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

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Acknowledgement

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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

Original SGC Compaction Effort

Design ESALs (millions)	Average Design High Air Temperature <39 °C			39 - 40 °C			41 - 42 °C			43 - 44 °C		
	N_{ini}	N_{des}	N_{max}	N_{ini}	N_{des}	N_{max}	N_{ini}	N_{des}	N_{max}	N_{ini}	N_{des}	N_{max}
< 0.3	7	68	104	7	74	114	7	78	121	7	82	127
0.3 - 1	7	76	117	7	83	129	7	88	138	8	93	146
1 - 3	7	86	134	8	95	150	8	100	158	8	105	167
3 - 10	8	96	152	8	106	169	8	113	181	9	119	192
10 - 30	8	109	174	9	121	195	9	128	208	9	135	220
30 - 100	9	126	204	9	139	228	9	146	240	10	153	253
> 100	9	143	233	10	158	262	10	165	275	10	172	288

SGC Compaction Effort 1999

ESAL's	N ini	N des	N max	App
< 0.3	6	50	75	Light
0.3 to < 3	7	75	115	Medium
3 to < 30	8	100*	160	High
10 to <30	8	100	160	High
≥ 30	9	125	205	Heavy

Base mix *(< 100 mm)* option to drop one level, unless the mix will be exposed to traffic during construction.

Thoughts on N_{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

NCHRP 9-9(1) Field Projects

Verification of N_{design} Table

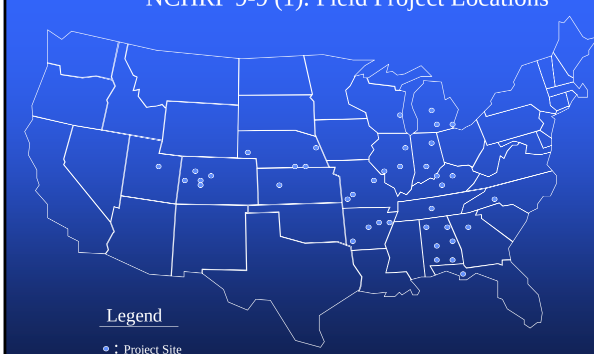
Experimental Plan

- 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)

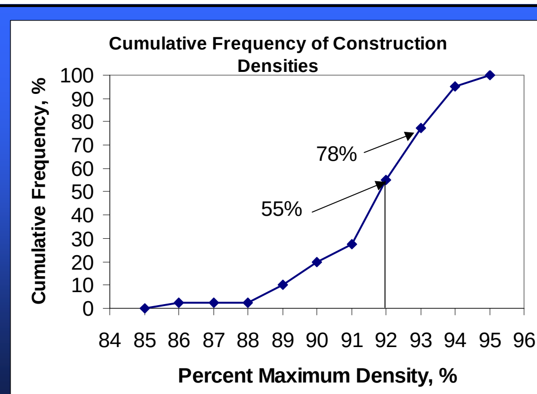
Experimental Plan

- Roadway cores taken at construction, 3 months, 6 months, 1 year, and 2 years after construction from right wheel path
- Project extended to monitor projects 4 years after construction
- Goal: predict gyrations to match field density

