Illinois Bituminous Paving Conference

IN SEARCH OF THE TRUE N-DESIGN

DETERMINING THE CORRECT LEVEL OF LABORATORY COMPACTION

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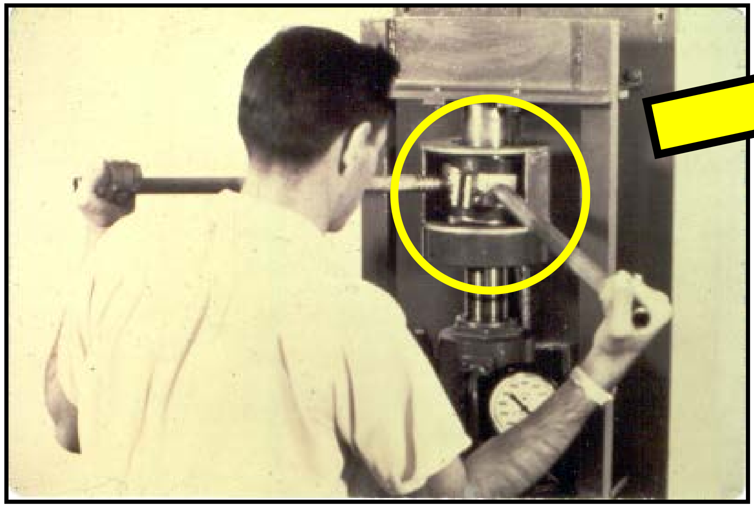
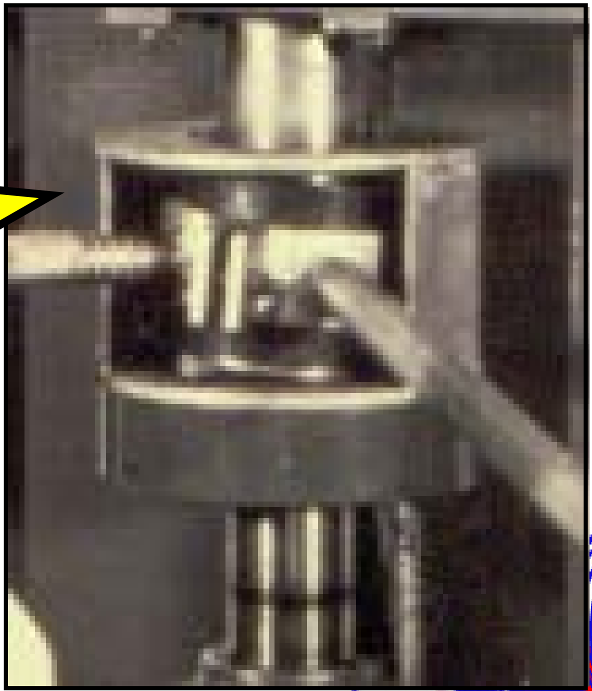
GYRATORY HISTORY

• Texas Four Inch Manual	1930s
• Texas Four Inch Motorized	1960
• Texas Six Inch Motorized	1960s
• Corps of Engineers	circa 1960
• French	circa 1970
• Superpave	1992

