North Central Asphalt User/Producer Group

NCAUPG

January 10, 2007

# N-DESIGN

## The Search for the Holy Grail

# SUPERPAVE DESIGN COMPATION EFFORT

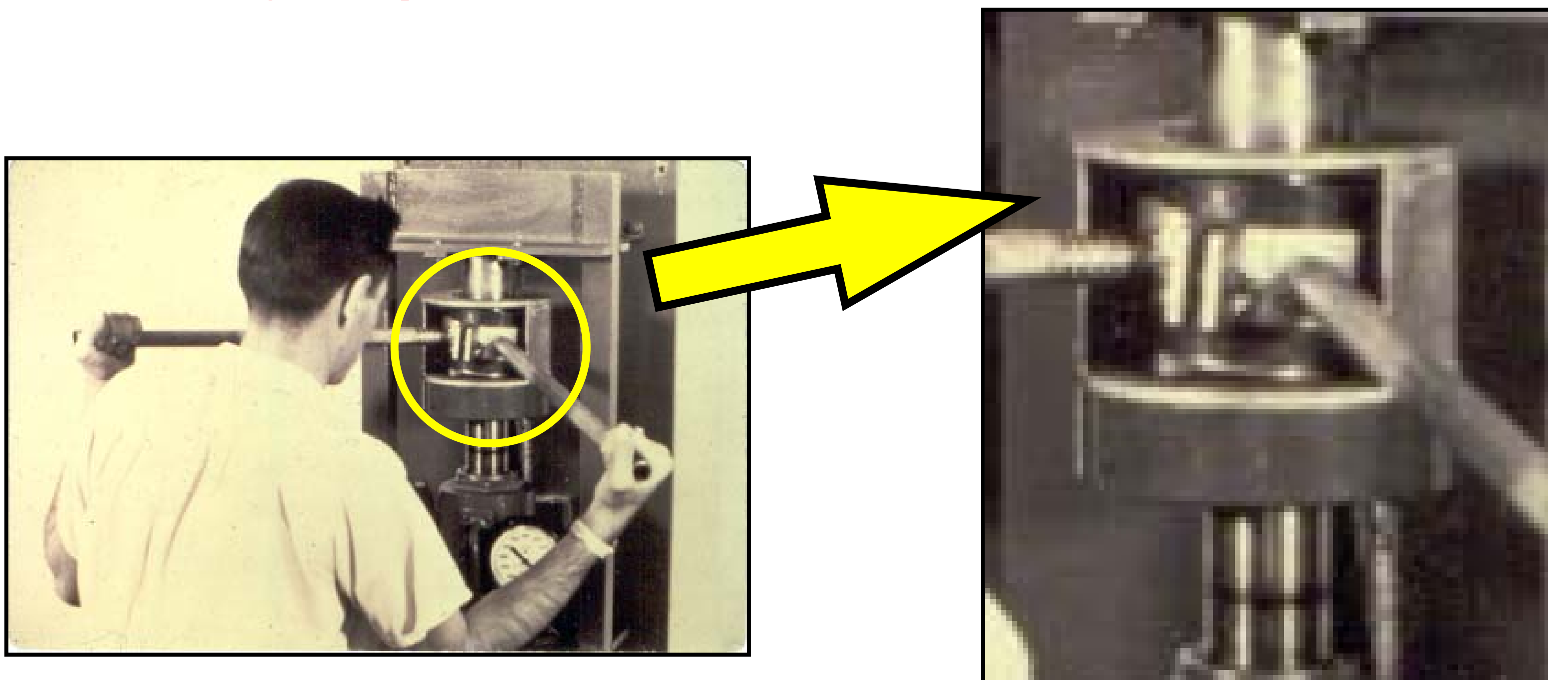
- Discussion of what is the “true” N-design
- To know where to go, it helps to know where we’ve been

# GYRATORY HISTORY

| | |
|---|---|
| • Texas Four Inch Manual | 1930s |
| • Texas Four Inch Motorized | 1960 |
| • Corps of Engineers | 1960 ish |
| • French | 1970 ish |
| • Superpave | 1992 |

