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Comparison of two methods for measuring filter constriction sizes

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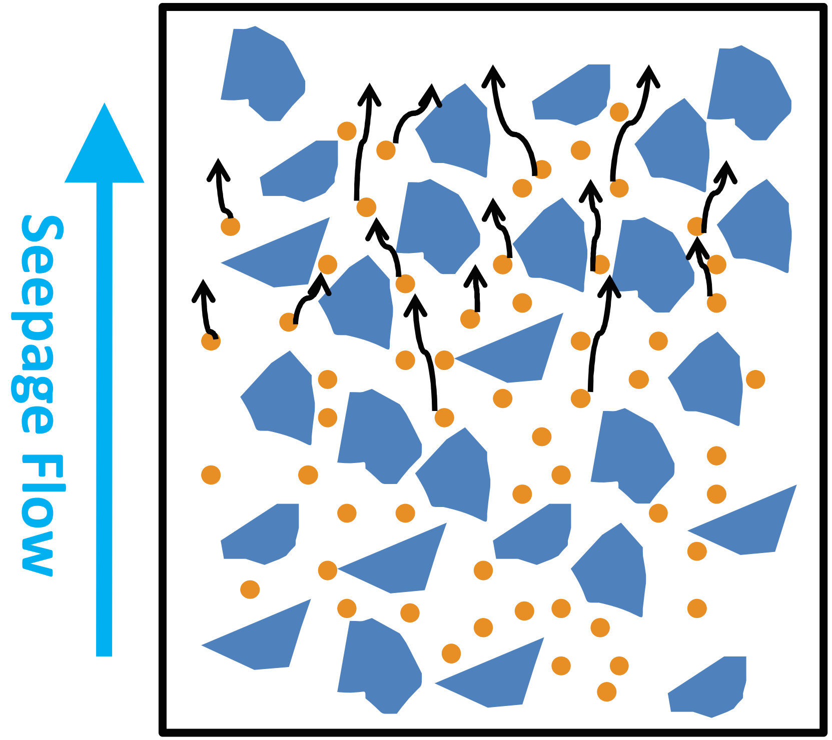
Overview

- Suffusion and constrictions
- Constriction measurement
  - Delaunay method (Reboul *et al*, 2010)
  - Maximal ball method (Dong and Blunt, 2009)
- Results

Suffusion

Loose fines eroded under seepage, coarse particles stay in place

Fines must be smaller than void constrictions between coarse particles!



$\mathbf{D_{fines} < d_{constriction}}$

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Current Criteria

Current empirical rules link the coarse particle size to constriction sizes:

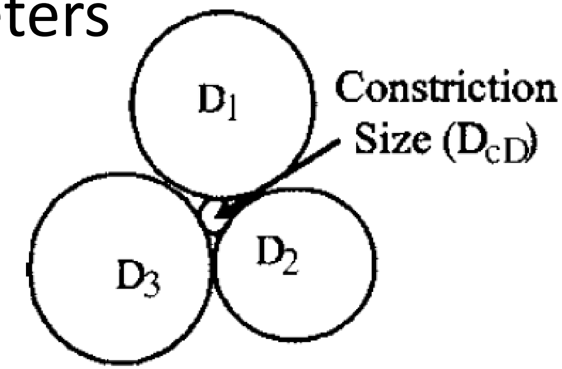
Kèzdi (1979) (after Terzaghi):

$D_{15,coarse} / d_{85,fine} < 4$ *($D_{15,coarse}$ / 4 is a proxy for constriction size)*

Indraratna *et al* (2011):

Calculated the constriction size distribution (CSD) based on combinations of spheres matching soil diameters

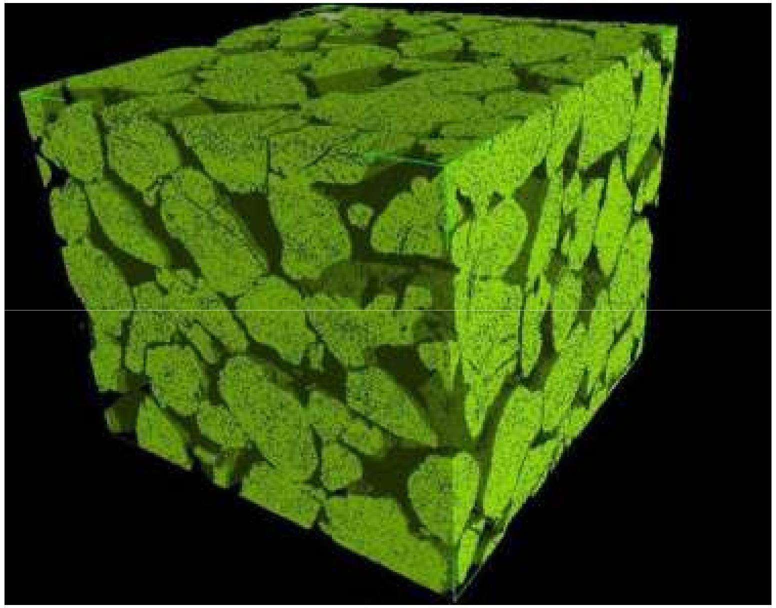
$D_{35,constriction}$ = "controlling constriction"



