Mix Design & Production Control Recertification

Quality Control / Quality Assurance

South Dakota DOT
Connecting South Dakota and the Nation
**IMPORTANT**

Recertification is only for individuals currently certified and actively participating on Asphalt Concrete Projects.
Course Materials

- QC/QA Asphalt Concrete Training Manual
- Standard Specifications for Roads and Bridges
  - Supplemental Specifications
- South Dakota DOT Materials Manual
  - Minimum Sample & Test Requirements
Course Agenda

- Specifications
- Aggregate Requirements
- Flat & Elongated Example
- Composites
- Mix Design Calculations
- Submittals
- SDDOT Verification
- Field Testing & Problems
- Recertification Exam
Contractor Design Requirements

- SD 319, SDDOT test procedures, and AASHTO and ASTM references
- Mix design must meet all SDDOT requirements and specifications (Special Provisions, standard specs, etc.)
- Furnish mix design including lab data and test results.
- Contractor must maintain calibration records for all lab testing equipment
Aggregate Requirements

- Get legal pit descriptions for all aggregate sources
- Quality tests completed on aggregate sources
- Use average stockpile gradation tests
- Determine proposed trial bin splits
Aggregate Tests Needed for Gyratory Control

- Fine Aggregate Angularity (SD 217)
- Sand Equivalent (SD 221)
- Lightweight Particles (SD 208 & SD 214)
- Crushed Particles (SD 211)
- Specific Gravity and Absorption of Aggregates (SD 209 & SD 210)
- LA Abrasion (SD 204)
- Sodium Sulfate Soundness Loss (5 cycles) (SD 220)
- Gradation (SD 202)
- Flat & Elongated Particles (SD 212)
Problem #1
Flat & Elongated (SD 212)

Given the following gradation, calculate the percent of flat and elongated particles.

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Retained (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;</td>
<td>0.0</td>
</tr>
<tr>
<td>5/8&quot;</td>
<td>0.0</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>227.8</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>696.9</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>1219.8</td>
</tr>
<tr>
<td>#4</td>
<td>922.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Total Sample Weight on Sieve</th>
<th>Weight of Tested Portion (100 pieces)</th>
<th>Weight of Flat/Elongated Particles</th>
<th>% Flat/Elongated (Individual Sieve)</th>
<th>% Flat/Elongated Weighted Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot; to 1/2&quot;</td>
<td>227.8</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/2&quot; to 3/8&quot;</td>
<td>222.2</td>
<td>7.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8&quot; to #4</td>
<td>61.1</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Sample Wt. F

Percent flat and elongated particles in the total sample (weighted average) rounded
### Problem #1 - Answer

**Flat & Elongated (SD 212)**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Gradation</th>
<th>Retained (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot;</td>
<td>227.8</td>
<td>0.0</td>
</tr>
<tr>
<td>5/8&quot;</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>696.9</td>
<td>0.0</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>1219.8</td>
<td>0.0</td>
</tr>
<tr>
<td>#4</td>
<td>922.8</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Table:**

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Total Sample Weight on Sieve</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4&quot; to 1/2&quot;</td>
<td>227.8</td>
<td>5.0</td>
<td>2.2</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>1/2&quot; to 3/8&quot;</td>
<td>222.2</td>
<td>7.3</td>
<td>3.3</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>3/8&quot; to #4</td>
<td>61.1</td>
<td>3.0</td>
<td>4.9</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td><strong>Total Sample Wt.</strong></td>
<td><strong>3067.3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **(F) Total Sample Wt.** = 227.8 + 696.9 + 2142.6 = 3067.3
- **(D) % F&E (individual sieve)** = \( \left( \frac{C}{B} \right) \times 100 = \left( \frac{5.0}{227.8} \right) \times 100 = 2.2 \) (1/2"
- \( \left( \frac{7.3}{222.2} \right) \times 100 = 3.3 \) (3/8"
- \( \left( \frac{3.0}{61.1} \times 100 = 4.9 \) (#4
- **(E) % F&E (weighted avg)** = \( \left( \frac{A}{F} \right) \times D = \left( \frac{227.8}{3067.3} \right) \times 2.2 = 0.2 \) (1/2"
- \( \left( \frac{696.9}{3067.3} \times 3.3 = 0.7 \) (3/8"
- \( \left( \frac{2142.6}{3067.3} \times 4.9 = 3.4 \) (#4
- **Total % F&E** = 0.2 + 0.7 + 3.4 = 4.3 = 4 (rounded)
Composite Mineral Aggregate Specification Requirements

