Reinforcing Steel - Chapter 7

- The “What and Where of Reinforcing Steel

“What” is Reinforcing Steel

- High strength steel rods

“Where” is Reinforcing Steel Used

- Placed in concrete to increase resistance to bending and tension

Types of Reinforcing Steel

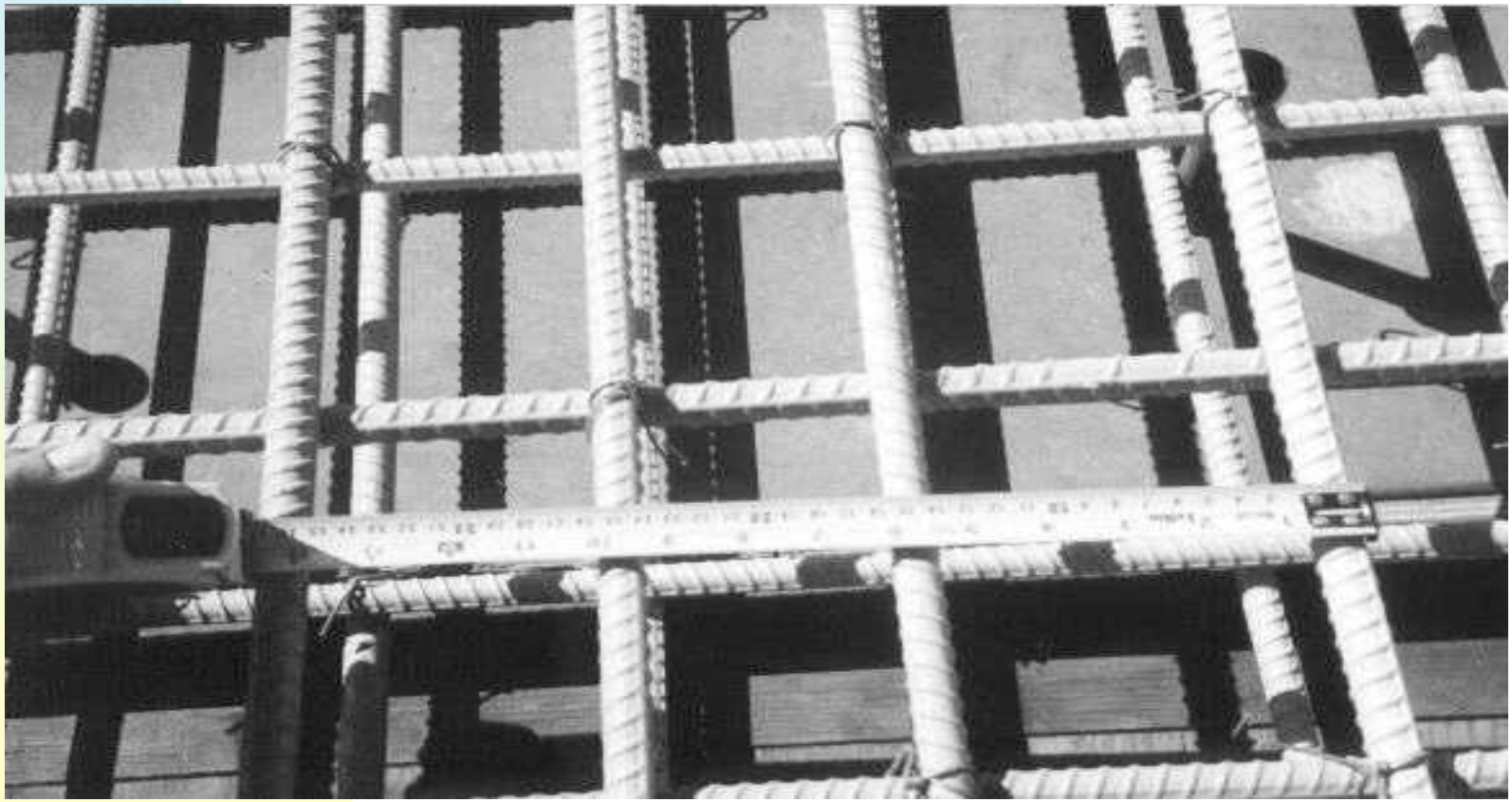
- **Smooth or Plain Bars**
  - Used in Spiral Steel placed in Columns
  - Normally fabricated in spiral form before delivered to work site

Types of Reinforcing Steel

- **Deformed Bars** (epoxy coated or plain)
  - Irregular surface so concrete can grip

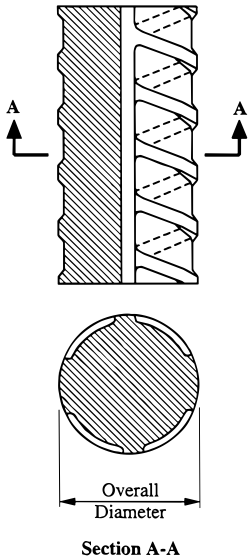
Types of Reinforcing Steel

- **Deformed Bars**



Types of Reinforcing Steel

- **Deformed Bars**



Section A-A

Acceptance Requirements

- When steel is delivered check who is supplier
- Certification & Testing depends on:
  - is steel from ***Certified Fabricator***
  - is steel from ***Non-Certified Fabricator***

Acceptance Requirements

- **Certified Fabricator**
  - uncoated bars - shipping list/bill of lading
  - uncoated bars - check list against list of steel for project
  - uncoated bars - inspect for rust, scales, proper grade markings and signs of mishandling

Acceptance Requirements

- **Non-Certified Fabricator**
  - certified copy of mill test report of chemical analysis for each lot/heat number is forwarded to Engineer
  - visual inspection of heat number, size, length, shape & condition of shipment. Inspector signs on certified mill test .

