Recent Research Topics at University of Minnesota

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Research at University of Minnesota

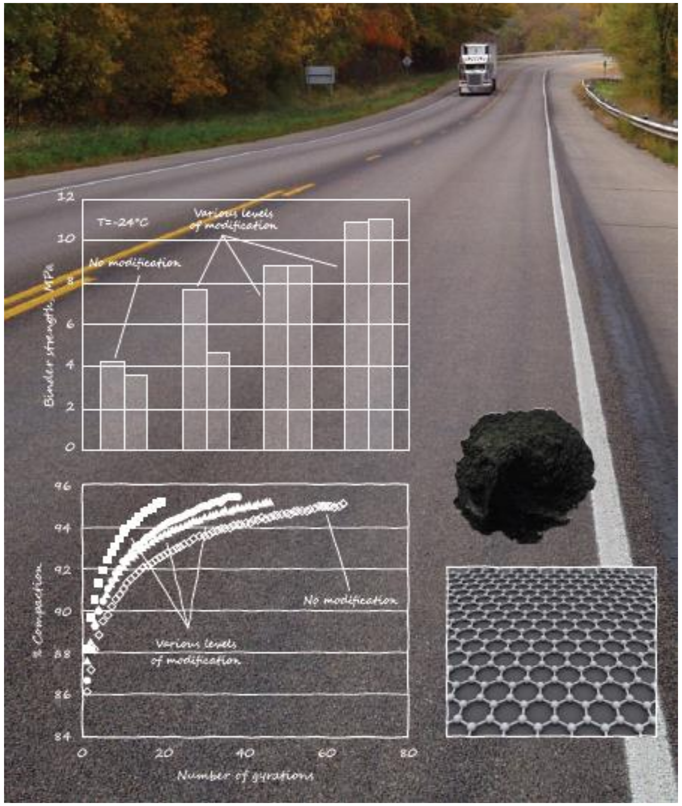
- Recent research efforts at University of Minnesota have focused on new materials and technologies and improved mix design
- They represent key components in achieving a sustainable pavement infrastructure that is well adapted to the climate and funding changes of the future.

GNP Modified Asphalt Paving Materials

- Graphite Nanoplatelets (GNP)
- Produced from either graphene or natural graphite.

GNP Modified Asphalt Paving Materials

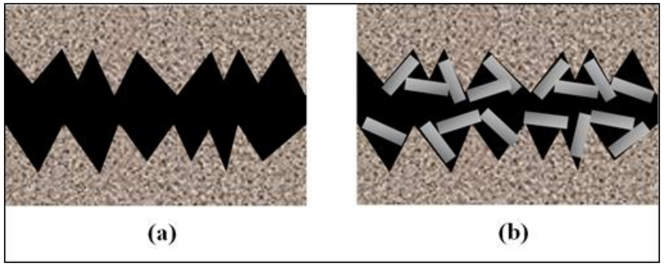
- Laboratory research performed on asphalt binders and mixtures showed that:
  - The addition of GNP (3 to 6% of binder weight) almost doubles strength of PAV binders at low temperatures
  - The addition of GNP almost doubled the SCB fracture energy of some mixtures



- The addition of GNP (3 to 6% of binder weight) increases mixture compactability

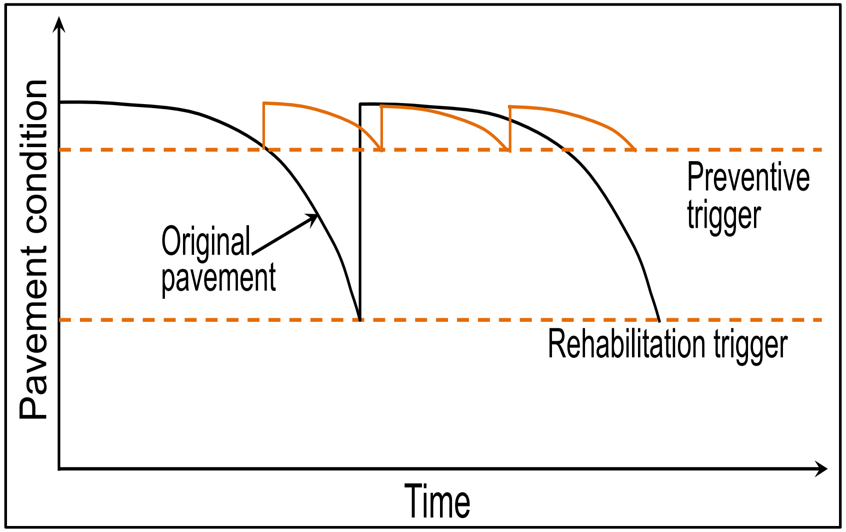
Tribology Study (with University of Ancona)

