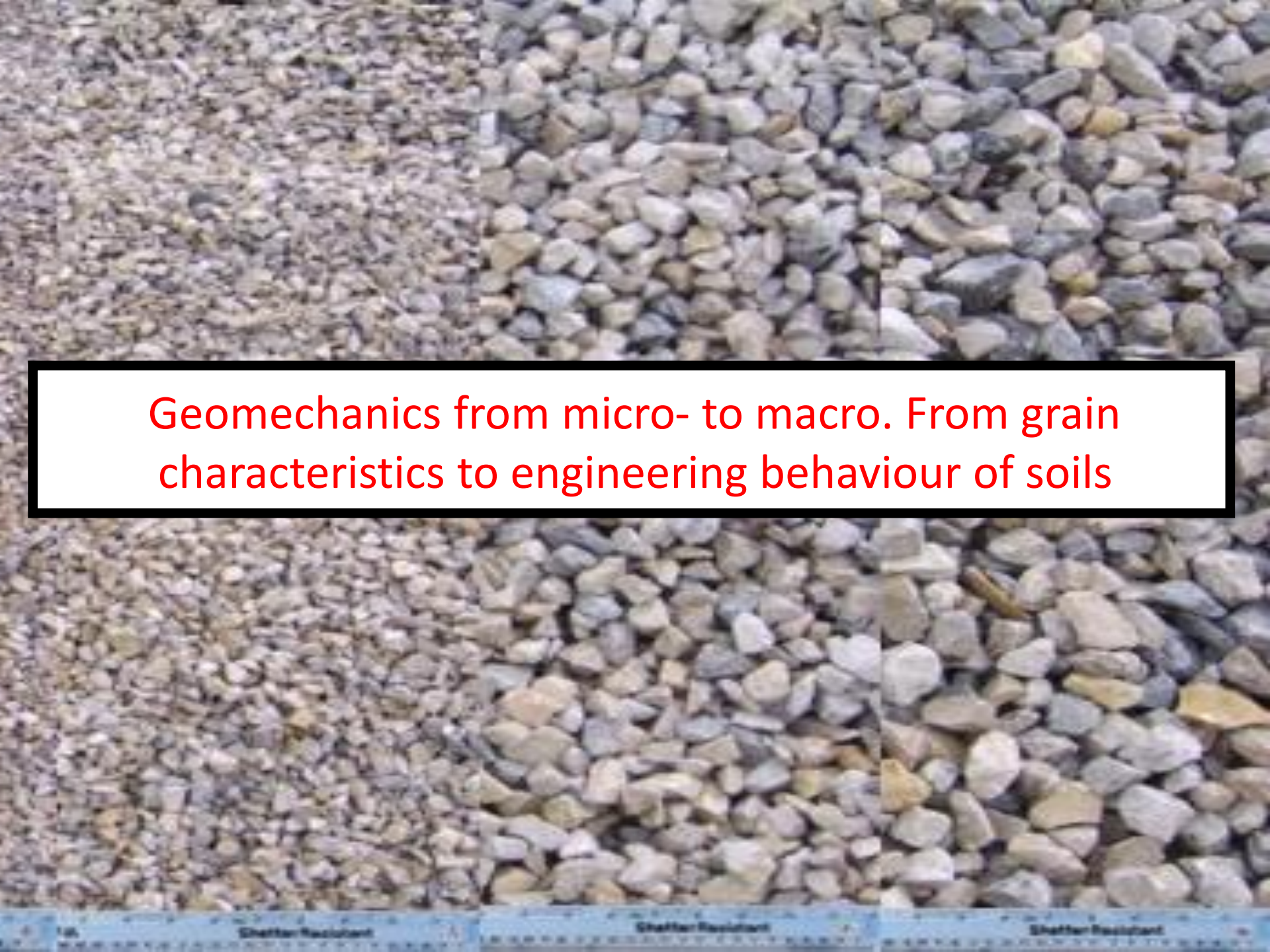
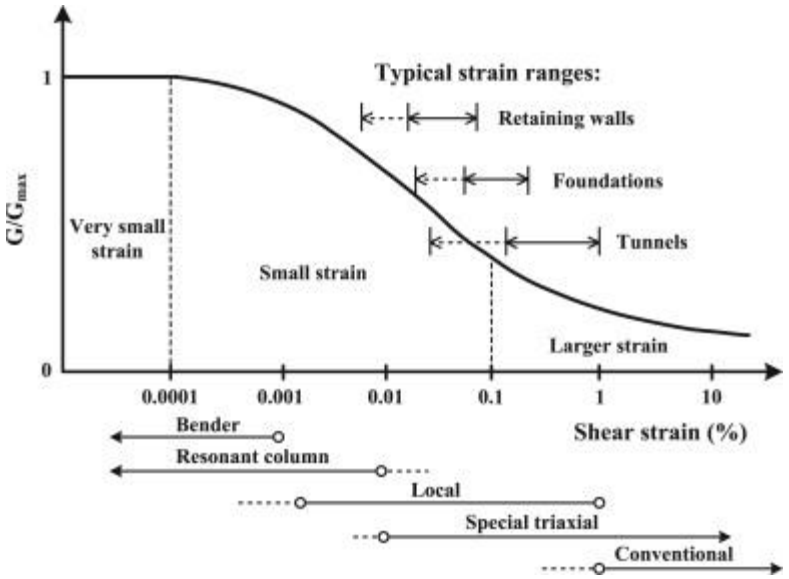
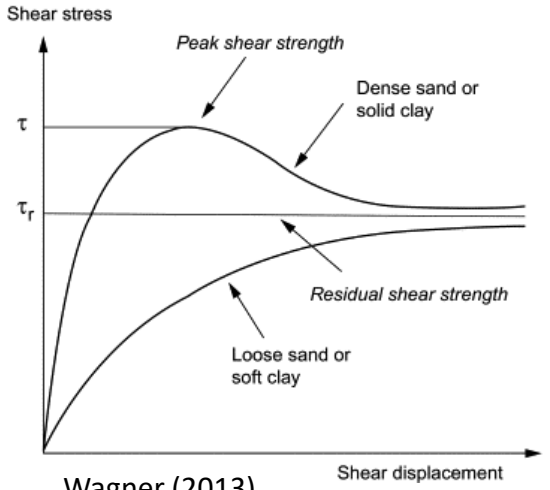


Geomechanics from micro- to macro. From grain characteristics to engineering behaviour of soils

Fundamentals of soil behaviour

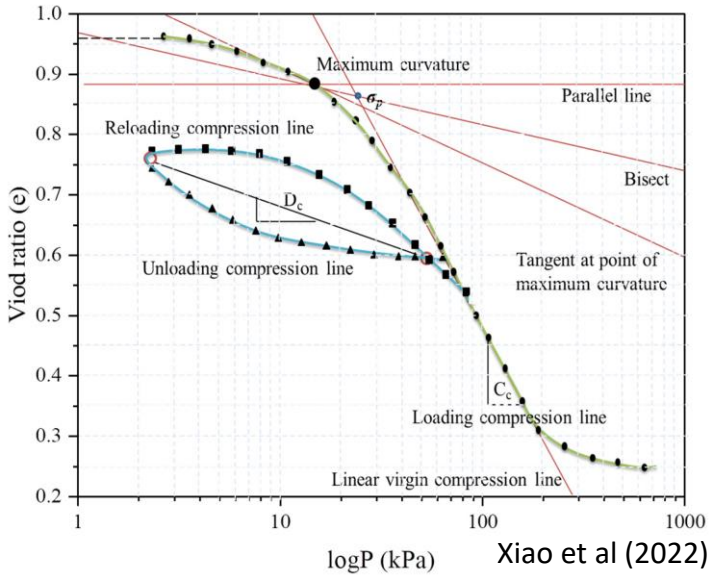


Modified after Atkinson and Sallfors (1991) and Mair (1993)



Wagner (2013)

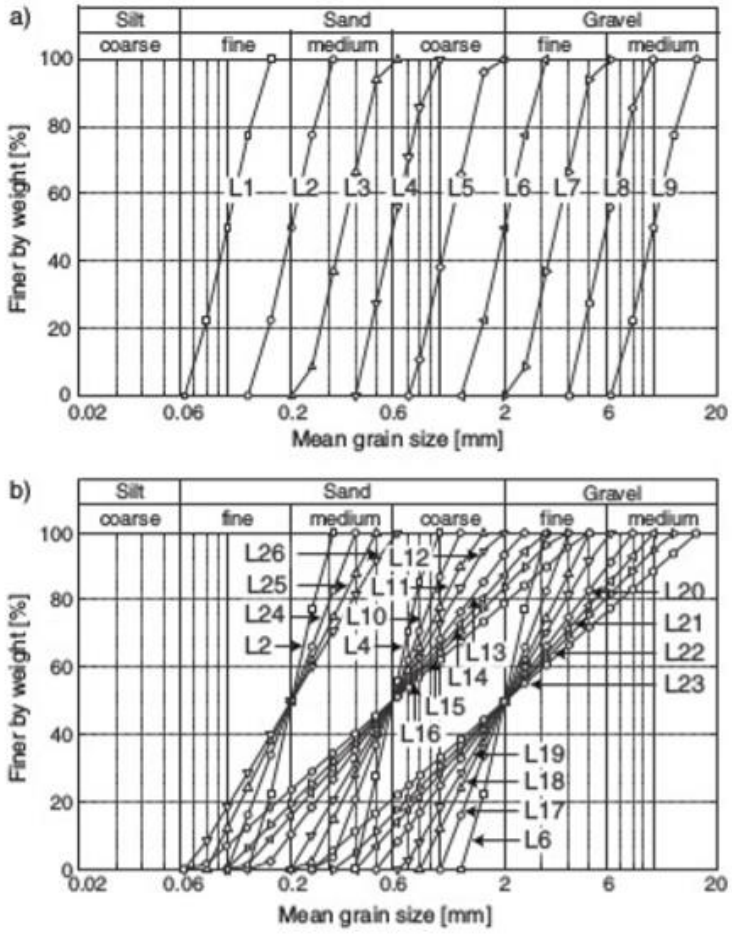
… and all properties also depend on particle properties and soil particle size distribution



Xiao et al (2022)

Particle size distribution (PSD)

PSD Characteristics

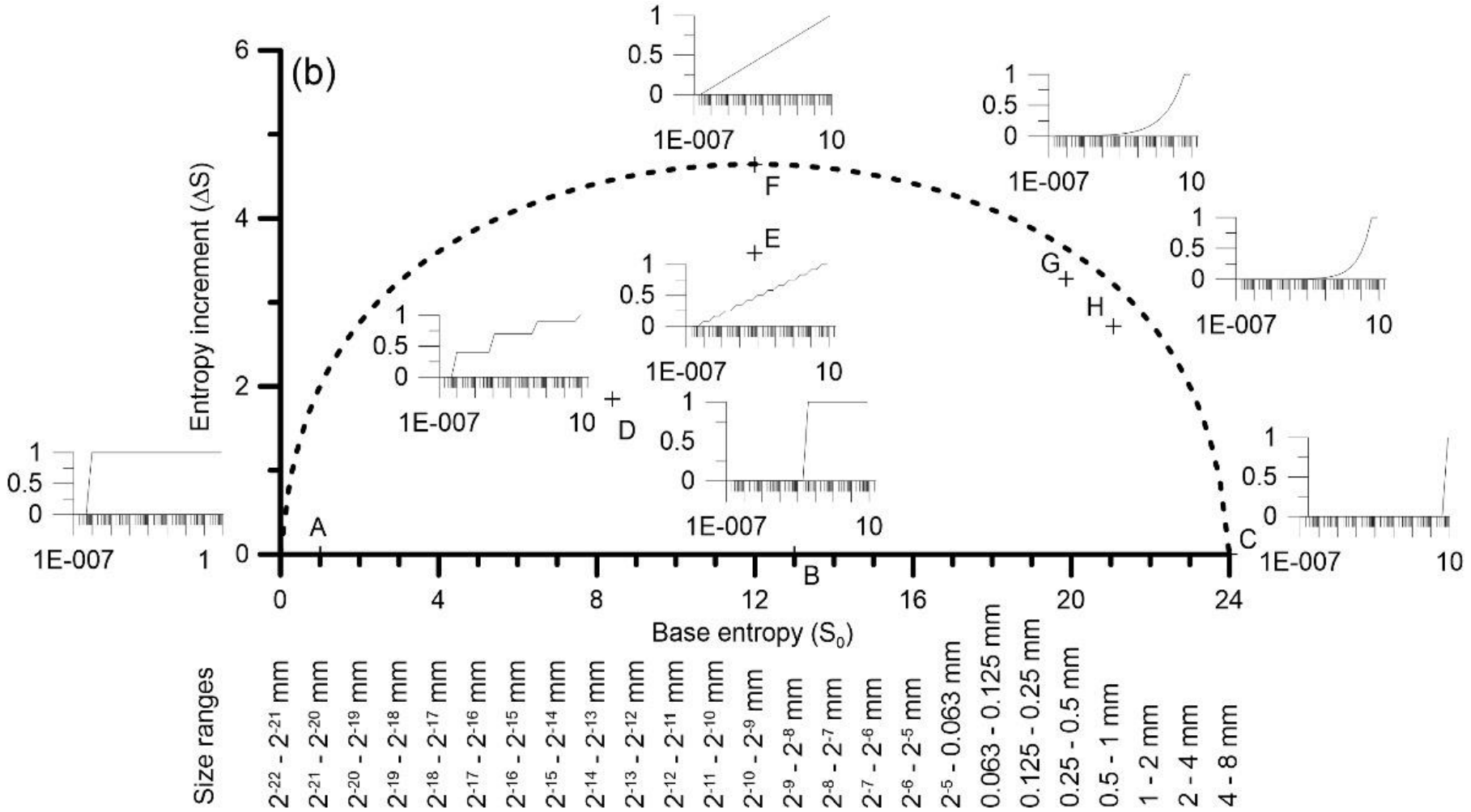


Wichtmann & Triantafyllidis (2009)