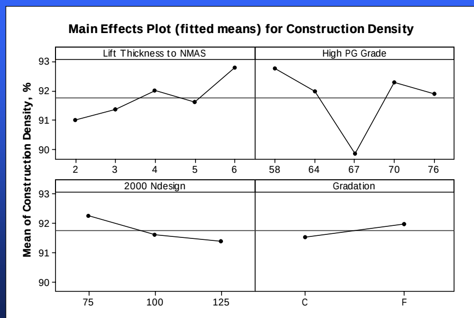
NCHRP 9-9 (1): Field Project Locations



Pavement Densification

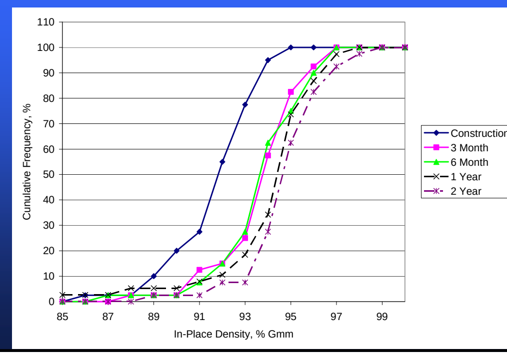


Factor Affecting As-Constructed Density

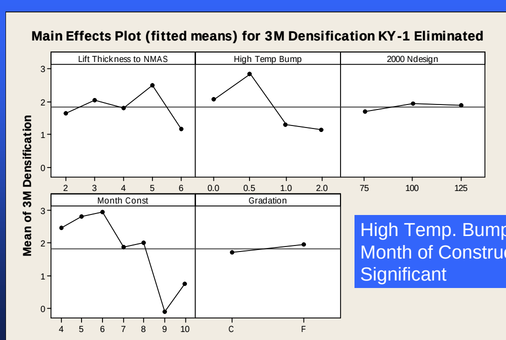


Agency was the only significant factor

Pavement Densification

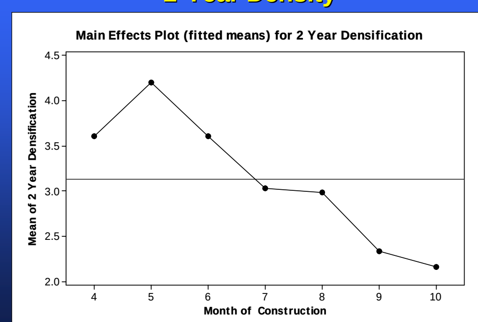


Factors Affecting 3-Month Densification



High Temp. Bump and Month of Construction Significant

Affect of Month of Construction on 2-Year Density



Ultimate Density

- 4-year density less than 2-year density in 15 of 35 cases
- Paired t-test significantly different in 8 cases, 4-year density higher in 6 of 8 cases
- Population t-test significantly different in one case, density lower
- Ultimate density reached after 2-years

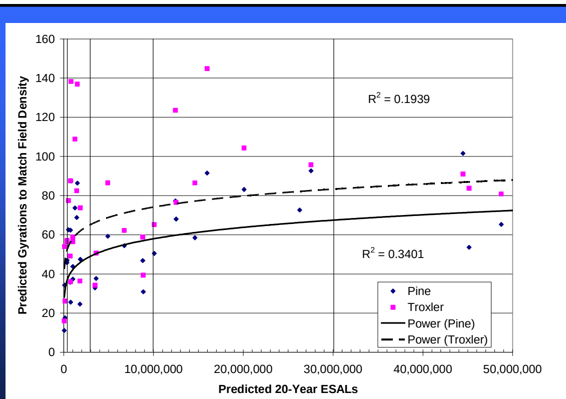
Summary of Performance of NCHRP 9-9(1) Projects

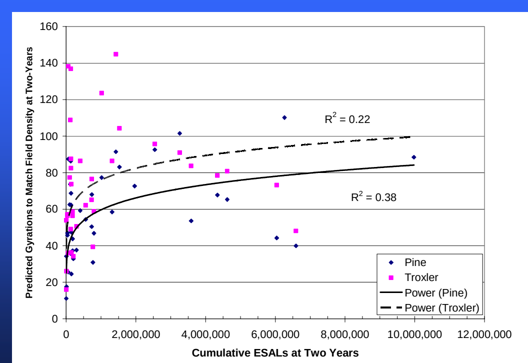
- Average rut depth 1.7 mm, one project with 6.4 mm (high traffic unmodified)
- Raveling common
- Overlays over PCC evidence reflective cracking, even when total (new) overlay 3.5 inches or more, most after 2-years
- Joints vary from fair to very good
- Some permeability evidenced by wet spots

N_{design} versus In-place Density

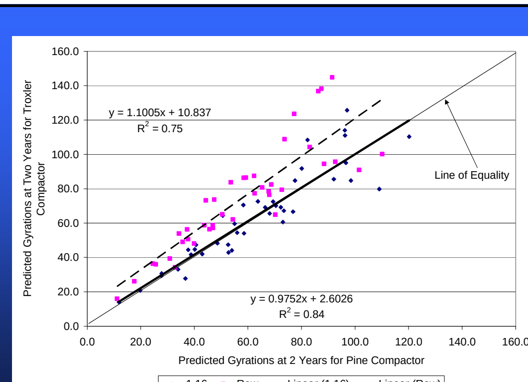
Estimation of Density at a Given Gyration Level

