indicators of the highest or lowest temperatures reached. The thermometers should be placed in a high position in the warm season and a low position in the cold season to assure that the critical temperatures are being measured. If variations from the specified temperature occur, you should notify the Office of Bridge Design.

Material should be received in undamaged and unopened containers. Minor dents, which do not result in spilled material or opening of containers, are acceptable. Containers should remain unopened until needed and the oldest material should be used first. Each type of material, including individual components, should be segregated. Damaged material should be segregated and removed from the job site. Removal decreases the possibility of inadvertent use.

Abrasive Inspection

The most common types of abrasive used for abrasive blasting of bridges are synthetic abrasives. The two inspection concerns regarding abrasives are if the abrasive will produce the specified anchor pattern and if the abrasive will contaminate the surface. The depth of the anchor pattern varies with the blast pressure, particle size, and hardness. Productive blasting is accomplished at a minimum pressure of 90 psi at the nozzle. Pressures below 90 psi reduce productivity and may reduce the anchor pattern.

Most abrasive suppliers sell several grades of abrasive and publish the anchor pattern created by each grade. This information should be obtained from the manufacturer and checked against the Specification. Specifications require that the anchor pattern or surface profile of the bare steel should be between 1-3 mils prior to application of the primer coat.

It is good practice to retain a sample of the abrasive regularly and visually compare it with the abrasive first used. During blasting operations, if you notice a significant change in particle size, you should remeasure the anchor profile and determine if corrective actions are needed.

In order to minimize the amount of hazardous leaching material generated, the Specifications require that Blastox (or an alternate approved product) be added to the blasting media. Blastox is a special blasting media that has the ability to absorb lead particles and effectively keep them from leaching. The Blastox should be added to the abrasive media in the amount of 15% by weight. The Contractor should thoroughly blend the Blastox with the other media using a portable concrete mixer or other method as approved by the Engineer. Note that typically the media is purchased and delivered pre-blended.

Normally, abrasive contamination of a blasted surface is inspected with unmagnified visual observation. Clear scotch tape may also be used to document surface contamination. If the surface appears to be contaminated, have the surface solvent washed again after blasting and prior to painting. The surface must be entirely dry prior to painting.

All types of abrasive must be stored dry. Wet abrasives will clog the blast pot and contaminate the surface. Bag storage must be off the ground and covered. Bulk storage is normally accomplished in the hopper that fills the blast pots. Samples of each shipment of abrasive should be retained for future reference. The samples can be used for comparative analysis since variations from one shipment to the next do occur.

Equipment Inspection

The selection and sizing of equipment is the Contractor's responsibility. The inspection concern is to assure that the equipment will not contaminate the surface or the material.

The chief contaminants supplied by the equipment are water and oil. To prevent contamination, you should verify that moisture traps and oil separators are installed in the air supply. Blotter tests should be conducted to verify dry, oil-free air. Air should always be tested when it is used for nozzle blast cleaning, power tool cleaning, blowing off the surface, or conventional spray coating. If a contamination is noted on the Blotter Test, the Contractor will need to add or clean moisture traps or oil separators. After the contamination problem is eliminated, the air should be reinspected prior to resuming production. Surfaces which have been contaminated should be re-blasted. The blotter test is discussed in the next section under Surface Preparation Inspection.

Ambient Conditions

Moisture on a freshly blasted steel substrate will cause rusting. Application of a protective coating when the air temperature, surface temperature, or humidity is too high or too low can cause blistering, pinholing, cracking, sagging, and many other defects. The Specifications require that paint can only be applied when the coating materials, substrate, and air temperatures are between 40 degrees F and 90 degrees F. It also states that the paint can only be applied when the surface to be coated is and remains at least 5 degrees F above the dew point. The relative humidity must be less than 85% during the paint application. Specifications require that paint must be applied within 24 hours of the blast cleaning. Although not required, it is a good idea to hold up on blast cleaning until the ambient conditions listed above are met, otherwise the Contractor may likely have to re-blast the steel prior to painting.

The verification of ambient conditions involves the use of a psychrometer, a surface temperature thermometer and a psychrometric chart or tables. These items are available in Paint Inspection Kits that the Department has available. You should have one of these kits on hand prior to the beginning of the project. Contact the Region Materials Engineer if you do not have one of these kits available.

The surface temperature thermometer contains magnets, which attach to any ferrous surface. The temperature is measured at the work location with a bimetallic sensing unit located between the magnets. The thermometer should be placed on the steel in a shaded location and not in direct sunlight. Temperature can be read approximately three minutes after installation.

A psychrometer is an instrument used to measure ambient air temperature and wet bulb temperature. These measurements are used to calculate the relative humidity and dew point temperature. The wet bulb reading results from the latent heat loss of water evaporating from the wick.

The sling or battery operated psychrometer contains two identical thermometers. The base of one thermometer is kept wet with a wick or sock to simulate 100% moisture saturation. This thermometer results in the wet bulb reading. The second thermometer gives the dry bulb or ambient temperature.

The psychrometric chart or table allows the user to determine the relative humidity and dew point temperature from the wet and dry bulb temperatures obtained from the psychrometer. The dew point temperature is the temperature at which water in the air will condense (at the present relative humidity). Definitions applicable to the use of this instrument are as follows:

- Relative Humidity - Relationship of the actual pressure of existing water vapor to maximum possible (equilibrium saturation) pressure of water vapor in the atmosphere at the same temperature, expressed as a percentage.

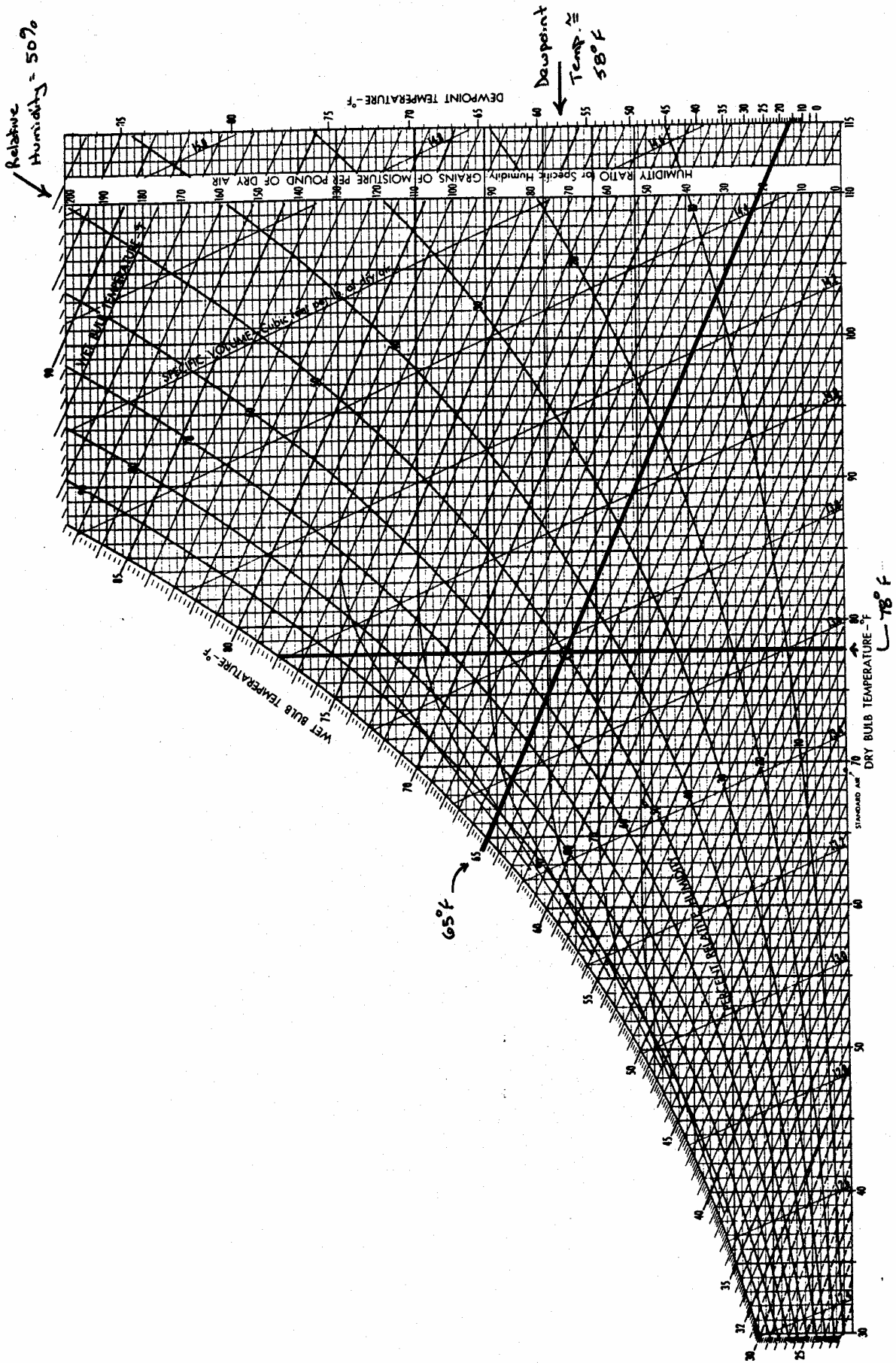
- **Dry-Bulb Temperature-** Temperature of the air as indicated by an accurate thermometer, corrected for radiation if significant.
- **Wet-Bulb Temperature-** Temperature indicated by the wet-bulb thermometer of a standard psychrometer when constructed and used in accordance with the standard procedure specified in this method. The wet-bulb thermometer is the one with a moistened cotton or linen wick covering the bulb.

The procedure for use of the sling psychrometer is as follows:

- 1** Assure that the wet bulb wick is clean prior to each use.
- 2** Saturate the wick with clean water. Do not wet the dry bulb.
- 3** Whirl for approximately 20 seconds, and record the wet and dry bulb temperature.
- 4** Repeat step 3 until the reading stabilizes.
- 5** Enter the psychrometric chart on the horizontal axis at the dry bulb temperature and draw a vertical line.
- 6** Enter the psychrometric chart on the curved line at the wet bulb temperature and draw a diagonal line.
- 7** Determine the relative humidity at the intersection of the two lines.
- 8** Draw a horizontal line from the intersection of the two lines, and determine the dew point temperature on the curved line.
- 9** Assure that the steel temperature is at least 5 degrees F above the dew point temperature and that the relative humidity is below 85%.

Readings must be taken where they are not affected by sun or thermal radiation. They must be taken at the actual work location. The conditions in hot, cold, and moist areas should be checked.

Figure 14.4 Example Psychrometric Chart



The interior supporting structural steel on bridges tends to stay cool and moist much longer than the exterior exposed structural steel. Treat each differently.

High wind can be detrimental to a coating job. Wind can cause excessive drift, overspray, dry spray, and unequal coating thickness. When the wind velocity is such that residue is falling outside the limits of the collector, or exceeds 20 mph during the coating operation portion of the job, work should be discontinued.

Becoming Familiar with the Bridge

The best place to determine where coatings are likely to fail first is on the existing structure prior to coating. During re-coating operations, particular emphasis should be placed on previously prematurely failed areas.

Paint Inspection Kit

The final pre-start action is to conduct an instrument inventory to assure that all of the required inspection instruments are on site and that they are calibrated. As stated previously, the Department has paint inspection kits available for use on bridge repainting projects. The kit should contain all the necessary tools and instruments necessary to adequately inspect the work. You should familiarize yourself with all the tools in the kit and how to use them. In addition, some of the tools require calibration both before and after each use to maintain their accuracy. You should make sure that these tools have been properly calibrated before using them for acceptance or rejection of the work.

Surface Preparation Inspection - General

The purpose of surface preparation is to clean and modify the existing surface sufficiently to achieve adhesion of the new coating. A coating system will adhere only as well as its weakest point. Adhesion is a primary key to coating effectiveness, and it determines whether the coating is merely a thin sheet of material lying on the substrate or whether it becomes an actual part of the substrate.

For repainting of bridges, adhesion is achieved by mechanical bonds associated with the surface roughness or anchor pattern. Adhesion requires that the existing surface be clean to allow intimate contact between the freshly applied coating and the substrate. Types of contamination which must be removed from an existing surface to assure good adhesion include:

- Mill scale
- Oil
- Grease
- Rust
- Chemical contaminants
- Existing loose paint

The most common referenced standards for evaluating surface preparation are those published by the Steel Structures Painting Council (SSPC). The South Dakota Standard Specifications reference SSPC as the limiting standard. Copies of pertinent sections of SSPC Standards have been included in the Appendix for your use and reference.

Solvent Cleaning

Solvent cleaning is a method for removal of all visible oil, grease, soil, drawing, or cutting compounds, and other soluble contaminants from the existing steel surfaces. It is necessary for two reasons:

- 1 The coating will not adhere to a surface containing oil or grease residue.
- 2 The abrasive blasting or power tool cleaning process can force deposits of oil and grease into the surface pores of the metal instead of removing it.

Note Unless otherwise specified, solvent cleaning is required for all existing visually contaminated surfaces to be repainted, regardless of the bridge repainting classification. It should always be performed first, prior to any subsequent removal operations.

You should check to make sure that the solvent is one of the products allowed under current specifications.

Bridge Repainting, Class I - Power Tool Cleaning

As stated previously, removal in Class I is limited to only the work affected areas. Generally this pertains to repairing the ends of girders that are more or less directly underneath open joints, and weld affected areas.

The removal of the existing paint is limited to power assisted hand tool cleaning in accordance with SSPC Standard SP 3. Power tool cleaning removes all loose mill scale, loose rust, loose paint, and other loose detrimental foreign material. It is not intended that adherent mill scale, rust, and paint be removed by this process. These can be considered adherent if they cannot be removed by lifting with a dull putty knife. The power tool cleaning should not remove any of the base metal.

Collection and Containment

By specifications, all power tools must be shrouded at the cleaning head and equipped with a vacuum collection system to contain the residue. A written 'Containment Plan' should be given to the Engineer at the pre-construction meeting. This plan should be forwarded on to the Office of Bridge Design for review and approval.

All paint residue shall be placed in a 55 gallon drum after collection. The 55 gallon drum shall be supplied by the Contractor. If the 55 gallon drum is not new, it shall not have previously contained any petroleum products and must meet the EPA definition of a reusable container. All paint removal, residue collection, and temporary storage shall be performed by the Contractor. Disposal will be performed by the Department.

If less than 220 pounds of paint residue is produced, then the waste will not require sampling, testing, and disposal as a hazardous waste. The Contractor will have to collect and weigh all of the paint residue to document that less than 220 pounds of waste material was produced. Only blasting or paint residue should be stored in the drum. If other refuse material (empty paint cans, etc.) is placed in the drum with the paint with the paint residue, then it too must be weighed and considered as part of the residue. If more than 220 pounds of waste material is produced, you should contact the Office of Bridge Design for further instructions.

Note The Contractor is responsible for complying with all regulations and for taking all necessary measures and precautions to ensure worker safety for work involved with lead particles.

Bridge Repainting, Class II - Abrasive Blasting

Bridge Repainting, Class II

Work under Class II involves the complete removal of the existing paint by abrasive blast cleaning. As stated previously, the abrasive is to have Blastox (or some other approved product) thoroughly blended into the media in order to eliminate the instance of residue testing as a hazardous material.

The specifications require that the entire surface be cleaned to a condition equivalent to the SSPC Standard SP-6, Commercial Blast Cleaning. A commercial blast cleaned surface, when viewed without magnification, shall be free of all visible oil, grease, dirt, dust, mill scale, rust, paint, oxides, corrosion products, and other foreign matter, with the exception of staining as described below.

Staining shall be limited to no more than 33% of each square inch of surface area and may consist of light shadows, slight streaks, or minor discoloration caused by stains of rust, stains of mill scale, or stains of previously applied paint. At least 2/3 (67%) of each square inch must be free of all visible residue.

Specifications require that the abrasive blasting prepare the bare steel to have a surface profile of 1-3 mils. Surface profile, or anchor pattern, is a measurement of the roughness of the surface. The roughness has a significant effect on the performance of the coating. If too smooth, there is little mechanical adhesion. If too rough, there is difficulty in obtaining adequate coating thickness because of the irregularities. When the DFT is measured, it is to represent that thickness required above the peaks of the profile.

Mock-Up Panel

Prior to the start to the abrasive blast cleaning operations, the Contractor should blast a mock-up test area of a girder web to SSPC Standard SP-6. The panel should be full depth of the web and 3 feet in length. Using the visual and profile standards (described in subsequent sections), inspect the area to determine when adequate surface preparation has been achieved. After adequate surface preparation has been achieved, this area shall be preserved for reference purposes during the remainder of the abrasive blast cleaning operation. If deterioration of the mock-up panel occurs due to weathering, dampness, or other conditions, a new area should be prepared at no additional cost to the Department. The Contractor may be allowed to clear coat the mock-up panel to protect it against the elements provided the mock-up area is re-blasted prior to being painted with the bridge coatings. Approval must be given by the Office of Bridge Design prior to allowing the Contractor to clear coat the mock-up panel.

Collection and Containment

Federal regulations on solid waste under the Resource Recovery and Conservation Act (RCRA) are different for collected material weighing more than 220 pounds versus material weighing less. Unfortunately, abrasive blasting nearly always generates more than 220 pound of residue. In order to comply with Federal regulations, all material must be treated as a hazardous waste until it can be tested and proven that it is not. For this reason, all paint residue and/or blasting media must be contained, collected, and temporarily stored during paint removal operations. Only blasting and/or paint residue should be stored in the drum. If other refuse material (empty paint cans, etc.) are placed in the drum with the paint residue, then it too must be weighed and considered as part of the residue. All drum collected material should then be loaded, transported to the location specified in the plans, and unloaded by the Contractor.

Like power tool cleaning, abrasive blasting requires that the Contractor submit a written Containment Plan to the Engineer at the pre-construction meeting. The Engineer will forward the proposed Containment Plan to the Office of Bridge Design for review and approval. Possible containment methods include draped collectors suspended from the structure, tarps laid on the ground below the structure (when not near a waterway or in an urban environment), or complete enclosures.

If a draped collector is used it shall conform to the following minimum requirements:

- The collector shall be suspended from the structure and shall extend a minimum of 10 feet wider, in all directions, than the area in which work is underway.
- The collector shall be positioned in a manner acceptable to the Engineer and such that no loss of blast cleaning/paint residue occurs.
- The collector shall be emptied at least once a day and shall not remain in place overnight without being emptied.

Paint residue, including abrasive blasting residue, should be placed in 55 gallon drums after collection. If the 55 gallon drums are not new, the drums shall not have previously contained petroleum products. The drums shall meet the EPA definition of a reusable container. The Contractor is responsible to provide, fill, properly seal, temporarily store, load, haul to a plan's specified location, and unload the 55 gallon drums. When the first 55 gallon drum is filled, you should collect a sample and immediately submit the sample to the Testing Engineer. Temporary storage of the material on the site should be at a location where there is no possibility of a spill entering any waterway.

Until test results are obtained to substantiate that the material is not hazardous, each 55 gallon drum shall be marked with the words "Hazardous Waste" and shall be dated with the date on which the drum was filled. This shall be done by using a permanent and waterproof marker.

Note The Contractor is responsible for complying with all regulations and for taking all necessary measures and precautions to ensure worker safety for work involved with lead particles.

Abrasive Blasting Surface Preparation Inspection

Quality control checks are needed to assure that the surface preparation will meet the requirements of the Specification. As the inspector, you should verify that:

- The compressed air is free of moisture and contaminants.
- The blasting pressure is adequate.
- The anchor pattern depth is as specified.
- The degree of surface cleanliness is acceptable.

Compressed Air Cleanliness

The presence of oil and moisture on a prepared surface is detrimental to coating performance. Rotary compressors utilize an oil bath to cool the compressed air prior to delivery. As compressors age, there is a tendency to discharge some oil and sometimes moisture into the compressed air. To remedy this situation, oil traps and moisture separators are installed in the compressed air supply lines. Oil and moisture on a prepared surface are not normally visible to the naked eye.

To assure that no oil or moisture reaches the surface to be coated, a 'blotter test' should be conducted prior to and periodically during the blasting operations. A common procedure as described in ASTM Practice 4285 for conducting a blotter test is as follows:

- 1 Shut off the flow of abrasive.
- 2 Place a white blotter or other suitable white absorbent material in the air flow. The material should be placed approximately 24 inches from an outlet that is downstream from the oil separator and moisture traps.
- 3 Allow free air flow for approximately two minutes.
- 4 Examine the material with the unaided eye for contaminants.
- 5 If contaminants are present, corrective action must be taken.
- 6 Test should be repeated at least at the start up of each operation and at least once every four hours. When the relative humidity is high, more frequent testing is in order.

Common corrective measures which may be used by the Contractor to eliminate contaminated air include - replacing dirty filters, bleeding moisture traps continuously, installing larger traps, cooling the compressed air, cleaning the interior of hoses, and replacing an old compressor with a new one.

Blasting Pressure

For proper removal operations, the blasting pressure at the nozzle should be maintained above 90 psi. Blasting pressures below this can result in reduced productivity and a lower anchor pattern. Low blasting pressure results from excessive pressure drop in the equipment and hoses or from using a compressor that delivers an insufficient volume of compressed air.

The instrument used to measure blast pressure is the needle gauge. The procedure for using this gauge is as follows:

- 1 Assure that all of the blast nozzles are operating.
- 2 Start up the blast operation with all blast nozzles functioning.
- 3 Insert the needle through the blast hose approximately 12 inches behind the blast nozzle. The tip of the needle should be slanted toward the nozzle to avoid becoming clogged with abrasive or damaging the gauge.
- 4 Read the gauge pressure.
- 5 Repeat this operation for each nozzle.

This test should be repeated when there is a change in equipment size or length. It can also be used throughout the system to determine where the pressure drops are occurring.

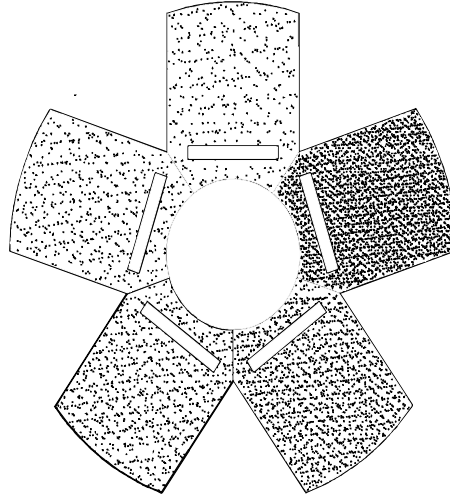
Anchor Pattern Depth

Two common field instruments are available for checking anchor pattern depth: the Surface Comparator, and the Testex Tape. The anchor pattern depth, or surface profile, should be verified by ASTM Specification D4417, "Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel". The methods for the tests in ASTM D4417 are as follows:

Method A

The blasted surface is visually compared to standards prepared with various surface profile depths and the mode determined. A complete comparator unit consists of a reference disc, a 5X illuminated magnifier with a magnetic holder, and a vinyl disc case.

Figure 14.5 Surface Comparator



A profile comparator consisting of a number of coupons (each approximately 1 square inch in size), usually side by side, with a different profile or anchor pattern depth. Each area is marked, giving the nominal profile depth in mils or microns. Typical comparator surfaces are prepared with steel shot, steel grit, sand, or other nonmetallic abrasive, since the appearance of the profile created by these abrasives may differ. The comparator areas are used with or without magnification of 5-10X.

The test procedure is as follows:

- 1** Select the comparator standard appropriated for the abrasive used for blast cleaning.
- 2** Place the comparator standard directly on the surface to be measured and compare the roughness of the prepared surface with the roughness on the comparator segments. This can be done with the unaided eye, under 5-10X magnification. When using magnification, the magnifier should be brought into intimate contact with the standard, and the depth of focus be sufficient so that the standard and surface are in focus simultaneously.
- 3** Select the comparator segment that most closely approximates the roughness of the surface being evaluated or, if necessary, the two segments to which it is intermediate.
- 4** Evaluate the roughness at a sufficient number of locations to characterize the surface as specified or agreed upon between the interested parties. At each location make three evaluations against the comparator and determine the mode. The mode of the three evaluations represents the profile at the specific location, with the mode of all locations representing the profile of the entire surface.

Method B

A composite plastic tape is compressed into the blast cleaned surface forming a reverse image of the profile, and the peak to valley height on the tape measured with a micrometer.

The composite plastic tape is a special tape containing compressible emulsion attached to a non-compressible uniform plastic film. A burnishing tool is used to impress the emulsion face of the tape into the surface to create a reverse replica of the profile that is measured using a spring loaded micrometer.

The procedure for use is as follows:

- 1** Locate a clean representative surface site. Ensure that surface dirt and dust have been removed from the surface. Any contaminants will distort the results.

- 2 Select a grade of film; 0-2 mils use "Coarse", 1.5-4.5 mils use "X-coarse".
- 3 Prepare snap gauge by cleaning the anvils of the dial gauge.
- 4 Adjust the micrometer to zero with the anvils closed.
- 5 Remove the waxed paper backing from the replica tape. Inspect the specimen of replica tape, discarding if visually damaged or distorted. Measure the unexposed film in the circular cutout with the spring micrometer, as the thickness of the emulsion may vary. The pre-measured thickness of the emulsion is the maximum profile height for which the replica tape may be used.
- 6 Place the film on the blast cleaned surface, dull side down. Hold firmly to avoid any movement of the tape. Rub a burnishing tool over the circular cutout of the replica tape. Rub repeatedly until the entire circular area has uniformly darkened. Excessively hard rubbing should be avoided as the polyester film could become distorted.
- 7 Remove the replica and place between the anvils of the micrometer. The profile measurement is the gauge reading minus 2 mils to compensate for the polyester film. If the profile measurement closely approaches the pre-measured thickness of the compressible tape, alternate procedures should be considered because the accuracy of this procedure may be affected.
- 8 If desired, and if the dial micrometer can be so adjusted, the micrometer with anvils closed may be set at minus 2 mils and subsequent readings of the compressible film made directly.
- 9 If a value greater than the thickness of the compressible film found in item #5 above is measured, disregard the value. This indicates that a contaminant (dirt, abrasive, etc.) is attached to the film.
- 10 Three individual readings should be taken on any given local area and averaged to determine the surface profile measurement.

If the Contractor cannot meet the minimum or maximum anchor pattern, then one or more of the following items should be adjusted until such a pattern can be obtained.

- Change the size of the abrasive particle.
- Change the type of abrasive. The most common type of abrasive used for bridge painting is mineral slag. However, due to environmental regulations, steel grit is becoming more popular.
- Change the velocity with which the particle reaches the surface (pressure variation or type of nozzle).

Degree of Surface Cleanliness

The Steel Structures Painting Council has prepared SSPC-VIS 1-89, "Visual Standard for Abrasive Cleaned Steel". The standard consists of a series of 1:1 (actual size) color photographs which represents various conditions of unpainted steel surfaces prior to and after surface preparation by abrasive blast cleaning. The standard illustrates four initial rust grades before surface preparation and covers the range from intact mill scale to rusted and pitted steel. These rust grades are:

- Rust Grade A - Steel surface completely covered with adherent mill scale; little or no rust visible.
- Rust Grade B - Steel surface covered with both mill scale and rust.
- Rust Grade C - Steel surface completely covered with rust; little or no pitting visible.
- Rust Grade D - Steel surface completely covered with rust; pitting visible.

The standard illustrates surfaces prepared by abrasive blast cleaning using sand. Photographs illustrative of some variations in color, texture, and general appearance that can result from the choice of abrasives are provided in an Appendix to the standard. The Appendix photographs represent adherent mill scale (rust grade A) blast cleaned to white metal (SSPC-SP 5) by various non-metallic and metallic abrasives. The variations in appearance are depicted only for white metal; however, these same variations must be considered when assessing steel prepared to other degrees of cleaning.

To use this standard, select the photograph of the rust grade (A, B, C, or D) that most closely represents the appearance of the steel to be cleaned. The steel to be cleaned may contain more than one of the initial rust grades. Compare the prepared surface with the photograph representing the SSPC SP 6 degree of cleaning.

When using visual standards, be they metal coupons or pictures, it is important to remember that other factors will affect appearance besides degree of cleanliness. These factors include average profile depth, type of abrasive used, type of steel, condition of the steel, and presence of coating. For example, all of the visual standards were made with new or rusted steel and none with a painted surface. In maintenance painting, 33% paint stain (SSPC SP 6) left on the surface will affect appearance. The use of visual standards does require some discretion and understanding.

Hard to Reach Areas

Improper preparation (or application techniques) are most likely to occur in difficult to reach or inaccessible areas. For this reason, pay particular attention to typical areas as listed below.

- The top side of bottom flanges of steel beams
- The backside of nuts and bolts
- Areas which require climbing
- Areas which are partially inaccessible due to design details

Coating Application Inspection

Careless application of a protective coating results in premature failure. A properly manufactured and specified coating material improperly applied over a well prepared surface will fail. Inspection of coating application requires verification that a continuous and highly adherent film has been applied at a reasonably constant thickness over the entire surface to be protected.

Time Restraints

The Contractor should not clean any areas that cannot be prepared and primed within 24 hours, the area to be coated must have abrasive blast cleaning repeated. You should adhere to the same requirement for power hand tool cleaning as well.

Ambient Conditions

Prior to allowing painting of any coat, whether it is the prime, mid-coat, or topcoat, the ambient conditions must be met and maintained. Only paint when the surface to be coated is and remains at least 5 degrees F above the dew point. The relative humidity must be less than 85% during the application, and the air temperature must be between 40-90 degrees F. Reference checking the ambient conditions discussed earlier in this chapter under Pre-Preparation Surface Inspection.

Mixing

To provide proper protection, a paint film must be:

- Impermeable
- Tightly adhered
- Smooth and continuous
- Resistant to chemicals
- Resistant to abrasion

While the material specified and level of surface preparation contribute to these properties, they can all be affected by improper application. Inspection of the coating application begins with mixing the coating.

All coatings must be thoroughly and completely mixed in clean containers before use. Where there is noticeable settling and mixing is done either by power stirrers or by hand, most of the vehicle should be poured off into a clean container. The settled material is first lifted from the bottom of the container with a clean, broad, flat, paddle. Lumps are broken up and the settled material thoroughly mixed with the vehicle present. The vehicle is then returned slowly to the original container with simultaneous stirring. It is also useful at this point to mix or pour repeatedly from one container to another, (boxing) until the composition is uniform. The bottom of the original container should be inspected for unmixed solids. Application problems, such as clogging of spray tips, result from the presence of solid particles in the material. Clogging is a common occurrence, and in addition to the solid particles in the material, flaking of old, dried paint from dirty equipment is a prime contributing factor. Mixing equipment should be cleaned with solvent or by mechanical methods at least after each day's use.

Other precautions which should be taken to assure a clean coating are:

- Strain all material as per the manufacturer's instructions. The strainers should be of a type to remove only lumps, etc., but not remove pigment. For example, a 30-60 mesh strainer is normally satisfactory for most coatings unless some specific size is required in the specification.
- Keep lids on mixed material to avoid dirt contamination prior to application.
- If the material is being applied by airless spray from an open bucket, cover the open portion of the bucket with cheesecloth.

Many materials such as zinc rich primers, catalyzed epoxies, and some urethanes are manufactured in more than one component and require mixing prior to application. Three items must be accomplished when using multi-component material.

- 1 Assure that the proper materials are being mixed. Mixing the wrong catalyst into a resin will result in an improper or no cure.
- 2 Prior to mixing the components together, mix each component individually to assure that settled materials are brought into suspension.
- 3 Assure that all of the material is mixed. This may involve scraping material from the sides or bottom of the can. It is also good practice to mix complete kits as packed by the manufacturer.

Coating materials should be agitated during application to ensure homogeneity without over-mixing, which traps air. Material with heavy pigments require constant agitation during use.

Material Thinning and Viscosity

Thinning should not be done unless absolutely necessary for paint application. The use of the wrong thinner or too much thinner may be detrimental to the coating. The

purpose of thinning is to change the viscosity or change the evaporation rate of the material so that it may be sprayed properly under the existing environmental conditions.

The manufacturer's Technical Data Sheets state the thinner to be used and the maximum amount to be used. Prior to thinning, the material temperature should not be allowed to reach the same temperature as the substrate on which the coating is to be applied. The viscosity of a paint is a measure of its ability to flow, i.e. - a measure of its consistency. Cold temperatures cause a material to thicken and the viscosity increases. Warm temperatures result in easier flow of the material and the viscosity decreases.

Application viscosity's are normally stated on the Manufacturer's Application Instructions. Thinning is used to adjust the material to the desired application viscosity. A common test for viscosity is described in ASTM D4212, "Standard Test Method for Viscosity by Dip-type Viscosity Cups". The test is accomplished as follows:

- 1 The cup is completely immersed in the material to be tested and then withdrawn so that the time of flow of the material, through a hole in the base of the cup, can be measured.
- 2 Choose the proper cup so that the time of flow will be between 20-80 seconds.
- 3 Immerse the cup in the container, which may be a can or beaker, but is more likely to be a thinning or mixing tank or even a resin reactor. Stir or agitate the fluid well to give uniform temperature and density. Allow the cup to remain in the fluid for at least five minutes.
- 4 Lift the cup vertically out of the material in a quick steady motion. As the top edge of the cup breaks the surface, start the timer. During the time of flow hold the cup vertically no more than 6 inches above the level of the liquid. Stop the timer at the first definite break in the stream at the base of the cup. The time in seconds constitutes the viscosity. It is common to make only a single measurement.

Induction Time

Many catalyzed materials specify that a period of time be allowed after mixing and before application. This time is normally 15-30 minutes and allows the components of the material to start their initial reaction. The Inspector should verify that this induction period has been observed.

Application Methods

Application methods commonly used for bridge coating include conventional (air) spray, airless spray, brushes, rollers, and mitts. You should be aware of when and where each of these methods is the appropriate selection, and should make every effort to understand how the various equipment functions in the field.

Conventional Spray

Conventional or air spray is used for spray coating both large and complicated objects. Conventional spray has the advantage of total control over the flow of material and therefore can be used to coat complicated areas such as bolt patterns. It can also be used for minor blow down operations, since the coating supply can be turned off.

The flow of material is controlled by adjusting the pressure in the spray pot (pot measure). Atomization is accomplished by adjusting the atomization pressure at the spray pot to break up the stream of liquid coating into particles. The chief concerns while observing conventional spray operations are:

- The spray pot must have two operating pressure regulators so that pot pressure and atomization pressure can be independently adjusted.
- The pot pressure must be sufficiently high to obtain an adequate material supply at the spray gun. This can be accomplished by shutting off the atomization air supply and observing the material flow. It is also good practice to have the spray pot at the same elevation as the spray gun.
- The atomization pressure must be just high enough to properly atomize the material. Over atomization causes dry spray which is detrimental to the film-forming characteristics of the coating.
- The spray gun must be held within 18 inches of the surface to be sprayed. Distances greater than this will also cause dry spray.
- The work being sprayed must be directly in front of the spray gun. Reaching too far with the spray gun violates the 18 inch rule and also causes erratic thickness results.

No matter which spray equipment is used (air or airless) there are proper techniques for application, including:

- Proper overlapping technique - The gun should be moved across the surface in a straight, uniform stroke, moving forward and backward with the spray pattern overlapping the previous pass by approximately 50%.
- Sectioning - Large flat surface areas should be broken down into stroke lengths of approximately 18-36 inches. The spray gun should always be held perpendicular to the surface.
- Triggering - The spray gun should be turned off at the end of each stroke and not turned on again until the gun is moving in the opposite direction.
- Outside corners - Outside corners should first receive a coat with the spray gun pointed straight at the corner. The flat areas on either side of the corner should then be coated in the normal manner.
- Inside corners - The best technique for inside corners is to coat each face of the corner separately. This is accomplished with a vertical stroke on both faces. The work is then coated in the horizontal direction in the normal manner.

Improper spray techniques can cause many deficiencies, including too thick or thin a coating thickness, holidays, dry spray, runs, and sags. Visual inspection and dry film thickness measurements will confirm these deficiencies.

Airless Spray

Airless spray is a method used to coat large areas. The chief advantage of airless spray is high production. Atomization is accomplished by high pressure, normally between 1200-4500 psi. With a given tip, there is no control over fluid flow. The spray gun is either full on or off. Airless spray is not recommended for coating complicated areas or for small surfaces, such as handrails, since the fluid flow cannot be adjusted. The chief concerns while observing an airless spray operation are as follows:

- The material must be atomized. This is accomplished by regulating the supply air at the pump.
- The spray gun must be held within 24 inches of the surface to be coated. Exceeding this distance will result in dry spray and erratic thickness.
- Other methods of application are used to coat complicated areas such as bolt patterns. It is difficult, if not impossible, to properly coat nuts and bolts using airless spray due to the high volume of material reaching the surface.