- Vary by traffic level (Q1, Q2, Q3, Q4, Q5)
- With or without hydrated lime
- RAP if required
- Example Problem
Problem #2

- Q2R mix with 20% RAP to be added by weight of aggregate
- Solvent extraction test result of 6.50% binder in RAP
- 1.00% hydrated lime added by weight of total mix
- Aggregate bin splits
  - 30% Crushed Rock
  - 25% Crushed Fines
  - 30% Natural Fines
  - 15% Sand
- Prepare a 4750 gram batch with 4.5% added new binder by weight of total mix
- Determine amount of added new binder, lime, RAP, rock, crushed fines, natural fines and sand to be added for a gyratory specimen
- Also determine total binder, new (added) and old (RAP) %
Answer Problem #2

- 4750 grams total for gyratory specimen

  - (4750 x 4.5) / 100 = 213.8 grams (new binder by weight of total mix)
  - (4750 x 1.00) / 100 = 47.5 grams (hydrated lime by weight of total mix)
  - (47.5 + 213.8) = 261.3 grams
  - (4750 - 261.3) = 4488.7 grams (aggregate and RAP)
  - (4488.7 x 20) / 100 = 897.7 grams (RAP)
  - (4488.7 - 897.7) = 3591.0 grams (Virgin MA aggr.)
     - or-
     - (4488.7 x 80) / 100 = 3591.0 grams (Virgin MA aggr.)
  - (3591.0 x 30) / 100 = 1077.3 grams (crushed rock)
  - (3591.0 x 25) / 100 = 897.8 grams (crushed fines)
  - (3591.0 x 30) / 100 = 1077.3 grams (natural fines)
  - (3591.0 x 15) / 100 = 538.7 grams (sand)
Answer Problem #2
(continued)

- Binder from RAP \( \Rightarrow \) \( \frac{897.7 \times 6.5}{100} = 58.4 \text{ grams (old binder from RAP)} \)

- 58.4 grams from RAP + 213.8 grams added binder = 272.2 grams (total binder)

- \( \frac{272.2}{4750} \times 100 = 5.73\% \text{ total binder in mix} \)

- \( \frac{58.4}{272.2} \times 100 = 21.45\% \text{ old binder from RAP} \)

- \( \frac{213.8}{272.2} \times 100 = 78.55\% \text{ new binder} \)

  - This assumes all old binder is effective. Probably not the case, but effective amount is not able to be determined at this time and varies by mix design.
Specifications

- Gradation Control Points
- Flat & Elongated
  - Only a spec. at mix design
- Bin splits adjusted up to 5 percent to meet gradation and mix design requirements
- 92.0% to 96.0% In-place density for all levels
- Asphalt Pavement Analyzer (APA) specification on all mix designs
- Contractors and Consultants doing mix designs must participate in Round Robin testing (Sample Proficiency Program)
Mix Design Specifications
(Gyratory Control)

- **Air Voids**
  - 4.0% ± 1.0% (unless changed by plan note)

- **Voids in the Mineral Aggregate (VMA)**
  - Min. 14.5% at mix design, 13.5% during production

- **Voids Filled with Asphalt (VFA)**
  - at mix design only

- **Densification at** $N_{\text{ini}}$, $N_{\text{des}}$, and $N_{\text{max}}$
  - $N_{\text{des}}$ only in field for spec.

