Fabric Analysis of Internally Unstable Soils

Fonseca, J., Sim, W. W., Shire, T., and O'Sullivan, C.

Imperial College London

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ice
Institution of Civil Engineers

Dr. Catherine O'Sullivan
Dept. Civil and Environmental Engineering
Imperial College London
cath.osullivan@imperial.ac.uk

Fabric Analysis of Internally Unstable Soils

- Consideration of the shape of the particle size distribution curve is often used to assess susceptibility to internal erosion
- What is the link between quantitative assessment of the PSD and the particle-scale fabric of the soil?
- Research considered Kézdi criterion using micro computed tomography

Micro Computed Tomography (microCT)

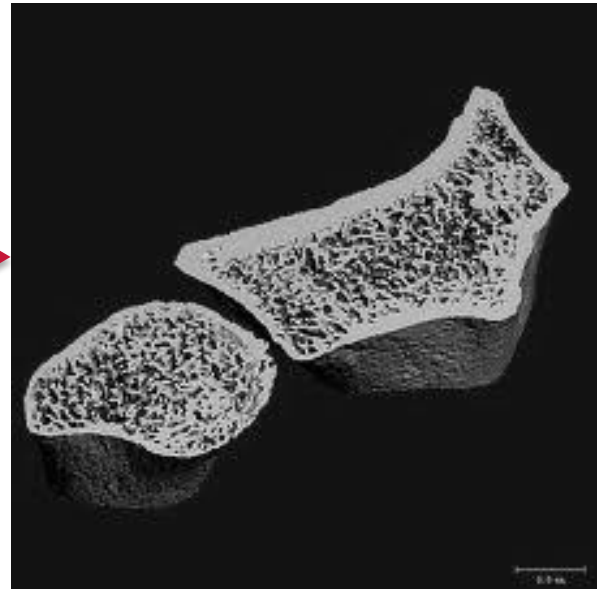
- High resolution, three-dimensional images created using X-rays
- Non-destructive

[Wikipedia]

2D X-ray radiograph

[http://orthoanswer.org]

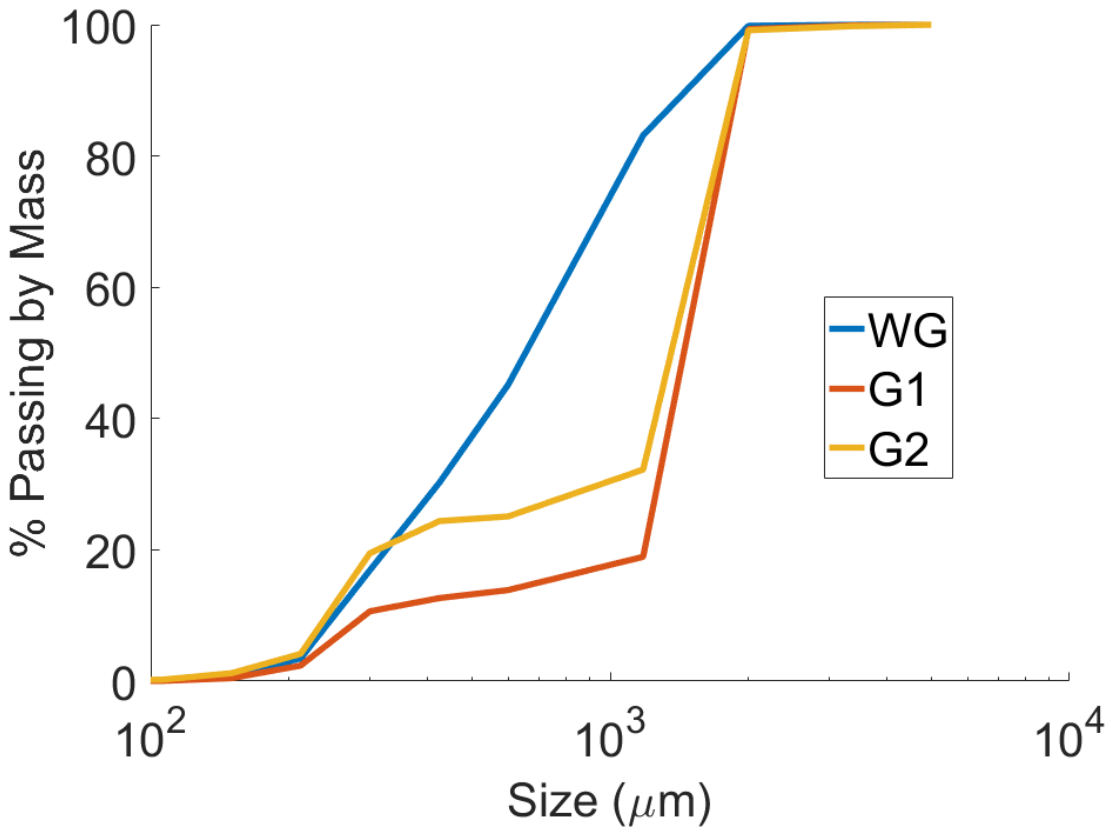
3D CT scan



[http://www.scanco.ch]