Soil Constrictions

Void space is 3D and continuous – definition of individual voids and hence constrictions is ambiguous

Scientific understanding of filter action requires improved knowledge of void space



Micro-CT Image sand (Fonseca, 2011)

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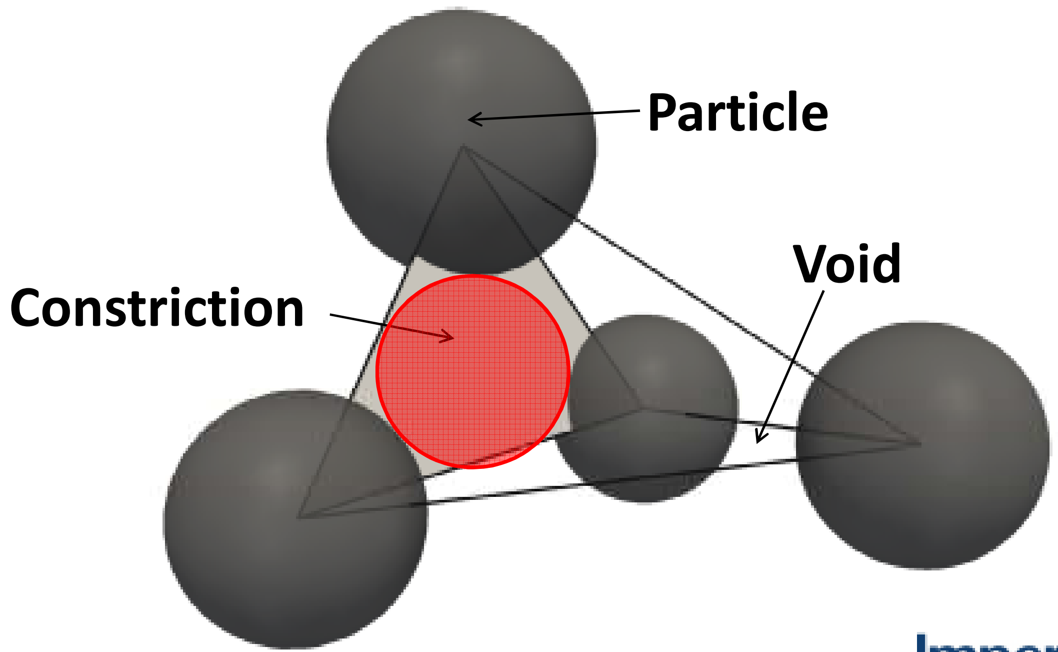
Delaunay Triangulation Method (Reboul *et al*, 2010)

