Verification of Gyration Levels in the Superpave $N_{\text{design}}$ Table

NCHRP 9-9(1)

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The compaction effort used in a volumetric mix design should produce laboratory samples which approximate the ultimate density of the pavement.

The goal of this project is to verify the laboratory compaction efforts established in 1999 for the Superpave gyratory compactor.
Overview

- NCAT Test Track
- NCHRP 9-9(1) Field Test Sections
- Affect of Internal Angle of Gyration
- Conclusions
# Original SGC Compaction Effort

<table>
<thead>
<tr>
<th>Design ESALs (millions)</th>
<th>&lt;39 °C</th>
<th>39 - 40 °C</th>
<th>41 - 42 °C</th>
<th>43 - 44 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N&lt;sub&gt;ini&lt;/sub&gt;</td>
<td>N&lt;sub&gt;des&lt;/sub&gt;</td>
<td>N&lt;sub&gt;max&lt;/sub&gt;</td>
<td>N&lt;sub&gt;ini&lt;/sub&gt;</td>
</tr>
<tr>
<td>&lt; 0.3</td>
<td>7</td>
<td>68</td>
<td>104</td>
<td>7</td>
</tr>
<tr>
<td>0.3 - 1</td>
<td>7</td>
<td>76</td>
<td>117</td>
<td>7</td>
</tr>
<tr>
<td>1 - 3</td>
<td>7</td>
<td>86</td>
<td>134</td>
<td>8</td>
</tr>
<tr>
<td>3 - 10</td>
<td>8</td>
<td>96</td>
<td>152</td>
<td>8</td>
</tr>
<tr>
<td>10 - 30</td>
<td>8</td>
<td>109</td>
<td>174</td>
<td>9</td>
</tr>
<tr>
<td>30 - 100</td>
<td>9</td>
<td>126</td>
<td>204</td>
<td>9</td>
</tr>
<tr>
<td>&gt; 100</td>
<td>9</td>
<td>143</td>
<td>233</td>
<td>10</td>
</tr>
<tr>
<td></td>
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</tr>
</tbody>
</table>
National Efforts to Address $N_{\text{design}}$

- **Asphalt Institute** - $N_{\text{design}}$ II Experiment
  - Examined field densification of SPS-9 pavements
  - Looked at mixture stiffness ($G^*$) with SST

- **NCAT** - NCHRP 9-9 Evaluation of the SGC Procedure
  - Looked at sensitivity of mix volumetrics to changes in $N_{\text{design}}$

- **A new** $N_{\text{design}}$ **Table was developed from each effort**
<table>
<thead>
<tr>
<th>ESAL’s</th>
<th>$N_{\text{ini}}$</th>
<th>$N_{\text{des}}$</th>
<th>$N_{\text{max}}$</th>
<th>App</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>6</td>
<td>50</td>
<td>75</td>
<td>Light</td>
</tr>
<tr>
<td>0.3 to &lt; 3</td>
<td>7</td>
<td>75</td>
<td>115</td>
<td>Medium</td>
</tr>
<tr>
<td>3 to &lt; 30</td>
<td>8</td>
<td>100*</td>
<td>160</td>
<td>High</td>
</tr>
<tr>
<td>10 to &lt; 30</td>
<td>8</td>
<td>100</td>
<td>160</td>
<td>High</td>
</tr>
<tr>
<td>≥ 30</td>
<td>9</td>
<td>125</td>
<td>205</td>
<td>Heavy</td>
</tr>
</tbody>
</table>

Base mix ($< 100 \text{mm}$) option to drop one level, unless the mix will be exposed to traffic during construction.
Thoughts on $N_{\text{design}}$

- Laboratory compaction effort should produce sample density approximately equal to ultimate pavement density.
- Ultimate pavement density believed to be reached after 2-3 years of traffic.
- Typically, select laboratory density of 96% of Theoretical maximum density or 4% air voids.
  - Too little air voids (<2%) results in rutting.
  - Too many air voids tend to cause durability problems.
NCAT Test Track
NCAT Test Track Average Densification

PG 67-22 Upper Lift $R^2 = 0.98$
PG 67-22 Lower Lift $R^2 = 0.96$
PG 76-22 Lower Lift $R^2 = 0.99$
PG 76-22 Upper Lift $R^2 = 0.98$

Winter 2001-2002

Pavement Density, % Gmm

ESALs

PG 67-22 Lower Lift
PG 76-22 Lower Lift
PG 67-22 Upper Lift
PG 76-22 Upper Lift
NCAT Test Track - Design Gyrations to Meet Pavement Density

PG 67-22 Upper Lift $R^2 = 0.97$

PG 67-22 Lower Lift $R^2 = 0.87$

PG 76-22 Lower Lift $R^2 = 0.95$

PG 76-22 Upper Lift $R^2 = 0.94$

Note: Samples compacted on Troxler Compactor

Winter 2001-2002
The Whole Truth – Predicted Gyrations to Match Test Track Density

\[ R^2 = 0.1944 \]

\[ R^2 = 0.5689 \]

ESALs

PG 67-22
PG 76-22

PG 67-22 Upper Lift
PG 76-22 Upper Lift
Predicted Gyrations after 8.5 million ESALs

70% of sections predicted less than 100 gyrations
Summary

- Test Track Data Indicates:
  - Modified binders densify less than unmodified binders
  - This may mean that mixes containing modified binders may be designed at lower gyrations or higher asphalt contents to enhance durability
  - Aggregate type, binder grade, nominal maximum aggregate size and gradation all affect predicted Ndesign values
NCHRP 9-9(1)
Field Projects

Verification of $N_{design}$ Table
Experimental Plan

• Sample 40 pavements at the time of construction with a range of:
  – Lift Thickness to NMAS (2-4)
  – Design Gyration Level (50-125)
  – Binder Grade (Normal to +2 bumps)
  – Gradation (Fine or Coarse)
Experimental Plan

- Plant mix taken at time of construction, compacted to 100 and 160 gyrations in three SGCs:
  - Baby Pine (AFG1A)
  - Small Troxler (4141)
  - Brovold/Test Quip
    - Used in 2001 only
    - Data not yet reduced
Experimental Plan

- Roadway cores taken at construction, 3 months, 6 months, 1 year and 2 years after construction from right wheel path
- Goal: predict gyrations to match ultimate field density
Summary of Projects with Two Years of Traffic
Comparison of One and Two Years Traffic

Predicted Gyrations to Match Field Density

ESALs

- Pine One Year
- Troxler One Year
- Pine Two Year
- Troxler Two Year

\[ R^2 = 0.3434 \]
\[ R^2 = 0.3292 \]
\[ R^2 = 0.3446 \]
\[ R^2 = 0.366 \]
Comparison of SGC and Field Air Voids

\[ y = 1.252x + 1.4732 \]
\[ R^2 = 0.416 \]

\[ y = 0.8941x + 1.586 \]
\[ R^2 = 0.3609 \]
Design Vs Predicted Gyrations

$R^2 = 0.2269$

$R^2 = 0.1911$

Predicted Gyrations to Match Field Density at 2 Years

- **Brand 1 SGC**
- **Brand 2 SGC**

Linear (Brand 1 SGC)
Linear (Brand 2 SGC)

Line of Equality
Performance Overview
NCHRP 9-9(1)
Two-Year Sections
Summary of Two-Year Performance of NCHRP 9-9(1) Projects

- Rutting generally non-existent. One project with approximately 0.25 inch
- Minor ravelling common
- Several overlays over PCC have evidence of reflective cracking, even when total (new) overlay 3.5 inches or more
- Some permeability evidenced by wet spots