- **Dust to Binder Ratio**
  - Based on effective asphalt content

- **Moisture Sensitivity (TSR ratio)**
  - Min. 80 required on all mixes (Q1, Q2, Q3, Q4, Q5).
  - (only if 1.00% lime is not added)
Mixture Tests
(Gyratory Control)

- Density and Air Voids of Asphalt Concrete by Gyratory Compaction Method (SD 318)
- Densification at $N_{ini}$, $N_{des}$ and $N_{max}$
- VMA calculation (SD 318)
- Dust to Binder Ratio
- Rice Test (SD 312)
- Moisture Sensitivity of Compacted Asphalt Concrete Paving Mixtures (SD 309)
Air Voids Specification

- $4.0\% \pm 1.0\% V_a$ for all gyratory control levels
  - unless plan note to change the target
- Allow for VMA drop when selecting mix design air voids, design for anticipated drop in field air voids
Mix Design Calculations

- Complete all needed calculations
- Determine:
  - Air Voids, VMA, VFA, Effective AC Content, Marshall Stability and Flow, and Dust to Binder Ratio
- Gyratory Compactive Effort
- PLOT DATA
- Example Problem
Complete the DOT-86 for a Q3R Mix.

Use the equations found in SD 318.
Problem #3

DOT-86
Gyratory Worksheet

\[
dust \quad (\#200) + \quad lime \quad = \quad 4.69 \quad + \quad 1.00 \quad = \quad 5.7
\]

\[
Spec.\, A: \quad \text{Gmb measured} \quad = \quad \frac{b}{(d - c)} \quad = \quad \frac{4697.7}{(4699.2 \quad - \quad 2667.0)} \quad = \quad 2.312
\]

\[
Spec.\, B: \quad \text{Gmb measured} \quad = \quad \frac{b}{(d - c)} \quad = \quad \frac{4698.9}{(4700.4 \quad - \quad 2668.2)} \quad = \quad 2.312
\]

\[
Spec.\, A: \quad \text{Gmb calculated} \quad = \quad \frac{(\text{Gmb(meas)} \times \text{height @ Ndes})}{(\text{height @ Nini})} \quad = \quad \frac{(2.312 \times 114.5)}{122.6} \quad = \quad 2.159
\]

\[
Spec.\, B: \quad \text{Gmb calculated} \quad = \quad \frac{(\text{Gmb(meas)} \times \text{height @ Ndes})}{(\text{height @ Nini})} \quad = \quad \frac{(2.312 \times 116.3)}{124.7} \quad = \quad 2.156
\]

Average Gmb @ Ninitial \quad = \quad \frac{(2.159 \quad + \quad 2.156)}{2} \quad = \quad 2.158

Average Gmb @ Ndesign \quad = \quad \frac{(2.312 \quad + \quad 2.312)}{2} \quad = \quad 2.312

- Spec. Book Sect. 322 (Q3R - Table G)
  - \( N_{\text{initial}} \) = 6
  - \( N_{\text{design}} \) = 60
  - \( N_{\text{max}} \) = 85
Problem #3
DOT-86
Gyratory Worksheet

@ N max:  \( Gmb \) measured  \[= \frac{b}{(d-c)} = \frac{4696.8}{(4697.4 - 2687.3)} = 2.337 \]

\( N \) max (@ \( N \) ini):  \( Gmb \) calculated  \[= \frac{(Gmb\,\text{meas}) \times \text{height @ } N_{\text{max}}}{\text{height @ } N_{\text{ini}}} = \frac{(2.337 \times 114.9)}{124.7} = 2.153 \]

\( N \) max (@ \( N \) des):  \( Gmb \) calculated  \[= \frac{(Gmb\,\text{meas}) \times \text{height @ } N_{\text{max}}}{\text{height @ } N_{\text{des}}} = \frac{(2.337 \times 114.9)}{116.1} = 2.313 \]