Acceptance Requirements

- For all **Epoxy Coated Bars**
  - certified copy of mill test report of chemical analysis for each lot/heat number is forwarded to Engineer
  - visual inspection of heat number, size, length, shape & condition of shipment. Inspector signs on certified mill test .
  - A ***Certificate of Compliance*** that epoxy coating and coating process conform to specs.
  - Check for voids, holes and cracks.

Storage and Handling

- Take care unloading to avoid kinking and other damage
- Support long bars at several points

Storage and Handling

- Do not drag on ground to prevent damage to the reinforcing steel or contamination of the steel rebar

Storage and Handling

- Do not stockpile where equipment could damage the steel rebar

Storage and Handling

- Lastly protect non-coated rebar to minimize rusting

Storage and Handling

- Epoxy-Coated Bars
  - use padded/non-metallic slings to unload and move
  - take care to prevent excess sagging during handling
  - do not drop or drag
  - if stored more that 30 days, cover with waterproof, opaque cover to protect from ultraviolet rays

Storage and Handling

Pre-Installation Check

- Verify size, grade, length and shapes before steel is installed in the structure
- Use Reinforcing Schedule found in project plans to verify size, length and shapes

Pre-Installation Check

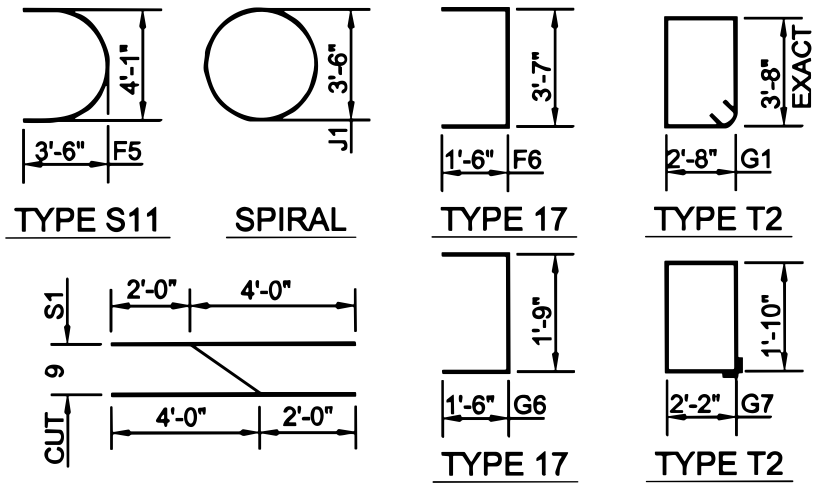
- **Reinforcing Schedule**

REINFORCING SCHEDULE
(FOR ONE BENT)

Mk.	NO.	SIZE	LENGTH	TYPE
F1	4	9	47'-9"	STR.
F2	2	9	49'-9"	STR.
F3	4	9	50'-5"	STR.
F4	4	9	14'-6"	STR.
F5	8	5	9'-4"	S11
F6	4	5	6'-7"	17
F7	4	5	47'-4"	STR.
G1	104	4	13'-6"	T2
G6	4	4	4'-9"	17
G7	1	4	8'-9"	T2
G8	4	4	2'-2"	STR.
H1	57	9	51'-0"	STR.
H2	57	9	36'-6"	STR.
J1	3	4	1773'-9"	SPIRAL
N1	10	8	2'-0"	STR.
⚠ S1	9	6	6'-0"	STR.

⚠ SEE CUTTING DIAGRAM

BENDING DETAILS



SPIRALS - USE 6" PITCH AND 1 1/2 EXTRA TURNS AT EACH END. USE 1 1/2 TURNS FOR LAP AT SPLICE AS REQUIRED, OR WELD AS APPROVED BY THE OFFICE OF BRIDGE DESIGN. USE 4 VERTICAL SPACER BARS PER COLUMN. SPIRALS MAY BE SMOOTH BARS. BAR LENGTH SHOWN DOES NOT INCLUDE SPLICES.

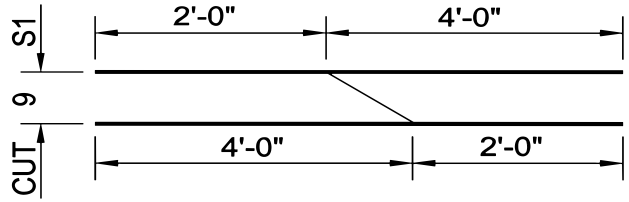
ALL DIMENSIONS ARE OUT-TO-OUT OF BARS.