3D Micro-CT scan

Materials Considered



Leighton Buzzard Sand

WG – Well graded

G1:
86%: 2360μm>D>1180μm
12%: 300μm>D>150μm

G2:
73%: 2360μm>D>1180μm
24%: 300μm>D>150μm

Sample preparation

Mould placed around membrane

Membrane rolled around mould and suction applied

Dry pluviation

Gap graded pluviated in 200g batches

Gentle vibration

50 kPa vacuum confinement

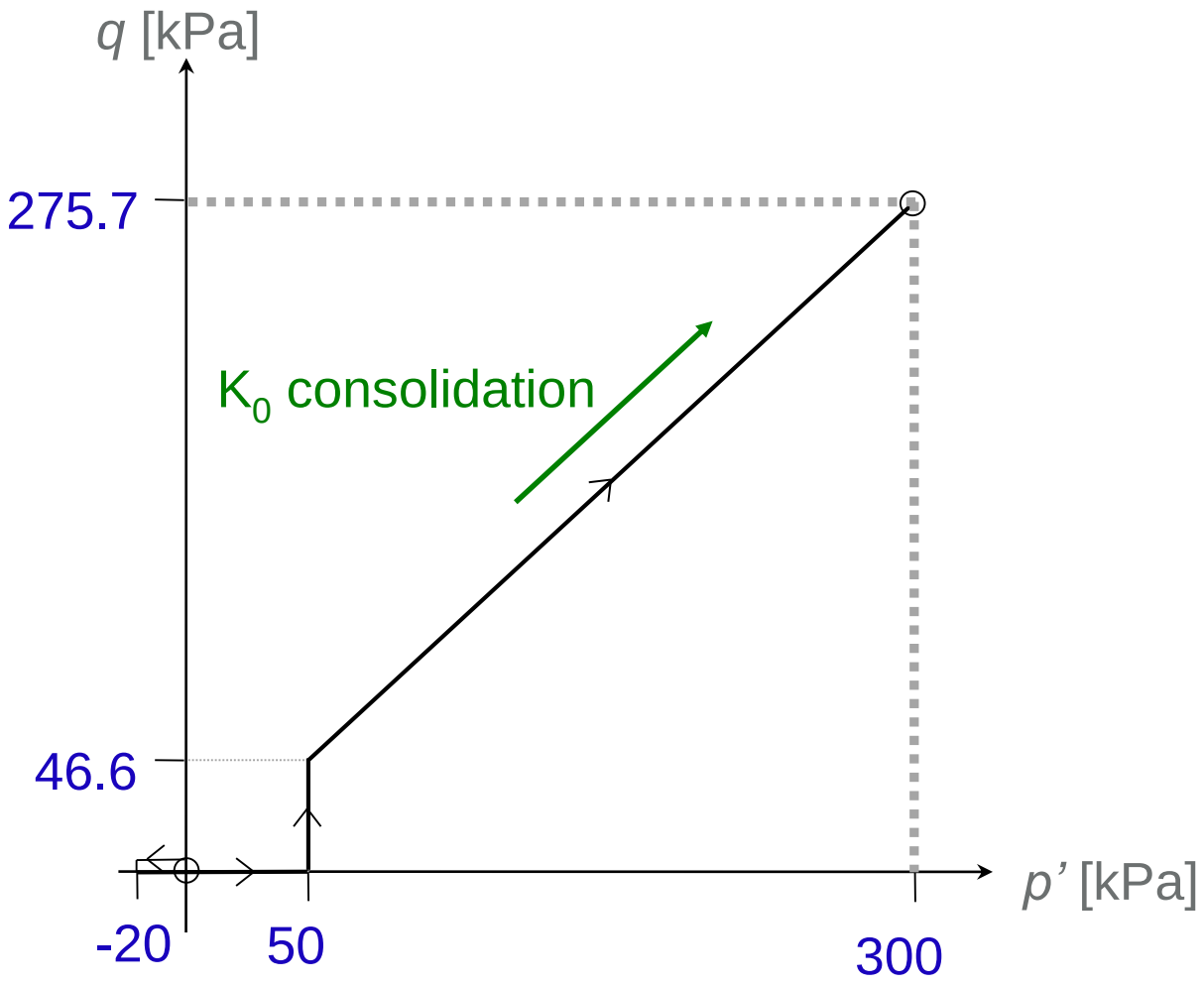
Mould removal

Cell chamber placed

Cell pressure applied

Suction removed

Sample preparation: Stress path

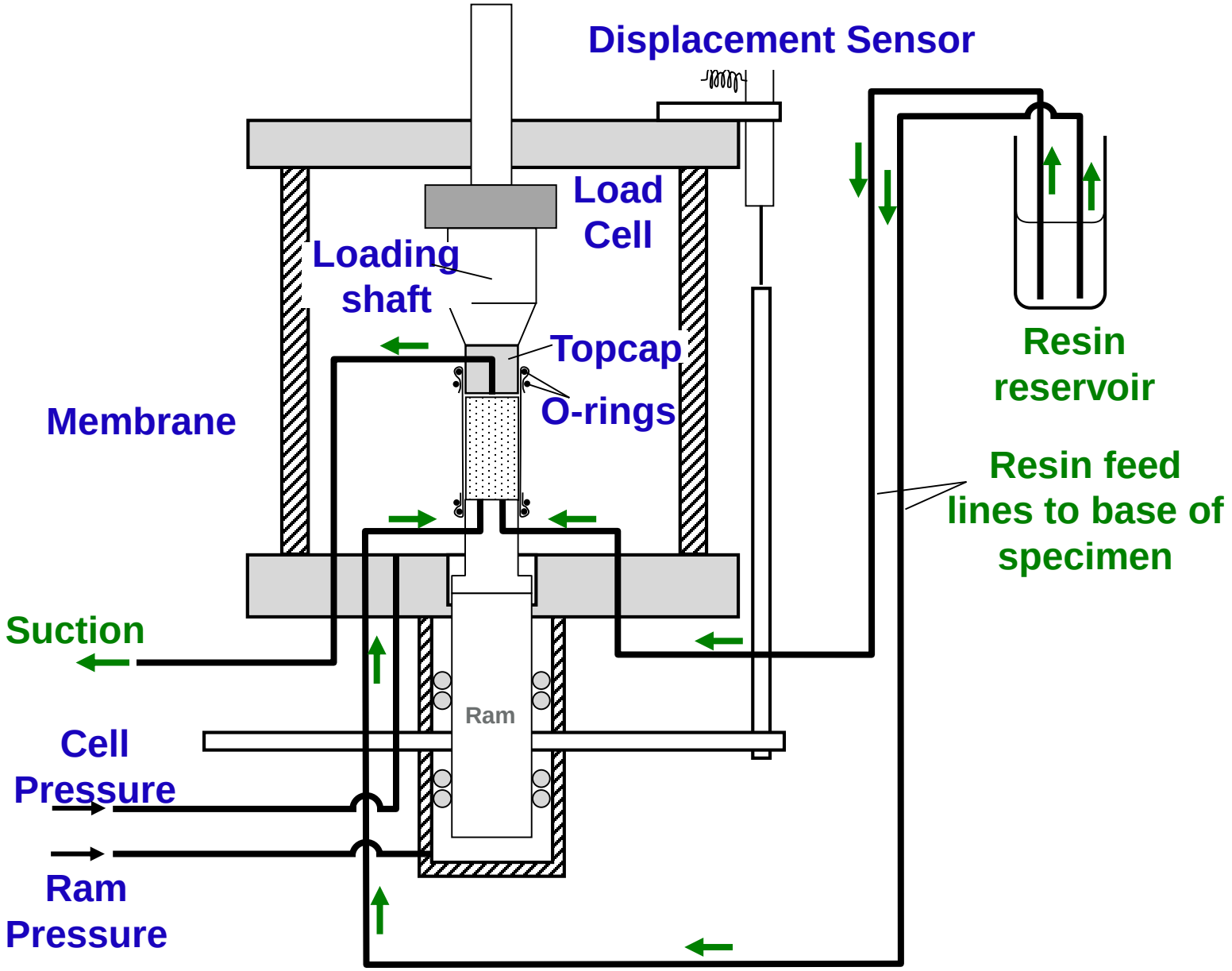


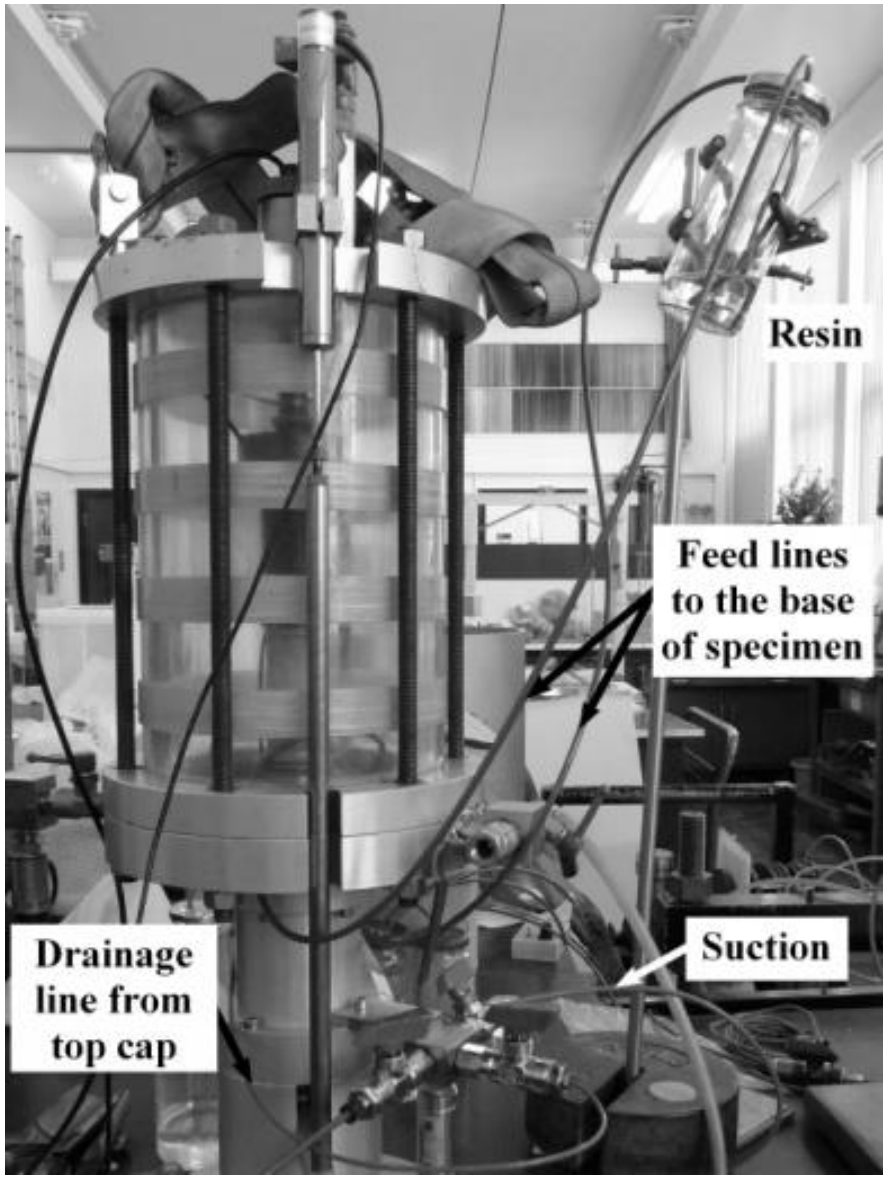
K_0 consolidation

$K_0 = 0.43$

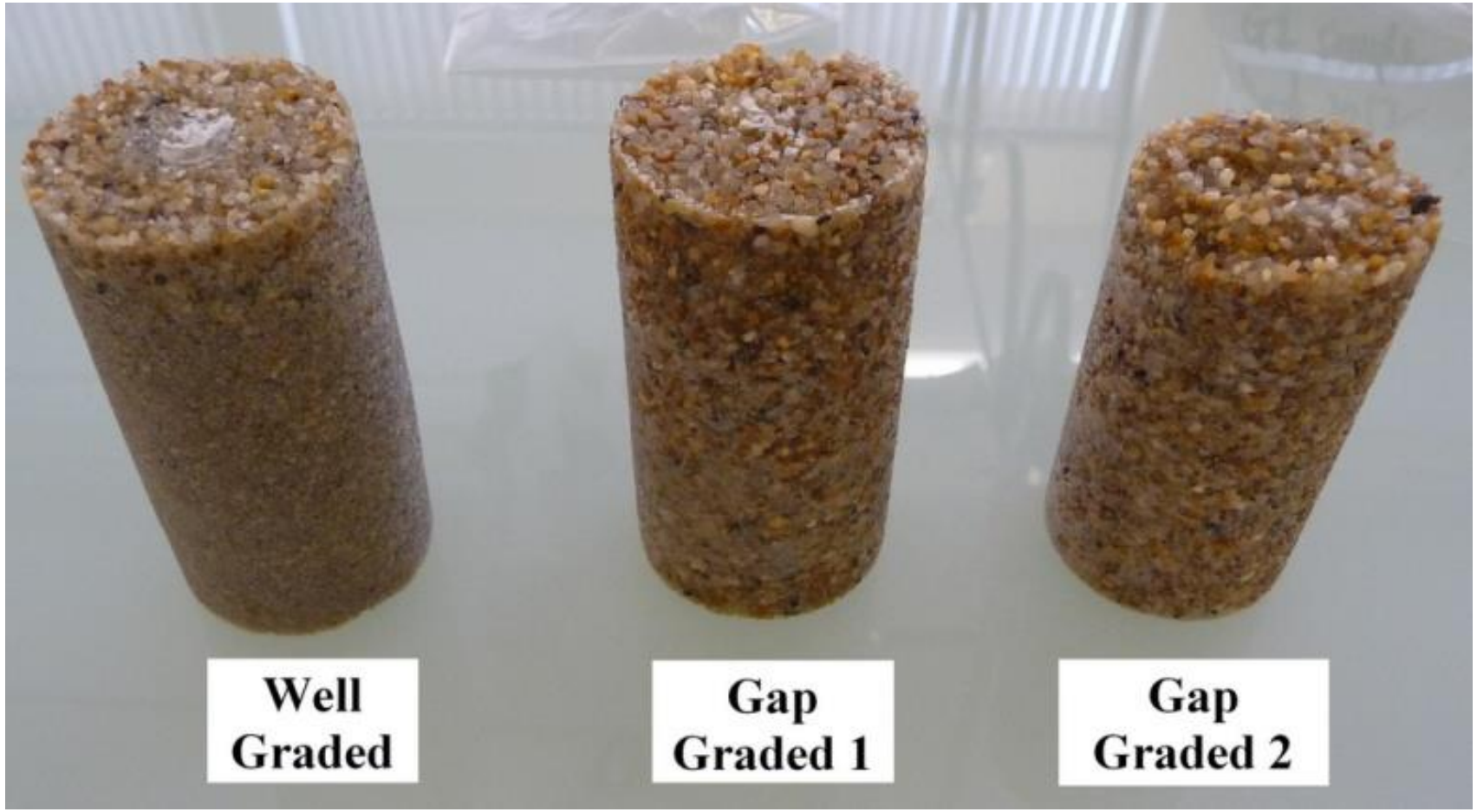
$\phi' = 35^o$

Sample preparation

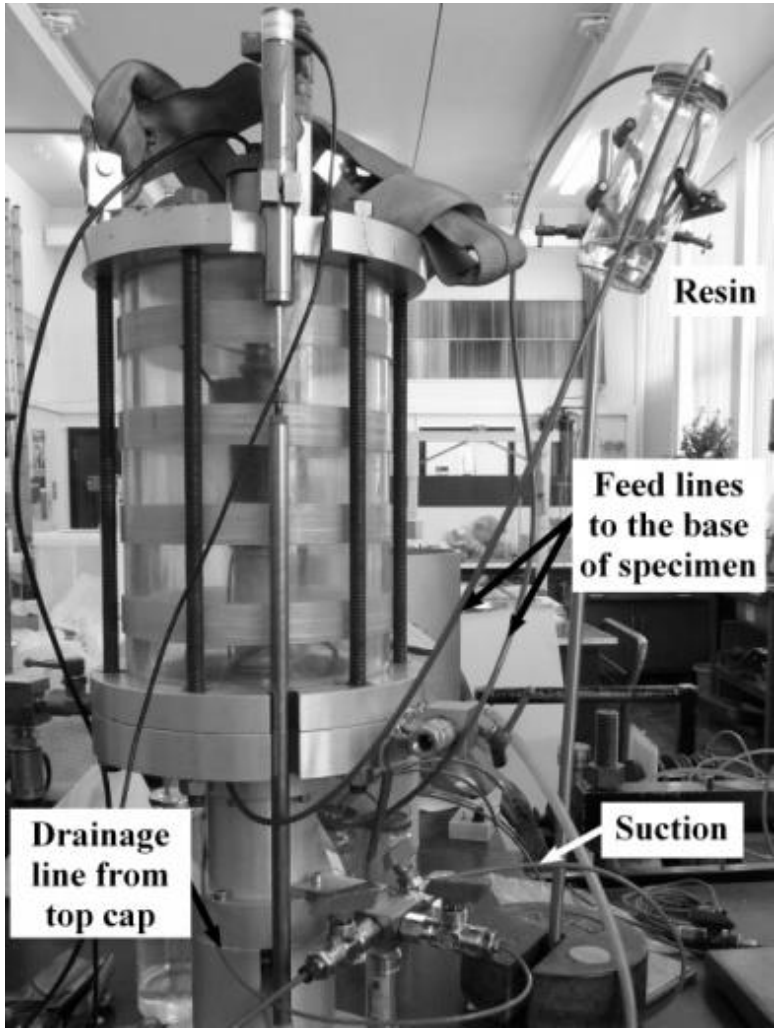


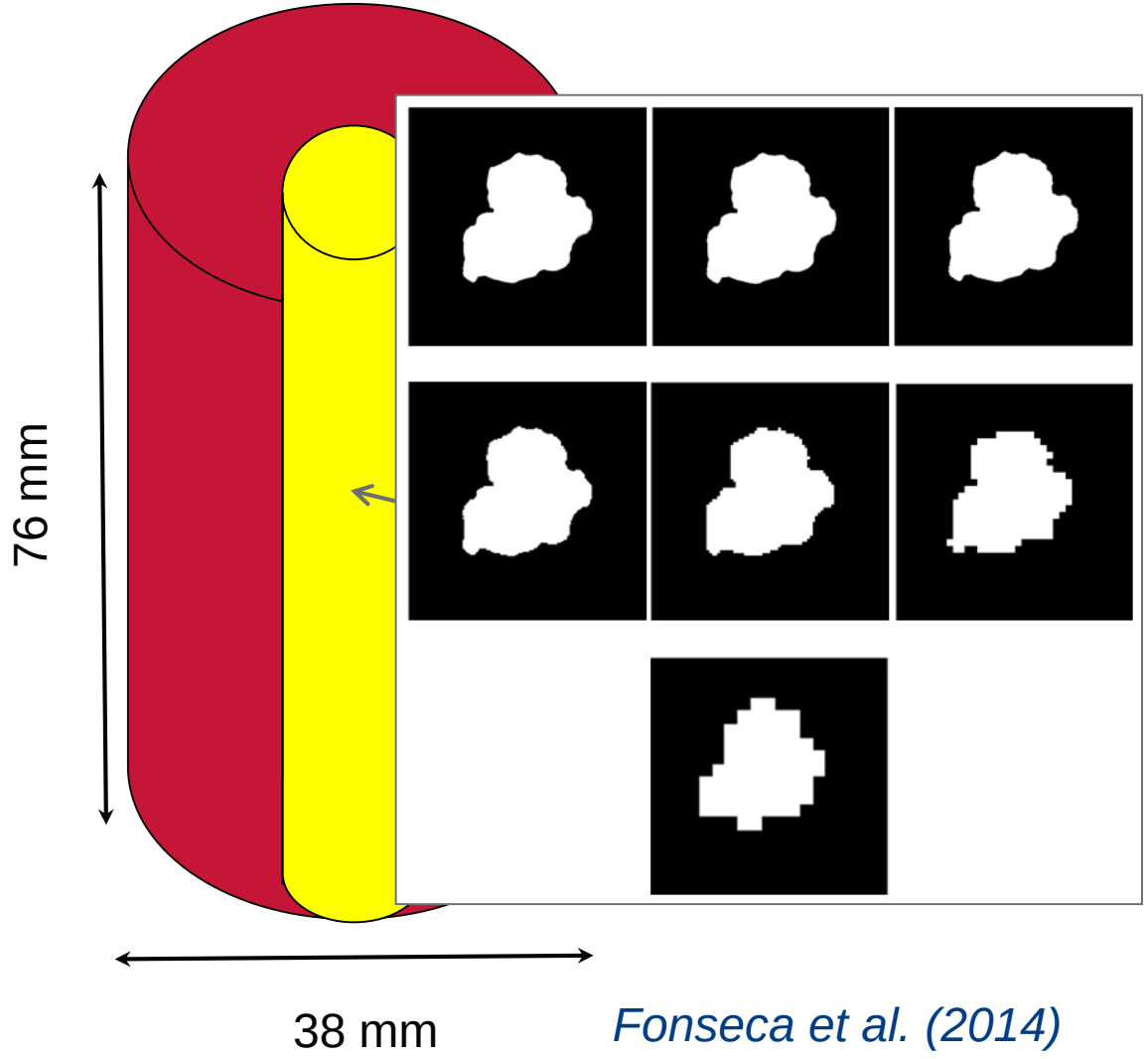


Sample preparation



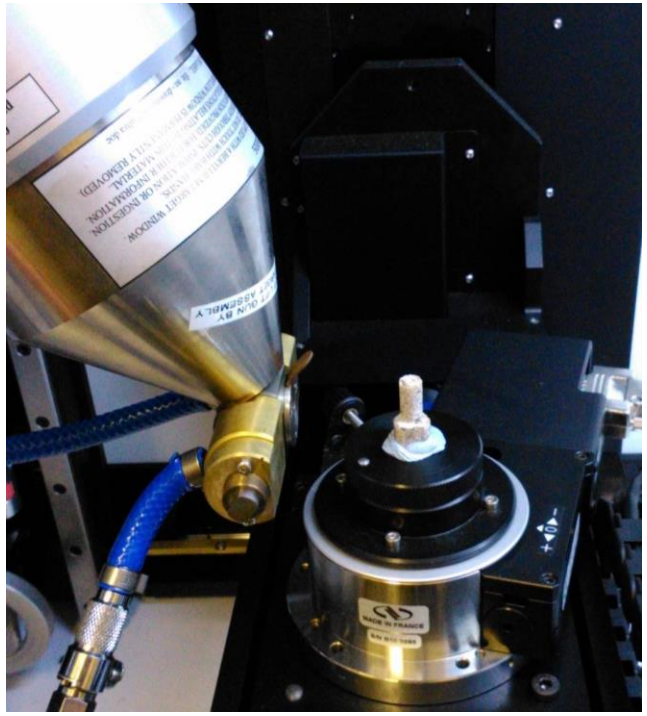
Micro Computed Tomography (microCT)