Brushes

Brushes are used in complex areas where spray application is not effective. This is a much slower method of application, and the achievable film build is more erratic and lower than spraying. As a result, additional costs are required to achieve the specified thickness. Fast drying coatings such as zinc-rich coatings should not be applied by this method since they dry quickly and require continuous agitation due to the heavy pigment. Vinyl coatings tend to "ball up" on the brush. Coating by brush must be done in a neat manner to produce a smooth coat as uniform in thickness as possible. Coating should be worked into all irregularities in the surface, crevices, and corners. Runs, sags, or curtains should be brushed out. Surfaces that are inaccessible for coating with brushes, and on which spraying is not permitted, should have coating applied by means of sheepskin daupers.

Note The edges and corners of all metal work, rivet heads, bolts, nuts, and all individual members, bars, shapes, and plates should be striped by brush coating in advance of the application of coating to other parts.

The selection of the proper bristle is important. In general, synthetic bristles are used for water-based materials and natural bristles are used for solvent-base material. The chief concern while observing a brushing operation is film build. With a spray gun, the gun applicator can make multiple passes until the application reaches the sag point of the material. Brushes spread the material and controlled film build is very difficult. A typical single brush application is less than 2 mils in thickness.

Rollers

Rollers are used for large flat areas where spraying is objectionable. Rollers come in different fabrics, core, and fiber length. The most common fabrics are lambskin, mohair, nylon, and polyester. The core is usually made of plastic impregnated fiber or wire mesh. Since certain coatings will attack certain fibers or cores, the manufacturer's data sheets should be consulted for the proper choices. Fiber length is dictated mainly by the condition of the surface being coated and the required final appearance. Long fiber is best for rough surfaces; short fibers give a smoother appearance.

Proper roller technique involves placing the coating from the loaded roller on the surface in the form of a "V" or "W", rolling out the coating to fill in a square area, and finishing off the area with light strokes in one direction. The inspection concern with rollers is film thickness. Besides being erratic, the tendency is to roll the coating out over too large an area, causing thin spots. Film thickness measurements will verify proper build.

Mitts

Painters mitts are normally made of lambs wool and are dipped directly into the material prior to application. Mitts are used to coat small continuous objects such as handrails, piping, and angles. Mitts are more productive than brushing for this type of target. Spraying results in excessive material loss and possible overspray on adjacent structures. The inspection concern with mitt application is thickness. Mitts are capable of higher thickness per application than brushes. Dry film thickness should be carefully verified.

Coating Thickness

By specifications, the coating must meet the following DFT requirements. The midcoat is required only on certain types of paint systems, reference the approved products list in the Materials Manual for more information. These requirements should be augmented with wet film thickness figures calculated from the composition of the coating so that the proper DFT is obtained. Wet film thickness figures are useful because you can often check, as the work progresses, to

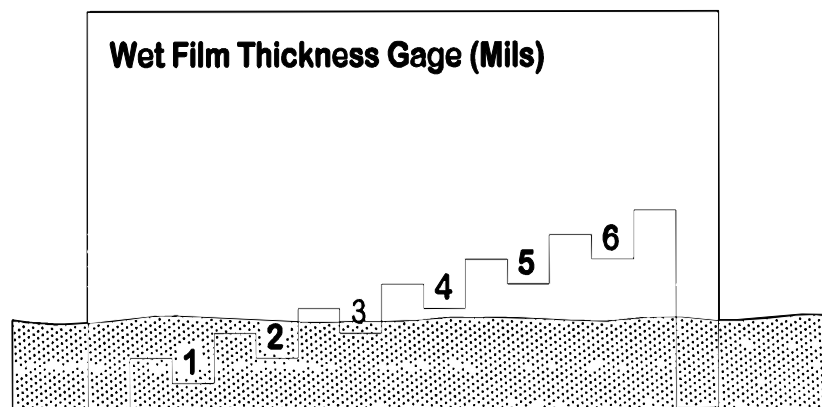
determine that the desired amount of coating is being applied. When the film is dry, you should check with a dry film measuring gauge to ascertain acceptability of the coatings.

Wet Film Thickness (WFT)

The most commonly used type of wet film gauge is a notch-type gauge that is made with two even end points and progressively deeper notches in between. Each notch depth is marked on the gauge. The use of this gauge is described in ASTM D4414, "Standard Practice for Measurement of Wet Film Thickness by Notch Gauges". The procedure use is as follows:

- 1 Apply the coating material to a rigid substrate and test. The gauge must be used immediately following application of the coating. Some coatings lose solvents quickly and spray application increases the loss. The resulting rapid reduction in wet film thickness can cause misleading readings.
- 2 Locate and area sufficiently large to permit both end tabs of the gauge to rest on the substrate in the same plane.
- 3 Push the gauge perpendicularly into the wet film so that the two end tabs rest on the substrate at the same time. Or, set one end tab on the substrate and lower the gauge until the other end tab is firmly in contact with the substrate.
- 4 Remove the gauge from the film and examine the tabs. The film thickness is determined as being between the clearance of the shortest tab wetted and the clearance of the next shorter tab not wetted by the film.
- 5 Clean the gauge immediately after each reading by wiping it on a dry or solvent dampened cloth so that subsequent readings are not affected. Do not clean with metal scrapers.
- 6 Repeat the procedure for at least three locations on the film. The number of readings required to obtain a good estimate of the film thickness varies with the shape and size of the article being coated and with the operator's experience.

Figure 14.6 Wet Film Thickness Notch Gauge



An estimate of the DFT can then be calculated (in mils) from the formula:

$$\text{DFT (in mils)} = \% \text{ solids by volume} \times \text{WFT}$$

To determine the wet film thickness of a thinned coating material, the percent volume of non-volatiles (solids) in the original coating must be known. This figure is readily obtained from the manufacturer. With this information the calculation may be made as follows:

$$W = \frac{D[1.0 + T]}{S}$$

W= Wet Film Thickness (WFT)

D= Desired Dry Film Thickness (DFT)

S= Percent of solids by volume of coating

T= Volume percent of thinner added

Several cautions should be noted regarding the use of the wet film gauge:

- Surface irregularities can distort the readings and a flat area should be selected for measurement.
- The measurement should be taken immediately following the application since solvent evaporation will distort the reading.
- The gauge should be cleaned after each measurement to avoid distorted readings.
- The WFT gauge should be placed on the surface and be perpendicular to the surface. The gauge should not be dragged across the surface.
- WFT gauges cannot be used on inorganic zinc because of its fast dry characteristics and its high zinc metal loading.

Wet film readings give a reasonable estimate of what the dry film reading will be. Since they are only an estimate, they must be used in conjunction with dry film readings.

Dry Film Thickness (DFT)

The DFT is a measurement of the thickness of the paint coat after it has completely cured. The method of measuring the DFT was covered previously. Remember that the thickness measurement is actually the combined thickness of all coats of paint that have been applied. When measuring the mid-coat or topcoat DFT, be sure to add the thickness of the sub-coats that have been applied.

Feathering Painting at Spot Locations

Bridge repainting, Class I entails only removal and repainting of work affected areas. When repainting these locations, the overlap between new paint and existing requires special attention. The junctions between sound coatings and spot cleaned areas should present a smooth, feathered appearance. The application of coatings to spot cleaned areas should overlap the old, adjacent coating to a slight extent in order to assure full coverage of the cleaned areas.

Before work has progressed too far, adhesion of the newly applied coat to the old coating should be checked carefully. Explore beneath the surface of the existing or new coating film for coverage over rust or loosening of the film. Where you discover such conditions, require that the surfaces to be re-cleaned and re-coated. The effect of any newly applied coats on the old underlying coating should be noted. Any coating that shows off curling, lifting, or excessive wrinkling should be removed and the area re-coated. If the defects are general, rather than existing in a few isolated area, use of a different type of coating may be necessary.

The following definitions will help in describing these concerns:

- Sound Coating - refers to an existing coating system which is well adhered to the surface and shows no signs of corrosion break down.
- Feathering Edging - refers to the process of sanding around a spot repair. This process is accomplished for two purposes:
 - To reduce or eliminate lifting caused by the solvent in the new coating. Lifting of adjacent coating causes small areas around the repair to be inaccessible to coating.

- For visual purposes to blend the repair in with the existing coating.

Over-blast

Over-blast refers to abrasive impinging on areas not directly in the blast nozzle's intended path. Over-blast damage most commonly occurs during spot blasting operation. Careful attention must be paid to the protection of adjacent coated areas. Abrasive from a blast nozzle may damage coating as much as 100 feet from the repair. Over-blast causes small cracks in sound coating. It can also dis-bond the coating from the steel without visual damage to the coating. Over-blast damage may not be easily visible but will ultimately result in pinpoint rusting.

Final Inspection, Repairs, and Acceptance

The final end product should be a coated surface that is slightly adhered, smooth and continuous. The DFT measurements should fall within the specified limits. In addition, you should check for the following possible defects:

- **Dry Spray** - Dry spray is a condition caused by the partial drying of the liquid coating prior to reaching the surface. Dry spray results in rough, sandpaper texture on the surface and in a loss of adhesion between coats. A common cause of dry spray is holding the spray gun too far from the target. Dry spray can also, however, be caused by excessive atomizing air pressure in air spray application, high winds, high temperatures, or low humidity.
- **Mud-cracking** - Mud-cracking is characterized by a broken network of cracks in the film resembling a dried mud flat. Common causes of mud-cracking are excessive film build per coat, over-atomization, and application to a hot surface. The most common location for mud-cracking is at the intersection of the flange and web, since this location tends to receive an excessive amount of coating during spray applications.
- **Runs and Sags** - A run is a narrow downward movement of coating on a vertical surface usually caused by the collection of excess quantities of paint at irregularities on the surface. A sag is the downward movement of a coating on a vertical surface between the times of application and drying, resulting in a thick lower edge. Both can be caused by too much material applied per coat, too much thinner, coating applied at too low a temperature, holding the spray gun too close to the surface, insufficient atomizing air pressure, or exceeding the pot-life of the material.
- **De-lamination** - De-lamination means a splitting apart into layers, either between coats or between the entire system and the substrate. Some typical causes are improper surface preparation in terms of removal of rust or chalking, a contaminated or wet surface prior to application, too long a dry time between coats, or stresses in the layers that can occur with coatings applied too thick.

If you find any of these defects, or other type of defect that you question, you should notify the Project Engineer. Dry spray or runs and sags can be accepted if they are contained to minor, isolated areas. Small areas of mud-cracking can be repaired by light sanding and applying another coat of light paint. Moderate to heavy defects and delamination generally require complete removal by abrasive blasting, and re-coating of the defective area. The Office of Bridge Design should be notified if there is any doubt as to the extent of repairs required.

Safety

Safety is the responsibility of all personnel involved on the job site. Although formal liability for safety rests with the Contractor, you should be able to recognize safety

violations since they involve both your own safety as well as those around you. You should never expose yourself to any unsafe condition, and should report any observed safety hazard to your Project Engineer or Engineering Supervisor immediately.

Blasting Equipment

The most common hazards involving abrasive blasting equipment are high pressure, static electricity, and hose ruptures.

A venturi type abrasive blasting nozzle is designed to increase velocity of an abrasive particle at pressures of 90-100 psi. The objective of this high pressure, high velocity, is to cut. An operating blast nozzle should be treated with the same respect as a loaded shotgun since the results of being shot and being abrasive blasted at close range are very similar. You should never walk into an area being blasted unless:

- The journeyman doing the blasting is aware of your presence
- You are wearing eye protection
- You are protected and clothed properly when going near the actual blasting operation

Rupturing and disconnecting the hoses often causes injury. When these occur, there is a loud bang similar to that of a shotgun firing. Unless the air supply is shut off, the hose will whip violently throughout the area of the break. A properly equipped "dead man" valve will avoid this situation. Hose breaks most often occur unexpectedly. Sometimes they can be predicted by bulges in the hose, indicating that one of the piles has delaminated. Any irregularities observed in a pressure hose should be reported immediately.

Abrasive blasting hoses are treated internally with carbon black, or a ground wire is embedded in the hose to make them conductive. This dissipates the static electricity built up in the hose by the passing abrasive; therefore, the blast pot should be grounded.

The blaster should use a completely contained blast hood with a supply of clean fresh air fed into the operator to assure that no dust can enter his respiratory tract. The hood should be Bureau of Mines approved to make sure that danger of silicosis to the operator is minimized. It is important to note that air fed hoods will not provide protection against oil or fumes from the compressor. Air purifiers are used in the breathing air line to clean this air supply.

Airless Spray Equipment

Airless spray equipment consists of a high ratio pump that may generate fluid pressures to 4,500 psi, specially designed fluid hose and fittings, and an airless spray gun that sprays through small orifices. Material to be sprayed is finely atomized by low boiling solvents under high pressure. It is obvious that a jet of material being released at such high pressure will pierce the human body if it comes into close proximity to the spray cap on the gun head. It is equally dangerous to pull the trigger on an airless gun when the cap has been removed. A large volume of material is then released at the same high pressure, and great bodily harm can result from contact with this stream.

Handling and Applying Coating Materials

Coating materials should be stored in safe, well ventilated areas where sparks, flames, and the direct rays of the sun can be avoided. Containers should be kept tightly sealed until ready for use. Warnings tags should be placed on toxic materials.

Protective devices and equipment required for application of coatings materials are determined by the type of coating as well as by the environment. The coating manufacturer should provide complete mixing and application instructions, including definite references to safety requirements. Unless definite information regarding explosion and toxicity hazards inherent in the material are provided by the manufacturer, a written request for a Material Safety Data Sheet (MSDS) should be made before starting the coatings application.

Flammability Hazards of Materials

A coating material may be considered a flammability hazard when it will burn under normal conditions.

Toxicity of Materials

Virtually all solvent solution coatings are volatile in liquid form. Vapors released in the process of application are explosive if concentrated in sufficient volume. Even vapors from ordinary enamels and oil based material may be accumulated in such density as to result in an explosive reaction if a source of ignition is present.

Solvents, as well as other components of many modern coatings, present other hazards which must be guarded against. Solvents of all groups are toxic to varying degrees and may cause serious effects to those working with them unless appropriate precautions are taken. Excessive breathing of concentrated solvent vapors may cause dizziness or nausea, excessive drying or irritation of the mucous membranes, and allergic reactions on the skin.

The amine hardener used in epoxy coatings and compounds is particularly irritating to the skin, and some people are seriously affected by allergic reaction if proper hygiene is not practiced while these materials are in use. Common reactions include swelling around the eyes or lips and rashes on the skin. Some epoxy coatings have polyamides as curing agents that react much like a mild acid on tender mucous membranes. Polyurethanes contain chemicals that are sensitizers. Once a person has an allergic reactions to it, they will not be able to come in contact with it without another allergic reaction.

Most existing paints removed by the abrasive blasting operations are lead based. The dust and residue generated while blasting will contain lead particles and should be treated as a hazardous material. Inhaling of the dust may cause lead poisoning. In addition, good hygiene practice (washing hands, etc.) should be practiced after handling abrasive residue containing lead paint particles.

Materials Requiring Special Handling

Acetone or MEK Solvents

Both acetone and MEK solvents are volatile and explosive liquids with low flash points. These materials should be handled in strict accordance with manufacturer's specifications. Spills of acetone or MEK solvents on absorptive materials, such as wood floors, ground in work areas, and asphalt paving should be avoided to prevent fire and explosive hazards. All acetone or MEK solvents should be removed from equipment after cleaning.

Vinyl Solvent Solution Coatings

These coatings contain highly flammable solvents that may be toxic or may dry to irritate the eyes, nose, throat, and skin. These solvents are explosive in concentration. Coating personnel should observe the following safety precautions when handling these materials.

Epoxy Coatings and Compounds

These materials contain flammable solvents that will dry or irritate the skin on contact. Solvent vapors may be toxic and cause irritation of the eyes, nose, and throat. Material components may cause serious allergic reactions, and curing agents may be irritating to the skin and mucous membranes.

Personal Protective Equipment

Respiratory Protective Equipment - When industrial work methods or processes create hazards of exposure to harmful vapors, gasses, dusts, mists, or fumes, the work areas should be enclosed or well ventilated to eliminate or minimize the hazards. If enclosure, ventilations, or other engineering methods of control are not possible, however, respiratory protection equipment should be provided for workmen and any other personnel, including Inspectors, who must be in the areas. Even when the area is enclosed or well ventilated, a supply of appropriate protectors should be readily available for emergency work or repairs under unusual conditions.

At the present time, the United States Bureau of Mines approves respiratory protective devices in the following categories:

- Self Contained Breathing Apparatus (SCBA) - This apparatus includes the compressed oxygen cylinder and the compressed air cylinder, demand type.
- Supplied Air Respirators - This apparatus includes hose masks with blower, Type A; special hose mask without blower, Type B; air line respirator, Type C; abrasive blasting helmet, Type CE; dispersoid (dust, fumes, and mist) respirators, and non emergency gas respirators (chemical cartridge separators).

It is essential that the user of a respirator be properly instructed in its selection, use, and maintenance. Competent personnel should give such instructions to the supervisors of all groups who may be required to wear respirators at their work. The supervisors, in turn, should instruct their workers. No person should be allowed to wear a respirator of any type until he has received such instruction.

Instruction should cover the following points:

- An explanation of the need for using the respirator
- Its operating principle
- Steps required to assure that it is in good operating condition
- Proper use and maintenance of the respirator
- Proper adjustments of the respirator to the wearer

The life of the wearer may depend on the proper functioning and ready availability of respirators, so it is highly important that respirators be properly maintained and stored. Several rules apply to the adequate care and maintenance of this equipment:

- All respirators shall be inspected at regular intervals to make sure they are ready for use
- All rubber parts such as face pieces, mouthpieces, exhalation valves, breathing tubes, and headbands shall be inspected carefully for signs of deterioration such as hardening, cracking, or tackiness. A check shall be made during this inspection to see that all gaskets are present and that they are held tightly in place. Metal parts shall be checked for signs of corrosion, and plastic and glass parts shall be checked for breakage.
- When it is necessary to replace worn or deteriorated parts, only those made specifically for the device shall be used, and repair work shall be accomplished by qualified personnel only.

- Respiratory protective equipment shall be cleaned and disinfected after each use. The manufacturer shall be consulted for the cleaning and disinfecting method best suited to his products.
- All types of respirators shall be stored in a clean and dry compartments under conditions of moderate temperature.

Goggles and Safety Glasses - Safety goggles and safety eyeglasses are familiar protective devices to those who work in modern industrial plants. In most chemical plants and refineries their use is mandatory. The main requirements are that the goggles and eyeglasses fit well, are not cumbersome, provide for adequate straight-ahead as well as peripheral vision, and be manufactured of tempered unbreakable glass, or unbreakable plastic.

Glass or plastic shields should be readily replaceable. Spare goggles, eyeglasses, and shields should be kept readily available. It is mandatory that these devices be kept clean.

Hearing Protection - Excessive noise can cause permanent hearing damage. A pneumatic chipping hammer (at 5 feet) produces a sound level of 115 dBA. Abrasive blasting greatly exceeds this level. At greater than 90 dBA exposure (8 hours per day) or for higher noise levels in excess of the allowable time, e.g. 100 dBA for more than two hours, hearing protection should be worn. This is one of the most commonly violated standards. Ear plugs must be worn in areas where excessive noise does or may occur. It is not difficult to identify these areas.

Hard Hats - Hard hats should always be worn as a matter of basic safety protection.

The importance of safety cannot be overlooked. An Inspector is subject to the same conditions as the Contractor's people. Besides the special safety precautions required from the coating operations, also remember to follow procedures for working around vehicular traffic.

TIMBER CONSTRUCTION

Checklist

Initial Inspection at Delivery

- Lengths, sizes, and hardware materials checked against plan dimensions and requirements
- Lumber fairly straight and free of large warpage or other defects
- Timber stamped with markings indicating grade required by plans
- Certificate of Compliance received for all treated timber
- Structural Glued Laminated Timber stamped with markings indicating correct grade

Handling and Storage

- Handled in a manner that does not deform or damage the timber
- Stored on adequate blocking at least 1 foot above ground that prevents bending or warpage of lumber
- If stored outdoors for a long time, is untreated timber stacked open (loose), and treated timber stacked close (tight)
- Hardware stored to prevent rusting and corrosion

General Timber Framing

- Field cutting and drilling done in a manner that maintains snug, tight connections and fitting
- Cut locations of treated lumber have preservative reapplied as per manufacturer's instructions
- Drift bolts driven across the grain wherever possible
- Bolts that are too long adjusted by adding washers to ensure tight connection
- Bolts that are too short should not be installed

Timber Decks

- Joints in longitudinal planks staggered by 2 feet
- Planks are nailed according to plan notes or pattern
- Care taken during placement of laminated decks to ensure squareness of laminates

- Planks attached to timber or steel stringers as per plan shown details

Connectors

- Nails, spikes, bolts, and special connectors match plan required sizes and type
- Pregrooving for split ring, claw plate, or shear type connectors performed properly

General

Timber is used in a variety of ways in South Dakota structures, ranging from timber piling and temporary falsework applications, to permanent more complicated applications such as the timber glulam arches used in the bridge shown in Figure 15.1. Occasionally, timber may be used strictly for aesthetic purposes. The bridge shown in Figure 15.2 is really a steel girder bridge with timber added cosmetically to give the appearance of timber framing. Whatever the application, timber should be considered as a viable product that can have a long and useful life when properly constructed. Like all other construction materials, good field inspection and a working knowledge of its properties, functions, and abilities, helps ensure that the structure will be properly constructed.

Figure 15.1 Keystone Wye Bridge on Hwy 16 and 16A.



Figure 15.2 Pigtail bridge on Hwy 16A



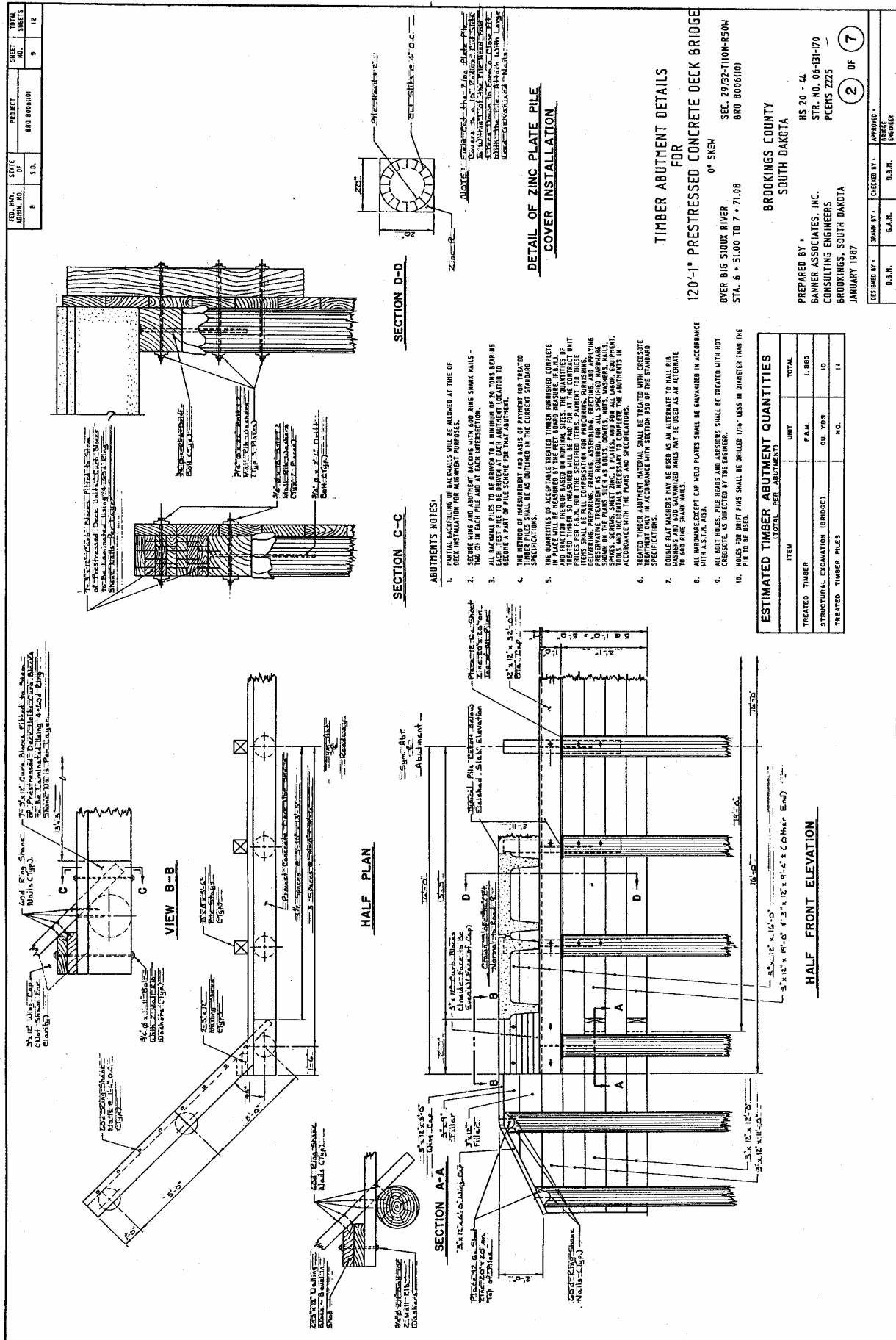
Although timber has a limited use in State projects, secondary roads and local governments use it quite extensively. Timber is used primarily because of its initial low cost, and although timber may have a higher degree of maintenance required, the actual maintenance itself can easily be handled by local government forces rather than having to hire contractors for repair. Not generally constructed as new bridges today, there still remain a great many existing bridges on county and township roads like the one shown in Figure 15.3.

Figure 15.3 Typical Existing Timber Bridge



One of the most common applications for timber on new bridges is that of timber abutments or timber bents. Figure 15.4 is a typical plan sheet showing a timber abutment for a precast channel bridge. This chapter will cover applications of permanent timber construction beyond the typical timber piling. Timber piling is covered in extensive detail in 'Chapter 4 - Piling'.

Figure 15.4 Timber Abutment



Material

Treated Timber

Like timber piles, most wood used for bridge construction is treated with a preservative to prevent rotting. The only exception is that Western Red Cedar need not be treated. The preservative is different for timber in contact with the ground versus timber not in contact with the ground. Lumber in contact with the ground shall be treated with ammoniacal copper zinc arsenate, creosote, copper naphthenate, pentachlorophenol, or chromated copper arsenate. Lumber not in contact with the ground can be treated with any of the above except creosote. A Certificate of Compliance should accompany the lumber shipment to the job site. The Certificate should list the lumber pieces by number, length, and size, and should state that the material meets the latest South Dakota Specifications.

Note Do not allow treated timber to be used on the project unless it has a Certificate of Compliance for the preservative treatment.

After logging the receipt of the Certificate in your diary, you should give it to the Project Engineer so that it can be forwarded on to the Testing Engineer.

Grade Stamping

Lumber has certain natural characteristics, such as knots, that can affect its strength. Such characteristics are factored into the values and properties used for the structural design of the timber. The amount of clear wood (wood free of defect) in the cross section, its length, plus other characteristics such as the slope of the wood's grain governs the strength of each grade.

Figure 15.5 Example Grade Stamp



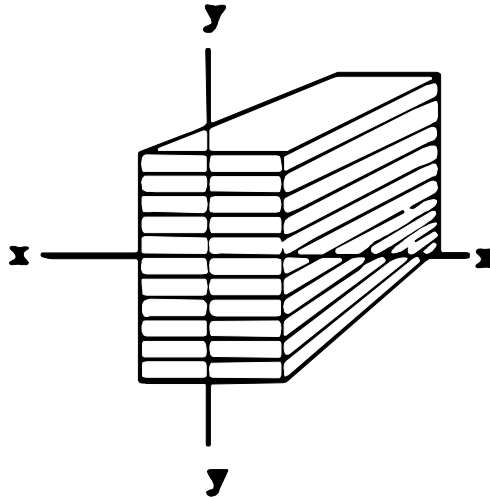
Each piece of lumber should have a stamp, similar to the one above, indicating the grade of lumber among other items. The following is a brief explanation of the markings that may be shown in the stamp:

- A.** Grading Agency Mark- Mark indicating the grading agency responsible (note that the mark shown in Figure 15.5 is a registered trademark of the Western Wood Products Association)
- B.** Mill Identification - Indicates the firm name, brand, or assigned mill number
- C.** Grade Designation - Gives the grade name, number, or abbreviation in accordance with the national adopted standard
- D.** Species Identification - Indicates the wood species type by individual species or species combination
- E.** Conditioning of Seasoning - Indicates the condition of seasoning (moisture content) at time of stamping

Structural Glued Laminated Timber

Structural Glued Laminated Timber, or glulam, is an engineered, stress-rated product of a timber-laminating plant. It consists of selected and prepared lumber laminations that are bonded together on their wide faces with structural adhesive. Glulam has been used successfully as a structural material in Europe since the early 1900's. In the United States, it has been used with excellent performance in bridges since the mid 1940's. An important point about glulam is that it is an engineered timber product rather than simply wood glued together. Laminated beams made with pieces of lumber that are nailed and glued together should not be confused with glulam.

Figure 15.6 Glulam Timber



The national product standard for glulam is the American National Standard for Wood Products - Structural Glued Laminated Timber, ANSI/AITC A 190.1. This standard, which as approved by the American National Standards Institute (ANSI) in 1983, contains nationally recognized requirements for the production, inspection, testing, and certification of structural glulam. It also provides material producers, suppliers, and users with a basis for a common understanding of the characteristics of glulam. The requirements in ANSI/AITC A 190.1 are intended to allow the use of any suitable method of manufacture that will produce a product equal or superior in quality to that specified, provided the methods of manufacture are approved in accordance with requirements of the standards.

Like other lumber, glulam timber should come stamped with a marking indicating the strength or grade of the piece along with other information. In addition to quality marks, straight or slightly curved glulam beams must be stamped TOP at both ends to indicate the proper orientation of the beam. Because the bending strength of glulam beams is often different for the tension and compression zones, this marking is important to ensure that the member is correctly placed.

General Handling

All lumber and related hardware materials should be checked against plan dimensions and be given an inspection as to grade, class, soundness, and galvanizing (where applicable on hardware).

Care should be taken during the process of unloading and placing the timber materials so as not to deform or damage the timber. When timbers are moved they should be lifted by methods which will prevent damage. If the timbers are to be stored before use, they should be piled in such a manner as to minimize warpage.

They should be piled on suitable blocking at least 1 foot above dry ground. The area should also be clear of weeds and debris. If timber is to be stored out of doors for a period of several months, untreated timber should be open stacked and treated timber should be close stacked.

All hardware, nails, and spikes should be stored above ground in suitable containers and, unless galvanized, should be kept in a dry, weatherproof room or shack.

Timber Framing

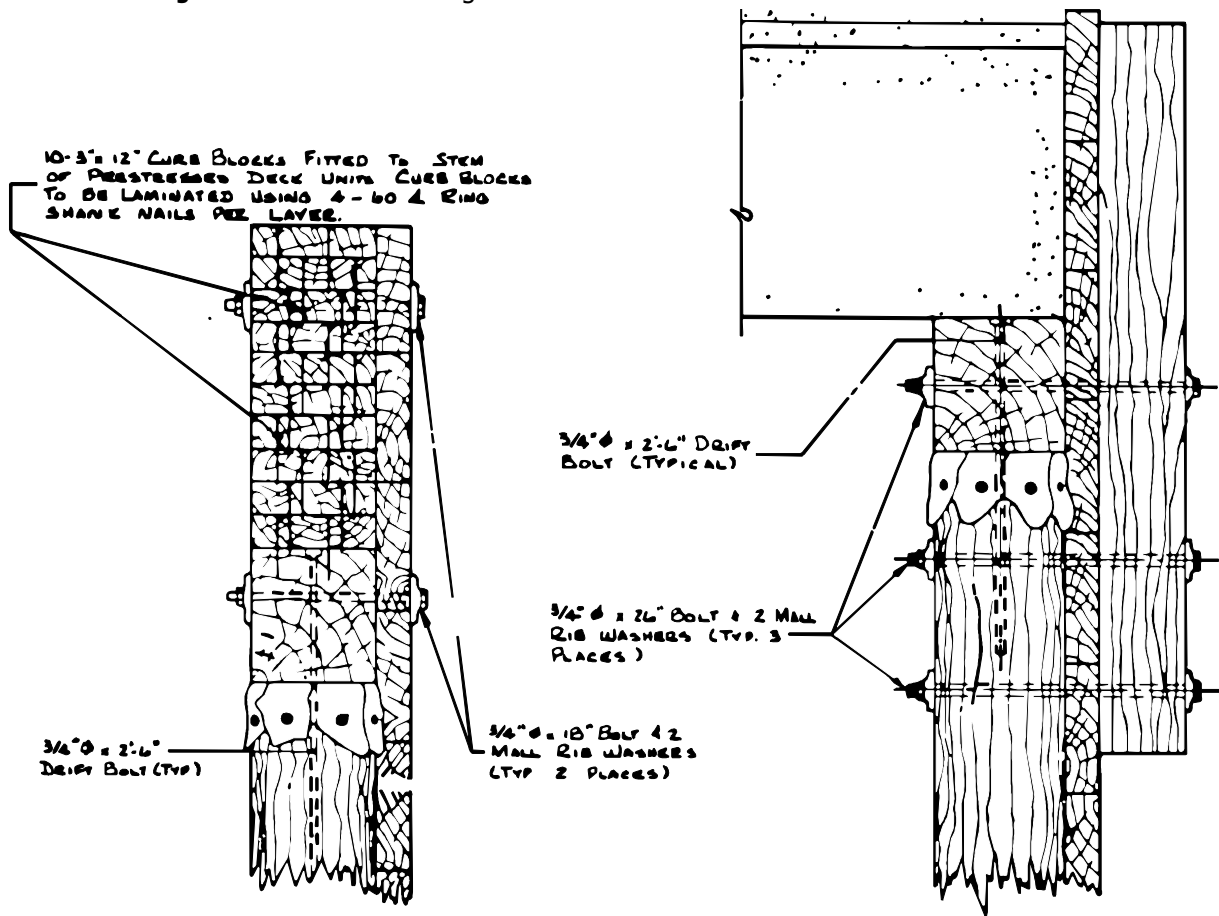
The fabricators of the various timbers will, in general, cut and drill them to the dimensions shown on the plans. However, some pieces may require cutting or drilling in the field. All field cutting should be done in a manner to maintain snug fit connections. Loose or sloppy connections can compromise the strength of the structure.

If treated timber is field cut, the newly opened surface should be treated with preservative applied in accordance with the manufacturer's directions. Lumber in contact with the ground should be given three brush coats of hot creosote.

Drift bolts holding caps, piles, or stringers should be driven with the chisel point across the grain so as not to split the timbers.

The specified lengths of various bolts may be found to be too long or too short. This condition generally occurs where bracing or caps are bolted to piling. If the bolt projection is so great as to cause the nut to run to the end of the thread without tightening against the timber, an additional washer may be added. It is, however, preferable to require that a shorter bolt be supplied than to stack too many washers, particularly for those connections where the bolts will be exposed to view. Should it become necessary to cut additional thread on a bolt, the freshly cut surface should be covered with zinc paint before running on the nut. If the bolts are too short for proper bolting, longer bolts should be used rather than notching into the timbers.

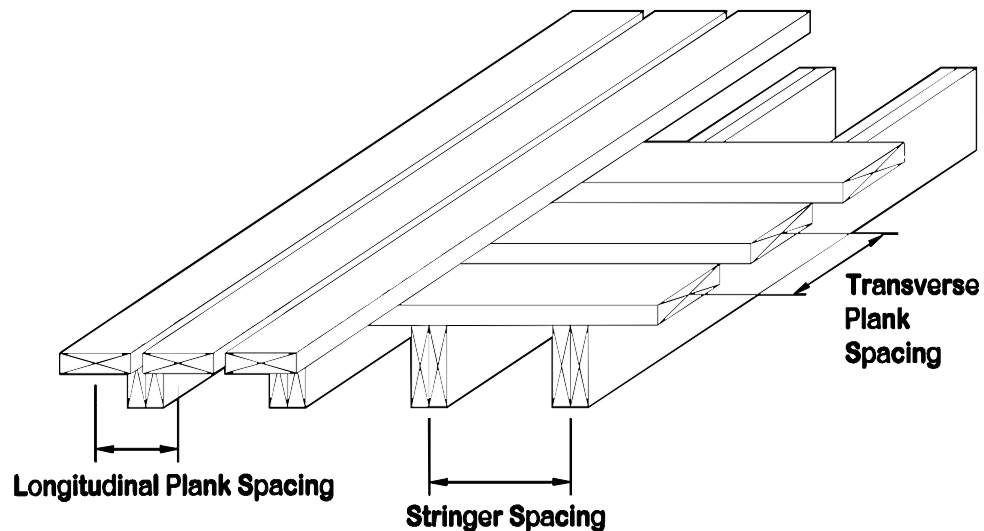
Figure 15.7 Timber Framing on Abutment



Timber Decks

Although very rare, occasionally timber boards may be used to form the actual driving surface of the bridge. Generally timber decks are either decks constructed of transverse and longitudinal planking as shown in Figure 15.8, or laminated transverse decking shown in Figure 15.9.

