Relating N_{design} to Field Compaction

–a Case Study in Minnesota

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Research Background

- Importance of field density has been well recognized.
  - Field density $\rightarrow$ durability.
- Current situation of field density:
  - Mixtures are designed to 96%G_{mm}, but typically can only reach 93%G_{mm} in the field.
  - A mismatch between design density and field density.
  - Durability related issues are prevalent.
- Reason for the low field density, in terms of mix design
  - Design compaction effort (N_{design}) is chosen too high (Prowell and Brown, 2007; Waston et al., 2008; Harmelink and Aschenbrener, 2002).

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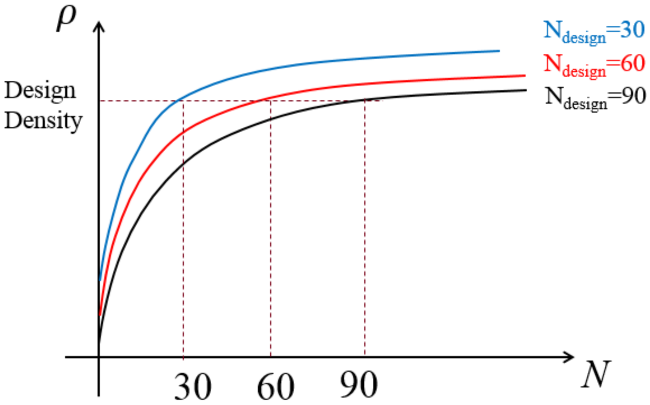
Effect of N_{design} on Compactability of Mixtures



- For fixed design air voids: ↑ N_{design} → ↓ compactability → ↓ field density level.
- What value of N_{design} should we use?

Previous Study

Superpave 5

- Developed by Purdue University, Heritage Research Group, and INDOT (Huber et al., 2016, Hekmatfar et al., 2015).
- Achieve a consistency between design density and field density.
  - "Design to 5% air voids and compacted to 5% air voids in the field".
- N_{design} must represent the field compaction effort.

Table: Values of N_{design}

Traffic level	3 (1-3m ESAL)	4 (3-10m ESAL)	5 (10-30m ESAL)
MnDOT Spec.	60	90	100
Superpave 5	30	50	50

Objective

- Propose a rational method to estimate field compaction effort as number of gyrations.

Outline

1. Analysis of field density data: effect of N_{design} on field density
2. Estimate field compaction effort by using field density data
3. Case study: a Superpave 5 project in Minnesota
4. Conclusions and future directions

Effect of N_{design} on Field Density

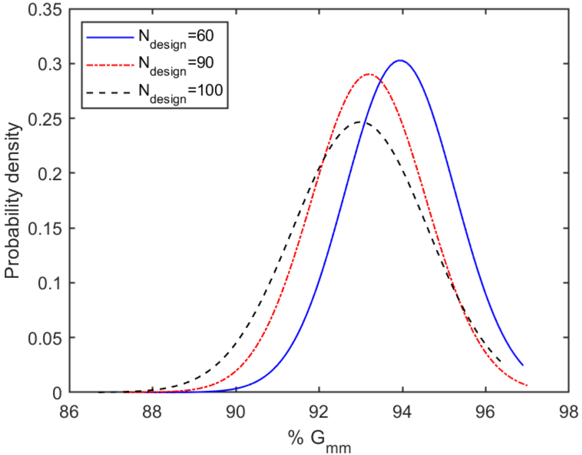


Figure: Field density distribution of projects of different traffic levels (N_{design})

- 1354 density data of field cores were collected from 15 projects, including traffic levels 3, 4 and 5.
- N_{design} for traffic levels 3, 4 and 5 are 60, 90, and 100 respectively.
- Field density decreases with the increase in N_{design}.
- N_{design} can serve as a design parameter to control field density.

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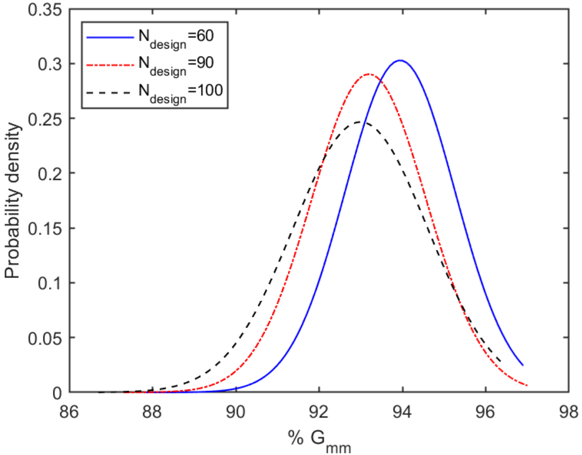

