The Future of the Discrete Element Method in Infrastructure Analysis

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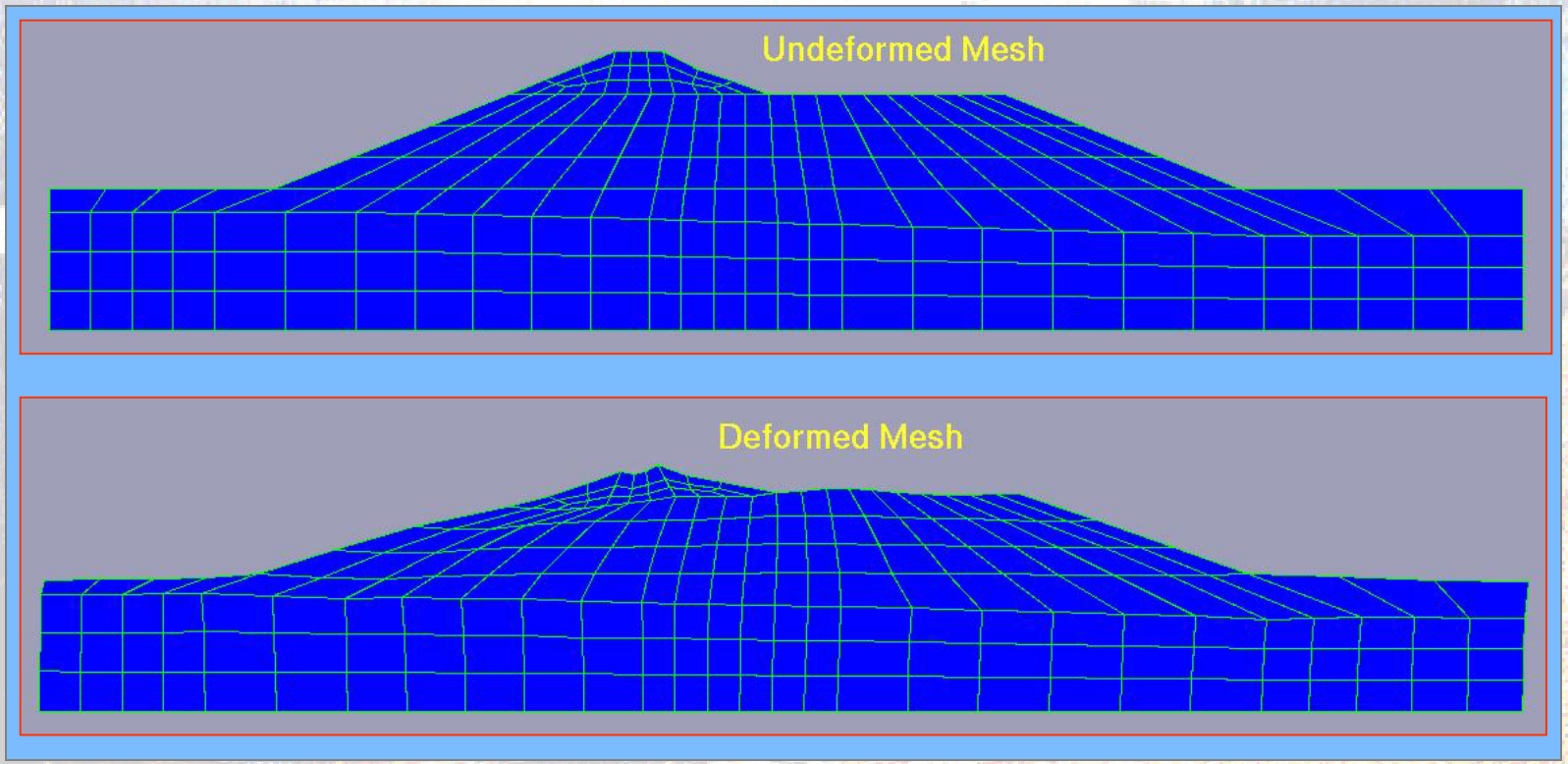
Finite Elements Imply Continuity