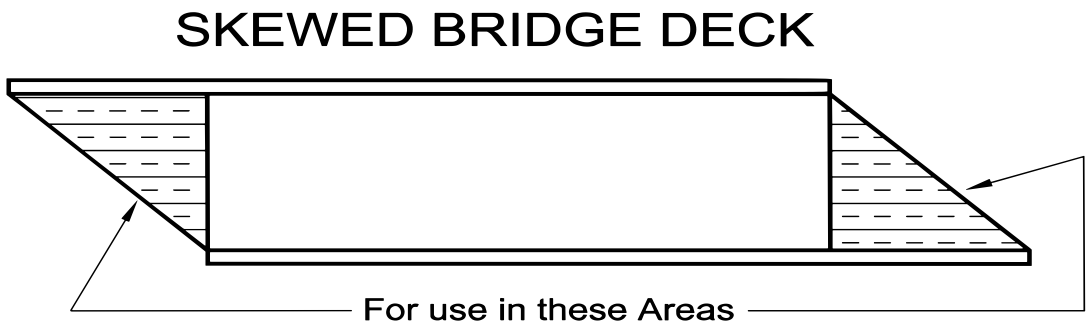
Pre-Installation Check

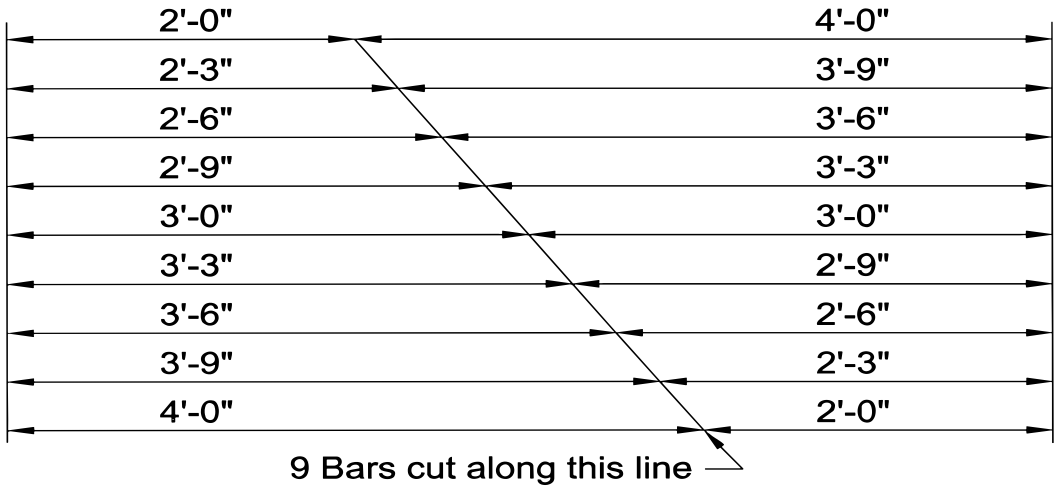
- **Cut Bars**
  - Straight bars are not detailed except when cut bars are needed

Pre-Installation Check

- **Cut Bars**







Bar Identification

Table 7.1 – Properties of Standard Reinforcing Bars

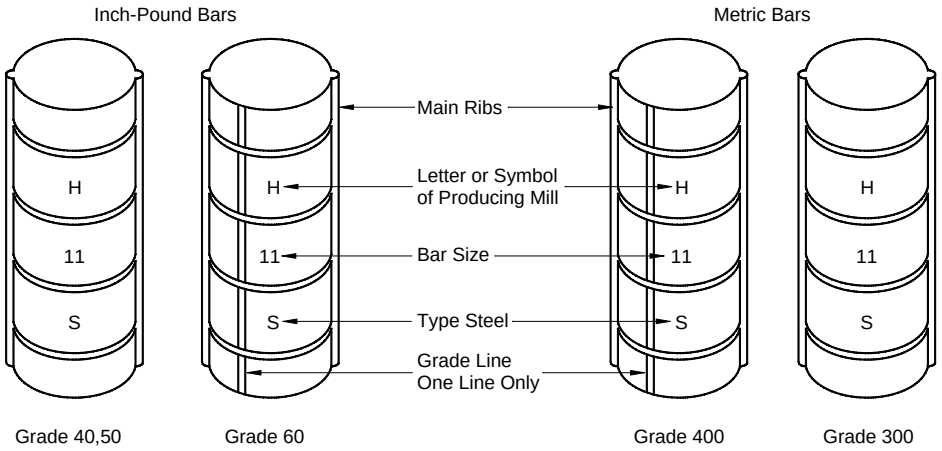
ASTM Standard Reinforcing Bars					
Inch-Pound Bar Size	**Metric Bar Size**	**Nominal Weight or Mass** Lb./Ft. (kg/m)	**Nominal Dimensions – Round Sections**		
			Diameter In. (mm)	**Cross Sectional Area** $In.^2$ (mm^2)	**Perimeter** In. (mm)
#3	#10	0.376 (0.560)	0.375 (9.5)	0.11 (71)	1.178 (29.8)
#4	#13	0.668 (0.994)	0.500 (12.7)	0.20 (129)	1.571 (39.9)
#5	#16	1.043 (1.552)	0.625 (15.9)	0.31 (199)	1.963 (50.0)
#6	#19	1.502 (2.235)	0.750 (19.1)	0.44 (284)	2.356 (60.0)
#7	#22	2.044 (3.042)	0.875 (22.2)	0.60 (387)	2.749 (69.7)
#8	#25	2.670 (3.973)	1.000 (25.4)	0.79 (510)	3.142 (79.8)
#9	#29	3.400 (5.060)	1.128 (28.7)	1.00 (645)	3.544 (90.2)
#10	#32	4.303 (6.404)	1.270 (32.3)	1.27 (819)	3.990 (101.5)
#11	#36	5.313 (7.907)	1.410 (35.8)	1.56 (1006)	4.430 (112.5)
#14	#43	7.650 (11.38)	1.693 (43.0)	2.25 (1452)	5.320 (135.1)
#18	#57	13.60 (20.24)	2.257 (57.3)	4.00 (2581)	7.090 (180.0)