Delaunay triangulation of soil particle centres to define voids

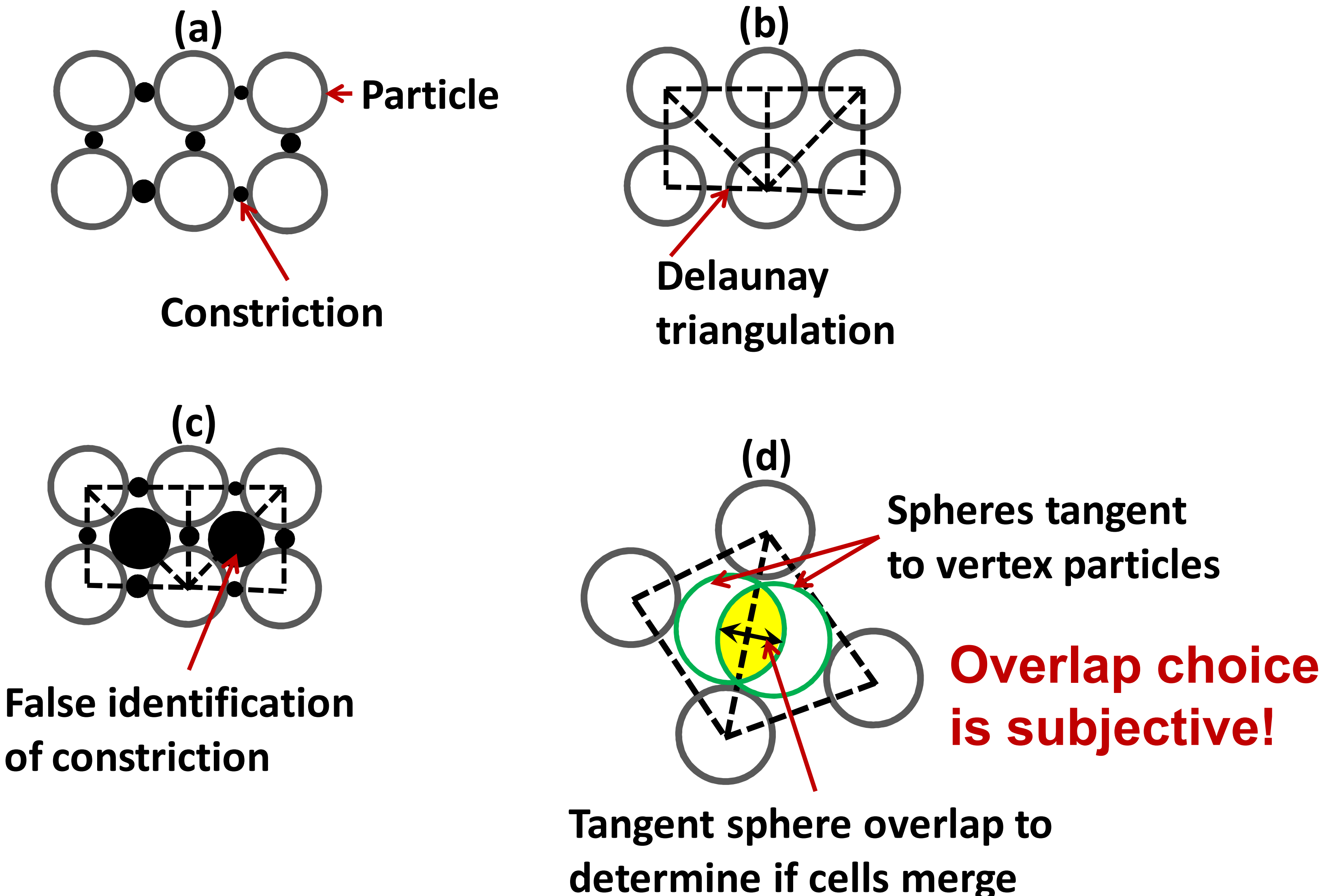
Tetrahedra vertices formed by four neighbouring particles

Constriction = smallest circle which can be inscribed on tetrahedron face



Delaunay Triangulation Method (Reboul *et al*, 2010)

Delaunay tetrahedra merge to make realistic voids (2D analogy):



Maximal Ball Method (Dong and Blunt, 2009)

Import voxelised image

↓

Build max balls in void space (= spheres which inscribe solid space)

↓

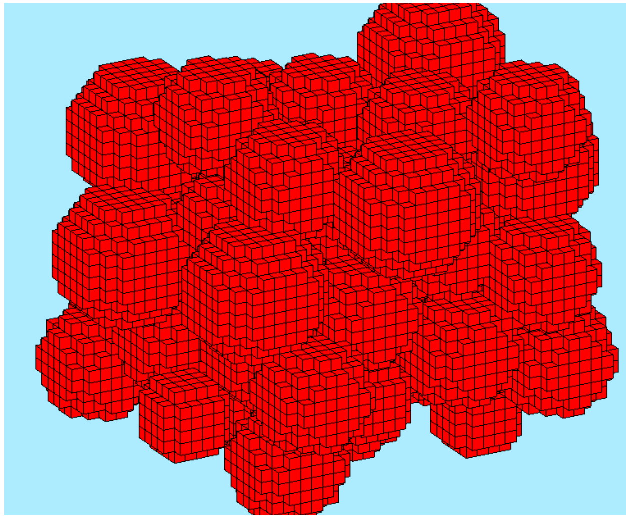
Create "family tree" = chains of successively smaller max balls