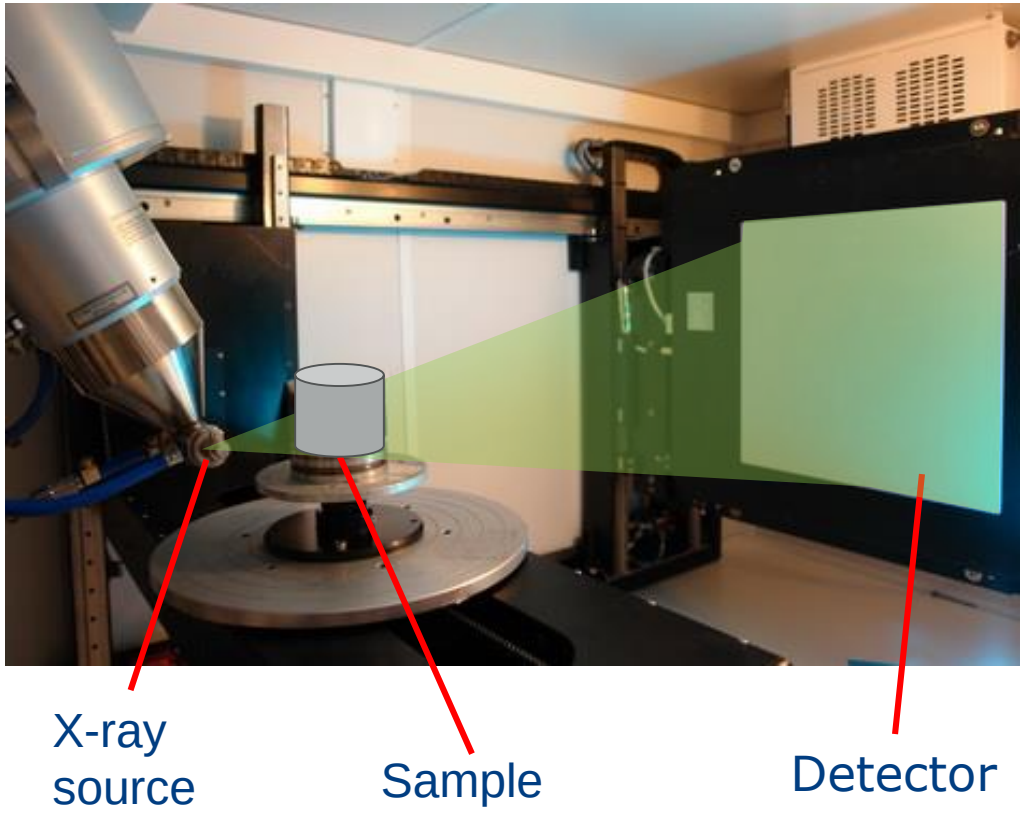


Fonseca et al. (2014) Géotechnique

MicroCT scanning



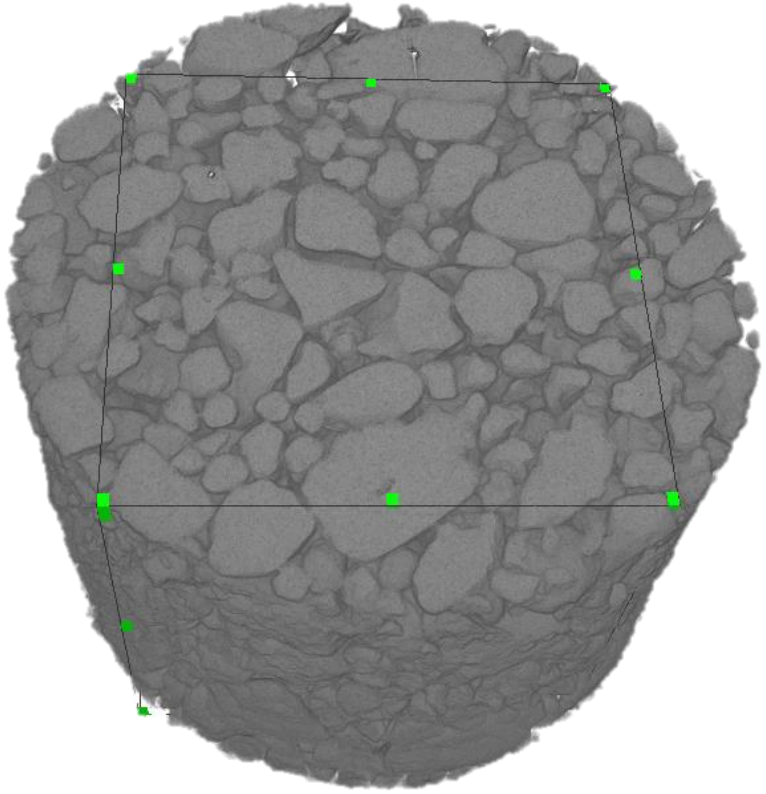
X-Ray source + typical sample for scanning



(H. Taylor, current PhD student)

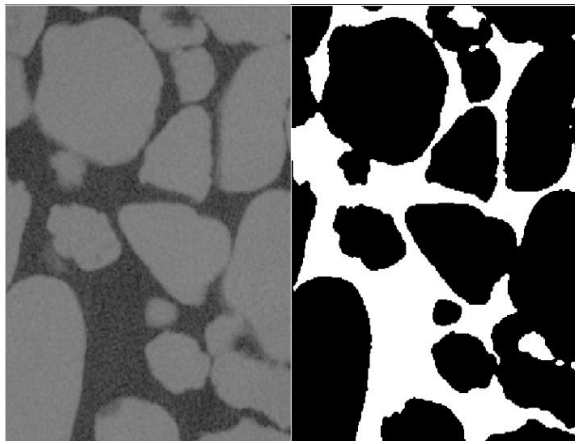
Image source: http://www.nikonmetrology.com

MicroCT Data Analysis



Raw output – 3D attenuation map

(H. Taylor)