Bar Identification

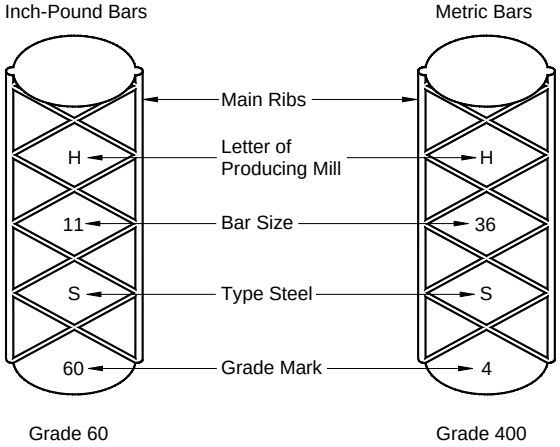
- **Material Sources**
  - N=*Billet Steel* - Grade 40 or 60 (new steel)
  - S=*Billet Steel* w/added reqs.
  - R=*Rail Steel* - Grade 40 or 60 (melted down railroad track)
  - A=*Axle Steel* - Grade 60 (from carbon steel RR car axles)
  - W=*Low Alloy Steel* - Grade 60

Bar Identification

continuous line system - grade marks



number system - grade marks



Dimensions & Bends

- **Straight Bars**
  - During inspection allow + or - 1” from specified length
  - Measure with steel ruler
  - If in bundle, measure several, eyeball the rest

Dimensions & Bends

- **Bent Bars**
  - check details in reinforcing schedule
  - check each dimension & overall length
  - measure a few, eyeball the rest
  - if any out of tolerence, reject it and measure remainder of shipment
  - check against *Standard Hook & Stirrup Dimensions Charts*

Dimensions & Bends

- **Bent Bars**

Table 7.2 – Standard Hook Dimensions

Standard Hook Dimensions					
Inch-Pound Bar Size	**Metric Bar Size**	**D** (mm)	**180° Hooks** (mm)		**90° Hooks** (mm)
			A or G	**J**	**A or G**
#3	#10	2 ¼” (125)	5” (125)	3” (75)	6” (150)
#4	#13	3” (80)	6” (150)	4” (100)	8” (200)
#5	#16	3 ¾” (95)	7” (175)	5” (125)	10” (250)
#6	#19	4 ½” (115)	8” (200)	6” (150)	1’-0” (300)
#7	#22	5 ¼” (135)	10” (250)	7” (175)	1’-2” (355)
#8	#25	6” (150)	11” (280)	8” (200)	1’-4” (405)
#9	#29	9 ½” (240)	1’-3” (380)	11 ¾” (300)	1’-7” (480)
#10	#32	10 ¾” (275)	1’-5” (430)	1’-1 ¼” (335)	1’-10” (560)
#11	#36	12” (305)	1’-7” (480)	1’-2 ¾” (375)	2’-0” (610)
#14	#43	18 ¼” (465)	2’-3” (685)	1’-9 ¾” (540)	2’-7” (790)
#18	#57	24” (635)	3’-0” (915)	2’-4 ½” (725)	3’-5” (1040)

