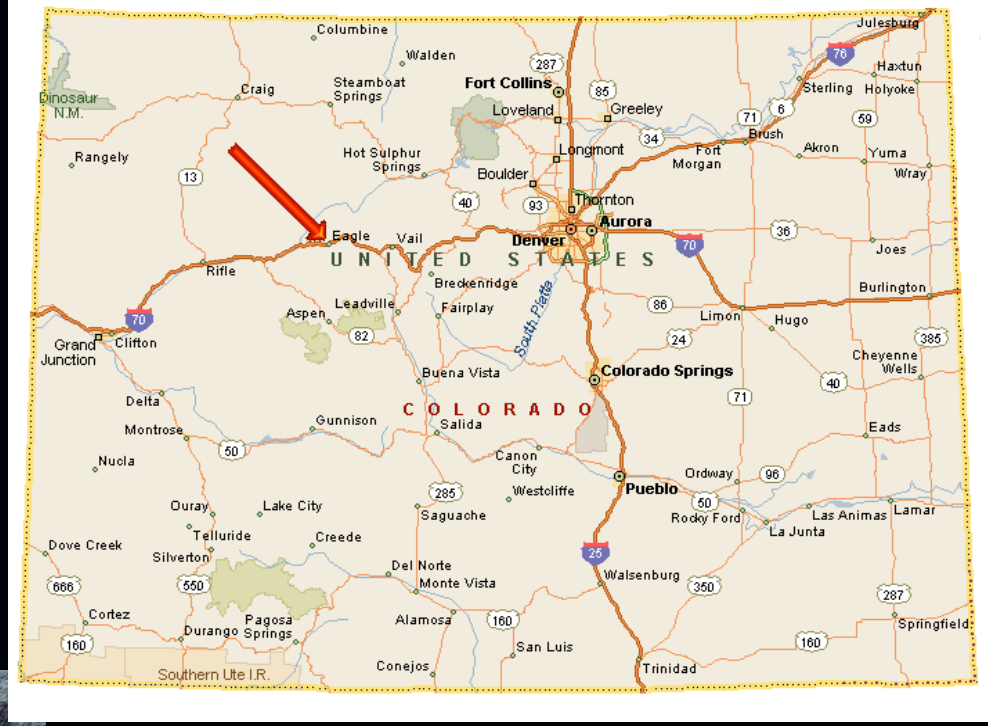
Greetings from the Central Rockies



Density of Asphalt Pavements: How to Specify and Measure to Ensure Pavement Performance

NCHRP Report 856

by

Dale S. Decker, P.E.

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 M
- S
- M
- In avement Associations

Thanks to all who participated!

100 Responses (50 DOT's plus DCDOT)

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

Tool	Quality Control		Acceptance		# Agencies
	Allowed	Commonly Used	Allowed	Commonly Used	
Cores	75	46	87	78	51
Nuclear	80	71	33	32	20
Thin Lift	58	42	22	20	13
Electro-magnetic	48	38	12	6	5

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**

Procedure	% Responses
Calibration	53.5
Standardization	40.0
Correlation	83.5

- **16% don't correlate gauge to cores!**

Construction Parameters Affecting Density

Vibrating Screed

Response	Percent Responses	
	Required	Used
Yes	39.4	51.0
No	50.5	30.6

Roller Types

Position	Percentage Responses				
	DDV	PTR	DDS	TWR	OSC
Breakdown	93.5	12.0	14.1	6.5	23.9
Intermediate	65.2	57.3	25.8	4.5	21.4
Finish	23.3	6.7	84.4	6.7	16.7

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!

Dale S. Decker, P.E.

Eagle, CO