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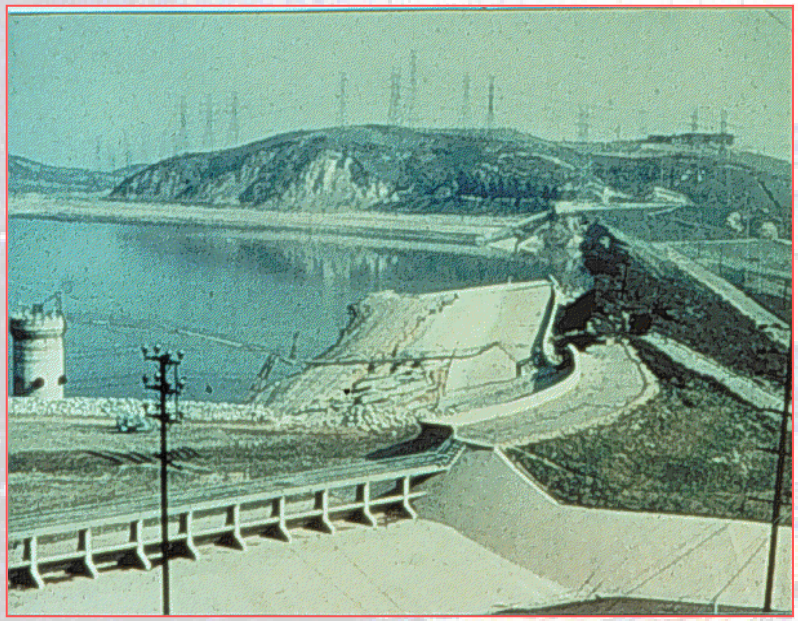
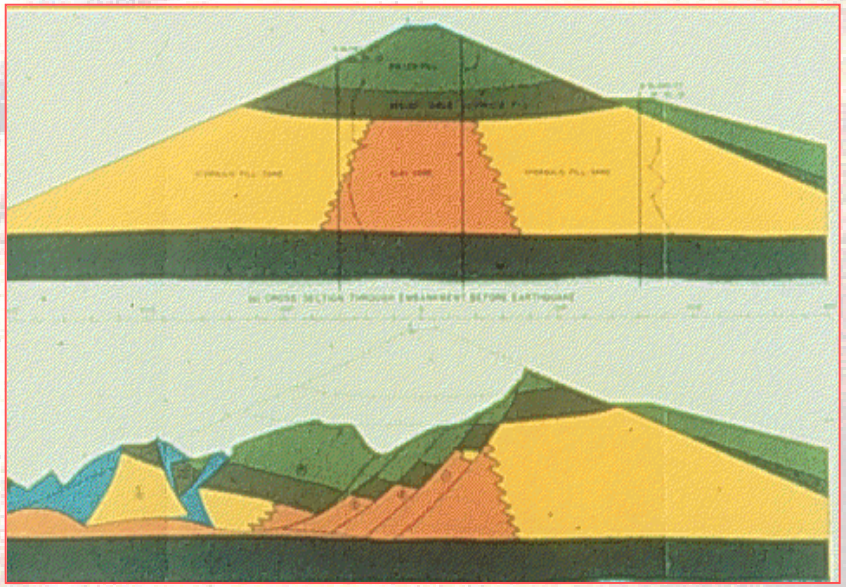
Challenges in Failure Mechanics



Large deformations with discontinuities are difficult to model by conventional finite elements.



Simply having a factor of safety not enough.