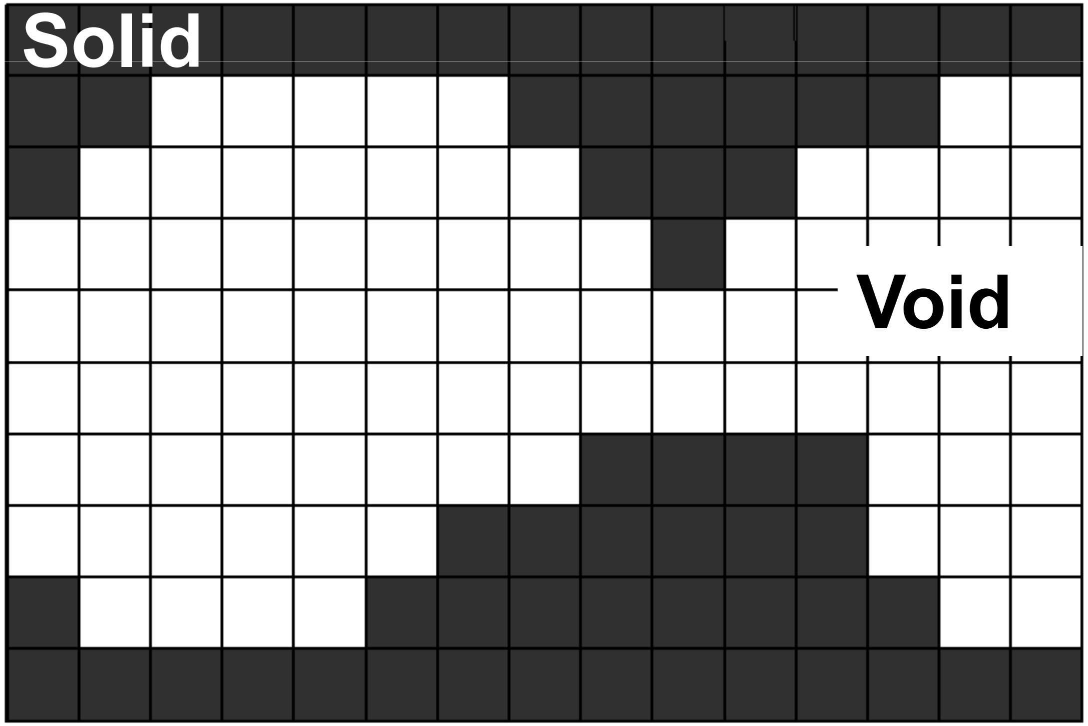
↓

Define constrictions using locally smallest max balls

↓

Output data





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