Early Gyratory Compactors

- 1939, Texas Highway Department
- Texas 4-Inch Gyratory Press





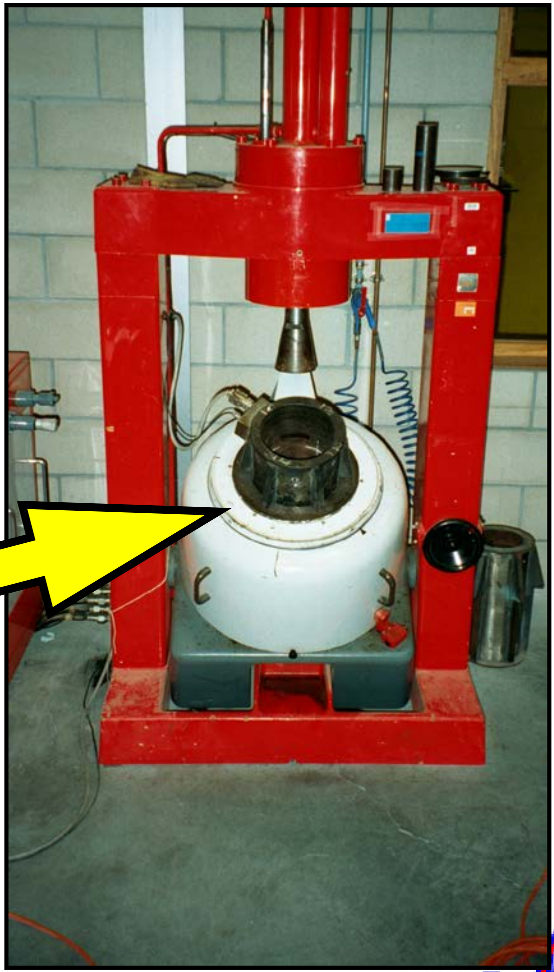
LCPC Gyratory Compactor

- 1959
  LCPC visit to Texas

- Developed Protocol
  - 160 mm
  - 1º angle
  - 6 gyrations/min

LCPC Gyratory Compactor

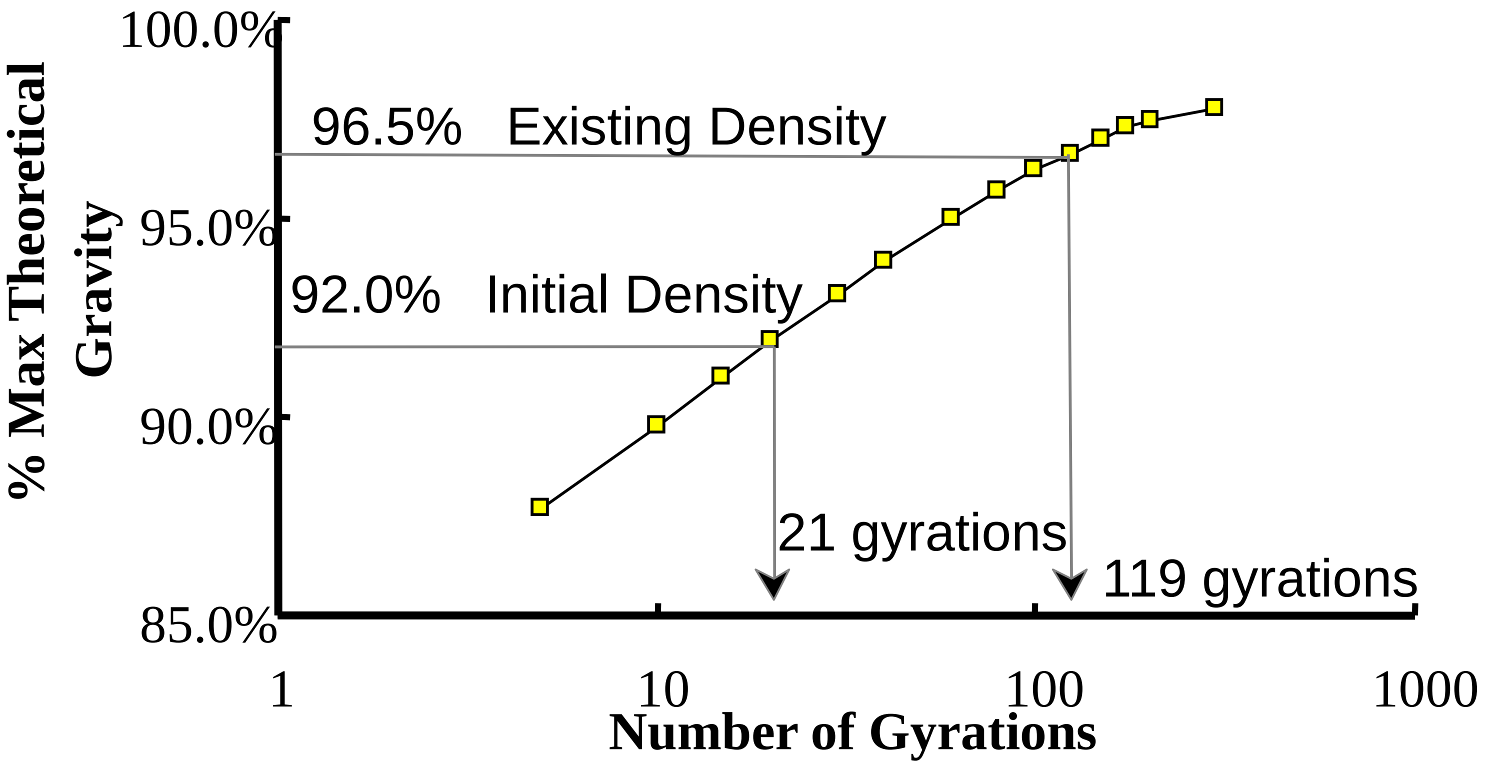
- Models
  - Texas-type
  - 1968, 2nd prototype
  - 1973, PCG1
  - 1985, PCG2



SUPERPAVE N DESIGN EXPERIMENT

- Basic principle
  - Determine number of gyrations to match the road density

N DESIGN RECOMPACTION



N DESIGN EXPERIMENT, TRAFFIC

- Three levels of traffic
  - – Low, less than three million ESAL’s.
  - – Medium, more than three million, less than ten million ESAL’s.
  - – High, more than ten million ESAL’s

N DESIGN, TEMPERATURE

- Three high temperature environments
  - Cool (monthly temperature < 90 F)
  - Warm (monthly temperature > 90 F, < 100 F)
  - High (monthly temperature >100 F)

N DESIGN, PAVEMENT DEPTH

- Two depths of pavement
  - Surface, within upper 100 mm of pavement.
  - ~~Lower, more than 100 mm from pavement surface~~.