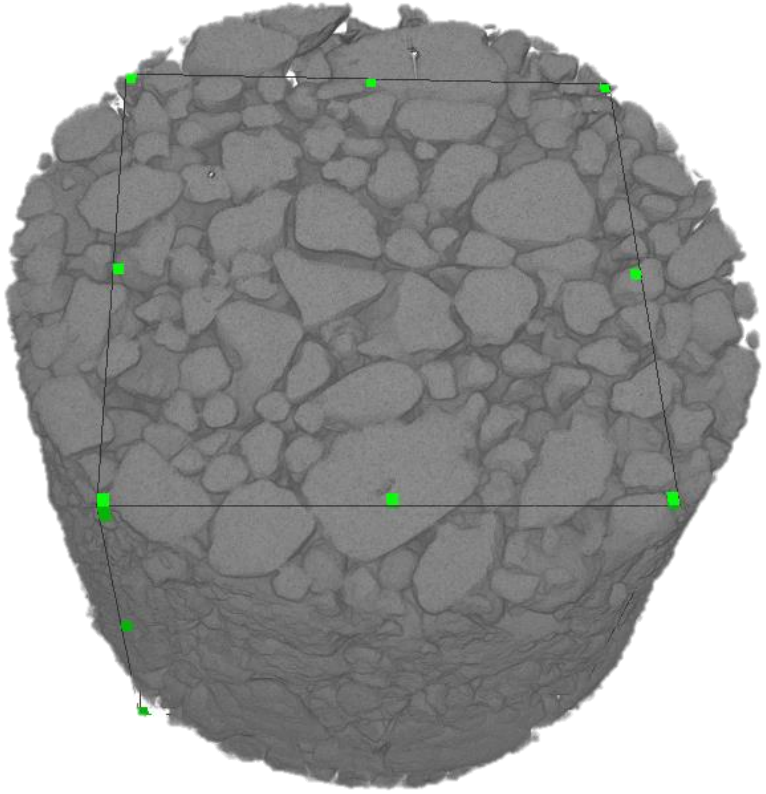


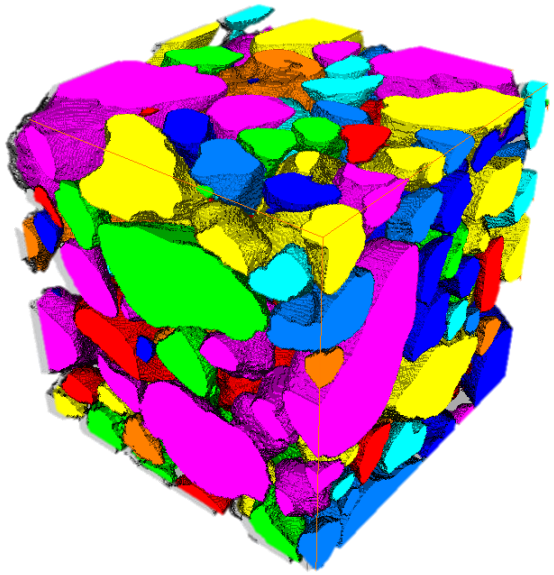
2D Slice from μCT image

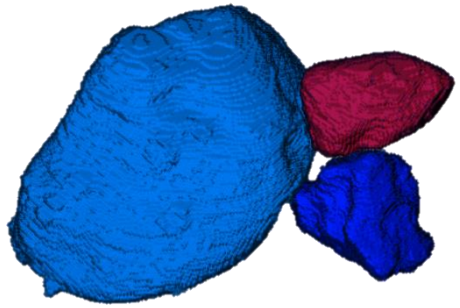
Binary image

Taylor et al. (2015)
Computers and Geotechnics

MicroCT Data Analysis



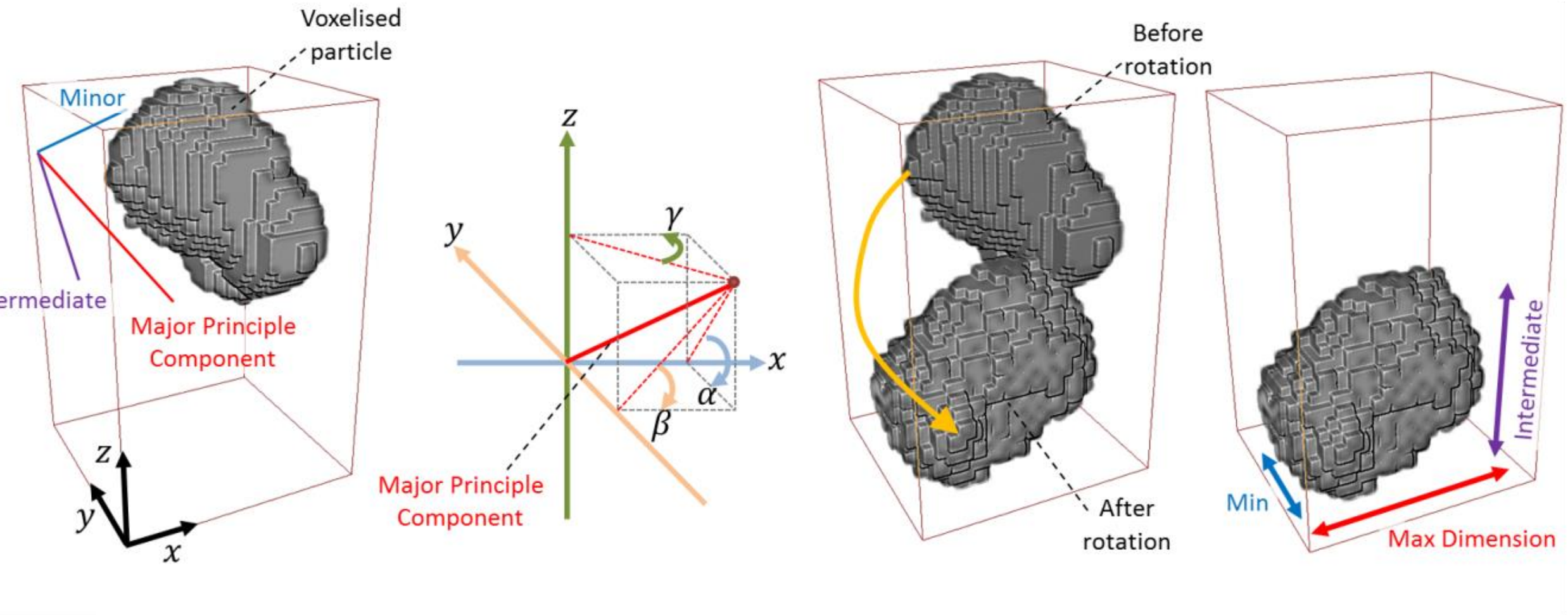




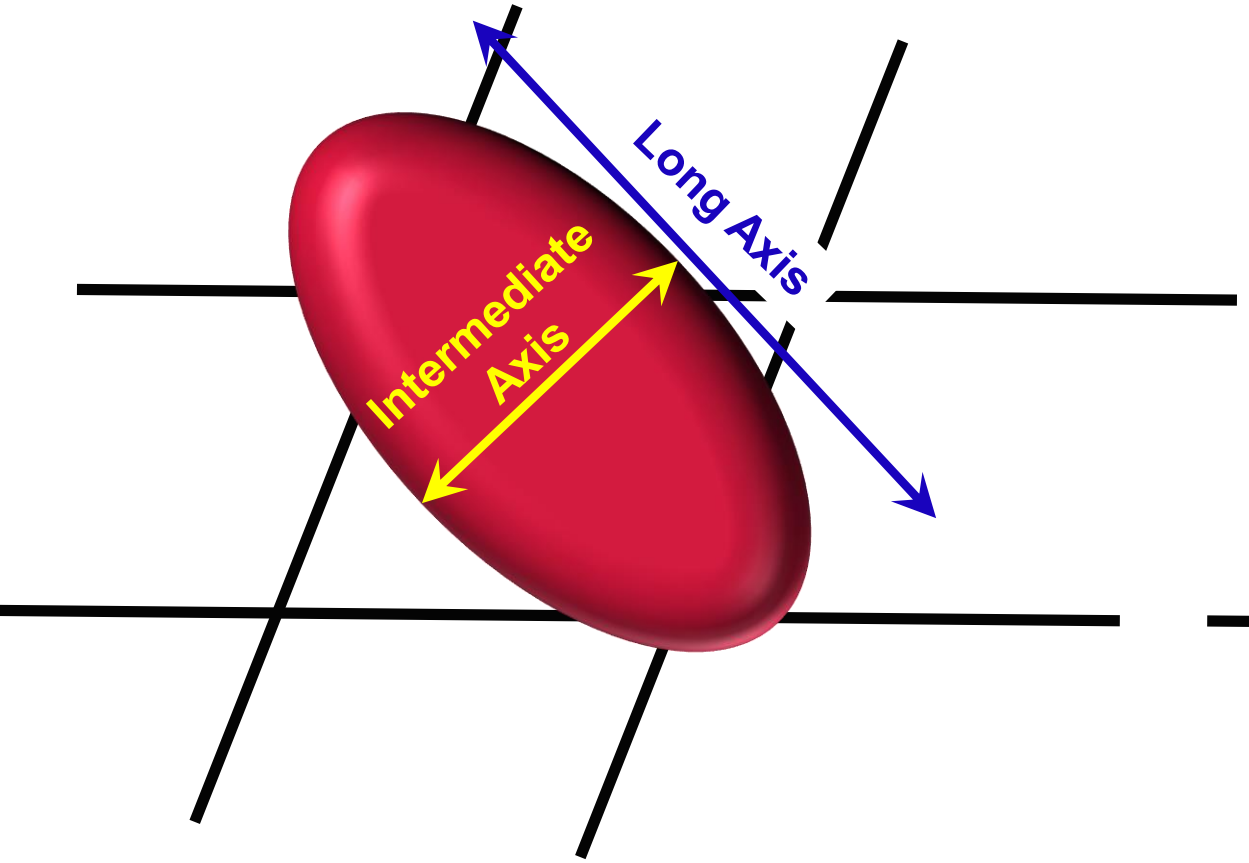
Individual particles and contacts from watershed segmentation

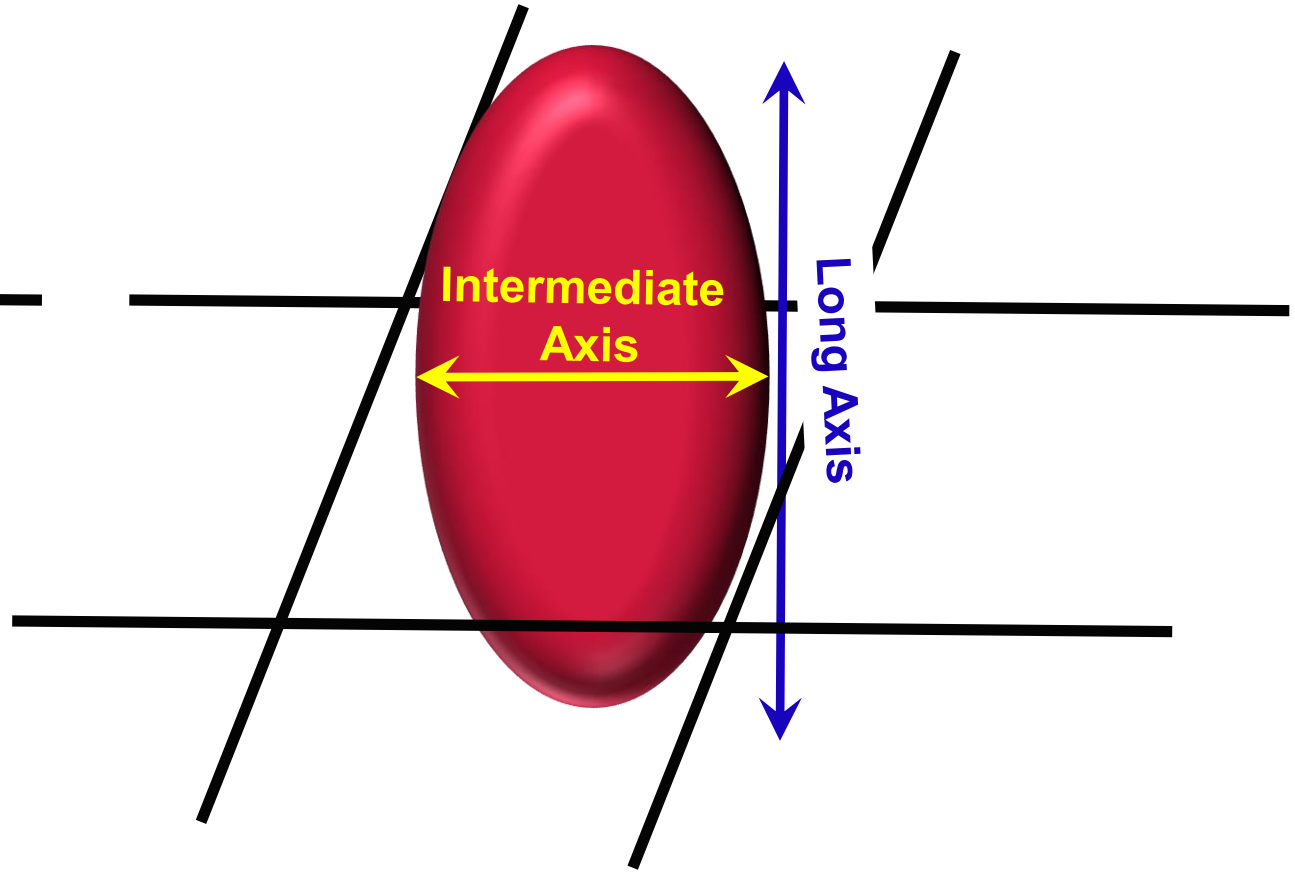
(H. Taylor)