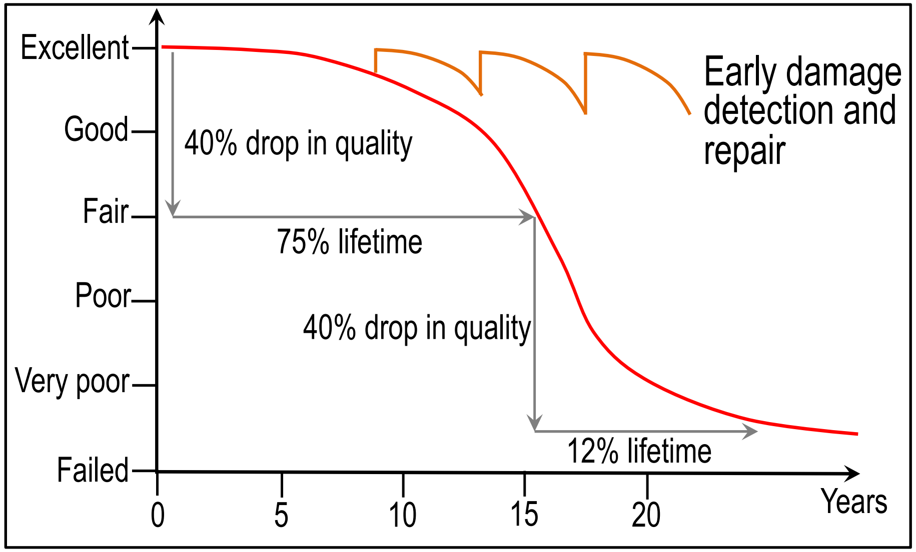
- Viscosity measurements indicate that the addition of GNP increases the viscosity of the binder!
- Reduction in friction coefficient when nanoparticles are added possibly due to mending



Electrical Conductivity for Sensing (on-going)

- Investigate electrical conductivity of Graphite Nano-Platelet (GNP) modified Asphalt Binders
- Early detection of cracking in pavements would allow timely repair, which is essential for extending the lifespan of the pavements