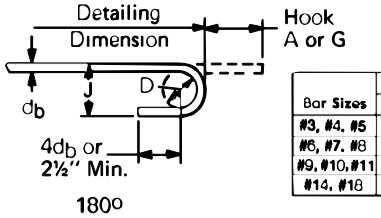
Dimensions & Bends

- **Bent Bars**

Table 7.3 – Stirrup Dimensions

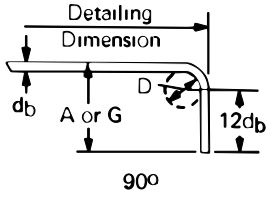
Stirrup Dimensions (Tie Bends Similar)					
Inch-Pound Bar Size	**Metric Bar Size**	**D** (mm)	**90° Bends** (mm)	**135° Bends** (mm)	
			A or G	**A or G**	**H**
#3	#10	1 ½" (40)	4" (100)	4" (100)	2 ½" (65)
#4	#13	2" (50)	4 ½" (115)	4 ½" (115)	3" (75)
#5	#16	2 ½" (65)	6" (150)	5 ½" (140)	3 ¾" (95)
#6	#19	4 ½" (115)	1'-0" (300)	7 ¾" (195)	4 ½" (115)
#7	#22	5 ¼" (135)	1'-2" (355)	9" (230)	5 ¼" (135)
#8	#25	6" (150)	1'-4" (405)	10 ¼" (260)	6" (150)

STANDARD HOOK DETAILS

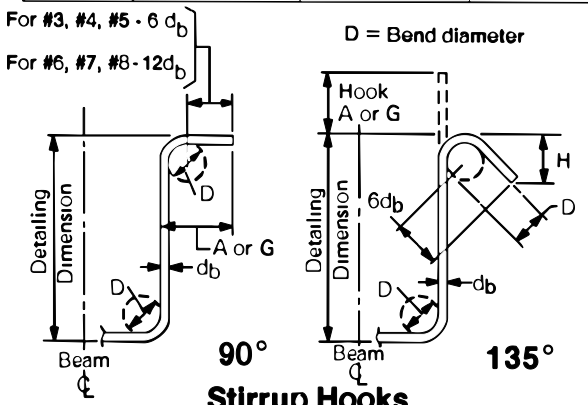


Bar Sizes	D = Finished Inside Bend Diameter	
	Standard Hooks	Stirrup Tie Hooks
#3, #4, #5	$6d_b$	$4d_b$
#6, #7, #8	$6d_b$	$6d_b$
#9, #10, #11	$8d_b$	$8d_b$
#14, #18	$10d_b$	$10d_b$

d_b = Nominal Bar Diameter



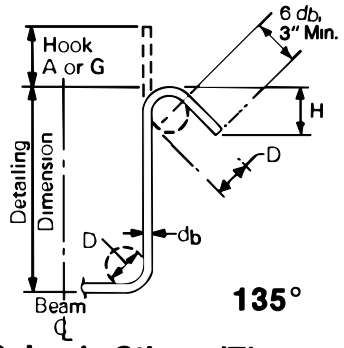
Bar Size	Dimensions of standard 180-deg hooks, all grades			Dimensions of standard 90-deg hooks, all grades	
	A or G	J	D	A or G	D
#3	5"	3"	2½"	6"	2¼"
#4	6"	4"	3"	8"	3"
#5	7"	5"	3¾"	10"	3¾"
#6	8"	6"	4½"	1'-0"	4½"
#7	10"	7"	5¼"	1'-2"	5¼"
#8	11"	8"	6"	1'-4"	6"
#9	1'-3"	11¾"	9½"	1'-7"	9½"
#10	1'-5"	1'-1¼"	10¾"	1'-10"	10¾"
#11	1'-7"	1'-2¾"	12"	2'-0"	12"
#14	2'-3"	1'-9¾"	18¼"	2'-7"	18¼"
#18	3'-0"	2'-4½"	24"	3'-5"	24"



Stirrup Hooks

(Tie Bends Similar)

Bar Size	D	90°	135°	
		A or G	A or G	Approx. H
#3	1½"	4"	4"	2½"
#4	2"	4½"	4½"	3"
#5	2½"	6"	5½"	3¾"
#6	4½"	1'-0"	7¾"	4½"
#7	5¼"	1'-2"	9"	5¼"
#8	6"	1'-4"	10¼"	6"



Seismic Stirrup/Tie

135° Seismic Hook			
Size	D	A or G	Approx. H
#3	1½"	4¼"	3"
#4	2"	4½"	3"
#5	2½"	5½"	3¾"
#6	4½"	7¾"	4½"
#7	5¼"	9"	5¼"
#8	6"	10¼"	6"