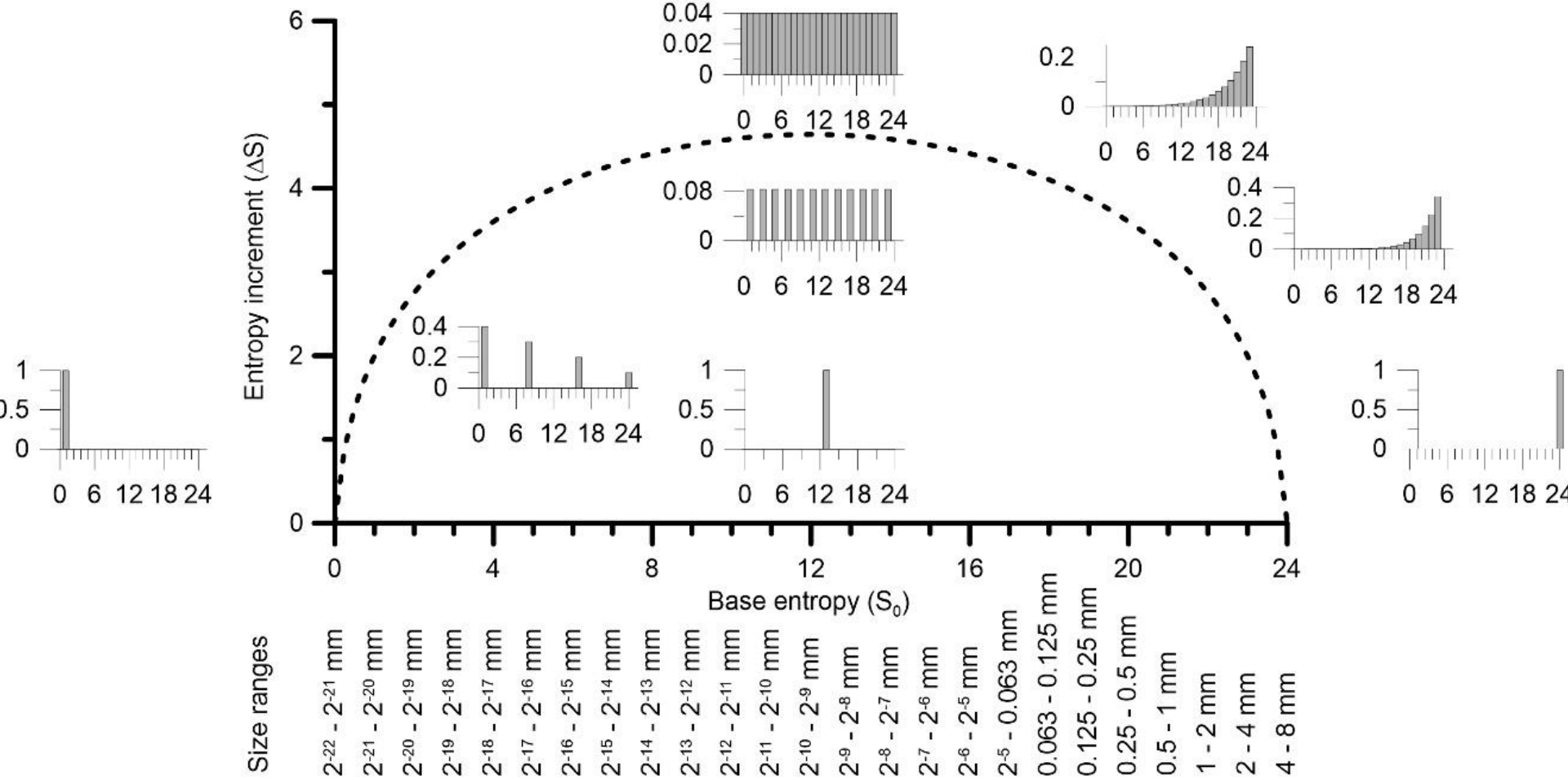
$$c_u = \frac{d_{60}}{d_{10}}$$

$$c_c = \frac{d_{30}^2}{d_{10} d_{60}}$$

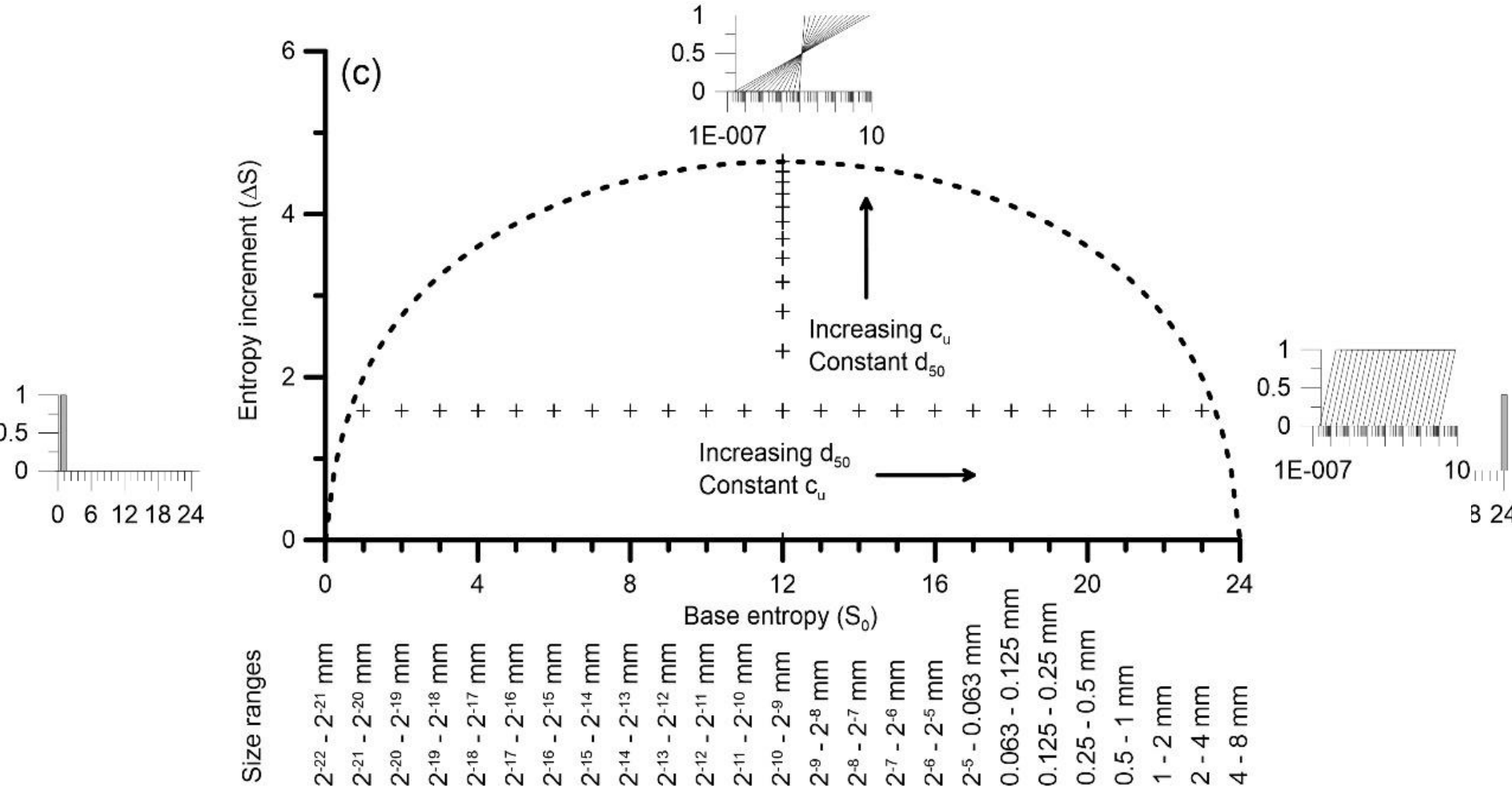
Entropy coordinates (Lörincz, 1986)



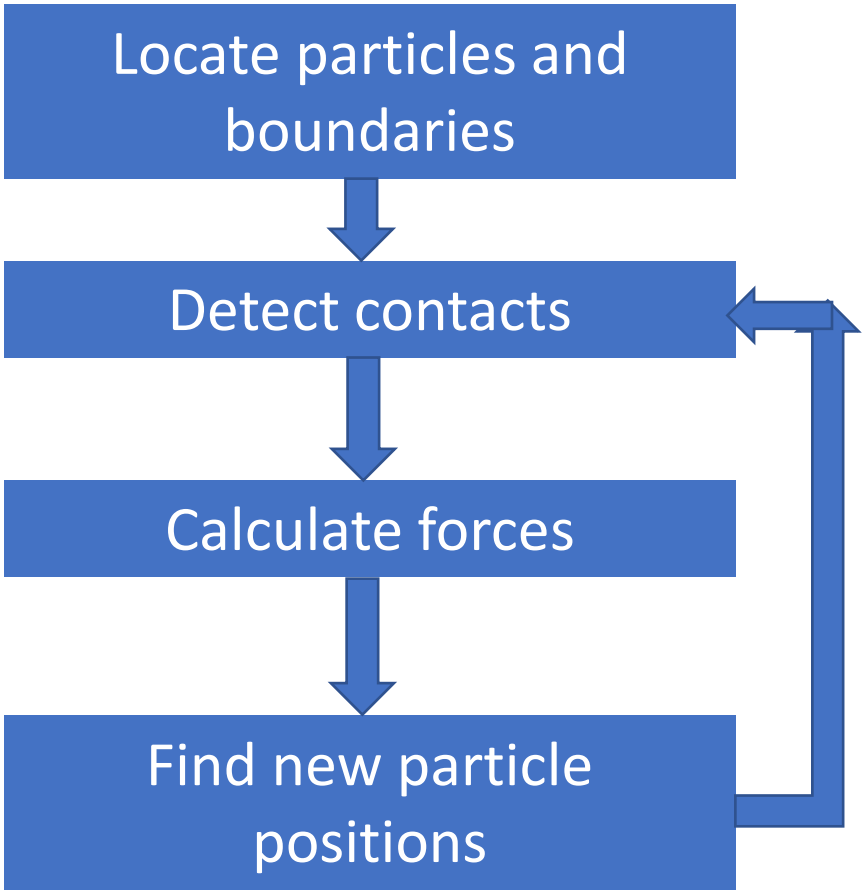
Entropy coordinates (Lörincz, 1986)

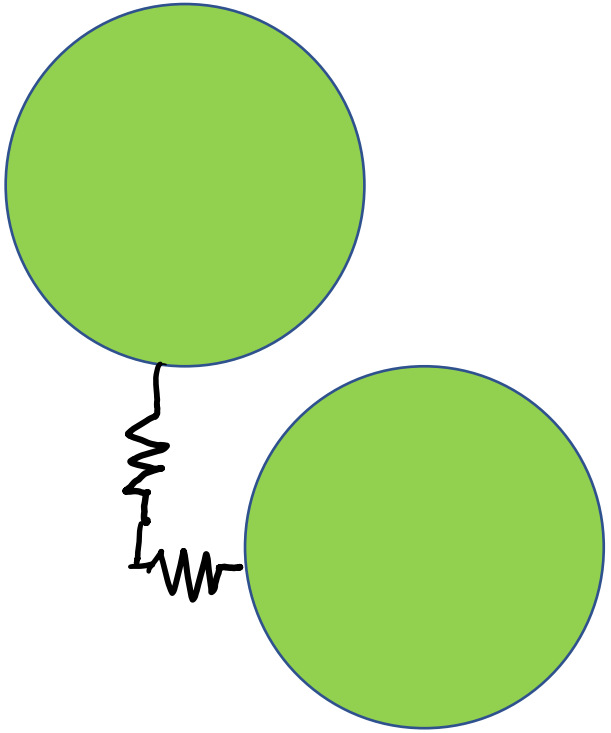


Entropy coordinates (Lörincz, 1986)

