Greetings from the Central Rockies
Density of Asphalt Pavements: How to Specify and Measure to Ensure Pavement Performance

NCHRP Report 856
by
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NCHRP Study Objectives

- Collect information on current practices
- Evaluate how density is measured and specified

Through
- Literature Search
- Technical Survey
Report Topics

- General Issues in Density of Asphalt Pavements
- Specification Types for Control of Density
- Density Measurements Techniques
- Construction Parameters Affecting Density
- Longitudinal Joint Construction
- Emerging Technologies in Determination of In-Place Density
Pavement Life

- 10 percent decrease in pavement life for each 1 percent increase in air voids

- Multiple researchers have confirmed
Cost and Performance

- Cost of Aggregate and Binder are significantly higher than cost of compaction

BUT

- Effect of achieving density is equal in importance to aggregate and binder in terms of pavement performance.
Definitions

- **Density** – weight per unit volume
- **Compaction** – process of increasing density of mix through paving and rolling operations
- **Reference Density** – value to which in-place density is compared
- **Percent Density** – percentage of reference density achieved during compaction process
Project Survey

- State DOT’s
  - Materials
  - Construction

- NAPA Membership

- Ministries of Transport Canada

- International Pavement Associations

100 Responses (50 DOT’s plus DCDOT)

Thanks to all who participated!
General Issues in Density of Asphalt Pavements
Factors Affecting Density

- Materials
- Initial Density
- Traffic
Issues Related to Density

- Roller Operations  5.45
- Mix Design          5.17
- Binder Content      5.06
- Aggregate Properties 3.44
- Paver Operations    3.22
- Environmental Factors 2.87
- Binder Stiffness    2.83
Weaknesses

- Trained Operators 78.8
- Adequate Quality Personnel 46.5
- Method of Density Measurement 45.5
- Density Measurement Equipment 33.3
- Other 28.3
- Compaction Equipment 27.3
- Laydown Equipment 15.2
Weaknesses

“Other” included:
- Effect of underlying layers
- Unplanned schedule interruptions
  - Accidents, weather, breakdowns, etc.
- Low bid contract environment encouraging low binder content
- Specifications requiring overly stiff and dry mixes
Problem Getting Density?

- Most respondents said they generally don’t have a problem achieving density.
  - Comments were that density may be marginal.
  - Some contractors using asphalt content to adjust density.

Most believe their density spec is adequate.
Under/Over Compaction?

- 98% believe under compaction is a problem
- Only 64% believe over compaction is a problem
- Literature recommends both an upper and lower specification limit for density
Specification
Types for Control of Density
Density Specification

- All have a density specification
- 60% waive for thin lift application
- 80% have end-result specification
  - Pay factor range from 25-50%
    - 90% between 35 and 50%
    - 70% between 40 and 50%
- 75% both incentive and disincentive
- 12 agencies use disincentive only
Reference Density

- Use of Gmm widely recommended in literature
- Recommended to be based on plant produced mix
- 92% use Gmm
- Only 74% from plant produced mix
Where is Gmm sample taken?

- Truck at plant: 42.7
- Uncompacted behind paver: 39.3
- At plant discharge: 12.4
- Truck at paver: 5.6

- Some are not following AASHTO/ASTM requirements for sampling location
Frequency of Gmm Test

- Brown/Cominsky: Routinely test/every sample
- 67% test on every sample
- 88% either every sample or daily
- Some rarely test (or never)
Density Measurements Techniques
Quality

- Quality cannot be tested or inspected into the mix; it must be “built in”.

  - Cominsky 1998
# Density Measurement

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<tr>
<th>Tool</th>
<th>Quality Control</th>
<th>Acceptance</th>
<th># Agencies</th>
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<tbody>
<tr>
<td></td>
<td>Allowed</td>
<td>Commonly Used</td>
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<tr>
<td>Cores</td>
<td>75</td>
<td>46</td>
<td>87</td>
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<tr>
<td>Nuclear</td>
<td>80</td>
<td>71</td>
<td>33</td>
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<tr>
<td>Thin Lift</td>
<td>58</td>
<td>42</td>
<td>22</td>
</tr>
<tr>
<td>Electro-magnetic</td>
<td>48</td>
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<td>12</td>
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Core Drying

- Literature recommends vacuum drying to achieve most accurate measurement of Gmb
- 70% use oven drying
- 44% use vacuum drying
Core Absorption

- 18% have a limiting value of 1%
- 30% have a limiting value of 2%
- 15% use dry back procedure
- 21% have no absorption evaluation

- Absorption testing not commonly done
- May create problems in volumetric control of mix
NDT Gauges

- **Nuclear:** Calibration, Standardization, and Correlation
- **Electromagnetic:** Standardization and Correlation

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- **16% don’t correlate gauge to cores!**
Construction Parameters Affecting Density
# Vibrating Screed

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<td>39.4</td>
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<tr>
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## Roller Types

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<th>Percentage Responses</th>
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<td></td>
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<tr>
<td>Breakdown</td>
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<tr>
<td>Intermediate</td>
<td>65.2</td>
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<tr>
<td>Finish</td>
<td>23.3</td>
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</table>
Compaction Additives

- WMA the primary additive
- 2016: 1/3 of total market*
- 75% of WMA is foaming*
- 82% use additives to enhance density achieved
- WMA often used at hot mix temperatures

* From NAPA
Paver Operations

- 88% said paver speed was 20-40fpm
- Europe: 10-15fpm
- Interesting to note that comments indicated that slower speed was used for PWL job
- 72% think a slower speed would improve density
- Same percentage said there shouldn’t be a max speed specification
Longitudinal Joint Construction
Longitudinal Joints

- AI Study
  - One of the highest reasons for premature failure of pavement
  - Overband or joint sealer if density is less than 92% of Gmm

- 41% have specification
- 44% don’t
- Many are considering specification
Longitudinal Joints

- 52% minimum density of 90%
  - Remaining are divided +/-
- Within 2% of mainline is common
- 41% use both incentive and disincentive
- 20% disincentive only
- Decision to use:
  - 33% Agency specification writer
  - 36% in standard specifications
Emerging Technologies in Determination of In-Place Density
Emerging Technologies

- IC is the main density related issue
- Two elements:
  - Density Control
  - Roller Management
- Research to date has shown that density control is not reliable in determination of density
- Tamping bar screed not widely used
Recommendations

- QC/QA activities should be uniformly performed
- Training for all personnel is key
- Frequency of testing is highly variable
- Density testing should be performed for all projects
- Both a minimum and maximum density should be specified
Recommendations

- Absorption evaluation of all cores should be performed
- Testing for Gmm should be performed during plant production of mix
- Standard procedures for NDT should be followed
- Ensure adequate testing is performed
Recommendations

- Consider requiring a vacuum drying procedure
- Roller management should be used to ensure consistency of roller patterns
- Consider requiring joint sealer for all longitudinal joints
Thank You!

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