Finite Element Analysis of Spherical Indentation Tests

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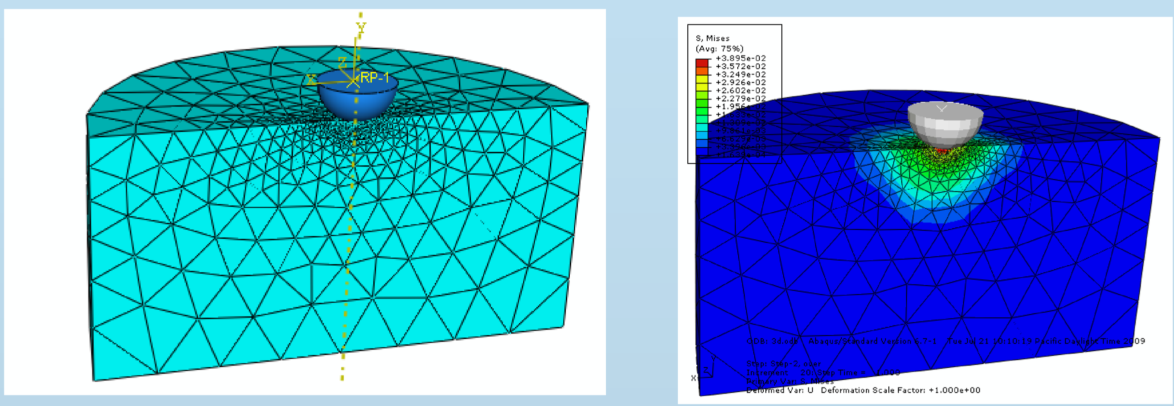
Objective

- Develop a finite element model to analyze:

i) Load-depth response in linear elastic and elastic-plastic materials using a spherical indenter.

ii) Resistance to lateral motion of the spherical indenter as a function of indentation depth.



A 3-dimensional finite element model of spherical indentation test.

Description

- A three dimensional finite element model of the half-space was constructed using tetrahedral solid elements.
- The radius of the cylinder (half-space) was twenty times the radius of contact.
- The spherical indenter was modeled as a rigid body.
- The contact between the sphere and the half-space was modeled as hard contact (does not allow penetration).
- Static analysis of the indentation tests were performed using the commercial finite element analysis program Abaqus 6.7.
- Runs were repeated using a dense mesh to ensure accuracy of the solution.

Hertz Theory of Elastic Contact

- Consider two spheres of radius R_1 and R_2 in contact:
- Equivalent radius:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

- Equivalent plane strain elastic modulus:

