State Highway Agency (SHA)
Density Specification
Data Mining

FHWA Co-op Task 2.15 State Density Maps
Background

Goals of data mining – how to SHA’s specify mat density:

• **Methods** of measure
  - Cores, gage, roller pattern

• **Baseline** measure
  - Max. Theoretical Gravity ($G_{mm}$), lab bulk sample ($G_{mb}$), control strip

• **Sampling**
  - Lot/sublot size and how averaged

• **Spec type**
  - PWL, other advanced statistics, simple average

• **Specification limits**

• Is there a compaction **incentive**?
The Process

• Asphalt Institute Regional Engineers gathered information from latest SHA specifications and direct agency contacts

• Data was sent to Phil Blankenship, AI Sr. Research Engineer to compile and review

• Data was reviewed with specs as much as possible
  o Since some specs leave some interpretation, there may be some mistakes.

• What we looked at:
  o Focus was on a high-level review of specifications to gather density requirements for SHA highest level compaction standard (interstate / primary route pavements)
The Process

• Sampling size refers to subplot since it is the most frequent sampling
  o Lot sizes were captured too

• Density limits were on acceptance of samples or QA
  o How low before pay is reduced below 100%?

• Minimum density acceptance
  o Some SHA’s specify a minimum or lowest density for 100% acceptance based on a simple average
  o Others referenced PLW or advanced statistics
    • If only PWL, the lower limit of the PWL was assumed to be lowest level for 100% acceptance.
    • When specifying PWL the minimum is usually about 1-1.5% about the lowest specified value.
Compaction Acceptance:

The compaction **lot pay factor** shall be the compaction pay factor determined as set forth in Subsection 417-7.05(B).

**Twenty paired cores** taken per lot, with ten tested (Gmb) and ten saved (in case of dispute; tested by an independent lab, selected by the DOT).

Target Value (TV) for compaction is \( Pa = 7.0\% \) (in-place Air Voids). **UL is 9.0\%** (or 91\% of \( G_{mm} \)) and LL is 4.0\%. (LL changed to 3.5\%).

The Engineer will determine the Total Percent within Limits (PT) for compaction in accordance with Subsection 406-9(I) and Table 406-1 to determine the compaction pay factor.

**PT Determination:**

The PT is calculated by statistics; using UL and LL, to determine a **two-sided “PWL”** (see Subsection 109.11).

**Pay Factors:**

If PT is 100, then Contractor gets +$1.00 per ton pay factor. (this is a bonus)

If PT is 89 or less there is a sliding scale pay reduction (for compaction down to -$3.00 per ton).

If PT is less than 50, rejection per Subsection 417-9(E). [Max negative pay for compaction is $5.]

[These have changed to different dollar figures].
The Good, Bad and Ugly

• Critical information was usually difficult to interpret or find. Seems to be known or understood locally.
  
  o “460.3.3.2 Pavement Density Determination. The engineer will determine the target maximum density using department procedures described in CMM 8-15. The engineer will determine density as soon as practicable after compaction and before placement of subsequent layers or before opening to traffic...”

  • The additional documents are not always easy to access. I created an account on one site and then it was going to cost to download.

  o Some specs had the critical information of Gmm, lots, density spread over many pages or books.

  o Some did not address when the Gmm is measured
    • It is probably assumed to be daily
The Good, Bad and Ugly

• EASY and to the POINT

  o “Five randomly selected cores (4” min./ 6” max. diameter), from the travel lane, will be tested to determine density compliance and acceptance. One core shall be taken from each subplot. The Bulk Specific Gravity ($G_{mb}$) of the cores shall be determined as stated above and the average calculated. The maximum theoretical gravity ($G_{mm}$) from acceptance testing for that shift’s production will be averaged and the percent density will be determined for compliance by dividing the $G_{mb}$ average by the $G_{mm}$ average.”

• Most everything you need about density in one paragraph!
Baseline for Density Acceptance

Baseline Used to Calculate Acceptance Criteria

- Plant Mixed, Control Strip Gmb: 1
- Field Lab Compacted Gmb: 1
- Design Gmm: 0
- Field Gmm: 49

Number of State Highway Agencies
Density Acceptance Methods

Acceptance Methods Used to Measure Density

- Core or Density Gage: 5
- Density Gage: 8
- Core: 38

Number of State Highway Agencies
How Is Acceptance Determined?

- Simple averaging: 23
- Other advanced statistics such as AAD: 4
- PWL: 24

Number of State Highway Agencies
PWL or Simple Average

Acceptance Determination

Compaction Study

Data: SHA Specifications. Source: Asphalt Institute-FHWA Co-op
Lowest Specification Density
Simple Average

Lowest Specification Density for 100% Pay
- Simple Average -

Number of State Highway Agencies

0  2  0  4  0  13  2  3  0  0  0  0
less than 90.0 90.0 - 90.4 90.5 - 90.9 91.0 - 91.4 91.5 - 91.9 92.0 - 92.4 92.5 - 92.9 93.0 - 93.4 93.5 - 93.9 94.0 - 94.4 greater than 95.0
PWL Lower Limit for 100% Pay

Number of State Highway Agencies

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<th>PWL Range</th>
<th>Count</th>
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<tr>
<td>greater than 95.0</td>
<td>0</td>
</tr>
</tbody>
</table>
Simple Average Specs

Lowest Specification Density by Simple Average (Lower Limit)

Compaction Study

Lower Limit

89.0%
89.5%
90.0%
90.5%
91.0%
91.5%
92.0%
92.5%
93.0%
93.5%

Data: SHA Specifications. Source: Asphalt Institute-FHWA Co-op
Compaction Incentive

Is There an Incentive (bonus) for Compaction?

- Yes: 35
- No: 16

Number of State Highway Agencies
Compaction Incentive

Incentive (Bonus) for Compaction

Compaction Study

Data: SHA Specifications. Source: Asphalt Institute-FHWA Co-op
How Much?

Maximum Incentive (%) for Compaction

Compaction Study

[Map of the United States showing different states with varying shades indicating the maximum incentive for compaction.]

Percent Bonus

0% 1% 2% 3% 4% 5% 6% 7% 8% 9% 10%

Data: SHA Specifications. Source: Asphalt Institute-FHWA Co-op
• $G_{mm}$ is the majority acceptance of the density baseline

• Cores are the majority for acceptance of pavement density

• About an equal split of states who use PWL and Simple Average method for acceptance
  o PLW seems to have scare that goes along with it...can I really understand this?

• 92% of Gmm is the majority target for states using a simple average
  o Same is true for PWL states but realize that PWL minimum is not a “real minimum”. The target minimum is about 1-1.5% above.

• Most states offer a compaction incentive
Broad Observations

• Most who do not offer an incentive are the Simple Average states
  o 13 out of 16 non-incentive states are Simple Average.

• Neighboring states tend to match specs and incentives

• Some specification were very difficult to understand.
  o What is the baseline measure from? Field or lab
  o How often is G_{mm} measured? Average, daily
  o Information was spread over several specification sections or multiple inspector books.

• Usually 2-3 levels of compaction including roller pattern and non-inspection.
  o We reported the highest level only
Broad Observations

• Some base specifications allow lower densities
  o Superpave memo from ~1994 recommended to use 1 less gyration level to allow for more compaction for layers <4” from the surface

• Several specifications allow for > 4% air voids design (~4.3 to 4.5%) or field adjustments up to 5% air voids.
  o Making field density at 3-4x NMAS even more difficult to achieve