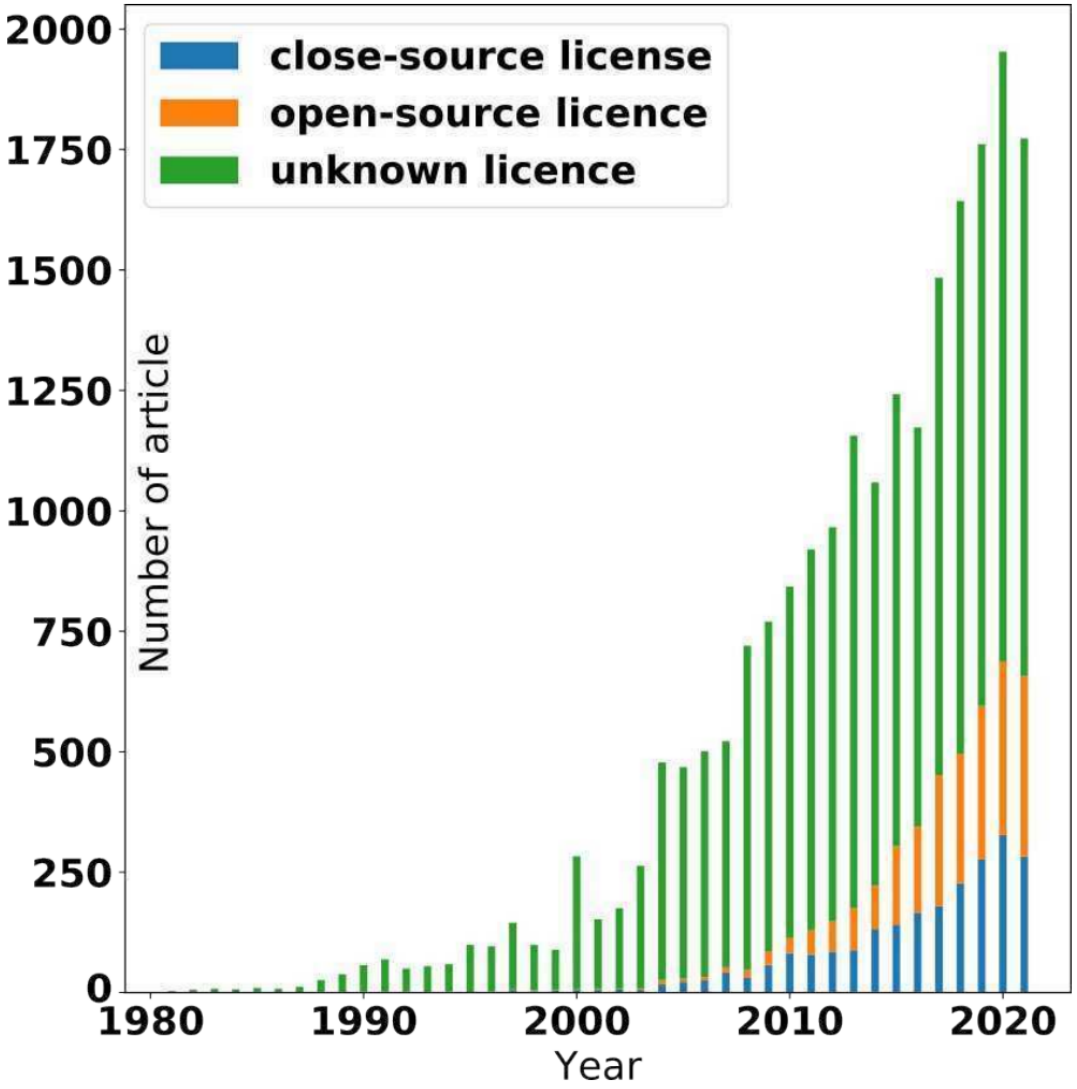


DEM – Basic algorithm



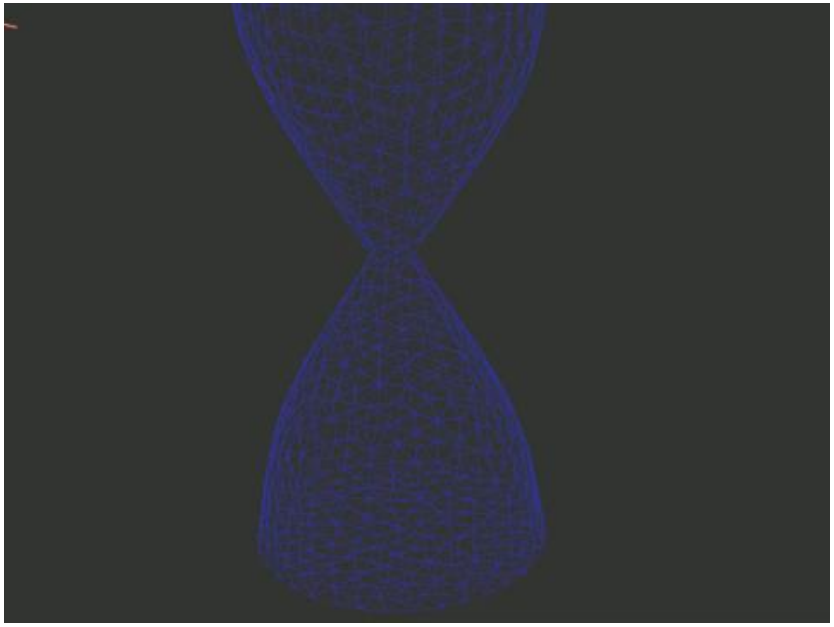


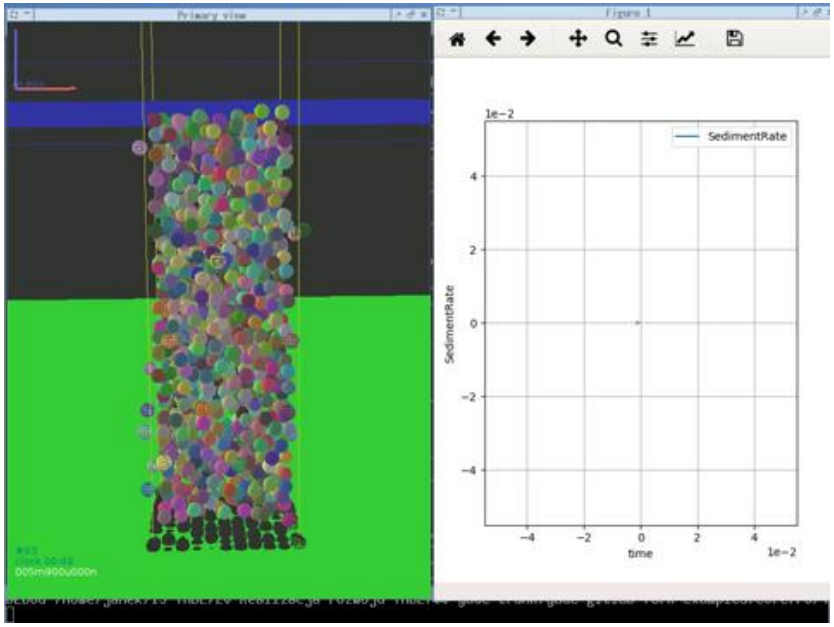
DEM Publications



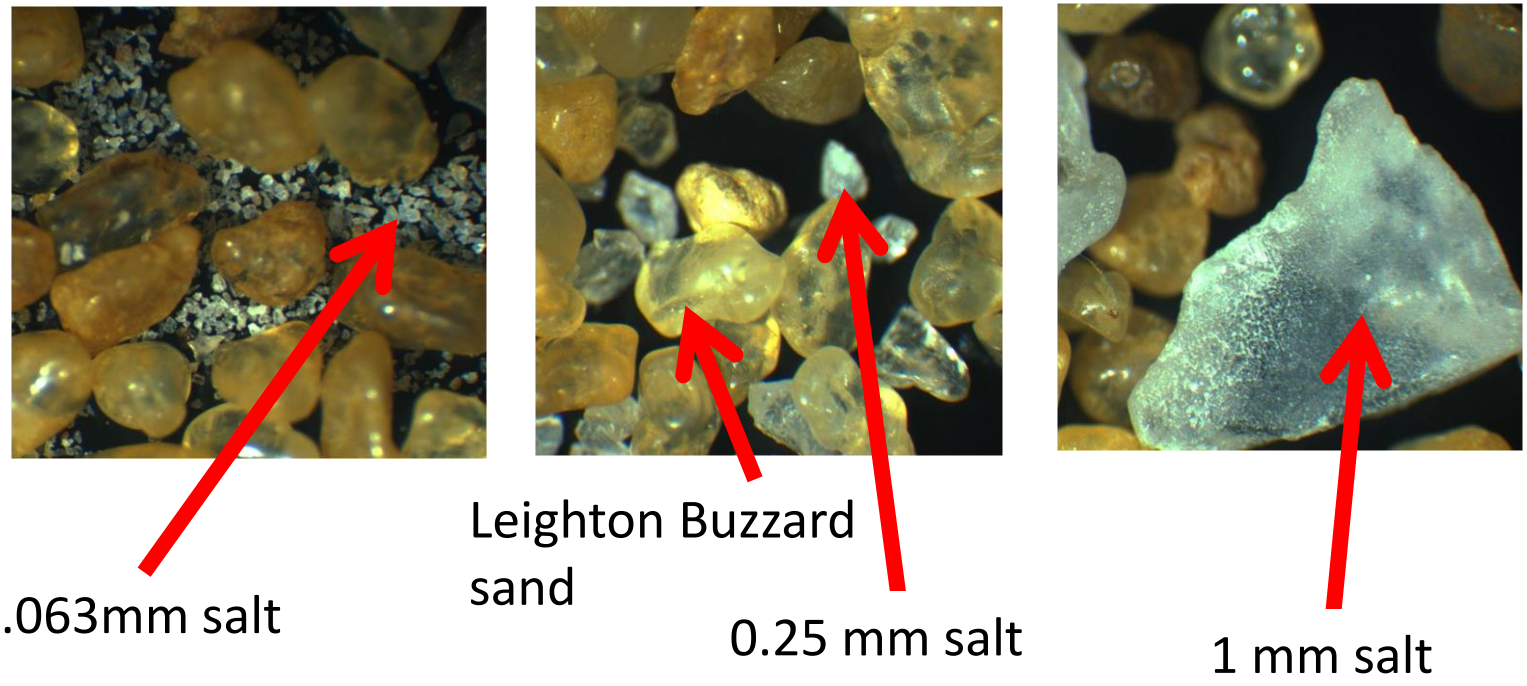
DEM - Some capabilities

More examples at https://yade-dem.org/doc/



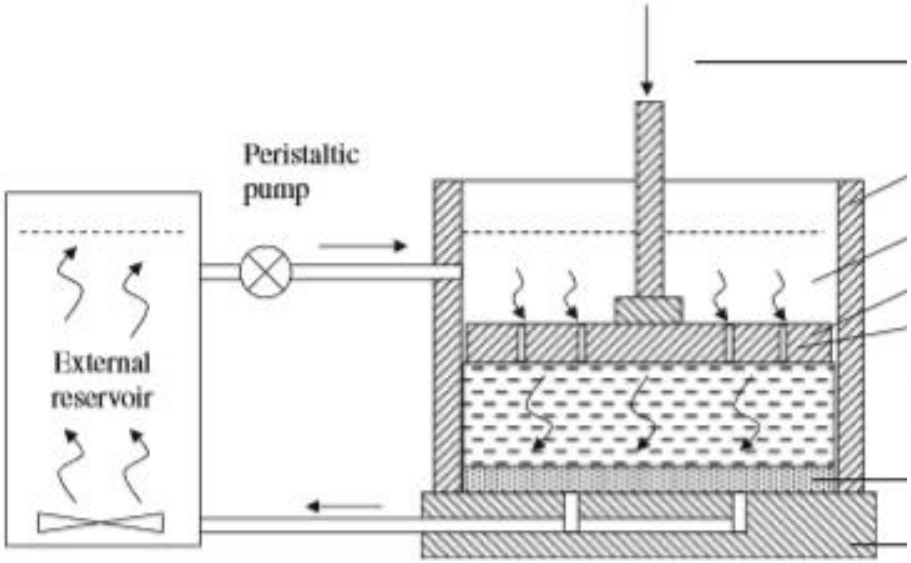


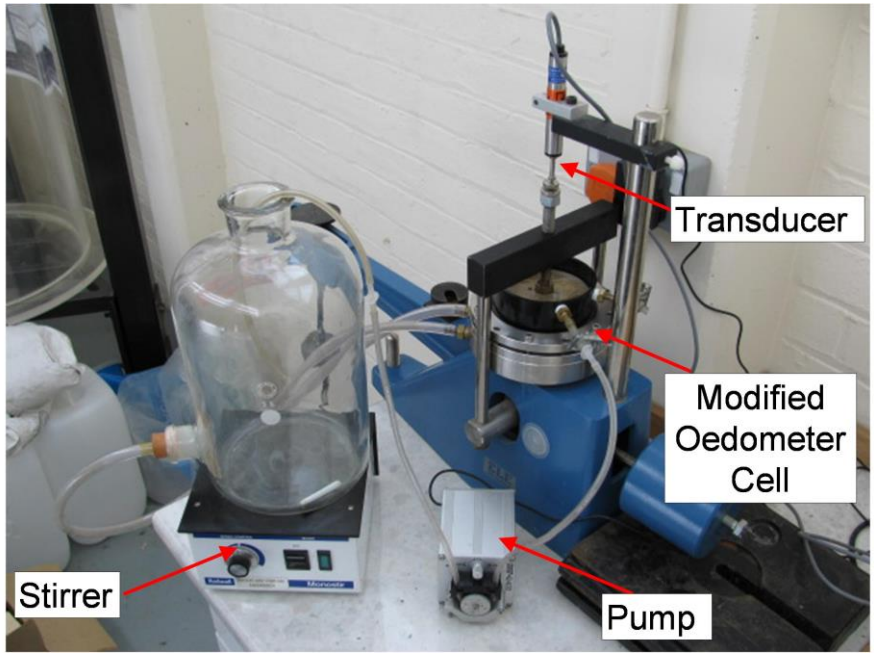
Dissolving soils' tests - Materials



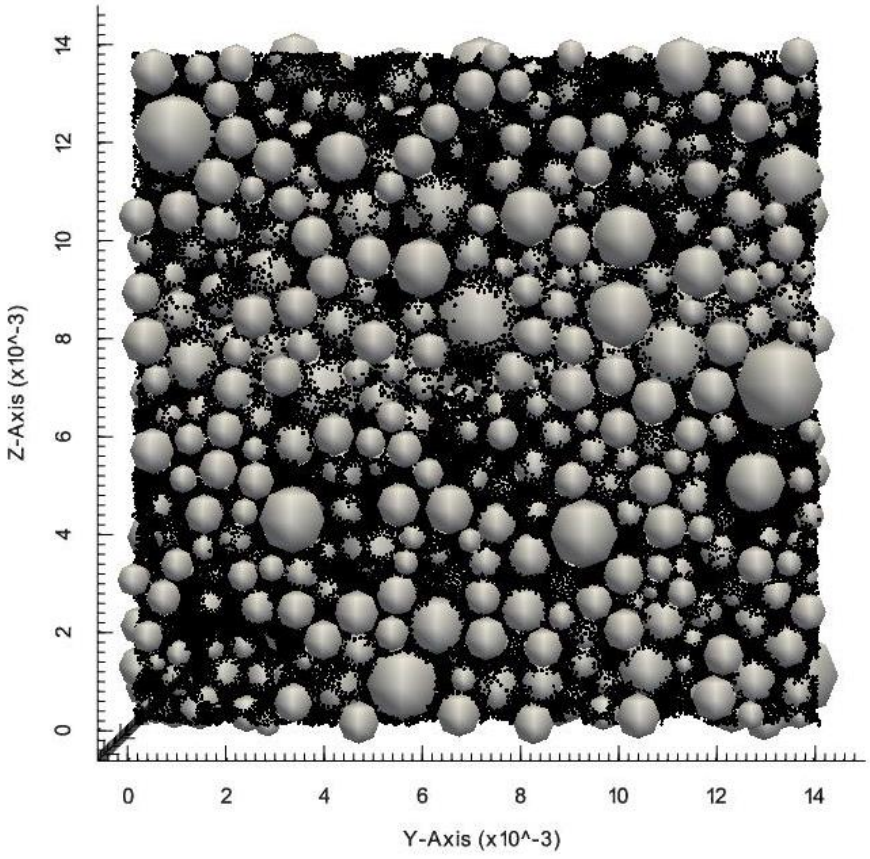
Salt sizes: 0.063, 0.125, 0.25, 0.5 and 1 mm
Salt amounts: 2%, 5%, 10%, 15% (by mass of sand)

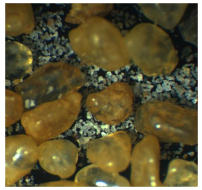
Equipment

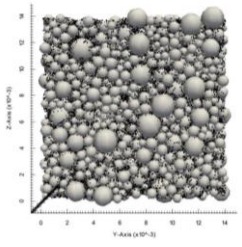

Peristaltic pump
External reservoir

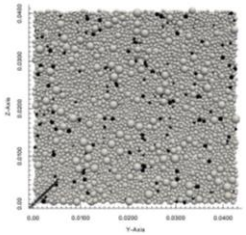

Transducer
Modified Oedometer Cell
Stirrer
Pump

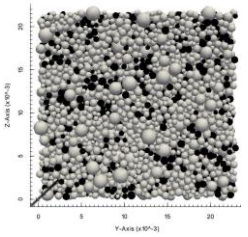
DEM specimens











Internal stability, piping, etc.