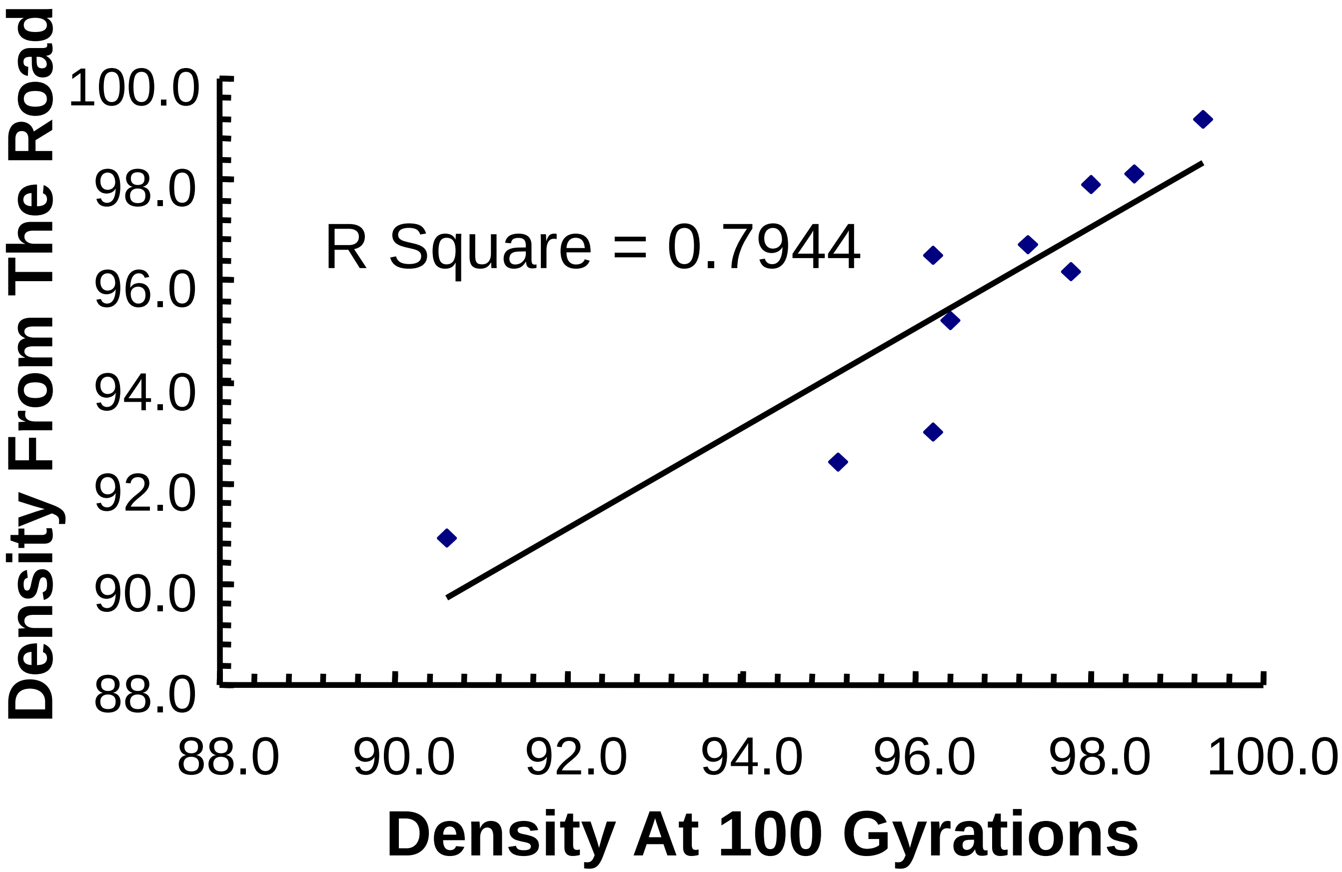
N DESIGN, PAVEMENT AGE

- Three ages of pavement
  - ~~Young, less than three years old~~.
  - ~~Middle age, more than three years, less than twelve years~~ old.
  - Old, more than 12 years old.

N DESIGN EXPERIMENT

- In total, 108 cells were required
- Reduced the number of cells to nine and the number of sites to 18.
- In total, 15 sites were obtained and evaluated

CORRELATION



DESIGN GYRATION TABLE

	Average High Air Temperature		
ESALs (millions)		<39ºC	
	$N_{initial}$	N_{design}	N_{max}
< 0.3	7	68	104
0.3 - 1	7	76	117
1 - 3	7	86	134
3 - 10	8	96	152
10 - 30	8	109	174
30 - 100	9	126	204
> 100	9	142	233

BUT WHAT HAPPENED?

- Two studies done
  - Asphalt Institute
  - NCAT
- Couldn't replicate first experiment

SO. . .

