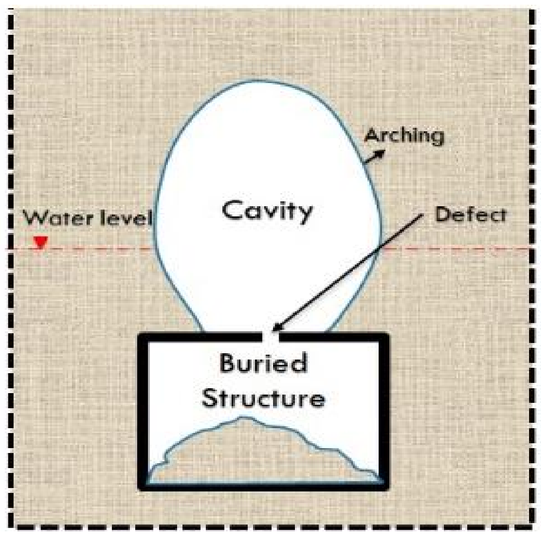
DEM Simulations on Development of Subsurface Cavity using Suction-Tension Model

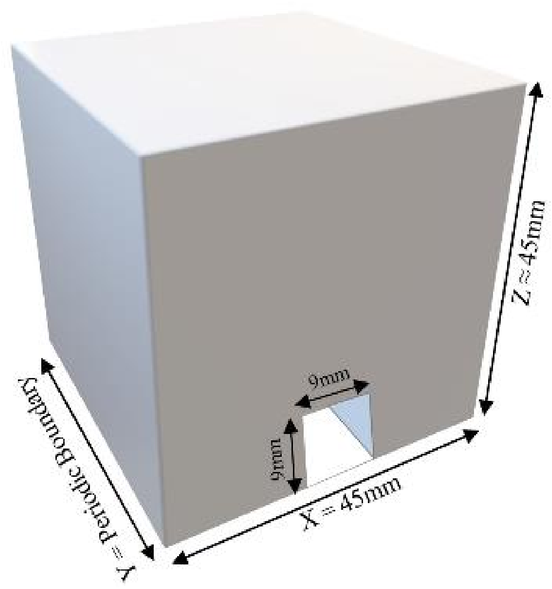
不飽和サクションモデルによる地中空洞DEMシミュレーション

Defects in buried structures along with ground water interaction, can cause formation of underground cavities. Typical DEM models do not account for capillary forces that are needed for realistic simulations of cavity growth. A new suction-tension model was introduced in the present DEM simulations to study the stability of cavity and the soil arching developed around the cavitated region. It was found that the inter-particle capillary force is a key to sustain a subsurface cavity, and both particle shape and particle size also play a vital role for the stability. A strong arching was visible in the ground with stable subsurface cavities.

地下埋設物の破損は地下水の影響を受けて地中空洞を形成する原因になると考えられています。地盤工学の分野で一般的なDEMモデルでは空洞の形成に不可欠な毛細管力を考慮していません。そこで、空洞の安定性と空洞周辺のアーチ効果を表現するため、DEMシミュレーションに新しいサクションテンションモデルを導入しました。結果として、空洞の安定には粒子間のサクションが最も重要であり、さらに粒子形状と粒径も重要な役割を担うことが明らかとなりました。また、安定した空洞を形成した地盤では強いアーチ効果も観察されました。