Measuring size in µCT data

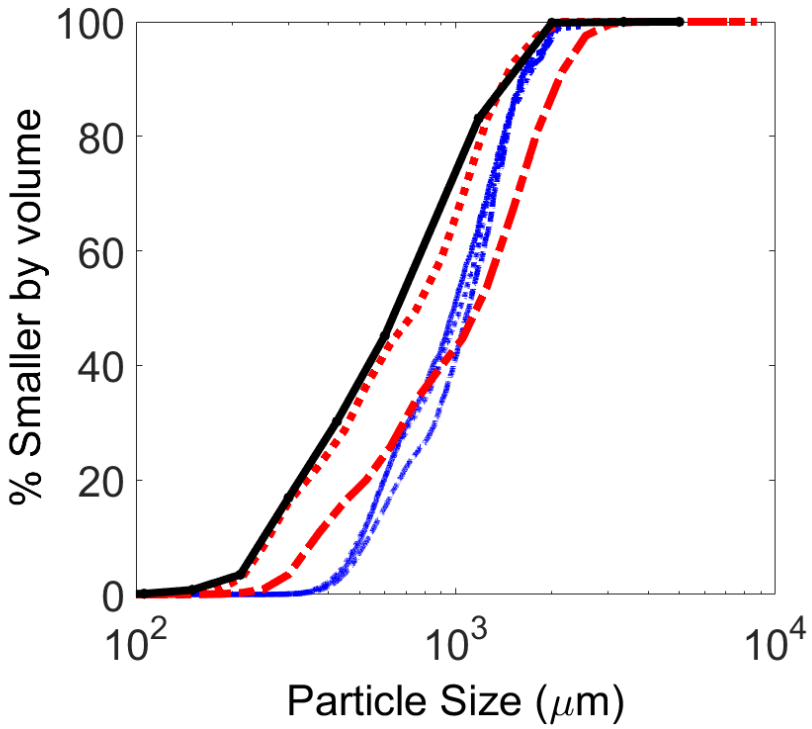


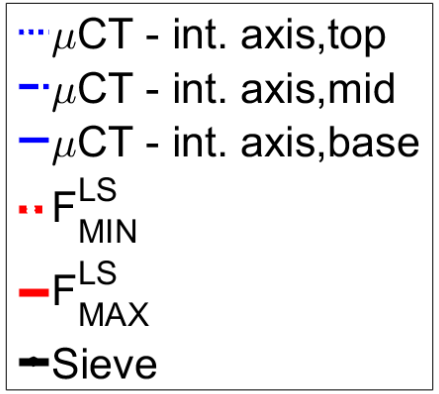
Measuring size in sieve



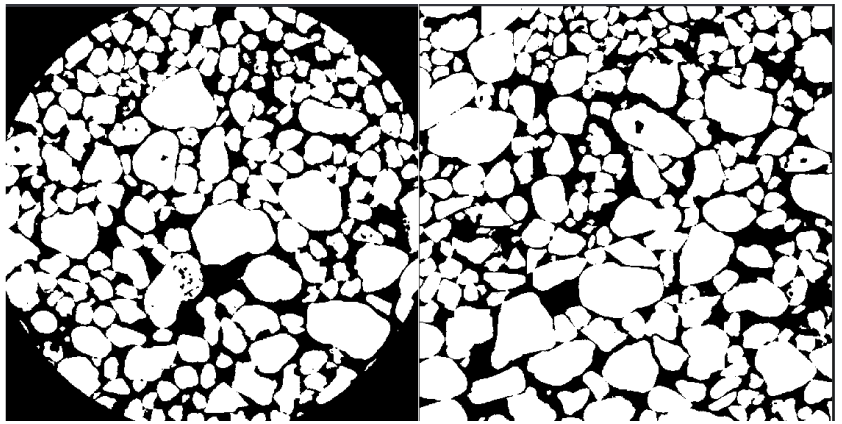


Well Graded Sample

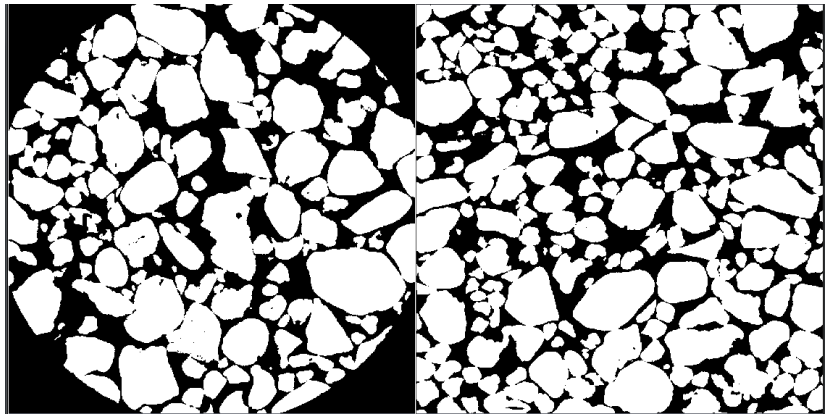




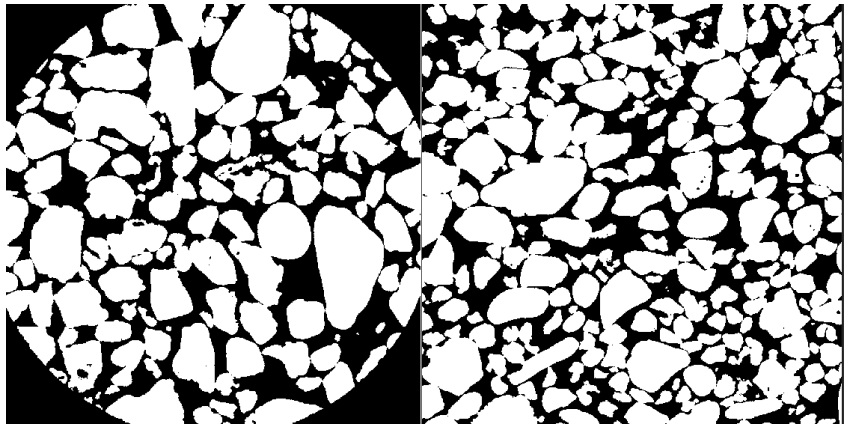
WG Top



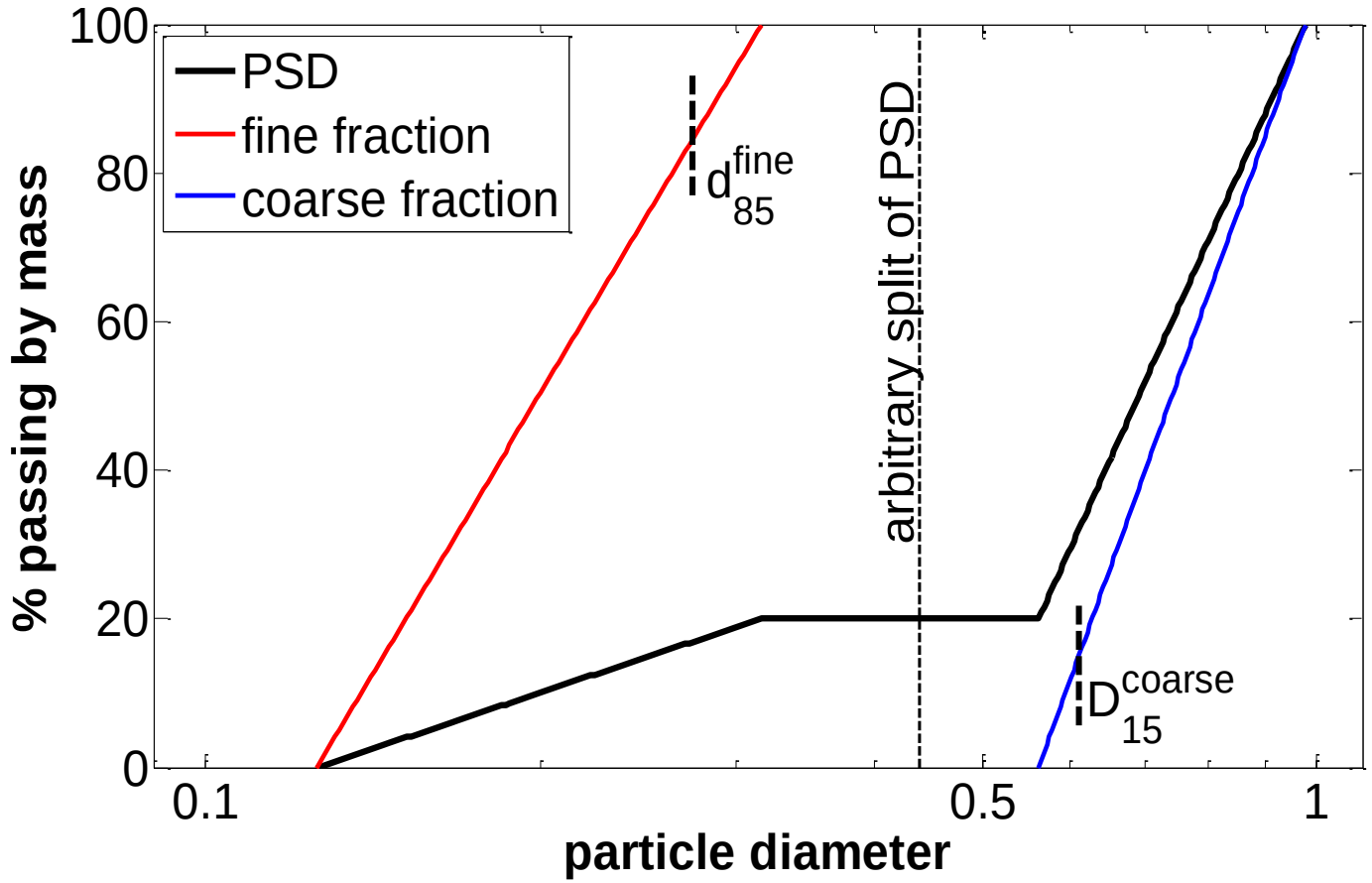
WG Middle



WG Bottom



Empirical Filter Criteria: Kézdi (1979)



Relates to Terzaghi filter rule

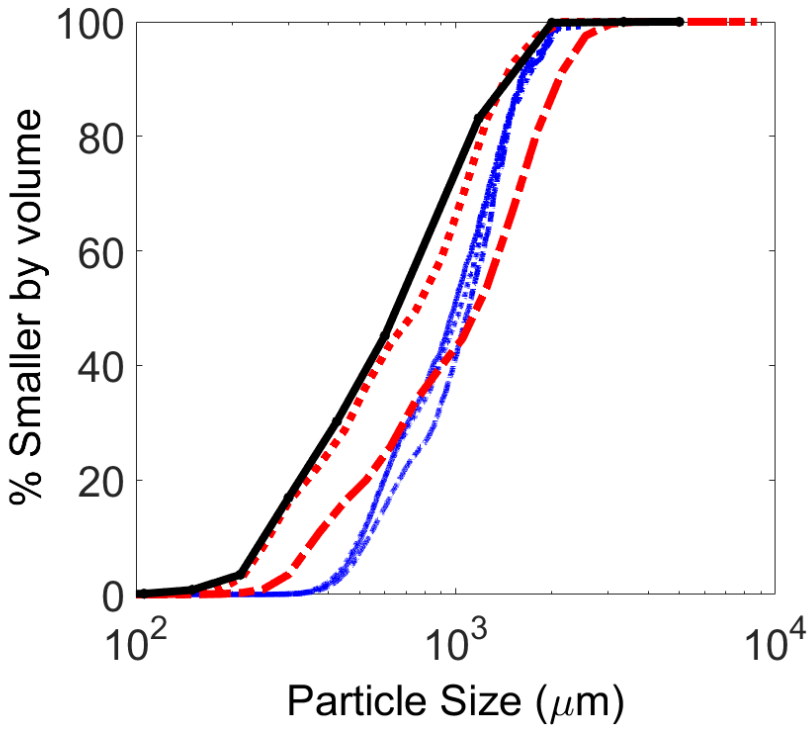
Split PSD into coarse and fine "PSDs"

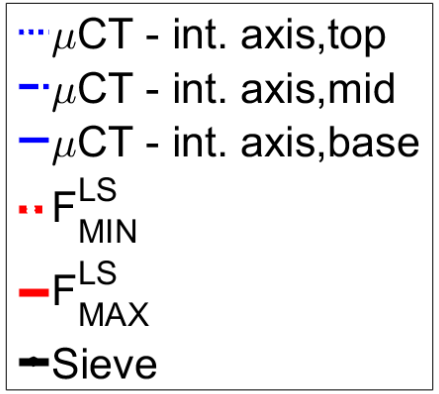
Stable if: $d_{85}^{fine} > (D_{15}^{coarse}/ 4)$