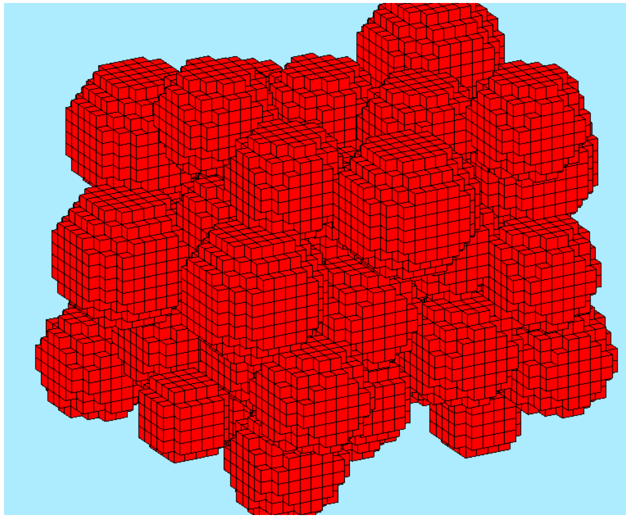
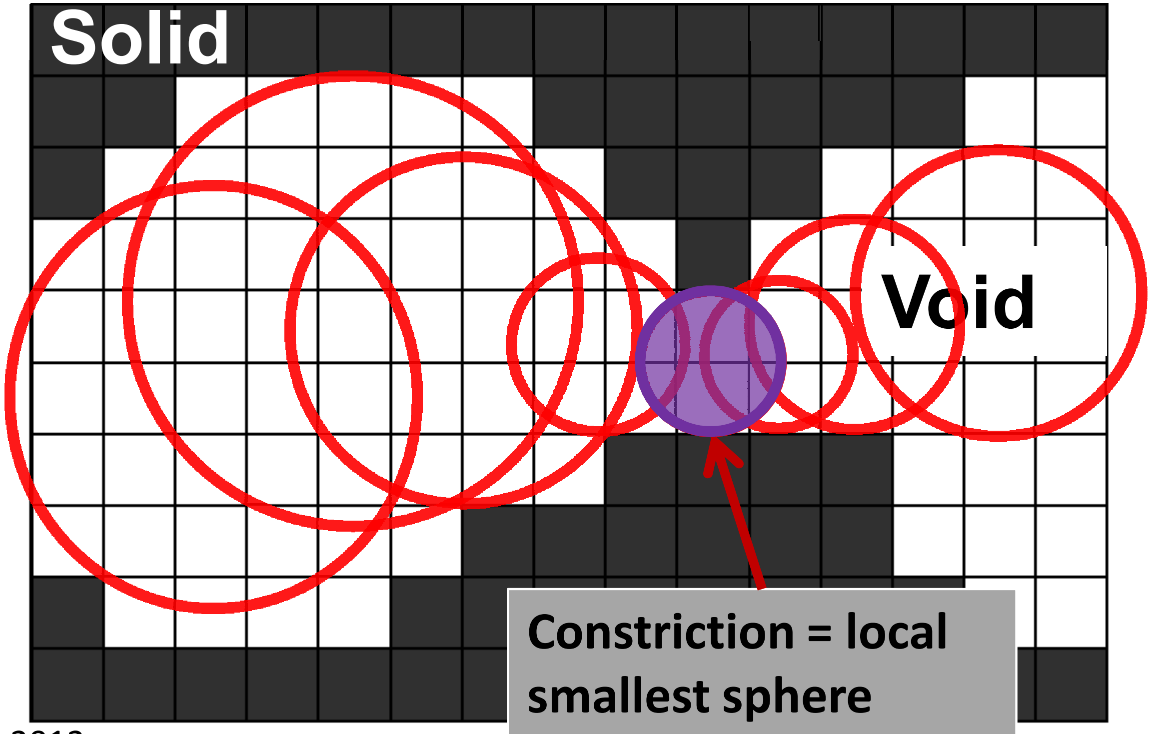
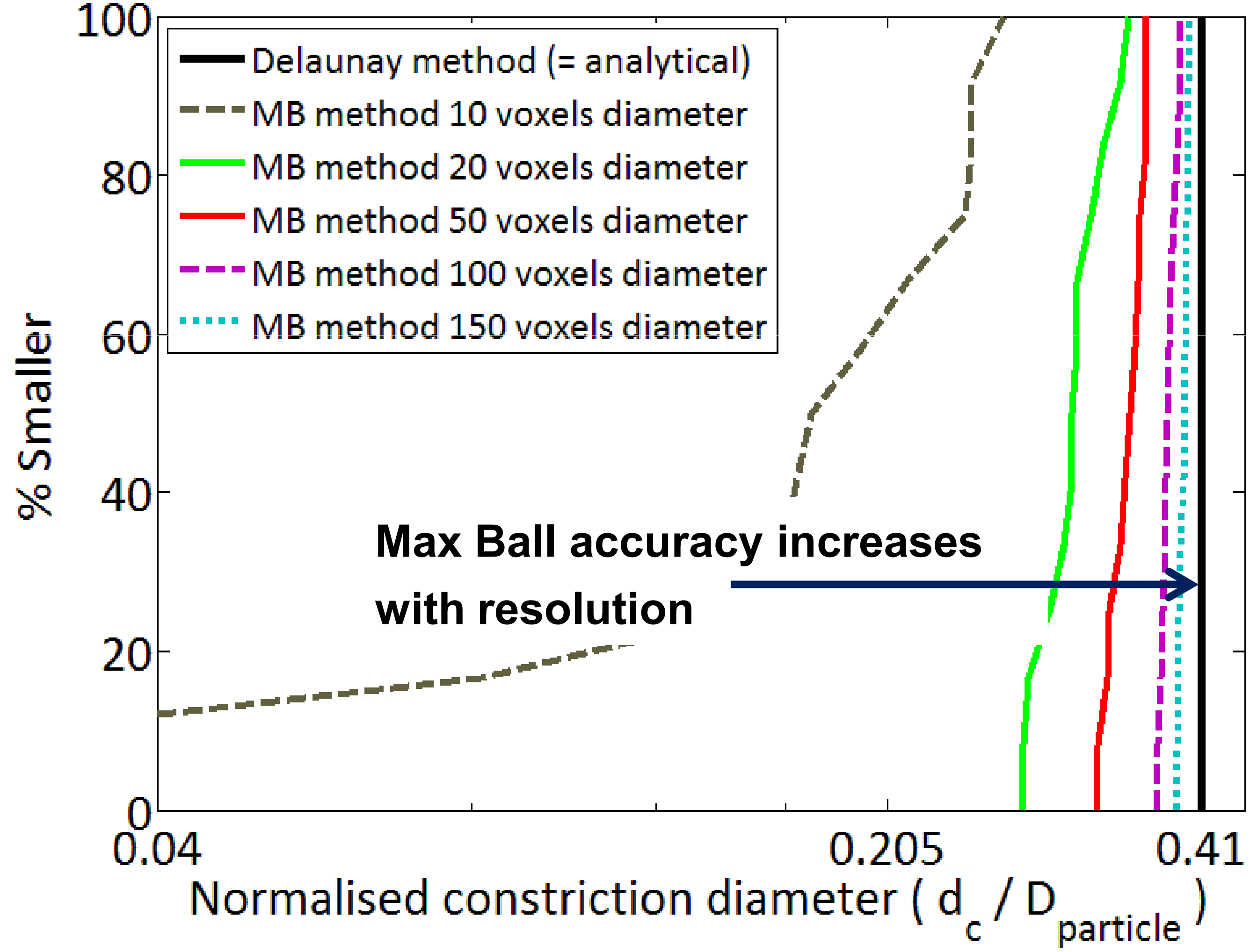
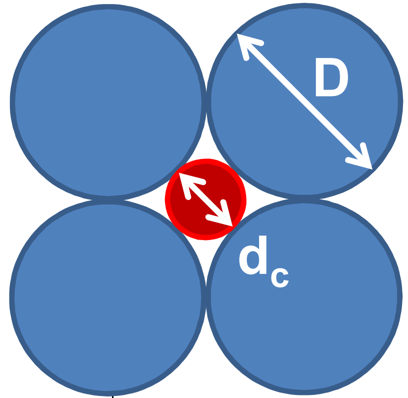