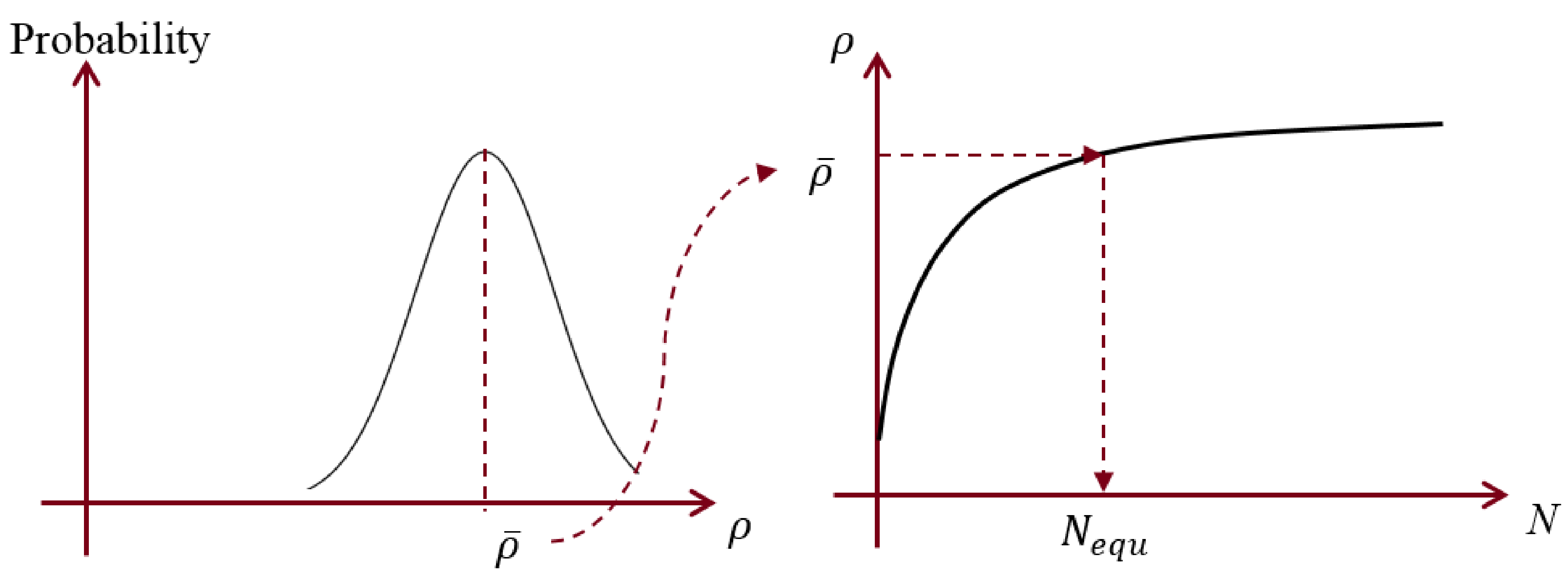


Superpave 5 Mix Design

- Importance of field density has been well recognized
  - Better compaction → higher density → better mechanical properties and increased durability
- Current situation:
  - Mixtures are designed to 96% G_{mm}, but can only be compacted to 93% G_{mm} in the field
  - A mismatch between design density and field density
  - Durability-related issues are prevalent
- Superpave **5** approach: design mix to 95% G_{mm} (**5**% air voids) and compaction it to 95% G_{mm} in the field

Equivalent Number of Gyrations

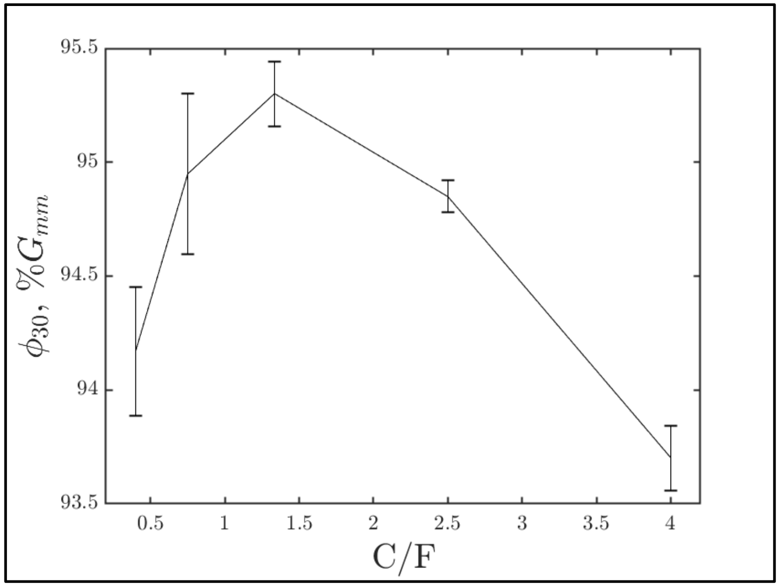
- A concept, "equivalent number of gyrations to field compaction" (N_{equ}) is proposed to characterize field compaction effort.



(a) Field density distribution (b) Compaction curve

Superpave 5 Mix Design

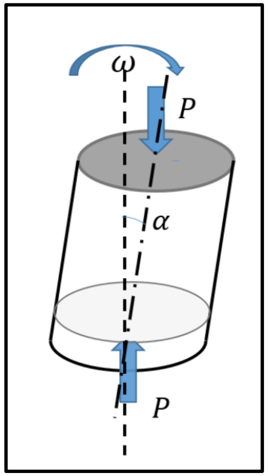
- New design adjusts the aggregate gradation so that at an approximate value of 30 gyrations, 95% G_{mm} can be achieved in the laboratory
- No change in binder content is necessary
- Research showed that there is an optimum value of the ratio between Coarse and Fine aggregates that maximizes the compactability at 30 gyrations of the mixture.