Placement of Reinforcing Steel

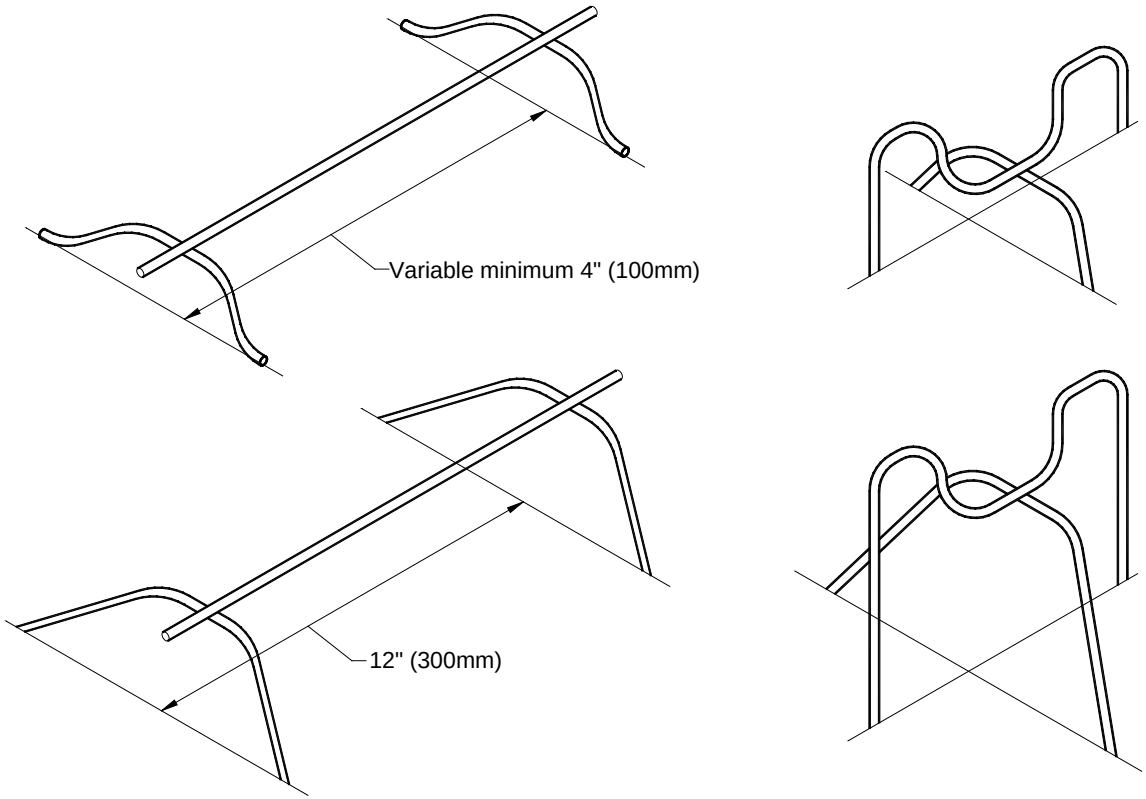
- Place steel according to plans
- Maintain proper Clear *Cover & Spacing*
  - Clear Cover - distance between finished surface of concrete and nearest surface of rebar
  - Spacing - distance between centers of rebar

Placement of Reinforcing Steel

- **Supporting Devices**
  - Metal Chairs & Bolsters
    - premanufactured
    - light to heavy gauge wire
    - support rebar from bottom of slab
    - for epoxy coated bars use epoxy or plastic coated chairs & bolsters
    - *all* plastic chairs & bolsters are not allowed

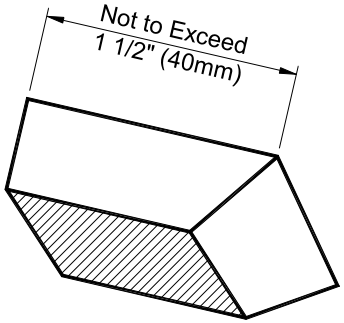
Placement of Reinforcing Steel

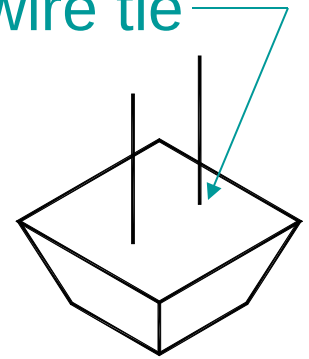
- **Supporting Devices**
  - Metal Chairs & Bolsters



Placement of Reinforcing Steel

- **Supporting Devices**
  - Precast Mortar Blocks
    - used in place of chairs or bolsters
    - have a tapered trapezoidal shape
    - made of concrete of the same or higher strength
    - can be precast with wire tie





Placement of Resteel

- **Wire Hangers and Ties**
  - use 16 gauge wire or larger to fasten bars where they cross
  - for epoxy bars use coated wires

Placement of Reinforcing Steel

- **Wood**
  - used to hold reinforcement
  - most often used to hold circular patterns for columns
  - placed outside the poured concrete
  - must be removed after concrete has enough strength to self support

Placement of Reinforcing Steel

- **Support devices NOT allowed**
  - Pebbles - tend to tip
  - Broken Stone or Brick - undesirable appearance
  - Metal Pipe - mortar doesn't flow into pipe leaving a void
  - Embedded Wooden Blocks - wood rots - not same strength as concrete
  - Metal Devices - if exposed they rust

Placement of Reinforcing Steel

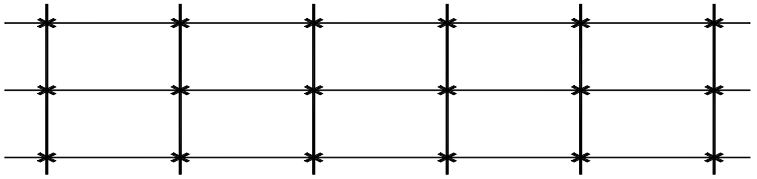
- **Placement Methods**
  - **by single piece or by section**