Some background – filter criteria

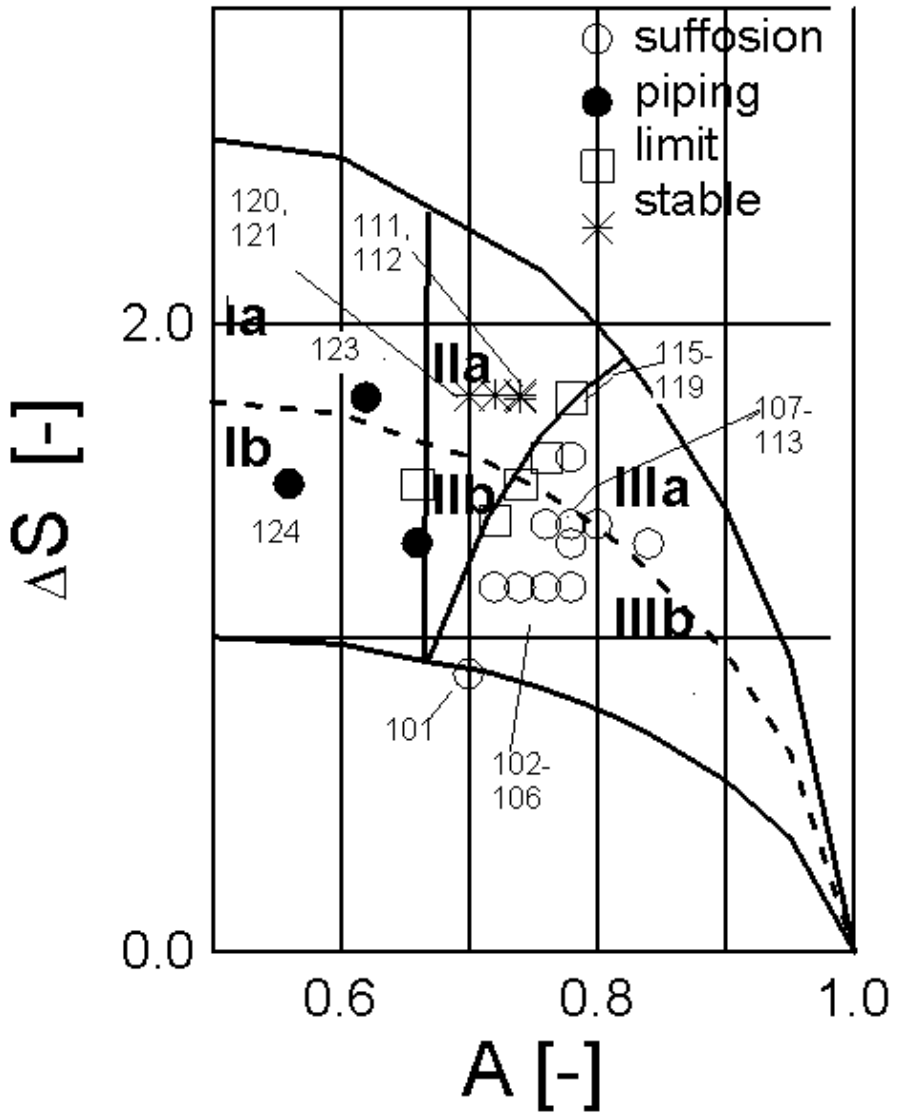
$$\frac{D_{\min}}{d_{\max}} \leq 4$$

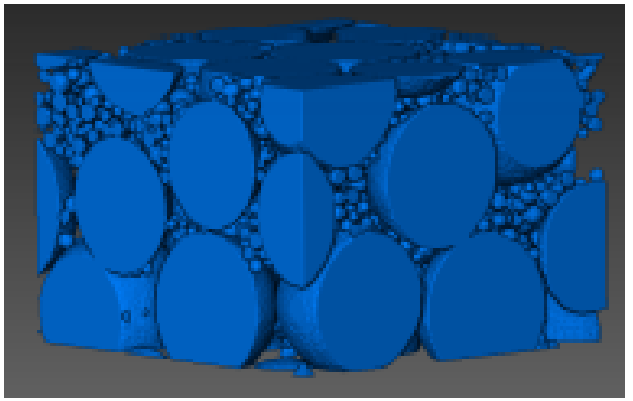
- *D* and *d* refer to the filter and the base soil, resp. If there are more than two empty fractions, the base soil cannot be filtered. (Terzaghi's filter criterion for uniform filters)

- Kezdi's self-filtering theory states on the basis of this filter rule that if the ratio between the minimum particle diameter of the filter and the maximum particle size of the base soil is between 1 and 4, then particle migration from the base soil is prevented.

- *Suffosion may occur only in case of near gap-graded mixtures with 3 empty fractions.*

Particle migration rule - internal stability and internal structure

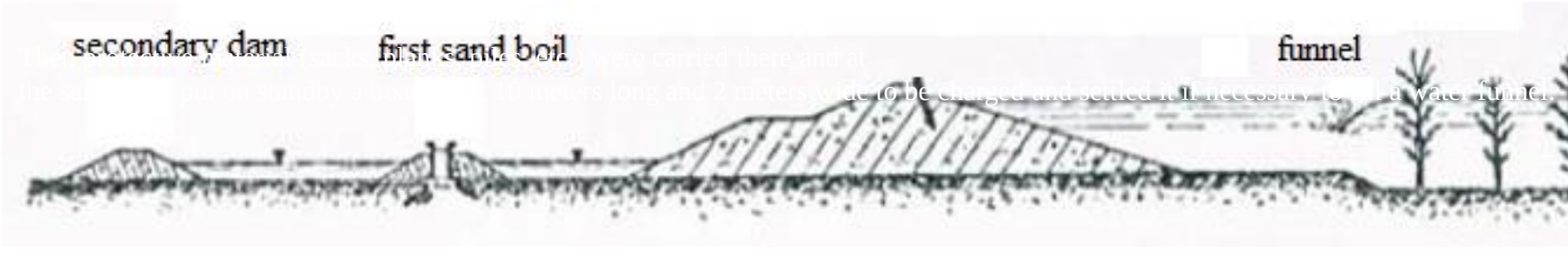


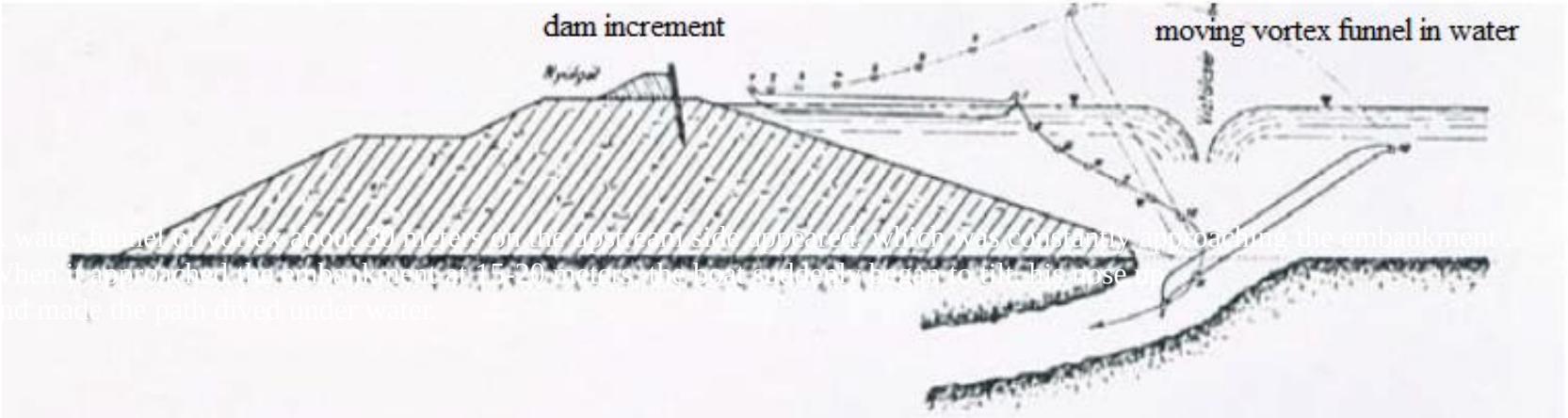


Zone I (A < 2/3): soil is internally unstable - coarse particles float in a matrix of fines. Unstable when fines are removed by water flow. For A >=2/3 Zone II (stable) coarse particles in contact have stable structure with continuous force chain In Zone III (transition, the stable structure builds up, elongated gradings)

Piping in Hungary

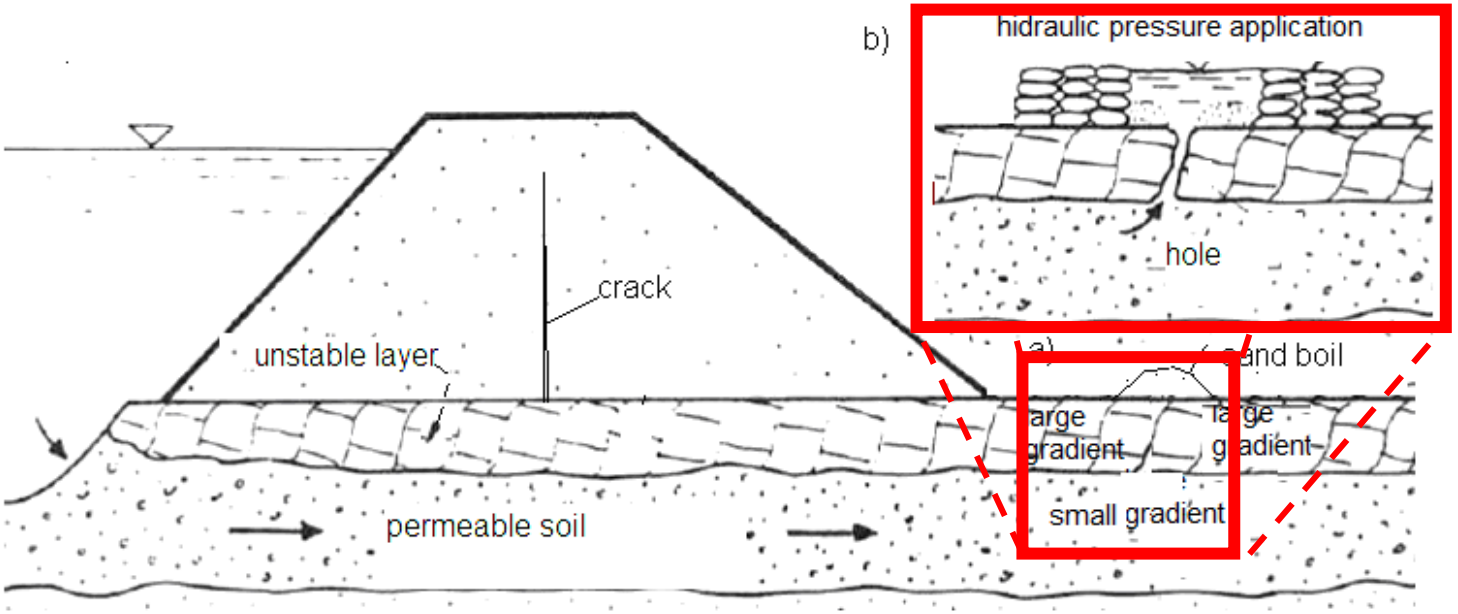
Piping not uncommon in Hungary. Measurement of the size and path of the pipe using sinking boats, as well as management by controlling water level.





Thin erodible layer* - Slow piping

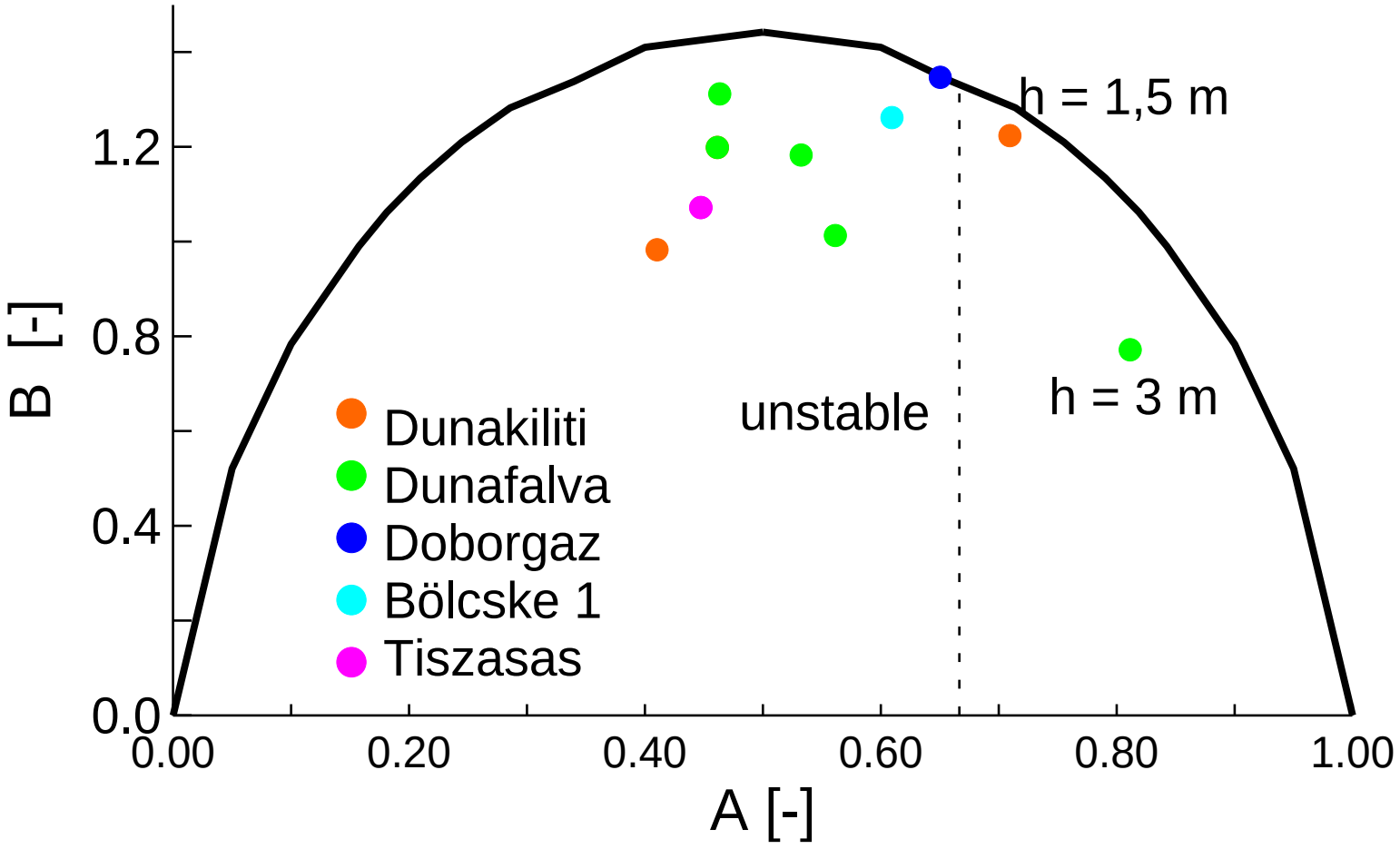
Failure within a few days



The sand boil is the first stage of a piping failure of river dikes – can be related to equlibrium of single surface grain.