i.e. if

$D_{15}^{coarse}/d_{85}^{fine} < 4$

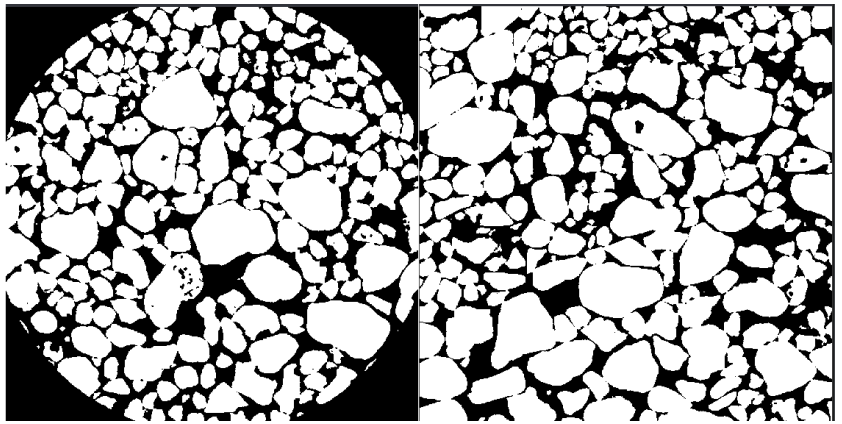
Well Graded Sample





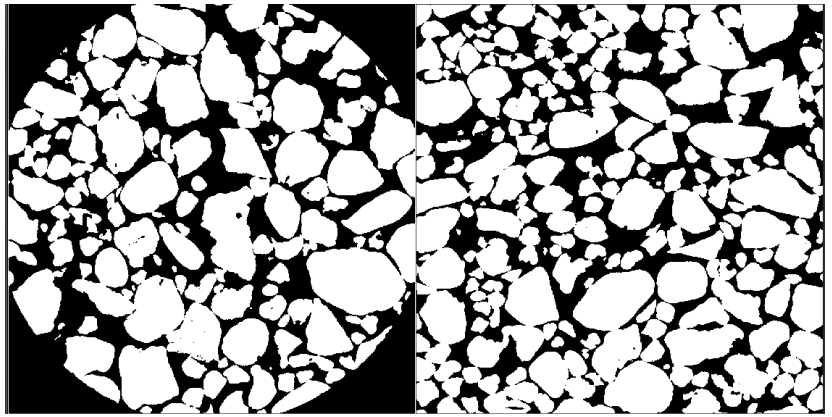
WG Top

$D_{15}^{coarse}/d_{85}^{fine}=1.56$



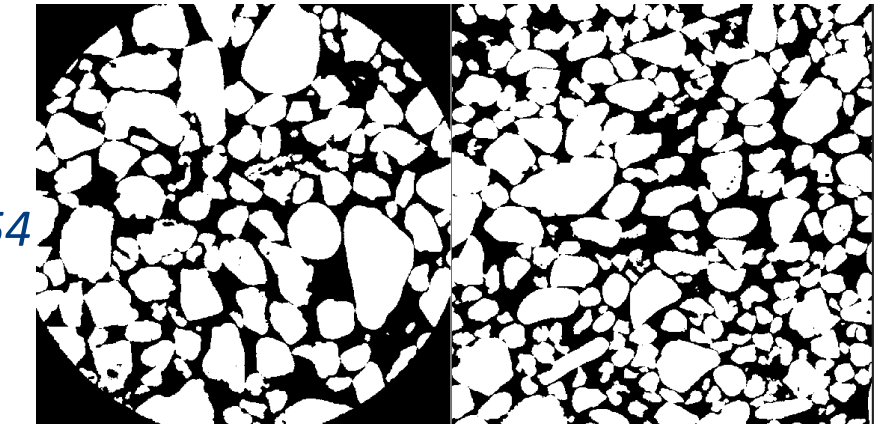
WG Middle

$D_{15}^{coarse}/d_{85}^{fine}=1.62$

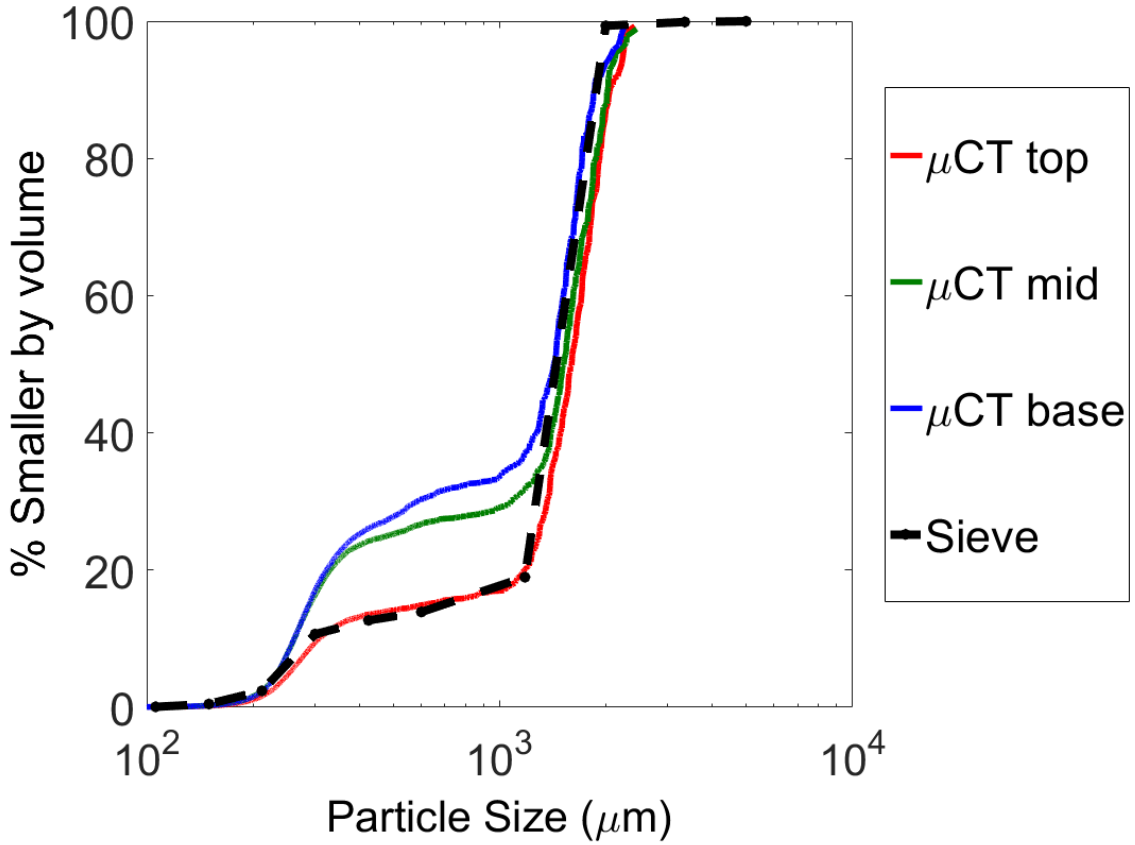


WG Bottom

$D_{15}^{coarse}/d_{85}^{fine}=1.54$

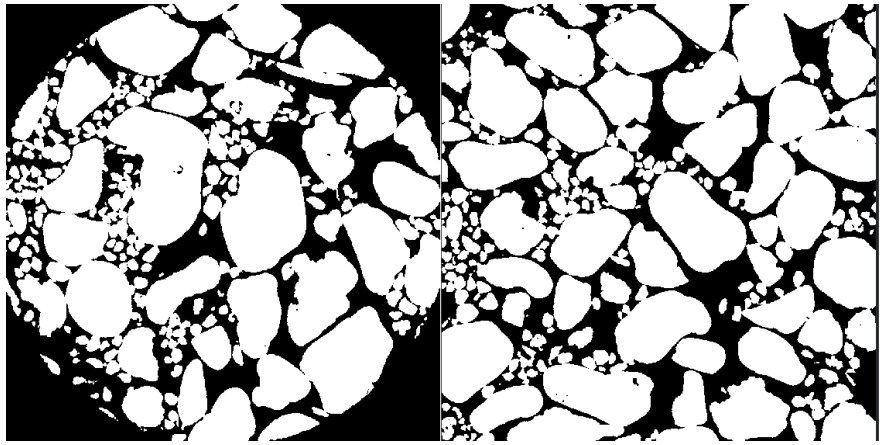


Sample G1 (12%: 300μm>D>150μm)



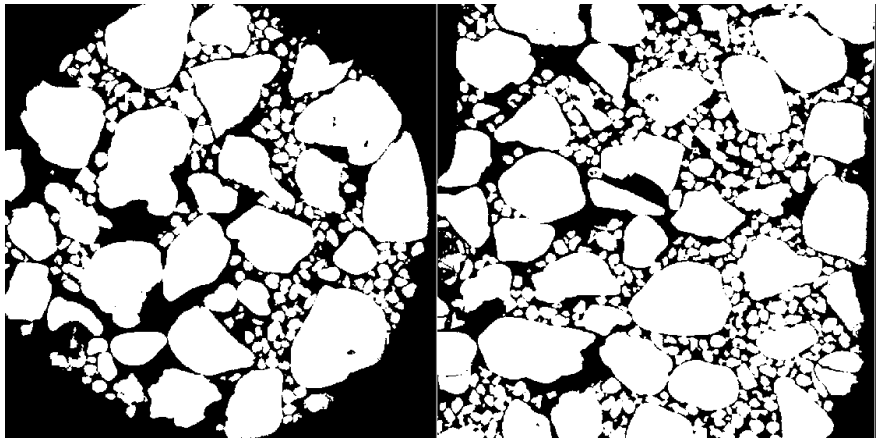
G1 Top

$D_{15}^{coarse}/d_{85}^{fine}=4.66$



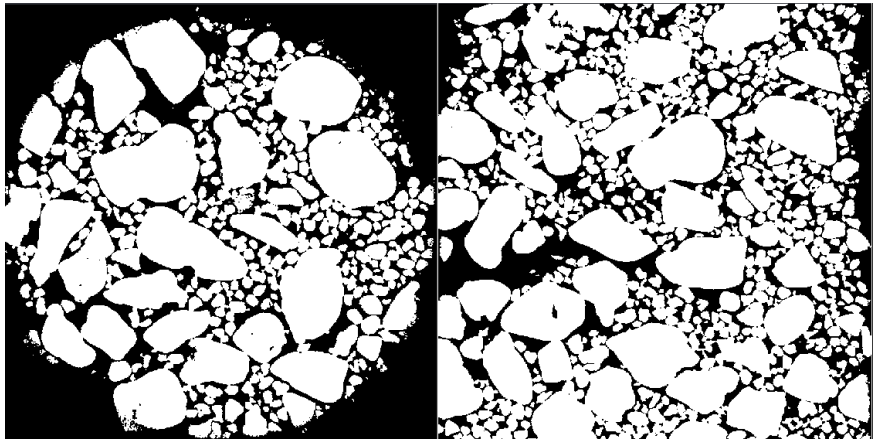
G1 Middle

$D_{15}^{coarse}/d_{85}^{fine}=3.90$

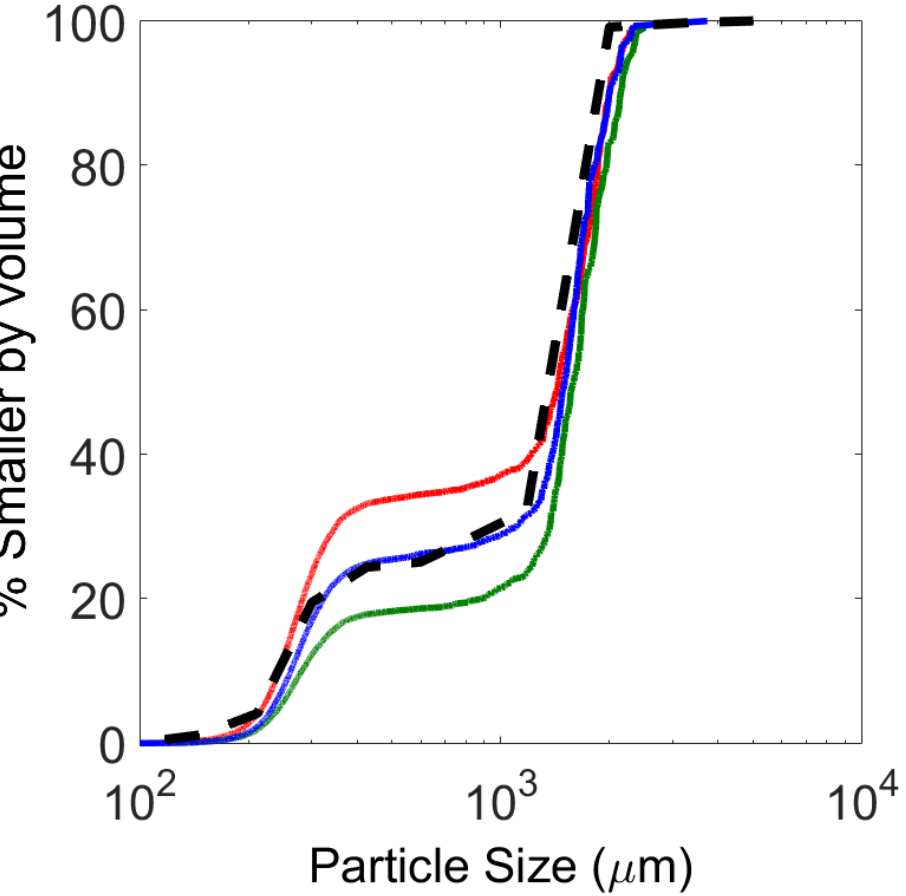


G1 Bottom

$D_{15}^{coarse}/d_{85}^{fine}=3.30$

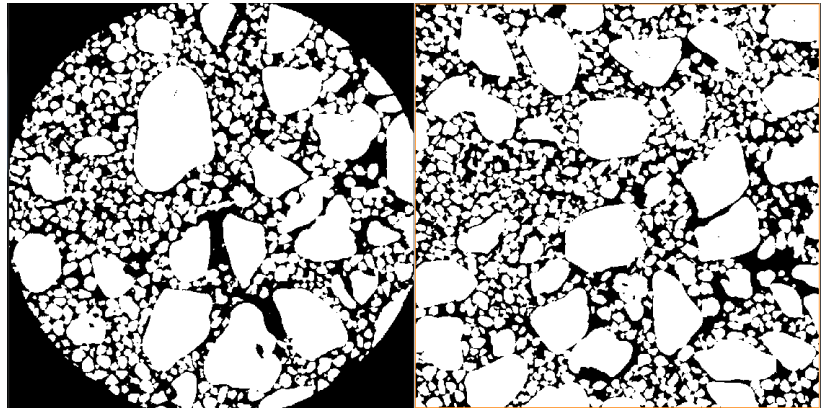


Sample G2 (24%: 300μm>D>150μm)



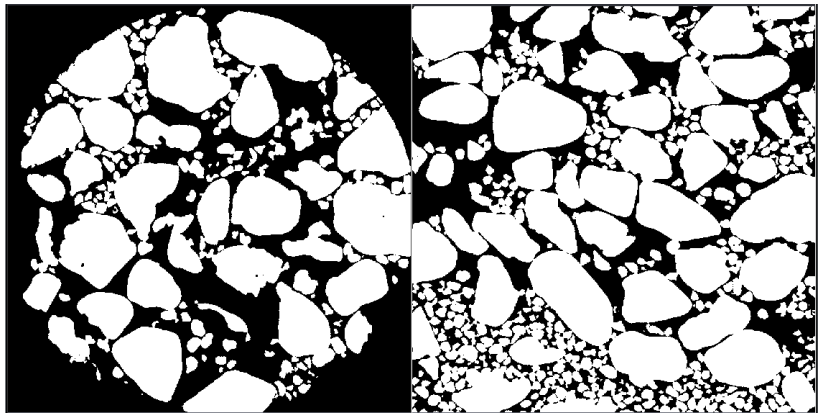
G2 Top

$D_{15}^{coarse}/d_{85}^{fine}=4.01$



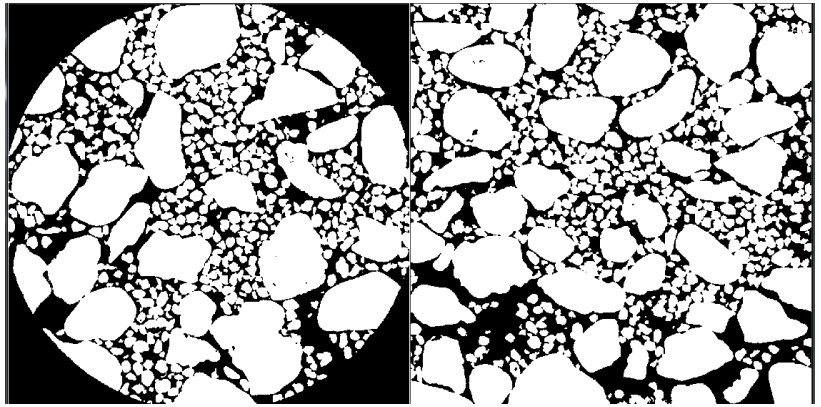
G2 Middle

$D_{15}^{coarse}/d_{85}^{fine}=4.29$



G2 Bottom

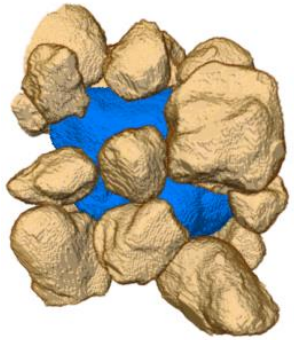
$D_{15}^{coarse}/d_{85}^{fine}=4.07$



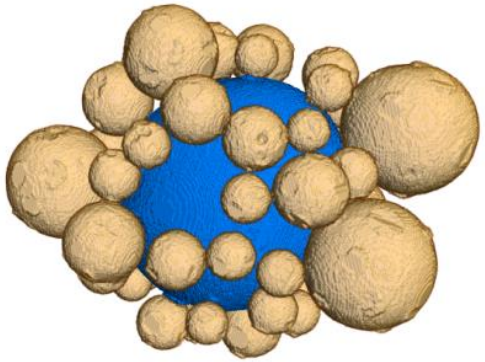
Coordination Number

N_c = Coordination number

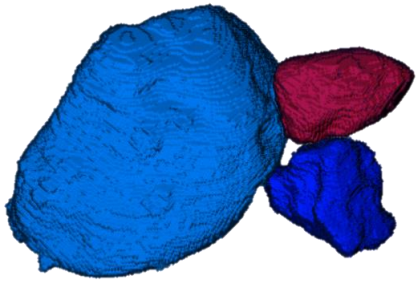
No of contacts per particle



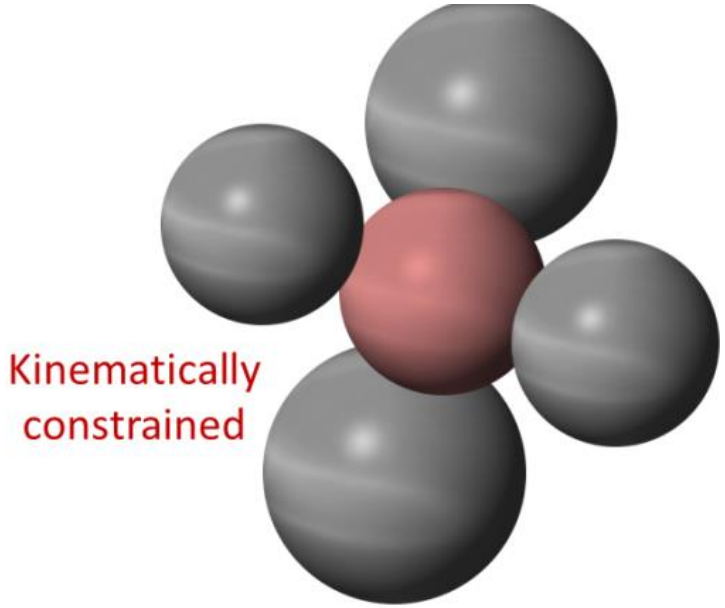
Leighton Buzzard
Sand
Blue particle
20 contacts