1996 Revised Table

Estimated Design Traffic Level (Millions[1] ESALs)	Compaction Parameters		
	N_{init}	N_{des}	N_{max}
< 0.3	6	50	75
0.3 to < 3	7	75	115
3 to < 30	8	100	160
≥ 30	9	125	205

NCHRP 9-9(1)

- Continued Basic principle
  - Follow projects from construction (4 yr)
- Large number of projects

Best Fit with Outliers Removed

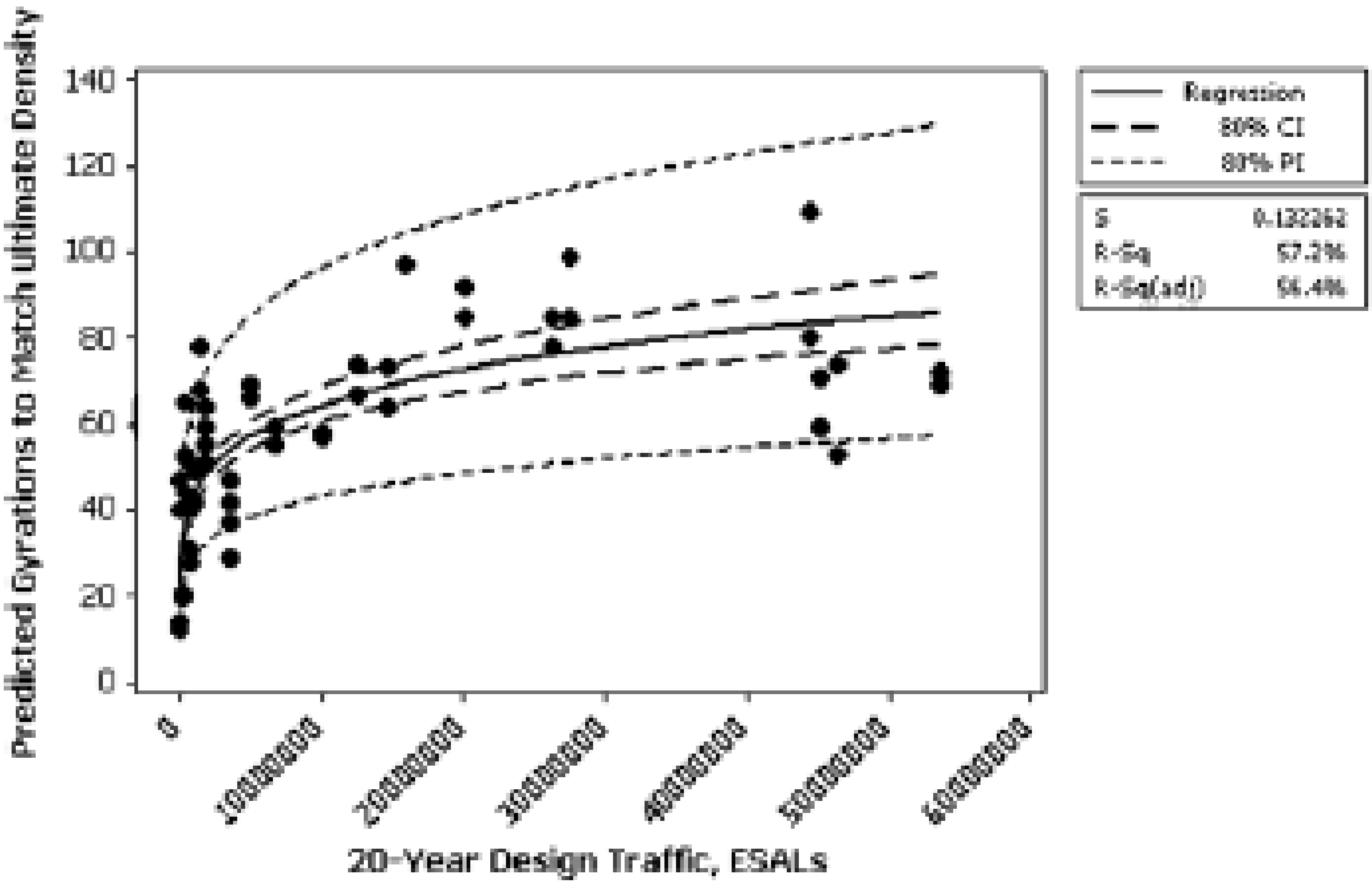


Figure 4.24. Predicted gyrations versus 20-year design traffic without PG 76-22 data.