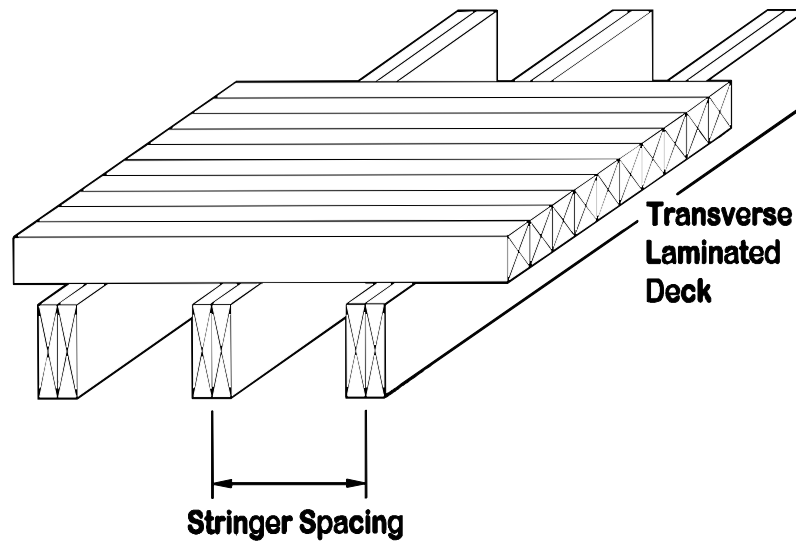
Figure 15.8 Longitudinal Plank Deck



Longitudinal Plank Decks

Planks that are used for the wearing course (top driving surface) should be laid longitudinally. Breaking joints in each longitudinal line should be at least 2 feet from joints in adjacent longitudinal lines. The end of the planks should be squared to keep the joint opening at a minimum. All planks used for wearing course should be surfaced on at least one side and one edge. Any plank having heart center appearing on one side should be surfaced on the heart side and the plank should be laid on the heart side (surfaced side) down. If not shown on the plans, the planks should be nailed into place using 40d galvanized barbed nails, spaced not over 10 inches and staggered across the surface of the plank. Not less than two nails should be used at each plank end. Planks of the same width should be used in each longitudinal line of flooring.

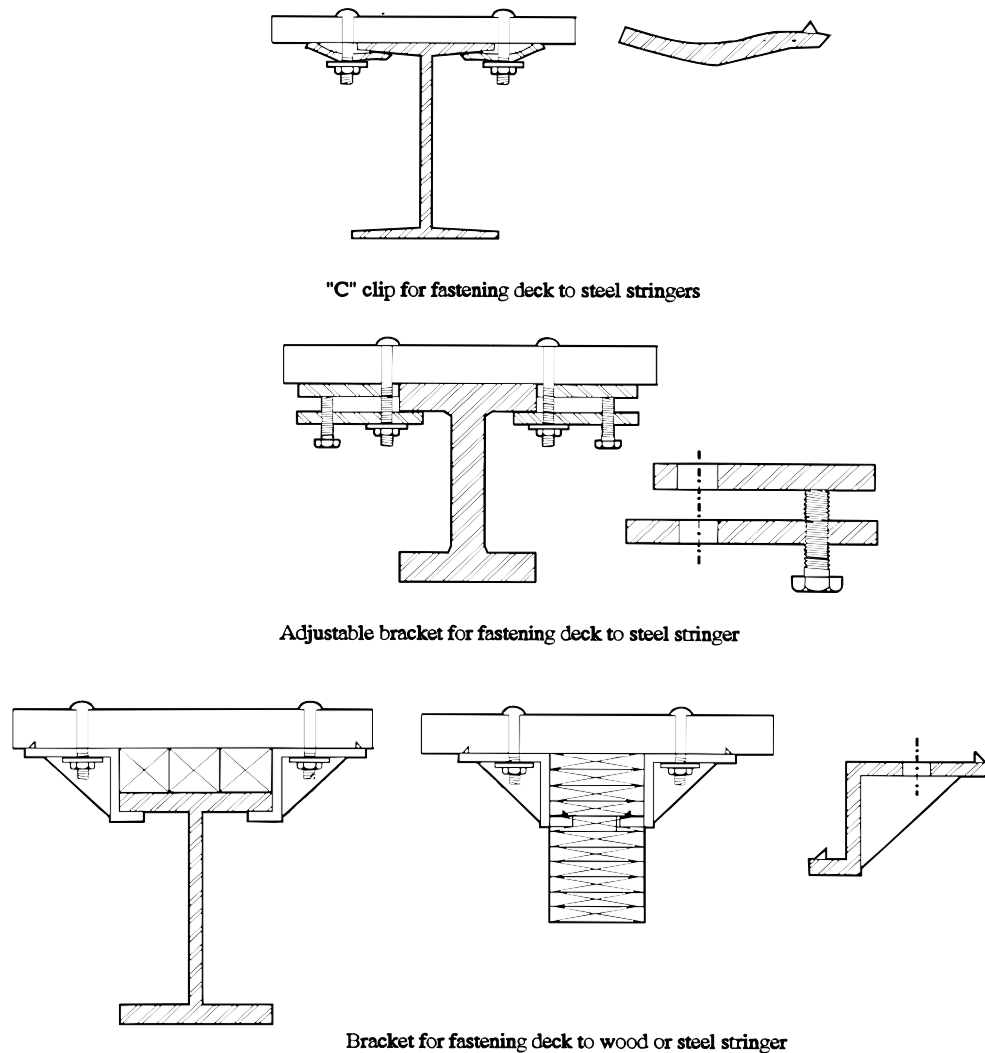
Figure 15.9 Transverse Laminated Deck



Transverse Laminated Decks

An alternate to a timber plank deck is that of a laminated timber deck. During the placing of laminated flooring, frequent checks should be made and corrective measures taken to keep the work properly squared. Tight nailing and careful selection of material for uniform thickness in each lamination should prevent unequal gain. The number of nails or spikes required by the plans is the minimum that should be used, however, it may be necessary to use additional nails or spikes to draw the planks tightly into place. The method of securing the timber deck to the steel to timber stringers will be shown in the plans. Various connection systems are shown in Figure 15.10.

Figure 15.10 Typical Deck to Stringer Attachments



Connectors

Joints in timber can be made much stronger by the use of connectors rather than with conventional bolt and plate fastenings. Several different types of connectors are manufactured and their use varies with the type and purpose of the joint. See Figures 15.11 and 15.12 for illustrations of various connectors and information on nails and spikes.

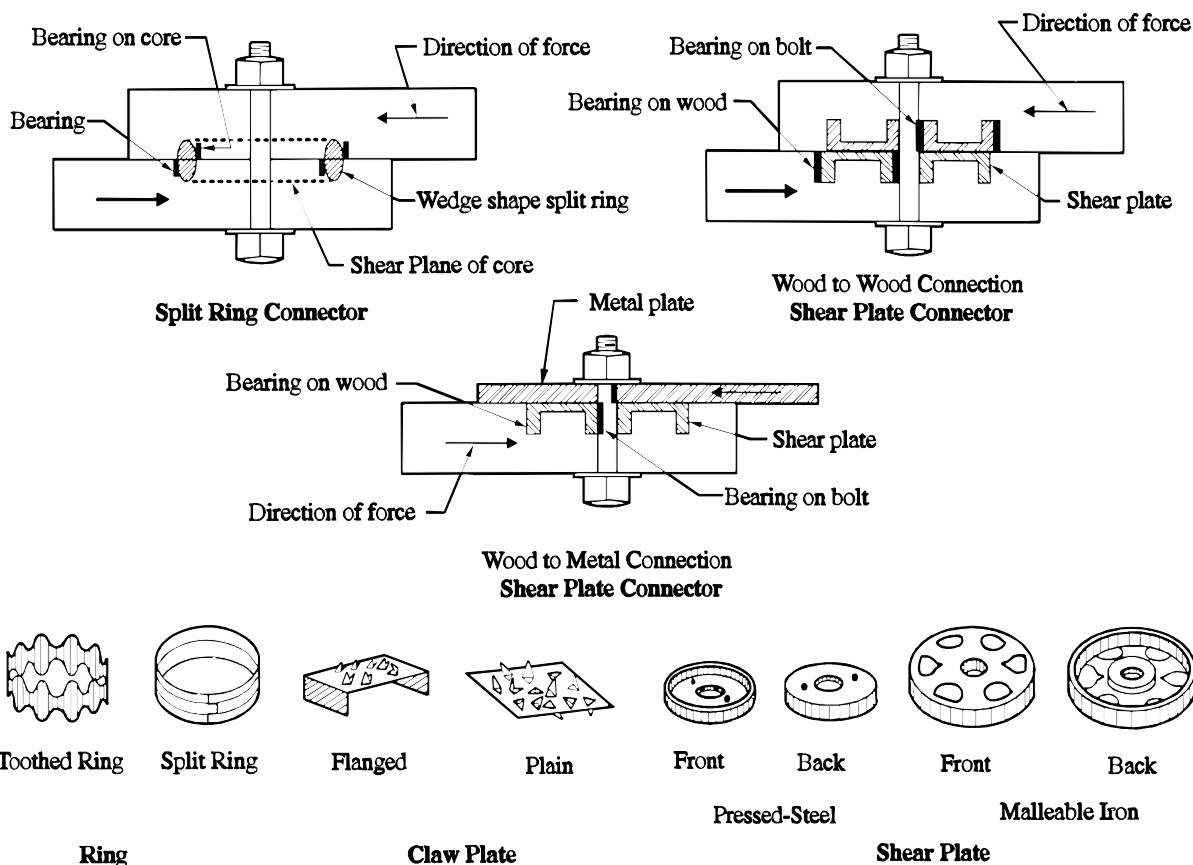
The split ring and toothed ring types are the most common of timber-to-timber connectors. The claw plate and shear plate types are used for timber-to-steel as well as timber-to-timber connection, and they have the advantage of being framed flush with the member. Spike grids are used largely in trestle bracing and are made in different shapes for various types of connections. The split ring, claw plate, and shear plate type connectors require pregrooving which must be done accurately to proper depth and close fit. In pregrooving for the split ring, the groove is made slightly larger to facilitate installation and provide a slight opening in the ring at the split, resulting in bearing on both sides of the ring. The claw plate is pregrooved to the depth of the connector less its teeth.

The tooth ring and spike grid type connectors do not require pregrooving of the members and they depend on pressure for embedment. This is often accomplished by means of a high tensile bolt with special long nuts and ball bearing washers. After the connector is embedded, the special bolt is replaced with the regular bolt.

Figure 15.11 Common Timber Connectors

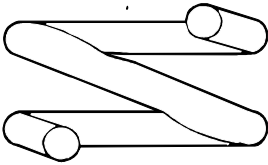
Pennyweight	Length		Wire Box Nails Dia.		Common Wire Nail Dia.		Threaded Hardened-Steel Nails Dia.		Common Wire Spikes Dia.	
	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches
6d	51	2	2.5	0.099	2.9	0.113	3.1	0.120	-	-
8d	64	2 1/2	2.9	0.113	3.3	0.131	3.1	0.120	-	-
10d	76	3	3.3	0.128	3.8	0.148	3.4	0.135	4.9	0.192
12d	83	3 1/4	3.3	0.128	3.8	0.148	3.4	0.135	4.9	0.192
16d	89	3 1/2	3.4	0.135	4.1	0.162	3.8	0.148	5.3	0.207
20d	102	4	3.8	0.148	4.9	0.192	4.5	0.177	5.7	0.225
30d	114	4 1/2	3.8	0.148	5.3	0.207	4.5	0.177	6.2	0.244
40d	127	5	4.1	0.162	5.7	0.225	4.5	0.177	6.7	0.263
50d	140	5 1/2	-	-	6.2	0.244	4.5	0.177	7.2	0.283
60d	152	6	-	-	6.7	0.263	4.5	0.177	7.2	0.283
70d	178	7	-	-	-	-	5.3	0.207	-	-
80d	203	8	-	-	-	-	5.3	0.207	-	-
90d	229	9	-	-	-	-	5.3	0.207	-	-
5/16	178	7	-	-	-	-	-	-	7.9	0.312
3/8	216	8 1/2	-	-	-	-	-	-	9.5	0.375
3/8	254	10	-	-	-	-	-	-	9.5	0.375

NAIL AND SPIKE SIZES



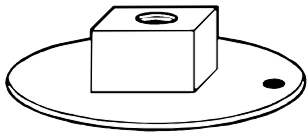
CONNECTORS

Figure 15.12 Common Timber Connectors



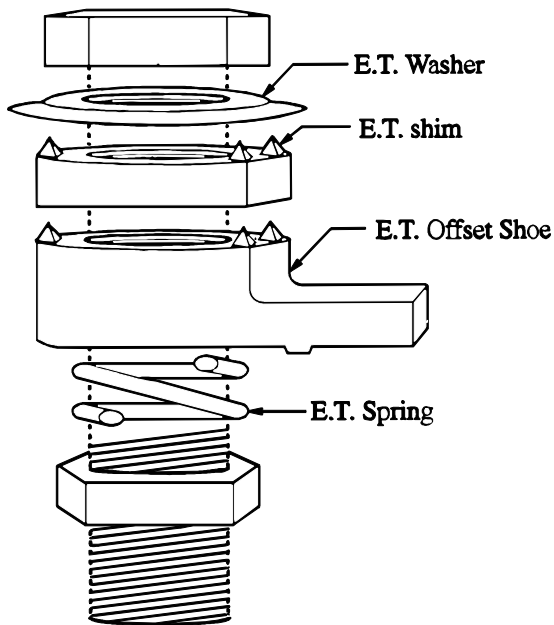
SPRING LOCK

Maintains tension on Hook Bolts and bracing bolts even as timber changes by weather or wear. Thackery crimp distributes load evenly.



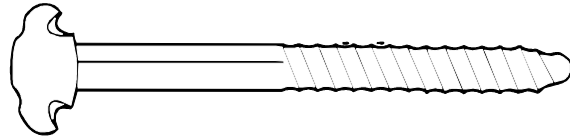
WASHER NUT

One-piece washer-and-nut. Eliminates separate washer. Seals water out of bolt hole. Hole in washer for nail to prevent loosening.



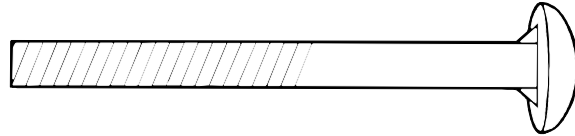
EVER TIGHT

DECKING ASSEMBLY
Decking assembly fastener for wherever rail ties or timbers are secured to steel beams.



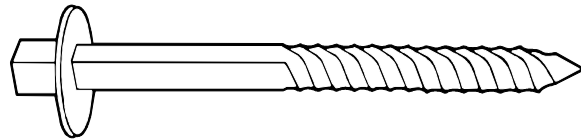
DOME HEAD DRIVE SPIKE

Fastens timbers and plank decking on bridges. Wide, smooth head eliminates counter boring, seal openings, wears well.



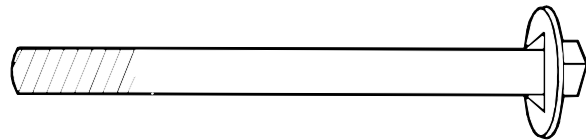
GUARD RAIL DOME HEAD BOLT

Wide, smooth head for bridges, fender systems and docks. No counter-boring to weaken timbers. Fins prevent turning. One person can install.



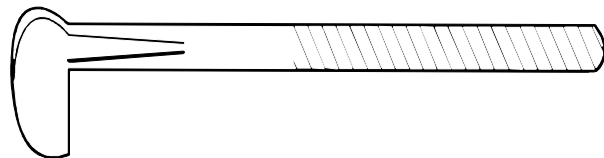
WASHER HEAD TIMBER DRIVE SPIKE

Fastens highway crossing planks, bridge guard rails and general timber construction. One-piece head.



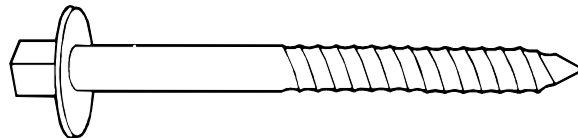
WASHER HEAD TIMBER BOLT

For all timber construction. One-piece forged head helps prevent rot and rust. Fins prevent turning for one-person installation.



HOOK BOLT

Fastens timbers and ties to steel beams. Easy to install, long life. Fins prevent turning. Spring lock holds tension.



WASHER HEAD LAG SCREW

For all timber construction. One-piece head incorporates washer to seal out moisture and prevent rotting.

BRIDGE REHABILITATION

Checklist

General Concrete Repairs

Concrete Breakout

- Saw cuts at correct locations and to proper depth
- Care taken around existing items to remain
- Existing concrete adjacent to breakout monitored for cracking or spalling
- Following breakout, blast clean the surfaces of concrete and reinforcing steel to remove loose laitance and mortar

Cleaning, Splicing, and Repairing Reinforcing Steel

- Remove all old concrete, mortar and/or rust by hand equipment or abrasive blasting
- Bars to be bent by field bending bent on a radius
- Heating required to straighten large bars
- Damaged areas of existing bars coated with an epoxy coating touch-up material
- Mechanical rebar splices approved by the Office of Bridge Design

Grout and Epoxy Injection Repairs

- Void or crack to be repaired adequately cleaned to remove all loose mortar or other contaminants
- Blown out with compressed air
- Grout as per Section 460.3.R of the Standard Specifications
- Grout thoroughly packed in voids so as to ensure no gaps or cracks
- Grout moisture cured for a minimum of three days following placement
- Epoxy meets plans requirements for type, grade, and class
- Applied as per manufacturer's instructions

Installing Dowels in Concrete

- Holes field drilled to proper depth and diameter
- Hole blown out, dry, and clean prior to epoxy resin adhesive application

- Epoxy resin adhesive meets plan requirements for type, grade, and class
- Beginning at the back of the hole, fill holes 1/3 to 1/2 full of epoxy resin adhesive, or as per manufacturer's instructions
- Care taken to keep epoxy from running out of the hole
- Dowel inserted by rotation
- No loads should be placed on the dowels until the epoxy resin adhesive has fully cured

Bridge Deck Overlays

Rubberized Asphalt Chip Seal Removal (where applicable)

- Heated to 125-140 degrees F
- Equipment coated with nonflammable lubricant
- Loader bucket operated at 60-70 degrees from bridge deck

Type 1A Concrete Removal

- Scarifier (or grinder) capable of removing at least 1/4 inch from surface in one pass
- If removing previous concrete overlays, closely monitor the depth of removal such that no removal exceeds the maximum depths noted on plans
- Care taken to ensure the top mat of reinforcing steel is not damaged

Subsequent Concrete Removal (Type 1B through 1D when required)

- After scarification, surface of deck chain dragged and marked to identify unsound concrete areas
- Jack hammers limited to 30 lbs for general removal, 15 lbs. for removal adjacent to reinforcement or structural steel
- Breakout operations frequently stopped, cleaned out, and chain dragged to see if depth of removal is adequate
- Concrete adjacent to reinforcement checked for bond to resteel
- Take care to ensure that removal does not expose so many top bars such that the strength of the bridge for construction activities is compromised

Filling Type 1C and 1D Removal Areas

- Thoroughly clean removal areas by blast cleaning
- Removal areas below the top mat (i.e. Type 1C and 1D) filled with Class A45 (A31) concrete
- Concrete placed and tested as per 'Chapter 8 - Concrete' requirements
- Concrete cured with wet burlap and polyethylene sheeting until 2000 psi compressive strength

Mobile Concrete Mixer

- Annual calibration performed
- General condition and cleanliness of mixer acceptable
- Filters and traps for water and admixtures clean
- Conveyor in good condition
- Yield test performed

Non-metallic fiber reinforced concrete overlay

- Finish machine set up, dry runs made, etc. prior to concrete placement
- Air temperature and concrete surface temperature requirements met
- Entire surface abrasive blast cleaned within 24 hours of concrete placement
- Surface wetted for minimum of one hour prior to placement
- Grout mixture brushed onto surface ahead of concrete pour
- Concrete placement rate of 40 feet per hour maintained
- Concrete temperatures maintained between 45-80 degrees F during the pour and the first 48 hours after
- Metal-tine finish performed
- Wet burlap applied as soon as surface can support weight. Plastic applied within one hour of wet burlap, cure for 48 hours minimum like this
- Traffic is not permitted for 72 hours following pour

Low Slump Dense Concrete Overlay

- Finish machine set up, dry runs made, etc. prior to concrete placement
- Anticipated air temperature less than 80 degrees F for the duration of the pour, and existing concrete surface temperature greater than 40 degrees F
- Abrasive blast clean entire surface within 24 hours prior to concrete placement
- Grout applied to dry surface
- Concrete placement rate of 40 feet per hour maintained
- Concrete temperatures must be maintained between 45-80 degrees F during the pour and maintained at or above 45 degrees F for the next 72 hours
- Broom and metal-tine finish performed
- Wet burlap applied as soon as surface can support weight
- Cure shall be by wet burlap for 72 hours after placement
- Traffic not permitted for 72 hours following pour

Epoxy Chip Seals

Surface Preparation

- Rubberized Asphalt Chip Seal removed
- Grinding performed to remove tining and other surface coatings
- Shot blasting performed
- Use compressed air, fan, or vacuum to clean surface
- De-laminated concrete removed and repairs to reinforcement made
- Fill removed portions of deck with concrete

Material Requirements

- Cover aggregate shall be new manufactured washed dark rock and meets plan's gradation requirements and Mohs hardness

Application

- Epoxy manufacturer's representative on site during application operations (if required in plans)

- Temperature of air, existing deck, and epoxy must be between 50° F and 100° F and the air temperature is at least 5° F above the dew point temperature and no rain is forecast for the anticipated duration of the placement.
- Existing surface dry
- Protective gloves, clothing, boots, and goggles provided for all workers and inspectors
- Epoxy applied uniformly as per manufacturer recommendations
- Cover aggregate applied within time limits
- Initial cover aggregate application, applied at plans required rate
- Final cover aggregate application, broadcast until no wet spots remain
- Excess cover aggregate removed after epoxy has adequately cured

Bridge Deck Widening or Replacement

Concrete Breakout and Containment

- Demolition plan submitted and approved by the Office of Bridge Design (if required in plans)
- Canopy constructed as per the approved demolition plan
- Breakout by sections defined with saw cuts
- Take care at existing girders and other items to remain in place

Making Bridge Decks Continuous and/or Composite

Concrete Breakout

- Take care around existing items to remain in place

Shear Connectors

- First two studs applied each day tested for proper weld by visual inspection of weld and by bending 30 degrees with hammer or pipe
- All studs visually inspected for 360 flash

Girder Strengthening

Field Welding to Existing Steel

- Substrate steel properly cleaned and prepared
- Refer to checklists provided in 'Chapter 11 - Welding'

Bridge Rail Retrofits

Design 1T Rail Retrofit

- Locations of spacer blocks as per plan requirements
- Spacer thickness field verified and modified as required for proper fit
- Plywood exterior grade
- Linseed oil applied to each layer of spacer
- Guardrail splices/laps in correct direction or orientation for traffic

- After installation, spacer top and vertical edges painted with oil-based paint as per plan notes

Design 2T Rail Retrofit

- Wedge anchor on approved product list
- Solid spacers free of checks or splits more than 1/4 inch wide and deeper than 3 inches
- Certificate of preservative treatment received
- Guardrail splices/laps in correct direction or orientation for traffic

General

The Department performs inspection on all bridges at regular intervals to evaluate the overall condition, performance, and strength of its structures. Periodically, structures or portions of structures are found to be deficient and inadequate in certain areas. When this occurs, the Office of Bridge Design makes a decision as to whether the bridge can be restored to a reasonable state of structural capacity and function, or if total bridge replacement is necessary. When practical, and when economic factors are considered, bridge rehabilitation is often the best choice.

You may encounter as many bridge rehabilitation projects as new structures projects. In many ways, bridge rehabilitation or bridge repairs can be more complicated than building a new structure from scratch.

Types of Bridge Rehabilitation

Just as there are many different types of structures in use today on South Dakota Highways, there are also many different types of rehabilitation projects. While the types of repair are similar from bridge to bridge, many rehabilitation projects may have some aspect of work that is unique in and of itself.

The following is a partial list of typical bridge repair work that you may encounter:

- Bridge Deck Overlays
- Bridge Deck Widening and/or Replacement
- Making Bridge Decks Composite and/or Continuous
- Expansion Device Repair or Replacement
- Bridge Rail Retrofits
- Bridge Repainting
- Girder Strengthening or Post Tensioning
- Bearing Repair or Replacement
- Substructure Repair or Replacement

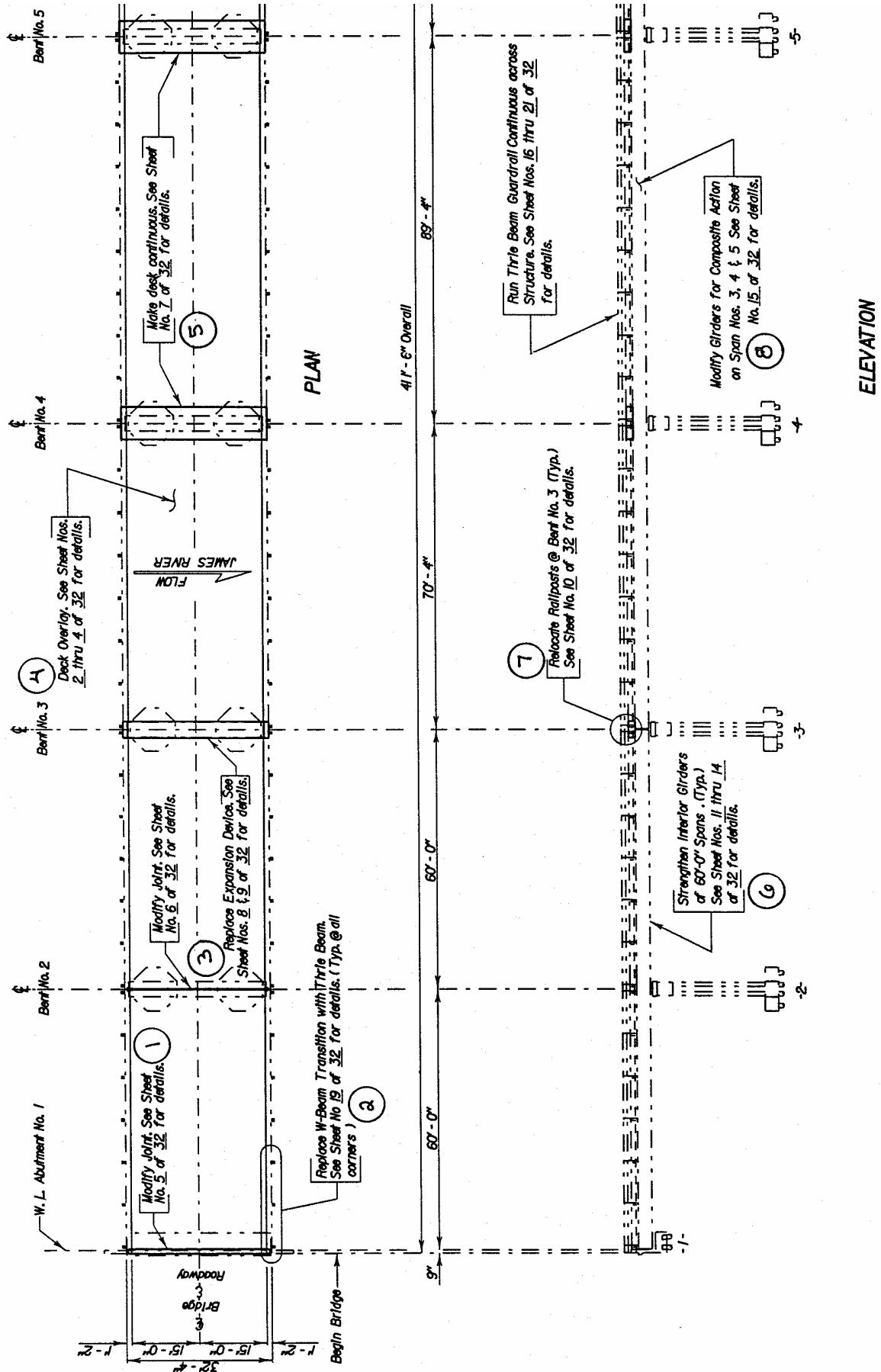
Often a single bridge will have more than one type of bridge repair item to be done. Usually each type of repair will be designated and noted on the General Layout sheet of the bridge. The partial general layout shown in Figure 16.1 has eight different types of bridge rehabilitation work to be performed on the bridge.

Existing Dimensions

Plans for bridge rehabilitation projects are prepared based on the dimensions shown on original construction plans and many shop plans that the Office of Bridge Design may have on file. Typically these dimensions are not field verified. The Contractor is

responsible to verify the actual field conditions and dimensions that may affect any aspect of the repair work. Never assume that the dimensions shown in the plans pertaining to the existing bridge are correct, all dimensions must be field verified.

Figure 16.1 Example Bridge Rehabilitation General Layout

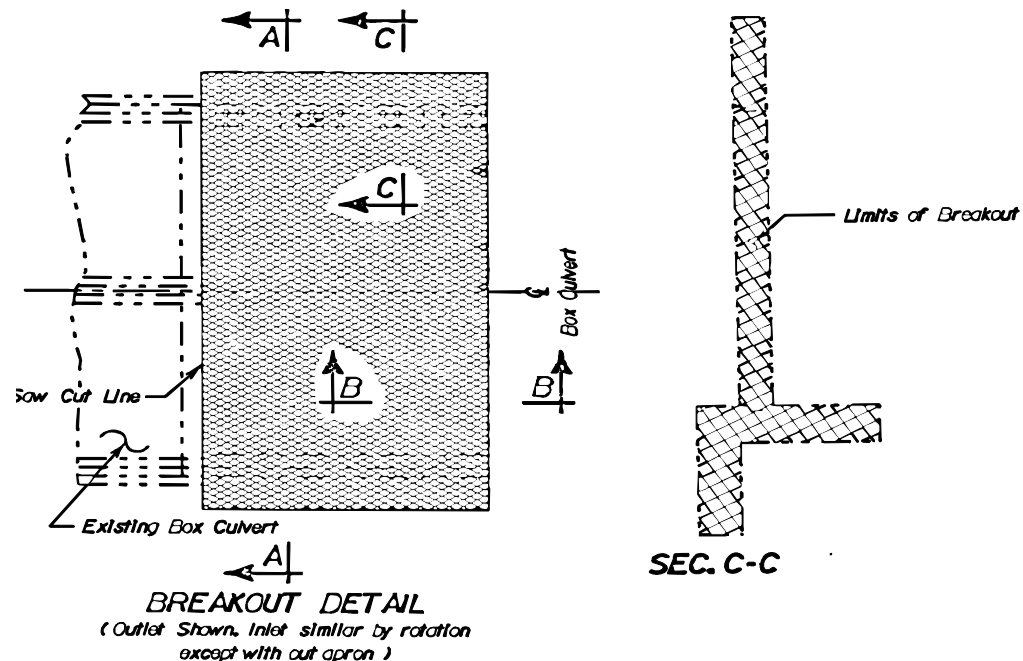


General Concrete Repairs

Nearly every type of bridge rehabilitation work involves concrete repairs in some manner or fashion. Some, like bridge deck replacement, involve large scale concrete demolition and concrete replacement. Others, like rail retrofits or expansion device replacements, involve only limited select concrete breakout and replacement. Whatever the case, most concrete repair work involves some form of concrete breakout, reinforcement cleaning and restoration, grouting or epoxy injection of cracks, and then pouring and placement of the new concrete.

Concrete Breakout

Figure 16.2 Typical Concrete Breakout Designation



The plans will designate the limits of concrete to breakout. The breakout is first defined by saw cutting the perimeter or area to be removed. This helps to ensure that the breakout will stay within the defined limits as well as provides a clean edge for the joint between existing and new concrete. Typically the plans will require that a 1/2 inch to 3/4 inch depth saw cut be used. For vertical or odd shaped sections, the saw cut will usually be formed with a hand held power saw. On large flat slabs, the saw will typically be a walk behind model.

Concrete breakout equipment varies in a wide range, depending on the extent and amount of removal required. Large scale demolition operations typically use vibratory or hydraulic equipment that attach to the end of a backhoe in lieu of the bucket. Small scale demolition is done with hand powered equipment like jackhammers and chippers.

Depending on the situation and the type of removal, all or portions of the existing reinforcing steel may be required to remain in place. Be sure to note if the existing reinforcing is to be salvaged. If so, watch to make sure that the concrete breakout and removal operations take care and use small equipment around the reinforcing steel, so as not to dent or damage the rebar in any manner. If reinforcement is damaged, notify your Project Engineer, the damaged reinforcement may need to be replaced or repaired.

In addition to working around salvaged reinforcement, the Contractor should also take care around the existing portions of the structure to remain. This includes the concrete adjacent to the breakout as well as existing steel or concrete girders, joints,

or other miscellaneous items. Steel girders are of particular importance as they can develop fatigue cracks from even the seemingly smallest nicks or gouges. Absolutely no nicks or gouges should be allowed on existing steel girders. Inadvertent nicks or gouges should be reported to the Office of Bridge Design immediately. Excessive spalling or cracking of the adjacent concrete may require that additional concrete will need to be removed. You should notify the Project Engineer of any damage that has propagated into the existing concrete to remain. Following breakout, all concrete surfaces and reinforcement on which new concrete is to be cast should be thoroughly cleaned by sandblasting. This removes any loose concrete mortar or pieces that could create a defect in the joint.

Cleaning, Splicing, and Repairing Reinforcing Steel

As stated earlier, often reinforcing steel is salvaged from the concrete breakout and incorporated into the new work. In order to ensure good bond to the concrete, the existing resteel must be cleaned and prepared for use. Old concrete must be removed from the steel using hand equipment in a manner that prevents damaging the bar. Generally speaking, a jack hammer (or chipper) no larger than 15 lbs. should be used for the removal. Following removal of the concrete, the entire surface of the reinforcement should be thoroughly cleaned by abrasive blasting as described previously.

Straightening Reinforcement

Despite best efforts by the Contractor during concrete removal, the salvaged reinforcement may require field bending back into position. Generally reinforcement smaller than a #4 bar can be field bent with little or no difficulty. Large bars may require more effort. All bars should be bent around a radius such as that a sharp kink is not placed in the bar. A kink essentially means that the reinforcement has yielded (at the kink) and is no longer functional or effective for use. Heat may be used to bend bars that are too large to be bent cold. When used, the bar should be heated to a dull red before bending, and should be allowed to cool down naturally based on air temperature only. Do not allow a heated bar to be sprayed or immersed in cold water to be cooled down, as this changes the physical properties of the reinforcement.

Epoxy Coating Existing Reinforcement

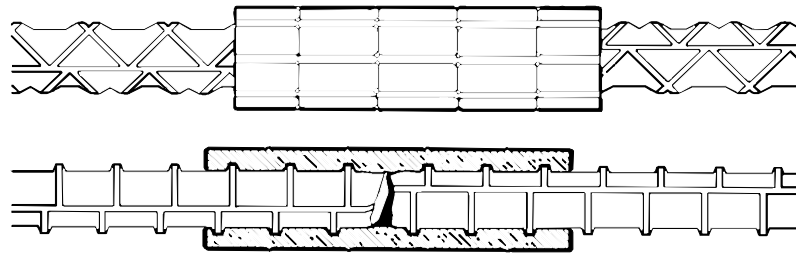
At times the plans may require the existing reinforcement that is to be cast into the new concrete to be coated with an epoxy coating. The coating should be the same epoxy touch-up coating material that is supplied by the manufacturer of the new epoxy coated reinforcement. Touch-up coatings from aerosol spray cans are not allowed. The epoxy coating should be applied immediately after abrasive blasting the existing reinforcement in order to prevent detrimental oxidation from occurring.

Note The coating should be allowed to cure for 24 hours or as per manufacturer's recommendations, whichever is more stringent, before allowing concrete placement.

Mechanical Reinforcement Splices

Often it is necessary to splice new reinforcement with the salvaged existing resteel. Generally a lap is used to splice the bars where there is adequate room, and where enough existing reinforcement has been salvaged to permit the lap. In cases where this is not possible, and where dictated by plans, mechanical rebar splices are used. These manufactured devices are designed and built to couple or splice two pieces of reinforcement together. Generally the rebar must be the same size on both sides, however, there are some manufactured splicers that can splice bars of different size.

Figure 16.3 Mechanical Splicer



Note Mechanical rebar splicers must not be allowed unless specifically specified in the plans or approved in advance by the Office of Bridge Design. In addition, the model of the mechanical rebar splice must be submitted to the Office of Bridge Design for approval. It shall be capable of developing 125% of the reinforcing bar's yield strength.

