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

NEAUPG

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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

- Background of N_{design}
- NCAT Test Track
- NCHRP 9-9(1) Field Test Sections
- Affect of Internal Angle of Gyration
- Conclusions

SHRP N_{design} Experiment

- Looked at three traffic levels and three climates, two replicates for each except “hot” climate (nine cells)
- Sites selected from LTPP GPS pavement sites 12 years old or older - reached “design” air voids of 3% - 5%
- Construction air voids assumed to be 8%

SHRP N_{design} Experiment Cont.

- Fifteen 12 inch diameter cores were taken, one from each project.
  - Asphalt was extracted
  - Recovered aggregate re-mixed with virgin AC-20
  - Aged for four hours
  - Compacted to 230 gyrations (design levels were back calculated).

Original SGC Compaction Effort

Design ESALs (millions)	Average Design High Air Temperature											
	<39 ºC			39 - 40 ºC			41 - 42 ºC			43 - 44 ºC		
	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

National Efforts to Address N_{design}

- Asphalt Institute - N_{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_{design}
- A new N_{design} Table was developed from each effort

SGC Compaction Effort 1999

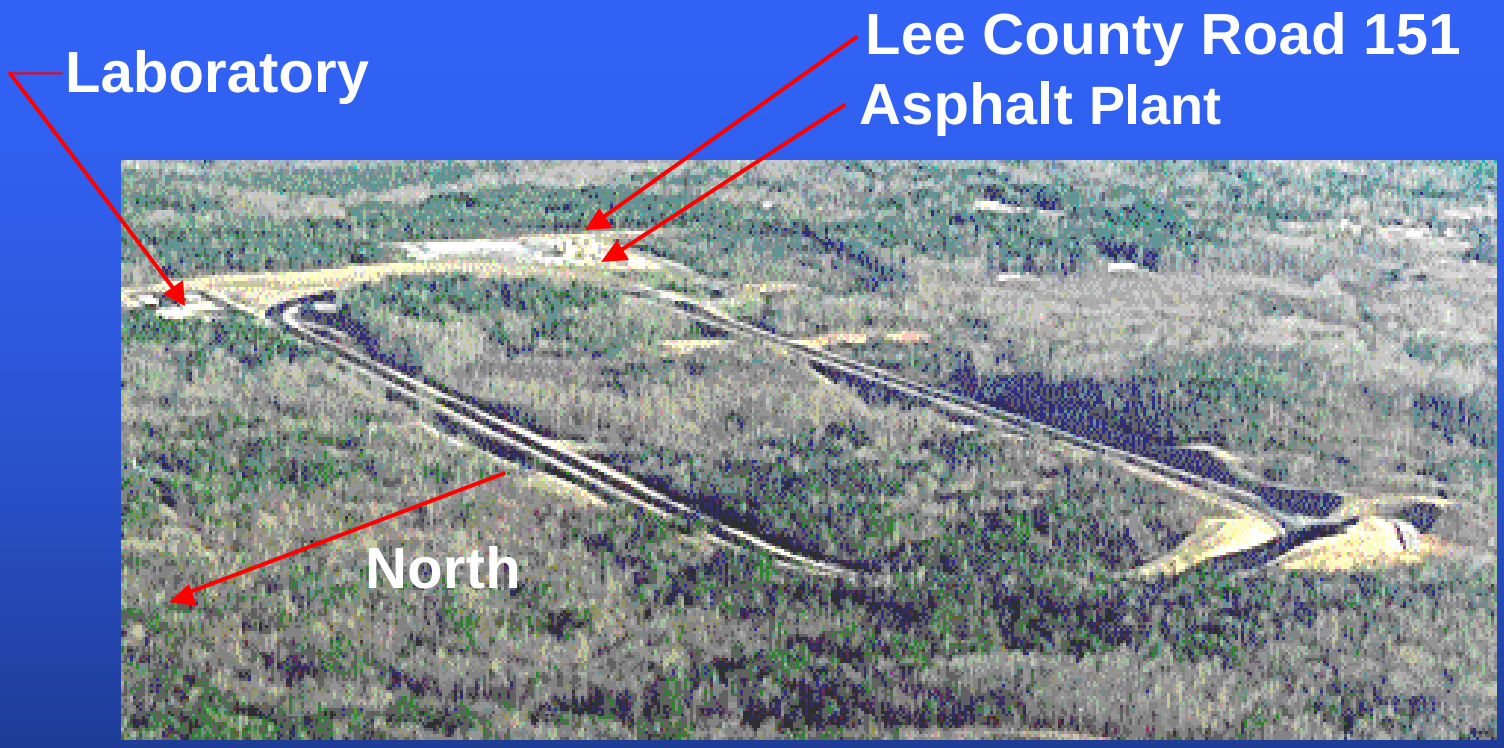
ESAL's	N_{ini}	N_{des}	N_{max}	App
< 0.3	6	50	75	Light
0.3 to < 3	7	75	115	Medium
3 to < 30	8	100*	160	High
10 to <30	8	100	160	High
≥ 30	9	125	205	Heavy

