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Evaluation of high-density asphalt mix designs for sustainable pavements

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Summary

- Problem: How to increase the field density of asphalt pavement?

Background

- In the late 1970s and 1980s, rutting became prevalent in the US, due to the increase in the heavy truck traffic and the use of radial tire.
- In the 1990s, The SHRP (Strategic Highway Research Program) was carried out to solve the rutting problem. Superpave Mix Design method was a product of SHRP.
- In the late 2000s, after the implementation of Superpave in the US, it was found that rutting distress was reduced, but, instead, durability related distresses (water damage, cracking, and raveling) became the most prevalent issues.
- Numerous studies have shown that the durability issues are results of the low field density.

Background

- Reasons why Superpave mix design method tend to cause low field density.
  - A general believe: Low air voids mixtures (density > 97% of Gmm) tend to have rutting issue.
  - Based on that, Superpave designs mixture having an as-constructed density of 92% Gmm, which will be finally compacted by traffic to an ultimate density of 96%.
  - In practice, a large proportion of pavements cannot achieve the ultimate density of 96% Gmm.
  - Clearly, The 92% as-constructed density is very low, and is inadequate to guarantee the durability.

Objective

- How to solve the low field density problem
  - 1. Improve the field compaction.
  - 2. Change the mix design to make the mixture more compactable
    - 2.1 Change binder content
    - 2.2 Change aggregate gradation

- Objective: Increase the field density of asphalt pavement through mix design.

- Main problem we are solving: the relationship between material composition and compactability of mixtures.

Approach

Material composition:
- Binder content
- Aggregate gradation

$\longleftrightarrow$ Relationship

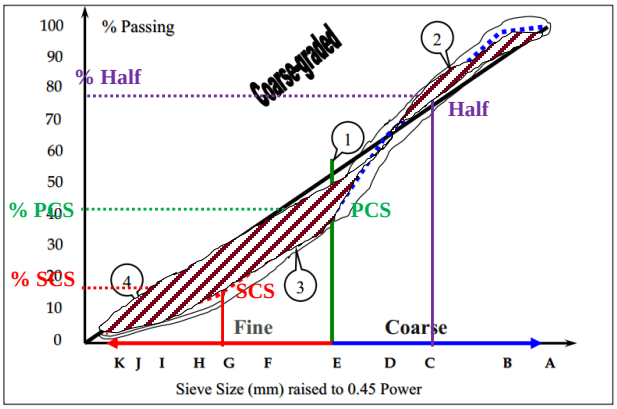
Compactability of mixture

- Correlation analysis
  - How to characterize aggregate gradation
  - How to characterize compactability

Results

Characterization of Aggregate Gradation Curve

- Bailey Method Parameters: $\%PCS, CA, Fa_c,$
- Distance to maximum density line: d_{MDL}



PCS=0.22* NMAS

SCS=0.22* PCS

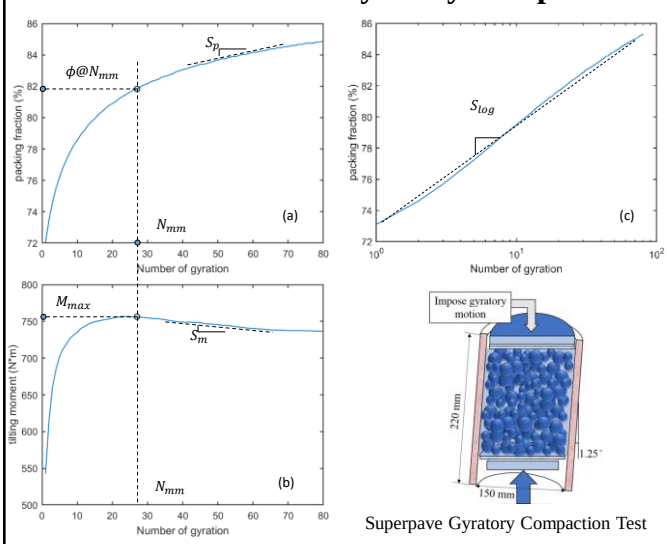
$$CA = \frac{(\%\text{Half} - \%\text{PCS})}{(100\% - \%\text{Half})}$$

$$Fa_c = \frac{\%\text{SCS}}{\%\text{PCS}}$$

d_{MDL}= area of the shade

Results

Characterization of Gyratory Compaction Curve



Superpave Gyratory Compaction Test

N_{mm} : Number of gyration when reaching the maximum shear resistance.