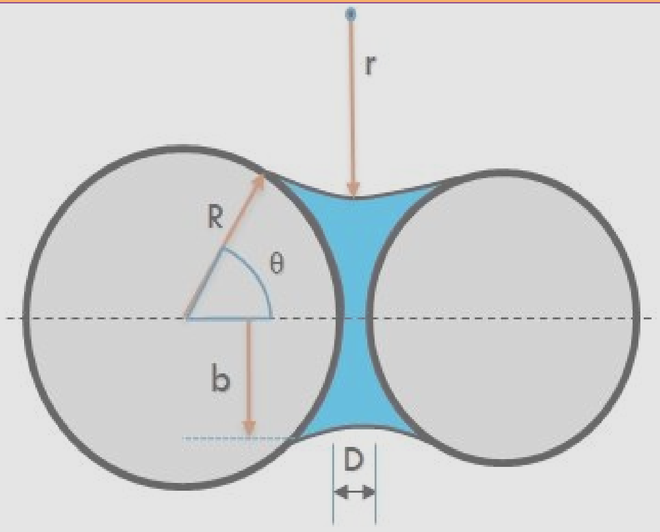
Cavity formation due to a defect in substructure



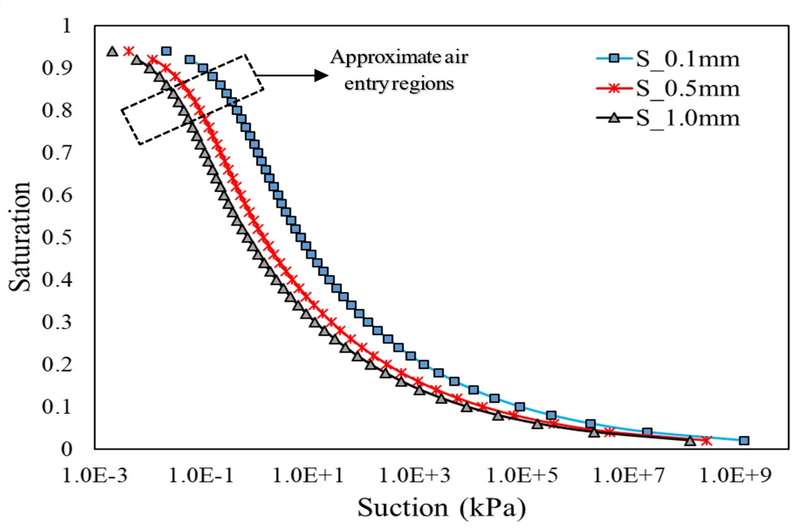
Model space for DEM simulations

DEM Simulations: X: 45 mm Y: 10xD_{50} Z: 45 mm **Diameter of particle:** 0.6 – 1.7mm **Particle type:** Spherical & non-spherical

Friction coefficient (μ): 0.35 **Young's modulus:** 71.6 GPa **Poisson's ratio:** 0.23 **Specific gravity:** 2.5



Contacting particles through water bridge



$$b = R(S_r)^3$$

$$\theta = sin^{-1}\left(b/R\right)$$

$$b' = R(tan\theta + 1 - sec\theta)$$

$$r = R(sec\theta - 1)$$

$$S = T_c\left(1/r - 1/b\right)$$

$$f_c = S(\pi b')^2 + 2\pi T_c b'$$

$$f = f_c + f_N \quad \text{if } D < 0$$

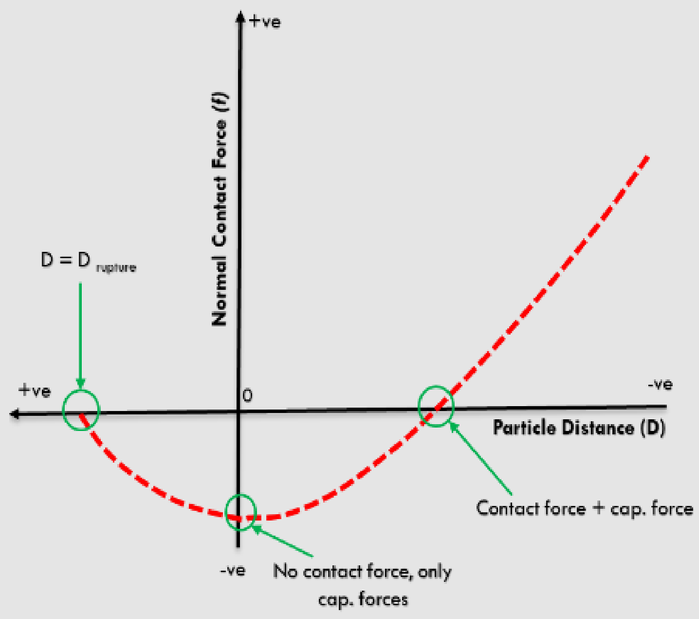
$$f = f_c \quad \text{if } 0 \le D \le D_{rupture}$$