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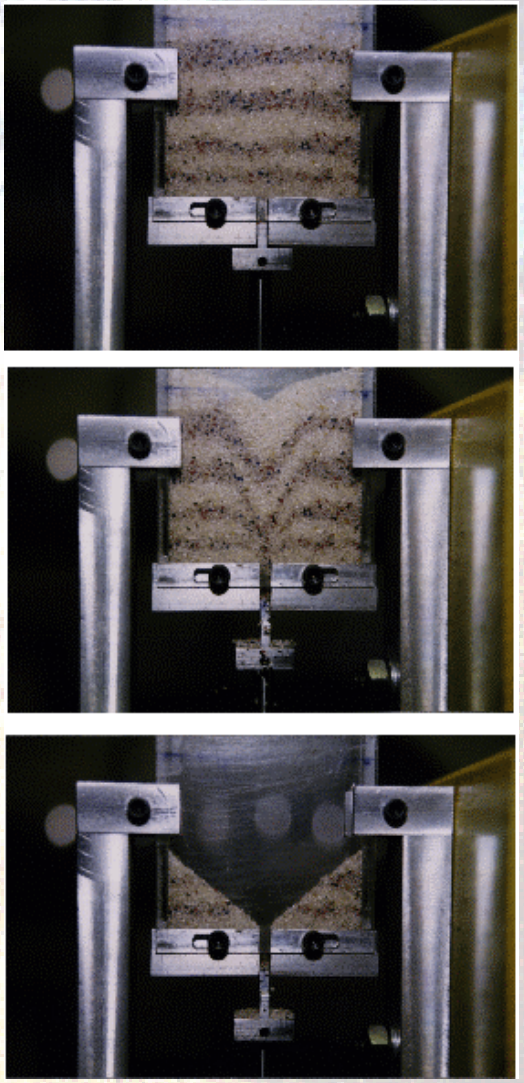
Particle Methods for Large Deformation Problems

- The trap door experiment is a classical geotechnical problem from earth pressure theory
- Soil behavior ranges from solid to flowing fluid.
- Particle methods are a natural way to address such problems



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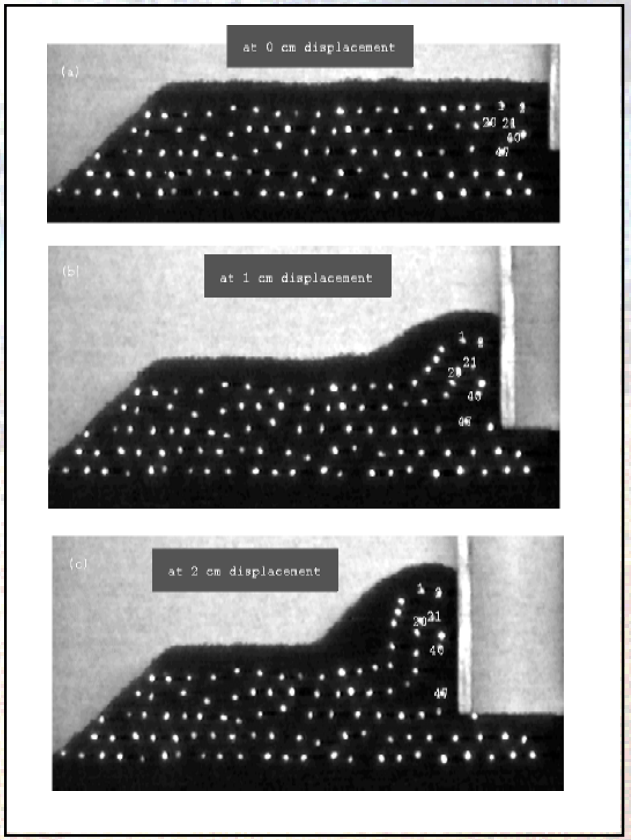
Discontinuous Shear

- The passive resistance to motion a rigid wall into sand is an example of very large deformation
- The discontinuous nature of the motion at the base of the wall is especially challenging for traditional numerical methods.