Average \( Gmb \) @ \( N_{\text{max}} \)  \[= 2.337 \]
**Problem #3**

**DOT-86**

**Gyratory Worksheet**

\[
\text{Rice SpGr} = \left[ \frac{\text{wt.of sample in air}}{\text{(wt.of sample in air) + (wt.of canister + H}_2\text{O) - (wt.of canister + H}_2\text{O + sample)}}} \right] \times \text{Corr. Factor}
\]

\[
\text{Gmm} \#1 = \left[ \frac{1545.1}{(1545.1 + 1365.4 - 2271.5)} \right] \times 1.0000 = 2.418
\]

\[
\text{Gmm} \#2 = \left[ \frac{1534.2}{(1534.2 + 1365.4 - 2264.1)} \right] \times 0.9999 = 2.414
\]

Average Max SpGr (Gmm) = \( \frac{(2.418 + 2.414)}{2} \) = 2.416

\[
\% \text{ of Rice SpGr (Gmm) @ Ninitial} = \frac{\text{Avg. Gmb}}{\text{Avg. Max SpGr}} \times 100 = \frac{2.158}{2.416} \times 100 = 89.3 \%
\]

\[
\% \text{ of Rice SpGr (Gmm) @ Ndesign} = \frac{\text{Avg. Gmb}}{\text{Avg. Max SpGr}} \times 100 = \frac{2.312}{2.416} \times 100 = 95.7 \%
\]

\[
\% \text{ of Rice SpGr (Gmm) @ Nmax} = \frac{\text{Avg. Gmb}}{\text{Avg. Max SpGr}} \times 100 = \frac{2.337}{2.416} \times 100 = 96.7 \%
\]
Problem #3

DOT-86
Gyratory Worksheet

% Air Voids (Va) = \left( \frac{Gmm - Gmb}{Gmm} \right) \times 100 = \left( \frac{2.416 - 2.312}{2.416} \right) \times 100 = 4.3\% 

Ps = 100 - Pb = 100 - 6.0 = 94.0\% 

% VMA = 100 - \left( \frac{Gmb \times Ps}{Gsb} \right) = 100 - \left( \frac{2.312 \times 94.0}{2.554} \right) = 14.9\% 

% VFA = \left( \frac{VMA - Va}{VMA} \right) \times 100 = \left( \frac{14.9 - 4.3}{14.9} \right) \times 100 = 71\% \ (\text{whole percent}) 

Gse = \frac{100 - Pb}{\left( \frac{100}{Gmm} \right) - \left( \frac{Pb}{Gb} \right)} = \frac{100 - 6.0}{\left( \frac{100}{2.416} \right) - \left( \frac{6.0}{1.024} \right)} = 2.646
Problem #3
DOT-86
Gyratory Worksheet

\[ P_{ba} = 100 \times \left( \frac{G_{se} - G_{sb}}{G_{se} \times G_{sb}} \right) \times G_b = 100 \times \left( \frac{2.646 - 2.554}{2.646 \times 2.554} \right) \times 1.024 = 1.4\% \]

\[ P_{be} = P_b - \left( \frac{P_{ba} \times P_s}{100} \right) = 6.0 - \left( \frac{1.4 \times 94.0}{100} \right) = 4.7\% \]

Dust to Binder Ratio \[ = \left( \frac{\text{dust} - \#200 + \text{lime}}{P_{be}} \right) = \left( \frac{5.7}{4.7} \right) = 1.2 \]

**Specs:** Spec Book - Sect. 322 (Q3R mix)
- TABLE L ( % Air Voids) \( \rightarrow 4.0\% \pm 1.0\% 
- TABLE I ( % VMA) \( \rightarrow \text{minimum} 14.5\% 
- TABLE J ( % VFA) \( \rightarrow 65\% - 78\% 
- Dust to Binder Ratio \( \rightarrow 0.6 \text{ to } 1.4 \) -or- \( 0.8 \text{ to } 1.6 \) (depends on gradation @ mix design)
Problem #3
DOT-86
Gyratory Worksheet

Complete the DOT-86 for a Q3R Mix.