Placement of Reinforcing Steel

- **Inspections**
  - Inspectors job is to insure correct bars are properly placed & secured
  - Count bars; compare to plans
  - Check bar sizes. **Substitution of bar sizes is not an option without authorization from Office of Bridge Design**
  - Check for proper tie pattern

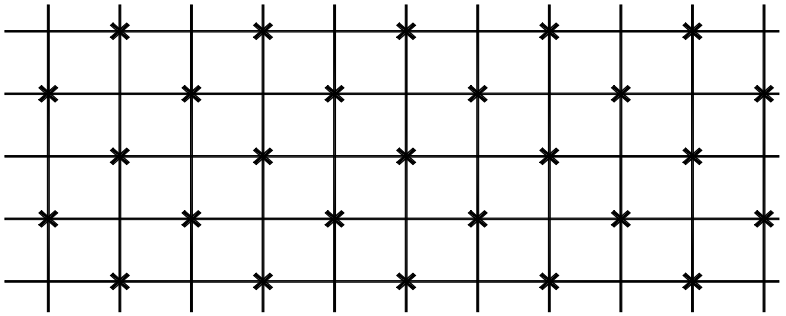
Placement of Reinforcing Steel

- **Inspections**
  - Tie Pattern where two bars cross



Greater than 12” spacing in one direction

Less than 12” spacing

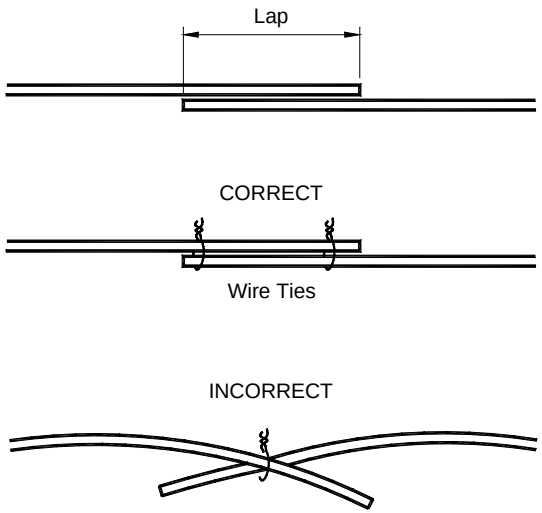


Placement of Reinforcing Steel

- **Inspections**
  - Tie Pattern - Bridge Deck & Box Culverts
    - Tie top mat to lower supporting member to prevent mat from “floating” up during concrete pour
    - Girder Bridges - tie every 8 feet
    - Slab Bridges/Box Culverts - tie every 12 feet

Placement of Reinforcing Steel

- **Inspections**
  - Check Splices
    - Overlap should be wired in two places
    - check plans for overlap