Using Best Fit to Predict

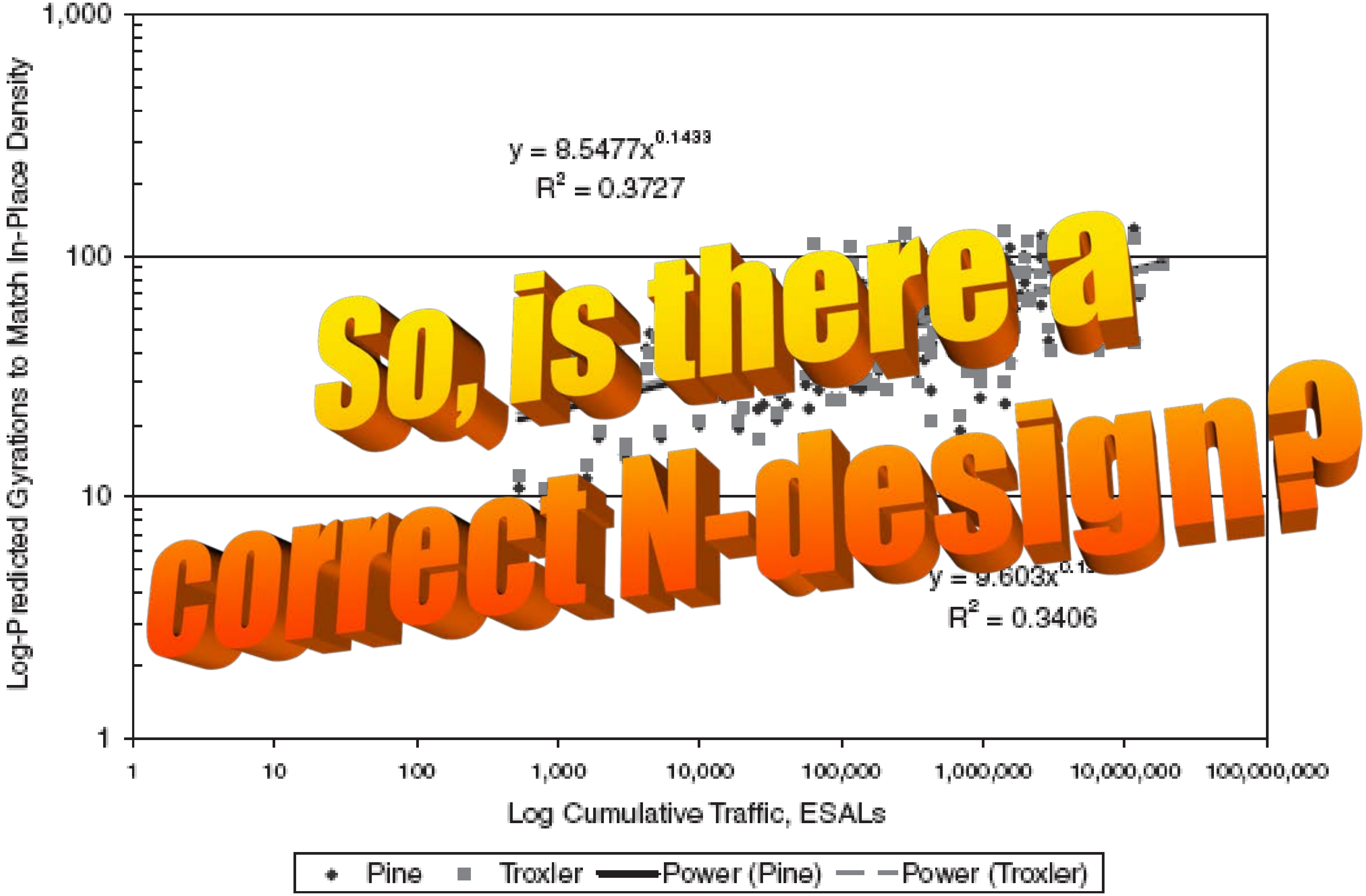


Figure 4.26. Predicted gyrations to match in-place density for all post-construction sampling periods.

Why Change (Decrease)?

It will change the asphalt content.

???

What Changes Asphalt Content?

Changed by N-design?

MAYBE

- Only if asphalt binder and mix are separate bid items.
- Even then, maybe not . . .If owner has
  - Maximum asphalt content
  - Or maximum VMA

Changed by N-design?

For Sure NOT, if

- Binder and mix are one bid item.
- Owner will have
  - Minimum asphalt content
  - Or minimum VMA
- Asphalt Contents will be as low as spec allows