# First Gyratory Compactor

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



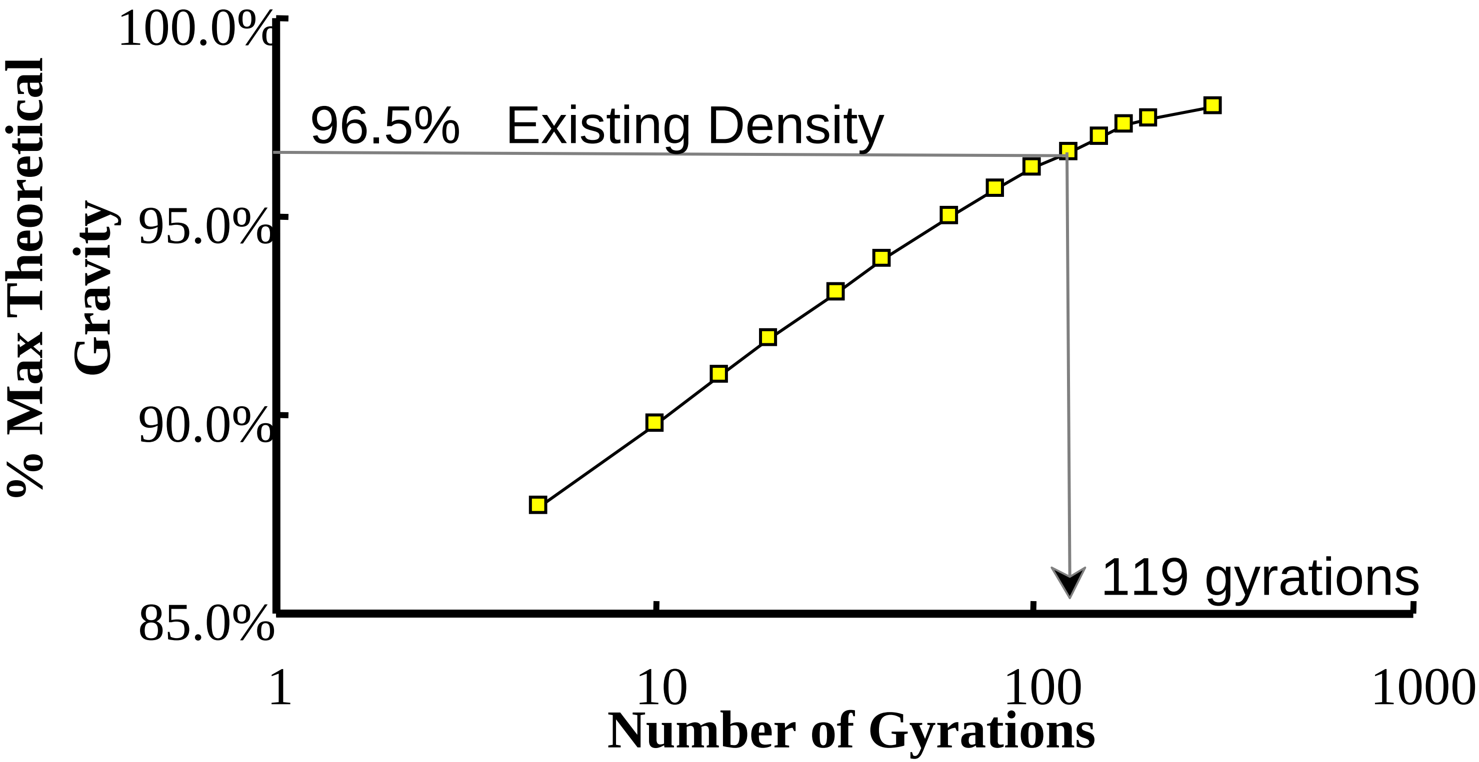
# LCPC Gyratory Compactor

- 1959 visit to Texas
- Developed Protocol
  - 160 mm
  - 1º angle
  - 6 gyrations/min

# SUPERPAVE GYRATORY

- N Design Experiment
  - Determine number of gyrations to match the road density