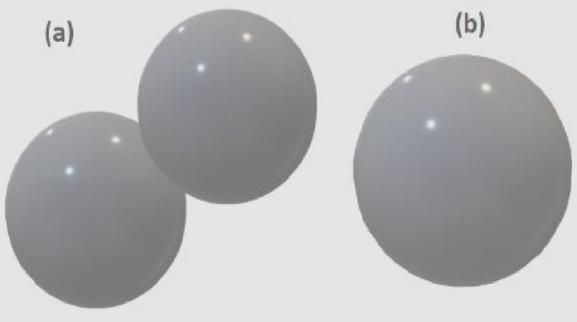
$$f = f_c = 0 \quad \text{if } D > D_{rupture}$$

f = Total force

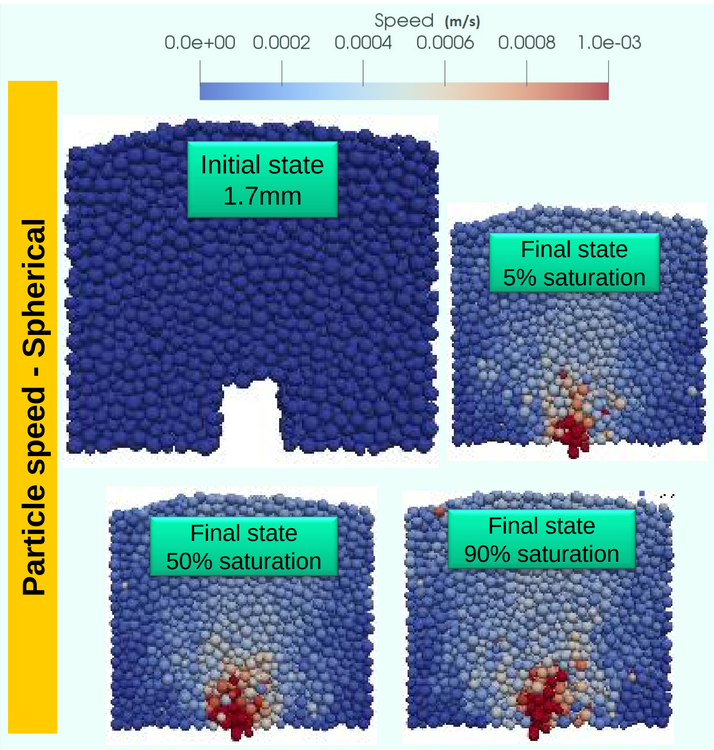
f_c = Capillary force