Use the equation sheet in the Problems Packet.

Mix Temp: 275

<table>
<thead>
<tr>
<th>% binder Pb</th>
<th>N initial</th>
<th>Gse</th>
<th>N design</th>
<th>Pba</th>
<th>N max</th>
<th>Pbe</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0</td>
<td>6</td>
<td>2.646</td>
<td>60</td>
<td>1.4</td>
<td>85</td>
<td>4.7</td>
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</table>

<table>
<thead>
<tr>
<th>binder Gb</th>
<th>Ns</th>
<th>Gs</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

<table>
<thead>
<tr>
<th>dust (- #200)</th>
<th>Ns</th>
<th>Gs</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.69</td>
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<table>
<thead>
<tr>
<th>lime</th>
<th>Ns</th>
<th>Gs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>dust(#200) + lime</th>
<th>Ns</th>
<th>Gs</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---|---
@ N ini | @ N des | @ N ini | @ N des | @ N ini | @ N des | @ N ini | @ N des |
| 122.6 | 114.5 | 116.3 | 124.7 | 114.9 | 116.1 | 2.312 | 2.313 |
| 4697.7 | 4698.9 | 2668.2 | 2667.9 | 4696.8 | 4697.4 |
| 2667.0 | 2668.2 | 2667.9 | 4696.8 |
| 4699.2 | 4700.4 | 2687.3 | 2678.3 |
| 2.312 | 2.312 | 2.313 | 2.337 |

Gmm #1

| Weight of sample in air | 1545.1 |
| Weight of canister + H2O | 1365.4 |
| Weight of canister + H2O + sample | 2271.5 |
| Temperature of water | 77.0 |
| H2O correction factor | 1.0000 |
| Rice SpGr (Gmm) | 2.418 |

Average Max SpGr (Gmm) 2.416

Gmm #2

| Weight of sample in air | 1534.2 |
| Weight of canister + H2O | 1365.4 |
| Weight of canister + H2O + sample | 2264.1 |
| Temperature of water | 78.0 |
| H2O correction factor | 0.9999 |
| Rice SpGr (Gmm) | 2.414 |

Average SpGr (Gmm) 2.416

<table>
<thead>
<tr>
<th>Average Gmb</th>
<th>N initial</th>
<th>N design</th>
<th>N maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.158</td>
<td>2.312</td>
<td>2.337</td>
<td></td>
</tr>
</tbody>
</table>

% of Rice SpGr (Gmm) 89.3

% Air Voids (Va) 4.3

Specs: 4.0 ± 1.0

% VMA 14.9

% VFA 71

Dust to Binder Ratio 1.2

-0.8 – 1.6
Mix Design Reports

- Submit all lab aggregate test data
- Submit all lab mix design test data
- Submit lab graphs
- Contractor Recommended Job Mix Formula and Asphalt Binder Content
Mix Design Verification Submittal to SDDOT

- Send materials to PIERRE DOT MATERIALS LAB on Truck Route (104 S Garfield Ave Bldg. B) at least 21 calendar days prior to hot mix production.
- Provide aggregate stockpile tests per 1500 tons of material produced (certified testers).
- Label all materials (aggregate and binder).
- Include legal descriptions of all materials.
- DOT Area Offices witness and send in samples or secure samples (green security tags) if Contractor brings to Pierre.
Submitted Aggregate To SDDOT

- Must be representative of stockpiles produced or will need to resubmit samples
- Sample size is large enough to do all required mix and quality tests
- Submitted by Contractor or representative when secured by SDDOT field tags to Bituminous mix design section in Pierre
RAP Testing

- 1 per day for gradation
  - (100% passing 1 ½” and 95-100 passing 1”)
- 1 per day for moisture content
- RAP content (end of day)
SDDOT Verification