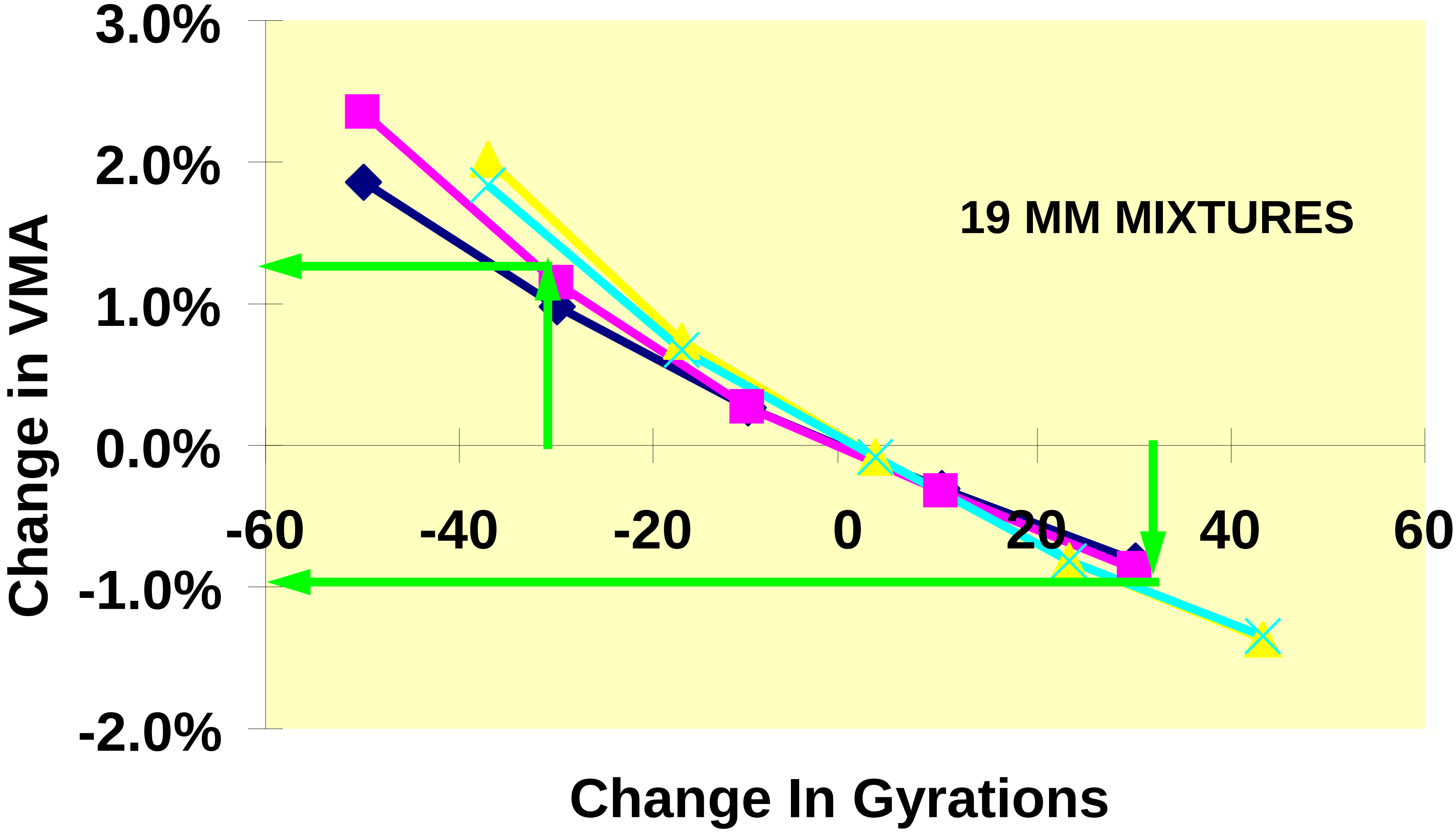
Let's Consider

Effect of N-design on Mixture Properties

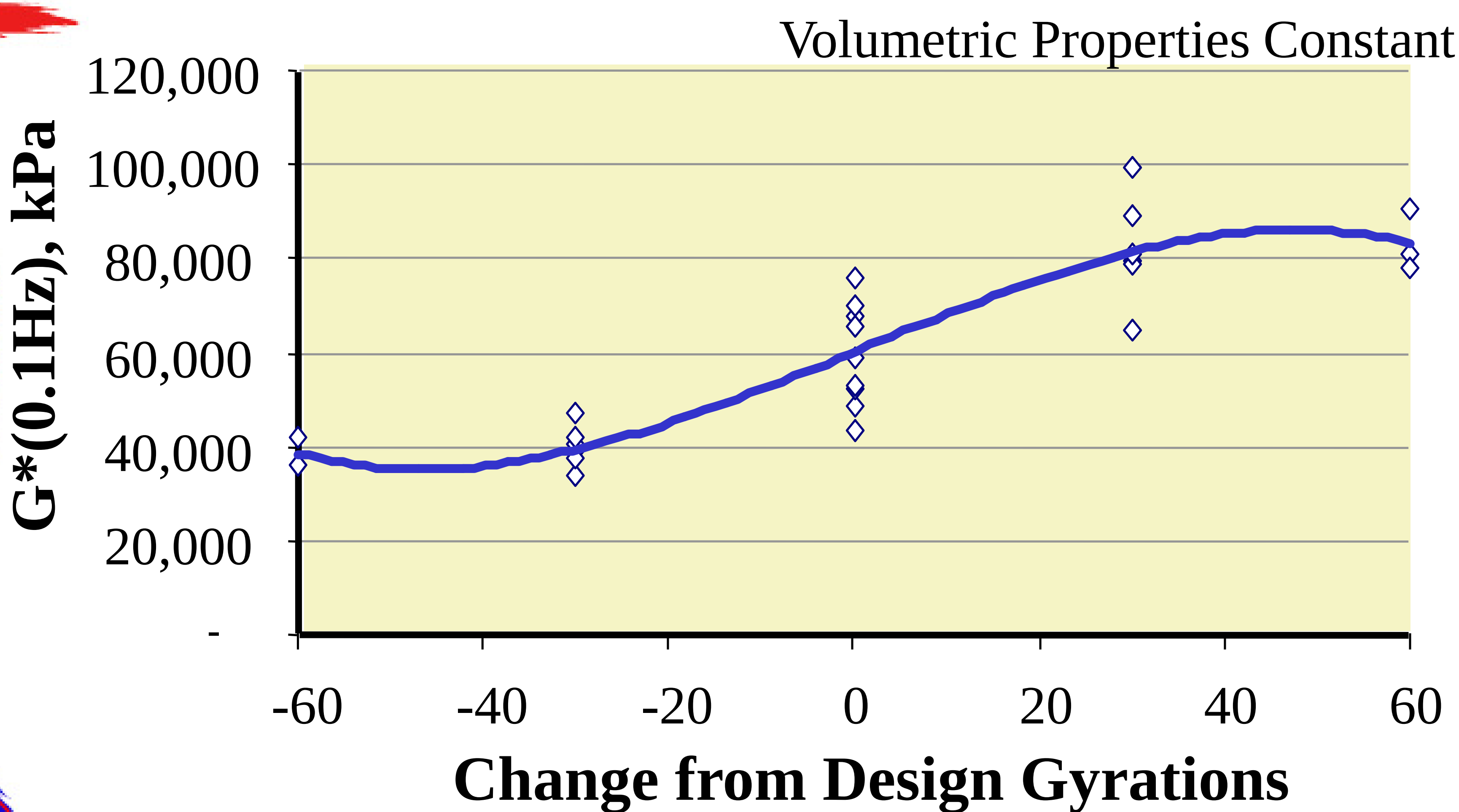
What Should Design Gyrations Be?