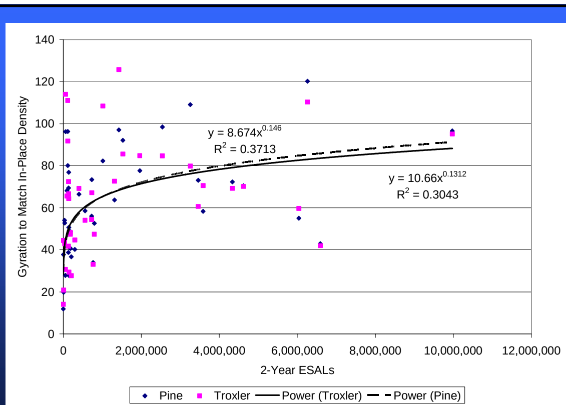
$$\text{Density at Gyration } X = \text{Density at NDesign} \times \frac{\text{Height at NDesign}}{\text{Height at Gyration } X}$$



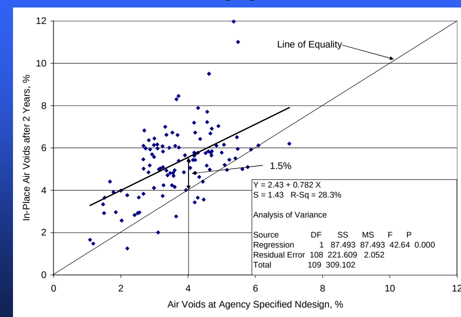


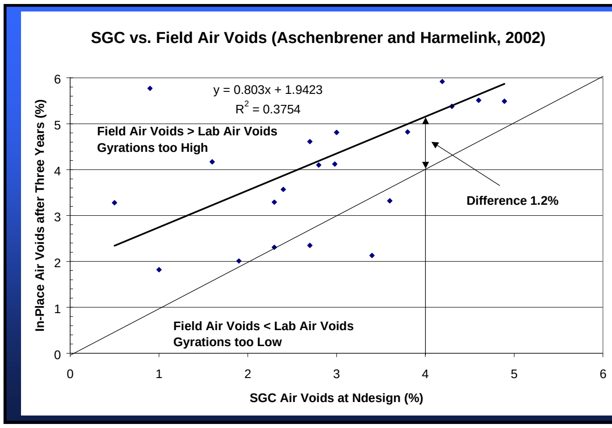
Dynamic Angle Verification Kit





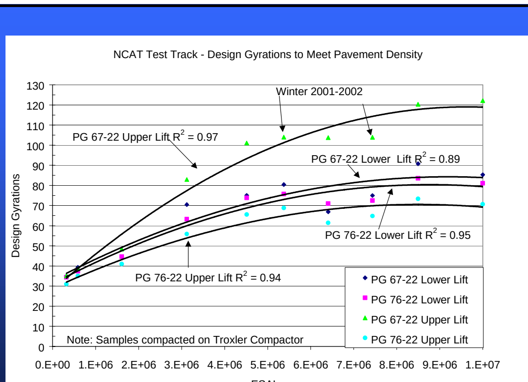
NCHRP 9-9 (1) Field Data



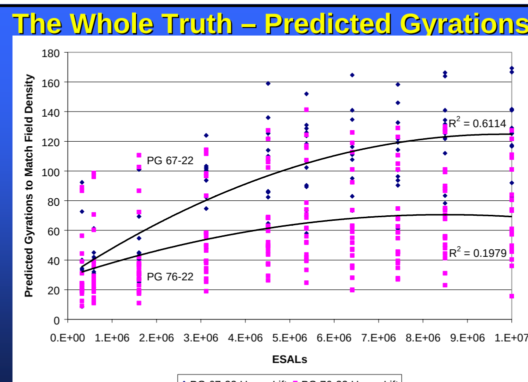


CO Density Study Conclusions Aschenbrener and Harmelink, 2002

- Mixes have not reached their design level of compaction after six years
- Six-year trend indicates they never will
- Majority of the densification occurred in the first three years
- Based on data from these 25 sections, the optimal number of gyrations is too high – mixes too stiff for climate and traffic