*Lörincz criterion

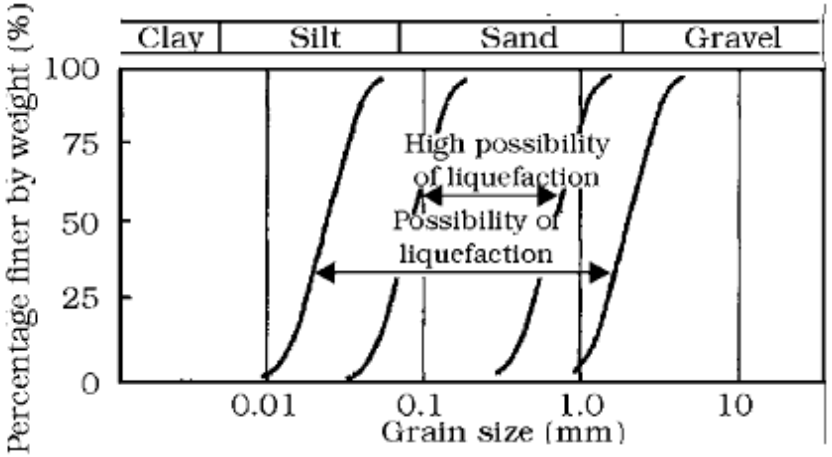
Entropy diagram – Hungarian data



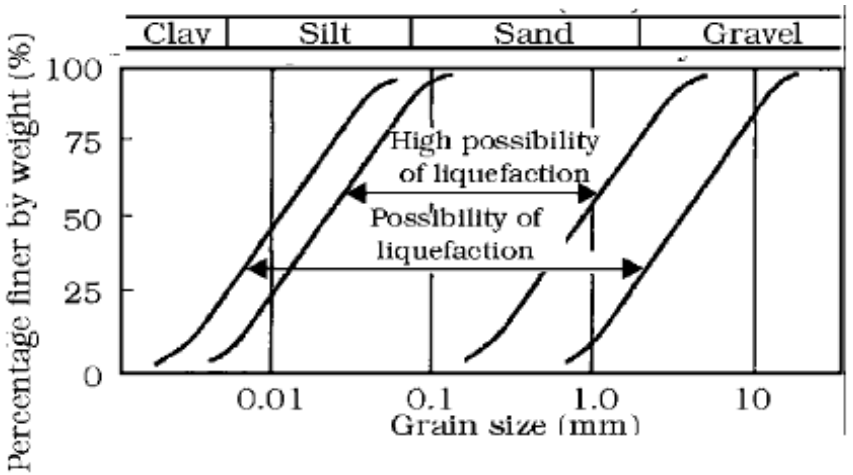
Soil liquefaction

Liquefaction potential/susceptibility

Tsuchida & Hayashi, 1971



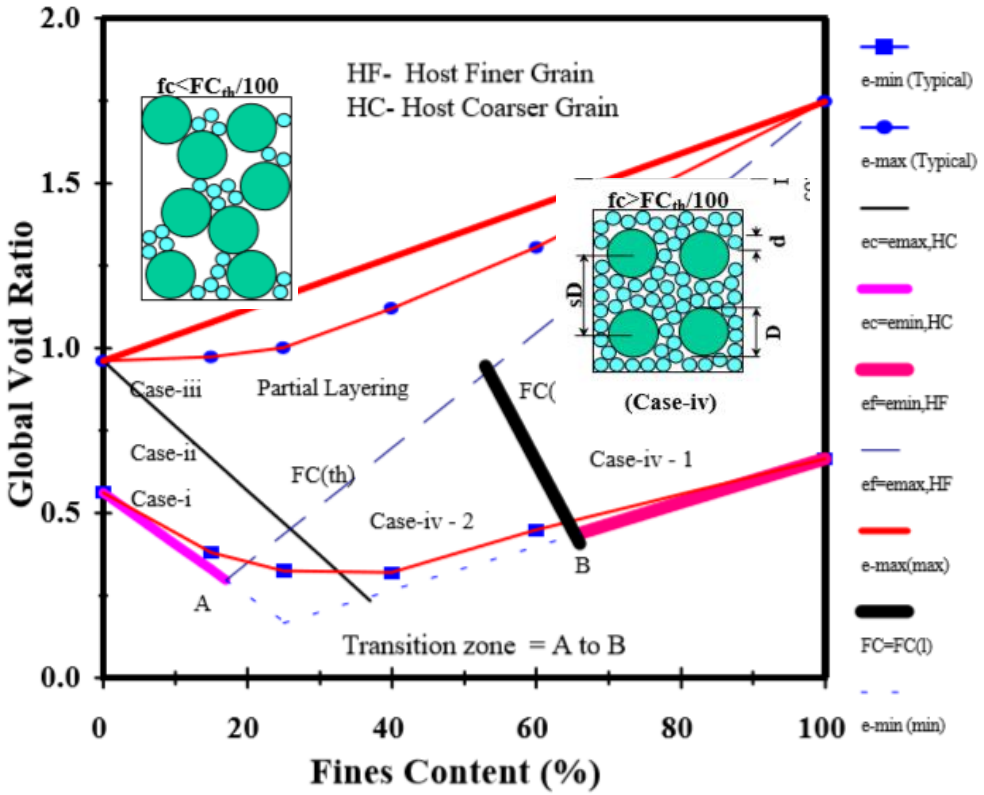
$C_u < 3.5$



$C_u \geq 3.5$

It is well recognised that both size, size range and PSD shape (C_u) are important when assessing susceptibility to liquefaction

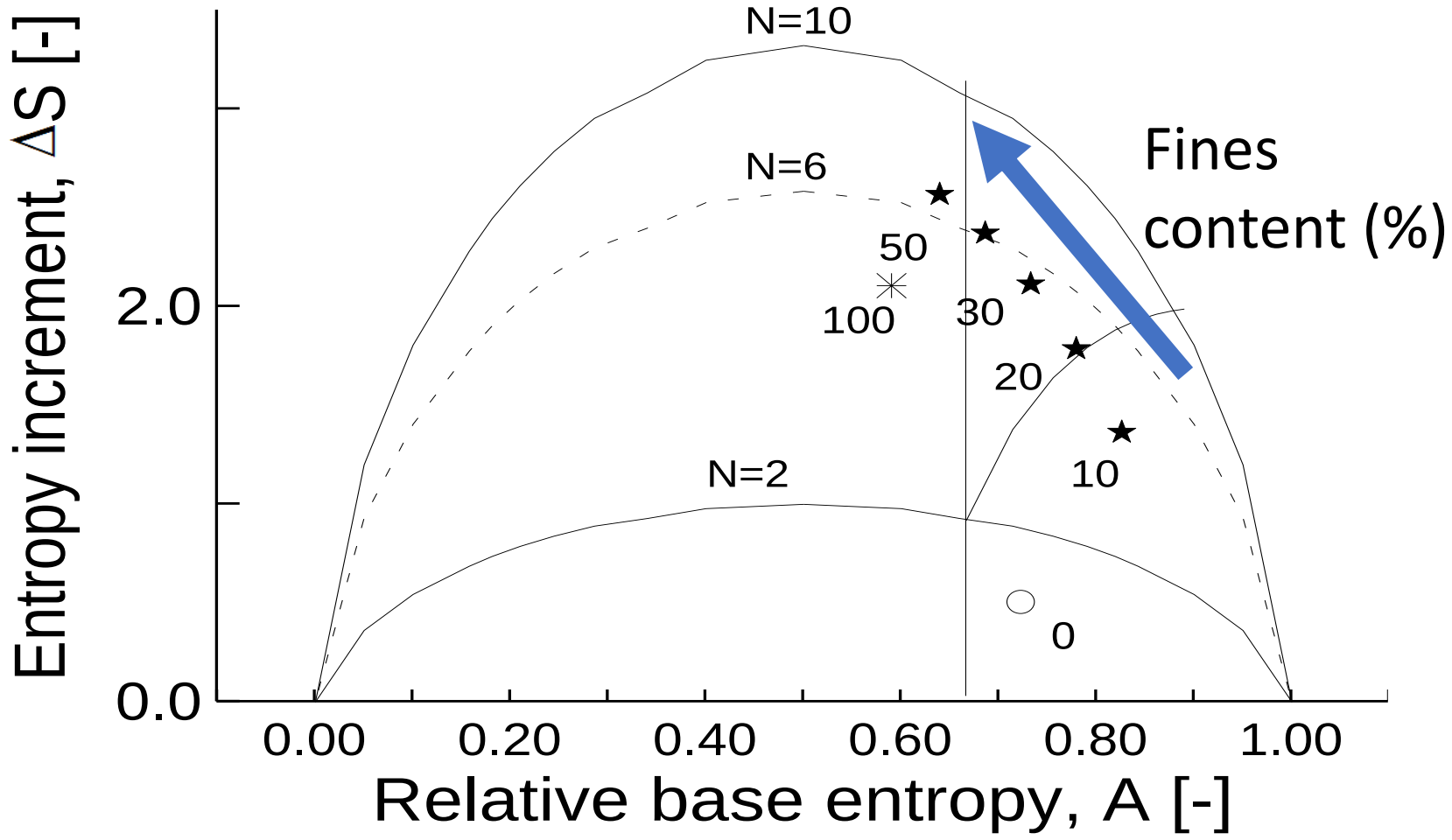
The effect of fines' content



Thevanayagam (2000)

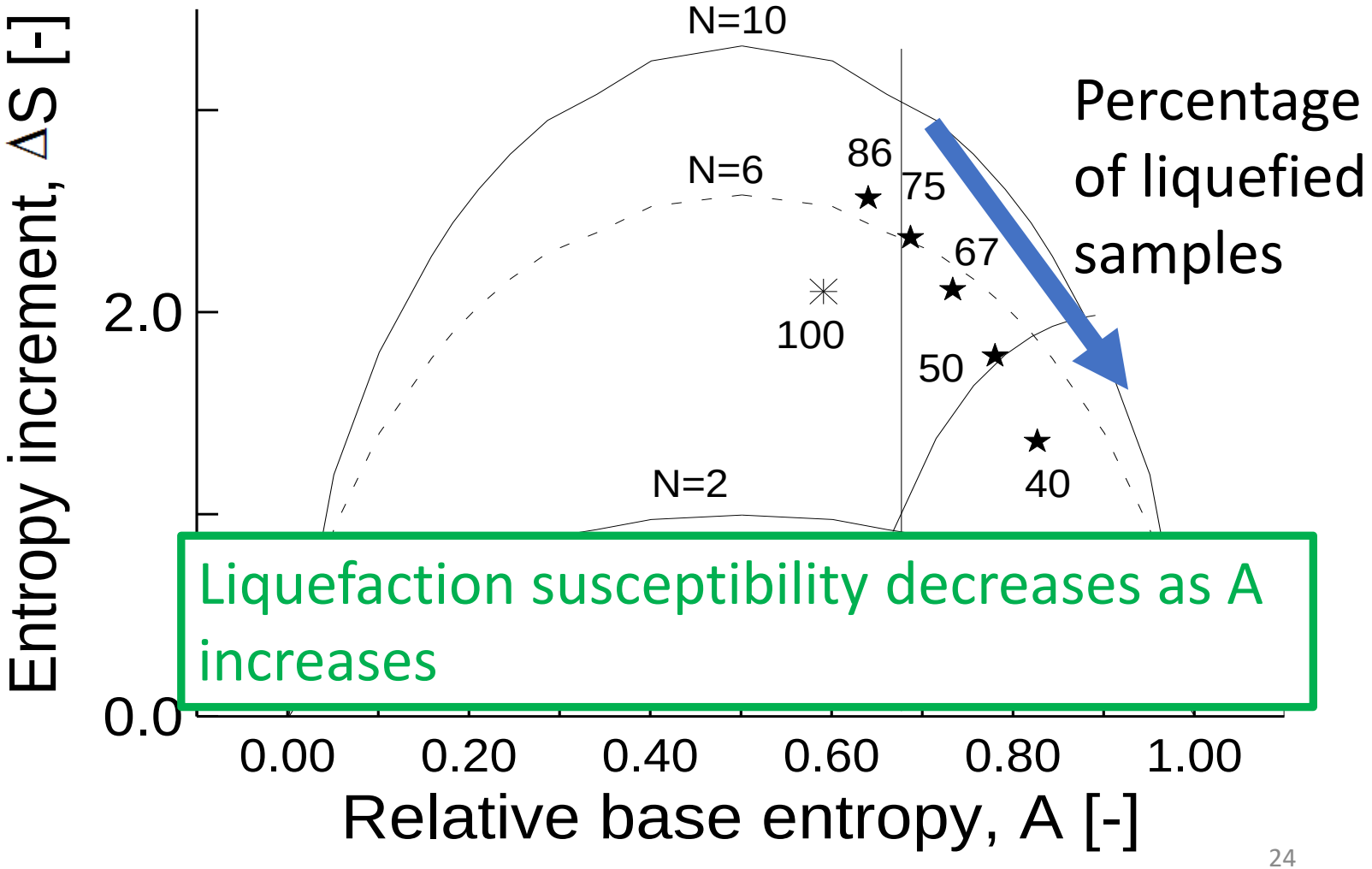
Liquefaction – Experiments on effect of fines