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

Thoughts on N_{design}

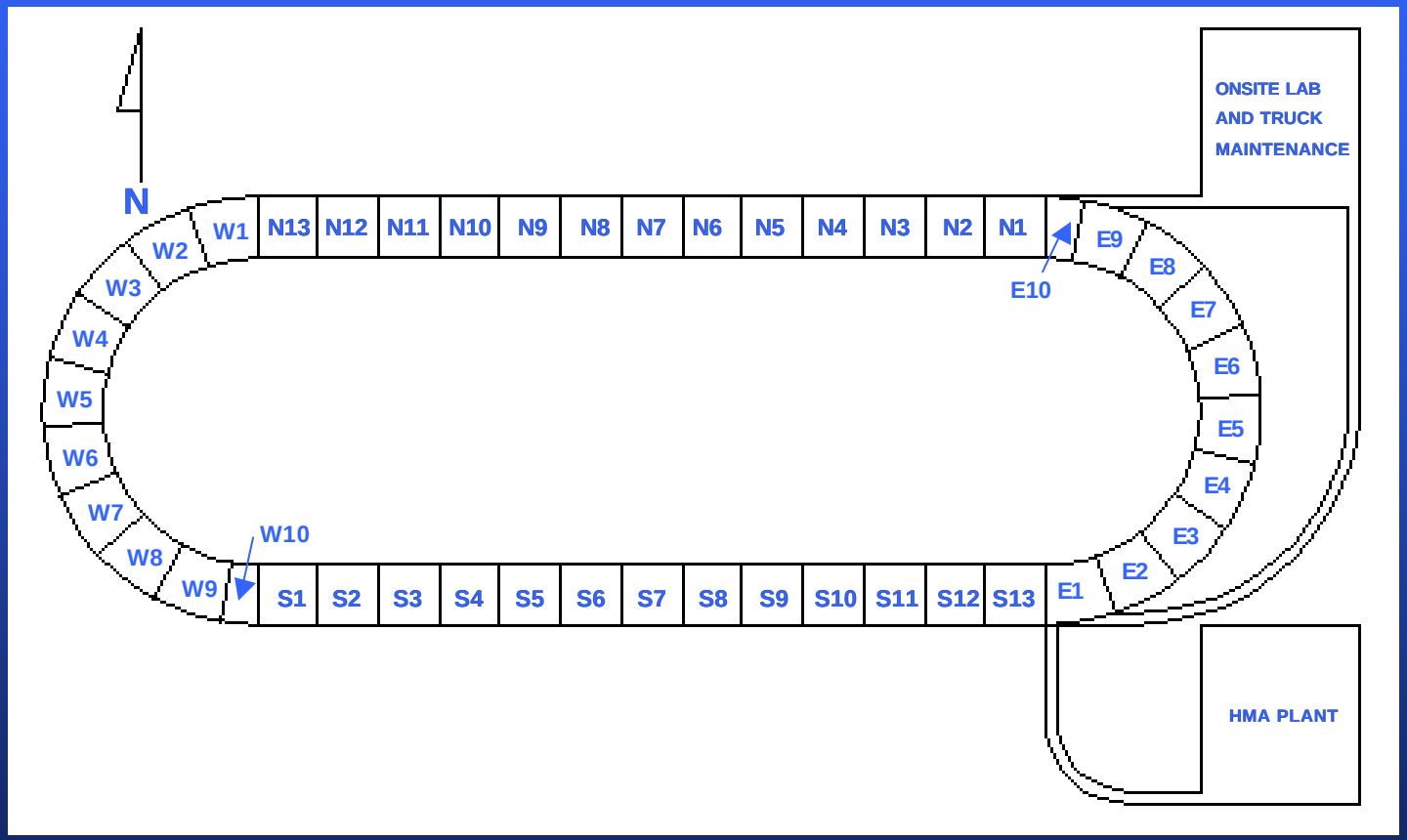
- Laboratory compaction effort should produce sample density approximately equal to ultimate pavement density
- Ultimate pavement density believed to be reached after 2-3 years of traffic
- Typically, select laboratory density of 96% of Theoretical maximum density or 4% air voids
  - Too little air voids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

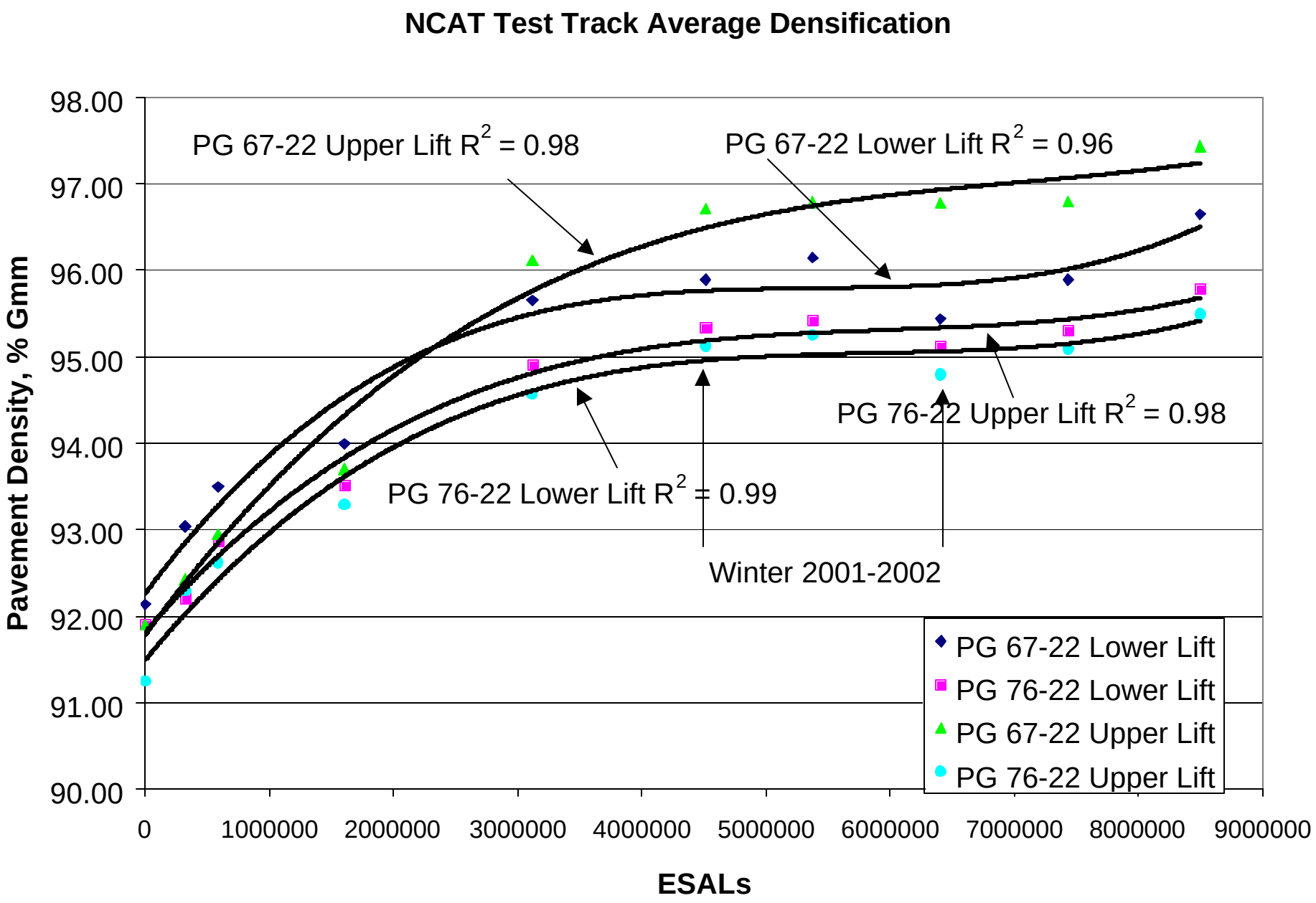
NCAT Test Track near Auburn, Alabama U.S.A.