- 20-30 gyrations changes
  - VMA by 1%
    0.4% asphalt content
  - Mixture stiffness by 25 to 30%
    (about one PG high temp grade difference)

If Gradation is Kept Constant



If New Mix Design Done



EFFECT OF DESIGN COMPACTION ON MIX PROPERTIES

Influence of N_{design} on Volumetric Properties

Property	Increased N_{des}	Decreased N_{des}
Air Voids	none ↔	none ↔
VMA	none ↔	none ↔
VFA	little ↔	little ↔

Influence of N_{design} on Aggregate Properties

Property	Increased N_{des}	Decreased N_{des}
Crushed Faces	crush ⇧	crush ⇩
FAA	nat sand ⇩	nat sand ⇧
Gradation	coarser ⇩	finer ⇧

Influence of N_{design} on Mix Properties

Property	Increased N_{des}	Decreased N_{des}
Stiffness	increase	decrease
Compaction	difficult	easy

Influence of N_{design} on Asphalt Content

NONE

Why Change (Decrease)?

"N-design is not CORRECT"

What is CORRECT?

IT DEPENDS . . .
On how it is defined!

If “CORRECT” is

- Ability to achieve successful designs
  - N-design too high
    - need very hard, low LA Abrasion aggregates

If “CORRECT” is

- Ability to successfully construct pavement
  - – N-design too high
    - Very difficult to get compaction
  - – N-design too low
    - Mix prone to be tender

If "CORRECT" is

- Pavements that perform
  - N-design too high
    - Permeable pavements
    - Subject to moisture damage
  - N-design too low
    - Low strength and rut resistance
    - High densification under traffic