M_{max}: Maximum shear resistance at N_{mm}.

$\phi@N_{mm}$: Volume percentage of aggregate at N_{mm}.

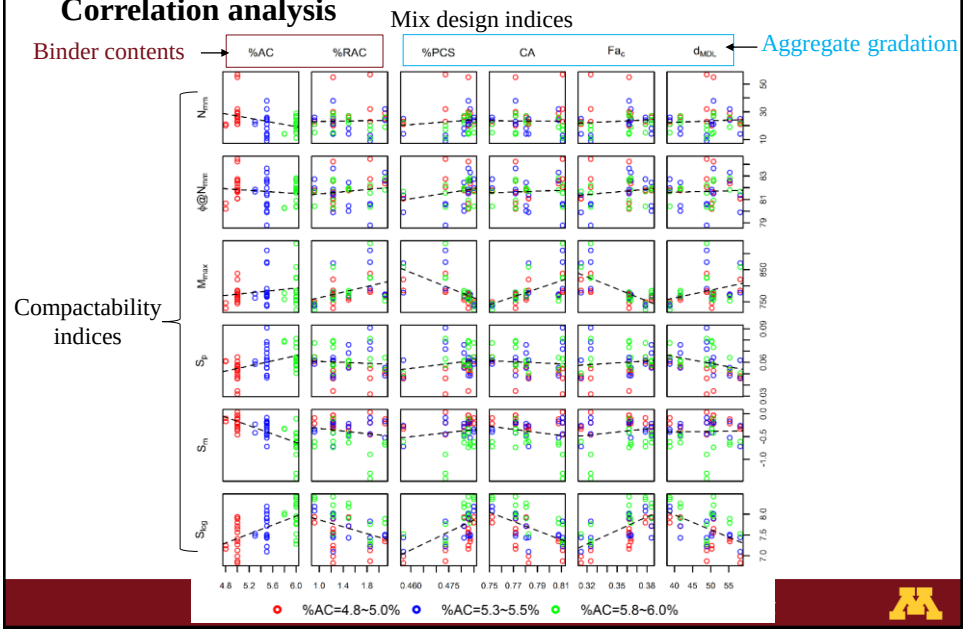
S_p: compaction rate in the second phase.

S_m: Decreasing rate of the shear resistance in the second phase.

S_{log}: overall compaction rate

Results

Correlation analysis



Results

Correlation analysis

	%AC	%RAC	%PCS	CA	FA_c	d_{MDL}
N_{mm}	-0.35					
$\phi@N_{mm}$						
M_{max}		0.37	-0.60	0.57	-0.71	0.34
S_p	0.41					-0.32
S_m	-0.65					
S_{log}	0.55	-0.38	0.59	-0.54	0.66	-0.54

- Binder content (%AC) increases compaction
  - It increases the compaction rate,
  - and decreases shear resistance.
- Reclaimed binder content (%RAC) has a negative effect on the compaction
  - It decreases compaction rate,
  - and increases shear resistance.
- The correlation between Bailey method parameters and compactability show that
  - An increase in the fineness of fine aggregates improves compaction,
  - while an increase in the fineness of coarse aggregates makes the mixture harder to compact.
- The distance to the maximum density line has a clear trend of decreasing compactability.

Conclusions

- The proposed indices based on compaction curves can characterize the compactability of mixture very well
- Correlations between mix design indices and compactability were identified
- These correlations can be used in mix design to adjust binder content or aggregate gradation to enhance field compaction, and thus increase field density.

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Thank you!