# N DESIGN RECOMPACTION



# N DESIGN EXPERIMENT

- 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 EXPERIMENT

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

# N DESIGN EXPERIMENT

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

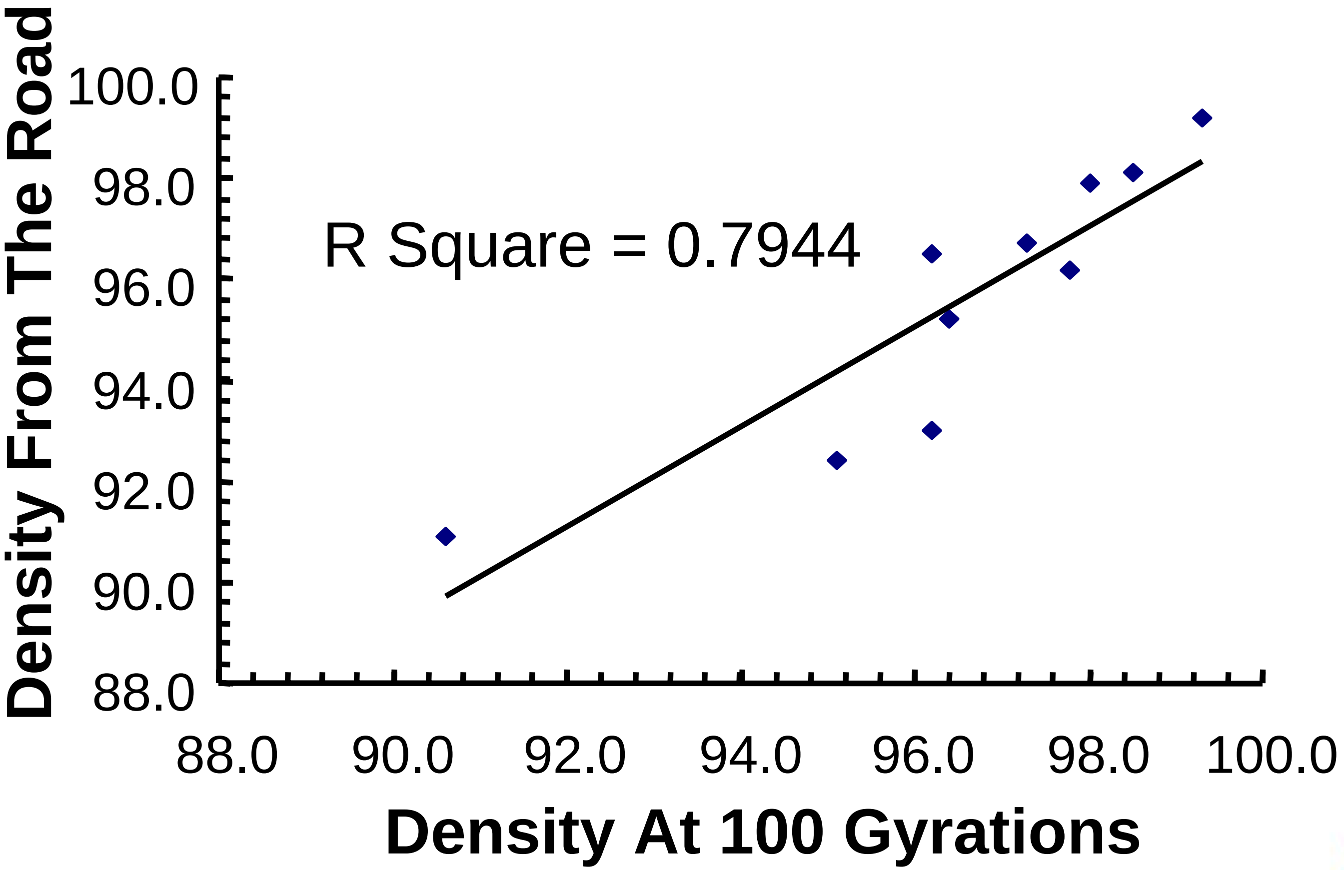
# N DESIGN EXPERIMENT

- 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

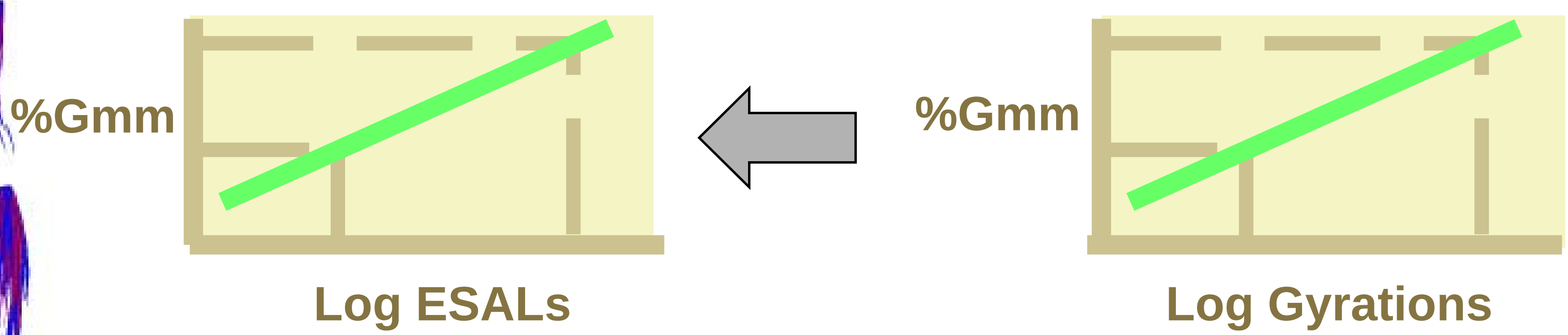