- Aggregate and binder submitted
- DOT conducts aggregate quality tests
- DOT does mix design verification
- DOT does moisture sensitivity verification
- Send out Mix Design Report (DOT-64)
  - e-mail to Contractor and DOT Area Office
Asphalt Pavement Analyzer (APA)

Specification at mix design, tested by SDDOT Central Lab
Asphalt Pavement Analyzer (APA) - Specs

<table>
<thead>
<tr>
<th>Table K - Asphalt Pavement Analyzer Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>APA, Maximum Rutting (mm)</strong></td>
</tr>
<tr>
<td>Class Q1</td>
</tr>
<tr>
<td>Class Q2</td>
</tr>
<tr>
<td>Class Q3</td>
</tr>
<tr>
<td>Class Q4</td>
</tr>
<tr>
<td>Class Q5</td>
</tr>
</tbody>
</table>
Field Correlation Testing
Gyratory Control

- Between QC and QA technicians
- Sample supplied by Contractor
  - May be plant produced, if spot leveling
- Gyratory (SD 318)
- Theoretical Max. Sp. Gr. [Rice] (SD 312)
- Air Void calculation on form DOT-69
Field Samples

- **Location**
  - sample obtained from windrow at paver at a random location (SD 312)

- **Sample size**
  - enough for 4 splits, large enough for all tests required

- **Split down to testing size, quartering method**

- **Frequency of needed tests**
  - QC 1 per 1,000 tons, minimum QA 1 per 5,000 tons, IA one per 15,000 tons

- **Retention of split portions of samples**
  - QA until F and t tests completed by Bituminous Engineer
Field Bulk Specific Gravity
Reheat Correlation

- 1st sublot of material
- Cool to room temperature, reheat to compaction temperature
- Used for IA tolerances and if QC vs. QA correlation problems occur
- Shows aggregate and asphalt mixture absorption rates
Moisture in the Mix
SD 305

- One sample per 10,000 tons of hot mix
- DOT sampled from paver area
- 1,500 to 3,000 gram sample
Field Production Control Charts

- QC maintains charts for all required properties shown in Specifications
- Contractor (QC) is responsible for maintaining all process control charts and adding QA and IA tests to charts
Field (mix) Problems

Air Void Problems

- Low Voids
  - Drop in VMA
  - Increase in amount passing -#200 sieve

- High Voids
  - Low binder content
  - Change aggregate gradation
  - No lime
In-Place Density Problems

- High gyratory air voids
- Low VMA
- Not measuring field in-place density
- Temperature of mix at time of compaction rolling is too low or not uniform
- Mix instability
- Base problems
- Compaction equipment problems or not enough rollers
Common Gradation Problems

- Incorrect or inconsistent stockpile gradations
- Job Mix Formula tolerances
  - Table N - Sect. 322
- Variable or segregated stockpiles
- Insufficient stockpile samples at design
- Bin splits incorrect
- Improper loading of cold bins
- Inconsistent feeds from the cold bins
  - wet material sticking in or bridging bins
Segregation
F and t tests (Example)

<table>
<thead>
<tr>
<th>Quality Control Tests</th>
<th>Quality Assurance Tests</th>
<th>Independent Assurance Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test No.</td>
<td>Gmm</td>
<td>Gmb</td>
</tr>
<tr>
<td>avg</td>
<td>2.457</td>
<td>2.369</td>
</tr>
<tr>
<td>stdev</td>
<td>0.0123</td>
<td>0.0106</td>
</tr>
<tr>
<td>F-test</td>
<td>0.2064</td>
<td>0.1477</td>
</tr>
<tr>
<td>between QC AND QA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>OK</td>
<td>OK</td>
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*Must be completed before QA discards back-up samples*
Low Temperature Cracking Resistance

- Disc-Shaped Compact Tension (DCT) test
- Semi-Circular Bend (SCB) Test
Recertification Exam

- The Exam is open book/notes
- A score of 70% or better is required to pass the exam.