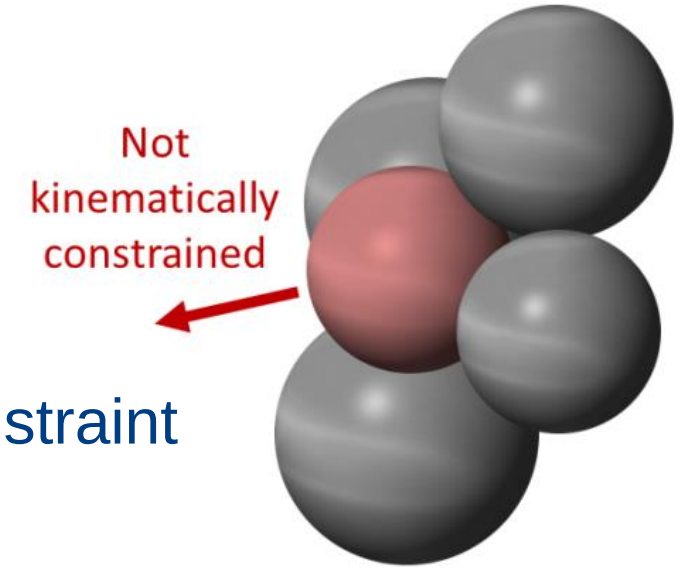


Glass beads
Blue particle
50 contacts



Leighton Buzzard
Sand
Blue particle
2 contacts

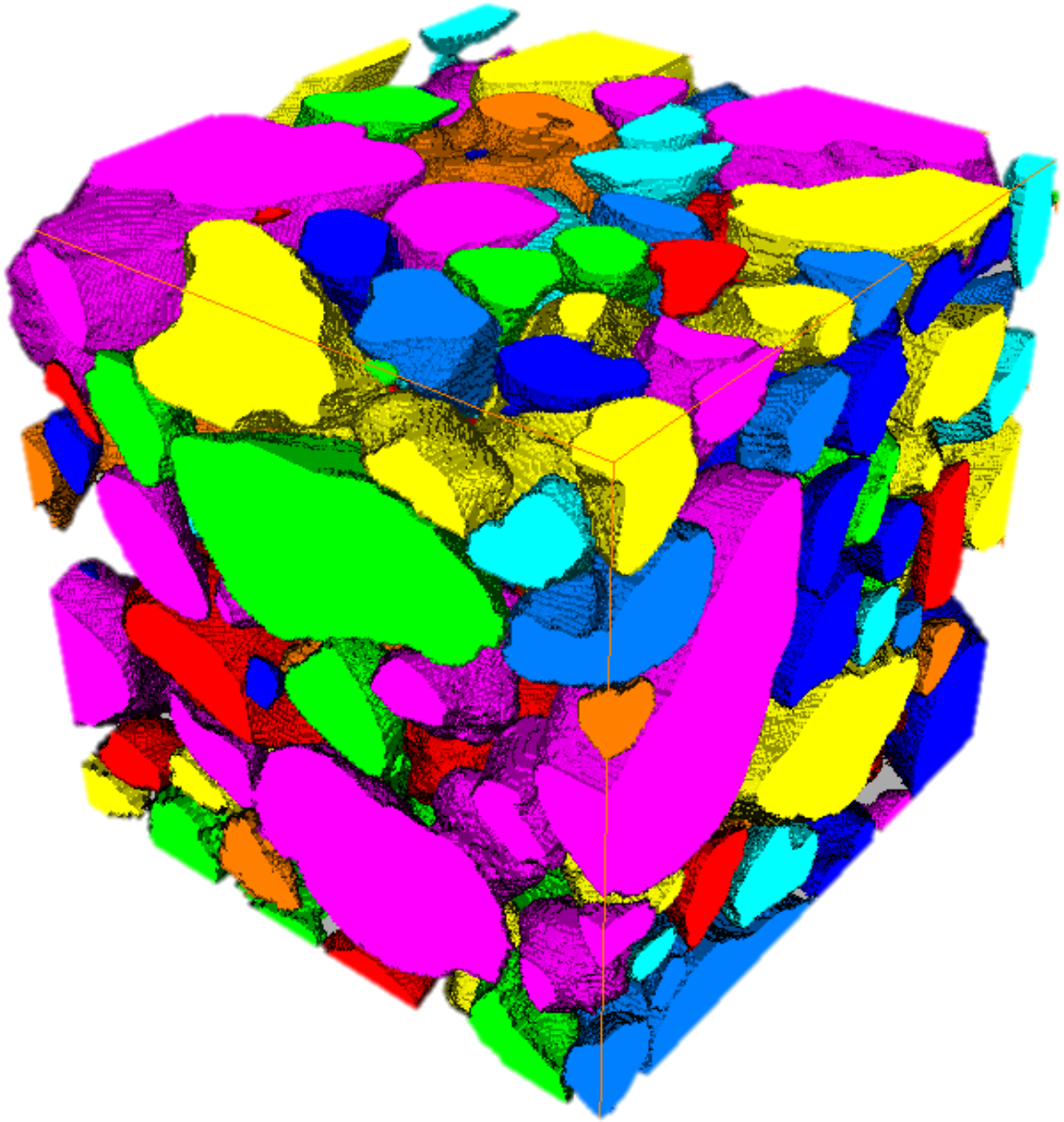


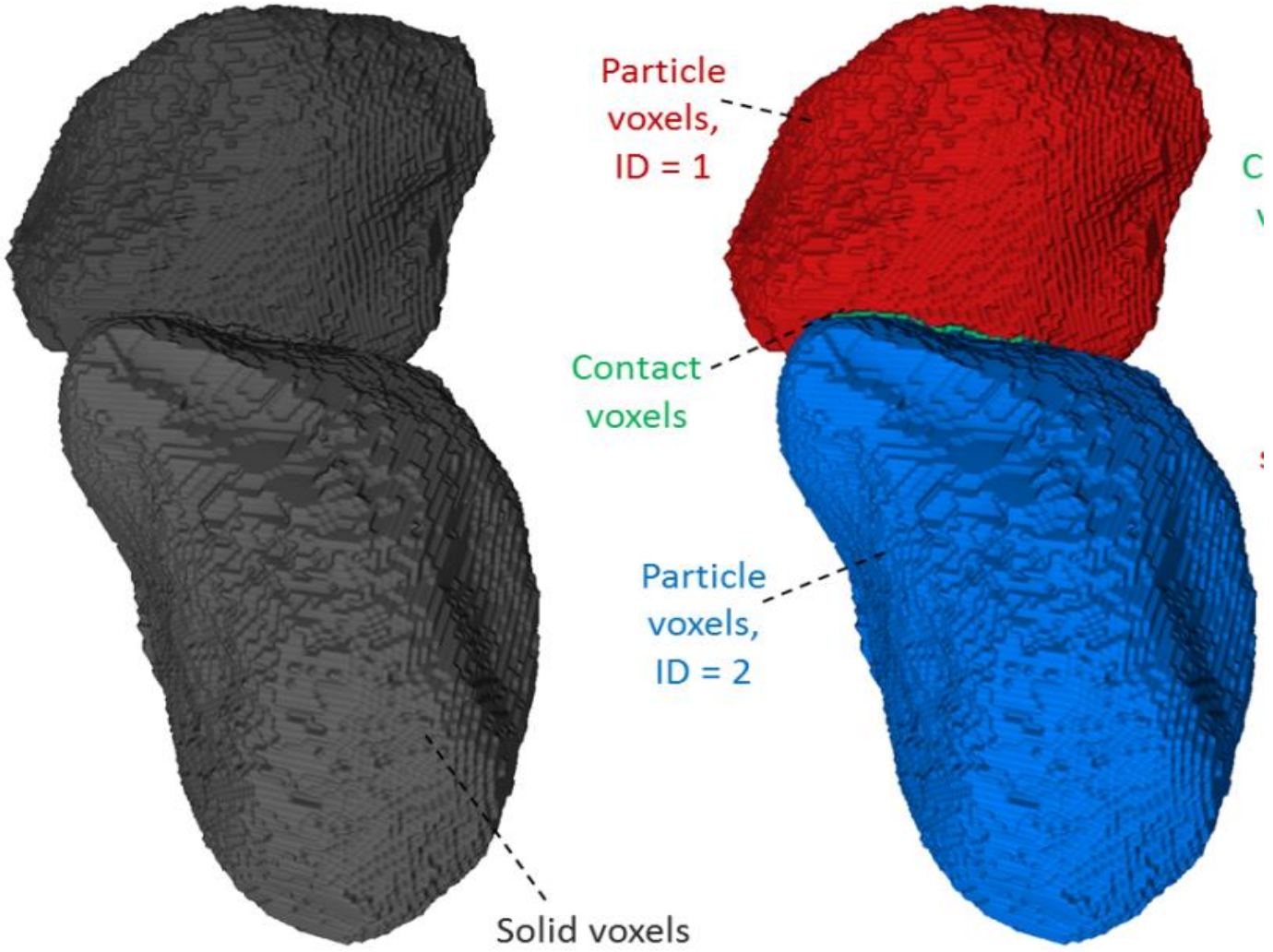


No of contacts gives indication of kinematic constraint

Images from H. Taylor

Contact Identification

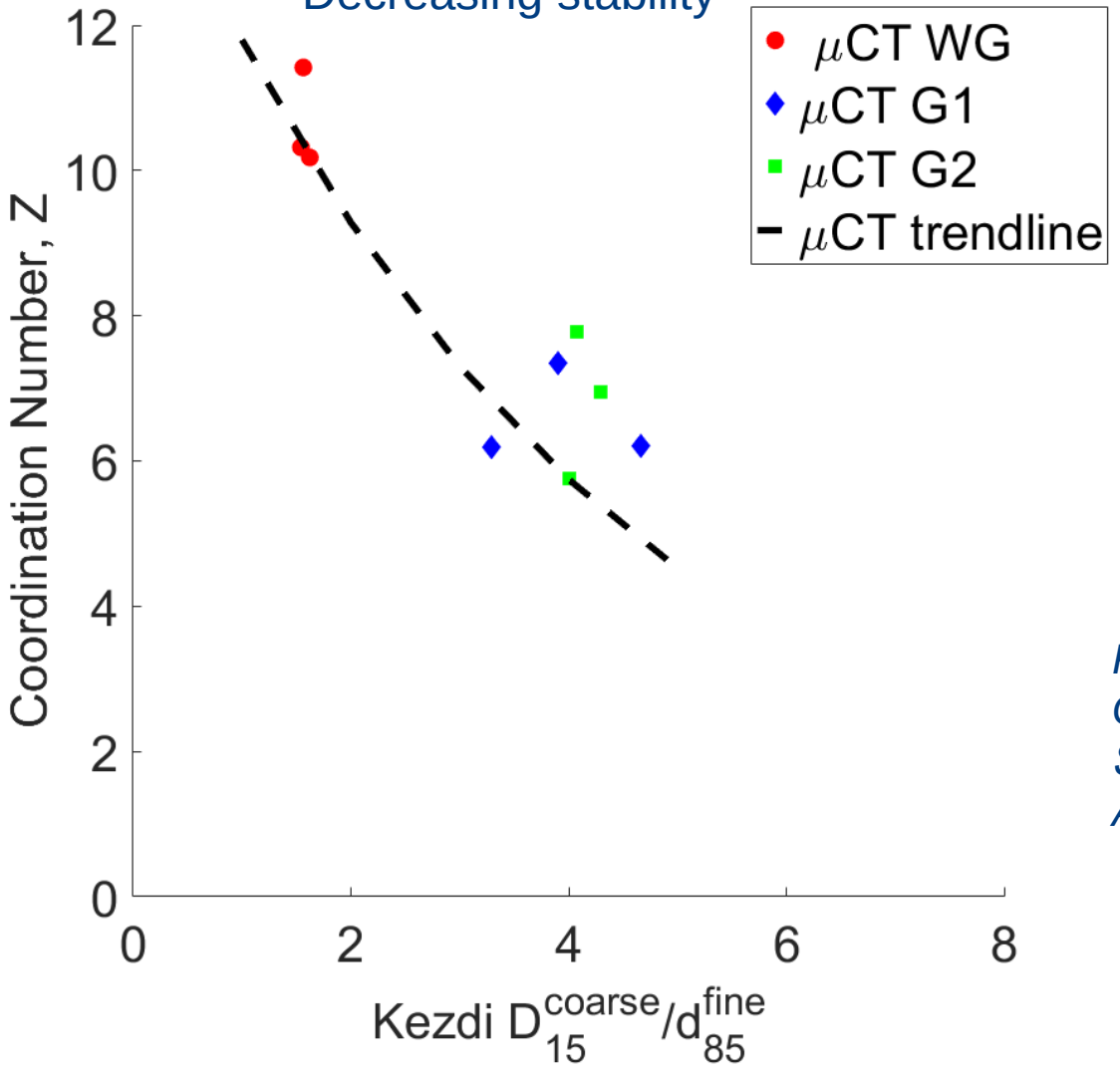




Variation in Coordination No. with Kézdi Ratio

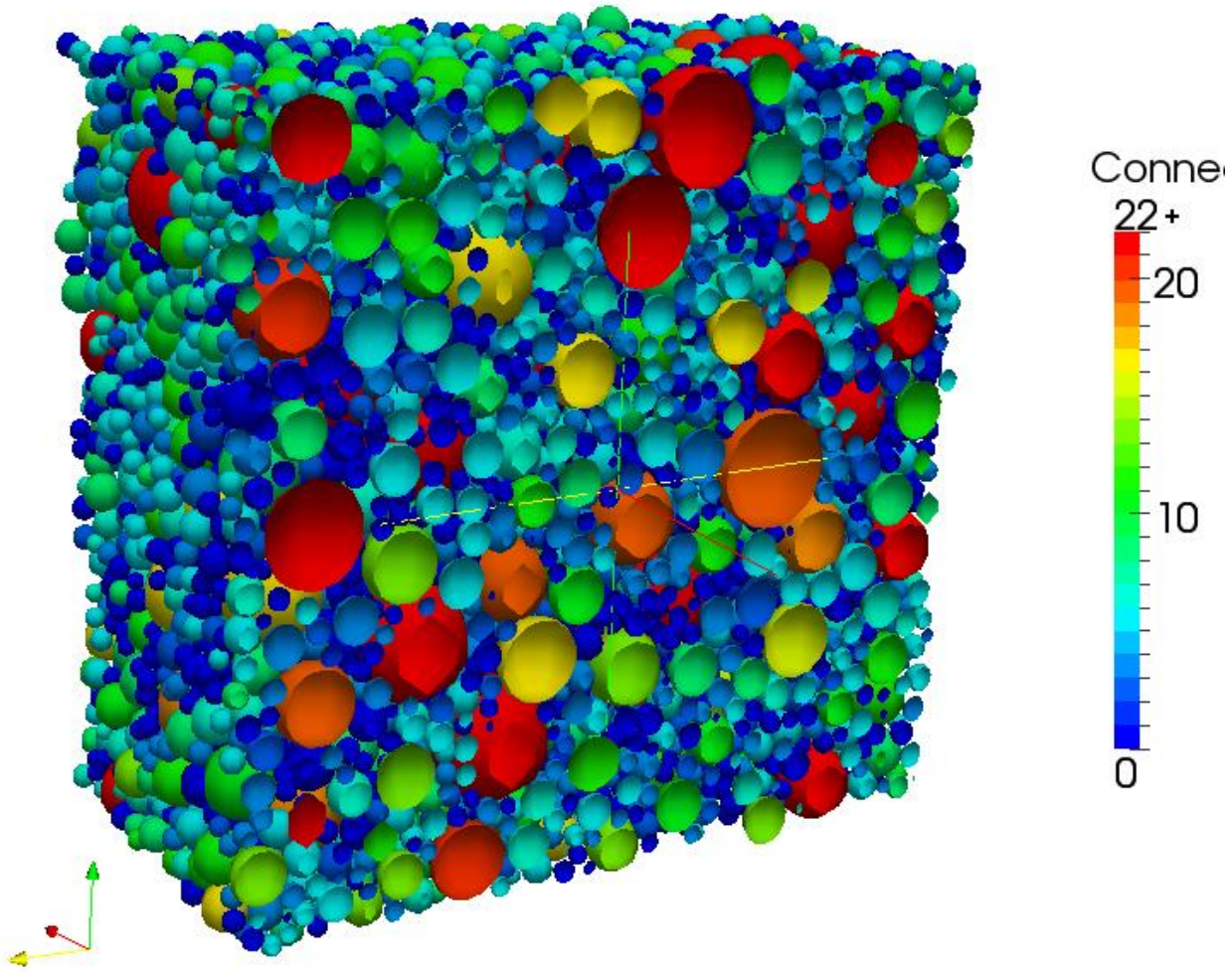
Increasing Kézdi no.

Decreasing stability



Fonseca et al. (2014)
Géotechnique
Shire and O'Sullivan (2013)
Acta Geotechnica

Discrete element method simulations