# CORRELATION



# DESIGN GYRATION TABLE

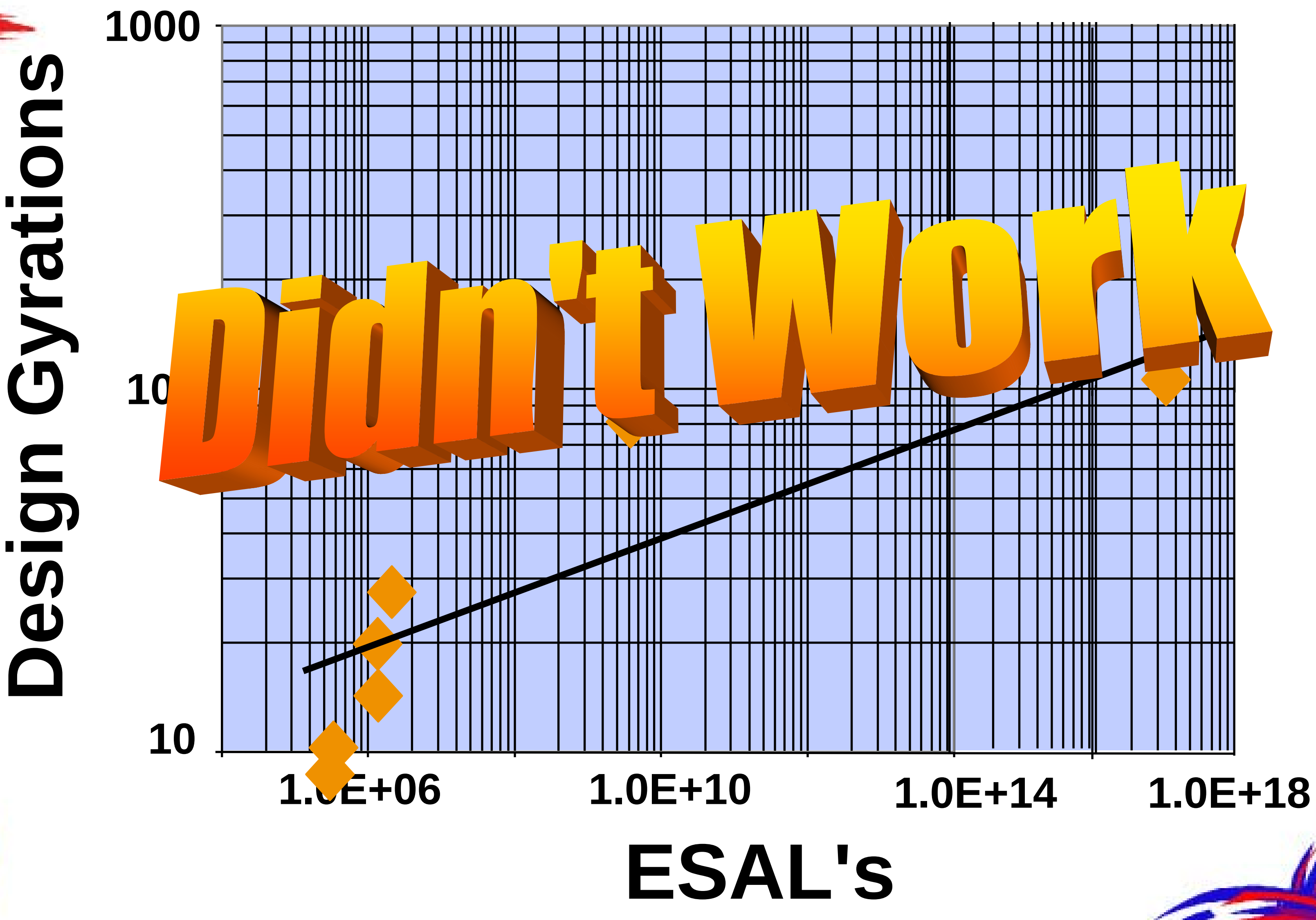
| | Average High Air Temperature | | |
|---|---|---|---|
| ESALs (millions) | | $<39^{o}C$ | |
| | $N_{initial}$ | $N_{design}$ | $N_{max}$ |
| < 0.3 | 7 | 68 | 104 |
| 0.3 - 1 | 7 | 76 | 117 |
| 1 - 3 | 7 | 86 | 134 |
| 3 - 10 | 8 | 96 | 152 |
| 10 - 30 | 8 | 109 | 174 |
| 30 - 100 | 9 | 126 | 204 |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