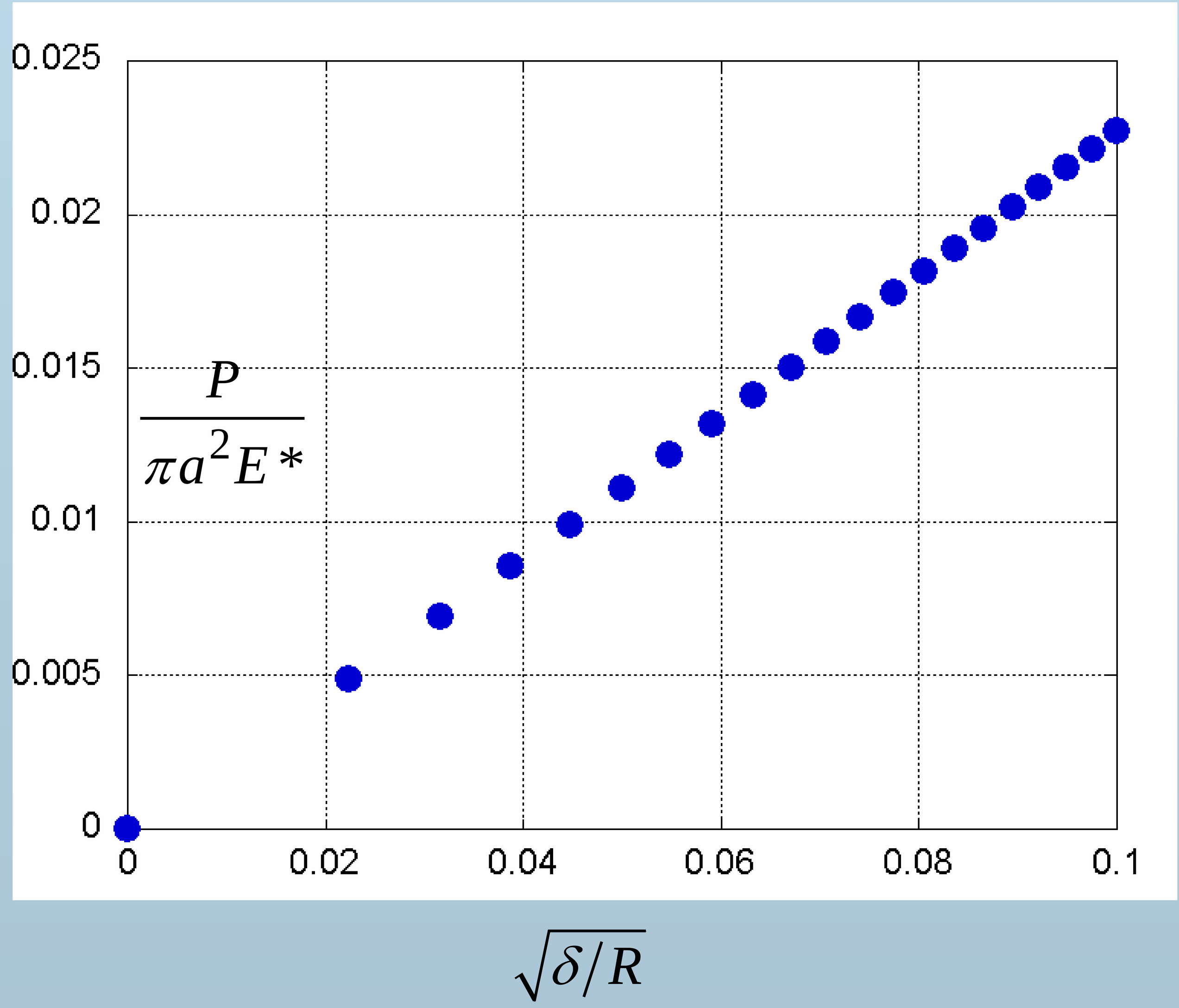
$$\frac{1}{E^*} = \frac{1}{E_1^*} + \frac{1}{E_2^*}$$

- Contact radius (a) as a function of depth (δ)

$$a = \sqrt{\delta R}$$

- Contact radius (a) as function of load (P)