Mechanical rebar splices that are used to splice epoxy coated reinforcement must themselves have an epoxy coating, or be made of and approved corrosion resistant material. After installation, any nicks or scratches in the epoxy coating must be field touched up the same as all other epoxy coated rebar.

Grout and Epoxy Injection Repairs

There are instances when concrete breakout and replacement is not necessary to restore the capacity of the structure. This is especially true of structures that are having cracking problems, or structures that have suffered impact from traffic or construction equipment. Repairs can be made to concrete having voids or cracks by filling them with grout or epoxy that is equal to or greater in strength than the existing concrete.

Grout Repairs

Grout is usually used for larger gaps or voids that are easily accessible and can be cleaned prior to installation. The plans should indicate the ratio of cement to sand to be used for the grout. If not, the grout should be assumed to be a 1:3 ratio as specified in Section 460.3.R of the Standard Specifications. Typically a commercially available non-metallic, non-shrink grout will be specified. You should make sure that the grout does not contain any aluminum powder.

Concrete areas to be grouted should be cleaned of all loose or foreign material that would in any way prevent bond. The surfaces should then be flushed with water and allowed to dry to a surface dry condition immediately prior to placing the grout. The grout should be tightly packed into all recesses and holes to completely fill all voids. After placement, the grout should be cured by continuous wetting or other means as approved by the Engineer for a period of not less than three days, or as required in accordance with the grout manufacturer's instructions.

Epoxy Injection Repairs

Tighter cracks and voids can be repaired using epoxy injection. There are many different manufacturers and types of epoxy out on the market today. Typically the epoxy will be required to meet AASHTO M235 (ASTM C 881), and will be further noted to meet a certain category in each of the following three classifications:

- Type - Separates the epoxies into specific allowable applications, such as non-load bearing, load-bearing, concrete to concrete, concrete to other material, etc. Usually the epoxy will be required to be either Type IV or V.

- **Grade** - Separates the epoxies into three categories based on their flow characteristics or viscosity. Grade 1 is low viscosity (very flow-able), grade 2 is medium, and grade 3 is non-sagging (or stiff). Depending on the application, horizontal or vertical, a different grade will be specified.
- **Class** - Defines the allowable temperatures at which the epoxy may be applied. The time of the year and time of application will dictate what class the epoxy should meet. The table below gives the allowable temperature range for each class.

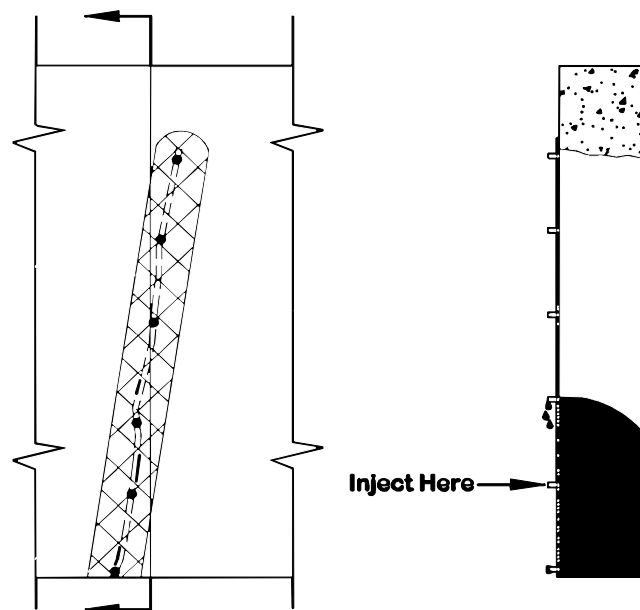
Figure 16.4 Allowable Temperature Ranges for Epoxy Classifications

Class	Temperature Range
A	< 40° F
B	40° F to 60° F
C	> 60° F to Maximum as Defined by the Manufacturer
D	40° F to 65° F
E	60° F to 80° F
F	75° F to 90° F

Note You must make sure that the epoxy meets each of these three classification categories. If the epoxy does not meet one or more of them, do not allow the epoxy to be placed.

Before applying the epoxy, first have the crack and surface of concrete along the crack cleaned as best as possible. Have the crack blown out with compressed air. The epoxy should then be applied as per manufacturer's recommendations. Generally, epoxy for cracks and tight voids is placed by first covering over the crack with a sealer of some type (as specified by the manufacturer). Holes at regular intervals are then punched through the sealer. The hole spacing should match closely the depth of crack to be filled. Starting at the bottom or lower location, the epoxy is then injected into the void. When the epoxy material begins to leak out of the next higher hole, filling is stopped, the lower hole plugged, and operations resume again at the next higher hole. This is done until the entire crack is filled. In order to completely ensure that the crack is filled and epoxy is not simply leaking out somewhere else, the crack should be sealed on both sides of the member wherever possible.

Figure 16.5 Epoxy Injection of Crack



Installing Dowels in Concrete

Bridge repair often involves the use of dowels to tie the existing concrete surface to the new concrete construction. The plans will show the size and spacing of the dowels required, as well as the embedment depth that must be obtained. The holes are field drilled into the existing concrete at a diameter slightly larger than the diameter of the dowel to be inserted. The hole is then blown clean with compressed air and an epoxy resin adhesive is injected into the hole. The epoxy will be called out to a certain type and grade as described earlier for epoxy injection. For horizontal holes, use an epoxy resin adhesive for horizontal applications.

Beginning at the back of the hole, fill holes 1/3 to 1/2 full of epoxy resin adhesive, or as per manufacturer's recommendations. The dowel is then inserted by rotating the bar to ensure that all surfaces are covered. Care should be taken to ensure that the epoxy does not run out of the hole prior to inserting the bar. Dipping the dowel bar into the adhesive and then inserting into the hole is not an acceptable procedure. The epoxy should then be allowed to cure, again as per manufacturer's instruction, before any new concrete can be poured or any subsequent loads are applied.

Bridge Deck Overlays

One of the most common bridge rehabilitation projects is that of the bridge deck overlay. A bridge deck overlay entails removing deteriorated portions of the bridge deck, then overlaying the existing deck with new concrete. While this sounds simple at the onset, the actual work involved can get quite complicated.

There are two types of overlay concrete that may be used on bridge decks, Low Slump Dense Concrete or Non-metallic fiber reinforced concrete overlay. The plans will designate which type of concrete to use.

Low Slump Dense Concrete is the concrete used for most bridge overlays today. It is a very stiff Class "A" concrete made with small rock. Low slump concrete is generally placed with a slump ranging from 0-3/4 inch, with a maximum slump of 1 inch. Its low water-cement ratio and denseness makes it a very low permeable concrete, thereby providing good protection against chlorides. It takes a special finish machine to place low slump concrete. Generally it is placed to a minimum thickness of 2 inches.

Non-metallic fiber reinforced concrete overlay uses a polymer fiber with A45 concrete to create a structural overlay.

Surface Preparation and Partial Deck Removal

Critical to the performance of the overlay is the bond between the existing concrete deck surface, and the new concrete to be placed. In order to ensure a good bond, the surface of the existing deck is prepared first by scarifying the entire area. Specific deteriorated areas of the deck are then removed with hand operated demolition equipment.

Equipment

The following is a list of the minimum required equipment that the Contractor will need to have in order to perform the work properly:

- Scarifier - A power operated mechanical scarifier or grinder that is capable of removing at least 1/4 inch from the existing concrete surface in one pass.
- Concrete Saws - Sawing equipment capable of sawing concrete to the plans required depth.

- **Power Hand Tools** - Power driven hand tools for the removal of concrete in specific deteriorated areas. Jack hammers cannot be heavier than 30 lbs., and chipping hammers cannot be heavier than 15 lbs.
- **Abrasive Blasting**- Blasting equipment capable of removing rust and old concrete from exposed reinforcement and removing surface latence from existing substrate concrete.

Concrete Removal

The removal of the existing concrete is done in stages, depending on the extent of deterioration and damage. The first removal to take place is scarifying of the deck. This is classified as Type 1A Removal. Decks that have not previously been overlaid with concrete will generally be scarified to a depth of 1/4 inch. If the bridge was previously overlaid with a concrete overlay, then plans will specify the depth based on the existing overlay thickness. Since the existing concrete overlay thickness may vary, multiple passes of the scarification equipment may be required to assure that the entire existing overlay is removed, but that no removal depths in excess of the plan specified depths occurs. It is critical during Type 1A Removal that the existing top mat of reinforcement is not damaged. If damage occurs, notify the Office of Bridge Design immediately.

Once scarification is complete, a chain drag is used to locate areas that require further removal. The chain drag sounds 'hollow' when drug over an area of delaminated or unsound concrete. Spray paint is commonly used to mark the areas requiring further removal.

Figure 16.6 Zones of Removal

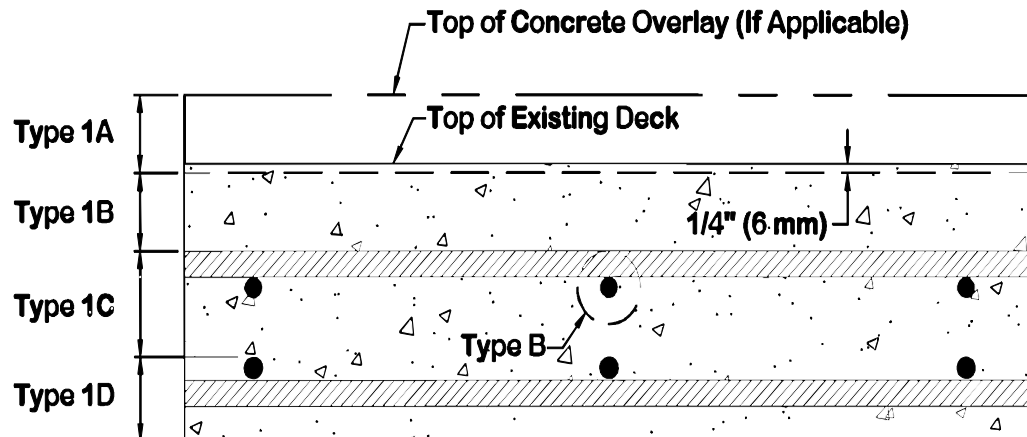


Figure 16.7 Typical Bridge Deck Overlay Breakout Sheet

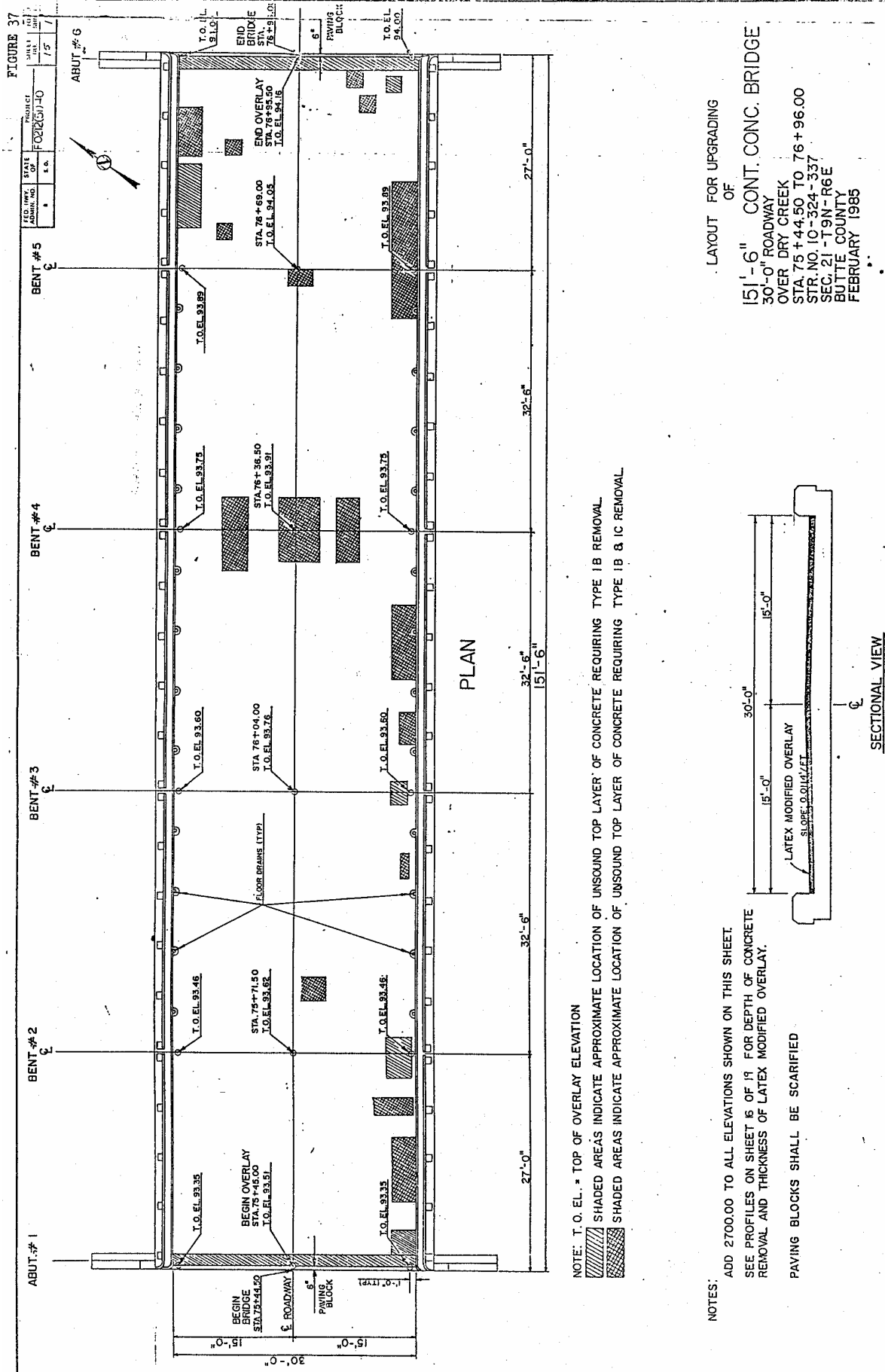
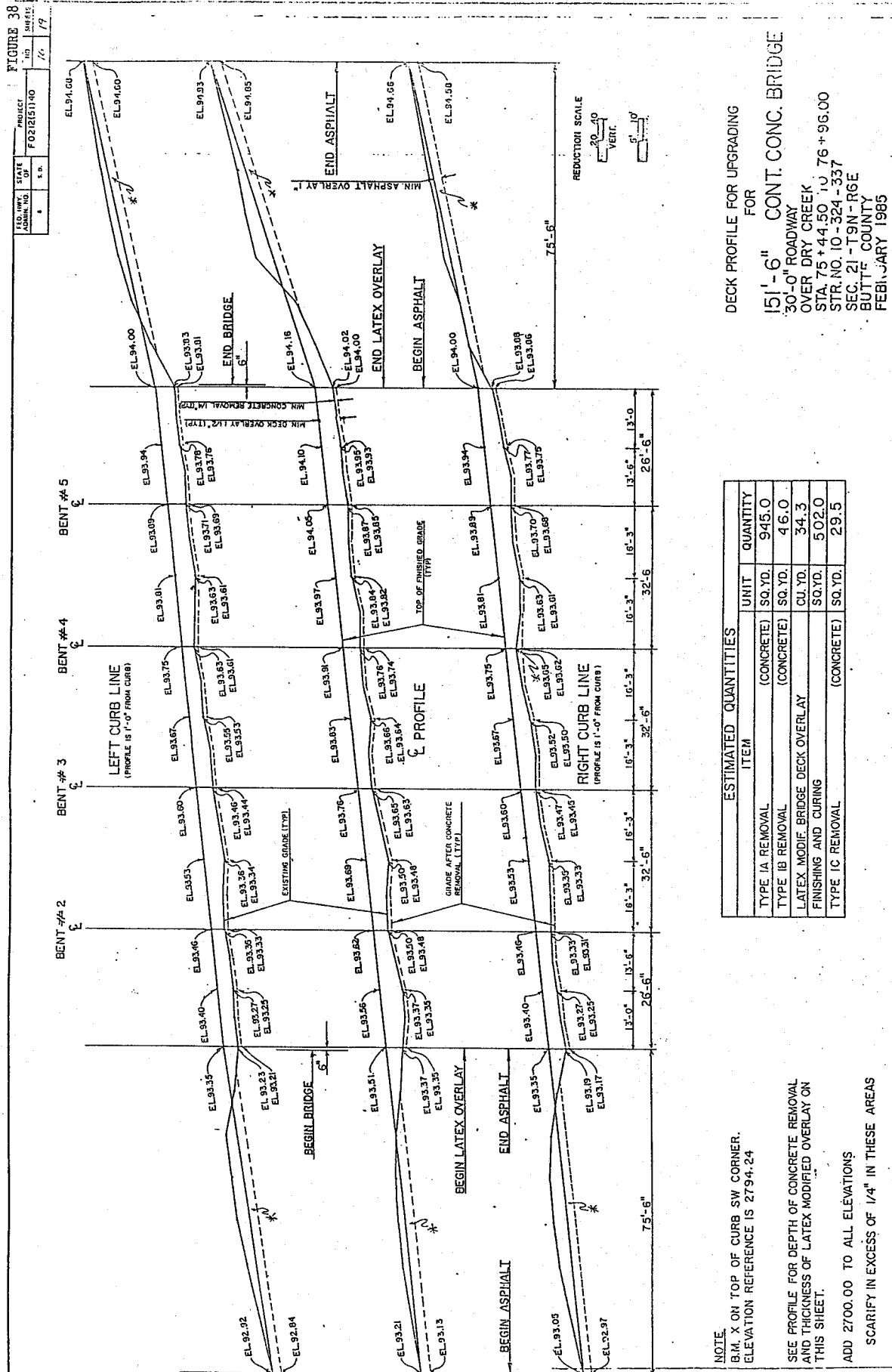


Figure 16.8 Typical Deck Profile Sheet



After scarification, it is critical that traffic not be allowed on the deck and that construction equipment be kept to a minimum, so as to assure that the deck is kept clean of contaminants that may affect the bond of the overlay. Construction equipment that is used on the deck after scarification should be equipped with 'diapers' to prevent oil and grease from contaminating the surface. If oil or grease does contaminate the surface, it must be removed by further scarification or detergent cleaning.

Jack hammers not heavier than the 30 lb. class, are used to remove the unsound concrete down to, but not below, the top of the mat of reinforcing steel. This type of removal is paid for as Type 1B Removal. Type 1B Removal should not proceed deeper than necessary. The workmen should use a chain drag or hammer to check the concrete as they work, stopping when they no longer detect unsound concrete.

Note Jackhammers and chipping tools should not be allowed to be operated at an angle in excess of 45 degrees measured from the surface of concrete, except in areas of Type 1D Removal as described below.

Once removal has reached the top mat of steel, check the exposed bars to see if the concrete is bonded tightly to them. If the chain drag or hammer indicates that the bar is not bonded tightly, Type B removal can be used to remove unsound concrete from around the bar. If removal is required from more than half the circumference of the bar, then complete removal around the bar is necessary to provide a minimum of 3/4 inch clearance around the entire bar. Chipping hammers not heavier than the 15 lb. class are used when working around the rebar. Care should be used not to nick or damage the bar. If concrete is unsound between the bars of the top mat, as well as around the bars, then Type 1C Removal is required between and below the top mat bars.

If Type 1C Removal extends all the way to the top of the bottom mat, then full depth removal, known as Type 1D, will be ordered. The edges of the hole in the deck should be nearly vertical or tapered inward from the top down. A reverse taper is not permitted. Saw cutting the underside of the deck may be required if satisfactory results cannot be achieved by other means. Note that Type 1D Removal is rarely used.

Any time concrete is removed from around more than half of the top bars, or between and below the top bars, one must be careful how many bars are freed-up at one time. When it appears more than 30% of the longitudinal top bars in any given 10 foot wide strip on a continuous concrete bridge, or 30% of the transverse bars in any given 10 foot wide strip on a girder bridge, will be freed-up, call the Office of Bridge Design for advice before continuing work. Full depth removal may require extensive shoring.

You may encounter a deck where most of the concrete seems unsound through the entire deck. Delaminations may have been removed, but the concrete still sounds 'hollow' even though the concrete may be fairly good quality. Before beginning extensive removal operations, check with the Bridge Construction Engineer. On some decks, removal may be adequate even though the chain drag indicates additional unsound material.

Cleaning

Once the various types of concrete removal are complete, the deck and exposed resteel is abrasive blast cleaned. This is done to remove contaminants that will prevent the overlay from bonding to the substrate. The exposed reinforcing steel should be well cleaned. Once abrasive blasting is complete, the deck should be thoroughly blown off with compressed air. If precipitation or any other contamination occurs on the deck surface within 24 hours, the deck will need to be re-blasted and cleaned.

Abrasive blasting must be performed no more than 24 hours prior to the overlay placement.

Reinforcement Repairs

Following removal and general cleaning, any reinforcement that may be damaged is repaired or replaced. Bars that are heavily damaged are removed and replaced with bars using lap splices or mechanical rebar splices as described earlier. You should always contact the Office of Bridge Design for direction on repairing damaged reinforcement.

Joint Raising

In order to match the elevation of the new overlay, often it is necessary to raise, modify, or replace the existing joint. In order to do so, it is typically necessary to perform extra depth removal by hand around the joint itself. Removal of the concrete around the joint is limited to 15 lb. chipping hammers like those used around reinforcement. Care should be taken not to damage the existing reinforcement or other structural items that are to be reused. Following removal and cleaning, the joint should be modified and reset, or replaced as detailed in the plans in order to match the top of the new driving surface.

Concrete

Full depth holes created by Type 1C or Type 1D Removal shall be filled up to the level of the surrounding prepared deck area with Class A45 (A31) Concrete and cured prior to placement of the overlay. The concrete should be properly tested and placed as described in 'Chapter 8 - Concrete'.

Mobile Concrete Mixer

Specifications require that both types of overlay concrete be proportioned and mixed by a self-contained, mobile continuous mixing unit. The Mobile Concrete Mixer is usually truck mounted and carries unmixed material, including water, to produce fresh concrete at the job site.

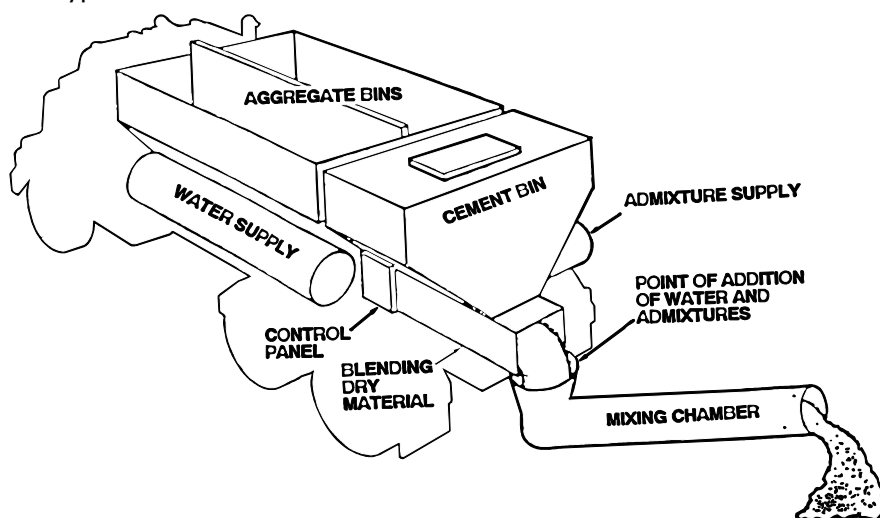
Figure 16.9 Mobile Concrete Mixer



An annual calibration and inspection by the SDDOT will be required for each mixer before the start of the first project each year. The calibration establishes the meter count, i.e., the number of revolutions, and discharge time in seconds required to dispense 94 pounds of cement. Gate openings and pointer adjustments for aggregates and general operating condition of the equipment will also be inspected, as per the manufacturer's recommendations.

The Contractor must have a qualified mixer operator who is completely familiar with the procedures necessary to calibrate the machine. The Contractor should supply necessary scales, containers, stop watches, operating manuals, and other materials and equipment necessary for calibration and inspection.

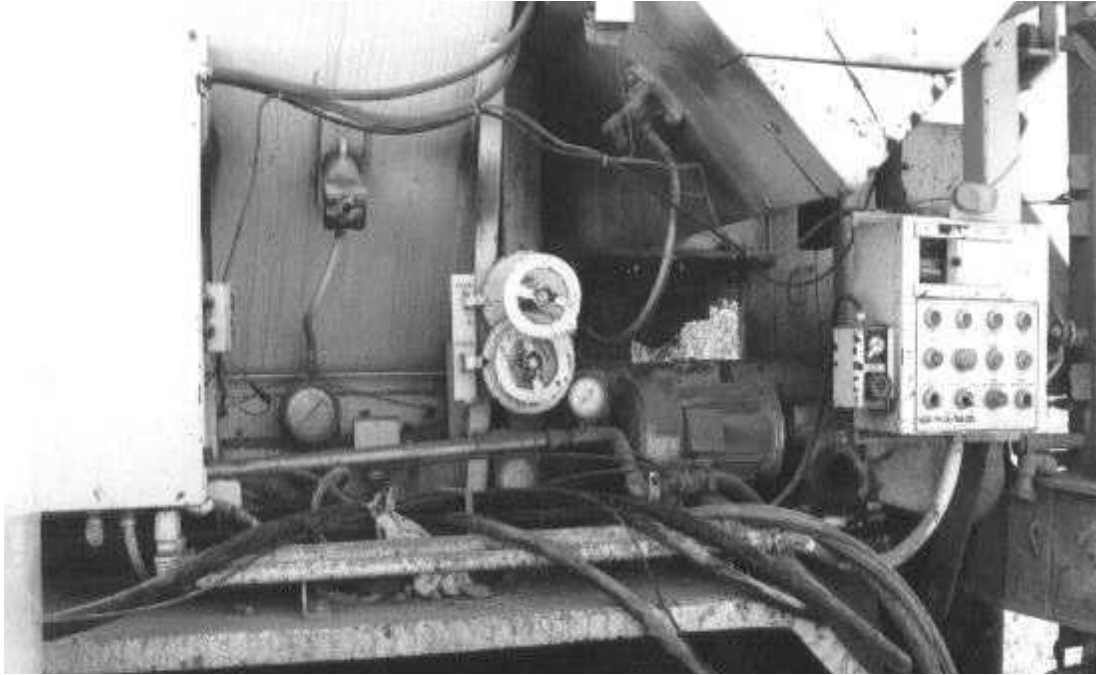
Figure 16.10 Typical Mobile Concrete Mixer Schematic



For actual calibration procedures, see the mixer operating manual. The Cement Mixer Feeder Calibration is recorded on DOT-293 (Figure 16.12). The form is signed by both the Contractor's representative and the inspector. The rock and sand gates

are also calibrated in accordance with the operating manual. An example calibration is worked through in Figure 16.13 and 16.14 on the following pages.

Figure 16.11 Mobile Mixer Controls



Once calibrated, the mobile mixer does not need to be calibrated prior to each use. A yield test is run before each pour. The yield test is the proper way to determine whether the mobile mixer is still in proper calibration and in good mechanical working order. The yield test involves discharging 1/4 cu. yd. of concrete into a 1/4 cu. yd. container. The machine is set using the predetermined design mix settings. Concrete is discharged until the meter-register indicates the "count" for 1/4 cu. yd. Any difference would indicate the need to re-calibrate. See the operating manual for proper yield test procedures. Before running the yield test, you should inspect the general condition of the mixer. Make sure the bins, gates, and belts are free of dried mortar, mud, or other contaminants. Also ensure that filters and traps are clean.

Figure 16.12 Mobile Mixer Calibration Worksheet (DOT-293)

DOT-293 (6/84)

DEPARTMENT OF TRANSPORTATION

PLANT CALIBRATION VOLUMETRIC BATCHING
& CONTINUOUS MIXING OF CONCRETEJ. V. BAILEY Co. INC

CONTRACTOR

Peter P. Nikkila

CONTRACTOR'S (or REP.) SIGNATURE

7 May 1986

DATE

Field Calibration of

Concrete Mobile Mixer # TCM52880N/365 Calibrated in Gear # _____ (When Applicable)

RECORD THE WEIGHTS OBTAINED AND ACTUAL COUNT FOR EACH OF SIX TEST RUNS IN
STEP 1: THE SPACES BELOW - THEN TOTAL RESULTS FOR THE 6 RUNS. CAUTION: USE WEIGHT
OF CEMENT ONLY - NOT INCLUDING WEIGHT OF CONTAINER.

	RUN #1	RUN #2	RUN #3	RUN #4	RUN #5	RUN #6	TOTALS
<u>(1800 RPM)</u> WEIGHT	88.5	90.8	94.5	90.7	90.0	90.8	545.3 POUNDS
METER COUNT	68.0	71.0	73.0	72.5	73.0	73.2	430.7 COUNTS

STEP 2: DIVIDE THE TOTAL COUNT (ACTUAL CEMENT METER COUNT FOR SIX RUNS - FROM STEP 1)
BY THE TOTAL WEIGHT - LBS. (FROM STEP 1)

TOTAL COUNTS (FROM STEP 1)	TOTAL WEIGHT	FACTOR (TO 4 DECIMALS)
430.7	545.3	0.7898

GATE SETTING
Low Slump
SAND 3.0
Rock 3.3
GATE SETTING
CLASS A 45 M
No. 169-45-83

STEP 3: DETERMINE THE NEW CEMENT METER COUNT FOR THIS CONCRETE-MOBILE BY MULTIPLYING
THE FACTOR DETERMINED IN STEP 2 BY 94.

FACTOR	NEW CEMENT METER COUNT	NOTE: RECORD YOUR ANSWER TO TWO DECIMALS AS THE NEW RE-CALIBRATED CEMENT METER COUNT (FOR ONE 94 LB. UNIT OF CEMENT)
0.7898 x 94	= 74.24	NEW CEMENT METER COUNT 74.24

SAND 3.2
Rock 5.5

CALCULATING TIME (IN SECONDS) TO DISCHARGE ONE 94 LB. UNIT CEMENT

STEP A: RECORD THE TIME NOTED DURING EACH OF THE SIX TEST RUNS ABOVE IN THE SPACES
BELOW - THEN ADD UP THE TOTAL NUMBER OF SECONDS YOU HAVE RECORDED.

SECONDS RUN #1	SECONDS RUN #2	SECONDS RUN #3	SECONDS RUN #4	SECONDS RUN #5	SECONDS RUN #6	TOTAL SECONDS
29.3	30.5	31.3	30.5	30.7	31.0	183.3

STEP B: DIVIDE TOTAL SECONDS (FROM STEP A) BY TOTAL WEIGHT (FROM STEP 1 IN CALCULA-
TION FOR CEMENT REGISTER COUNT)

TOTAL SECONDS STEP A	TOTAL WEIGHT STEP 1	FACTOR (TO 4 DECIMALS)
183.3	545.3	0.3361

STEP C: DETERMINE THE NEW TIME TO DISCHARGE ONE 94 LB. UNIT OF CEMENT BY MULTIPLYING
THE FACTOR DETERMINED IN STEP B BY 94.

FACTOR (STEP B)	NEW TIME	NOTE: RECORD YOUR ANSWER TO TWO DECIMALS AS THE NEW RE-CALIBRATED TIME IN SECONDS TO DISCHARGE ONE 94 LB. UNIT OF CEMENT. ENTER THIS FIGURE IN THE BOX.
0.3361 x 94	= 31.59	NEW TIME 31.59

INSPECTOR: Jim MixPROJECT NO. IR 90 Z(90)60DATE 7 May 1986

MOBILE MIXER CALIBRATION

Contractor XYZ, Inc. Mobile Mixer Serial No. TCM52880N/365
 Inspector John Doe Operating Speed 1800 RPM
 Date August 31, 1997

STEP 1.: Set Mobile Mixer to Operating Speed.

Using the meter count designated in the Mobile Mixer Operators Manual or the Previous Years Calibrated Meter Reading as a starting point, Make six test runs discharging cement. Record the "Weight of Cement", "Actual Meter Count" and "Time" for each of the six test runs in the table below.

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	TOTALS
CEMENT WEIGHT	89.8	92.8	96.3	95.3	94.8	95.3	564.3
METER COUNT	43	44	45	45	45	45	267
TIME	18.28	18.98	19.73	19.53	12.20	19.34	115.06

STEP 2.: Divide the Total Meter Count by the Total Cement Weight as determined in STEP 1. (Record to 4 Decimal Places):

$$\frac{(B) \text{ 267 } \text{ Counts}}{(A) \text{ 564.3 } \text{ Lbs}} = \underline{0.4732} \quad (\text{Factor 1})$$

STEP 3.: Divide the Total Number of Seconds by the Total Cement Weight as determined in Step 1. (Record to 4 Decimal Places):

$$\frac{(C) \text{ 115.06 } \text{ Seconds}}{(A) \text{ 564.3 } \text{ Lbs}} = \underline{0.2039} \quad (\text{Factor 2})$$

STEP 4.: Determine new "Cement Meter Count" by multiplying Factor 1 obtained in Step 2 by 94:

$$(\text{Factor 1}) \text{ 0.4732 } \times 94 = \underline{44.48} \quad (\text{New Meter Count})$$

STEP 5.: Determine new "Time to Discharge One 94 Lb. Unit of Cement" by multiplying Factor 2 obtained in Step 3 by 94:

$$(\text{Factor 2}) \text{ 0.2039 } \times 94 = \underline{19.17} \quad (\text{New Time})$$

Figure 16.13 Example Mobile Mixer Calibration Calculations-1

1 Bag Cement (94 lbs.) = (D) 44.5 ← rounded Counts (from Step 4.)
 1 Bag Cement = (E) 19.17 Seconds (from Step 5.)
 Moisture Content of Sand (G) 3.5% (from test results)
 Sand Setting (Dial Setting) (H) 3.0 (from operators manual or previous calibration)
 Rock Setting (Dial Setting) (I) 4.2 (from operators manual or previous calibration)
 Determine Cement Meter Reading for Discharge of 1 Cu. Yd. of Concrete by multiplying new cement meter count by the no. of bags in the mix design.
 STEP 6.: (D) 44.5 Counts X 8.75 Bags = 389.38 Counts (J)
 Determine Time to Discharge 1 Cu. Yd. of Concrete by multiplying the new Time by the No. of bags in the mix design.
 STEP 7.: (E) 19.17 Sec. X 8.75 Bags = 167.74 Seconds (K)
 Determine weight of sand per cement meter count:
 Adjust for moisture content by multiplying the weight of sand required by the mix design by (1 + moisture content):
 (Wt.) 1394 X (1 + 0.035(G)) = 1442.7 Lbs. (L)
 Determine weight of sand per cement count by dividing the adjusted weight by the cement meter count for 1 Cu. Yd.:
 (L) 1442.79 / (J) 389.38 = 3.71 Lbs/Count (M)
 STEP 9.: Determine new sand setting (dial setting) by dividing a measureable weight of sand (Between 80 and 90 lbs.) by the weight of sand per cement meter count:
 85 lbs. / (M) 3.71 = 23 Counts (N) (round off to whole no.)
 (N) 23 X (M) 3.71 = 85.33 Lbs New Sand Wt.

Figure 16.14 Example Mobile Mixer Calibration Calculations-2

Step 9.: Set Dial for Sand to setting in (H) of Step 5.
(Continued)

Discharge sand and try to stop discharging when cement meter reading is at the Count calculated above. Record the Sand Dial Setting, Weight of Sand Discharged, and the Actual Cement Meter Reading. Compute the Weight of Sand Discharged per Count. Continue until three successive runs are made in which the Weight of Sand Discharged per Count equals the value (M) from Step 8.:

	DIAL SETTING	WEIGHT	CEMENT METER COUNT	WEIGHT OF SAND PER COUNT
Run 1	3.0	90.3	21	4.30
Run 2	2.9	88.8	23	3.86
Run 3	2.9	92.4	24	3.85
Run 4	2.8	85.5	23	3.72
Run 5	2.8	85.3	23	3.71
Run 6	2.8	85.4	23	3.71
Use Sand Dial Setting = 2.8				

} ≈ 3.71

STEP 10.: Determine weight of rock per cement meter count by dividing the weight of rock required by the mix design by the cement meter count for 1 Cu. Yd.:

$$\begin{array}{r} \text{(Wt.) } 1394 \\ \text{(J) } 389.38 \end{array} \div \begin{array}{r} 3.58 \\ \text{Lbs/Count (P)} \end{array}$$

STEP 11.: Determine new rock setting (dial setting) by dividing a measureable weight of rock (Between 80 and 90 lbs.) by the cement meter count for 1 Cu. Yd.:

$$\begin{array}{r} \text{(Wt.) } 85 \\ \text{(P) } 3.58 \end{array} \div \begin{array}{r} 23 \\ \text{Counts (Q)} \end{array} = \begin{array}{r} 3.58 \\ \text{X (P)} \end{array} = \begin{array}{r} 82.34 \\ \text{Lbs New Rock Wt.} \end{array}$$

Set Dial for Rock to setting in (I) of Step 5.