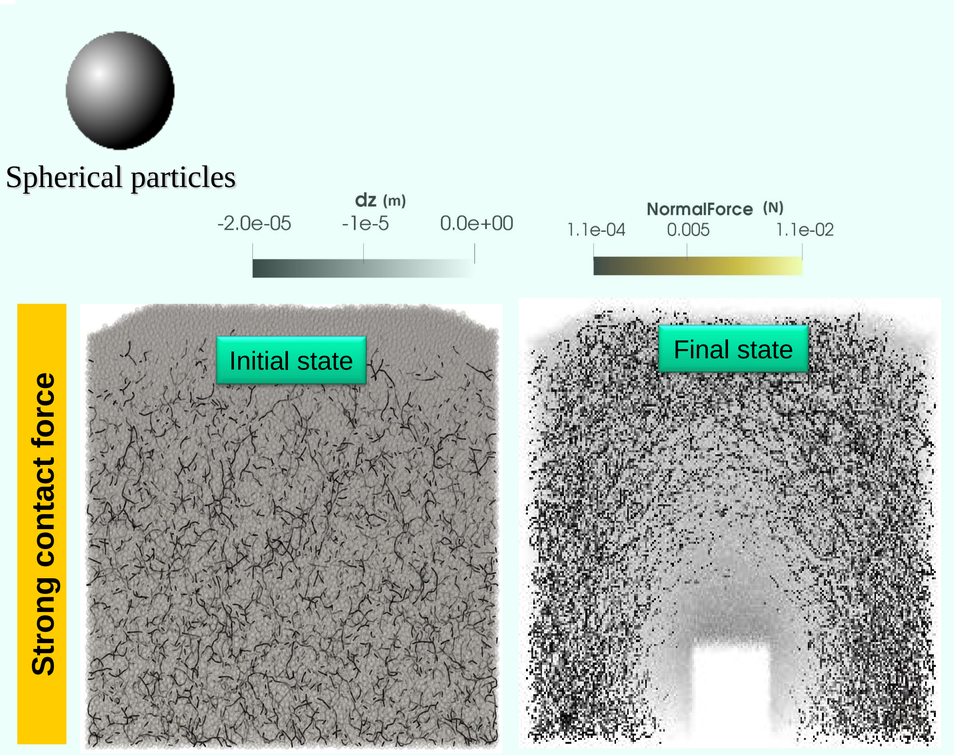
f_N = Hertzian force

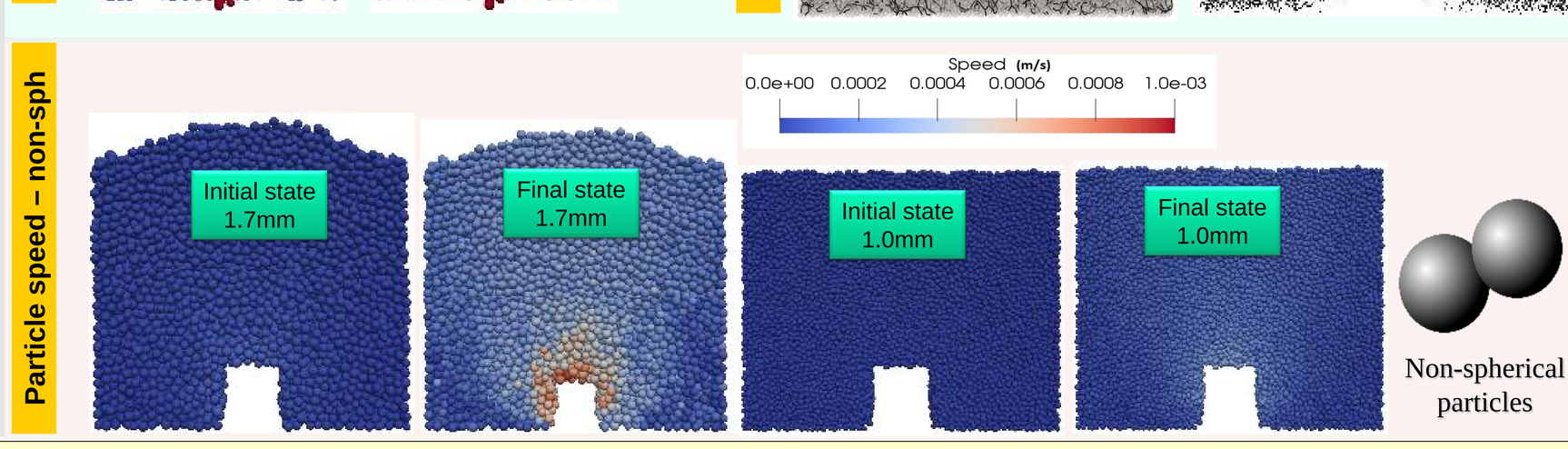




(a) non-spherical (b) Spherical particle







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