$$a = \left(\frac{3PR}{4E^*}\right)^{1/3}$$



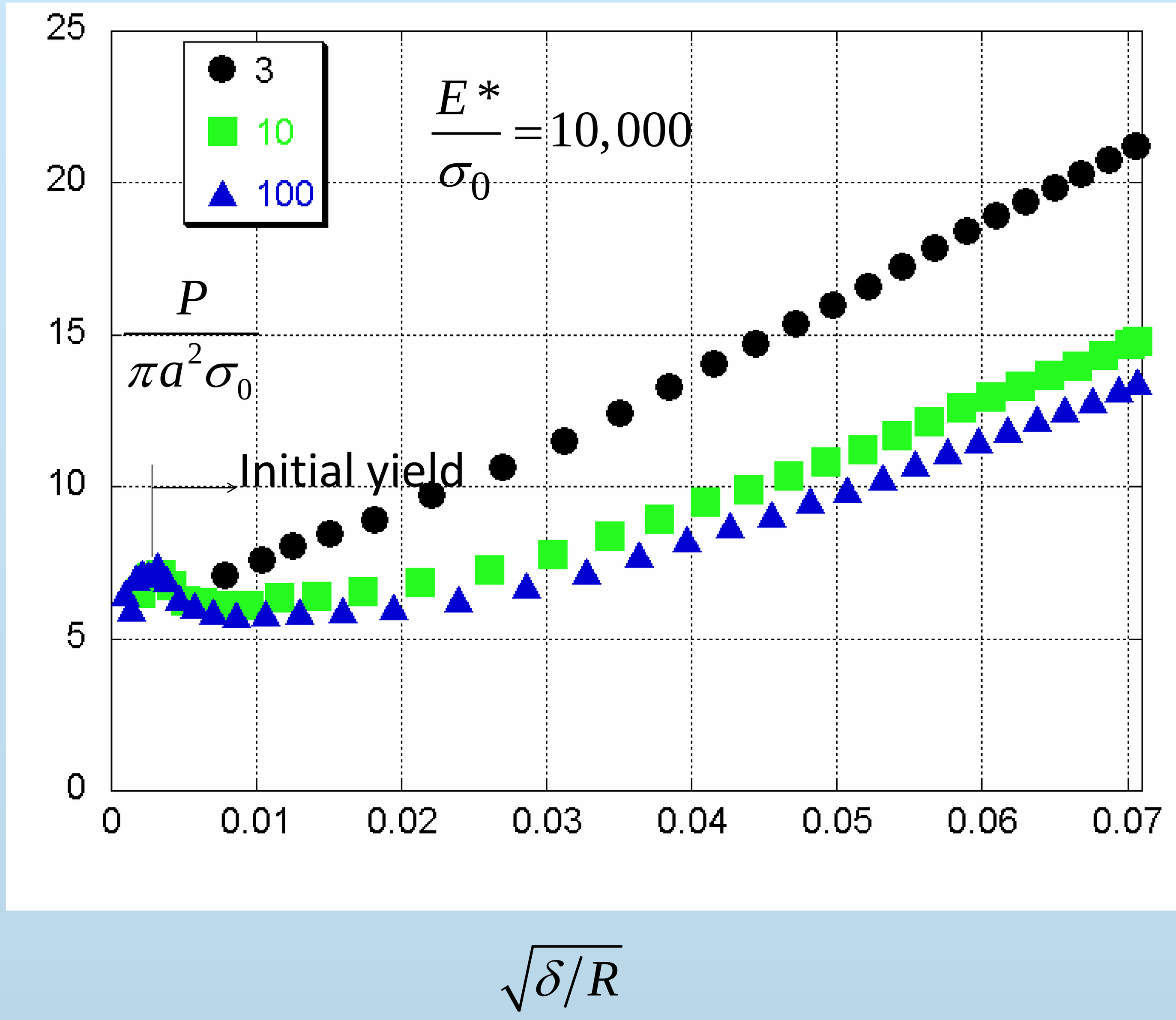
Numerical results of the Normalized load vs. Normalized depth

Elastic-Plastic contact

- Material is modeled using Ramberg-Osgood law
- Constitutive law:

$$\varepsilon = \frac{\sigma}{E} + \alpha\frac{\sigma_0}{E}\left(\frac{\sigma}{\sigma_0}\right)^n$$

- Where ε is the strain; σ is stress; E is Young's modulus; σ_0 is yield stress; α is yield offset and n is an exponent



Numerical results of the Normalized load vs. Normalized depth for different values of n

Sliding Contact

- Resistance to sliding motion of the spherical indenter at various depths of indentation was studied.
- In both linear elastic and elastic-plastic materials, the resistance was negligible.

Conclusion

i) The response of linear elastic and elastic-plastic materials under spherical indentation tests were studied and compared with theory.

ii) The sliding resistance of elastic-plastic materials was negligible indicating that the plastic dissipation did not influence the solution.

References

i) Contact Mechanics, KL Johnson, Cambridge University Press 1985.

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