Discharge rock and try to stop discharging when cement meter reading is at the Count calculated above. Record the Rock Dial Setting, Weight of Sand Discharged, and the Actual Cement Meter Reading. Compute the Weight of Rock Discharged per Count. Continue until three successive runs are made in which the Weight of Rock Discharged per Count equals the value (P) from Step 10.:

	DIAL SETTING	WEIGHT	CEMENT METER COUNT	WEIGHT OF ROCK PER COUNT
Run 1	4.2	82.7	22	3.76
Run 2	4.1	83.3	23	3.62
Run 3	4.1	83.7	23	3.64
Run 4	4.0	86.2	24	3.59
Run 5	4.0	82.3	23	3.58
Run 6	4.0	82.3	23	3.58
Use Rock Dial Setting =				

} ≈ 3.58

WATER ADJUSTMENTS MADE BY TIME

Non-metallic fiber reinforced concrete overlay Placement, Finishing, and Curing

Deck Treatment Prior to Placement

Immediately prior to placement of Non-metallic fiber reinforced concrete overlay, the clean surface should be thoroughly wetted for a minimum of one hour. After the wetting, all standing water in depressions or holes should be blown out with compressed air or other acceptable means. A Non-metallic fiber reinforced concrete overlay grout mixture is then brushed onto the wetted prepared surface. All vertical and horizontal surfaces should receive an even and thorough coating. The grout application should be timed such that it is not dry before the concrete is placed over it.

Finish Machine

The finishing machine for Non-metallic fiber reinforced concrete overlay is the same standard finish machine that is used on new bridge deck construction as described in 'Chapter 8 - Concrete'. It should be a self-propelled rotating cylinder type, with one or more rotating steel cylinders, augers, and variable frequency vibrator pans. The cylinders, augers, and vibratory pans must be capable of placing and consolidating the concrete to the established profile by traveling transverse to the roadway center line.

Temperature Requirements

Non-metallic fiber reinforced concrete overlay must be between 50-80 degrees F at the time of placement and should be maintained in this temperature range for at least 48 hours after placement. The concrete surface at the time of placement of the mixture should be at least 40 degrees F. You can measure the surface temperature by placing a thermometer under an insulating blanket and laid against the surface. The latex modified concrete cannot be placed after October 1 or before May 1 without written authorization by the Office of Bridge Design.

The Non-metallic fiber reinforced concrete overlay cannot be placed when the air temperature in the shade exceeds 85 degrees F. It may be necessary to place concrete during evening or early morning hours to comply with this requirement. If concrete placement is planned during hours of darkness, make sure that acceptable lighting is in place.

Special Placement Requirements

Under normal working conditions, placement and finishing should proceed at a rate of not less than 40 feet per hour, measured parallel to the center line of the bridge. Longitudinal construction joints in the overlay should be located on the lane lines as much as practical, with no pour to be less than 24 feet wide.

If there is a delay in the concrete placement for more than one hour, a construction dam or bulkhead should be installed. During minor delays of less than one hour, the end of the concrete can be protected from drying with several layers of wet burlap. You should ensure that adequate precautions are taken to protect freshly placed concrete from sudden or unexpected rain. Placing operations should stop when it starts to rain. If any fresh concrete is damaged by rainfall, it must be removed and replaced.

Tining

After placing the concrete, a transverse metal-tine finish is installed in the fresh surface of the concrete. The tining should begin when a tight, uniform surface has

been achieved on the concrete, and before any plastic film begins to form. The metal-tine finish provides a groove depth of 3/16 inch +/-1/8 inch. The spacing between the individual grooves are randomly spaced and should vary between 5/8 inch to 1 5/8 inches. 50% of the spaces between grooves should be 1 inch or less. A uniform repeating pattern on the tining device should be avoided. When placing the grooves, the tining device should be placed immediately adjacent to the previous pass, but not as to overlap.

Curing

As soon as the surface can support the burlap without deformation, and following tining, a single layer of clean, wet burlap should be applied.

Within one hour of covering with wet burlap, a layer of four mil thick polyethylene film should be placed. The surface should be cured with the wet burlap and plastic in place for 7 days. Following this, the burlap and plastic can be removed, and the concrete cured an additional 48 hours by ambient air. The Contractor can substitute combination wet burlap-polyethylene sheets for the polyethylene film, this however should not replace the initial wet burlap.

Traffic cannot be permitted on the Non-metallic fiber reinforced concrete surface until concrete reaches design strength. A longer curing period may be required when temperatures fall below 55 degrees F. After the bridge deck overlay has hardened, it should be straightedge tested in accordance with 460.3.O.4.d.

Low Slump Dense Concrete Placement, Finishing, and Curing

Deck Treatment Prior to Placement

Unlike latex modified concrete, grout for low slump concrete should be applied on a 'bone' dry surface. The grout should consist of equal parts by weight of portland cement and sand, mixed with sufficient water to form a thick slurry. The workers should use a broom to scrub a thin coating of grout into the surface, abutting curb faces, and the vertical surface of previously placed lanes immediately before concrete placement. Care should be taken to ensure that excess grout does not collect in pockets. Again, the time of application should be such that the grout is still wet when the concrete is placed on top.

Before an adjacent course is placed, transverse and longitudinal joints of a previously placed overlay course should be sawn and material removed back a minimum of 6 inches. This will provide a crisp, straight, and vertical edge for the joint between courses. Note that the previously placed surface course must cure a minimum of 12 hours prior to sawing. If this work is started before the end of the 72 hour curing period, the work shall be restricted as follows:

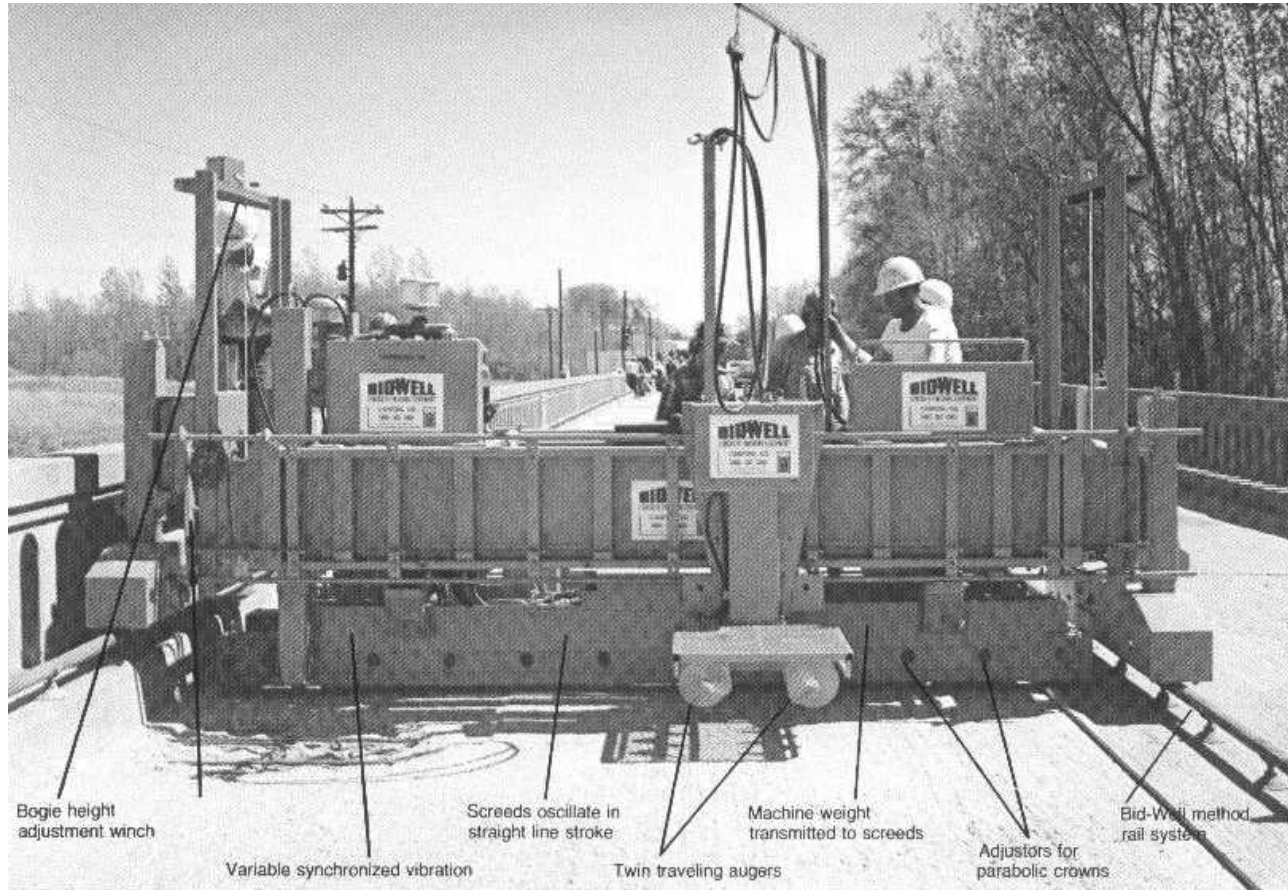
- Sawing or other operations which interfere with the curing shall be kept to a minimum time and in the immediate work area
- Curing shall be resumed promptly upon completion of the work
- The exposed area shall be kept damp until the curing media is replaced
- Power driven tools heavier than a 15 lb. chipping hammer will not be permitted

Finish Machine

Low slump dense concrete is too stiff for a standard bridge deck finish machine to finish properly. Therefore, a specialized finish machine, specifically designed for low slump dense concrete overlays, is required. Rather than using traveling rollers, the machine uses an oscillating and vibrating screed to finish the concrete. In addition, the machine places downward pressure on the concrete, thus providing compaction

of the concrete. The finish machine should have a strike off auger to provide a uniform thickness of concrete in front of the machine. The actual finishing is performed by a vibrating, oscillating screed or screeds. There should be at least one vibrator for each 5 feet of screed length. The bottom face of the screed should be at least 5 inches in width, and should have a turned up or rounded leading edge to minimize surface tearing. Each screed should be capable of applying a downward pressure of at least 75 pounds per square foot of bottom face area. Each screed should be capable of position control for vertical position, tilt angle, and crown shape.

Figure 16.15 Low Slump Dense Concrete Finish Machine



Temperature Requirements

The existing surface at the time of concrete placement shall be at least 40 degrees F, measured by a thermometer placed against the surface and covered with an insulated blanket. The concrete should be between 45-80 degrees F at the time of placement, and should be maintained at or above 45 degrees F for 72 hours. During periods of extreme and sustained hot weather, it may become extremely difficult to maintain a temperature below the 80 degrees F maximum concrete temperature for low slump dense concrete. When such conditions exist, the Engineer may authorize the maximum concrete temperature to be increased to 85 degrees F provided that the concrete is placed when the ambient air temperature is below 80 degrees F and the following conditions are met.

- The coarse aggregate piles shall be flushed with cool water.
- A minimum rate of pour of 40 linear feet per hour must be maintained.
- The wet burlap shall be placed as soon as the concrete surface will support it without deformation.

- In an effort to keep the temperature of the water as cool as possible and minimize heating of the water due to warm weather, the water tank on the mobile mixer shall not be filled until immediately prior to the concrete placement, at which time the tank shall be filled with cold water. The addition of ice to the water will be allowed.

Concrete placement will not be permitted after October 1 or before May 1. In addition, the placement of low slump dense concrete will not be allowed to begin when it is anticipated that the ambient temperature will exceed 80 degrees F at any time during the duration of the concrete placement. It may be necessary to place concrete during evening or early morning hours during periods of low humidity and high wind in order to comply with this requirement. If the Contractor plans to pour during hours of darkness, acceptable lighting must be provided. It is permissible to raise the maximum ambient temperature requirement up to 85 degrees F if the Contractor has approved fogging equipment on the project that is ready for use. The fogging equipment must be capable of applying a fine fog (water droplets no larger than 75 microns), NOT A SPRAY, under pressure through an atomizing nozzle over the entire exposed concrete surface until such a time that the wet burlap can be applied. The manufacturer's literature, equipment specifications, and operating instructions for the fogging equipment must be approved by the Office of Bridge Design prior to use. Fogging should not be allowed when the wind conditions are such that the fog cannot be maintained over the exposed concrete surface. At no time shall low slump dense concrete be placed when the ambient temperature is above 85 degrees F.

Special Placement Requirements

Under normal working conditions, placement and finishing should proceed at a rate of not less than 40 feet per hour, measured parallel to the center line of the bridge. Pours should be restricted to less than 24 feet in width unless prior approval by the Office of Bridge Design is given. The Contractor should avoid placing longitudinal joints in the traffic wheel paths. All locations of longitudinal joints are subject to the approval of the Engineer.

Concrete cannot be placed adjacent to a previous overlay course that is less than 36 hours old. Continuation in the same lane from a transverse joint can be permitted after the concrete is 12 hours old. Specifications require that the low slump dense concrete overlay be mechanically consolidated to 98% of the rodded unit weight determined in accordance with ASTM C138. The most practical method of verifying the density is the use of a nuclear density meter. Refer to the Materials and Testing Manual for the testing procedures required. Hand finishing with a float may be required to provide a tight, uniform surface. Spud vibrators are required to consolidate the concrete along longitudinal joints at curb lines and for thickness greater than 3 inches.

Tining

As soon as finishing has been completed, all vertical joints with adjacent concrete should be sealed by painting with a thinned grout and the deck surface given a broomed finish. A transverse metal-tine finish is then placed the same as previously described under latex modified concrete.

Curing

Curing for the low slump dense concrete overlay is different than that of the latex modified. After the joint painting, brooming, and grooving is completed, and as soon as the surface can support the weight without deformation, a single layer of clean wet burlap should be applied. Generally, the burlap can be placed within ten minutes after final screeding of the concrete. Care should be taken to ensure that the burlap is well drained.

Note Failure to apply wet burlap within 30 minutes after the concrete has been deposited on the deck shall be cause for rejecting the work. Surface concrete in all rejected areas shall be removed and replaced.

The surface should receive the wet burlap cure for at least 72 hours. For the first 24 hours, the burlap should be kept continuously wet by means of an automatic sprinkling or wetting system. After 24 hours, the Contractor may cover the wet burlap with a layer of polyethylene film, or they may continue using a sprinkling/wetting system for the remaining 48 hours. Traffic will not be permitted on the completed surface for 72 hours after placement. A longer period of no traffic may be required when temperatures are below 55 degrees F. After the bridge deck overlay has hardened it should be straightedge tested in accordance with 460.3.O.d.

Two Coat Epoxy Chip Seals

Another bridge deck surface treatment that is sometimes used instead of the traditional low slump dense concrete overlay is a Two Coat Epoxy Chip Seal. A two coat epoxy chip seal consists of an initial combination of an epoxy resin and a cover aggregate placed on a roughened surface, then another coat of epoxy resin and cover aggregate on top of the first. One of the largest advantages to the epoxy seal is the low weight involved. Like concrete overlays, two coat epoxy chip seals involve preparing the surface of the deck for the overlay, repairing any delaminated spots in the concrete, and then applying the seal.

Surface Preparation

Surface preparation entails the following steps:

- Grinding the concrete bridge deck to a specified condition
- Removing delaminated concrete, loose concrete and bituminous patches
- Filling depressions left in the deck from removal
- Shot blast
- Clean the deck surface

Grinding

When grinding is specified in the plans, the entire bridge deck surface should be ground to total coverage. The grinding should be accomplished utilizing diamond blades mounted on a self-propelled machine designed for grinding and texturing pavement. The equipment must be operated in such a manner that it will not strain or damage the underlying deck surface. Grinding equipment that causes ravels, aggregate fractures, or spalls should not be permitted. The residue or excess water generated by the grinding procedure is then removed with vacuum equipment from the deck surface before the residue has time to set up. Do not allow vacuuming residue or excess water to be expelled on the approach roadway or shoulder surfaces.

Grinding is done in a longitudinal direction that creates a parallel corduroy texture consisting of grooves between 0.090-0.130 inches wide. The distance between the grooves should be between 0.060-0.125 inches. The peaks of the ridges should not be greater than 1/16 inch higher than the bottom of the grooves.

Asphalt Removal

Many existing concrete bridge decks are overlaid with a Rubberized Asphalt Chip Seal (RACS) that must be removed prior to scarifying the deck. The removal consists

of heating the RACS and then scraping it from the bridge deck with a front-end loader and hand tools. The RACS should first be heated to a temperature of 125-140 degrees F with mobile heaters or portable propane heaters that are placed directly in front of the removal equipment. Before beginning removal, check the temperature of the asphalt with an infrared pyrometer that is furnished by the Department. You can tell it is nearing the desired temperature when small glossy black spots begin to form on the surface.

The removal equipment should be coated with a nonflammable lubricant that will prevent the heated asphalt from sticking to the blade. Reapply the lubricant as necessary to prevent sticking or build-up of the asphalt. The front-end loader should be operated such that a 60-70 degree angle is maintained between the bucket and the bridge deck. The bucket edge should be sharp and well lubricated, and should be kept with as much down force as possible. The speed of the loader should be maintained below the point which the bucket blade begins to 'chatter' on the deck. Areas like low spots or adjacent to curbs and joints that cannot be removed with the loader will required removal with hand tools or abrasive blasting.

Shot Blasting

Prior to placement of the two coat epoxy chip seal, the entire bridge deck surface is thoroughly cleaned of all loose and foreign material by shot blasting. The purpose of the shot blasting is to remove all the surface laitance that may interfere with the bonding or curing of the epoxy and to provide a good surface profile by exposing the coarse aggregate.

Removing and Replacing Loose and Delaminated Concrete

Like concrete bridge deck overlays, damaged or delaminated portions of the existing deck must be repaired prior to applying the epoxy overlay. Concrete removal and reinforcement repair are performed much like the repairs described earlier in this chapter for Type 1B through Type 1D Removal (refer to the Bridge Deck Overlays section of this chapter for further explanation).

Prior to placing concrete within the removal areas, the areas should be thoroughly cleaned of loose or foreign material by abrasive blasting. Again, the abrasive blasting should be to the extent that all surface laitance is removed, the coarse aggregate is exposed, and rust from any exposed reinforcing steel is removed. After abrasive blasting, the surface should be cleaned with compressed air.

Grout needs to be applied on all of the existing concrete surfaces that will be in contact with the new concrete immediately before concrete placement. A thin grout should be scrubbed into the surface, taking care to ensure that excess grout does not collect in pockets. Like concrete overlays, the grout rate of application should be limited to an amount that will be covered with concrete before it dries.

Typically the plans will provide a specific mix design to be used for the concrete. The Contractor can mix the concrete at the site in a portable mixer using hand tools. You should inspect the portable mixer and all other equipment used to prepare the concrete prior to actual mixing. Any dried mortar, dirt, or other foreign material must be removed before the equipment can be used. Be careful to watch the concrete mixing process to ensure that the right proportions have been maintained. Just like any other concrete work, testing of slump, air, temperature, and the making of cylinders is required.

The existing surface at the time of concrete placement should be at least 40 degrees F. The concrete temperature should be between 45-80 degrees F at the time of placement, and should be maintained at or above 45 degrees F for at least 72 hours. As soon as finishing has been completed, the concrete should be given a broomed finish. No tining is required. The fresh concrete should then be covered with clean wet burlap. Within one hour of covering with wet burlap, a layer of 4 mil minimum

thickness polyethylene film shall be placed on the wet burlap and the surface cured for 48 hours. Following this, the burlap and plastic are removed and the concrete is allowed to air cure for an additional 48 hours.

All new concrete placed in the existing deck shall be allowed to cure a minimum of 10 days prior to placement of the two coat epoxy chip seal. The bridge deck may be opened to traffic after placing the concrete but prior to the placement of the two coat epoxy chip seal when the newly placed concrete has attained a compressive strength of 4,000 psi. After the 10 day minimum cure period, and immediately prior to the two coat epoxy chip seal placement, the entire deck surface must be cleaned by shot blasting as previously discussed. There shall be no visible moisture present on the surface of the concrete at the time of application of the two coat epoxy chip seal.

Applying the Two Coat Epoxy Chip Seal

The two coat epoxy chip seal is a layer of epoxy with aggregate spread over it. The steps involved in the application are as follows:

First Coat:

- Epoxy Application at a minimum of 1 gallon per 40 square feet
- Aggregate Broadcast to Refusal
- Clean up of Excess Aggregate

Second Coat:

- Epoxy Application at a minimum of 1 gallon per 20 square feet
- Aggregate Broadcast to Refusal
- Clean up of Excess Aggregate
- Perform Pull-Off Tests before opening to traffic

Epoxy Requirements

Epoxy shall be a two component epoxy consisting of a base component and a hardener. Both components shall be supplied in tightly sealed undamaged containers. The containers shall be marked to identify each component and shall be clearly labeled with product name, mixing instructions and proportions, recommended storage temperature, lot number, batch number, date of manufacture and quantity contained. The epoxy shall be one of the epoxies from the Approved Products List.

A manufacturer's representative who has had past experience in the application of epoxy chip seal systems on bridge decks should be on site during epoxy chip seal applications to provide technical support. It is the Contractor's responsibility to arrange for the manufacturer's representative.

Aggregate Requirements

The cover aggregate shall be processed washed and dried dark gray or black rock. Washing shall remove dust covering the aggregate. Recycled cover aggregate shall not be used. Cover aggregate shall conform to the gradation and Mohs hardness provided in the special provision.

The aggregate must be stored in a dry, moisture-free atmosphere so as not to be exposed to rain or other moisture sources. It must be fully protected from any contaminants or moisture while at the job site.

Epoxy Application

The epoxy must be placed in accordance with the special provision and manufacturer's recommendations, as approved by the Engineer, and the following requirements:

- Temperature of air, existing deck, and epoxy must be between 50° F and 100° F and the air temperature is at least 5° F above the dew point temperature and no rain is forecast for the anticipated duration of the placement.
- The application of the Epoxy Chip Seal System shall not be made on a wet or damp surface. In the event of rain, the surface shall be dried for 24 hours prior to application. Application of the Epoxy Chip Seal System shall not be made when rain is forecast. Note, however, that high humidity will not impede the application of or effect the performance of the Epoxy Chip Seal System.
- After mixing the components, the resin shall be evenly distributed on the clean, dry deck surface.
- Epoxy shall be broadcast over the deck surface using a gauge rakes. The epoxy application rate is monitored by marking out a grid pattern on the deck.
- Protective gloves, clothing, boots, and goggles shall be provided to workers and inspectors directly exposed to the epoxy material. Product safety data sheets shall be supplied by the manufacturer and made available to all workers and inspectors exposed to the epoxy material.

Aggregate Application

Basalt aggregate shall be broadcast to refusal. This is done to completely saturate and cover the epoxy surface area without excessive buildup. Broadcast to refusal should be done by hand spreading aggregate, or other method approved by Engineer, in order to achieve a uniform layer of aggregate on the surface. No wet spots should be visible on the deck surface after application of aggregate to refusal.

Excess aggregate can be removed and disposed of by Contractor by brooming, high pressure air, or vacuuming as approved by the Engineer.

Bridge Deck Widening/Replacement

As the use of a road grows, particularly in urban situations, it may become necessary to add an additional lane or lanes to accommodate the traffic volume. Bridge deck widening takes place when the existing deck is not wide enough to allow the additional lane without modification. Sometimes it may be more economical to widen the existing deck rather than replace the entire structure. Bridge deck widening can be used in combination with deck overlays, where the existing deck is first widened, and then the entire deck (existing and new widened portion) is overlaid.

Deck replacements occur when the deterioration of a bridge deck becomes so widespread, that partial to full depth removal of the slab is required extensively. If the existing substructure units and supporting superstructure girders (where applicable) are in good condition, it may be more economical to replace only the existing deck rather than the entire structure itself.

Concrete Breakout and Containment

Demolition Plan

Thirty days prior to the start of work, the Contractor is required to submit a detailed Demolition Plan to the Office of Bridge Design for review and approval. Typical items required on the demolition plan are as follows:

- Canopy details (where required)
- Traffic control procedures (where required)
- Bridge deck breakout detail
- Sequence of bridge deck removal

The demolition plan is partially required in order to force the Contractor to think through his or her demolition and removal process, thereby eliminating any potential problems before they arise on the job site.

Canopy

Breakout above a roadway carrying traffic is of utmost concern. A rigid canopy is generally required in order to ensure safety from potential falling debris. A rigid canopy may also be required on stream crossings in order to keep debris from falling into the water. Like falsework, the configuration, makeup, and materials of the canopy are left entirely up to the Contractor. The canopy is not intended to be a catchall for large pieces of concrete during removal, but is only to function as an added safeguard for keeping small, aggregate to hand-size debris from falling on the roadway below.

Removal over Tops of Girders

On a girder bridge, it is critical that care be taken during the removal process to ensure that the existing girders are not damaged. Plans will require that the limits of the existing girder top flanges be marked (usually with spray paint) on the top of the bridge deck. The Contractor should not be allowed to use any impact type breakout equipment larger than hand tools for removal or saw cut of the slab within 6 inches of the actual limits of the flange. It is recommended that the Contractor be limited to a 15 lb. chipper hammer immediately above the girders.

Watch to make sure the breakout method does not nick, gouge, or scratch the top of the girder or any other structural steel that is to be reused. Steel girders are of particular importance as they can develop fatigue cracks from even the seemingly smallest nicks or gouges. Absolutely no nicks or gouges should be allowed on existing steel girders. If any nicks, gouges, or scratches occur, notify the Office of Bridge Design immediately. The Office of Bridge Design will most likely need to review the extent of the damage and then will recommend a method of repair.

Some existing girders have shear connector angles or studs that make the girder function integrally with the deck slab for flexural strength. If any of these existing connectors are failed or removed in demolition, they must be replaced. The plan notes will usually provide notification of the connectors, and direction for what is required to replace them if they are damaged. If not, contact the Office of Bridge Design for further instructions.

Breakout by Sections

The bridge deck should be cut into sections and lifted off the bridge. Do not allow the sections to fall into the canopy. Generally the Contractor will saw cut the deck at a depth that cuts at least the bottom mat of reinforcing steel. If the structure is a

girder bridge, watch to ensure that the depth is monitored such that the existing girder flanges are not damaged.

New Construction

Girder retrofits, substructure repairs, or other rehabilitation work is generally completed after the deck has been removed. When all retrofits and repairs are made, the new bridge slab is shored up and constructed the same as for new bridges. See 'Chapter 8 - Concrete' for further details on pouring new bridge decks.

Making Bridge Decks Continuous and/or Composite

Continuous Decks

Older bridges provide transverse openings in the bridge decks for temperature movements. The open bridge joints allowed water and debris to reach the underlying superstructure and superstructure units. Steel components would experience advanced corrosion rates and concrete members would experience delaminations, scaling, and spalling. Additionally, over time many of the substructure units on these bridges have moved causing the openings in the bridge deck to go to zero. The temperature movements the bridge will experience are thus forced into bridge components that were not originally designed to take these loads. Often times the locked-in forces will damage individual bridge components such as abutment back walls, bridge bearings, girder ends, and bridge deck joints. From a maintenance stand point, removing open joints from existing structures is a high priority item.

New bridges are designed as much as possible to eliminate deck joints. Most lengths of bridges constructed in South Dakota permit the use of integral abutments, whereby the joints are essentially moved off the deck and placed at the ends of the approach slabs.

There are many different ways South Dakota has rehabilitated open bridge joints. One method used to eliminate an open bridge joint adjacent to an abutment is to remove the existing abutment back wall, convert the abutment type to a semi-integral abutment, and place the bridge expansion joint in the approach slabs attached to the semi-integral abutment. This retrofit is limited to bridges that are less than a certain length and skew. Constructing a semi-integral bridge abutment involves a considerable amount of select concrete breakout and salvaging of a specified amount of the existing reinforcement.

One method used to eliminate open joints over bridge piers is to remove the existing open joint and make the deck continuous over the bent or pier. The open joint can be anything from an existing construction joint in a slab (that will let water through) to a fabricated expansion device. Eliminating a joint in a bridge deck also involves a considerable amount of concrete breakout and salvaging of a specified amount of the existing reinforcement.

As in bridge deck replacement, it is critical that care is taken around any existing structural steel or reinforcement that is to be salvaged and/or remain in place. The breakout equipment should be limited to 15 lb. hand chippers. You should watch to ensure the breakout method does not nick, gouge, scratch, or otherwise damage the top of the existing girders to remain.

Composite Decks

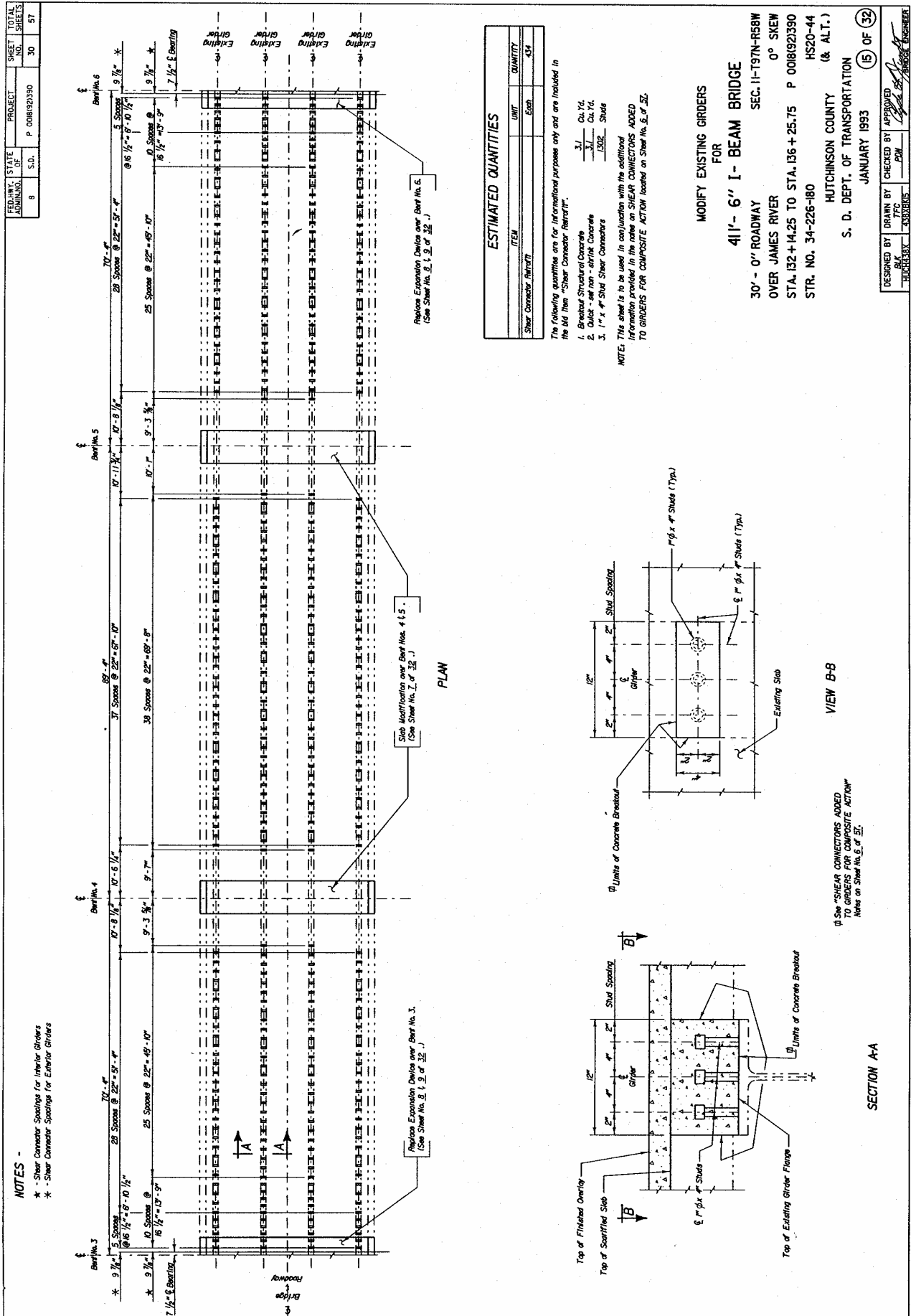
Traditionally many older steel girder or I-Beam bridges were designed and constructed as non-composite bridges. This means that the girders carried the full

load of the bridge without utilizing any strength contribution from the concrete deck. Today, most steel girder structures are designed and constructed as composite bridges, where the deck is anchored to the girder such that the girder can utilize some contributing strength from the concrete deck.

To strengthen the capacity of a bridge, the existing steel beams and concrete deck can often be modified to carry the load together, as a composite section. The modifications involve adding shear studs at regular intervals along the length of the girder to connect the deck and girder together. For bridge deck replacements this can easily be done as the concrete deck has already been removed and the girder flanges are readily accessible. For other bridges, however, the modification requires very select and repetitive concrete breakout in order to expose the top of the existing beam. Figure 16.16 is an example plan sheet showing the breakout and details required for this type of work.

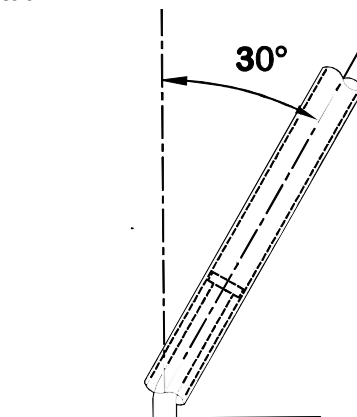
The locations for the shear connectors are first defined by saw cutting the perimeter of the area. The areas are then removed using small, hand operated tools. Again, it is critical during the removal operation that the tops of the girders themselves are not damaged. Fifteen pound chippers or smaller hand equipment should be used to prevent damage from occurring.

Figure 16.16 Typical Plans Sheet for Composite Girder Modifications



Shear studs should be welded to the existing steel beams with automatically timed stud welding equipment. Do not allow the Contractor to fillet weld the studs to the beam using conventional field welding equipment without approval of the Office of Bridge Design. If approval is given, some additional inspection requirements may be necessary. All studs should be given a visual inspection for full 360 flash (quality weld around the entire perimeter). Any that do not have full flash should be removed and replaced. In addition, the first two studs at the beginning of each day should be bend tested for the quality and adequacy of the weld. The bend test consists of bending the stud to a minimum of 30 degrees from its original axis by striking it with a hammer or prying it with a pipe (Figure 16.17). If either of the studs fail by cracking or dislodging of the weld, then procedures must be corrected and two more studs applied. Bend testing is required until two consecutive studs are tested and found to be satisfactory.

Figure 16.17 Bend Testing of Stud



Girder Strengthening

Many of South Dakota's existing bridges were not designed for today's loadings. Often times the load carrying capacity of these existing bridges can be increased by strengthening key components of the bridge. One such modification is that of girder strengthening.

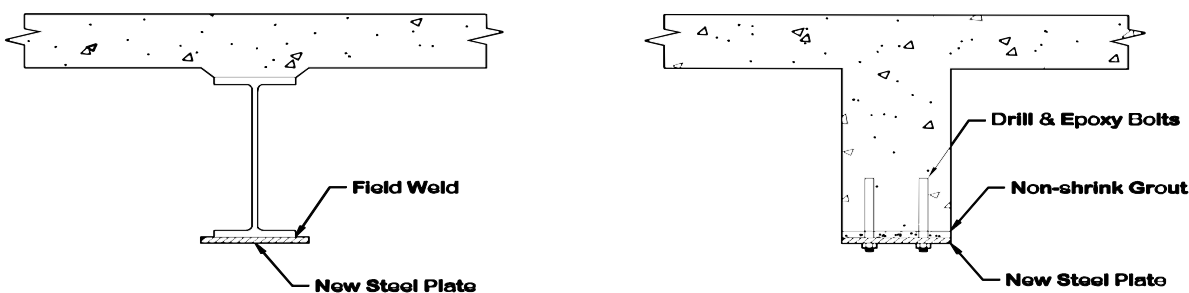
Typically girder strengthening can take place in two forms:

- 1 Adding additional section(s) to the girder in the form of a steel plate(s); or
- 2 Adding post-tension rod to the beam.

Steel Plates

The addition of a steel plate to the bottom flange of a girder (steel or concrete) increases the girder's capacity to resist loads in flexural bending by physically increasing its size. While adding a steel plate sounds relatively simple at first glance, in actuality, the process can be quite involved and very labor intensive.

Figure 16.18 Strengthening Girders with Steel Plates



Plates can be added to steel or concrete beams. On steel beams, the plate is typically sized slightly larger in width than the existing bottom flange width. The plate can then be field welded to the girder with a common fillet weld. A certified welder must perform the welds. Non-destructive testing of the welds may be required. You should watch for the following items:

- The existing girder flanges are properly prepared for the new welds by removal of all existing paint and rust in the weld areas.
- The welds are performed by a certified welder, of correct size and spacing (if applicable), and in good condition.
- The joint between the existing beam and new plate is properly sealed as per plans instructions to prevent water infiltration and future pack rusting problems.

Alternately, the plans may require that the plate be bolted to the steel beam instead of field welding. In this case, the flanges of the existing beam would need to be field drilled at incremental intervals to allow attachment by bolts.