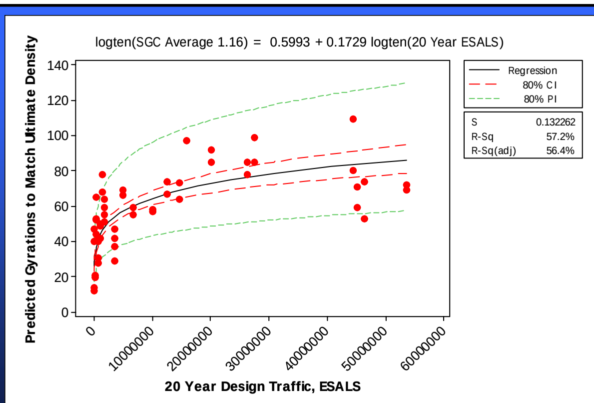
The Whole Truth – Predicted Gyrations



Summary of Pavement Densification at 2000 Track

- After initial consolidation/aggregate reorientation, densification only occurred when temperature above 28° C (82 °F)
- Mixes containing modified (PG 76-22) binders densified significantly less than unmodified (PG 67-22) binders (2%)
- Unmodified lower lift shows less densification (0.8%) – future trend unclear

Would NCHRP 9-9(1) relationships improve without PG 76-22?



Predicted Gyrations to Match Ultimate Density

20 Year Design ESAL	Current Ndesign	Predicted Ndesign	80 % Prediction Interval		80th Percentile		
			Low	High	Pine	Troxler	Avg.
300000	50	35	23	53	32	43	37
1000000	75	43	29	65	71	73	72
3000000	100	52	35	78	83	90	87
10000000	100	65	43	96	59	55	57
30000000	125	78	52	117	95	104	100
100000000	125	96	64	145	101	82	92

Proposed Ndesign Levels for an SGC DIA of 1.16 ± 0.02 Degrees

20-Year Design Traffic, ESALs	2-Year Design Traffic, ESALs	Ndesign
< 300,000	< 20,000	50
300,000 to 3,000,000	20,000 to 200,000	65
3,000,000 to 10,000,000	200,000 to 675,000	65
10,000,000 to 30,000,000	675,000 to 2,000,000	80
> 30,000,000	> 2,000,000	100

Locking Point

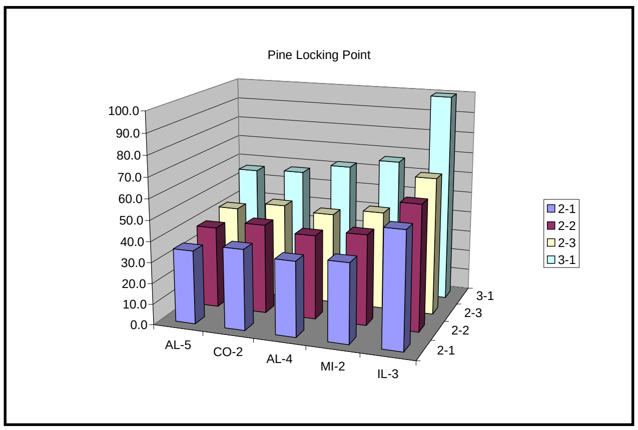
Locking Point

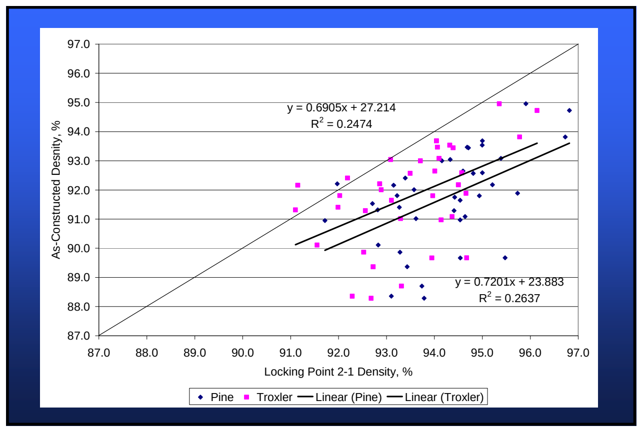
- Concept developed by Illinois DOT (Bill Pine)
- Plot of Log gyrations vs. density non-linear beyond locking point
- Point where aggregate locks together – additional gyrations degrade aggregate
- Point after which change rule 25 gyrations = 1% VMA = 0.4 AC% generally true