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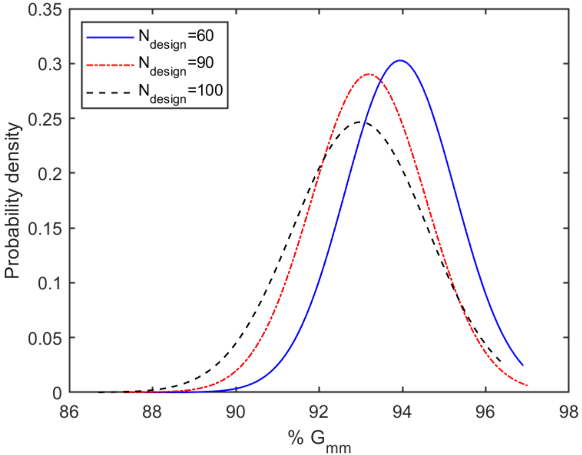

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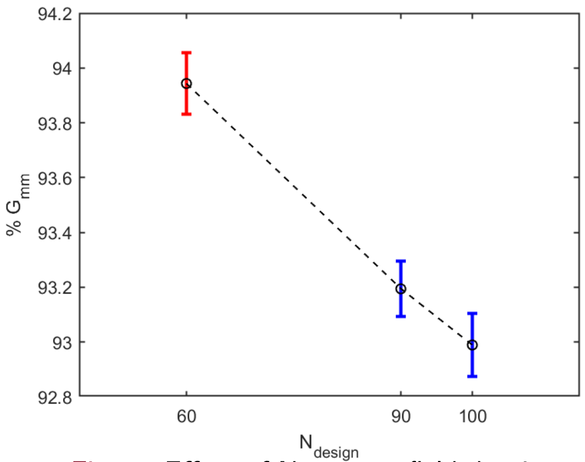

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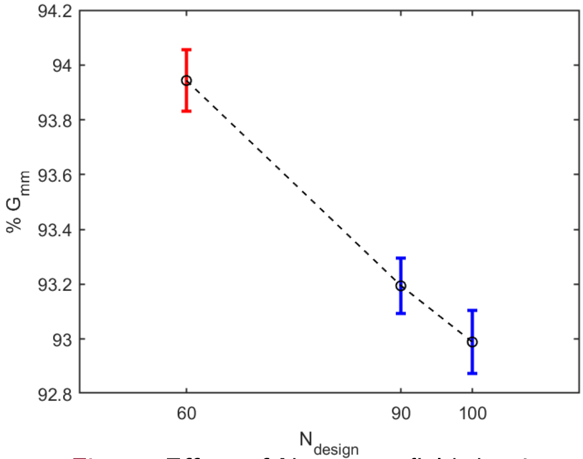

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Estimating Field Compaction Effort

- A concept, "the equivalent number of gyrations to field compaction", or $\mathbf{N_{equ}}$, is proposed to characterize field compaction effort.

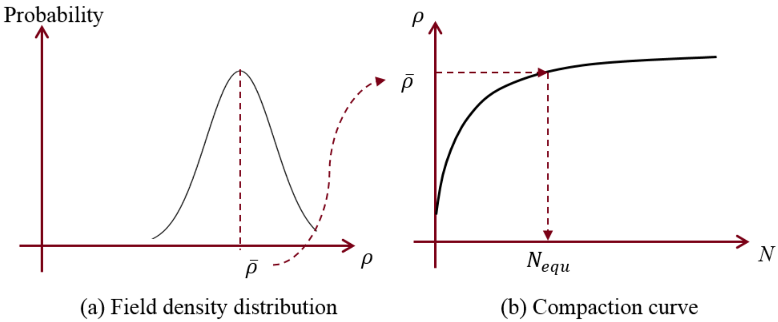


Figure: The idea of calculating N_{equ}

Results of N_{equ}

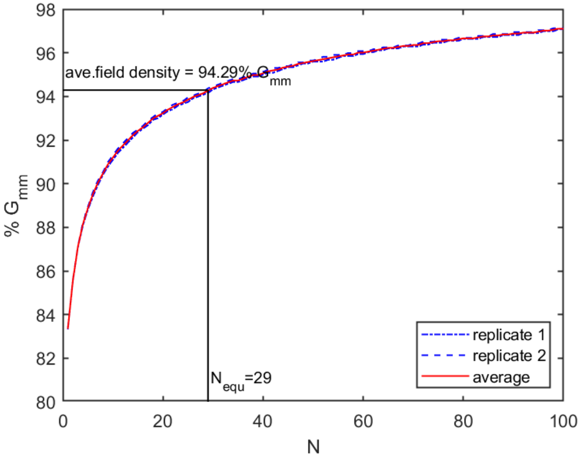


Figure: An example of calculating N_{equ}

Results of N_{equ} (cont.)

Table 3 N_{equ} values of the five recent Minnesota projects.

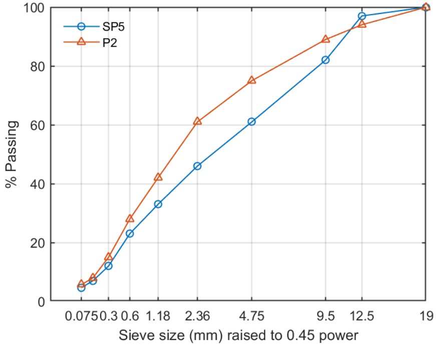
Traffic level	N_{design}	Project ID	Mean field density	N_{equ}	Ave. N_{equ}
3	60	P1	94.29	29	28.7
		P2	93.98	29	
		P3	94.72	28	
4	90	P4	93.10	26	26.5
		P5	93.28	27	

- $N_{equ} \approx 30$

Outline

Set N_{design} as N_{equ}

- A SP5 mixture was designed and placed on a project in Minnesota. The N_{design} was chosen similar to the computed N_{equ}.
  - $N_{design} = 30$, design air voids = 5%.
- The field density and performance test results of this project were compared with a traditional project (P2), which has the same NMAS and traffic level as the SP5 project.