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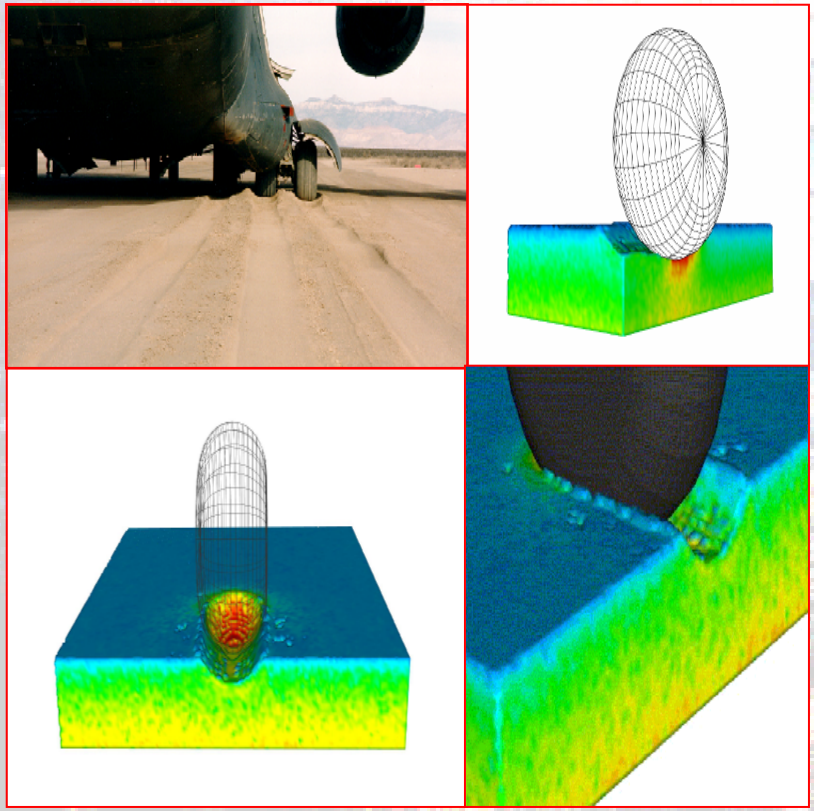
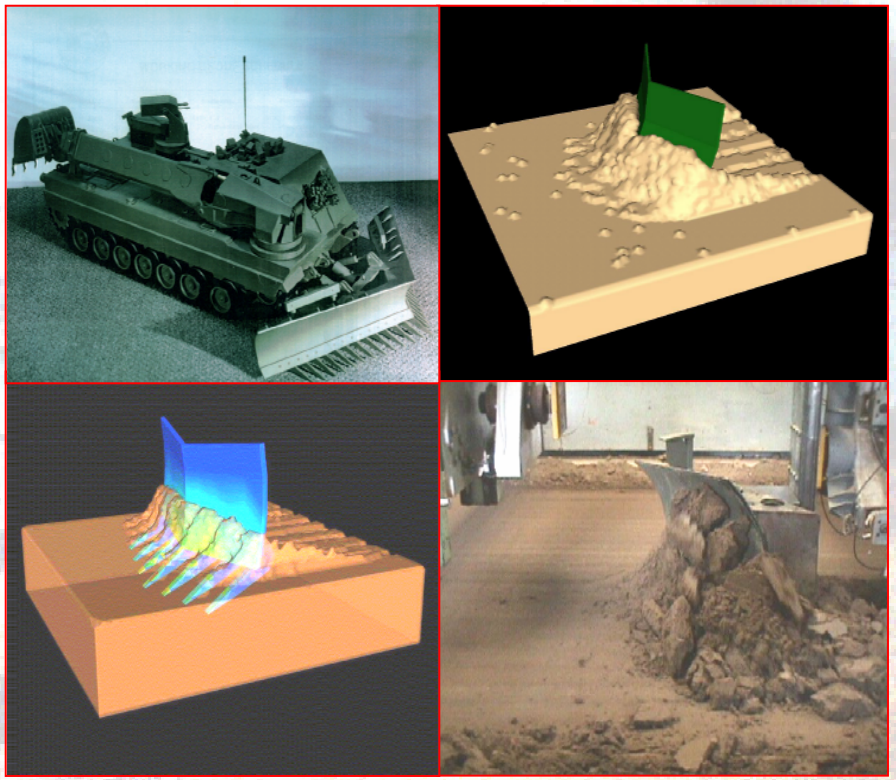
Numerical Methods for Mobility Modeling





- Vehicle mobility mechanics has much in common with failure mechanics in geotechnical engineering.

- Recent advances in particle methods for mobility modeling hold promise for failure mechanics in geotechnical applications.