- 2.74 km Oval Test Track on 309 acres
- 46 Cooperatively Sponsored 61 m Test Sections
- 437 sq m Testing Laboratory
- 242 sq m Truck Maintenance Facility

SECTION LAYOUT

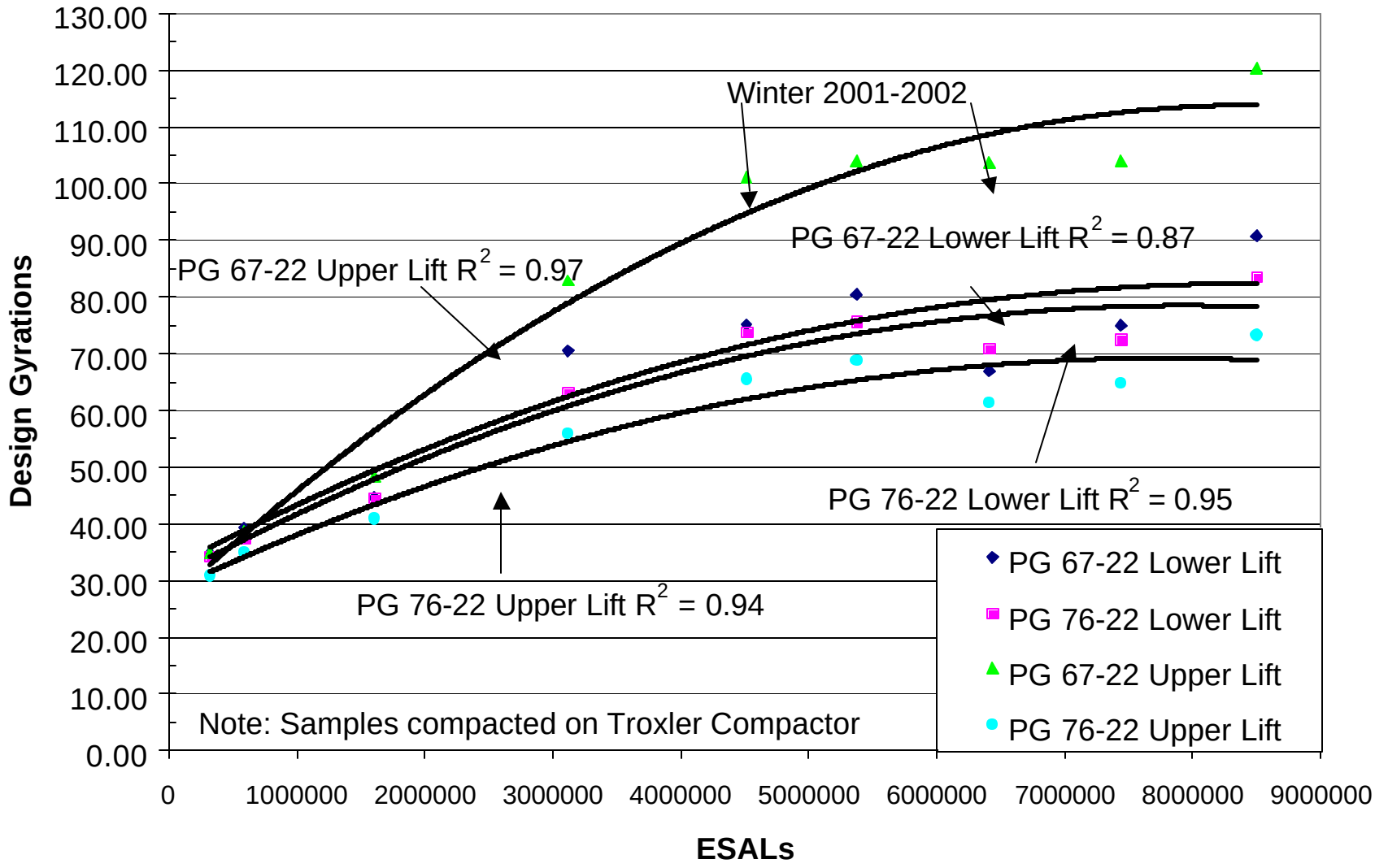



NCAT Test Track Average Densification
Pavement Density, % Gmm
98.00
97.00
96.00
95.00
94.00
93.00
92.00
91.00
90.00
0
1000000
2000000
3000000
4000000
5000000
6000000
7000000
8000000
9000000
ESALs
PG 67-22 Upper Lift R2 = 0.98
PG 67-22 Lower Lift R2 = 0.96
PG 76-22 Upper Lift R2 = 0.98
PG 76-22 Lower Lift R2 = 0.99
Winter 2001-2002
PG 67-22 Lower Lift
PG 76-22 Lower Lift
PG 67-22 Upper Lift
PG 76-22 Upper Lift

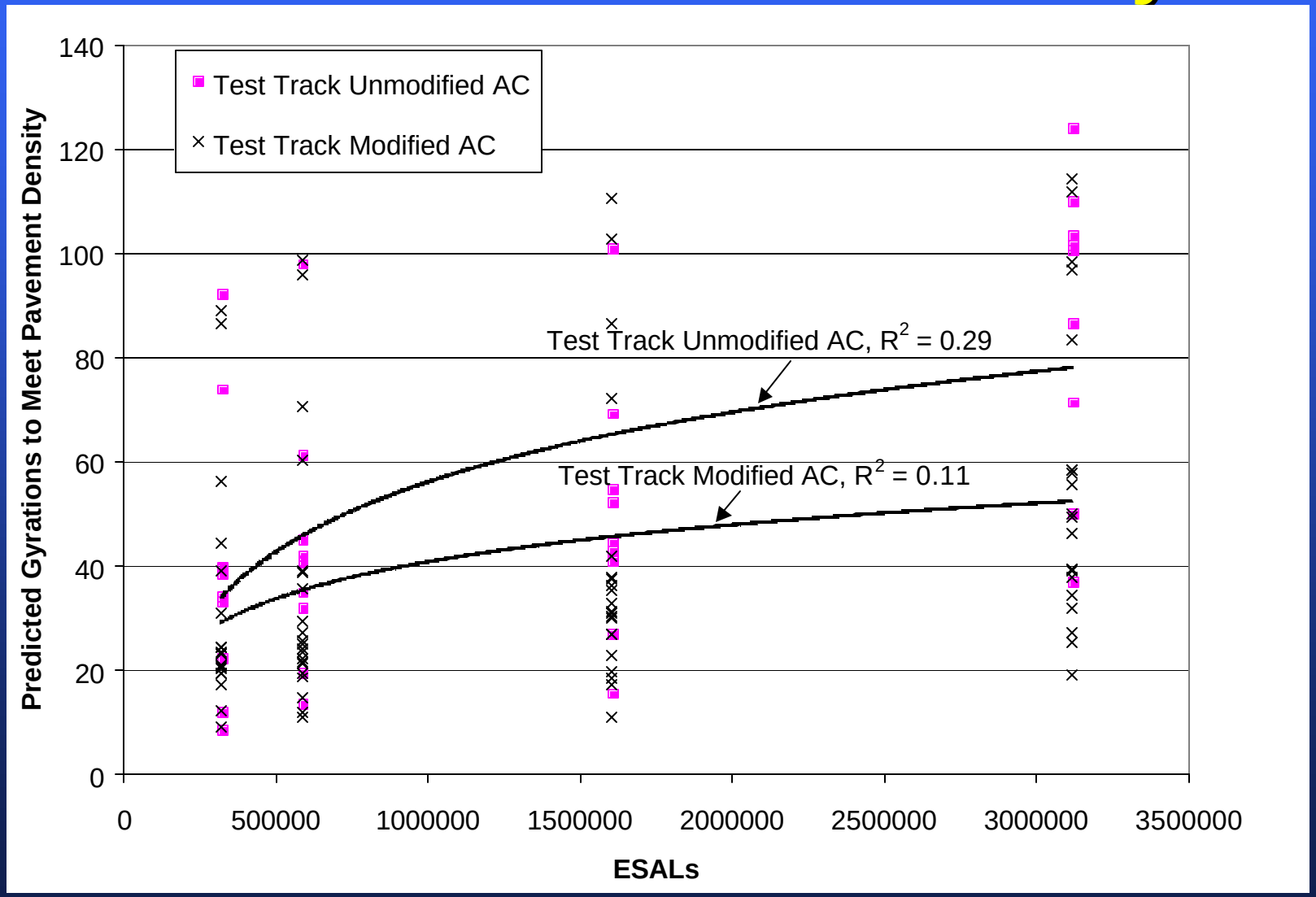
Estimation of Density at a Given Gyration Level