Rahemi (2017)

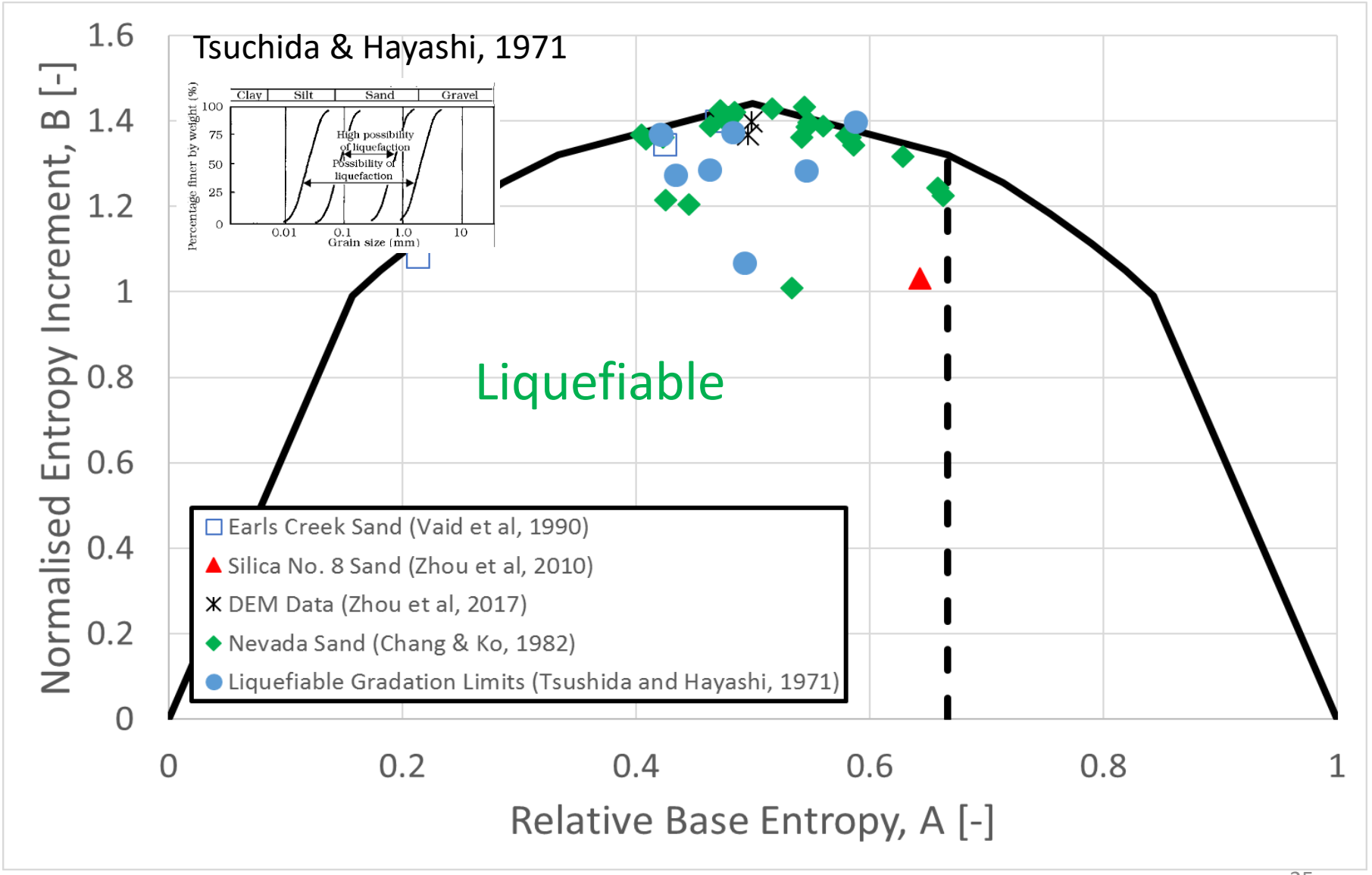


Liquefaction – Experiments on effect of fines

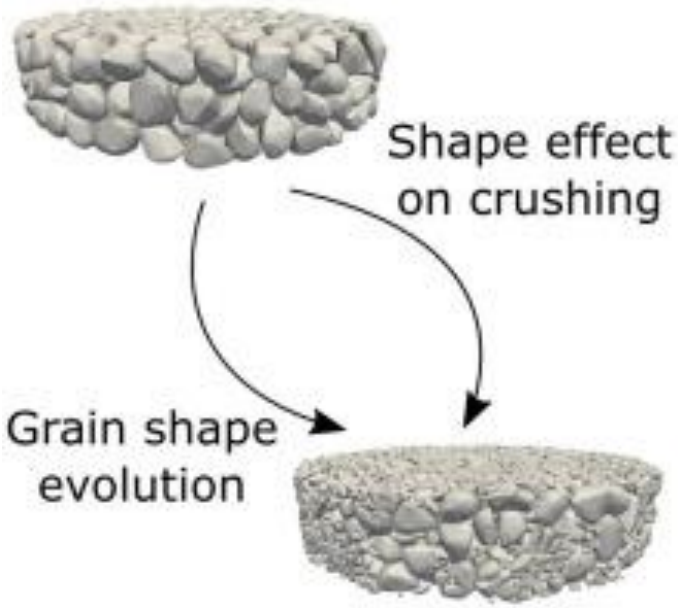
Rahemi (2017)



Liquefaction susceptibility



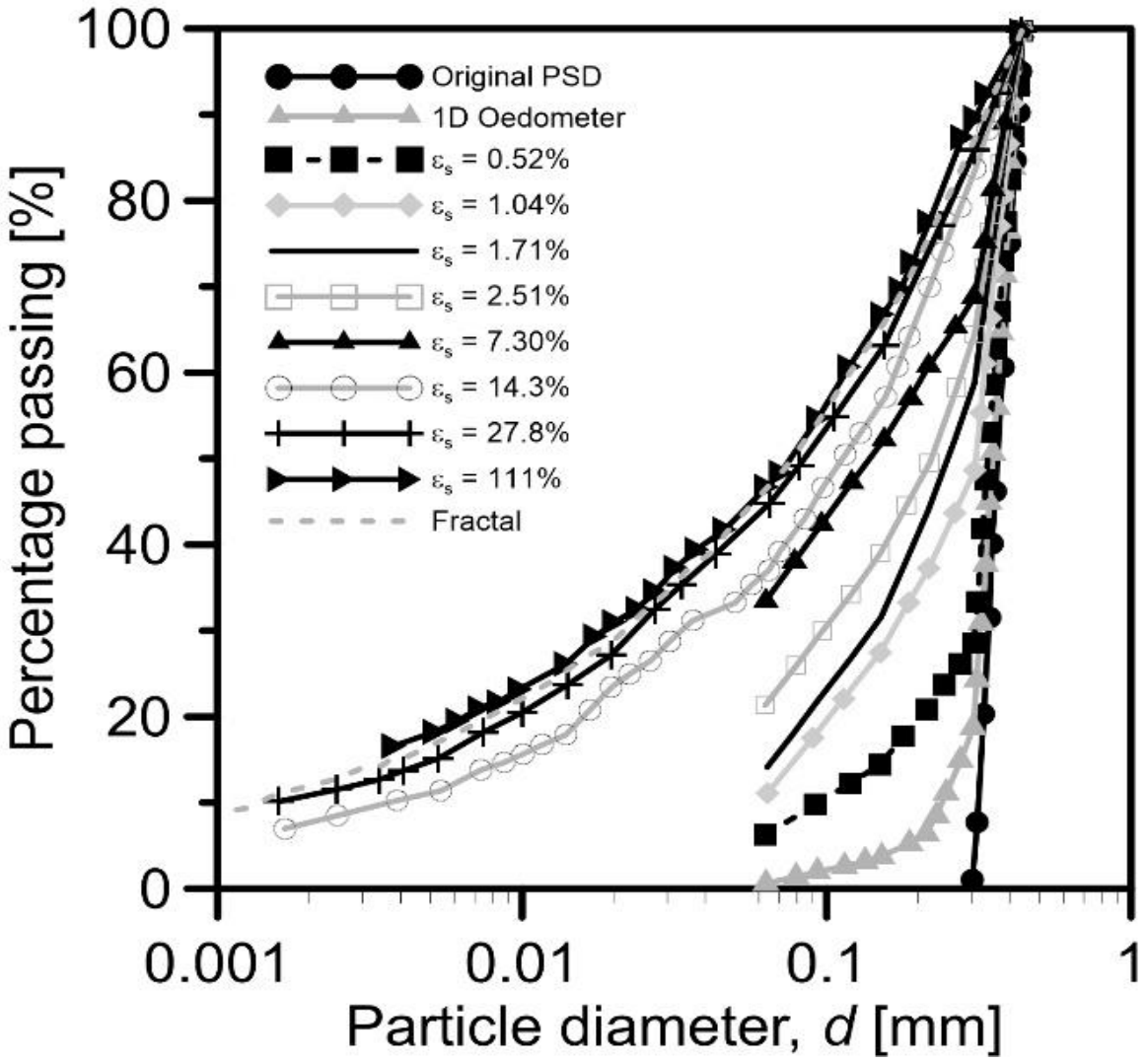
Particle breakage



Zhu & Zhao (2021)

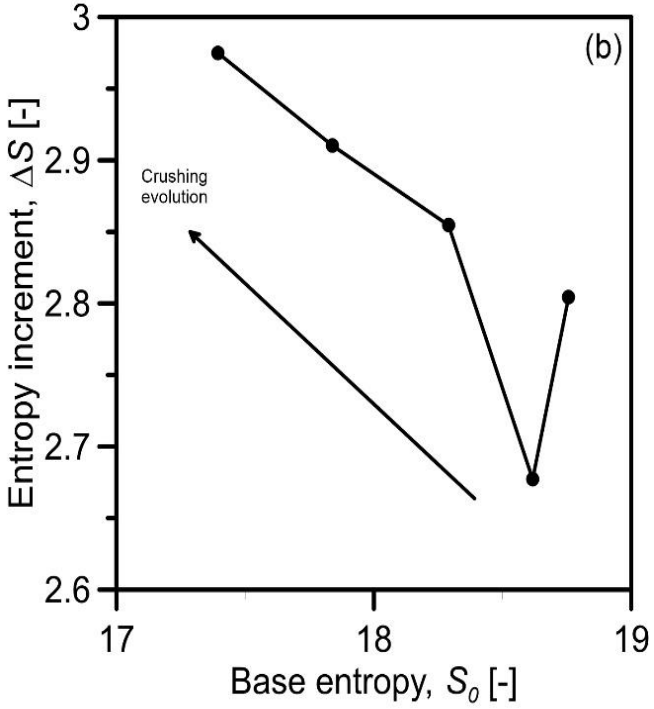
Particle breakage

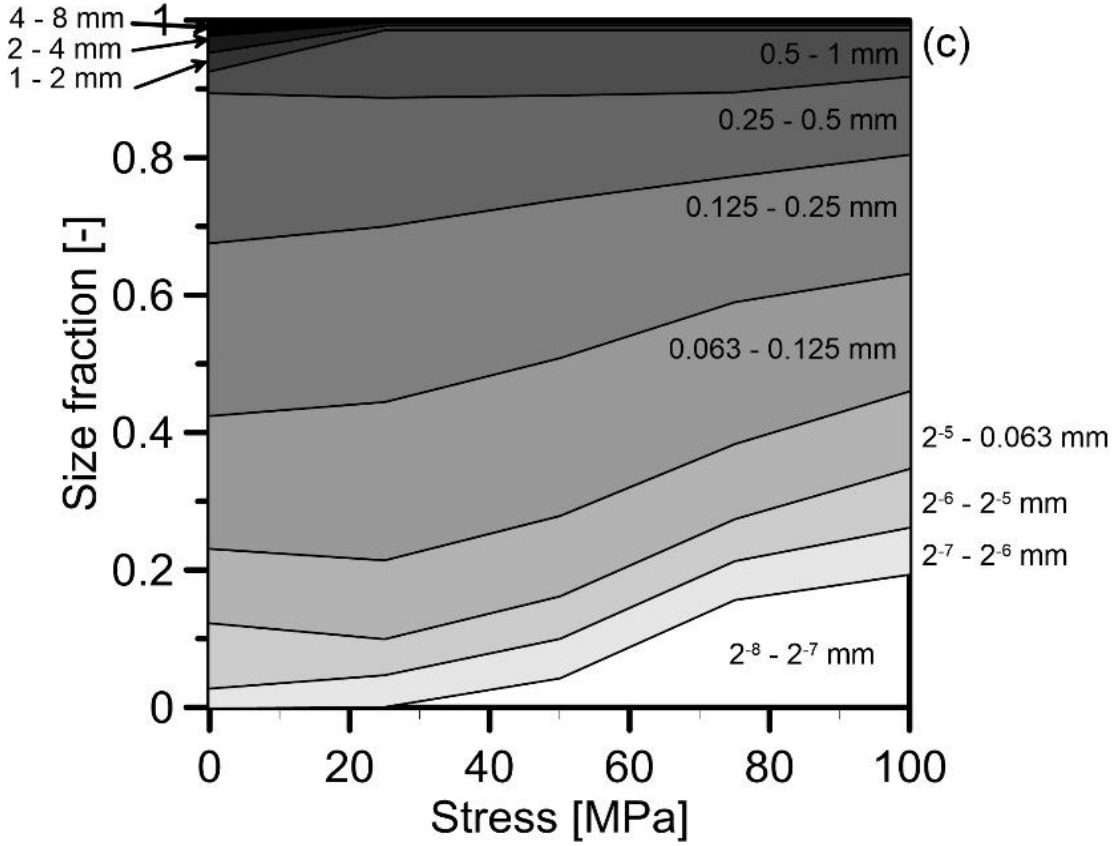
- Experiments by Coop et al (2004)



