An investigation of the contact behaviour of sands using the Finite Element Method

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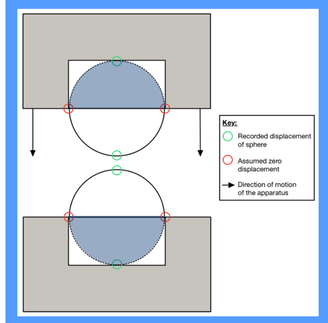
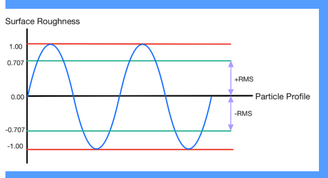
Objectives

- Develop FEM models to replicate normal and tangential loading of chrome steel balls, Leighton Buzzard sand, and carbonate sand, considering surface roughness, particle shape variations, and different loading conditions.
- Compare FEM models to theoretical models (Hertz for normal loading, Mindlin and Deresiewics for tangential loading) by analyzing experimental behavior
- Investigating contact area discrepancies for different particle types.

Assumptions

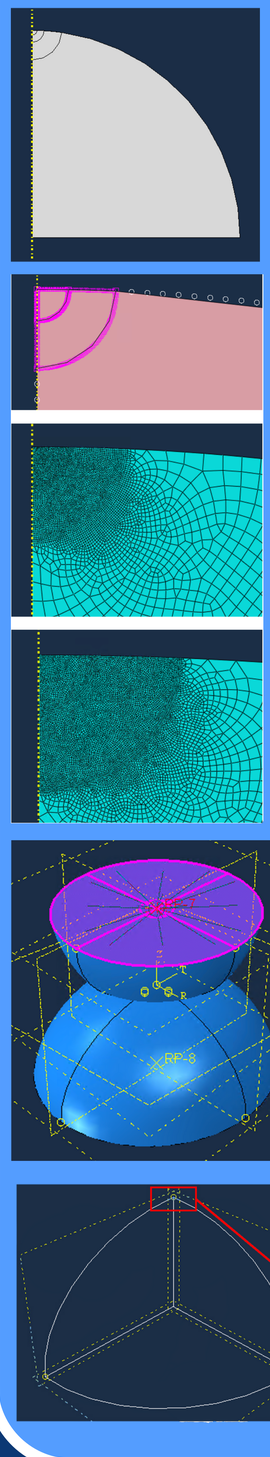


The analysis focuses on particle contact between the two halves. It assumes equal displacement deformation at the particle contact and the contact between their ends and the platens (circled in green).



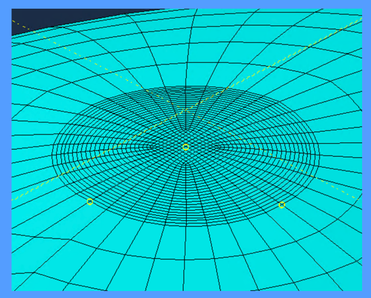
Roughness values chosen generally range from 1 to 2 times the Root Mean Square (RMS) roughness values for each material. Asperities are represented by a sine wave distribution, and the RMS roughness represents a positive average, neglecting the formation of asperities through surface indentations and extrusions.

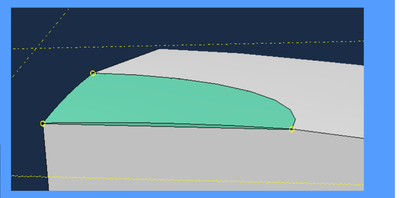
Methodology

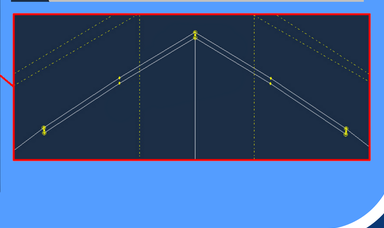


Various FEM models were used to improve accuracy and enable tangential loading modelling. These included a 2D spherical model revolved to form a hemisphere and a more advanced 3D semi-ellipsoid configuration. Partitions were implemented to:

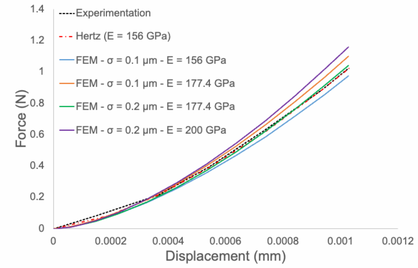
- increase element density near contact,
- ensure smoother transitions between element sizes,
- represent the surface roughness of a particle with a thin layer.



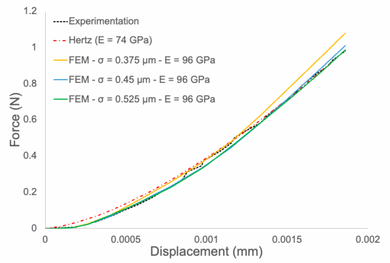




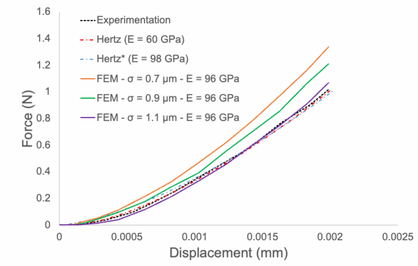
Results



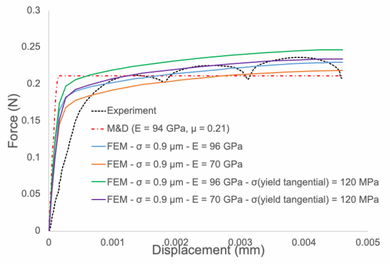
CSB



LBS - medium stiffness



LBS - low stiffness



LBS - tangential loading

KEY:
CSB = Chrome Steel Balls
LBS = Leighton Buzzard Sand

Conclusions

- The FEM models accurately replicate the contact behavior between chrome steel balls and Leighton Buzzard sand particles.
- The FEM models successfully accounted for variations in load and stiffness of LBS particles, with parameters aligned with literature or experiments.
- Ellipsoidal models captured the initial softness of normal loading, surpassing predictions from spherical and Hertz theories.
- The FEM models replicated the overall tangential behavior of Leighton Buzzard sand particles, although with less consistency compared to initial normal loading.
- However, the FEM model fell short in fully capturing the normal response of carbonate sand. The complex surface with micro pores and high porosity necessitates a different modeling approach.