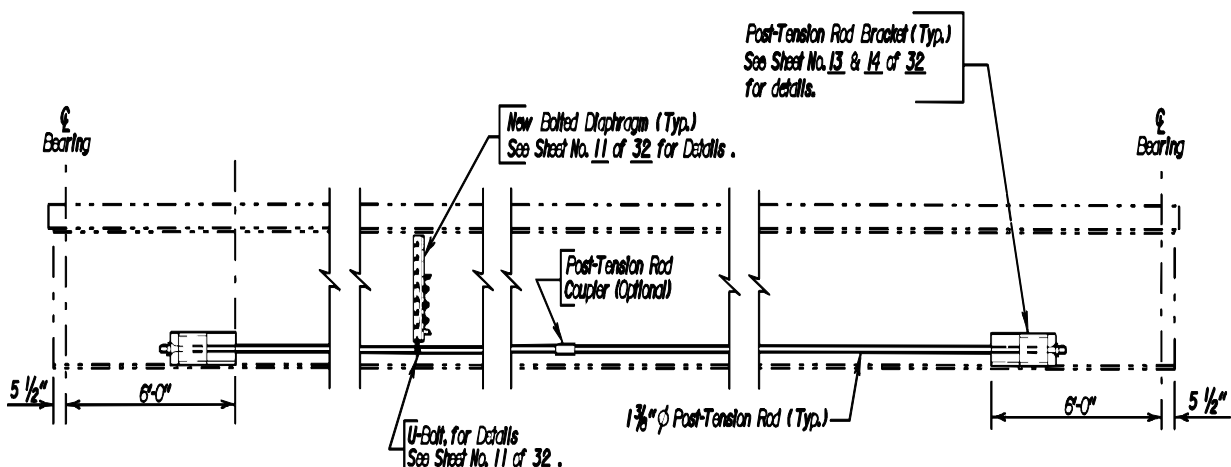
On concrete girders, the plate is typically added by bolting to the beam. The threaded rods or bolts are drilled and epoxied into the existing beam at a plans designated uniform spacing. The steel plate may or may not be placed flush with the bottom of the existing beam. When not placed flush, the plans will typically call for the gap to be filled solid with a non-shrink grout. The most critical items to watch for are:

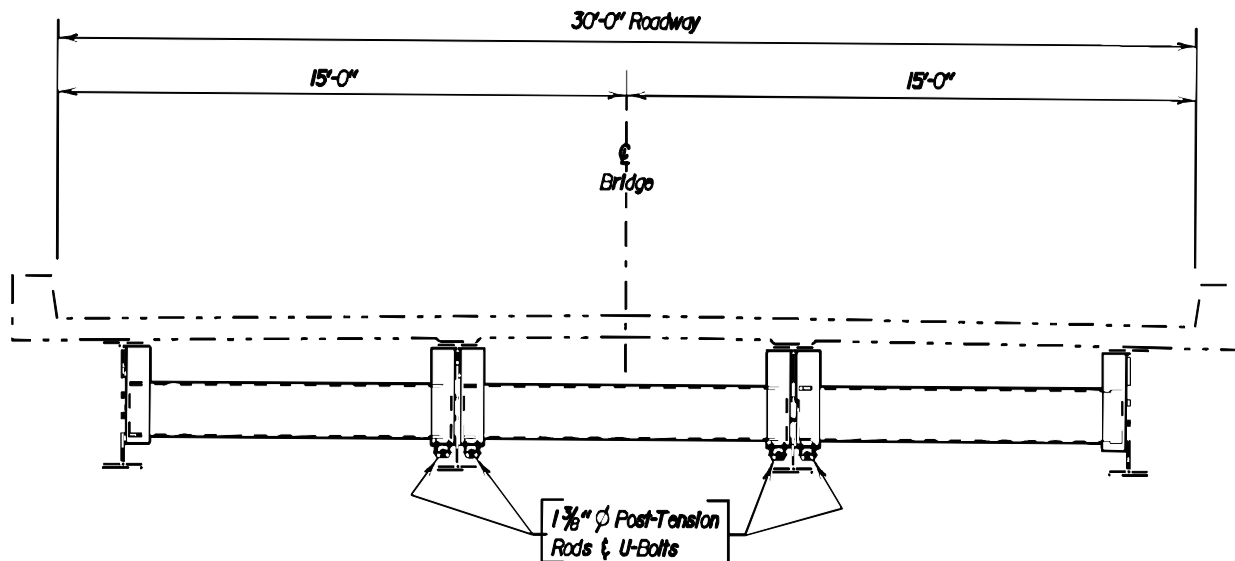
- The threaded rods or bolts are drilled into the existing beam at the proper locations with an epoxy intended for vertical applications. Make sure that the epoxy manufacturer's instructions are strictly adhered to and that there is no question as to the adequacy of the construction.
- The gap between the beam and steel plate (when applicable) is completely and thoroughly packed solid with grout. No voids should remain.
- The joint between the existing beam and new plate is properly sealed as per plans.

Post-Tension Rods

Modifying a girder with post-tension rods increases the girder's flexural strength by inducing compressive stresses or forces into the bottom flange. Under positive (midspan) bending loads, the bottom flange of the girder is in tension. By inducing a compressive force into the beam, the total tension stresses are reduced and the flexural capacity is increased.

Figure 16.19 Strengthening Girders with Post-Tensioned Rods





Generally this method is used on steel girders, although the application would be similar for concrete beams as well. The rods attach to the beam with a bracket assembly that is bolted to the bottom flange. The rods are threaded at the ends to permit tightening of the rod to specific loads that create the induced compressive load. Typically a diaphragm assembly is also added intermittently along the girders to keep the rods in proper position.

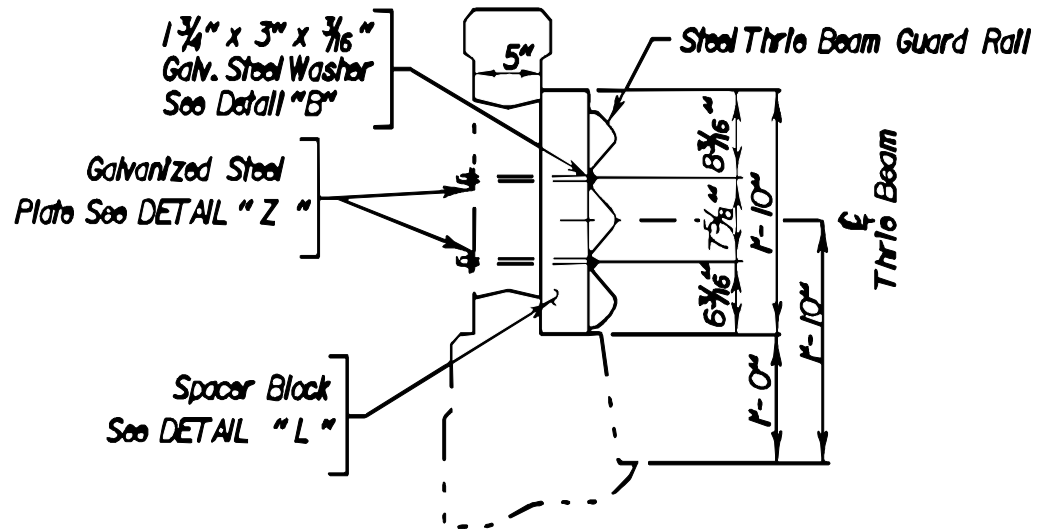
Bridge Rail Retrofits

Generally a bridge rail retrofit involves adding a steel thrie beam guardrail to an existing bridge rail. The guardrail is positioned flush with the curb line with the use of wood spacer blocks placed between the existing rail and the thrie beam rail. This type of rail retrofit can be part of a bridge rehabilitation project, part of roadway surfacing or roadway rehabilitation project, or can be a stand-alone project. There are two types of thrie beam rail retrofits, Design 1T or Design 2T. One or the other will be used depending on the type of existing rail the thrie beam will be attached to.

Design 1T Rail Retrofits

Bridge Guardrail Class B, Design 1T retrofits are generally used on bridges that have existing pigeon hole concrete type barriers. The modification involves placing wooden spacer blocks at regular intervals along the length of the barrier. The steel thrie beam railing is then bolted through the spacers to the existing concrete railing.

Figure 16.20 Design 1T Bridge Rail Retrofit

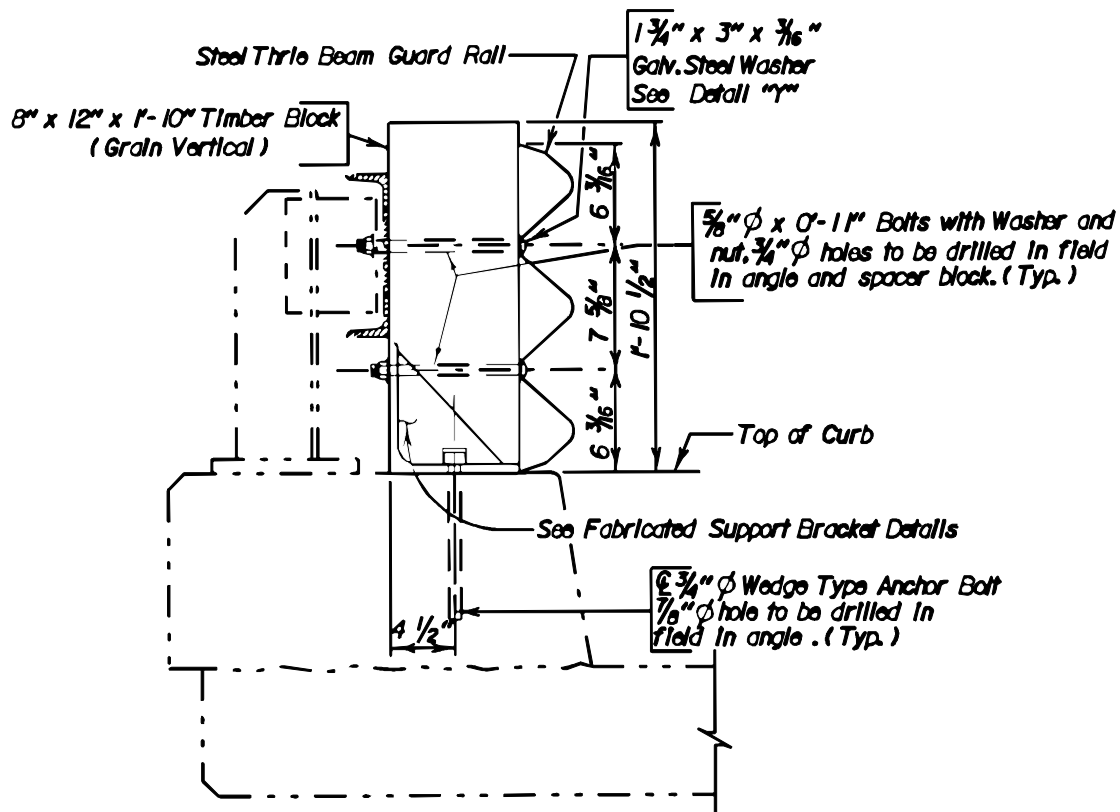


The wooden spacer blocks are constructed by laminating a number of layers of exterior grade plywood as required in order to bring the thrie beam flush with the concrete curb. Each layer of plywood is given a thorough coating of linseed oil prior to assembling the block. Once installation of the guardrail is completed, the top and vertical edges of the plywood spacer blocks should be painted with a white oil-base paint.

Design 2T Rail Retrofit

Bridge Guardrail Class B, Design 2T retrofits are generally used on bridges that have existing steel channel or tube railing. Modifications for the rail retrofit involve adding wood spacer blocks at each existing steel rail post location. The steel thrie beam railing is then bolted through the spacers to the existing steel railing.

Figure 16.21 Design 2T Rail Retrofit



Unlike Design 1T railing, the wood spacers for Design 2T railing are solid blocks of Douglas Fir or Pine. The timber blocks should be treated with preservative treatment as per Section 950 of the Standard Specifications.

The wood spacers are also anchored to the concrete curb with steel support brackets that are attached to the curb. Special bolts called wedge anchors are then used to fasten the bracket down. The wedge anchors used must be one of the anchors listed in the plans notes. Do not allow the anchors to be used if they are not listed in the plans without prior approval by the Office of Bridge Design. After installing the anchors, the holes should be sealed with a silicone sealant to prevent water penetration.

Thrie Beam Splices

Plans will generally call for the guardrail lengths to be 12 feet - 6 inches. Twenty-five foot lengths may be used provided they are compatible with the type called for in plans. Make sure that the splices or laps are oriented in the correct direction for traffic.

Miscellaneous Bridge Rehabilitation

As stated at the beginning of the chapter, bridge rehabilitation encompasses a large variety of work and applications. Many bridge repair projects are unique to themselves. These will require you to intimately review the plans, plan notes, special provisions, and any pertinent specifications in order to gain a full understanding of what will be involved and necessary for inspection. If you have any questions as to the intent of the repair work or the inspection that may be required to adequately ensure that the work is properly done, you should contact the Office of Bridge Design for further instructions.

MECHANICALLY STABILIZED EARTH (MSE) RETAINING WALLS

Checklists

Pre-construction Preparation

- Design calculations and construction plans (shop plans) approved by the Office of Bridge Design
- Review the plans, specifications, and approved construction plans. Become familiar with:
 - Construction sequence
 - Reinforcement types and locations
 - Backfill type, gradation, and compaction requirements
 - Drainage details and any special utility requirements
 - Batter or slope of the facing panels
- Check the site conditions and foundation requirements. Observe:
 - Any special requirements that might be needed for preparation of the foundation
 - Review the subsurface investigation sheet
 - Identify the ground water elevation

Materials Inspection

Concrete Facing Elements (Blocks or Panels). Check for:

- Imperfect molding
- Honey-combing
- Severe cracking, chipping, or spalling
- Variation in color of finish
- Out-of-tolerance dimensions
- Misaligned connections

Reinforcing Elements and Joint Materials

- Material delivered meets type specified and noted in the approved construction plans
- Flaws or other damage observed
- Materials stored and handled in a manner to prevent damage

Sample gradation and perform test on backfill material

Inspection During Construction

Foundation Preparation and Leveling Pad

- Excavate depths as shown in the approved construction plans
- Sub-base material properly compacted and prepared to meet grade requirements
- Concrete leveling pad (where required) meets minimum dimensions

Setting Facing Panels

- Alignment (both vertical and horizontal) maintained
- Temporary bracing and wedges installed

Setting Reinforcement and Placing Backfill

- Reinforcement lengths and spacing correct
- Reinforcing installed as per manufacturer's requirements
- Connections correct
- Geo-grids pulled taut
- Backfill moisture monitored and controlled
- Backfill properly compacted
- Walk behind vibratory compactors used within 3 foot zone of wall face

Beginning and End of Each Day's Work

- At the completion of each day, the fill should be graded to drain away from the wall face and lightly compacted
- At the beginning of each day, the surface of fill should be lightly scarified

Alignment Problems. Refer to 'Out-of-Tolerance Conditions and Possible Causes' at the end of this chapter.

General

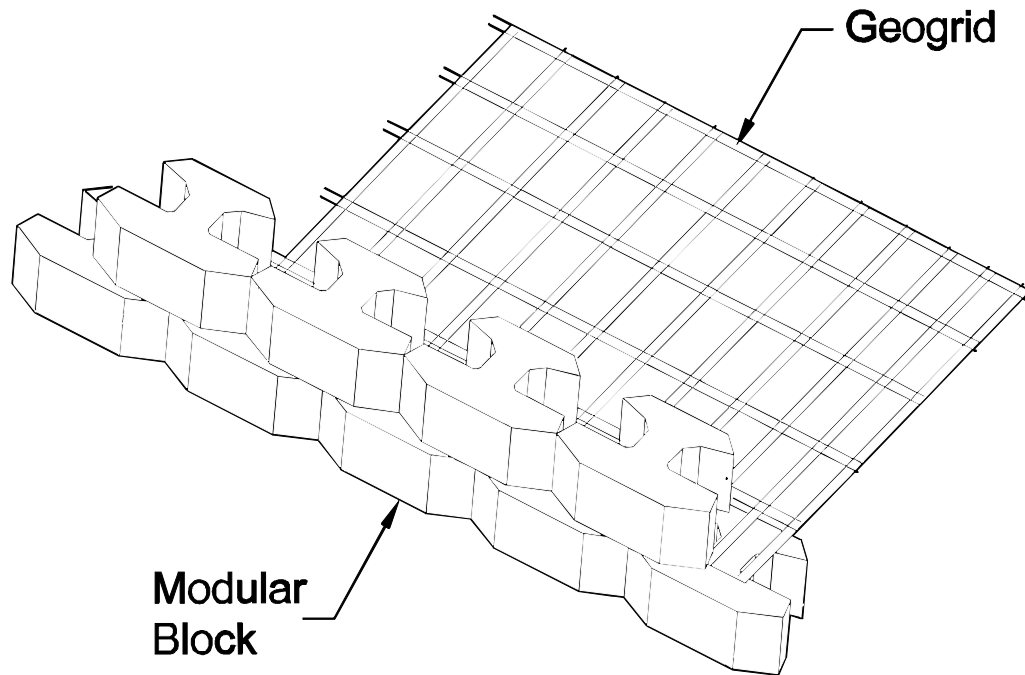
Recently Mechanically Stabilized Earth (MSE) retaining walls have begun replacing walls that traditionally would have been constructed of cast-in-place concrete. This is largely due to the MSE retaining wall's relatively simple and rapid installation. These retaining walls are really a structural system of elements that work together to hold the backfill in place. The earth or backfill material is held in place utilizing its own frictional strength by interlocking with layers of reinforcing materials that are attached to a concrete facing panel or block. The concrete blocks or panels comprising the face serve only as a cover to hold the immediate soil behind them in place and to provide an aesthetic covering. The key to the MSE retaining wall system is the proper placement of the reinforcement layers and the proper compaction of the backfill material between layers.

MSE retaining walls are thought to be more aesthetically pleasing than the cast-in-place retaining walls of the past. These walls can also accommodate larger degrees of movement of either the foundation or retained earth without seriously compromising the structural integrity of the wall system. There are currently two classifications of walls used on South Dakota State projects:

- MSE Segmental (Modular) Walls; or
- MSE (Large Panel) Walls

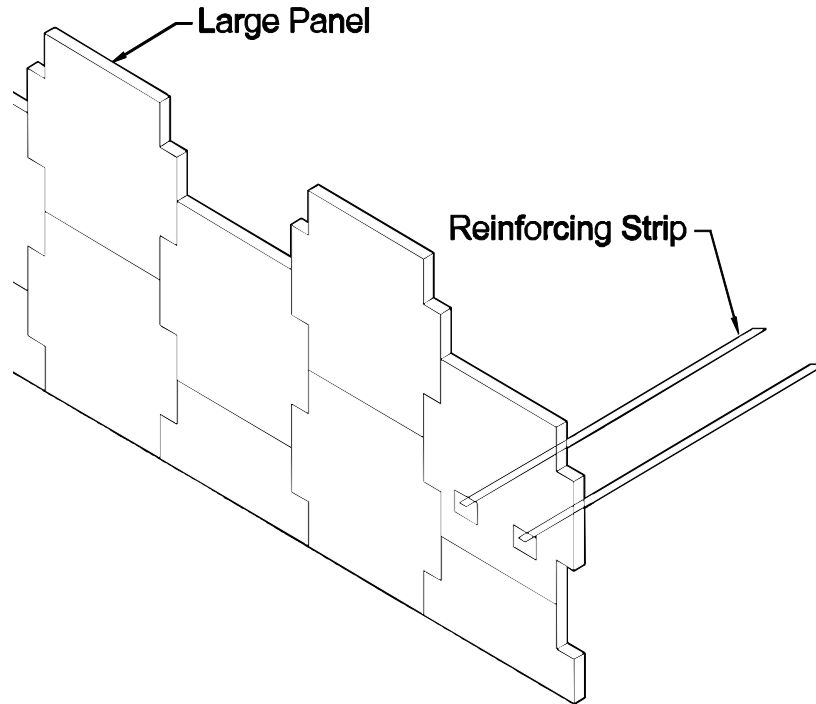
MSE Segmental (Modular) Walls are walls constructed of small modular concrete blocks that interlock together either by shape or with inserted pins. Generally these walls can be built up to 4 feet in height without the use of any supplemental geogrid reinforcement.

Figure 17.1 MSE Segmental (Modular) Wall



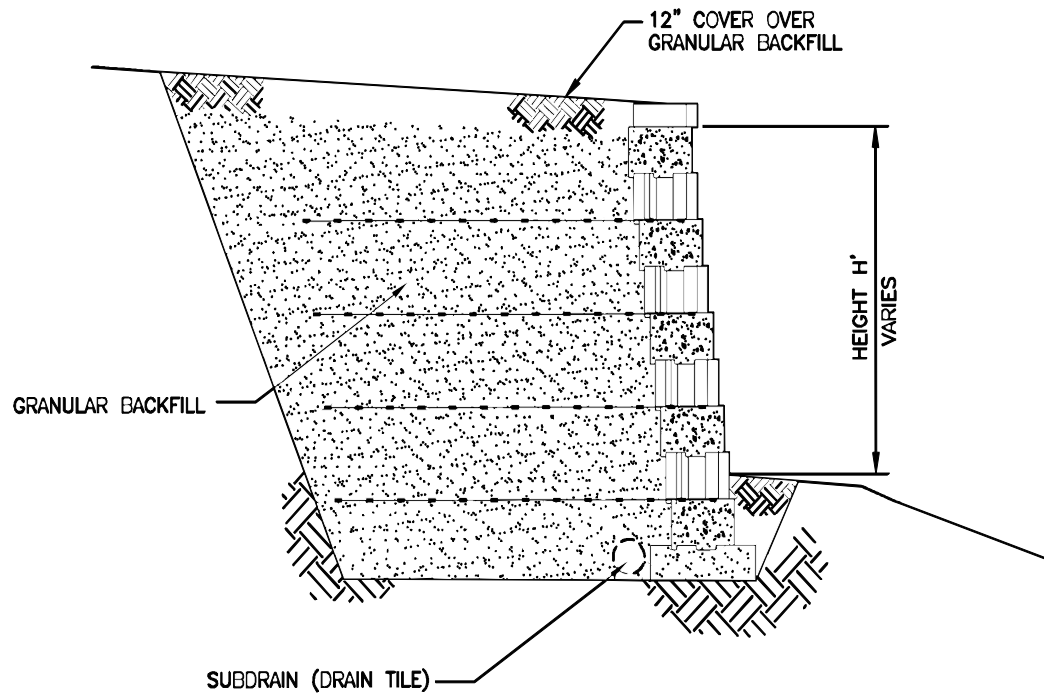
MSE (Large Panel) Walls are constructed of large, relatively flat precast concrete panels that also interlock together by shape or with pins. These walls can be built up to heights of 75 feet or more with proper reinforcement.

Figure 17.2



Construction of MSE wall systems is relatively simple and rapid. The construction sequence consists mainly of preparing the sub-grade, placing and compacting backfill in normal lift operations, laying the reinforcing layer into position, and installing the facing elements. Special skills or equipment are usually not required. Most wall manufacturers provide on-site training for construction of their systems.

Figure 17.3 MSE Segmental (Modular) Wall Section



Pre-construction Preparation

MSE walls are somewhat like precast box culverts in that the design and construction plans for the wall are entirely the responsibility of the Contractor with the aid of an approved wall manufacturer. The Contractor should work with an approved MSE wall company to obtain design calculations and construction plans. These design calculations and construction plans must be submitted to the Office of Bridge Design a minimum of two weeks prior to the start of construction. The wall system manufacturer must be from the approved products list held and maintained by the Office of Bridge Design. Prior to erection of the structure, you should become thoroughly familiar with the following items:

- The plans and specifications (including approved construction plans)
- The site conditions relevant to construction requirements

Plans and Specifications

You should read through the plans and specification requirements to become familiar with the layout, details, and construction sequencing required prior to the start of the work. Keep in mind that the information provided in the plans is only the minimal wall geometry data. The actual details of the gravel or leveling pad, face panel or block type, reinforcement type and spacing, backfill material requirements, and other pertinent information needed to build the wall should be obtained from the approved construction plans previously discussed. Special attention should be given to the construction sequence, special reinforcement requirements around obstacles or curves, backfill placement requirements to prevent damage to reinforcement, backfill gradation requirements, soil compaction restrictions, details for drainage requirements and utility construction, and construction of the facing panel slope.

Review of Site Conditions and Foundation Requirements

The site conditions should be reviewed to determine if there will be any special construction procedures required for preparation of the foundations, site accessibility, excavation for obtaining the required reinforcement length, and construction dewatering and other drainage features.

Foundation preparation involves the removal of unsuitable materials from the area to be occupied by the retaining structure including all organic matter and vegetation. Foundation preparation is important under the entire wall area (not just the leveling pad), so that settlement does not take place within the wall system. You should review the borings and information provided in the subsurface investigation sheet to help determine the anticipated extent of the removal required.

Groundwater and Drainage

Pay attention to the groundwater level, especially when adjacent to any nearby bodies of water that might affect drainage requirements. Construction dewatering operations should be required for any excavations performed below the water table to prevent a reduction in soil shear strength due to hydrostatic water pressure. Slopes into which a cut is to be made should be carefully observed, especially following periods of precipitation, for any signs of seeping water.

MSE walls are usually designed to permit drainage of any seepage or trapped groundwater in the retained soil. Typically an under-drain system will be installed behind and beneath the wall. Internal drainage of the reinforced fill is usually attained by use of a free-draining granular material that is free of fines. Because of its high permeability, this type of fill will prevent retention of any water in the soil fill

as long as a drainage outlet is available. Surface water infiltration into the retained fill and reinforced fill is usually minimized by providing an impermeable cap and adequate slopes to nearby surface drain pipes or ditches with outlets to storm sewers or to natural drains.

Materials Inspection

When delivered to the project site, you should carefully inspect all material (precast facing elements, reinforcing elements, bearing pads, facing joint materials, and reinforced backfill). All system components should be stored and handled in a manner to avoid damage. The approved shop plans may dictate storage and handling requirements for facing panels or reinforcement materials.

Concrete Facing Elements

Facing elements delivered to the project site should be examined prior to erection. You should check for the following deficiencies or defects:

- Imperfect molding
- Honey-Combing
- Severe cracking, chipping, or spalling
- Color of finish variation on the front face
- Out-of-Tolerance dimensions
- Misalignment of connections

Large Panel precast concrete units should meet the following dimension tolerances:

- Overall dimensions-----1/2 inch
- Connection device locations---1 inch
- Panel squareness-----1/2 inch difference between diagonals

Segmental (Modular) Block concrete units should meet the following dimensional tolerances:

- Overall dimensions-----1/8 inch
- Height of each block-----1/16 inch

In cases where repair to damaged facing elements is possible, it should be accomplished to the satisfaction of the Project Engineer.

Reinforcing Elements

Reinforcing elements (strips, mesh, sheets) should arrive at the project site securely bundled or packaged to avoid damage. These materials are available in a variety of types, configurations, and sizes (gauge, length, product styles), and even a simple wall may have different reinforcement elements at different locations. You should carefully review the approved construction plans for the type of reinforcement required. Check to ensure that the reinforcement material delivered and installed is that specified in the plans. Usually the material will be noted and identified to meet specific specification designations (AASHTO, ASTM, or other agency specifications). Material verification is especially important for geotextiles and geogrids where many product styles look similar but have different properties. Mesh reinforcement should be checked for gross area and length, width, and spacing of transverse members. For strip reinforcements, the length and thickness should be checked.

Facing Joint Materials

Bearing pads (cork, neoprene, SBR rubber), joint filler (synthetic foam), and joint cover (geotextile) should be properly packaged to minimize damage in unloading and handling. For example, polymer filler material and geotextiles must be protected from sunlight during storage. Although these items are often considered as miscellaneous, it is important to recognize that use of the wrong material or its incorrect placement can result in significant structure distress.

Backfill Material

The backfill in MSE structures is the key element in satisfactory performance. Both, use of the appropriate material and its correct placement are important properties. Backfill material is up to the choice of the MSE wall designer, and should be specified and noted on the approved construction plans to meet certain gradation requirements. A gradation test should be run prior to construction for quality assurance and to form the basis for approval. Depending on the volume of fill to be placed and whenever the appearance or behavior of the backfill changes noticeably, additional periodic tests should be performed.

Inspection During Construction

Each of the steps in the sequential construction of a MSE wall is controlled by certain method requirements and tolerances. The wall should be installed in strict adherence to the proprietary MSE wall companies' instructions and specifications as detailed on the approved construction plans. The following is a brief description of general construction requirements that are common to most wall systems.

Foundation Preparation

The existing soil conditions, height, and type of wall will dictate the extent of foundation preparation necessary. Short, modular block walls may only require excavation to the bottom of the wall and compaction of the existing in-place soils with a vibratory roller. Other areas may require some degree of undercut and backfill with a granular material. The plans will note the degree of foundation preparation required. The intent is to provide a thoroughly compacted, 'to-grade' subbase that is free of voids or depressions. Any voids encountered should be filled with a granular material and compacted as specified or noted in the plans.

Leveling Pad

Large panel walls (and at times modular block walls) require a concrete leveling pad be placed prior to erecting the panels. The concrete pad serves to provide an accurate working grade line to begin setting panels, as well as supports the weight of the facing panels themselves. The size of the leveling pad should be shown in the approved construction plans provided by the wall supplier. Generally, the pad should have minimum dimensions of 6 inches thick by 12 inches wide. The Special Provisions for MSE walls require that the concrete for the pad be Class M6 Concrete. The concrete should cure for a minimum of 12 hours before facing panels are placed. Careful inspection of the leveling pad to assure correct line, grade, and offset is important. A vertical tolerance of 0.01 feet to the design elevation is recommended. If the leveling pad is not at the correct elevation, the top of the wall will not be at the correct elevation. An improperly placed leveling pad can result in subsequent panel misalignment, cracking, and spalling.

Erection of Facing Elements

Precast facing panels are purposely set at a slight backward batter (toward the reinforced fill) in order to assure correct final vertical alignment after backfill placement. Minor outward movement of the facing elements from backfill placement and compaction cannot be avoided and is expected as the interaction between the reinforcement and reinforced backfill occurs. Most systems with segmental precast large panels also have some form of construction alignment dowels between adjacent elements that aid in proper erection. Typical backward batter for large panel walls is 1/8 inch per foot of panel height. The wall system manufacturer's field representative will assist the Contractor in establishing the proper construction batter to use. Most modular block walls have precast setbacks in the block that form a predefined batter when laying subsequent courses.

First Row of Facing Elements

Setting the first row of facing elements is a key detail. Construction should always begin adjacent to any existing structure and proceed toward the open end of the wall. The panels should be set directly on the concrete leveling pad (large panel walls) or prepared foundation (modular block walls). Some important details when setting the first row of facing elements are:

- Horizontal joint material or wooden shims should not be permitted between the first course of panels and the leveling pad. Temporary wood wedges may be used between the first course of panels and the leveling pad to set panel batter, but they must be removed during subsequent construction.
- For large panel walls, panel spacing bars, which set the horizontal spacing between panels, should be used so that subsequent panel rows will fit correctly.
- The first row of panels must be continuously braced until several layers of reinforcements and backfills have been placed. Adjacent panels should be clamped together to prevent individual panel displacement.
- After setting and battering the first row of panels, horizontal alignment should be visually checked with survey instruments or with a string line.
- Most MSE systems use a variety of panel types on the same project to accommodate geometric and design requirements (geometric shape, size, finish, connection points). The facing element types must be checked to make sure that they are installed exactly as shown on the approved shop plans.

Reinforced Fill Placement, Compaction

Moisture and density control is imperative for construction of MSE wall systems. Even when using high quality granular materials, problems can occur if compaction control is not exercised. Reinforced wall fill material should be placed and compacted at or within 2% dry of the optimum moisture content. If the reinforced fill is free draining with less than 5% passing a No. 200 U.S. sieve, water content of the fill may be within +/- 3 of the optimum. Placement moisture content can have a significant effect on reinforcement-soil interaction. Moisture content wetter of optimum makes it increasingly difficult to maintain an acceptable facing alignment, especially if the fines content is high. Moisture contents that are too dry could result in significant settlement during periods of precipitation.

The construction plans should note the degree of compaction necessary for proper function of the wall. Generally a density of 95% of maximum dry density is recommended for typical retaining walls, with 100% of maximum dry density recommended for abutments and walls supporting structural foundations abutments. Usually 3-5 passes with conventional vibratory roller compaction

equipment is adequate to attain the maximum practical density. The actual requirements should be determined based on field trials.

Reinforced backfill should be dumped onto or parallel to the rear and middle of the reinforcements and bladed toward the front face. Soil layers should be compacted up to or even slightly above the elevation of each level of reinforcement connections prior to placing that layer of reinforcing elements.

Note At no time should any construction equipment be in direct contact with the reinforcements because protective coatings and reinforcements can be damaged.

Compaction Equipment

With the exception of the 3 foot zone directly behind the facing elements, large, smooth-drum, vibratory rollers should generally be used to obtain the desired compaction. Sheepsfoot rollers should not be permitted because of possible damage to the reinforcements. When compacting uniform medium to fine sands (in excess of 60% passing a No. 40 sieve) use a smooth-drum static roller or lightweight (walk behind) vibratory roller. The use of large vibratory compaction equipment with this type of backfill material will make wall alignment control difficult.

Within 3 feet of the wall face, use small single or double drum, walk-behind vibratory rollers or vibratory plate compactors. Placement of the reinforced backfill near the front should not lag behind the remainder of the structure by more than one lift. Poor fill placement and compaction in this area has in some cases resulted in a chimney-shaped vertical void immediately behind the facing elements. Excessive compactive effort or use of too heavy equipment near the wall face can result in excessive face panel movement and overstressing of reinforcement layers.

Inconsistent compaction and under compaction caused by insufficient compactive effort of allowing the Contractor to "compact" backfill with trucks and dozers will lead to gross misalignments and settlement problems and should not be permitted. Flooding of the backfill to facilitate compaction should not be permitted. Compaction control testing of the reinforced backfill should be performed on a regular basis during the entire construction project. A minimum frequency of one test within the reinforced soil zone per every 5 feet of wall height for every 100 feet of wall horizontally is recommended.

Placement of Reinforcing Elements

Reinforcing elements should be installed in strict compliance with spacing and length requirements shown on the approved plans. Reinforcements should generally be placed perpendicular to the back of the facing panel. In specific situations, abutments and curved walls, for example, it may be necessary to skew the reinforcements from their design location in either the horizontal or vertical direction. In all cases, overlapping layers of reinforcements should be separated by a 3 inch minimum thickness of fill.

Difficulties arise when constructing MSE walls around deep foundation elements or other interfering items such as fence posts and light pole footings. Typically hollow casings or sonotubes are placed at pile or footing locations during reinforced fill erection. It is critical to monitor the location and plumbness of the casings or sleeves as the backfill material is placed and compacted. Compacting within 3 feet around these items should be limited to walk behind vibratory equipment much the same as previously described for the wall face.

Connections

Each MSE system has a unique facing connection detail. All connections must be made in accordance with the manufacturer's recommendations. For example, on Reinforced Earth structures, bolts must fit and be located between tie strips, be

perpendicular to the steel surfaces, and be seated flush against the flange to have full bearing of the bolt head. Nuts are to be securely tightened.

Flexible reinforcements, such as geotextiles and geogrids, usually require pretensioning to remove any slack in the reinforcement or in the panel. The tension is then maintained by staking or by placing fill during tensioning. Tensioning and staking will reduce subsequent horizontal movements of the panel as the wall fill is placed.

Placement of Subsequent Facing Courses (Segmental Facings)

Throughout construction of segmental panel walls, facing panels should only be set at grade. Placement of a panel on top of one not completely backfilled should not be permitted.

Alignment Tolerances

The key to a satisfactory end product is maintaining reasonable horizontal and vertical alignments during construction. Generally, the degree of difficulty in maintaining vertical and horizontal alignment increases as the vertical distance between reinforcement layers increases. The following alignment tolerances are recommended:

- Adjacent facing panel joint gaps-----3/4 inch +/- 1/4 inch
- Precast face panel-----1/16 inch/foot- horizontal and vertical
- Reinforcement placement elevations----1 inch of connection elevation

Failure to attain these tolerances when following suggested construction practices indicates that changes in the Contractor's procedures are necessary. These might include changes in reinforced backfill placement and compaction techniques, construction equipment, and facing panel batter.

Facing elements that are out of alignment should not be pulled back into place because this may damage the panels and reinforcement and, hence, weaken the system. Appropriate measures to correct an alignment problem are the removal of reinforced fill and reinforcing elements, followed by the resetting of the panels. Occasionally, lower modular panels may experience some movement after several lifts of panels have been placed. This could be due to foundation settlement, excess moisture content following heavy rain, or excessive compaction. Construction should be stopped immediately and the situation evaluated by the Geotechnical Engineering Activity when these 'post-erection' deformations occur.