# N-Design II Experiment

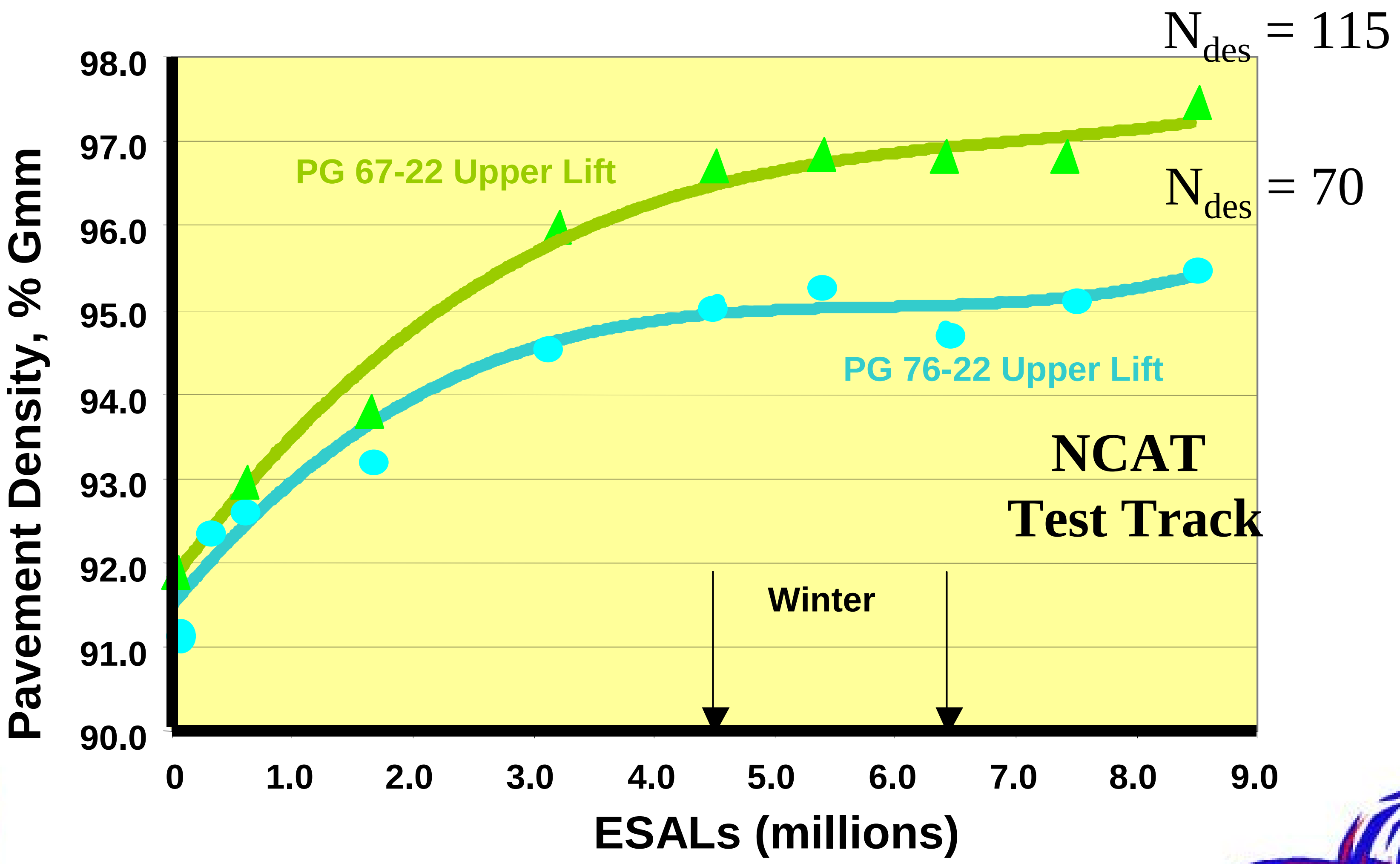



**Relate Density
to
Gyrations**

# Relate Gyrations To