Field Density

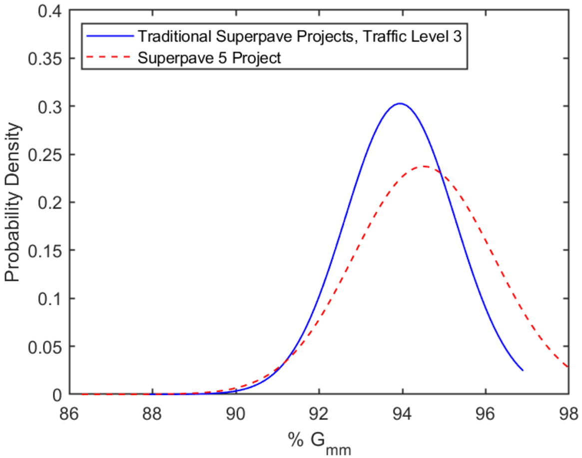


Figure: Comparison of field density distribution

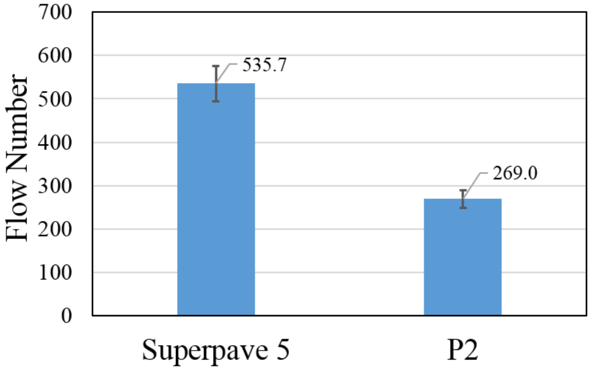
- Mean field density:
  - SP5 (94.69%) > Traditional SP (93.94%)
- Standard Deviation (variability):
  - SP5 (1.98%) > Traditional SP (1.32%)

Performance Tests

- Rutting Resistance: Flow Number Test
- Dynamic Modulus: Diametral E* Test
- Cracking Resistance: SCB Test

Performance Tests

Rutting Resistance, Flow Number Test



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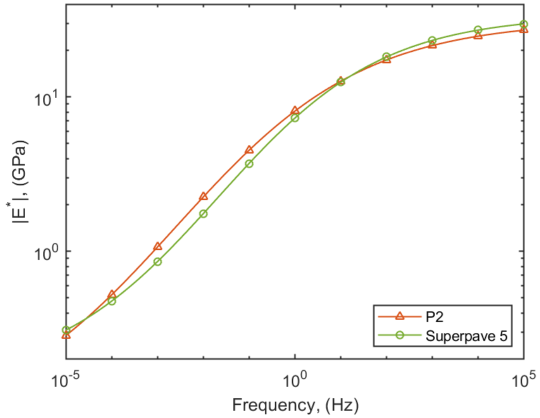
Dynamic Modulus, Diametral E* Test



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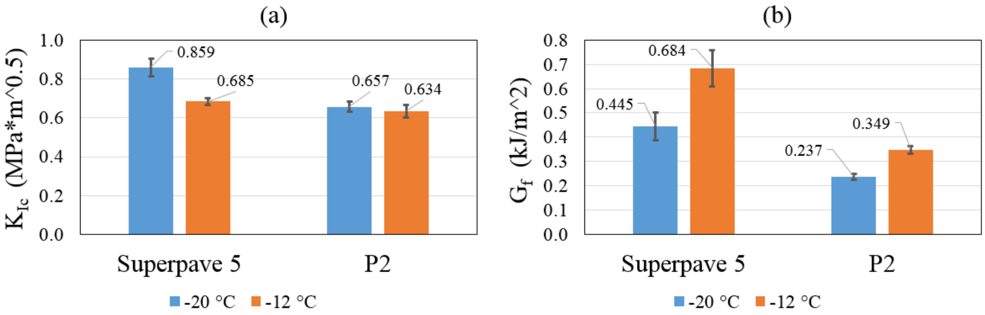

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- There is a clear negative correlation between N_{design} and field density.
- A new parameter, N_{equ}, was proposed to characterize the field compaction effort.
- $N_{equ} \approx 30$, regardless of traffic level or NMAS.
- By setting N_{design} as N_{equ}, the field density level of the SP5 mixture is significantly improved to the design density level.
- Performance tests results show that the rutting and cracking performance of SP5 mixture are not sacrificed compared with the traditional SP mixture.

Future Directions:

- Understand the randomness in field density distribution.

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Thank you!