Particle breakage

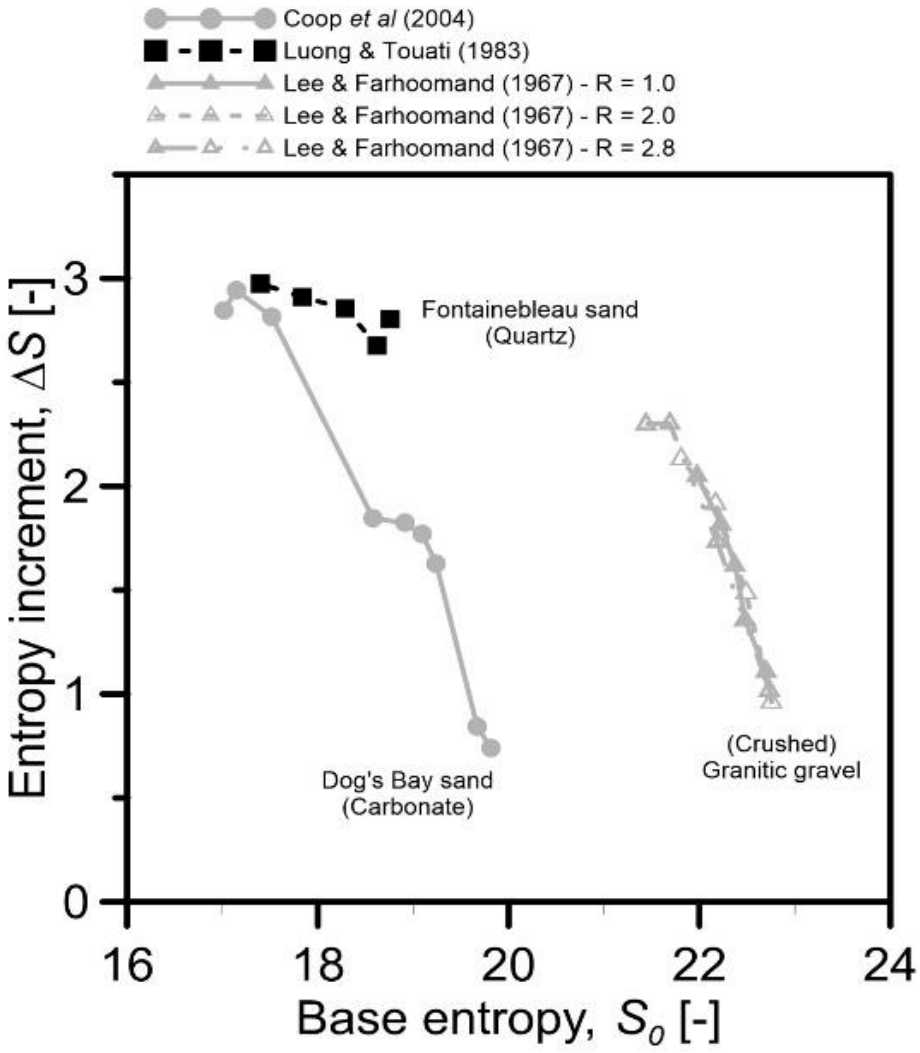
- Experiments by Luong & Touati (1983)



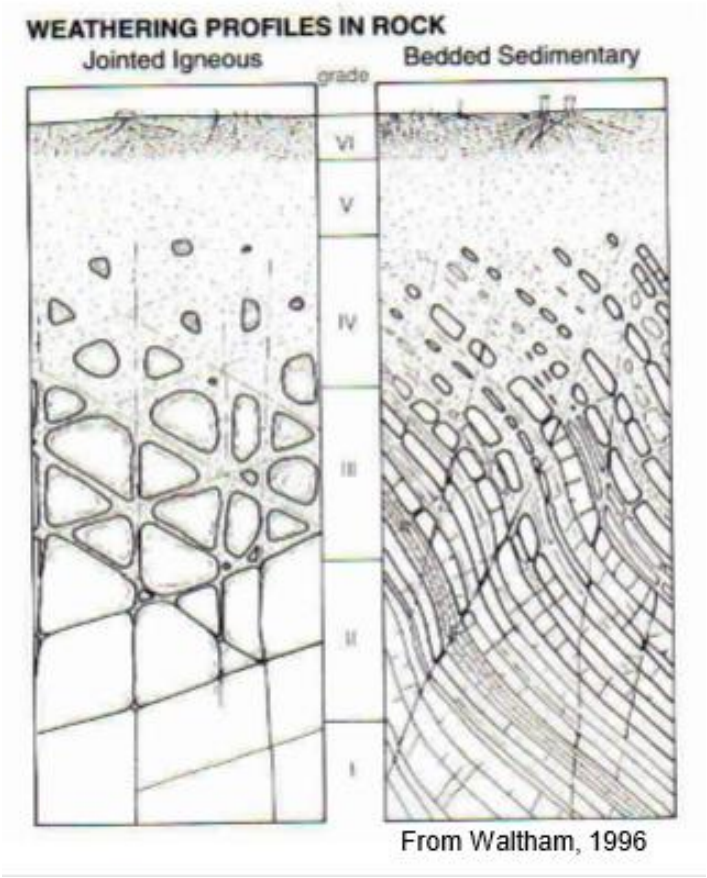


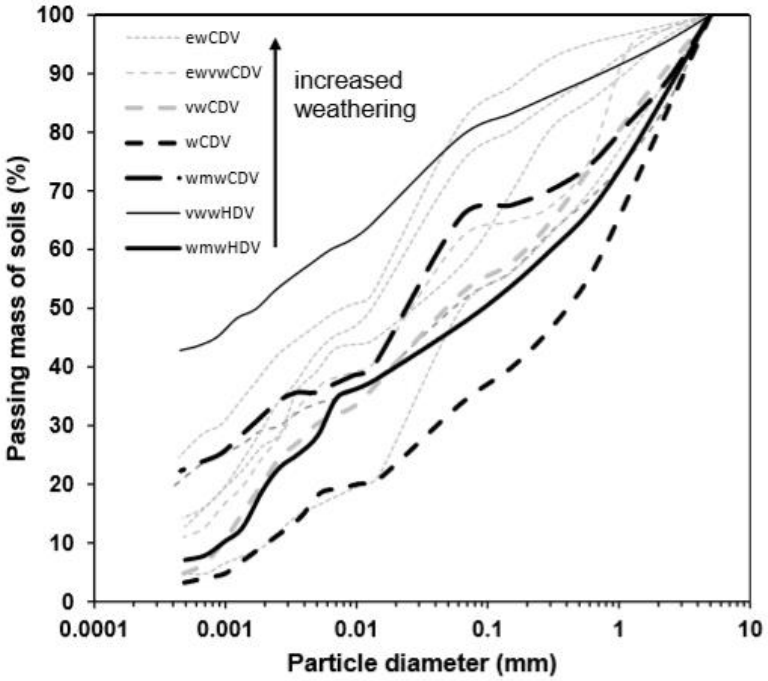
Particle breakage

- Effect of mineralogy



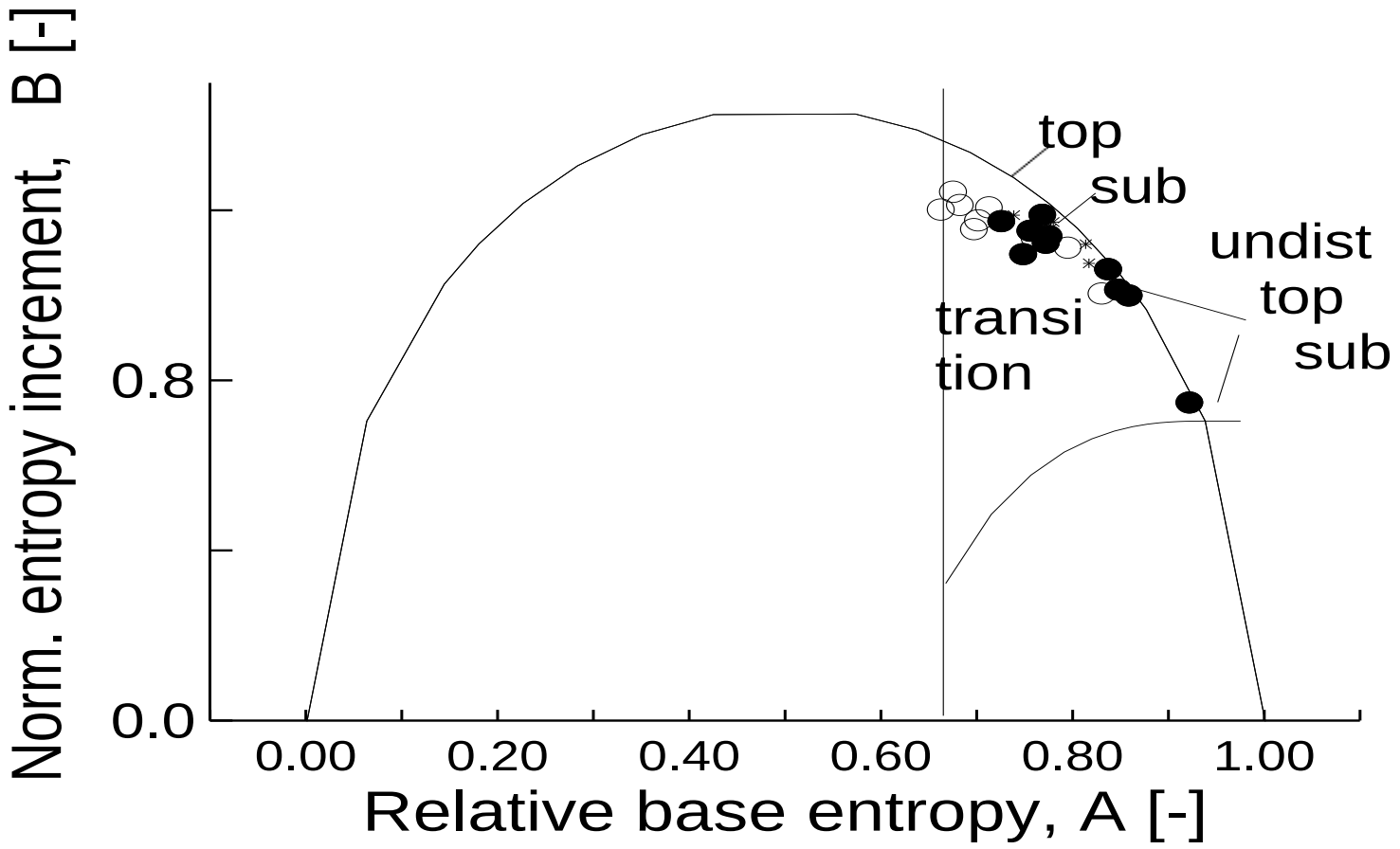
Weathering processes



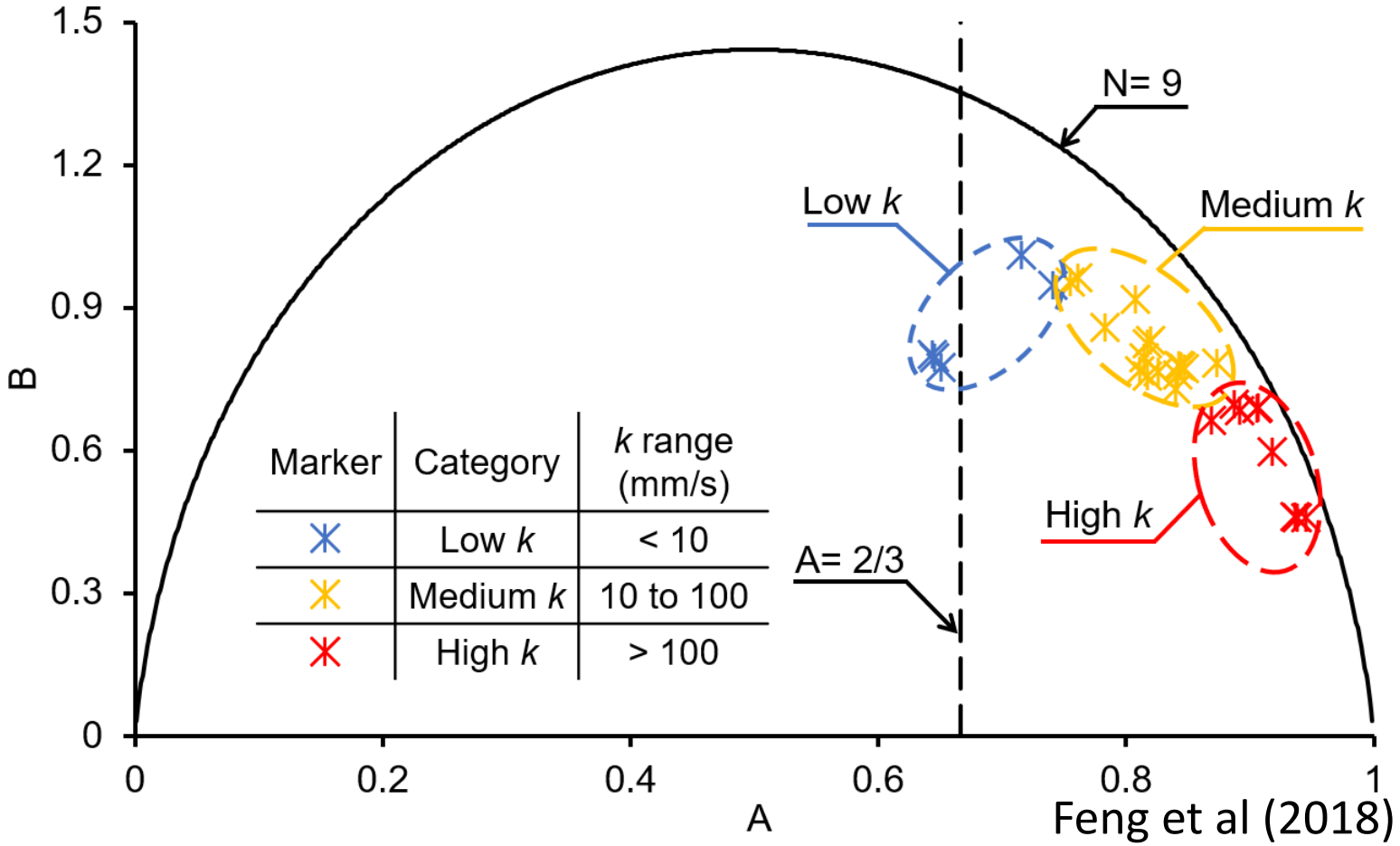


Okewale & Coop (2016)