Density at Gyration X ?

$$\textit{Density at NDesign} ? \quad \frac{\textit{Height at NDesign}}{\textit{Height at Gyration X}}$$


NCAT Test Track - Design Gyrations to Meet Pavement Density
Design Gyrations
130.00
120.00
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
1000000
2000000
3000000
4000000
5000000
6000000
7000000
8000000
9000000
ESALs
Winter 2001-2002
PG 67-22 Upper Lift R2 = 0.97
PG 67-22 Lower Lift R2 = 0.87
PG 76-22 Lower Lift R2 = 0.95
PG 76-22 Upper Lift R2 = 0.94
Note: Samples compacted on Troxler Compactor
PG 67-22 Lower Lift
PG 76-22 Lower Lift
PG 67-22 Upper Lift
PG 76-22 Upper Lift

The Whole Truth – Predicted Gyrations to Match Test Track Density



What Factors Cause this Variability?

Source	DF	P-Value	Significant
Lift	1	0.018	Yes
Binder	2	0.000	Yes
Aggregate Type	7	0.000	Yes
Gradation	2	0.000	Yes
NMAS	2	0.017	Yes
Error	177	NA	NA

Based on Analysis of Variance

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

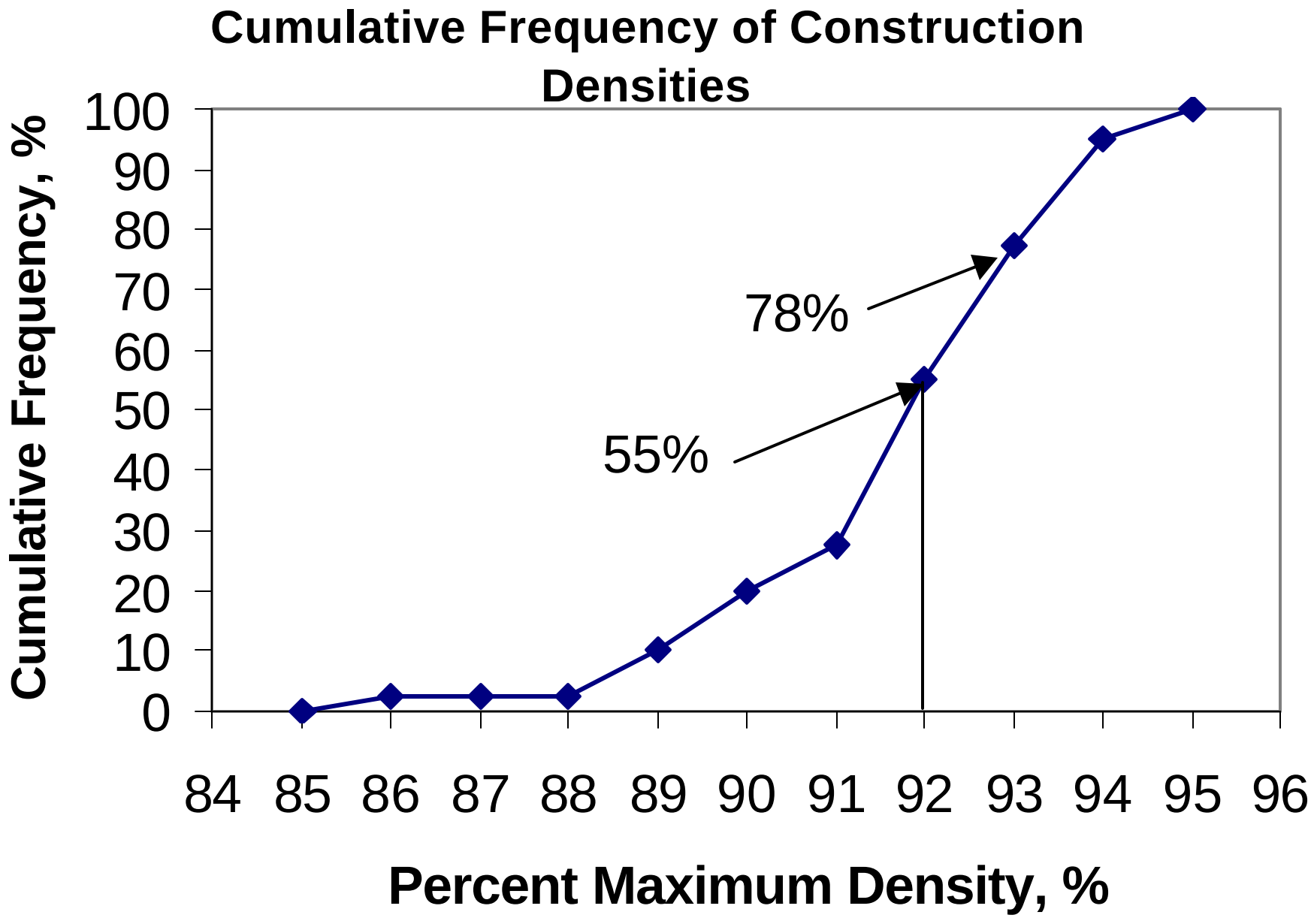
Experimental Plan

- 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 field density

NCHRP 9-9 (1): Field Project Locations

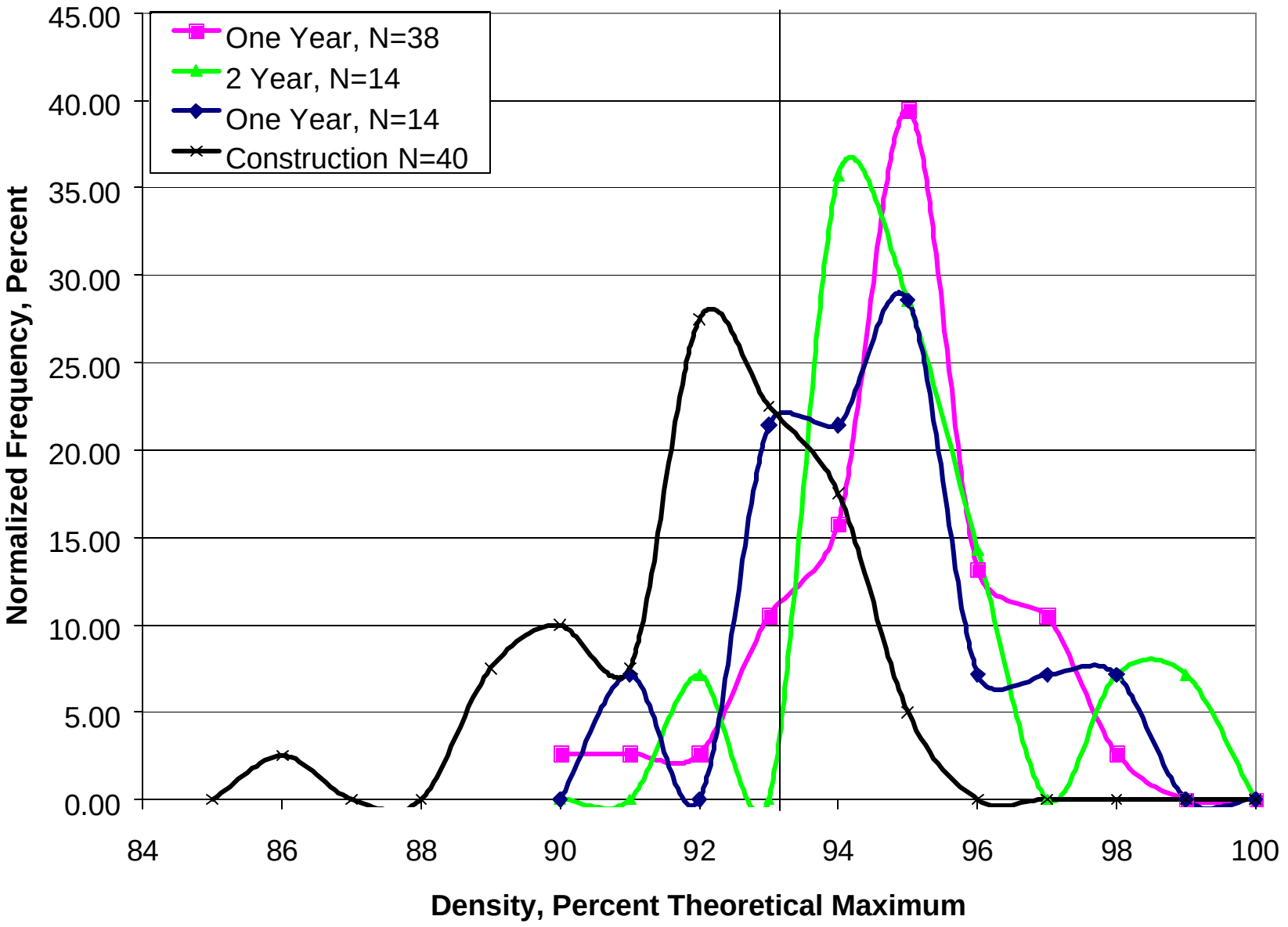
General Observations

- Gradation, coarse or fine, was related to compaction level:
  - Almost all 75 gyration mixes were fine graded
  - Two-thirds of 100 gyration mixes were coarse graded
  - All 125 gyration mixes were coarse graded
- Binder Grade Bumps:
  - 15 of 17, 100 gyration mixes included at least one binder grade bump
  - All 125 gyration mixes included at least a one grade bump

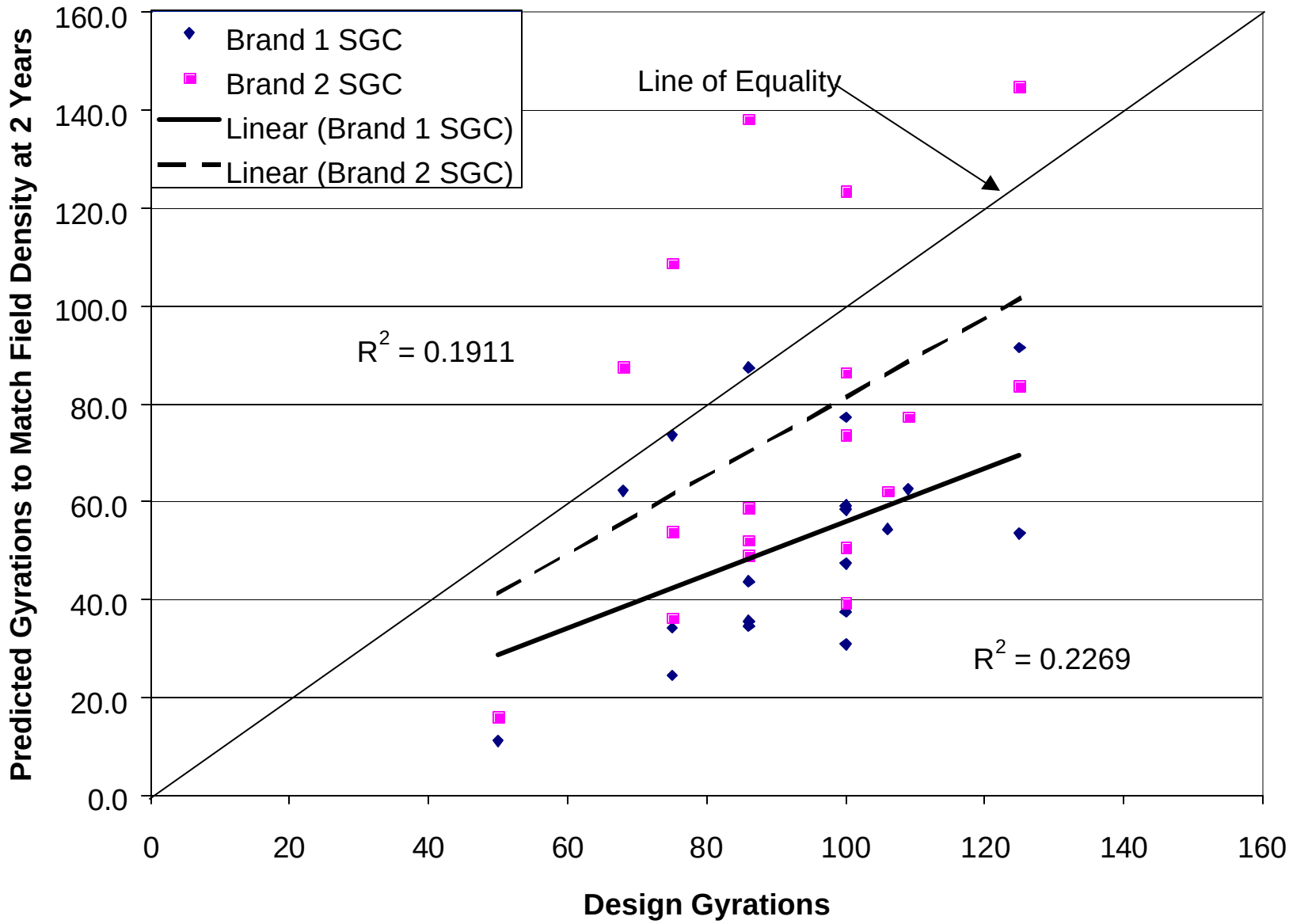

Cumulative Frequency of Construction Densities
Cumulative Frequency, %
100
90
80
70
60
50
40
30
20
10
0
78%
55%
84
85
86
87
88
89
90
91
92
93
94
95
96
Percent Maximum Density, %