ESAL's



# TRAFFIC COMPACTION

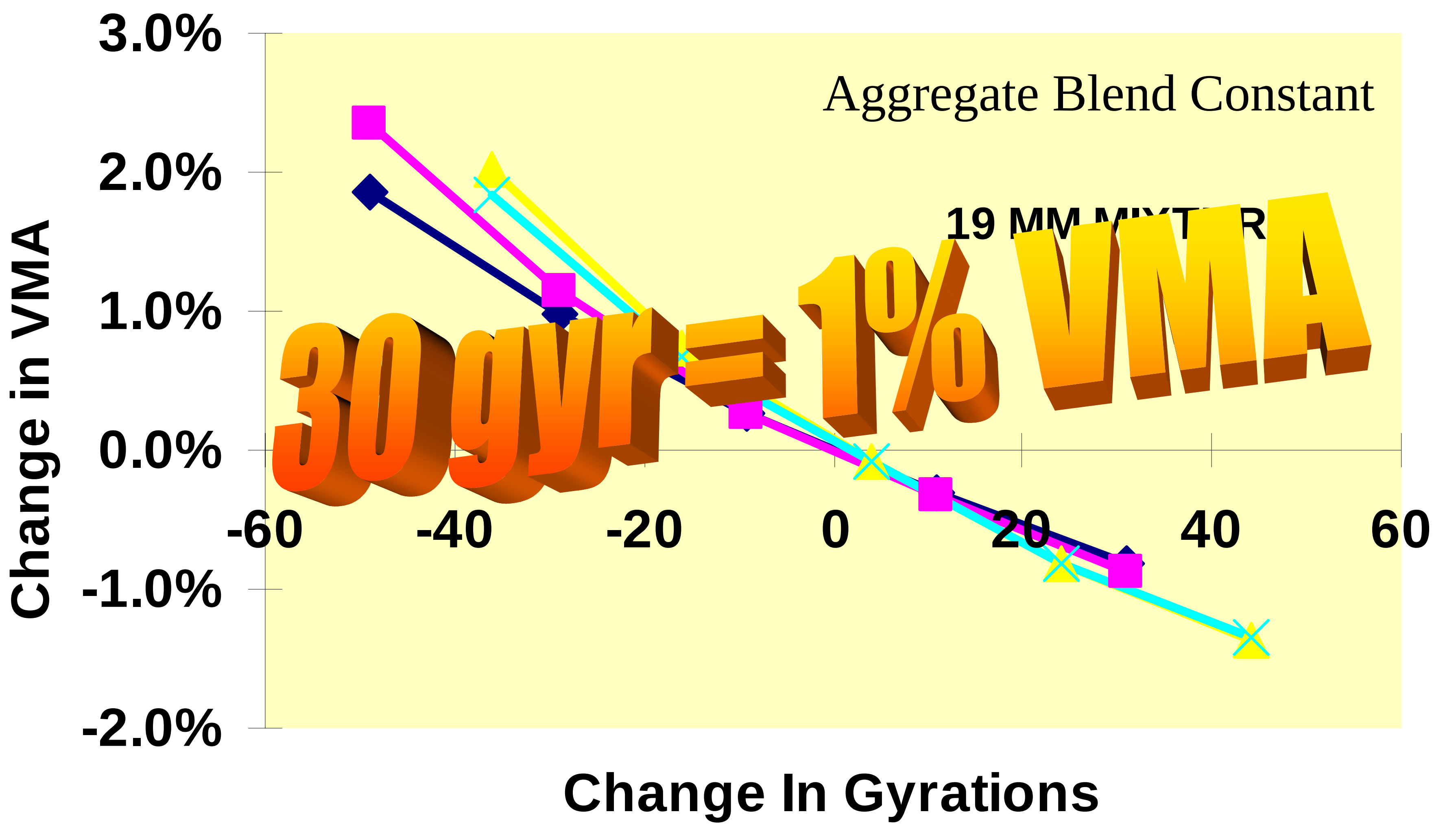


# So What To Do?

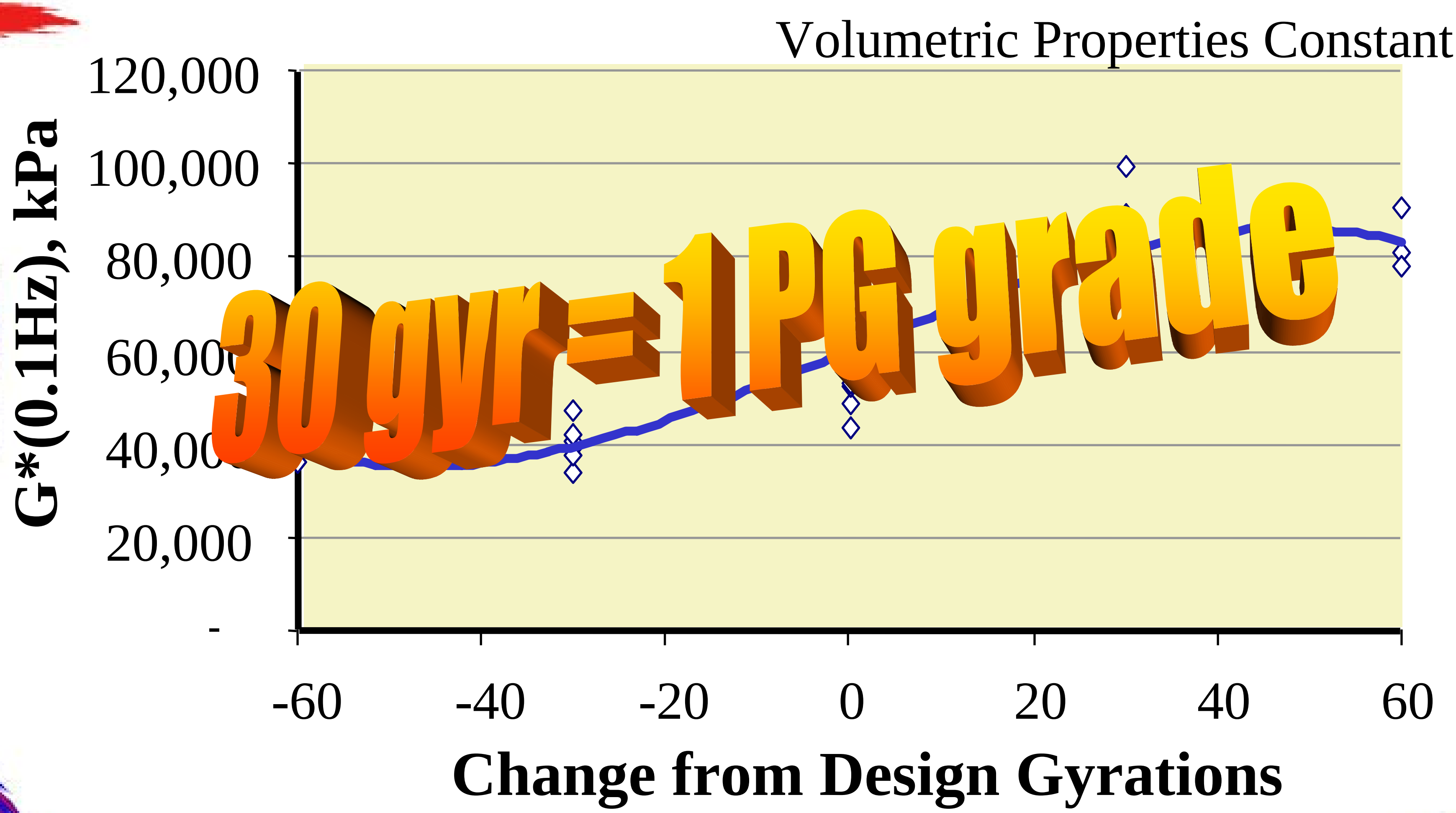
Look at the effect of N-design on mixes

- For Same Aggregate Skeleton N Design will cause change in
  - VMA
  - Mix Stiffness