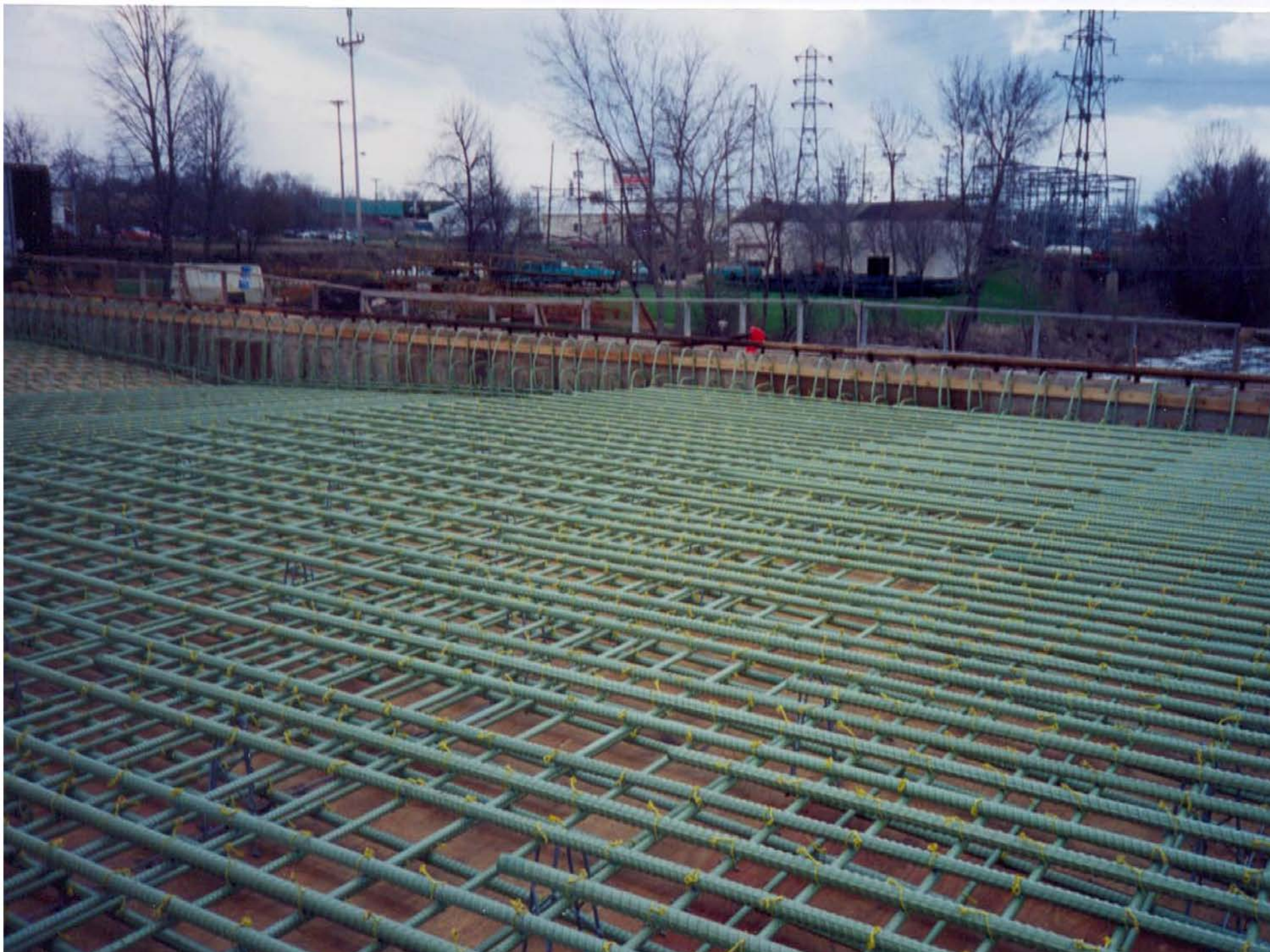


Placement of Reinforcing Steel

- **Inspections**
  - Check for proper spacing of bars
  - Verify with plan requirements
  - *reinforcement spacing should be within + or - 1/2 inch of plan location*
  - Uneven distribution of rebar can cause concrete cracking

Placement of Reinforcing Steel

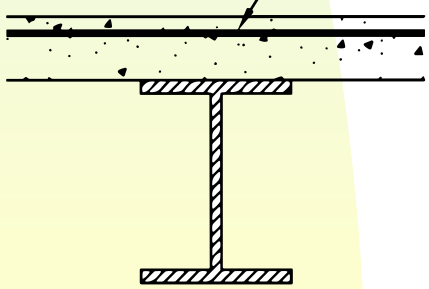
- **Inspections**
  - check for proper cover
  - proper cover helps prevent
    - buckling under compressive loads
    - rusting from exposure
    - scaling of concrete surface because reinforcement is too close to surface
  - Maintain cover within + or - 1/4” of plan specs.



Placement of Reinforcing Steel

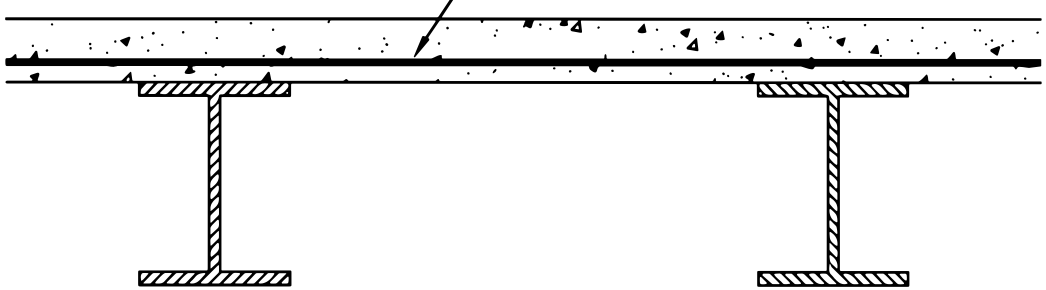
- **Inspections**
  - results of improper cover

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

Placement of Reinforcing Steel

- **Inspections**
  - check beginning and end point of steel bars
  - verify against plans

Placement of Reinforcing Steel

- **Inspections**
  - **Check Condition of Bars**
    - free of dirt, oil, grease or mortar
    - thin film of rust or mill scale is OK
    - remove dirt with burlap or washing
    - remove grease/oil with MEK
    - remove old mortar with wire brush

Placement of Reinforcing Steel

- **Inspections**
  - **Epoxy Coated Reinforcement**
    - repair not necessary for areas < 1/4” square or where sum of damage per 1 foot of bar is < 2% of bar surface
    - bars with >2% of surface damage shall be rejected
    - sheared ends are normal problem areas

Welding Reinforcing Steel

- **Not normally welded**
  - carbon content too high
  - becomes brittle when heated
  - verify welding with plans

Mechanical Reinforcement Splices

- **Couplers vs Direct Overlap**
  - maybe required for retrofit projects when existing rebar is too short to overlap or when bars are too big and when overlapped don’t allow enough space for concrete to flow between them for proper bond.
  - check plans to verify mechanical splicing requirements (125% yield strength of rebar).

Questions?