Weathering processes



Permeability – Sands with N = 3



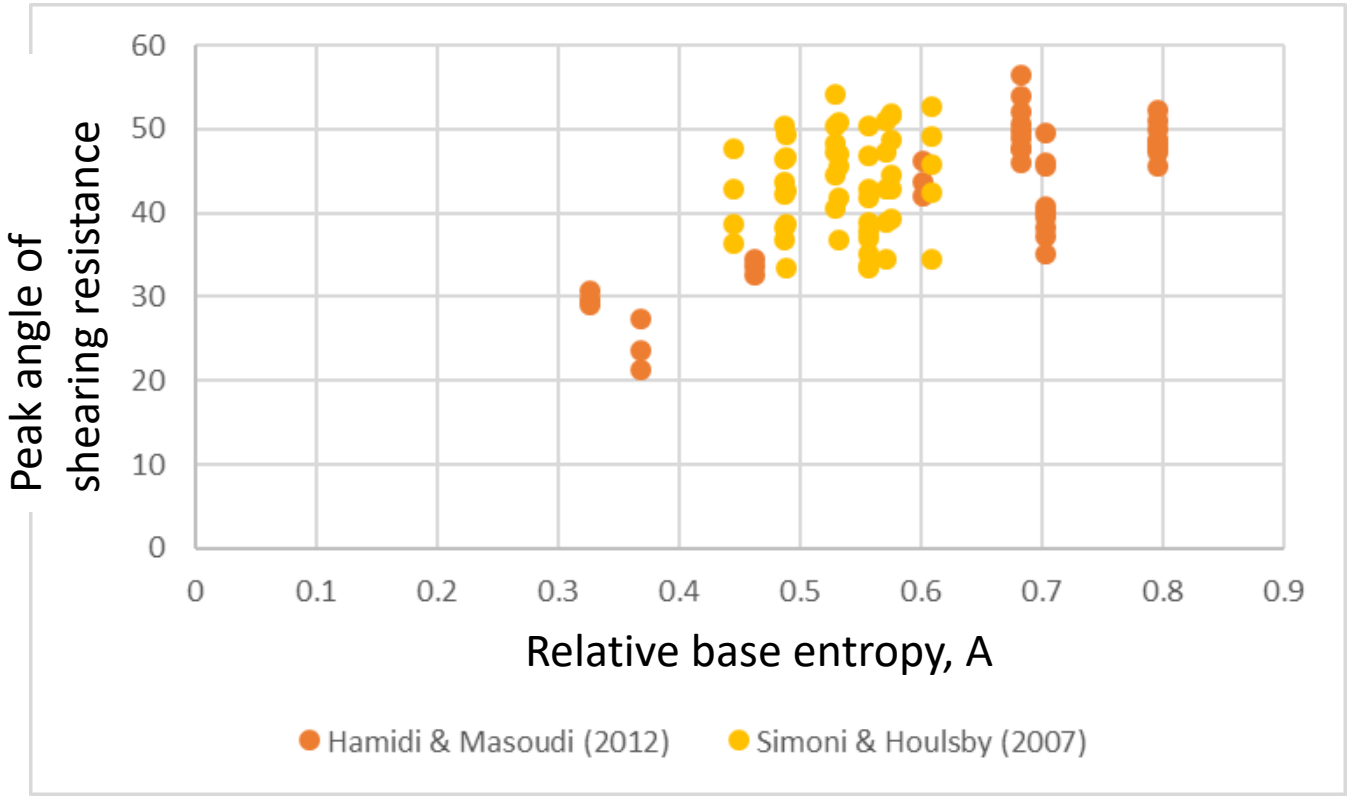
Gravel content effect on shear strength

Parameters	Soil type	Relation to increase the percentage of coarse materials	References
FA	Mixture of clay, silt, sand and gravel	Increase	[4]
FA	Mixture of clay and gravel	Increase	[6]
SH	Mixture of clay and gravel	Increase	[6]
FA	Mixture of sand and gravel	Increase	[7]
USH	Mixture of clay, silt, sand and gravel	Start to increase when the percentage of fine materials is less than 75%	[9]
FA	Mixture of clay, silt, sand and gravel	Increase	[16]
FA	Mixture of sand and gravel	Increase till specific point then decrease	[17]
USH	Mixture of clay and sand	High at 90% percentage of coarse material then decrease from 70% to 50% (the lower shear strength) and then decrease from 30% to 0%	[18]
USH	Mixture of sand and gravel (gravel <50%)	Decrease	[19]
FA	Mixture of sand and gravel	Increase	[20]
SH	Mixture of sand and gravel	Increase	[20]
SH	Mixture of sand and gravel	Increase	[21]
SH	Sand	Increase	[22]
FA	Simulation of mixture of soil	Increase	[23]
SH	Mixture of sand and gravel (gravel ≤60%)	Increase	[24]
FA	Mixture of sand and gravel (gravel ≤60%)	Increase	[24]
FA	Mixture of sand and gravel (gravel ≤50%)	Increase	[25]

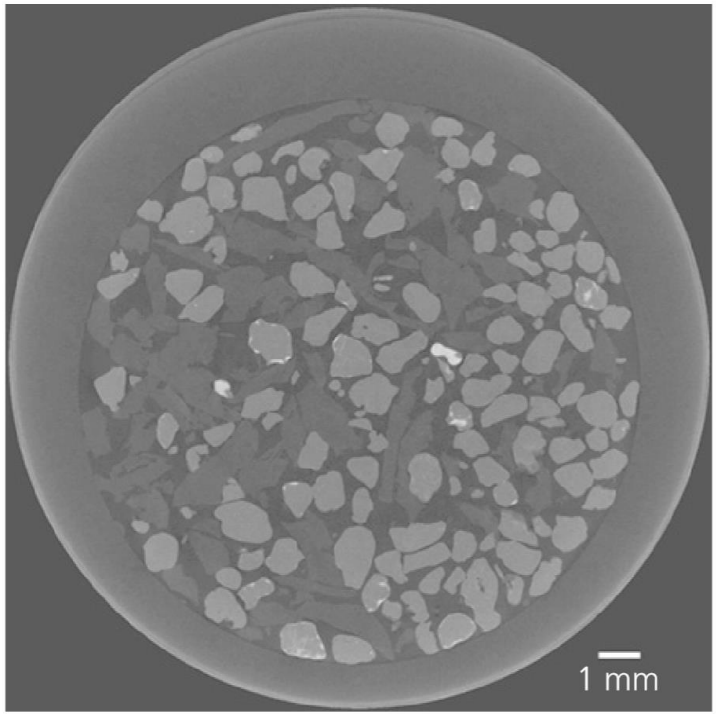
SH is shear strength. FA is friction angle. USH is undrained shear strength.

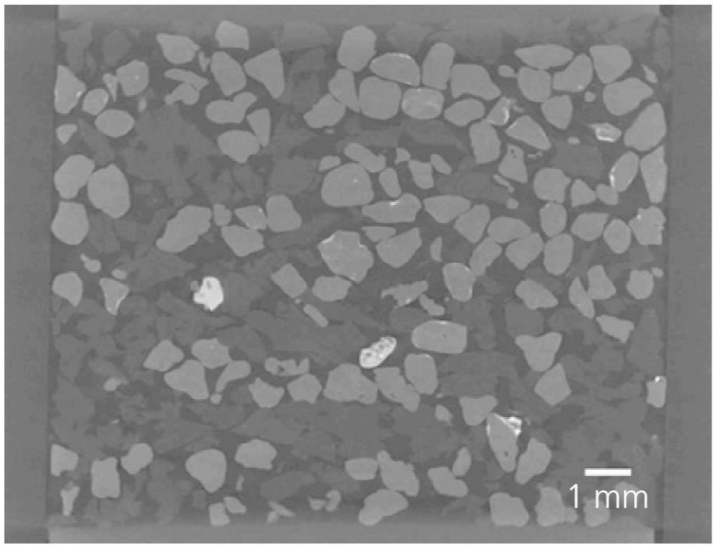
Alshameri et al (2016)

Influence of gravel content on ϕ_{peak}



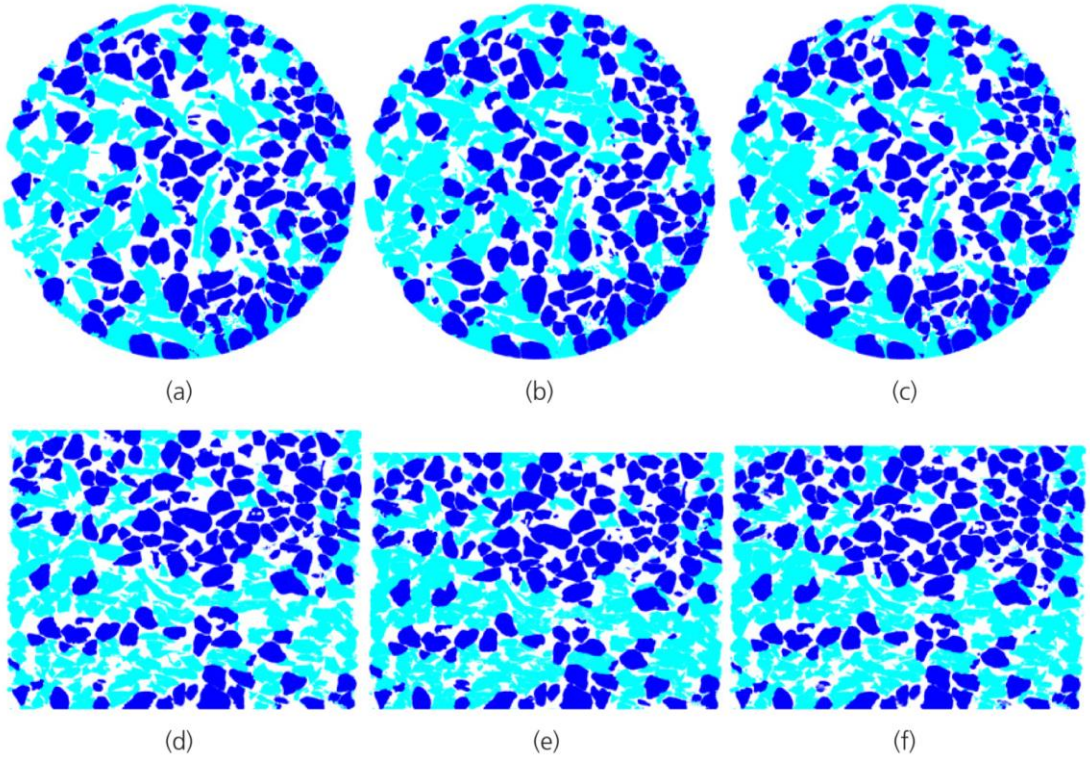
Sand-rubber mixtures





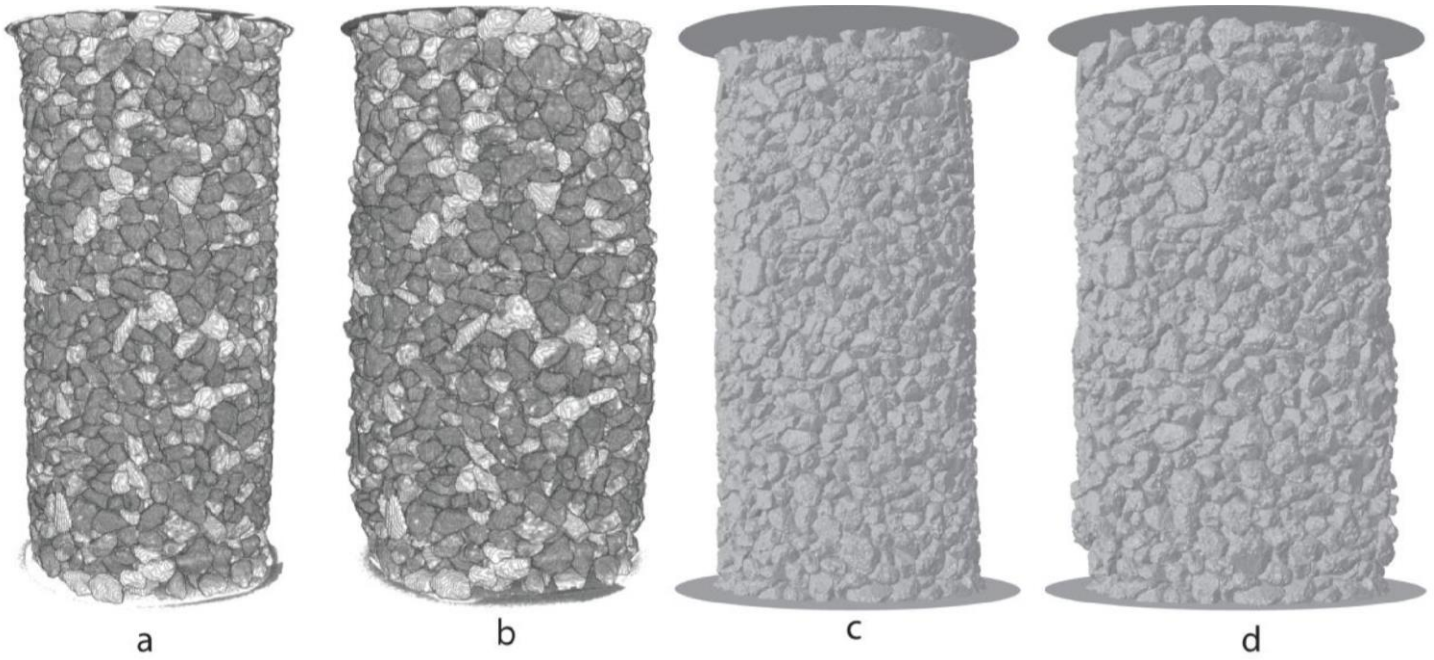
Fonseca et al (2019)

Sand-rubber mixtures



Fonseca et al (2019)

What’s next…



Nadimi et al (2019)

What's next…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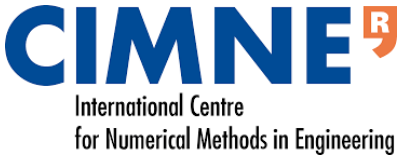
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