# Effect on VMA



# Effect on Stiffness

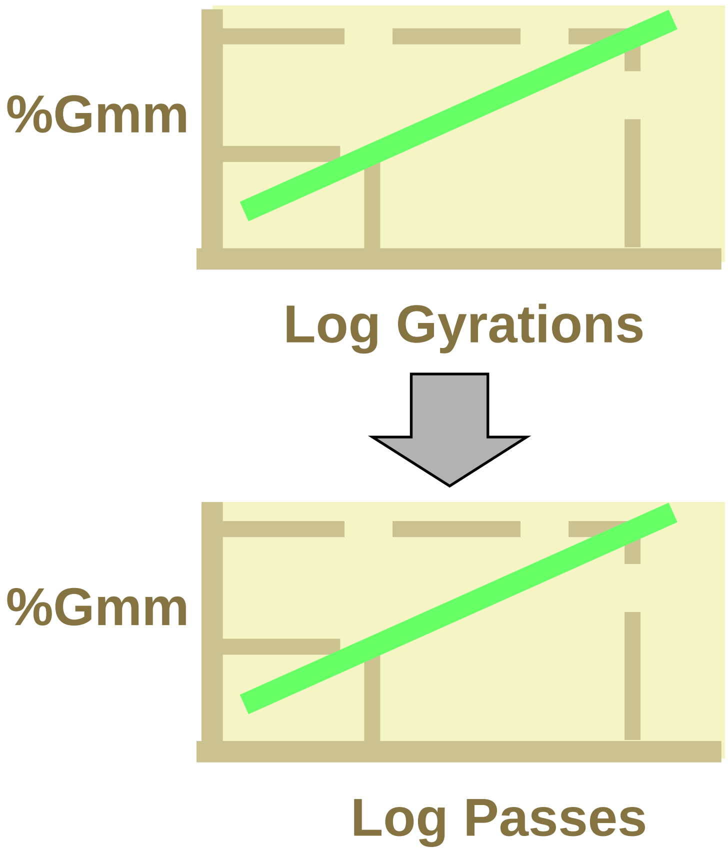


# Revised Table

| 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 |

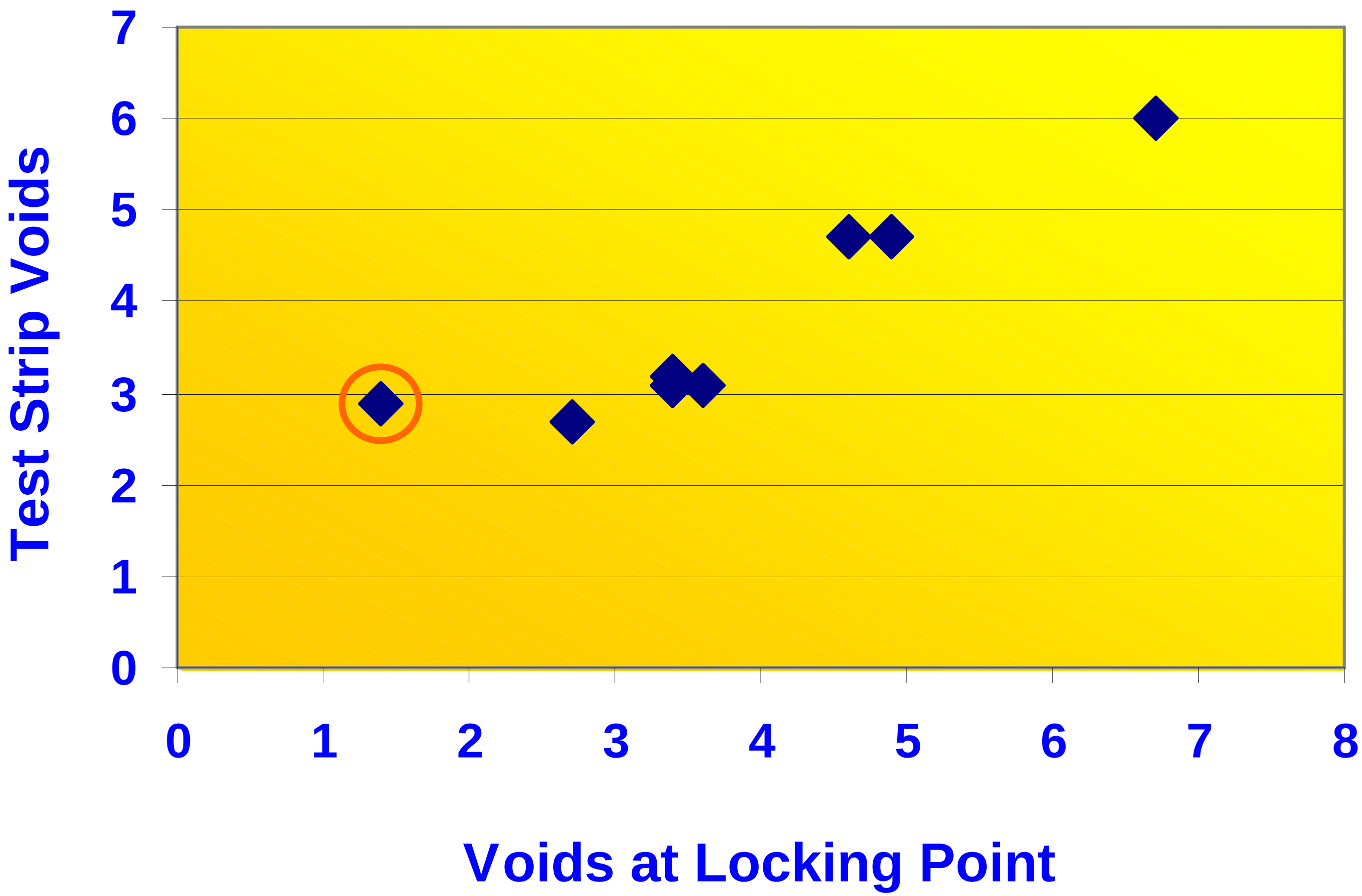
# N-Design III Experiment

**Relate Density**
**to**
**Compaction**



# Relate Gyrations to Passes

# Relating Compaction to Locking Point



# BUT!!!

- Compaction depends on
  - Gradation
  - Lift thickness
  - Base temperature
  - Available rollers
  - Etc.

# ....SO?.....

- Is our current N-design OK?
- Or should we do more research?

- What is the effect of N-design on mixes??

# 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 Volumetric Properties

| Property | Increased $N_{des}$ | Decreased $N_{des}$ |
|---|---|---|
| Air Voids | none | none |
| VMA (%AC) | none* | none* |
| VFA | little | little |

# Influence of $N_{design}$ on Mix Properties

| Property | Increased $N_{des}$ | Decreased $N_{des}$ |
| --- | --- | --- |
| Stiffness | increase ↑ | decrease ↓ |
| Compaction | difficult ↓ | easy ↑ |

# CONCLUSIONS

- Density at end of service life not rational to define N design
- Current spec based on engineering judgment (and is reasonable)
- Test strip density is more rational (would require more research)

# SO!!!!
# There is no TRUE N-Design