Validation using regular packings

Analytical solution for simple packing: $d_c = 0.41D$





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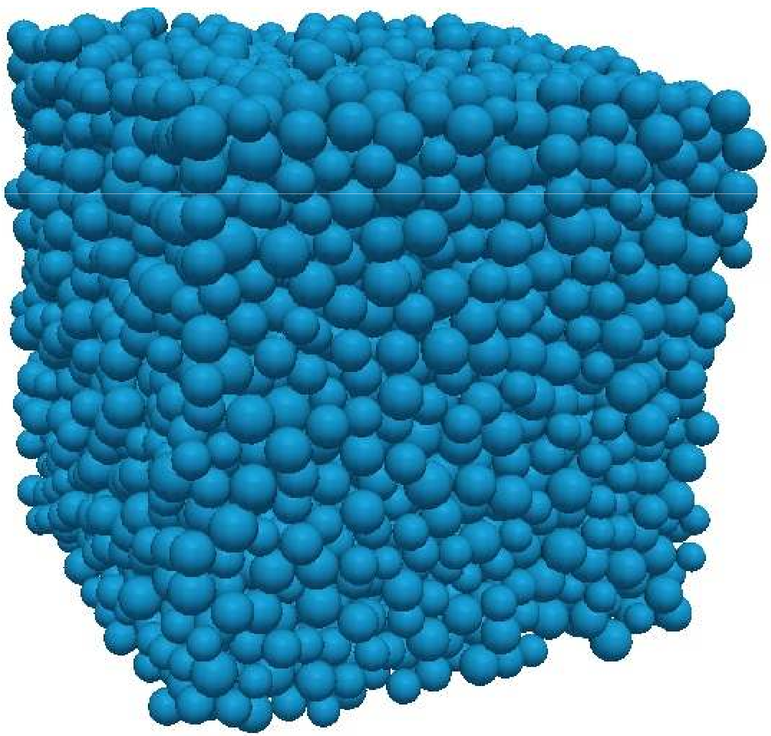
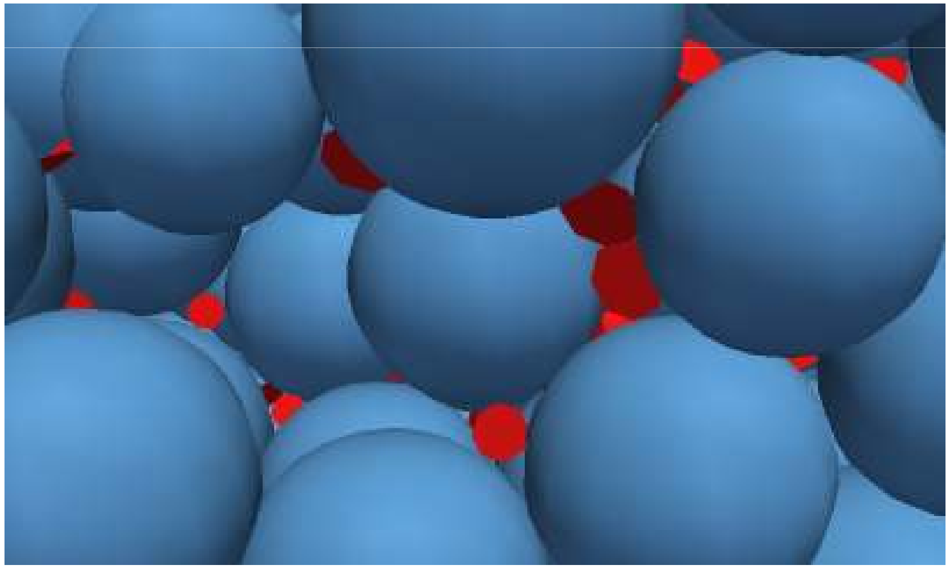
Results – Random Packing