Improper horizontal and vertical joint openings can result in face panel misalignment, and cracking and spalling due to point stresses. Wedging of stones or concrete pieces to level face panels should not be permitted. All material suppliers use bearing pads on horizontal joints between segmental facing panels to prevent point stresses (cork, neoprene, or rubber are typically used). These materials should be installed in strict accordance with the plans and specifications, especially with regard to thickness and quantity. Other joint materials are used to prevent point stresses and erosion of fill through the facing joints (synthetic foam and geotextile details are typically used). Excessively large panel joint spacings or joint openings that are highly variable result in a very unattractive end product. Wooden wedges placed in the exterior panel face during erection to aid in alignment should remain in place until the third layer of modular panels are set, at which time the bottom layer of wedges should be removed. Each succeeding layer of wedges should be removed as the succeeding panel layer is placed. When the wall is completed, all temporary wedges should be removed.

At the completion of each day's work, the Contractor should grade the wall fill away from the face and lightly compact the surface to reduce the infiltration of surface water from precipitation.

Out-of-Tolerance Conditions and Possible Causes

MSE retaining walls are to be erected in strict compliance with the structural and aesthetic requirements of the plans, specifications, and contract documents. The desired results can generally be achieved through the use of quality materials, correct construction/erection procedures, and proper inspection. However, there may be occasions when dimensional tolerances and/or aesthetic limits are exceeded. Corrective measures should quickly be taken to bring the work within acceptable limits. Presented below are several out-of-tolerance conditions and their possible causes.

- Condition: Distress in wall due to the following:
 - Differential settlement or low spot in wall.
 - Overall wall leaning beyond vertical alignment tolerance.
 - Panel contact, resulting in chipping or spalling.

Possible Cause: Foundation (subgrade) material too soft or wet for proper bearing. Fill material of poor quality or not properly compacted.

- Condition: First panel course difficult (impossible) to set and/or maintain level. Panel-to-panel contact resulting in chipping or spalling.

Possible Cause: Leveling pad not within tolerance.

- Condition: Wall out of vertical alignment tolerance (plumbness) by leaning out.

Possible Cause: One or more of the following:

- Panel not battered sufficiently
- Oversized backfill and/or compaction equipment working within 3 foot zone of back of wall facing panels
- Backfill material placed wet of optimum moisture content. Backfill contains excessive fine materials (beyond the specifications for percent of materials passing a No. 200 sieve)
- Backfill material pushed against back of facing panel before being compacted above reinforcing elements
- Excessive or vibratory compaction of uniform, medium-fine sand (more than 60% passing a No. 40 sieve)
- Backfill material dumped close to free end of reinforcing elements, then spread toward back of wall, causing displacement of reinforcements and pushing panel out
- Shoulder wedges not seated securely
- Shoulder clamps not tight
- Slack in reinforcement to facing connections
- Condition: Wall out of vertical alignment tolerance (plumbness) by leaning in.

Possible Cause: One or more of the following:

- Excessive batter set in panels for select granular backfill material being used
- Inadequate compaction of backfill
- Possible bearing capacity failure

- Condition: Wall out of horizontal alignment tolerance, or bulging.

Possible Cause: one or more of the following:

- Backfill material placed wet of optimum moisture content. Backfill contains excessive fine materials (beyond the specifications for percent of materials passing a No. 200 sieve)
- Backfill material pushed against back of facing panel before being compacted above reinforcing elements
- Excessive or vibratory compaction of uniform, medium-fine sand (more than 60% passing a No. 40 sieve)
- Backfill may be saturated by heavy rain or improper grading of backfill after each day's operations

- Condition: Panels do not fit properly in their intended locations.

Possible Cause: One or more of the following:

- Panels are not level, or differential settlement (see cause 1)
- Panel cast beyond tolerances
- Failure to use spacer bar

- Condition: Large variations in movement of adjacent panels.

Possible Cause: One or more of the following:

- Backfill material not uniform
- Backfill compaction not uniform
- Inconsistent setting of facing panels

18

SUMMARY OF STANDARD SPECIFICATIONS FOR TOLERANCES FOR CONCRETE CONSTRUCTION AND MATERIALS (ACI 117)

This is a summary of ACI 117, Standard Specifications for Tolerances for Concrete Construction and Materials. It has been tailored to reflect those specific construction tolerances that govern on structures constructed under the South Dakota Standard Specifications for Roads and Bridges. Should an item or tolerance not be found in this summary listing, then ACI 117 shall govern as the contract specification.

Section 1 -- General Requirements

1.1 Scope

- This specification designates standard tolerances for concrete construction.
- The indicated tolerances shall govern unless otherwise specified.

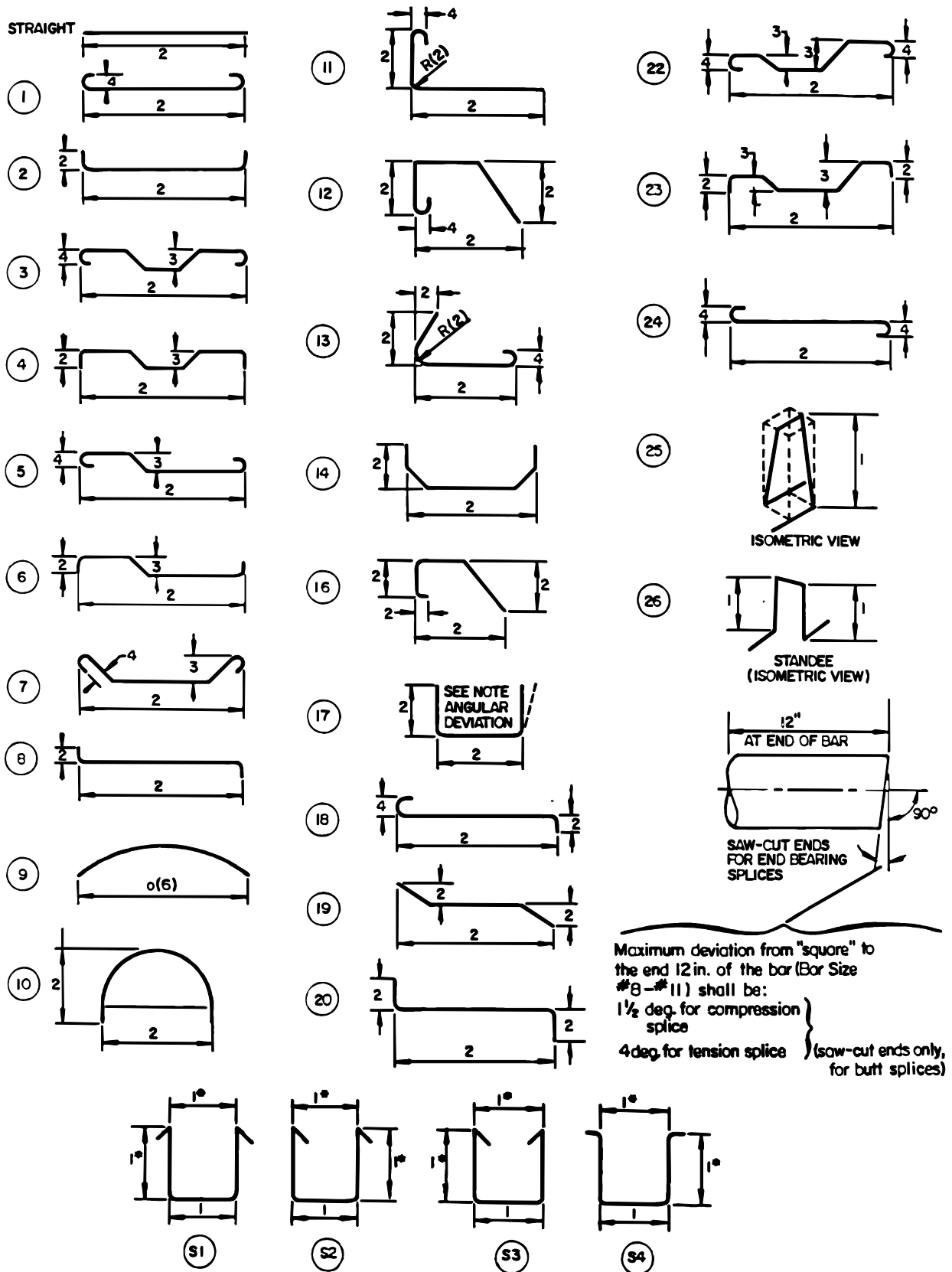
1.2 Requirements

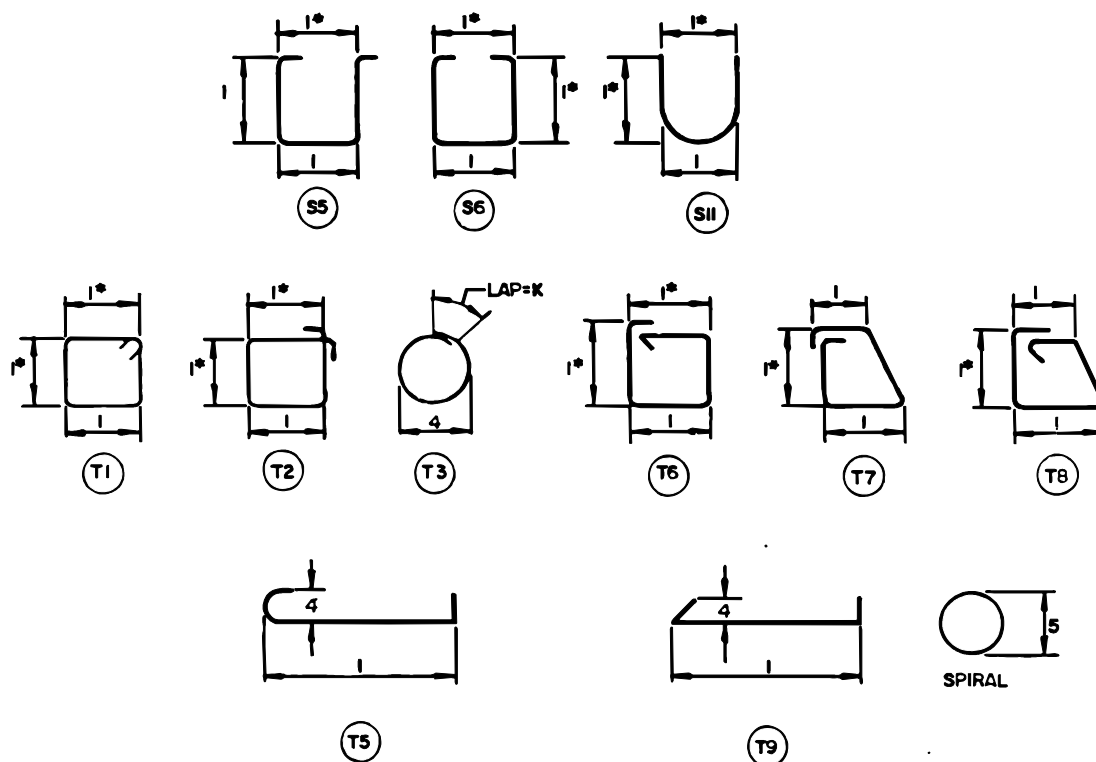
- Concrete construction shall meet the specified tolerances.
- Tolerances shall not extend the structure beyond legal boundaries.
- Tolerances are not cumulative. The most restrictive tolerance controls.
- Plus (+) tolerance increases the amount or dimension to which it applies, or raises a level of alignment. Minus (-) tolerance decreases the amount or dimension to which it applies, or lowers a level alignment. A non-signed tolerance means + or -. Where only one signed tolerance is specified (+ or -), there is no limit in the other direction.

Section 2 -- Materials

2.1 Reinforcing Steel Fabrication Tolerances -- The bending and length fabrication tolerances for reinforcing steel shall be as shown in Figure 18.1.

Figure 18.1 Reinforcing Steel Bending Tolerances





Notes for Figure 18.1

- Entire shearing and bending tolerances are customarily absorbed in the extension past the last bend in a bent bar.
- All tolerances single plane as shown. Tolerances for Type S1 through S6, S11, and T1 through T9 apply only to the bar sizes #3 through #8 (#10 through #25).
- * Dimensions on this line are to be within the tolerance shown, but are not to differ from opposite parallel dimension more than 1/2 inch.
- Angular deviation -- Maximum plus or minus 2 1/2 degrees or plus or minus 1/2 inch per foot, but not less than 1/2 inch on all 90 degree hooks and bends.

Tolerance symbols for Figure 18.1

1 Bar sizes #3, #4, #5 (#10, #13, and #16):

- = plus or minus 1/2 inch when gross bar length < 12 feet.
- = plus or minus 1 inch when gross bar length \geq 12 feet.

2 Plus or minus 1 inch

3 Plus 0, minus 1/2 inch

4 Plus or minus 1/2 inch

5 Plus or minus 1/2 inch for diameter \leq 30 inch

- Plus or minus 1 inch for diameter > 30 inch

6 Plus or minus 1.5% of o dimension \geq plus or minus 2 inch minimum. If application of positive tolerance to Type 9 results in a chord length equal to or greater than the arc or bar length, the bar may be shipped straight.

2.2 Reinforcement Placement

2.2.1, 2.2.2, and 2.2.3 Clear Cover

- Plus or minus 1/4 inch

2.2.4 Distance between Reinforcement

- 1/4 specified distance not to exceed 1 inch

2.2.5 Spacing, Deviation from Specified Location

- In slabs and walls other than stirrups and ties, 3 inches
- Stirrups, 2 inches
- Ties, 3 inches
- Total number of bars shall not be less than that specified

2.2.7 Longitudinal Location of Bends and Ends of Bars

- At discontinuous ends of members, 1 inch
- At other locations, 2 inches

2.2.8 Embedded Length of Bars and Length of Bar Laps

- #3 through #11 (#10 through #36) bar sizes, 1 inch

2.3 Placement of Embedded Items

2.3.1 Clearance to reinforcement,

2.3.2 Vertical alignment, lateral alignment, and level alignment, 1 inch

Section 3 -- Foundations

3.1 Vertical Alignment

3.1.1 Drilled Shafts

- 1/4 inch per foot but not more than 3 inches

3.2 Lateral Alignment

3.2.1 Footings

- 0.02 times the width of footing in direction of misplacement but not more than 2 inches

3.2.2 Drilled shafts

- 1/12 of the shaft diameter but not more than 3 inches

3.3 Level Alignment

3.3.1 Footings

- + 1/2 inch, - 2 inches

3.3.2 Drilled Shafts

- Top of shaft elevation, plus or minus 1 inch

3.4 Cross-Sectional Dimensions

3.4.1 Footings

3.4.1.1 Horizontal dimension of formed members

- + 2 inches, - 1/2 inch

3.4.1.2 Horizontal dimension of unformed members cast against soil

- 2 feet or less: + 3 inches, - 1/2 inch
- Greater than 2 feet but less than 6 feet: + 6 inches, - 1/2 inch
- Over 6 feet: +12 inches, - 1/2 inch

3.4.1.3 Vertical dimension (thickness), minus 5%

3.4.2 Drilled Shafts

- Minus 0, + 2 inches

3.5 Relative Alignment

3.5.1 Footings

- Footing side and top surfaces may slope with respect to the specified plane at a rate not to exceed 1 inch in 10 feet

Section 4 -- Cast-in-Place Concrete Members (other than foundations)

4.1 Vertical Alignment

- 1 inch

4.2 Lateral Alignment

4.2.1 Members, 1 inch

4.2.2 Location of openings, 1/2 inch

4.2.3 Saw cuts and Joints, 3/4 inch

4.3 Level Alignment

4.3.2 Elevation of formed surfaces before removal of forms, 1/2 inch

4.4 Cross-Sectional Dimensions

Member, such as columns, beams, piers, walls (thickness only), and slabs (thickness only)

- 12 inch dimension or less, + 3/8 inch, - 1/4 inch
- More than 12 inch dimension but not over 3 feet, + 1/2 inch, - 3/8 inch
- Over 3 feet dimension, +1 inch, - 3/4 inch

4.5 Relative Alignment

4.5.1 Stairs

- Difference in height between adjacent risers, 1/8 inch
- Difference in width between adjacent threads, 1/4 inch

4.5.2 Grooves

- Specified width 2 inches or less, 1/8 inch

4.5.3 Formed surfaces may slope with respect to the specified plane at a rate not to exceed the following:

- Concrete exposed to view, 1/4 inch per 10 feet
- All other conditions, 3/8 inch

4.5.4 The offset between adjacent pieces of formwork facing material shall not exceed the following:

- Concrete exposed to view, 1/8 inch

- All other conditions, 1/4 inch
- 4.6 Openings through Members
- 4.6.1 Cross-Sectional size of opening: - 1/4 inch, + 1 inch
- 4.6.2 Location of center line of opening: 1/2 inch

Section 11 -- Cast-in-Place Bridges

- 11.1 Vertical Alignment
- 11.1.1 Exposed surfaces, 3/4 inch
- 11.1.2 Concealed surfaces, 1 1/2 inches
- 11.2 Lateral Alignment
- Center line alignment, 1 inch
- 11.3 Level Alignment
- 11.3.1 Profile Grade, 1 inch
- 11.3.2 Top of other concrete surfaces and horizontal grooves
- Exposed, 3/4 inch
 - Concealed, 1 1/2 inches
- 11.3.3 Mainline pavements in longitudinal direction, the gap below a 10 feet unleveled straight line resting on highs pots shall not exceed 1/8 inch
- 11.3.4 Mainline pavements in transverse direction, the gap below a 10 feet unleveled straightedge resting on highs pots shall not exceed 1/4 inch
- 11.3.5 Ramps, sidewalks, and intersections, in any directions, the gap below a 10 feet unleveled straightedge resting on highs pots shall not exceed 1/4 inch
- 11.4 Cross-Sectional Dimensions
- 11.4.1 Bridge slabs, vertical dimension (thickness): + 1/4 inch, - 1/8 inch
- 11.4.2 Members such as columns, beams, piers, walls, and other (thickness only): + 1/2 inch, - 1/4 inch
- 11.4.3 Openings through concrete members, 1/2 inch
- 11.5 Relative Alignment
- 11.5.1 Location of openings through concrete members, 1/2 inch
- 11.5.2 Formed surfaces may slope with respect to the specified plane at a rate not to exceed the following amounts in 10 feet:
- Watertight joints, 1/8 inch
 - Other exposed surfaces, 1/2 inch
 - Concealed surfaces, 1 inch
- 11.5.3 Unformed exposed surfaces, other than pavements or sidewalks, may slope with respect to the specified plane at a rate not to exceed the following:
- In 10 feet, 1/4 inch
 - In 20 feet, 3/8 inch
- 11.6 Neck Reinforcement Cover, +1/4"

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SELECT SPECIFICATION SECTIONS OF STEEL STRUCTURES PAINTING COUNCIL (SSPC) - VOLUME 2

The following are select specifications copied from the Steel Structures Painting Council publication 'Systems and Specifications - Volume 2'. These specifications have been copied with the approval of the SSPC, and have not been modified in any manner. The page numbering at the bottom of the page is the page number found in the Volume 2 specification. The following is a Table of Contents of the sections that have been copied.

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GLOSSARY

A

Abutment - A substructure composed of stone, concrete, brick, or timber supporting the end of a single span or the extreme end of a multi-span superstructure and, in general, retaining or supporting the approach embankment placed in contact therewith.

- ***Cantilever*** - An abutment in which the stem or breast wall is fixed rigidly to the footing. The stem, acting as a cantilever beam transmits the horizontal earth pressure to the footing, which maintains stability by virtue of the dead weight of the abutment and of the soil mass resting on the rear portion, or heel, of the footing.
- ***Gravity*** - A heavy abutment which resists the horizontal earth pressure by its own dead weight.
- ***Integral*** - A small abutment cast monolithically with the end diaphragm of the deck. Although such abutments usually encase the ends of the deck beams and are pile supported, spread footings with a combination backwall and end diaphragm may also be used.
- ***Spill-thru*** - Consists essentially of two or more columns supporting a grade beam spanning the space between them. The approach embankment is retained only in part by the abutment since the embankment's sloped front and side portions extend with their normal slope to envelop the columns. Also called an arched abutment.

Addendum - Changes to the contract proposal documents issued by the contracting agency prior to the time of opening proposals.

Advertisement - A public announcement inviting bids for work to be performed or materials to be furnished.

Anchor Bolt - A threaded bolt commonly fitted with a nut and washer at the end only, used to secure in a fixed position upon the substructure the end of a truss or girder, the base of a column, a pedestal, shoe, or other member of a structure. Manufactured with a head at the end of the threaded stud.

Anchor Rod – Similar to anchor bolt except that the piece is a threaded or non-threaded rod rather than a bolt.

Approach Slab - A heavy reinforced concrete slab placed on the approach roadway adjacent to and usually resting upon the abutment back wall. The function of the approach slab is to carry wheel loads on the approaches directly to the abutment, preventing the transfer of a horizontal dynamic force through the approach fill to the abutment stem.

Area Engineer - A representative of the Director of Operations acting under the supervision of the Region Engineer and in charge of assigned operations with a designated Area.

Average Daily Traffic (ADT) - This is the total traffic volume during a given period divided by the number of days in the period.

Award - The acceptance by the Department of Transportation of a bid proposal.

B

Back Face (B.F.) – The side of the abutment or retaining wall against the earth.

Backfill – 1. Material placed next to an abutment, pier, footing, or wing wall to fill open areas of a foundation excavation. 2. Granular material used to stabilize the ground for the pouring of a foundation or slab.

Back-slope – Portion of ground beyond the ditches which rejoins the in-place groundline.

Backwall - The top most portion of an abutment above the elevation of the bridge seat, functioning primarily as a retaining wall with a live load surcharge. It may serve also as a support for the extreme end of the bridge deck and the approach slab.

Backwater - The water of a stream retained at an elevation above its normal level through the controlling effect of a condition existing at a downstream location such as a flood, an ice jam, or other obstruction.

The increase in the elevation of the water surface above normal produced primarily by the stream width contraction beneath a bridge. The wave-like effect is most pronounced at and immediately up-stream from an abutment or pier, but extends downstream to a location beyond the body of the substructure part.

Ballast – Filler material used either to stabilize a structure (as in filling a crib) or to transmit a vertical load to a lower level (as in railroad track ballast).

Bar (Steel) – Structural steel fabrication piece 6 inches or less in width and 0.203 inches or more in thickness, or between 6 to 8 inches in width and 0.230 inches or more in thickness.

Base Course - The layer or layers of specified selected material placed on a subbase or subgrade to support a surface course.

Base Metal - The metal at and closely adjacent to the surface to be incorporated in a welded joint which will be fused, and by coalescence and inter-diffusion with the weld will produce a welded joint.

Base Plate – A plate-shaped piece of steel made an integral part of the base portion of a column, pedestal or other member. It transmits and distributes the load uniformly to the supporting structure or to another member.

Batter - The inclination of a surface in relation to a horizontal or a vertical plane or occasionally in relation to an inclined plane. Batter is commonly designated upon bridge detail plans as so many inches to one foot.

Bay - As applied to a stringer of multi-beam structure, the area between adjacent stringers.

Beam – A structural member that supports loads from a bridge deck. A beam is supported at its ends and/or intermediately by the abutments and piers. The beam can be constructed of cast-in-place concrete, prestressed concrete or steel members. See also Girder(s).

Bearing Failure - Concerning the usual materials of construction, a crushing under extreme compressive load on an inadequate support; concerning soil, a shear failure in the supporting soil caused by excessively high pressures applied by a footing or pile.

Bearing Pad - A thin sheet of material placed between a masonry plate and the masonry bearing surface used to fill any voids due to imperfection of the masonry plate and bearing surface, to seal the interface, and to aid in even distribution of loads at the interface. The bearing pads may be made of alternating layers of red lead and canvas, of sheet lead, or of preformed fabric pads.

Bearing Seat - Top of masonry supporting bridge bearing.

Bearing Stiffener - A thick or heavy web stiffener placed immediately over the center of the bearing shoe on a beam or girder to help carry the end reactions of the bridge.

Bench Mark - A relatively permanent object, natural or artificial, bearing a marked point whose elevation above or below an adopted datum is known. Usually designated as a BM, such a mark is sometimes further qualified as a PBM (permanent bench mark), or as a TBM (temporary bench mark).

Bent - A supporting unit of a trestle or a viaduct type structure made up of two or more columns or column-like members connected at their top-most ends by a cap, strut, or other member holding them in their correct positions. This connecting member is commonly designed to distribute the superimposed loads upon the bent, and when combined with a system of diagonal and horizontal bracing attached to the columns, the entire construction functions somewhat like a truss distributing its loads into the foundation. When piles are used as the column elements, the entire construction is designated a "pile bent" or "piled bent" and, correspondingly, when those elements are framed, the assemblage is termed a "framed bent."

Bent Cap – The top or horizontal portion of a bent that supports the superstructure deck or girders. The cap is usually a large reinforced concrete beam spanning across and cantilevering from the supporting columns.

Berm (Berme) - The line, whether straight or curved, which defines the location where the top surface of an approach embankment or causeway is intersected by the surface of the side slope. This term is synonymous with "Roadway Berm."

A horizontal bench located at the toe or slope of an approach cut, embankment or causeway to strengthen and secure its underlying material against sliding or other displacement into an adjacent ditch, borrow pit, or other artificial or natural lower lying area.

Bid Schedule - The list of bid items, together with estimated quantities appearing in the proposal form.

Bond - 1. In reinforced concrete, the grip of the concrete on the reinforcing bars, thereby preventing slippage of the bars. 2. The mechanical bond resulting from irregularities of surface produced in the manufacturing operations is an important factor in the strength of a reinforced concrete member. For plain round bar reinforcement, it is the difference between the force required to produce initial slip and ultimately, producing failure. "Deformed" bars utilize this mechanical bond in conjunction with the surface bond. 3. The mechanical force developed between two concrete masses when one is cast against the already hardened surface of the other.

Box Beam - A rectangular-shaped precast, and usually prestressed, concrete beam. These beams may be placed side by side, connected laterally, and used to form a bridge deck, with or without a cast-in-place slab or topping. In such cases the beam units act together similar to a slab. Where a C-I-P slab is used and the units are spread, they act as beams.

Box Girder (Concrete) - A large concrete box-shaped beam, either reinforced or prestressed, usually multi-celled with several interior webs. The bottom slab of the girder serves as a flange only, while the top slab is both a flange and a transverse deck slab.

Box Culvert - A structure not classified as a bridge which provides an opening under the roadway for passage of water, animals, and equipment.

Bridge - A structure, including supports, erected over a depression or an obstruction, such as water, highway, or railroad, said structure having a length measured along the center of roadway of more than 20 feet between under-copings of abutments or extreme ends of openings for multiple boxes and pipes where the clear distance between openings is less than half of the smaller contiguous opening.

Bridge Length - The greater dimension of a structure measured along the center of the roadway between backs of abutment backwalls or between ends of bridge floor.

Bridge Roadway Width - The clear width of structure measured at right angles to the center of the roadway between the bottom of curbs or, if curbs are not used, between the inner faces of parapet or railing.

Bridge Seat - The top surface of an abutment or pier upon which the superstructure span is placed and supported. For a sill it is the surface forming the support for the superstructure and from which the backwall rises. For a pier it is the entire top surface.

Bridging - A carpentry term applied to the cross-bracing, nailed or otherwise, fastened between wooden floor stringers, usually at the one-third span points, to increase the rigidity

of the floor construction and to distribute more uniformly the live load and minimize the effects of impact and vibration.

Bulkhead - 1. A retaining wall-like structure commonly composed of driven piles supporting a wall or a barrier of wooden timbers or reinforced concrete members functioning as a constraining structure resisting the thrust of earth or of other material bearing against the assemblage. 2. A retaining wall-like structure comprised of timber, steel, or reinforced concrete members commonly assembled to form a barrier held in a vertical or an inclined position by members interlocking therewith and extending into the restrained material to obtain the anchorage necessary to prevent both sliding and overturning of the entire assemblage.

Bumper - A mechanism designed to absorb the concussion or impact of a moving superstructure or other moving part when it swings, rises or falls to its limiting position of motion.

Butt Weld - A weld joining two abutting surfaces by depositing weld metal within an intervening space. This weld serves to unite the abutting surfaces of the elements of a member or to join members or their elements abutting upon or against each other.

C

Caisson – 1. A watertight box of wood or steel sheeting or a cylinder of steel and concrete used for the purpose of making an excavation. See also Cofferdam or Crib. 2. Another term for Drilled Shaft.

Camber - The slightly arched form or convex curvature, provided in a single span or in a multiple span structure, to compensate for dead load deflection and to secure a more substantial and aesthetic appearance than is obtained when uniformly straight lines are produced. In general, a structure built with perfectly straight lines appears slightly sagged. This optical illusion is unsatisfactory and is most manifest in relatively long structures over rivers or other water areas.

Cantilever - A projecting beam, truss or slab supported at one end only.

Cast-in-Place – Refers to concrete that is placed in the field in forms or excavations versus concrete that is formed in a fabrication yard and transported to the site.

Cement - (Portland) - The commercial product used in combination with fine and course aggregates and water to produce concrete.

Centerline of Roadway - This is a line drawn on highway plan sheets representing the middle of the roadbed with equal distance of roadbed to either side of the drawn line.

Change Order - A written order issued by the Engineer to the Contractor, covering changes in plans, specifications, or quantities within the scope of the contract and establishing the basis of payment and time adjustments for the work affected by the changes.

Channel Cleanout (or Change) – A man-made change in the path of the waterway.

Channel Profile - Longitudinal section of a channel.

Chord - In a truss, the upper and the lower longitudinal members, extending the full length and carrying the tensile and compressive forces which form the internal resisting moment, are termed chords. The upper portion is designated the upper, or top, chord and correspondingly the lower portion is designated the lower, or bottom, chord. The chords may be parallel, or the upper one may be polygonal or curved (arched) and the lower one horizontal, or both may be polygonal. In general, the panel points of polygonal top chords are designed to follow the arch of a parabola and are, therefore, truly parabolic chords. Polygonal shaped chords are commonly described as "broken chords."

Chord Members - Trusses are commonly divided lengthwise into panels, the length of each being termed a panel length. The corresponding members of the chords are described as upper or top, chord members and lower, or bottom, chord members.

Clearance – 1. The unobstructed width and height of the roadway or waterway under a structure. 2. The clear space between reinforcement bars or between the reinforcing bar and a concrete surface.

Clear Span - The unobstructed space or distance between the substructure elements measured, by common practice, between faces of abutments and/or piers. However, when a structure is located upon a stream, river, tidal inlet or other waterway used by navigation, the clear span dimension is measured at mean low water elevation and may be the distance between guard or fender piers, dolphins or other constructions for the protection of navigation.

Coefficient of Thermal Expansion - The unit strain produced in a material by a change of one degree of temperature.

Cofferdam - In general, an open box-like structure constructed to surround the area to be occupied by an abutment, pier, retaining wall or other structure and permit unwatering of the enclosure so that the excavation for the preparation of a foundation and the abutment, pier, or other construction may be effected in the open air. In its simplest form the dam consists of interlocking steel sheet piles.

Cold Joint – 1. A joint in a concrete structure made by placing fresh concrete against hardened or partially hardened concrete. 2. A joint made by placing hot bituminous mixture against a bituminous mixture that has cooled.

Column - A leg or legs (called bent or bents) which hold up a structure. Columns (plural) are jointed with a cap.

Clockwise Angle - A horizontal angle measured from left and right. A clockwise angle may have any value between zero degrees and 360 degrees. Azimuths are clockwise angles measured from either north or south.

Composite Beam - A beam which has angle, channel, or stud shear connectors attached to its top flange which, during construction, are embedded in the concrete slab. This embedment rigidly attaches the slab to the beam and causes the slab to assist the top flange of the beam in carrying compressive stresses due to live loads.

Compression – A force which causes a body to shorten in the direction of the applied force.

Concrete - A composite material consisting essentially of a binding medium within which are embedded particles or fragments of a relatively inert mineral filler. In Portland Cement Concrete, the binder or matrix, either in the plastic or the hardened state, is a combination of Portland Cement and water. The filler material, called aggregate, is generally graded in size from fine sand to pebbles or stones which may in some concrete, be several inches in diameter.

Concrete is used in conjunction with stone fragments or boulders, of "one man" size or larger, imbedded therein to produce "cyclopean" or "rubble" concrete.

Concrete Box Girder Structure - A structure where poured concrete around reinforcing bar is formed into a hollow box. The box acts like a beam and supports the roadway.

Construction Joint – A joint or break between successive pours of concrete.

Continuous Concrete Structure - A structure where no beams or girders are used to support the deck or roadway; the roadway supports itself due to hundreds of steel reinforcing bars inside the concrete of the roadway.

Contract Item (Pay Items) - A specified unit of work for which a price is provided in the contract.

Control Point – Any station in a horizontal or vertical grid that is used to identify or represent alignment data of a structure.

Connection Angle (Clip Angle) - A piece or pieces of angle serving to connect two elements of a member or two members of a structure.

Continuous Spans - A beam, girder or truss type superstructure designed to extend continuously over one or more intermediate supports.

Continuous Weld - A weld extending throughout the entire length of a joint.

Corrosion - The general disintegration and wasting of surface metal or other material through oxidation, decomposition, temperature, and other natural agencies.

Cotter Bolt - A bolt having a head at one end and near the opposite end a round hole or a hexagonal slot fitted with a cotter pin in the former or a tapered wedge in the latter. A cotter pin is usually formed by bending a piece of half-round rod to form a loop eye and a split body permitting its end to be splayed, thus holding it in position while a cotter wedge may be split for the same purpose, but either of these locking devices may be undivided and only bent sharply to prevent withdrawal. Cotter bolts are commonly fitted with one or two washers. A cotter bolt fitted with a key is sometimes termed a "key bolt."

Counter - A truss web member which functions only when the span is partially loaded and shear stresses are opposite in sign to the normal conditions. The dead load of the truss does not stress the counter.

Counterclockwise Angle - A horizontal angle measured in a counterclockwise direction. Used primarily for the measurement of deflection angles.

Cover - In reinforced concrete, the clear thickness of concrete between a reinforcing bar and the surface of the concrete.

Cover Plate - A plate used in conjunction with flange angles or other structural shapes to provide additional flange section upon a girder, column, strut or similar member.

Cracking - Linear fractures in concrete. The most common designations for cracking or cracks are as follows:

- **D-Cracks** - These are usually defined by dark colored deposits, generally near joints and edges. They may widen gradually and eventually produce failure. Vertical cracks near vertical expansion joints in abutments and walls can also be classified as D-cracks. This type of cracking may be indicative of alkali reactive concrete.
- **Diagonal** - These cracks appear roughly parallel in slabs skewed to the center line of the bridge. They are usually shallow and are of varying lengths, widths and spacings. When found in the vertical faces of beams or pier caps they may be deeper than usual, and thus pose a more serious problem.
- **Horizontal** - Cracking of this kind will occur in walls, abutments, pier stems, and columns. They are similar in nature to transverse cracks, and may be listed as such.
- **Longitudinal** - These are fairly straight cracks (in slabs) running parallel to the centerline of the roadway. They are of variable widths, lengths, and spacings. These cracks may extend partially or completely through the deck.
- **Pattern or Map** - These interconnected cracks form networks of varying size, and appear similar to that of sun-cracking seen on dried flats. They vary in width from barely visible, fine cracks to well defined openings. They are found in both slabs and walls.
- **Random** - These are meandering irregular cracks appearing on the surface of slabs. They have no particular form and do not logically fall into any of the classifications described previously.
- **Transverse** - These are fairly straight cracks that are roughly perpendicular to the center line of the roadway. Transverse cracks vary in length, width, and in spacing. They frequently occur over the main slab reinforcement on stringer bridges. Cracks may extend completely through the slab. These same cracks may extend through curbs, sidewalks, and parapets. On skewed bridges where the transverse deck steel is not placed at right angles to the roadway center line, this type of crack may appear parallel to the deck steel. On continuous structures, pronounced transverse cracking may be noted in or near the negative moment zones over the piers. Pier caps are also subject to transverse cracking.
- **Vertical** - Vertical cracks in walls, abutments, pier stems, and caps are similar to longitudinal cracking in slabs, and should be described as such.

Creep - An inelastic deformation that increases with time while the stress is constant.

Cross Frames - Transverse bracings between two main longitudinal members. See also Diaphragms.

Crown of Roadway - 1. The crest line of the convexed surface. 2. The vertical dimension describing the total amount the surface is convexed or raised from gutter to crest. This is sometimes termed the cross fall of roadway.

Cubic Yard Stations - A quantity of earth to be hauled through 10 centerline stations times the distance (over the 10+ stations) which the earth must be hauled.

Curtain Wall – 1. A term commonly applied to a thin masonry wall not designed to support superimposed loads either vertically or transversely. 2. A thin vertically placed and integrally built portion of the paving slab of a culvert intended to protect the culvert against undermining by stream scour. A similar construction placed in an inclined position is termed an "apron wall" or "apron."