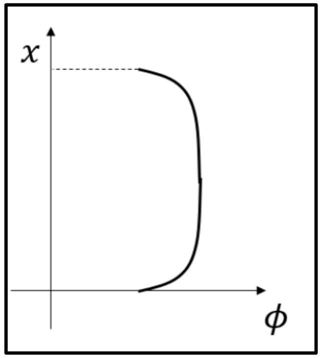


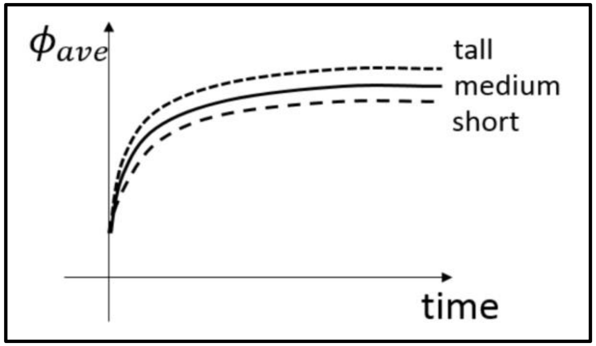
Modeling of Gyratory Compaction

- Model of gyratory compaction needed to explain the process by physical mechanisms and identify parameters responsible for compactability and field variability

- Experimental observations that have to be captured by the model:
  - Vertical Density profile has a bathtub shape.
  - Rate of densification decreases with time.
  - Size effect: taller specimens are easier to compact than shorter ones.

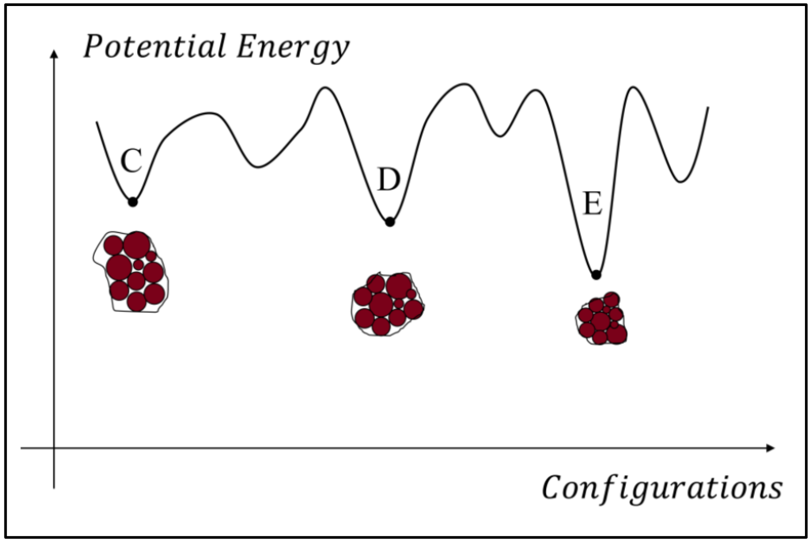






Physical Mechanism

- Static compression alone leads to limited compaction
  - Aggregates jam to a stable packing state (jammed state)
  - Represented by a local minimum (metastable state) in the energy landscape.



- Shear or vibration excitation provides the aggregates with kinematic energy to jump out of the energy well and evolve to denser packing states with lower potential energy