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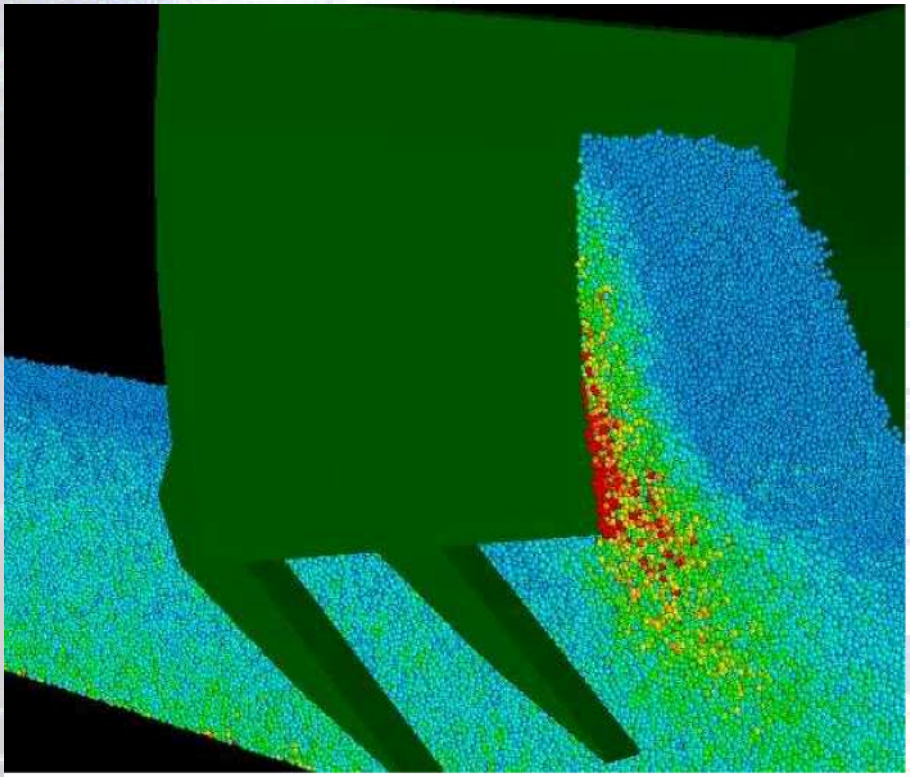

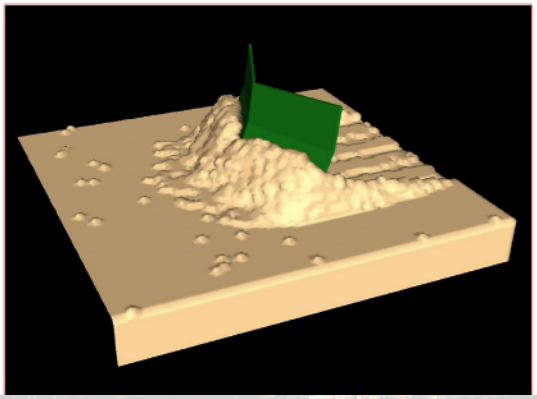

Particle Modeling with the Discrete Element Method

- DEM depicts the soil as individual particles rather than connected elements.
- The particles move in accordance to simple interaction laws rather that complicated constitutive models.

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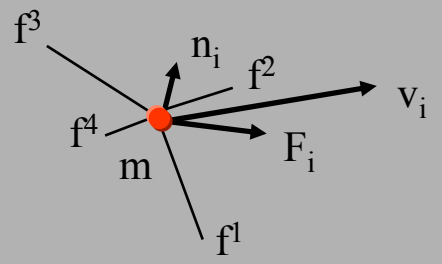
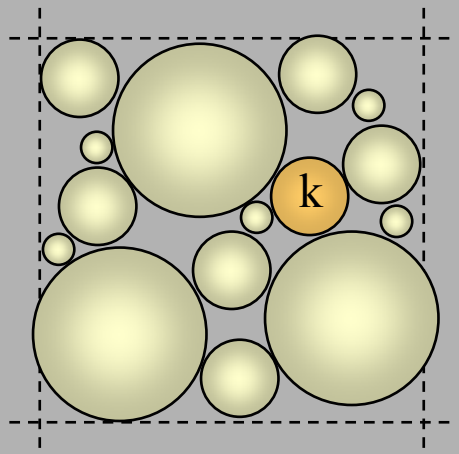
DEM Mechanics

- Physics based
- Replicates particulate nature of soil
- Slip planes and separations form between groups of particles thus capturing evolving failure mechanisms more realistically