Curves in Plan and Profile - A roadway may be curved in its lateral alignment, its vertical contour, or in both alignment and contour combined. The primary curves are described as:

- ***Horizontal*** - A curve in the plan location defining the alignment.
- ***Vertical*** - A curve in the profile location defining the elevation.

Cut (Cutting) - That portion of a highway, railway, canal, ditch or other artificial construction of similar character produced by the removal of the natural formation of earth or rocks whether sloped or level. The general terms "slide hill cut" and "through cut" are used to describe the resulting cross sections of the excavations commonly encountered.

D

Datum - A reference element such as a line or plane, in reference to which the positions of other elements are determined. SEE: Horizontal Datum, Level Datum, and Vertical Datum.

Dead Load - A static load due to the weight of the structure itself.

Debris Rack (Trash Rack) - A grill type barrier used to intercept debris above a sewer or culvert inlet.

Deck - That portion of a bridge that provides direct support for vehicular and pedestrian traffic. The deck may be a reinforced concrete slab, timber flooring, a steel plate or grating, or the top surface of abutting concrete members or units. While normally distributing load to a system of beams and stringers, a deck may also be the main supporting element of a bridge, as with a reinforced concrete slab structure or a laminated timber bridge.

Deck Bridge - A bridge having its floor elevation at, nearly at, or above the elevation of the uppermost portion of the superstructure.

Decking - A term specifically applied to bridges having wooden floors and used to designate the flooring only. It does not include the floor stringers, floor beams, or other members serving to support the flooring.

Deflection - The bending of a beam, girder or truss under a load.

Degradation of Channel - The gradual lowering of the flow line of a stream due to material in the stream bed being washed away.

Design Hourly Volume (DHV) - The peak hourly volume of vehicles expected in the 30th highest hour during the chosen design year.

Design Load - The loading comprising magnitudes and distributions of wheel, axle or other concentrations used in determination of the stresses, stress distributions and ultimately the cross-sectional areas and compositions of the various portions of a bridge structure. The design loading or loadings fixed by a specification are very commonly composite rather than actual, but are predicted upon a study of various types of vehicles. In lieu of a loading so determined for use as "standard" an equivalent uniform load designed to produce resulting structures practically identical with those evolved by use of such loadings may be used. One or more concentrated loads may be used in conjunction with the uniform load to secure the effect corresponding to the incorporation of especially heavy vehicles within the normally maximum traffic considered as likely to pass upon a given bridge or a series of bridges. Such equivalent loadings are merely a convenience facilitating design operations.

Diagonal - See Web Members.

Diaphragm - A reinforcing plate or member placed within a member or deck system, respectively, to distribute stresses and improve strength and rigidity.

Directional Distribution (D) - This is a measure of the highest traffic volume in one direction during peak traffic hours. It is expressed as a percentage of Design Hourly Volume.

Dowel – A steel pin or bar that extends into two members of a concrete structure or pavement.

Drainage Area - The area from which the run-off water passing beneath a bridge or passing a specific location in a river or stream is produced.

Drilled Shaft – A foundation that provides structural support in the form of cylindrical excavation filled with reinforced concrete.

Drip Bead (Drip Groove) - A channel or groove in the under side of a slab, coping, or other projecting exposed portion of a masonry structure intended to arrest the downward flow of rain water and cause it to drip off free from contact with surfaces below the projection.

E

Efflorescence - A white deposit on concrete or brick caused by crystallization of soluble salts brought to the surface by moisture in the masonry.

Elastomeric Bearing – A rectangular, synthetic, rubberlike material (neoprene) used as a bearing with prestressed or steel girders.

Elevation – 1. The vertical distance of a point above or below a reference surface, or level datum. Often abbreviated as Elev. or El. 2. A view looking at an object from the side.

End Block - On a prestressed concrete beam, the thickening of the web or increase in beam width at the end to provide adequate anchorage bearing for the post-tensioning wires, rods, or strands.

End Post - The end compression member of a truss, either vertical or inclined in position and extending from chord to chord, functioning to transmit the truss end shear to its end bearing.

Epoxy - A synthetic resin which cures or hardens by chemical reaction between components which are mixed together shortly before use.

Erosion Control - Those items necessary to the completed highway which provide for the preservation of landscape materials and features. The rehabilitation and protection against erosion of areas disturb by construction through seeding, sodding, mulching, and the placing of other ground covers. Such suitable planting and other improvements as may increase the effectiveness and enhance the appearance of the highway.

Estimate of Quantities - plan shown summary of the estimated quantities of work necessary to complete the project.

Expansion Bearing - A general term applied to a device or assemblage designed to transmit a reaction from one member or part of a structure to another and to permit the longitudinal movements resulting from temperature changes and superimposed loads without transmitting a horizontal force to the substructure. The expansion bearing is designed to permit movement by overcoming sliding, rolling, or other friction conditions.

Expansion Dam - The part of an expansion joint serving as an end form for the placing of concrete at a joint. Also applied to the expansion joint device itself.

Expansion Joint - A joint designed to provide means for expansion and contraction movements produced by temperature changes, loadings or other agencies.

Expansion Rocker - An articulated assemblage forming a part of the movable end of a girder or truss and facilitating the longitudinal movements resulting from temperature changes and superimposed loads. Apart from its hinge connection the rocker proper is a cast or built-up member consisting essentially of a circular segment integrally joined by a web-like portion to a hub fitted for hinge action either with a pin hole or by having its ends formed into trunnions. In its service operation the rocker is commonly supported upon a show plate or pedestal. Strictly speaking, this is a segment of a roller. A short cast or built-up member hinged at both ends, or instead hinged at one end and provided with a circular segment or spherical type bearing at the other to facilitate expansion and contraction on other longitudinal rotational movements.

Expansion Shoe (Expansion Pedestal) - An expansion bearing member or assemblage designed to provide means for expansion and contraction or other longitudinal movements.

In general, the term "shoe" is applied to an assemblage of structural plates or plate-like castings permitting movement by sliding while the term "pedestal" is used to describe assemblages of castings or built-up members securing a somewhat greater total depth and providing for movement either by sliding or by rolling.

The masonry plate or casting is commonly held in a fixed position by anchor bolts and the superimposed shoe plate or pedestal is free to move longitudinally upon it or upon intervening rollers but is restrained from transverse movement either by a rib and slot, by pintles, by anchorage or by anchorage in combination with one of the first two mentioned. The term "bed plate" is sometimes used to designate the bottom of the assemblage.

Extra Work - An item of work not provided for in the contract as awarded but found by the Engineer essential to the satisfactory completion of the contract within its intended scope.

Extra Work Authorization - An agreement between the Department and the contractor to perform extra work at agreed price or on a force account basis.

Eyebars - A member consisting of a rectangular bar body with enlarged forged ends or heads having holes through them for engaging connecting pins.

An adjustable eyebars are composed of two sections fitted with upset threaded ends engaging a sleeve nut or a turnbuckle.

F

Factor of Safety - A factor or allowance predicated by common engineering practice upon the failure stress or stresses assumed to exist in a structure or a member or part, thereof. Its purpose is to provide a margin in the strength, rigidity, deformation and endurance of a structure or its component parts compensating for irregularities existing in structural materials and workmanship, uncertainties involved in mathematical analysis and stress distribution, service deterioration and other unevaluated conditions.

Falsework - A temporary wooden or metal framework built to support the mass of a structure during its construction and until the structure becomes self-supporting.

Fascia (or Facia) - An outside covering member designated on the basis of architectural effect rather than strength and rigidity, although its function may involve both. Thus the 'fascia beam' is the outside beam.

Fatigue - The tendency of a member to fail at a lower stress when subjected to cyclical loading than when subjected to static loading.

Fender - 1. A structure placed at an upstream location adjacent to a pier to protect it from the striking force, impact and shock of floating stream debris, ice floes, etc. This structure is sometimes termed an "ice guard" in latitudes productive of lake and river ice to form ice flows. 2. A structure commonly consisting of dolphins, capped and braced rows of piles or of wooden cribs either entirely or partially filled with rock ballast, constructed upstream and downstream from the center and end piers (or abutments) of a fixed or movable superstructure span to fend off water-borne traffic from collision with these substructure parts, and in the case of a swing span, with the span while in its open position.

Fill – Material, usually earth, used to raise or change the surface contour of an area, or for constructing an embankment.

Filler Plate - In wooden and structural steel construction. A piece used primarily to fill a space beneath a batten, splice plate, gusset, connection angle, stiffener or other element.

Fillet - 1. A curved portion forming a junction of two surfaces which would otherwise intersect at an angle. 2. In metal castings and rolled structural shapes a fillet is used to disseminate and relieve the shrinkage or other stresses tending to overstress and, perhaps, rupture the junction material. In castings it may also provide means for movement to take place at locations where the rigidity of the mold would otherwise resist and obstruct this action. 3. In concrete construction the use of forms not only serves the purposes applying to castings but also facilitates both the placing of concrete and the subsequent removal of forms.

Fillet Weld - A weld joining intersecting members by depositing weld metal to form a near-triangular or fillet shaped junction of the surfaces of the members so jointed. This weld serves to unite the intersecting surfaces of two elements of a member.

Fish Belly - A term applied to a girder or a truss having its bottom flange or its bottom chord, as the case may be, constructed either haunched or bow-shaped with the convexity downward.

Fixed Bearing - The plates, pedestals or other devices designed to receive and transmit to the substructure or to another supporting member or structure the reaction stress of a beam, slab, girder, truss, arch or other type of superstructure span. The fixed bearing is considered as holding the so-termed "fixed end" of the structure rigidly in position, but in practice the clearance space commonly provided in the anchorage may permit a relatively small amount of movement.

Flange - The part of a rolled I-shaped beam or of a built-up girder extending transversely across the top and bottom edges of the web. The flanges are considered to carry the compressive and tensile forces that comprise the internal resisting moment of the beam, and may consist of angles, plates or both.

Flange Angle - An angle used to form a flange element of a built-up girder, column, strut or similar member.

Floor Beam - A beam or girder located transversely to the general alignment of the bridge and having its end framed upon the columns of bents and towers or upon the trusses or girders of superstructure spans. A floor beam at the extreme end of a girder or truss span is commonly termed an end floor beam.

Floor System - The complete framework of floor beams and stringers or other members supporting the bridge floor proper and the traffic loading including impact thereon.

Flow Line - The surface elevation of the dirt, gravel etc. which comprises the stream bed.

Footing – The enlarged, or spread-out, lower portion of a substructure which distributes the load to either the earth or to supporting piling or shafts.

Forms – Wooden or metal framework used to hold plastic concrete in place while it hardens.

Foundation Seal – A mass of concrete placed underwater within a cofferdam for the base portion of an abutment, pier, retaining wall or other structure in order to close or seal the cofferdam against incoming water from underneath.

G

Galvanic Action - Electrical current between two unlike metals.

Girder – 1. A flexural member which is the main or primary support for the structure, and which usually receives loads from floor beams and stringers. 2. Any large beam, especially if built up.

Grade Crossing - A term applicable to an intersection of two or more highways, two railroads or one railroad and one highway at a common grade or elevation; now commonly accepted as meaning the last of these combinations.

Grade Separation - As term applied to the use of a bridge structure and its approaches to divide or separate the crossing movement of vehicular, pedestrian or other traffic, by confining portions thereof to different elevations.

Grid - A network composed of two sets of equidistant parallel lines intersecting at right angles.

Grillage - A platform-like construction or assemblage used to insure distribution of loads upon unconsolidated soil material.

A frame composed of I-beams or other structural shapes rigidly connected and built into a masonry abridge seat, skewback or other substructure support to insure a satisfactory distribution of the loads transmitted by the superstructure shoes, pedestals, or other bearing members.

Ground Control - In photo-mapping, control obtained from surveys as distinguished from control obtained by photo-grammetric methods.

Grout - A mortar having a sufficient water content to render it a free flowing mass, used for filling (grouting) the interstitial spaces between the stones or the stone fragments (spalls) used in the "backing" portion of stone masonry; for fixing anchor bolts and for filling cored spaces in castings, masonry, or other spaces where water may accumulate.

Guard Stake - A stake driven near a hub, usually sloped with the top of the guard stake over the hub. The guard stake protects, and its markings identify the hub.

Gusset - A plate serving to connect or unite the elements of a member or the members of a structure and to hold them in correct alignment and/or position at a joint. A plate may function both as a gusset and splice plate while under other conditions it may function as a gusset and stay plate.

H

H-Beam or H-Pile - A rolled steel bearing pile having an H-shaped cross section.

Hammerhead Pier – A pier which has a cantilever cap extending outward from the column and is somewhat similar in shape to a hammer. Usually used with one column bents or piers.

Hanger - A tension element or member serving to suspend or support a member attached thereto. A tension member, whether a rod, eyebar or built-up member supporting a portion of the floor system of a truss, arch or suspension span.

Haunch - A deepening of a beam or column, the depth usually being greatest at the support and vanishing towards or at the center. The curve of the lower flange or surface may be circular, elliptic, parabolic, straight or stepped.

The concrete placed immediately between the top flange of a beam or girder and the bottom of the roadway slab to make up for irregularities in the beam and dead load deflection due to the weight of the beam and slab.

Hinged Joint - A joint constructed with a pin, cylinder segment, spherical segment or other device permitting movement by rotation.

Horizontal Angle - An angle measured in a horizontal plane.

Horizontal Direction - A direction in a horizontal plane.

Horizontal Distance - The distance measured in a horizontal plane, as distinguished from a distance measured on a slope.

Hub - A wooden stake set in the ground, with a tack or other marker to indicate the exact position. A guard stake protects and identifies the hub.

I

Impact – Forces above the weight of a vehicle that are produced on a structure due to the vehicle's movement.

Inspector - The Engineer's authorized representative assigned to make detailed inspections of contract performance.

Intermittent Weld - A non-continuous weld commonly composed of a series of short welds with intervening spaces arranged with fixed spacing and length.

J

Joint – 1. In Stone Masonry, the space between individual stones. 2. In Concrete Construction, the divisions or terminations of continuity produced at predetermined locations or by the completion of a period of construction operations. These may or may not be open. 3. In a Truss or Frame Structure, (a) A point at which members of a truss or frame are joined, (b) the composite assemblage of pieces or members around or about the point of intersection of their lines of action in a truss or frame.

K

Keeper Plate – A metal plate used to prevent the beam or girder from separating or moving from the bearing assembly. The keeper plate is bolted or welded to the sole plate or base plate.

Keyway – A projection or depression designed to prevent movement of adjoining parts of a structure.

Knee Brace – A member, usually short in length, engaging at its ends two other members, which are joined to form a right angle or a near-right angle. It serves to strengthen and make the connection joint more rigid.

L

Laboratory - The testing laboratory or the Department or other testing laboratory which may be designated by the Engineer.

Laminated Timber - In common usage a laminated timber deck is made up of 2" X 4"s or 2" X 6"s laid on edge and nailed together to form a continuous deck. The timber members are transverse to the beams or girders which support the deck.

Lap – The overlapping of two reinforcement bars to form a splice.

Lateral Bracing - The bracing assemblage engaging the chords and inclined end posts of truss and the flanges of plate girder spans in the horizontal or inclined planes of these members to function in resisting the transverse forces resulting from wind, lateral vibration, and traffic movements tending to produce lateral movement and deformation.

Latex Modified Concrete– Concrete which has been altered by the addition of a chemical admixture for increased strength and reduced permeability.

Lattice (Lacing) - An assemblage of bars, channels, or angles singly or in combination bolted, riveted or welded in inclined position upon two or more elements of a member to secure them in correct position and assure their combined action. When the bars form a double system by being inclined in opposite directions the assemblage is termed "double lattice." When so arranged, the bars are commonly connected at their intermediate length intersections.

Level Datum - A level surface to which deviations are referred. The generally adapted level datum for leveling in the United States is mean sea level. For local surveys, an arbitrary level datum is often adopted and defined in terms of an assumed elevation for some physical mark (Bench Mark).

Live Load - A dynamic load such as traffic load that is supplied to a structure suddenly or that is accompanied by vibration, oscillation or other physical condition affecting its intensity.

Longitudinal Reinforcement - Steel reinforcement in a concrete member running generally parallel with the long dimension of the member. In a column it is vertical, in a bent cap it is horizontal and in a deck it is horizontal and runs parallel to the direction of traffic.

Low Slump Dense Concrete– Concrete which has a low slump and a low water/cement ratio for increased strength and reduced permeability.

M

Masonry - A general term applying to abutments, piers, retaining walls, arches and allied structures built of stone, brick or concrete and known correspondingly as stone, brick or concrete masonry.

Masonry Plate - A steel plate or a plate-shaped member whether cast, rolled or forged, built into or otherwise attached upon an abutment, pier, column, or other substructure part to support the rocker, shoe or pedestal of a beam, girder or truss span and to distribute the load to the masonry beneath.

Materials - Substances specified for use in the construction of the project.

Meander - The tortuous channel that characterizes the serpentine curvature of a slow flowing stream in a flood plain.

Moment - The product of a force and distance to a particular axis or point. The bending action within a beam which produces stress and deflection.

Monument - Any object or collection of objects that indicate the position on the ground of a survey station. In military surveys, the term monument usually refers to a stone or concrete station marker containing a special bronze plate on which the exact station point is marked.

Mortar - The component of concrete composed of cement, or other indurating material with sand and water when the concrete is a mobile mass and correspondingly this same component after it has attained a rigid condition through hardening of its cementing constituents.

Mud Sill - A single piece of timber or a unit composed of two or more timbers placed upon a soil foundation as a support for a single column, a framed trestle bent, or other similar member of a structure.

A load distribution piece aligned with and placed directly beneath the sill piece of a framed bent is termed a "Sub-sill" although it may serve also as a mud sill.

N

Neutral Axis - The axis of a member in bending along which the strain is zero. On one side of the neutral axis the fibers are in tension, on the other side in compression.

Normal – Perpendicular, or at right angles.

Notice to Proceed - Written notice to the contractor to begin with the contract work.

O

Offset Points– Points established to the left and right of a structure unit in order to define the centerline alignment of the unit.

Overlay – A concrete or bituminous layer of varying or uniform thickness designed to provide a smooth roadway surface, increase the strength of the structure (if concrete), and provide extended durability to the structure deck.

P

Paddleboard - Striped, paddle-shaped signs or boards placed on the roadside in front of a narrow bridge as a warning.

Panel (Sub-Panel) - The portion of a truss span between adjacent points of intersection of web and chord members and, by common practice, applied to intersections upon the bottom chord. A truss panel divided into two equal or unequal parts by an intermediate web member, generally by a sub-diagonal or a hanger, forms the panel division commonly termed "subpanels."

Panel Point - The point of intersection of primary web and chord members of a truss.

Parapet - That portion of a box culvert consisting of a low wall or block running parallel to the direction of traffic and placed at the outer extremities of the top slab to retain the roadway fill over the box.

Pavement Structure - The combination of subbase, base course, and surface course placed on a subgrade to support and distribute the traffic load to the roadbed.

Pedestal – 1. A cast or built-up metal member or assemblage functioning primarily to transmit load from one member or part of a structure to another member or part. A secondary function may be to provide means for longitudinal, transverse or revolution movements. 2. A block-like construction of stone, concrete or brick masonry placed upon the bridge seat of an abutment or pier to provide a support for the ends of the beams.

Pier – A substructure unit that supports the superstructure of a bridge at intermediate points between the abutments. See called Bent.

Permanent Bench Mark - A bench mark of as nearly permanent character as it is practicable to establish. Usually designated bench mark.

Picture Point - In surveying, a terrain feature that is easily defined on an aerial photograph, and whose horizontal or vertical position has been determined by survey measurements. Picture points are marked on the aerial photographs by the surveyor and are used by the photo-mapper.

Pier - In common usage in South Dakota a pier is a massive substructure unit usually made of concrete whereas a bent is a lighter, framed unit made up of columns and a cap. A bent may be made of concrete, wood, or steel members.

Pier Cap (Pier Top) - The topmost portion of a pier. On rigid frame piers, the term applies to the beam across the column tops. On hammerhead and tee piers, the cap is a continuous beam.

Pile - A rod or shaft-like linear member of timber, steel, concrete, or composite materials driven into the earth to carry structure loads through weak strata of soil to those strata capable of supporting such loads. Piles are also used where loss of earth support due to scour is expected.

Pin - A cylindrical bar used as a means of connecting, holding in position, and transmitting the stresses of, the members forming a truss or a framed joint. To restrain the pin against longitudinal movement its ends are fitted with pin nuts, cotter bolts, or both. The nuts are commonly of the recessed type taking bearing at their edges upon the assemblage of members. To prevent the loosening of the nuts and the displacement of the pins by vibration, joint movements, and other service conditions, the pin ends may be burred or they may be fitted with cotters.

Pin-Connected Truss - A general term applied to a truss of any type having its chord and web members connected at the truss joints by pins.

Pintle – A small steel pin between two plates of a bearing that prevents horizontal movement, but allows rotation.

Pitch - The longitudinal spacing between rivets, studs, bolts, holes, etc., which are arranged in a straight line.

Plans - The contract drawings which show the location, character, and dimensions of the prescribed work, including layouts, profiles, cross sections, and contract documents.

Plate Girder - An I-shaped beam composed of a solid plate web with either flange plates or flange angles bolted, riveted or welded upon its edges. Additional cover plates may be attached to the flanges to provide greater flange area.

Plate Girder Structure - A structure (bridge) where welded, riveted, or bolted steel plates form a girder or beam used when the span between supports or the traffic loads will exceed the I-Beam maximum load capacity. Splices join girders together. Diaphragms space and hold girders in place.

Pony Truss - A general term applied to a truss having insufficient height to permit the use of an effective top chord system of lateral bracing above the bridge floor.

Pop-Out - Conical fragment broken out of concrete surface. Normally about one inch in diameter. Shattered aggregate particles usually found at bottom of hole.

Portal – 1. The clear unobstructed space of a through bridge forming the entrance to the structure. 2. The entire portal member of the top chord bracing which fixes the uppermost limit of the vertical clearance. The portal of a skew bridge is described as a "skew portal."

Post-Tensioning – A method of prestressing in which the tendon is tensions after the concrete has cured. Usually performed in the field at the job site as opposed to in a fabrication yard.

Pot Holes - Small worn or disintegrated areas of bridge floor or approach surface concaved by the wearing action of vehicle wheels.

Prestressed Beam or Girder - A concrete member, usually an I-shape, through which are stretched highly stressed tendons which when released from their end anchorage, produce a compressive stress in the member.

Prestressed Concrete Beam Structure - A structure where the girders or beams are made of concrete reinforced with steel (reinforcing bars).

Prime Coat – The first coat or base coat of paint applied to the substrate metal. When applied in the fabrication shop it is commonly referred to as the 'shop coat.'

Profile Grade - The trace of a vertical plane usually intersections the top surface of the proposed subgrade surface, usually along the longitudinal centerline of the roadbed. Profile grade means either elevation or gradient of such trace according to the context.

Project - The specific section of the highway together with all appurtenances and construction to be performed under the contract.

R

Region Engineer - A representative of the Director of Operations in charge of assigned operations within a region.

Right-of-way - A general term denoting land, property, or interest therein acquired for or devoted to a highway use.

Road - A general term denoting a public way for purposes of vehicular travel, including the entire area within the Right-of-Way.

Roadbed - The graded portion of a highway within top and side slopes, prepared as a foundation for the pavement structure and shoulders.

Roadside - A general term denoting the area adjoining the outer edge of the roadway. Extensive areas between the roadways of a divided highway may also be considered roadside.

Roadway - The portion of a highway within limits of construction.

Rocker Bent - A bent composed of metal, reinforced concrete or timber, hinged or otherwise articulated at one or both ends to provide the longitudinal movements resulting from temperature changes and the superimposed loads of the span or spans supported thereon.

Rolled Beams - Structural steel wide flange or I-beam members produced in a rolling mill. See also Wide Flange.

Rustication Groove – A decorative treatment used on exposed concrete surfaces to provide a more rustic or natural appearance. Usually constructed by installing a beveled or square wooden strips or boards to the inside of wooden concrete forms.

S

Safe Load - The maximum loading determined by a consideration of its magnitudes and distributions of wheel, axle or other concentrations as productive of unit stresses in the various members and incidental details of a structure, permissible for service use, due consideration being given to the physical condition of the structure resulting from its previous service use.

Scaling - Surface deterioration of concrete (usually a deck) generally due to the presence of de-icing chemicals and/or a weak mortar on the surface.

Scour - An erosion of a river, stream, tidal inlet, lake or other water bed area by a current, wash, or other water in motion, producing a deepening of the overlying water, or a widening of the lateral dimension of the flow area.

Scupper (Curb Inlet) - An opening in the floor portion of a bridge, commonly located adjacent to the curb or wheel guard, to provide means for rain or other water accumulated upon the roadway surface to drain through it into the space beneath the structure. Bridges having reinforced concrete floors with concrete curbs may be effectively drained through scuppers located within the curb face surfaces.

Shear - The force tending to slide the part of a member to one side of a cross section transversely with respect to the part of the member on the other side of the section.

Shear Connector (or Shear Stud) – Studs which are welded to the top flange of a steel beam and act to resist shear forces between the beam and the concrete bridge slab.

Sheet Piling (Sheeting) - A general or collective term used to describe a number of sheet piles taken together to form a crib, cofferdam, bulkhead, etc.

Shoe - In general, a pedestal-shaped member at the end of a plate girder or truss functioning to transmit and distribute its loads to a masonry bearing area or to any other supporting area or member. A shoe may be a cast or a built-up member; the base plate or plate-like part of which is commonly termed the "shoe plate," which may take bearing directly upon a masonry plate or upon an intervening expansion device.

Shoulder - The portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses.

Sidewalk - That portion of the roadway primarily constructed for the use of pedestrians.

Sill (Sill Piece) – 1. The base piece or member of a viaduct or trestle bent serving to distribute the column loads directly upon the foundation or upon mud sills embedded in the

foundation soil transversely to the alignment of the bent. 2. An end substructure unit upon which a truss, beam or girder structure rests. The truss or beams are not cast into the sill, but merely rest upon it.

Simple Span - A superstructure span having, at each end, a single unrestraining bearing or support and designed to be unaffected by stress transmission to or from an adjacent span or structure.

S-I-P Forms (Stay-In-Place) - A prefabricated metal concrete deck form that will remain in place after the concrete has set.

Skew Angle - As applied to oblique bridges; the skew angle, angle of skew or simply "skew" is the acute angle subtended by a line normal to the longitudinal axis of the structure and a line parallel to or coinciding with the alignment of its end.

Slab Bridge - A bridge having a superstructure composed of a reinforced concrete slab constructed either as a single unit or as a series of narrow slabs placed parallel with the roadway alignment and spanning the space between the supporting abutments or other substructure parts. The former is commonly constructed in place but the latter may be precast.

Slag Inclusion - Small particles of slag trapped inside a weld during the fusion process.

Slope Pavement (Slope Protection) - A thin surfacing of stone, concrete or other material deposited upon the sloped surface of an approach cut, embankment or causeway to prevent its disintegration by rain, wind or other erosive action.

Sole Plate - A plate bolted, riveted, or welded upon the bottom flange of a rolled beam, plate girder, or truss to take direct bearing upon a roller nest, bearing pedestal, or masonry plate. It distributes the reaction of the bearing to the beam, girder, or truss member. The sole plate may also function as a combined sole and masonry plate at the fixed end of a beam, girder, or truss.

Spalls (Spalling) – 1. Circular or oval depression in concrete caused by a separation of a portion of the surface concrete, revealing a fracture parallel with or slightly inclined to the surface. Usually part of the rim is perpendicular to the surface. 2. The pieces of spalled concrete themselves.

Special Provisions - Additions and revisions to the standard and supplemental specifications applicable to an individual project.

Specifications - A general term applied to all directions, provisions, and requirements pertaining to performance of the work.

Spread Footing – A reinforced concrete footing that is directly supported by soil or rock as opposed to piling or drilled shafts.

Spur Dike - A dam or dike (usually of earth and protected with rip-rap) running upstream from a bridge to ensure more even flow under the structure and minimize erosion. The upstream end is flared outward from the stream on a roughly parabolic curve.

Standard Specifications - A book of specifications approved for general applications and repetitive use.

Stay Plate (Tie Plate) - A plate placed at or near the end of a latticed side or web of a compression or other member and also at intermediate locations where connections for members interrupt the continuity of the latticing. This plate serves to distribute the lattice bar stress to the elements of the member and adds stiffness and rigidity to joint assemblages.

Steel I-beam Structure - A structure (bridge) where the steel I-Beams under the structure deck (roadway) support the deck and the traffic loads.

Stiffener - An angle, tee, plate or other rolled section riveted, bolted or welded upon the web of a plate girder or other "built-up" member to transfer stress and to prevent buckling or other deformation.

Stirrup - In reinforced concrete bridges: A U-shaped bar placed in beams, slabs or similar constructions to resist diagonal tension stresses.

Strain - The distortion of a body produced by the application of one or more external forces and measured in units of length. In common usage, this is the proportional relation of the amount of distortion divided by the original length.

Street - A general term denoting a public way for purposes of vehicular travel, including the entire area within the right of way.

Stress - The resistance of a body to distortion when a solid or plastic state and when acting in an unconfined condition. Stress is produced by the strain (distortion) and holds in equilibrium the external forces causing the distortion. It is measured in pounds or tons. Within the elastic limit the strain in a member of a structure is proportional to the stress in that member.

- **Unit Stress** - The stress per square inch (or other unit of surface or cross sectional area). The Allowable Unit Stress is: (a) Assumed in determining the composition and construction details of a member or the members of a proposed structure, or (b) assumed for judging the safe load-capacity of an existing structure; while working stress is (c) produced in the members and parts of an existing structure when subjected to loads, impacts and other stress-producing elements and factors to which the structure is proposed to be or may have been subjected.

Stress Sheet - A drawing showing a structure in skeletal form sufficient only to impart or suggest in conjunction with notations thereon its general makeup, major dimensions and the arrangement and composition of its integral parts. Special construction details may be shown by section views and sketches with or without dimensional data. Upon the skeletal outline of the structure or in tabulated form the drawing should show the computed stresses resulting from the application of a system of loads together with the design composition of the individual members resulting from the application of assumed unit stresses for the material or materials to be used in the structures. The assumed design load or loads should appear either in diagrammatic form with dimensions and magnitudes, or reference be made to readily available information relating thereto by a special note conspicuously displayed upon the drawing. A future investigation of a given structure to determine its reliability for a given

load or combination of loads may be greatly facilitated and expedited by an adequate stress sheet record of its original design conditions.

Stringer - A longitudinal beam supporting the bridge deck, and in large bridges or truss bridges, framed into or upon the floor beams.

Strip Seal – Waterproof expansion joint device consisting of steel extruded shapes embedded in the edge of a concrete slab which grip a neoprene gland that seals the opening between the extrusions.

Strut - A general term applying to a piece or member acting to resist compressive stress.

Structures - Bridges, culverts, catch basins, drop inlets, retaining walls, cribbing, manholes, endwalls, buildings, sewers, service pipes, underdrains, foundation drains and other features which may be encountered in the work and not otherwise classified.

Subbase - The layer or layers of specified or selected material of designated thickness placed on a subgrade to support a base course or a surface course.

Subgrade - The top surface of a roadbed upon which the pavement structure and shoulders, including curbs, are constructed.

Substructure - The abutments, piers, grillage or other constructions built to support the span or spans of a bridge superstructure whether consisting of beam, girder, truss, trestle or other type or types of construction.
That part of a structure below the bearings of simple and continuous spans, skewback or arches and tops or footings or ridge frames; including back walls, wing walls and wing protection railings. For reinforced concrete slab bridges, that portion below the deck slab.

Superelevation (Curve Banking) - The transverse inclination of the roadway surface within a horizontal curve and the relatively short tangent lengths adjacent thereto required for its full development. The purpose of superelevation is to provide a means of resisting or overcoming the centrifugal forces of vehicles in transit.

Superstructure - The entire portion of a bridge structure which primarily receives and supports highway, railway, canal or other traffic loads and in its turn transfers the reactions resulting therefrom to the bridge substructure. The superstructure may consist of beam, girder, truss, trestle or other type or types of construction.
A superstructure may consist of a single span upon two supports or of a combination of two or more spans having the number and distribution of supports required by their types of construction, whether consisting of simple, continuous, cantilever suspension, arch or trestle span-tower-bent construction.

Supplemental Specifications - Approved additions and revisions to the standard specifications.

Surface Course - One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion and the disintegrating effects of climate. The top layer sometimes called "Wearing Course."

Suspended Span - A superstructure span having one or both of its ends supported upon or from adjoining cantilever arms, brackets or towers, and designed to be unaffected by other stress transmission to or from an adjacent structure. The ordinary use of a suspended span is in connection with cantilever span construction.

Sway Bracing - The transverse overhead bracing in a truss normally at panel points and attached to the vertical web members.

T

Tack Weld – Usually a small or intermittent fillet weld intended only to hold an element of a member or a member of a structure in place prior to fully welding or final attachment by bolting.

Tendon - A prestressing cable or strand.

Tension - A force or stress caused by equal and opposite forces pulling at the ends of the members.

Test Piles – Initial piles that are driven to determine the required or 'ordered' length of remaining piles for a structure or a portion of a structure. Information gained from driving test piles should be compared with the Subsurface Investigation Sheet to confirm the planned foundation system and pile lengths.

Tie Rod (Tie Bar) - A rod-like or bar-like member in a truss or other frame functioning to transmit tensile stress.

Township, City, Town, Or District - A subdivision of the country used to designate or identify the location of a project.

Transverse Reinforcement - Steel reinforcement in a concrete member normally perpendicular to the long axis of the member. In a deck this is perpendicular to the direction of traffic.

Traveled Way - The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

Truck Average Daily Traffic (T ADT) - This is the total truck volume during a given time period divided by the number of days in the period, normally a year.

Truck Design Hourly Volume (T DHV) - This is the peak hourly volume of truck traffic expected in the 30th highest hour during the chosen design year.

Truss - A jointed structure having an open built web construction so arranged that the frame is divided into a series of triangular figures with its component straight members primarily stressed axially only. The triangle is the truss element and each type of truss used in bridge construction is an assemblage of triangles. The connecting pins are assumed to be frictionless.

Truss Bridge - A bridge having a truss for a superstructure: The ordinary single span rests upon two supports, one at each end, which may be abutments, piers, bents or towers, or combinations thereof. The superstructure span may be divided into three parts, viz.: (1) the trusses, (2) the floor system, and (3) the bracing.

W

Wale or Waler – A wooden or metal member placed inside (typically) or outside the wall portion of a cofferdam or crib. The member is usually placed in the horizontal position and acts as a support beam to maintain the cofferdam's shape.

Waterway - The available width for the passage of stream, tidal or other water beneath a bridge, if unobstructed by natural formations or by artificial constructions beneath or closely adjacent to the structure. For a multiple span bridge the available width is the total of the unobstructed waterway lengths of the spans.

Wearing Course – The top layer of concrete in a bridge deck slab that directly receives the traffic loading.

Web - The portion of a beam, girder, or truss, located between and connected to the flanges or the chords. It serves mainly to resist shear stresses.

Web Members - The intermediate members of a truss extending, in general, from chord to chord but not including the end posts. Inclined web members are termed diagonals. A "tie" is a diagonal in tension while a brace or strut is a diagonal in compression. A vertical web member in compression is commonly designated a post, while one in tension due entirely to the external forces applied at its lower end, is designated a hanger.

Web Plate - The plate forming the web element of a plate girder, built-up beam or column.

Welded Plate Girder – An I-shaped steel beam or girder composed of solid web and flange plates welded together. See also Plate Girder.

Wheel Guard (Felloe Guard) - A member placed longitudinally along the side limit of the roadway to guide the movements of vehicle wheels and safeguard the bridge trusses, railings and other constructions existing outside the roadway limit from collision with vehicles and their loads.

Wide Flange - A rolled member having an II-shaped cross section, differentiated from an I-beam in that the flanges are wider and the web thinner. Also known as Rolled Beam.

Wind Bracing - The bracing systems in girder and truss spans and in towers and bents which function to resist the stresses induced by wind forces.

Wing Dam - A stream deflector usually built of structural steel framing and sheet metal sheeting placed up stream from a bridge to direct the stream evenly through the bridge opening.

Wing wall – 1. The retaining wall portions of the inlet and outlet on a box culvert that retains the roadway embankment at the ends of the culvert. 2. The retaining wall extension

of an abutment intended to confine the side slope material of the roadway embankment at the ends of the bridge.

Work- Work shall include the furnishing of labor, materials, equipment, and incidentals necessary to the successful completion of the contract.

Work Drawings - Stress sheets, show drawings, erection plans, falsework plans, framework plans, bending diagrams for reinforcing steel, or supplementary plans or similar data which the Contractor is required to submit to the Engineer for review.

Working Points (W.P.) – The control point or reference point on a cast-in-place box culvert that marks the corners from which dimensions are given.

Written Order - An order, issued in writing by the Engineer, of a contractual status requiring performance by the Contractor without negotiation of any sort.