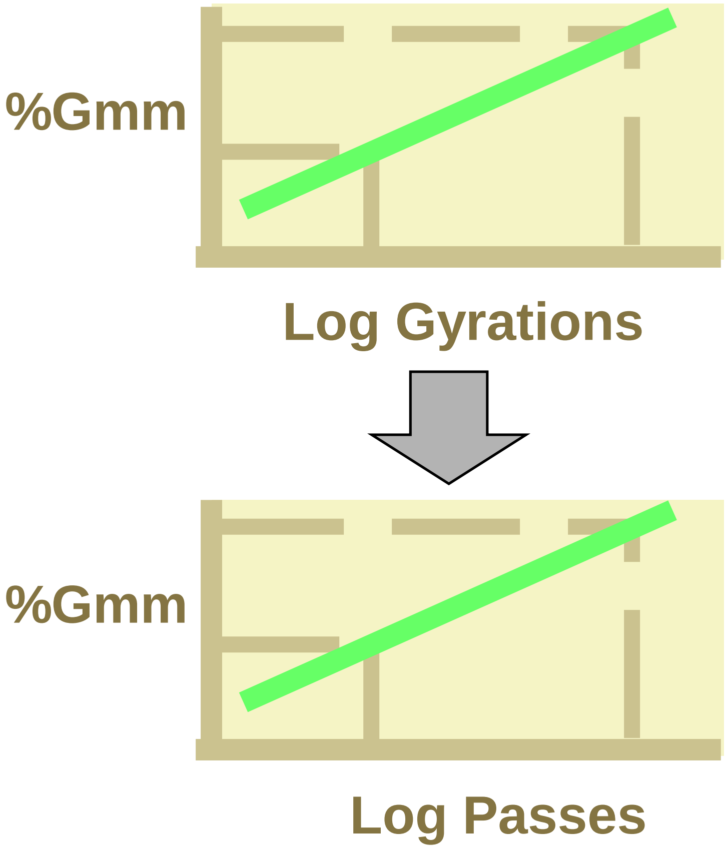
If “CORRECT” is

- Matching Density
  - In gyratory
  - After traffic

BUT

- Approach is inappropriate
  - Urban myth
  - No clear data

N-Design III Experiment

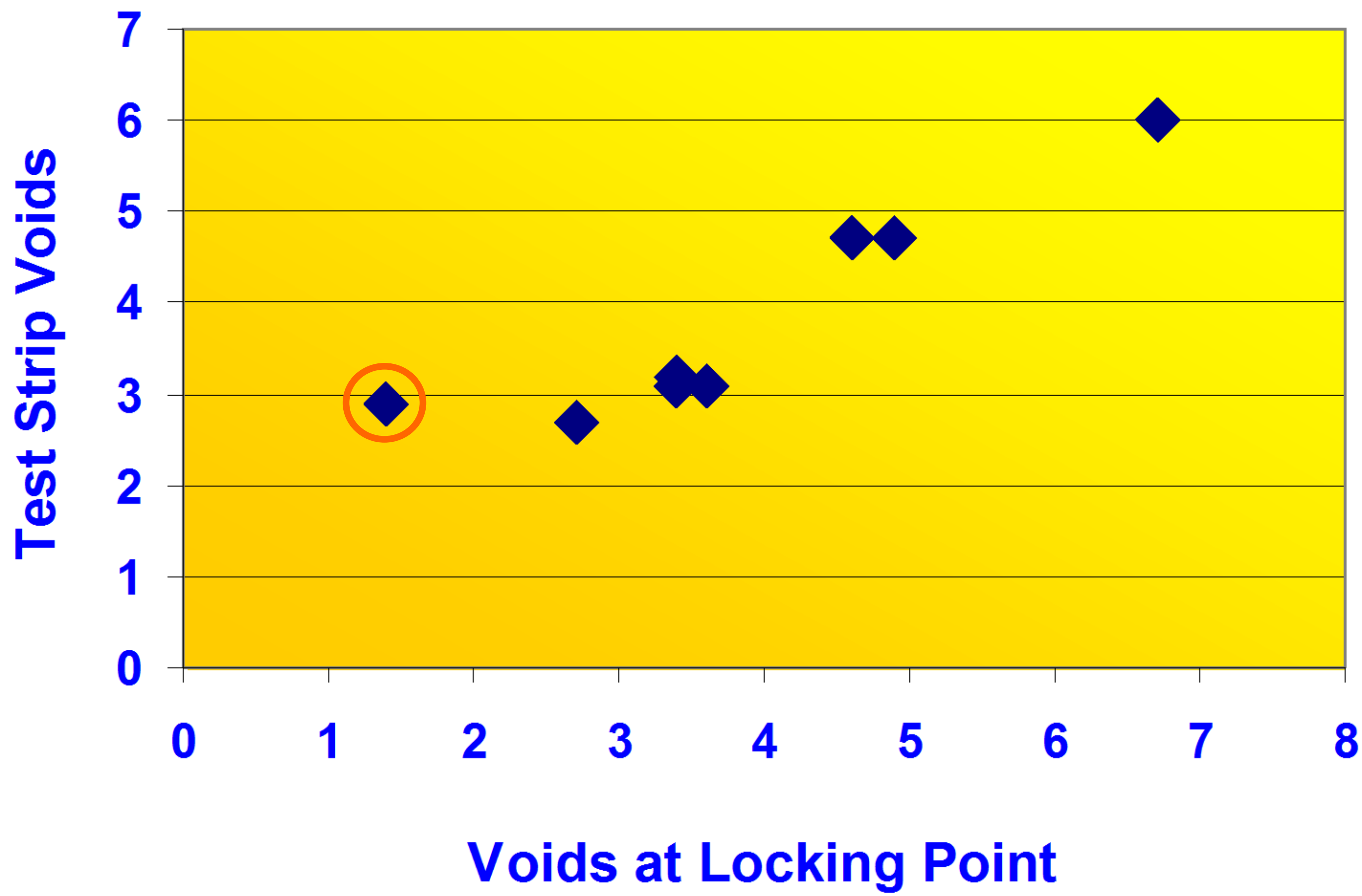


Relate Density to Compaction

Locking Point Definitions

- First gyration to repeat
- First gyration after two equal gyrations
- First of three successive heights to follow two equal heights
- Etc.

Relating Compaction to Locking Point



CONCLUSIONS

- Density at end of service life not rational to define N design
- Test strip density is a more rational method

SO!!!!

What is the correct N-design?