Discrete Element Study of Aggregate Damage during Asphalt Compaction

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Introduction

• **Aim:** Computational model for asphalt
  – Prediction of compaction and flow properties

• **Properties of stones and binder**
  – Easy to change binder content, gradation etc...
  – Possible to optimize mixtures
Introduction

• Large deformations
  – Mixing, transportation, handling, placement ...

• Load transfering mechanism
  – Stone – to – stone contacts

• Micromechanical modelling
  – Quantitative link between material and mixtrue properties
Agenda
1. Introduction
2. Discrete element method for asphalt
3. Simulation results
4. Conclusions and outlook
Discrete Element Method (DEM)

- Modeling single particles
- Explicit integration of Newton’s second law $F = ma$
- $F$ - contact force on each particle
- Time consuming!
DEM is well suited for compaction problems
- As long as all contact points can be treated independently [1]

[1] On the Effect of Particle Size Distribution in Cold Powder Compaction
Contact law is of utmost importance

- **Binder**
  - Viscoelastic
  - Cohesive

- **Stones**
  - Elastic
  - Can fracture
Contact model for asphalt particles

Stones surrounded by binder layer

Separation of stone and binder properties!

\[ R_{1,\text{stone}} + R_{2,\text{stone}} + 2t_{BP} - h \]
Stone properties

- Elastic, $E = 65$ GPa
- Fracture strength from experiments [2]

No compressive stiffness parallel to the crack

• Soft viscoelastic binder-binder contact [3]
• Stiff stone-stone contact
• Bonding by surface energy

Olsson and Jelagin, Submitted to Powder Technology (2018)
Simulation study
• Two different gradations
• Mass distribution -> number of particles
• Only stones > 4 mm — < 4 mm in mastics phase
Material properties

- Sand mortar (binder and < 2.36 mm)
- Viscoelastic response from [4]

Gyratory compaction

- Compactability and aggregate damage

Number of particles: 5000
Pressure: 600 kPa
Inclination: 1 °
Gyrations: 100
Gyration Speed 0.5 gyr/s
Gyratory compaction

Air void evolution

Aggregate damage
Flow test, developed at KTH [5]

- Flow and shear properties

Number of particles: 5000
Loading velocity: 15 mm/min
Loading force and uplift

Flow test

Force-displacement

Maximum uplift
Conclusions and outlook
• DEM is a promising tool for studying asphalt materials
• Possible to uncouple stone and binder properties
  – Enables optimization of mixtures
• Future: Quantitative predictions by in-house experiments