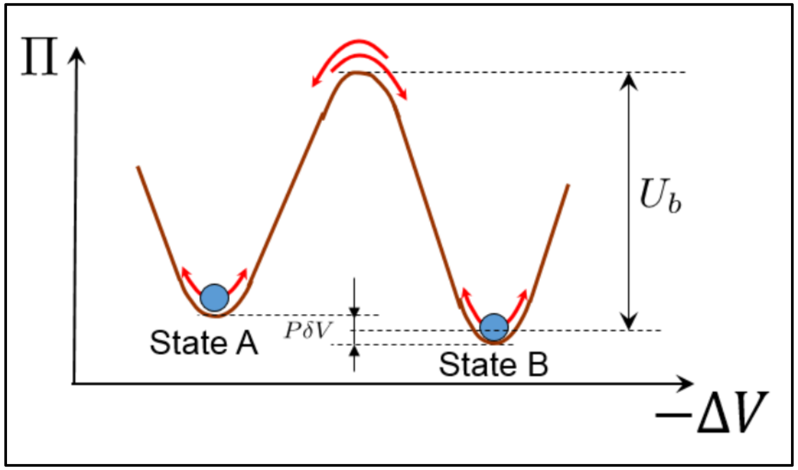
1D Model for Gyratory Compaction

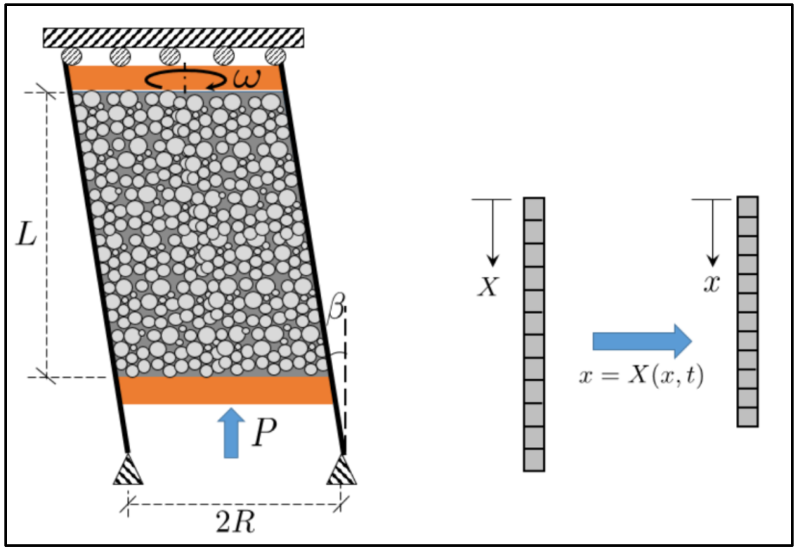
- The rate of densification at a material point can be estimated by the transition rate theory of statistical mechanics:

$$f = f_0 \exp(-U_b/E_s).$$

U_b is the energy barrier and E_s is the kinematic energy of the random motion of aggregates.

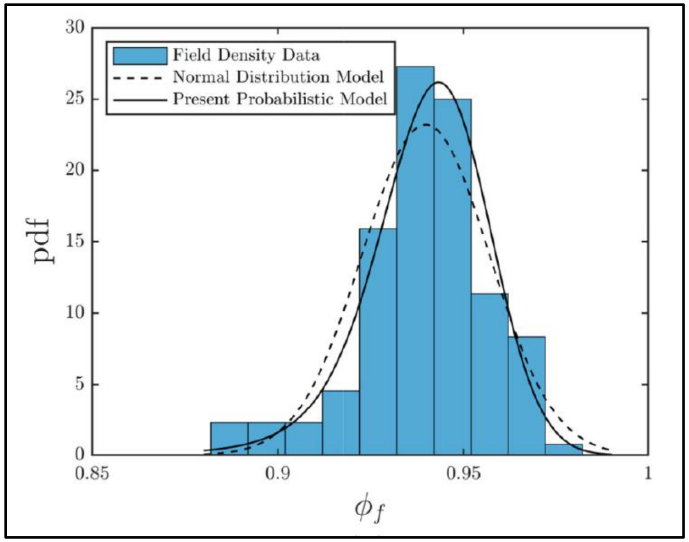
- The gyratory compaction process can be simplified to a 1D problem, and simulated by the densification rate model and the balance of mass.



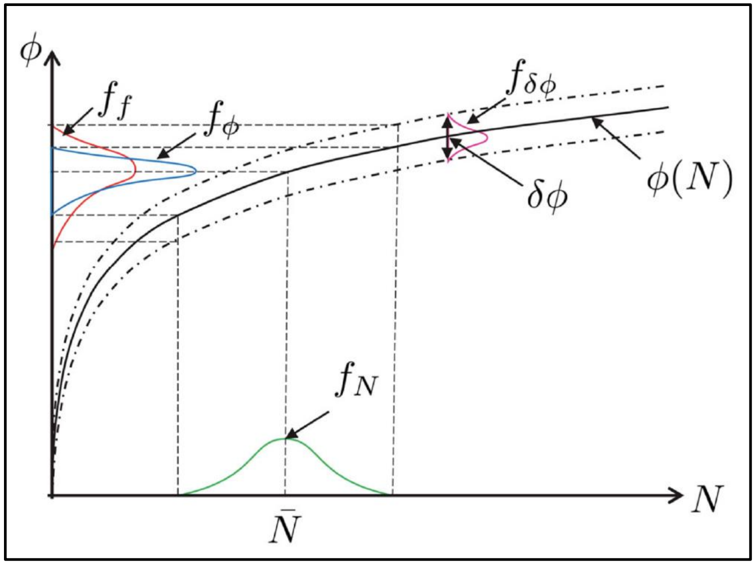


Probabilistic Model for Field Density Distribution

- Field density does not follow Gaussian distribution
  - Left-skewed (skewness < 0) and leptokurtic (kurtosis > 3)



- The stochastic features of field density distribution can be explained by the gyratory compaction model considering the randomness in the compaction curve and in compaction effort (N)



Comments and Questions

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