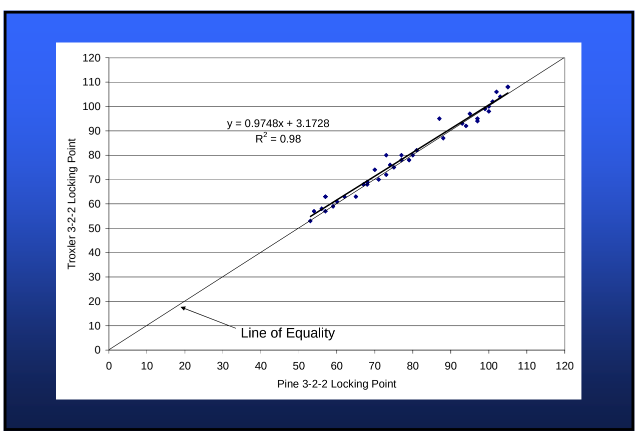
Definition of Locking Point

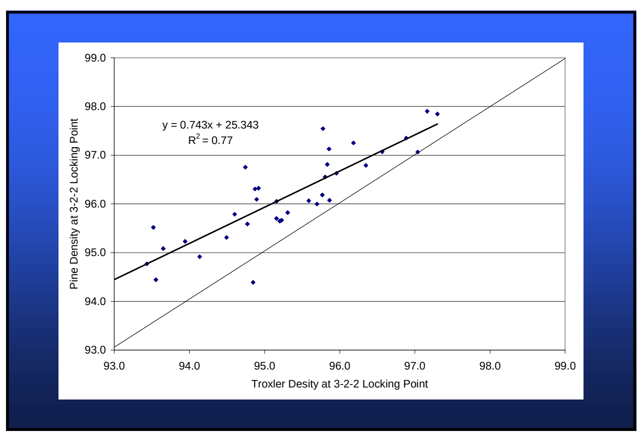
	1	2	3	4	5	6	7	8	9	10
60	111.9	111.9	111.8	111.8	111.7	111.7	111.6	111.6	111.5	111.5
70	111.4	111.4	111.3	111.3	111.2	111.2	111.2	111.1	111.1	111.0
80	111.0	110.9	110.9	110.8	110.8	110.8	110.7	110.7	110.7	110.6

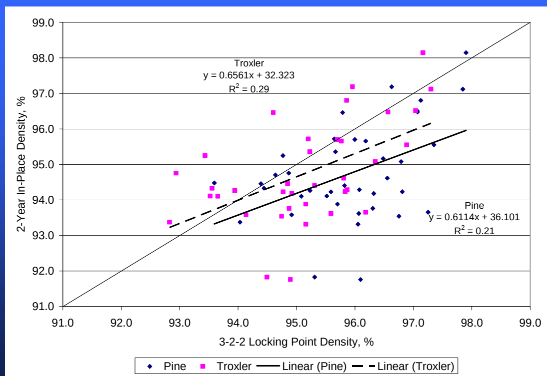
Locking Point











Mix Design requires a balance between *Rut Resistance* and *Durability*

Typically, we design for *Rut Resistance*

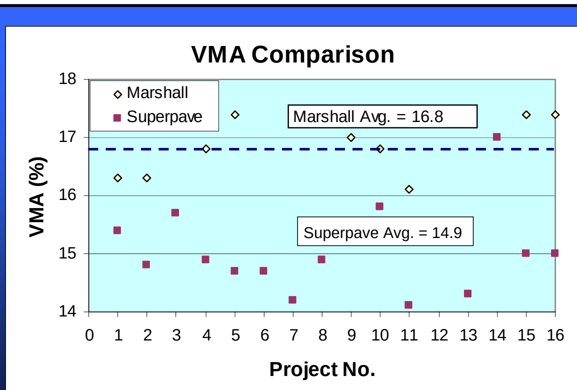
What Does This Mean for Mix Design?

- Test Track Data Indicates:
  - Modified binders densify less than unmodified binders
  - This may mean that mixes containing modified binders maybe designed at lower gyrations or higher asphalt contents to enhance durability

This may be a way to balance rut resistance and durability!

What Effect Would Lower Gyrations Have?

- Increase design asphalt content?
  - Not necessarily
  - Contractors tend to design mixes with lower laboratory compaction efforts with more of a “cushion” between design and minimum VMA
  - Could raise minimum VMA by 0.5%
- Should allow more compactable mixes (in field) and increase AC% slightly



Other Thoughts on Increasing AC%

- In-place density has a large effect on performance
- Lower design air voids
  - If design VMA above minimum VMA contractor may add more dust
- Raise minimum VMA
  - Increase in minimum VMA will increase AC%
  - If minimum VMA increased without changing gyration levels, then mix may be harder to compact
- It’s a system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Questions?