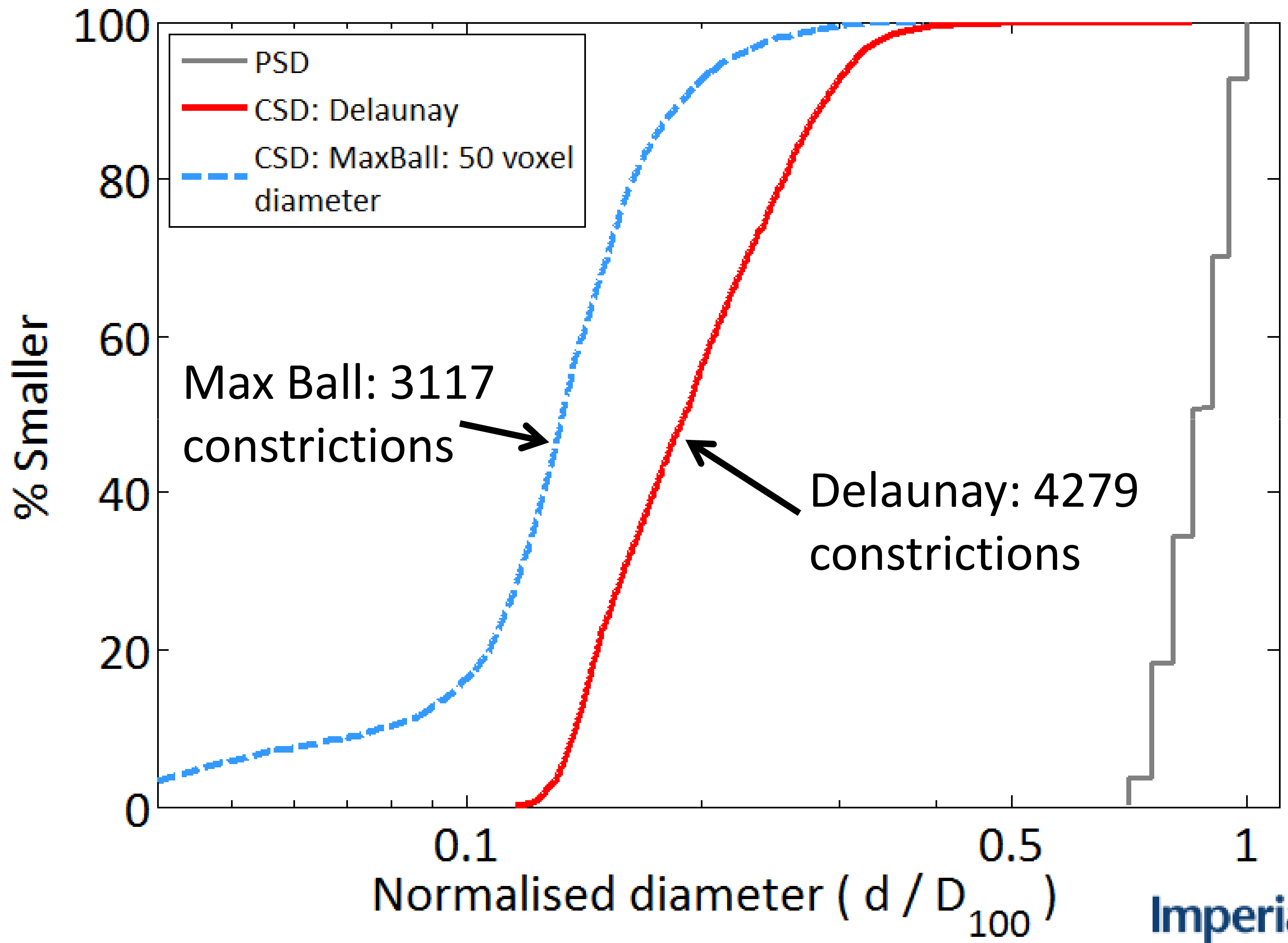
Random packing of 4000 spheres created by Discrete element modelling (DEM) – analogous to coarse matrix in suffusive soil