Forces Acting on Particle k



Discrete Particle System

force → acceleration → velocity → displacement

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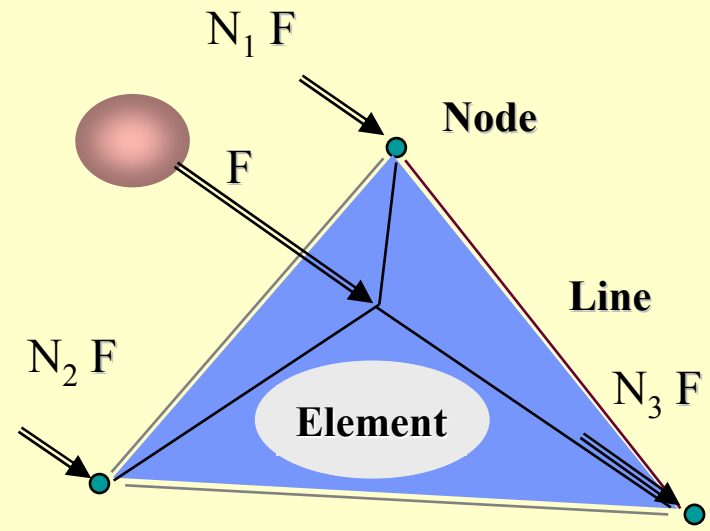
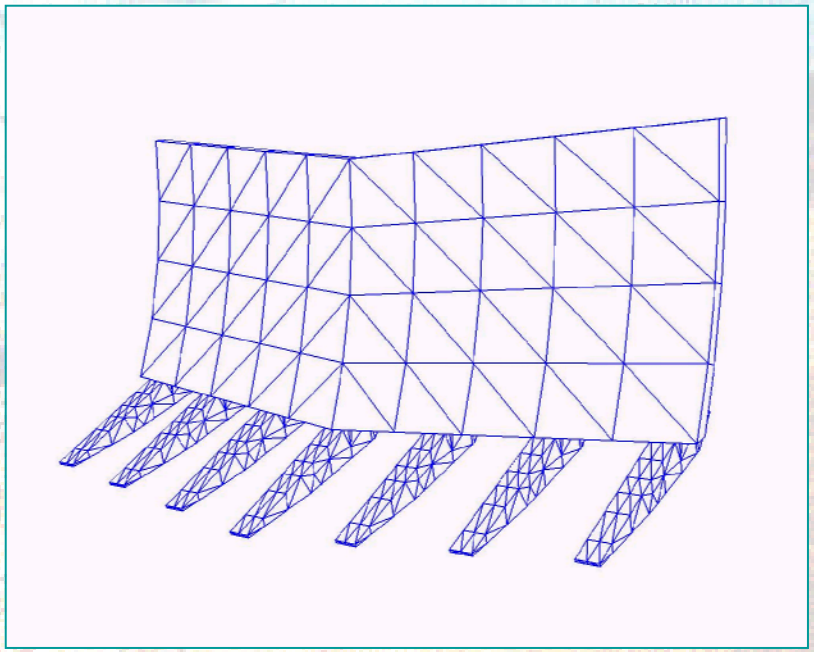
Interaction with Finite Element Structures