Spherical particles

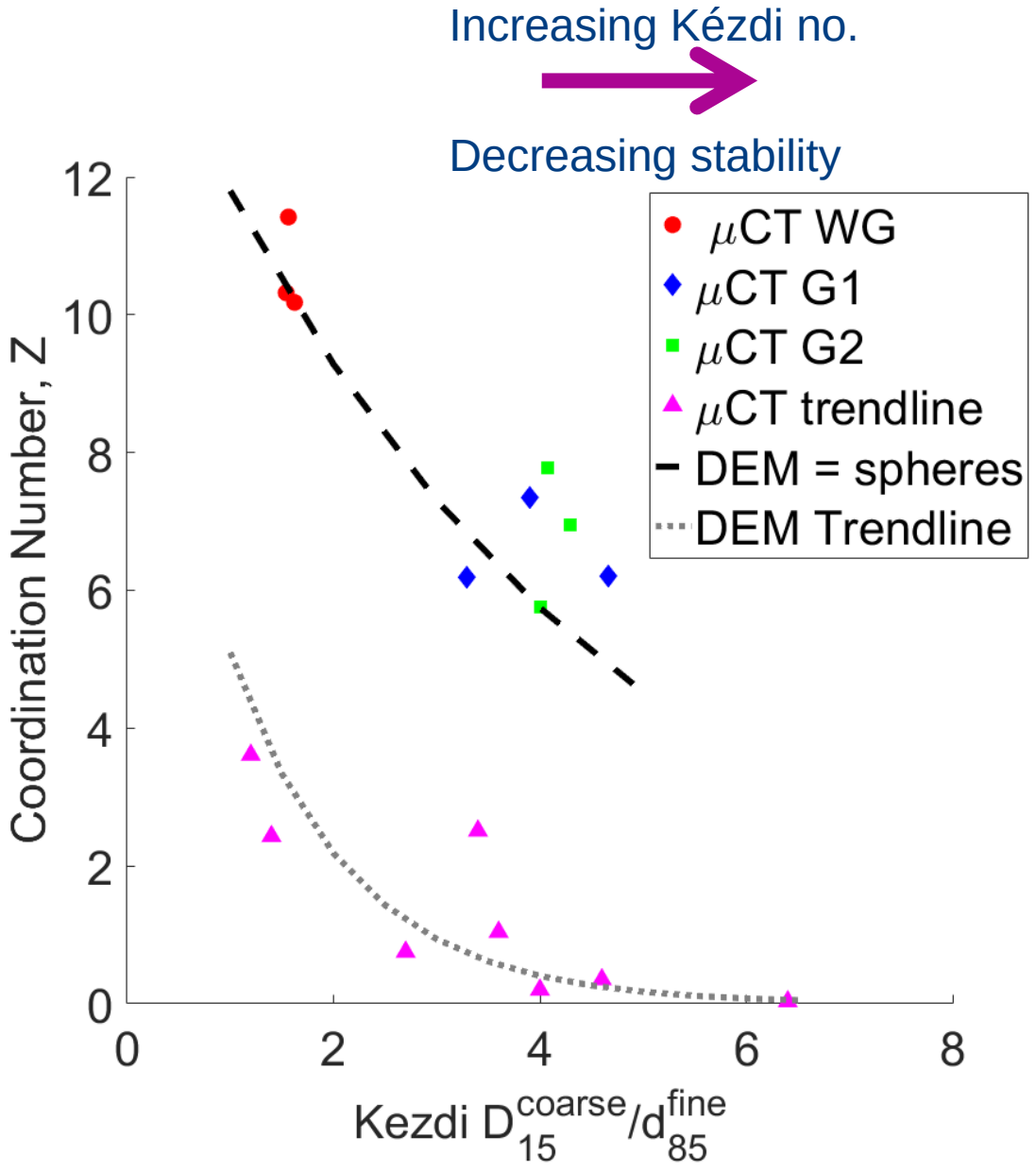
Simple contact models

Isotropic samples

Gravity neglected

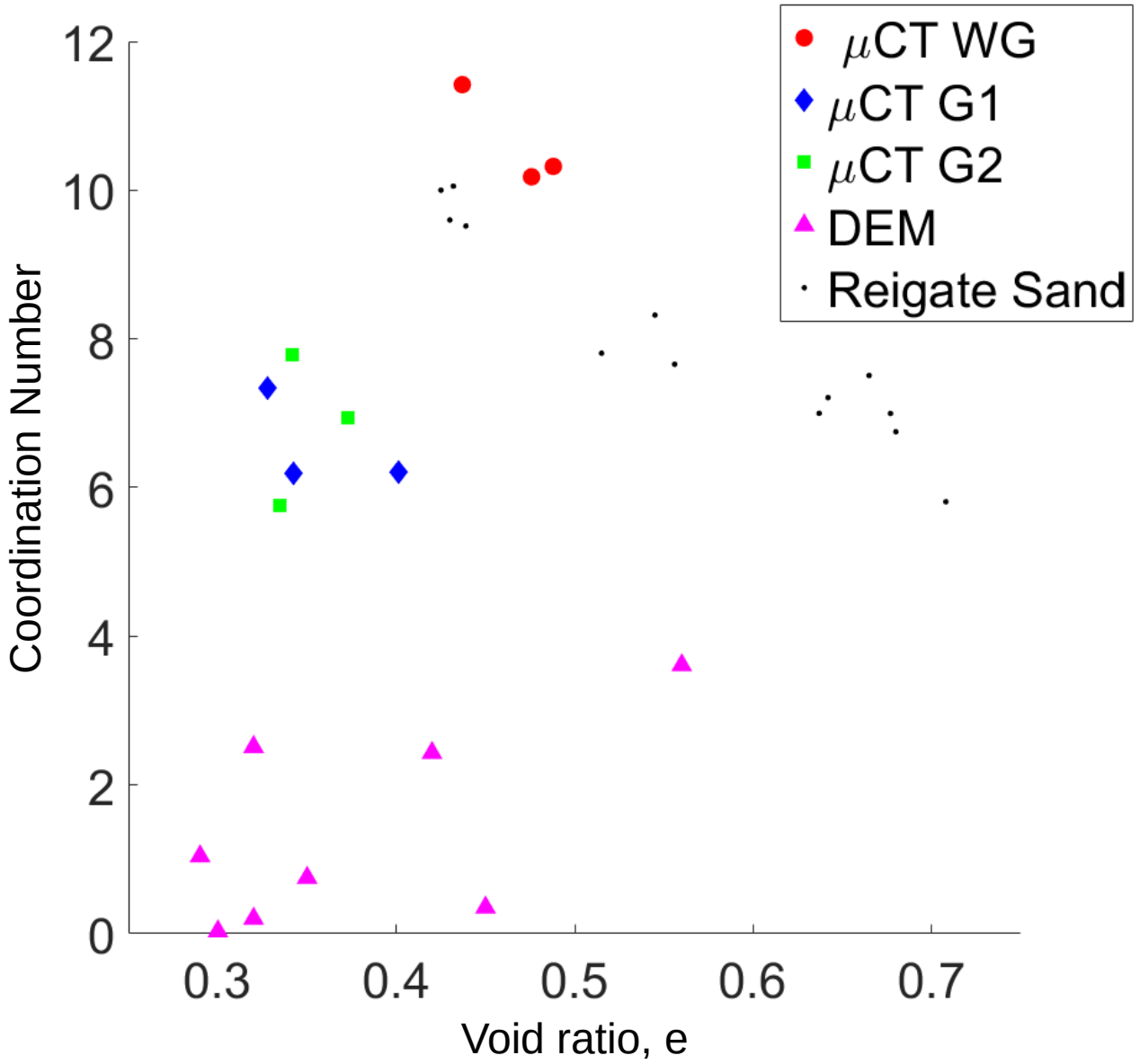
Shire and O'Sullivan (2013)
Acta Geotechnica

Variation in Coordination No. with Kézdi Ratio



Fonseca et al. (2014)
Géotechnique
Shire and O'Sullivan (2013)
Acta Geotechnica

Variation in Coordination No. with e



Conclusions

- Micro computed tomography enables us to quantify soil structure
- The need to achieve good resolution restricts sample size
- There is a clear correlation between the Kézdi ratio ($D_{15}^{coarse}/d_{85}^{fine}$) and coordination number