Summary of Projects with Two Years of Traffic

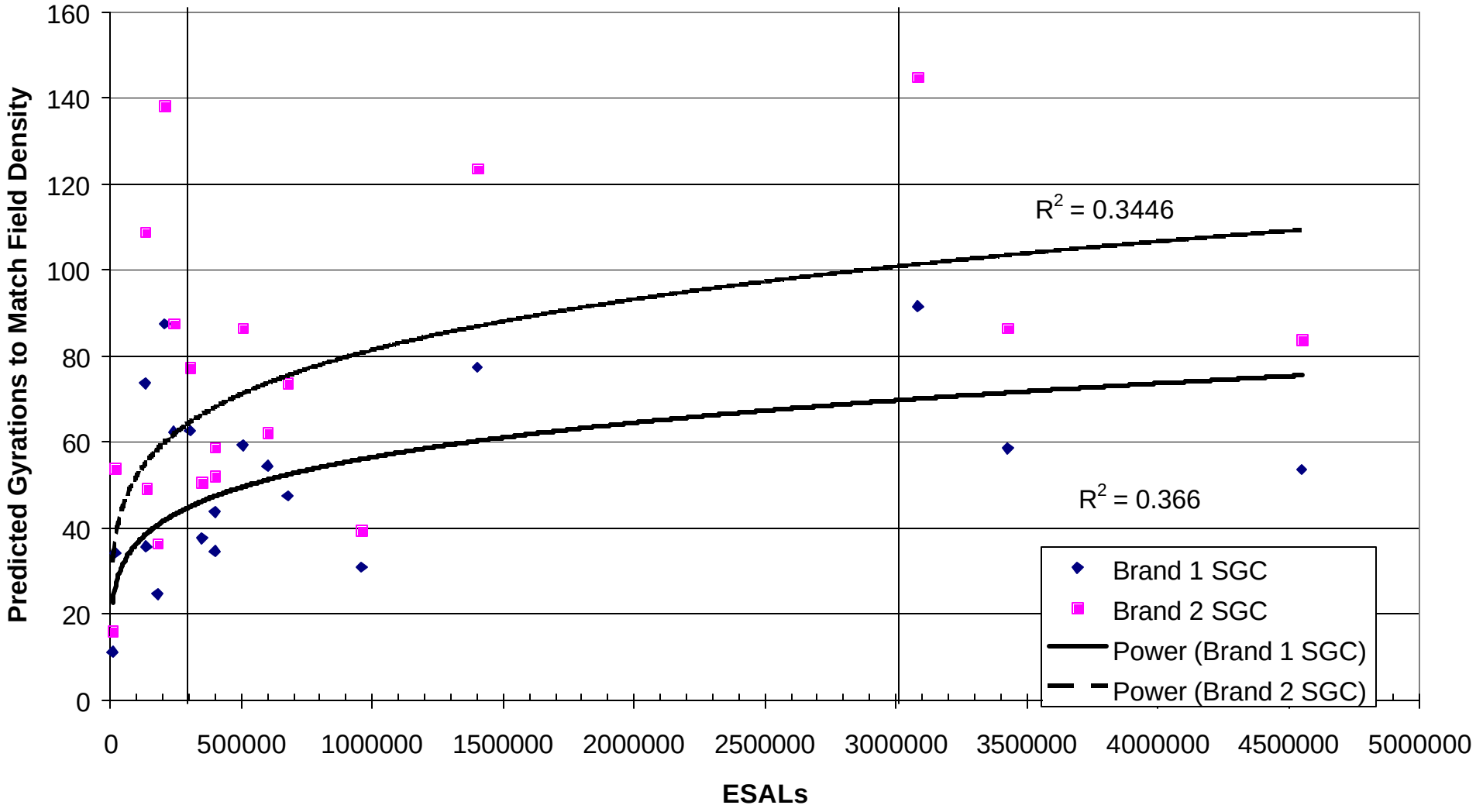
Pavement Densification



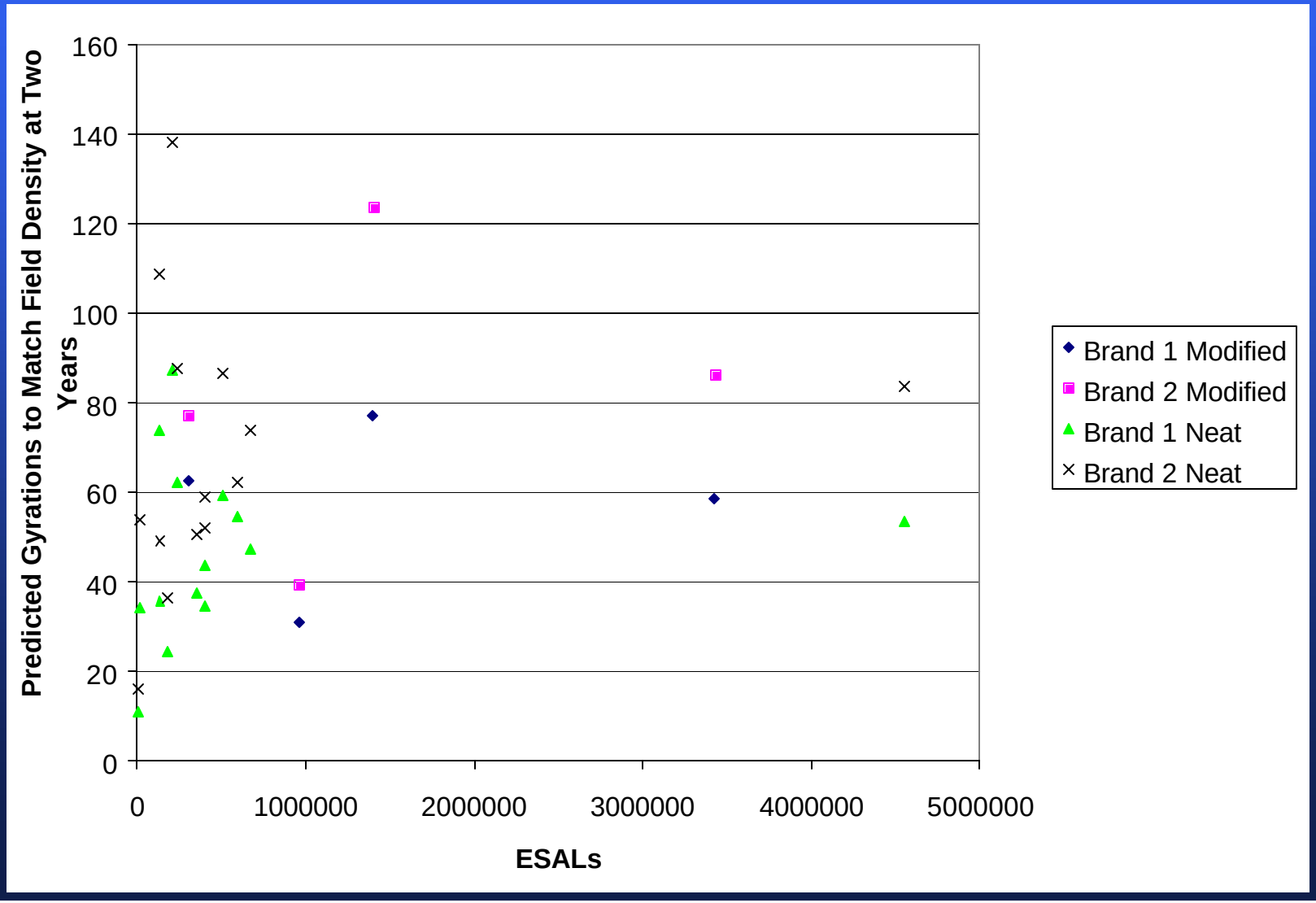
Design Vs Predicted Gyrations



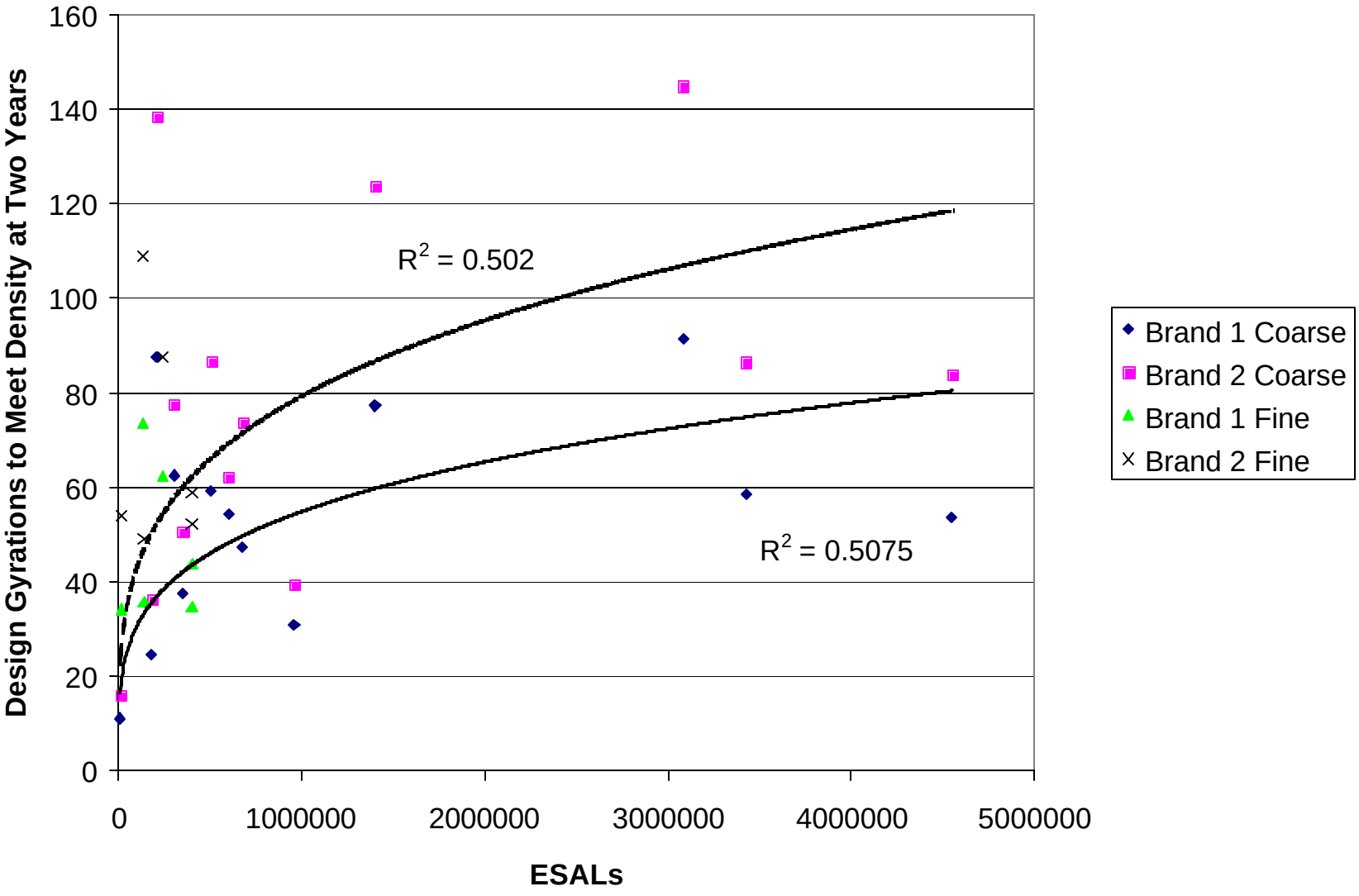
Design Gyrations Vs Two Year Traffic



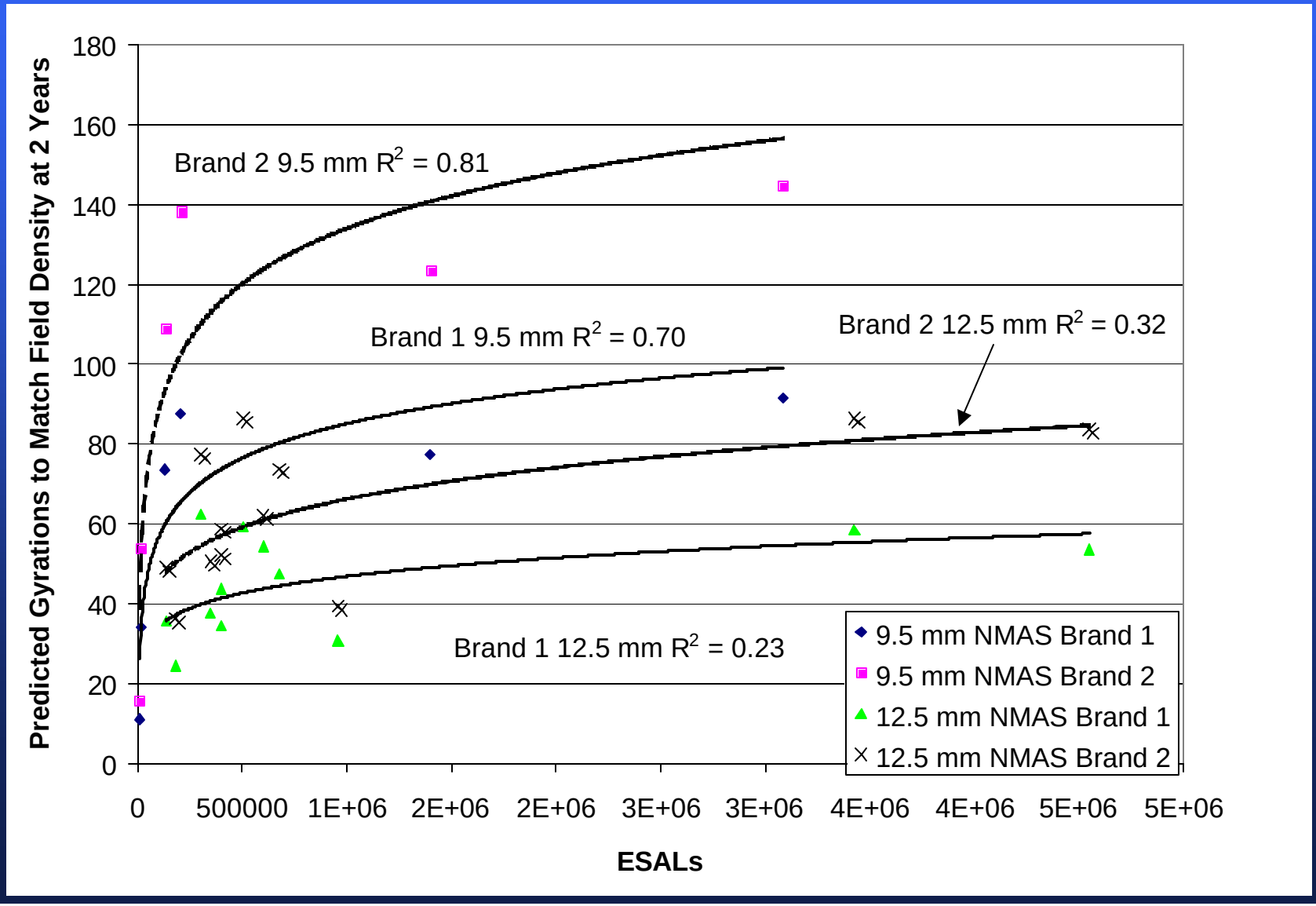
Comparison of Modified and Unmodified Sections After Two Years



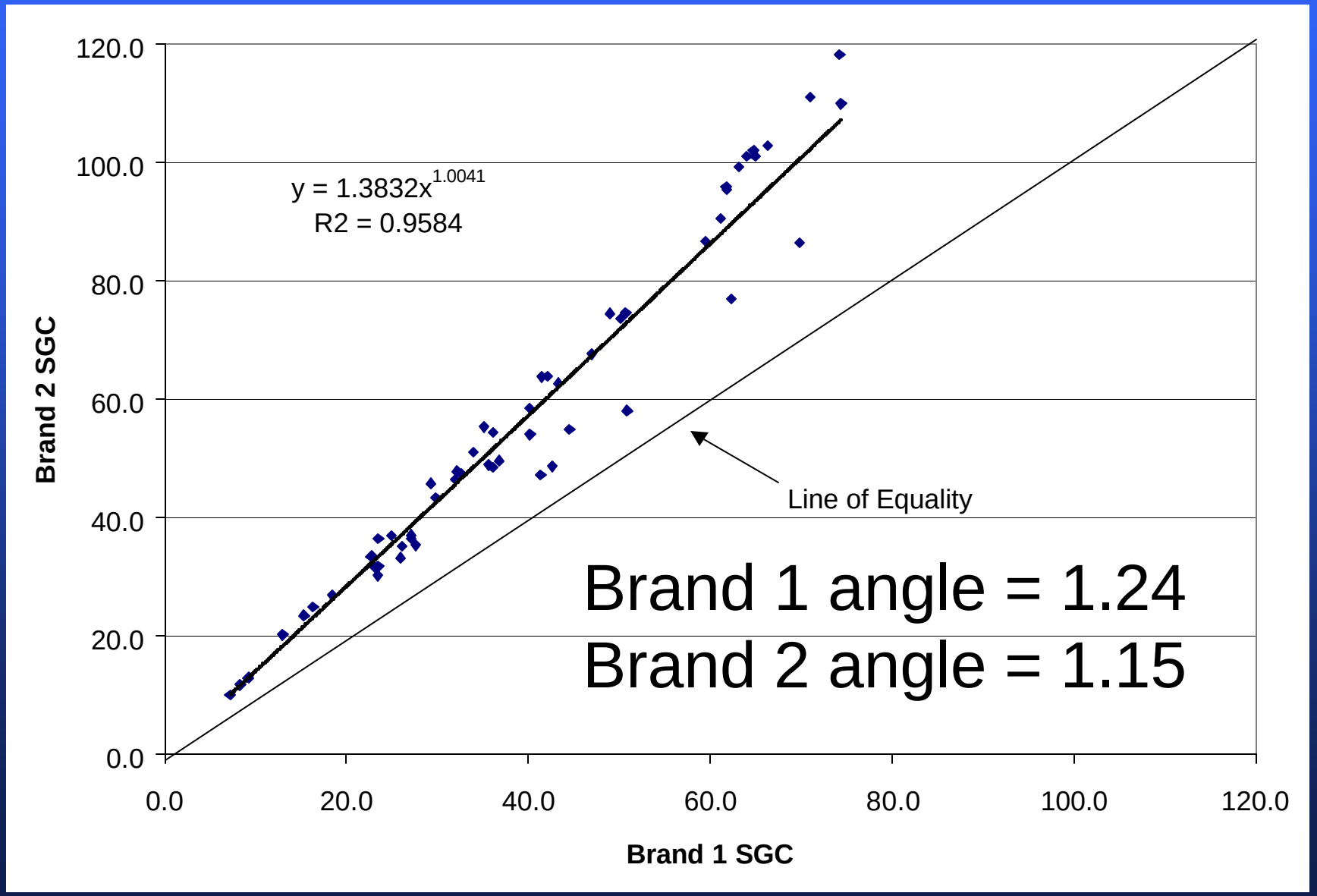
Comparison of Coarse and Fine Mixes - Two Years



Comparison of Nominal Maximum Aggregate Size – Two Years



Comparison of Number of Gyrations to Match Field Density for Two Compactors



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 evidence reflective cracking, even when total (new) overlay 3.5 inches or more
- Joints vary from fair to very good
- Some permeability evidenced by wet spots

Summary

- 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
  - Aggregate type, binder grade, nominal maximum aggregate size and gradation all affect predicted Ndesign values

Summary - Continued

- Data from Test Track and NCHRP 9-9 seem to confirm current compaction level 0.3 to 3 million ESALs
- Results indicate that different compactors provide different compactive efforts
- Scatter in 9-9(1) data decreases with additional traffic
- Trends developing, should be well founded once 2-year core data collected

Thank You!

Acknowledgements

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