$N_1 + N_2 + N_3 = 1$





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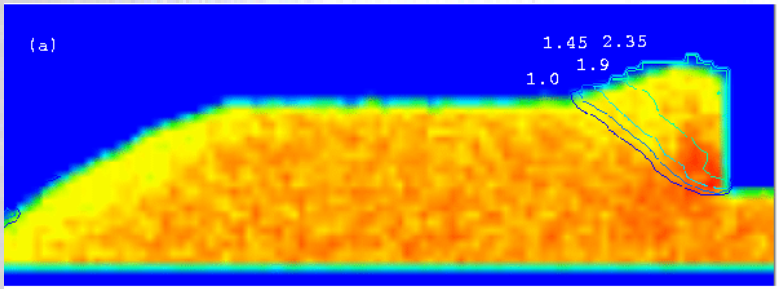
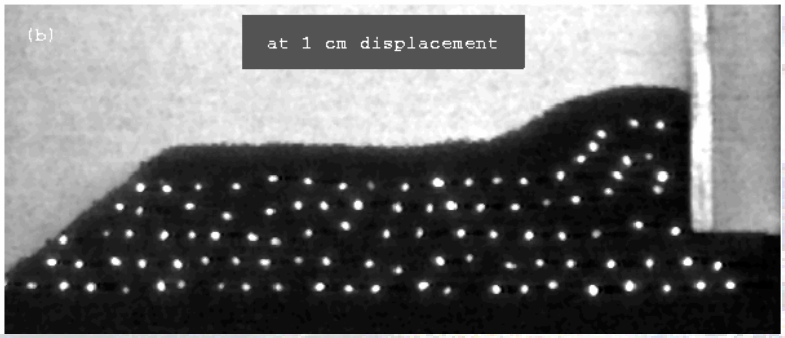
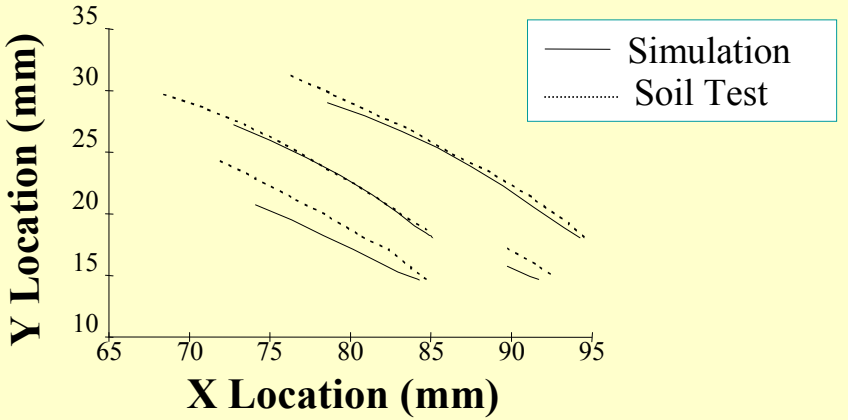
Simulation of Wall Experiment

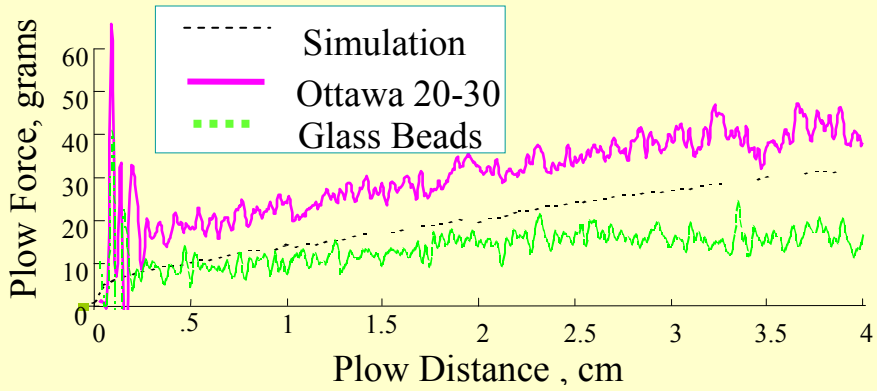




General character of deformation was reproduced well.



Quantitative agreement was achieved for displacement and force.



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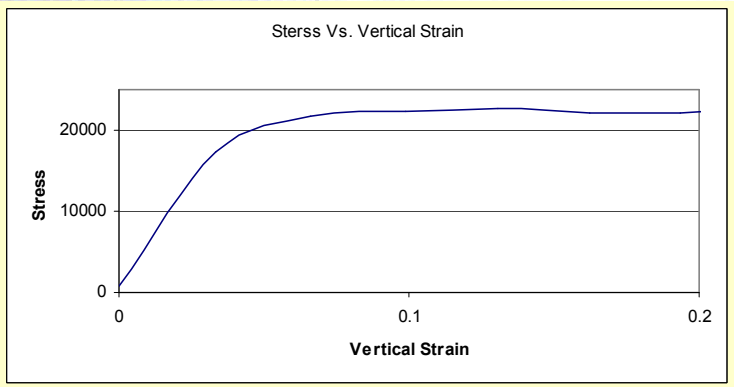
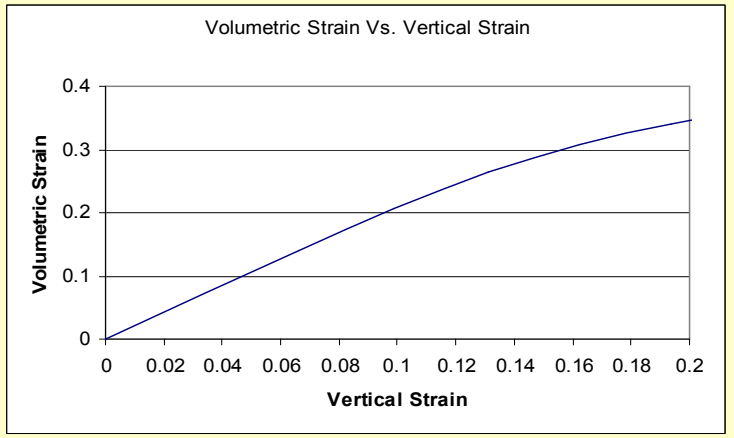
Simulated Laboratory Experiment