Constrictions computed using two methods



Results: Constriction size distributions (CSD)



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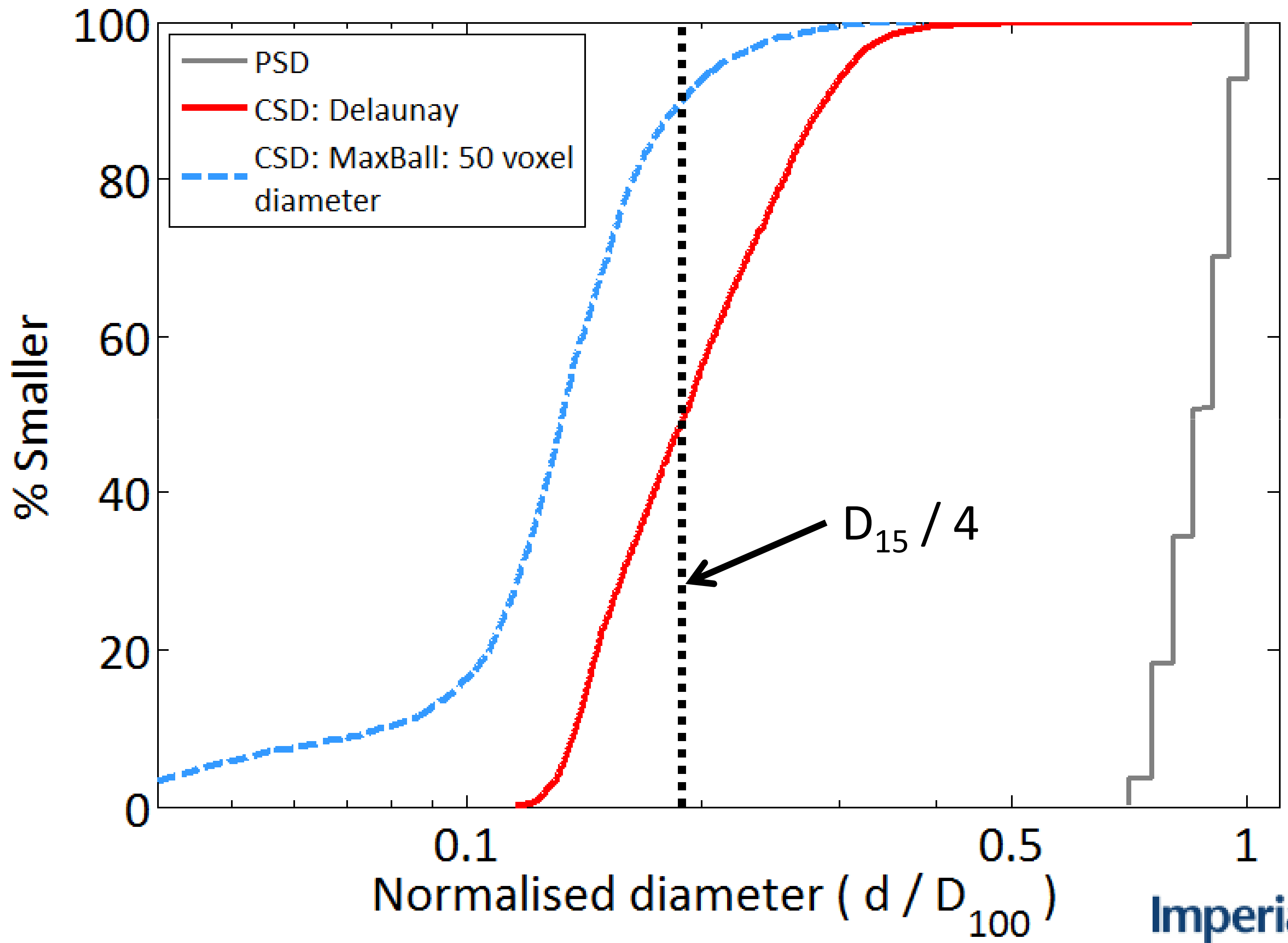

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Comparison of methods

Delaunay

Computationally efficient

Large numbers of particles can be considered

Spherical soil particles only: DEM data only

Maximal Ball

Accuracy of results limited by computer memory

Any shape of particle: DEM or Micro-CT data

Identifies fewer, smaller constrictions

Conclusions

Void constrictions control suffusion in filters

Defining where one void ends and another void begins is ambiguous – how to define constrictions?

Methods available for calculation of constriction sizes – no clear agreement

Analysis of broader PSDs underway

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