Simulated stress-strain and volume change curves

Simulate specimen after formation

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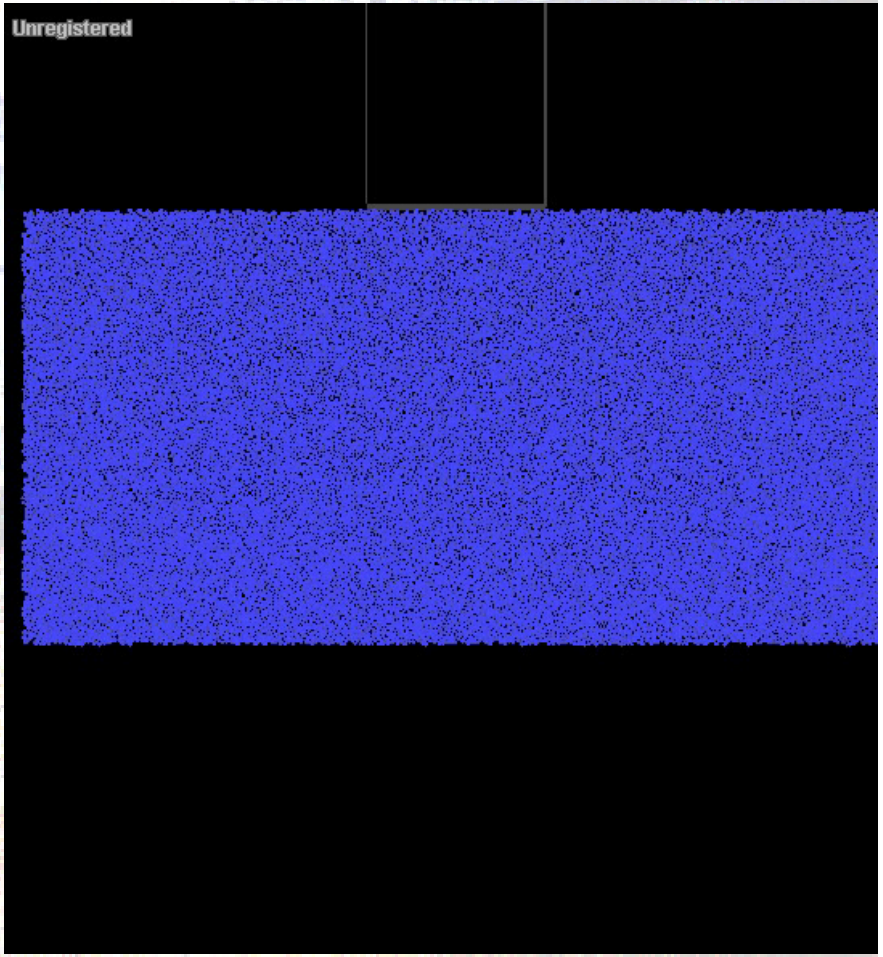
Modeling Large Discontinuous Deformation with Particles

- Bearing Capacity Problems
- Penetrometers
- Slope Stability



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Where is DEM Research Going

- Cohesive particles for slope stability problems
- Asphalt property test simulation
- Vehicle-soil interaction
- Water-soil interaction
- Non-spherical particles

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Future of DEM

- Earth pressure and slope stability problems with soil-structure interaction
- Consequences of failure
- Piping and fines migration
- Spillway erosion

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Thank You