# Study of Characteristic of Random Penetrable Grain Model and Gravity Driven Sedimentation Model

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# Introduction

## Characterization is important to understand structures of porous materials (rocks) and its physical properties

Measurements or characterization:

- Direct: Sample → equipment → result
- Indirect: Sample → ‘digitized’ → ‘measurements’ → results

Nowadays: digital ‘measurements’ are growing rapidly

# Why digital ‘measurements’ ?



- Digital equipment are highly developed
- Benefit of digital characterization/measurements:
  - non-destructive,
  - repeatable,
  - transferable ‘digital samples’,
  - clean (environmentally),
  - safe and user friendly,
  - easy,
  - becoming cheaper,
  - etc.

# Computational rock physics



- **Digital representation**
- **Digital characterization**

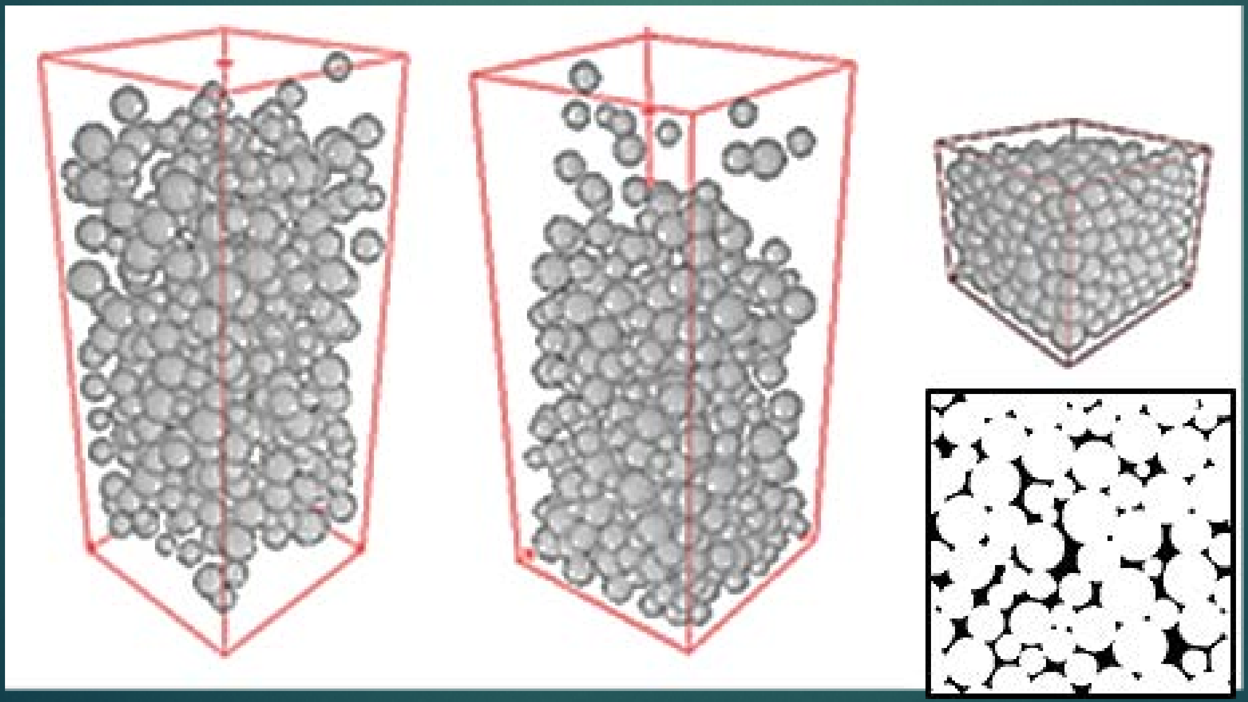
- Obtained from imaging devices (SEM, µCT, NMR, etc.)
  - Highly representative
  - Not widely available.
- Computer modeling
  - Highly feasible.
  - Flexible: parameters are easily adjusted.

- Non-destructive
- Repeatable
- Various methods are widely available
- Samples are intact, easily preserved

# Methods

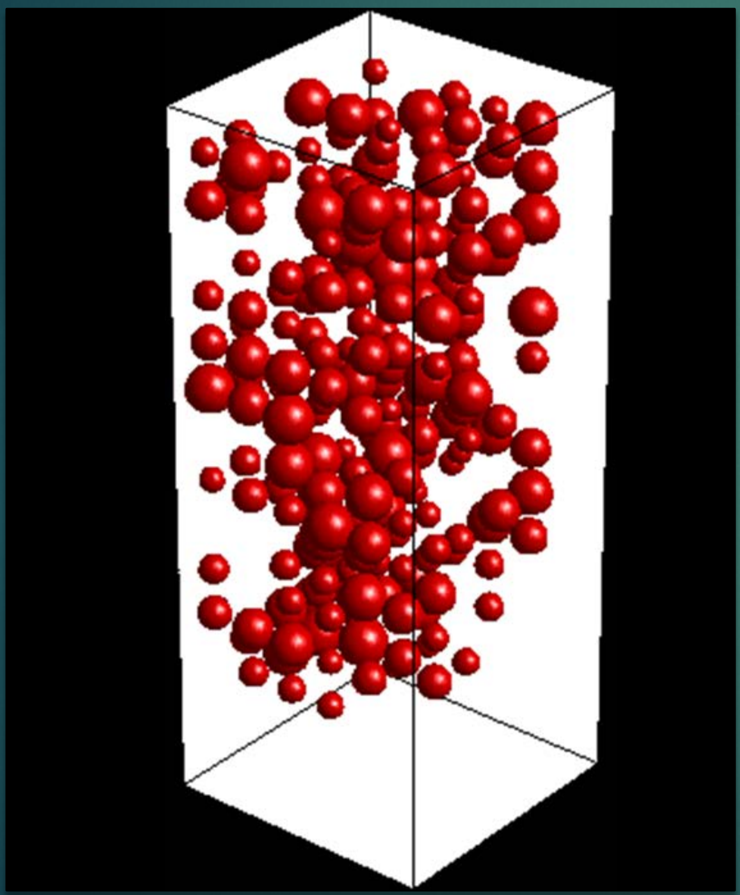
# Gravity Driven Sedimentation Model (Grv)

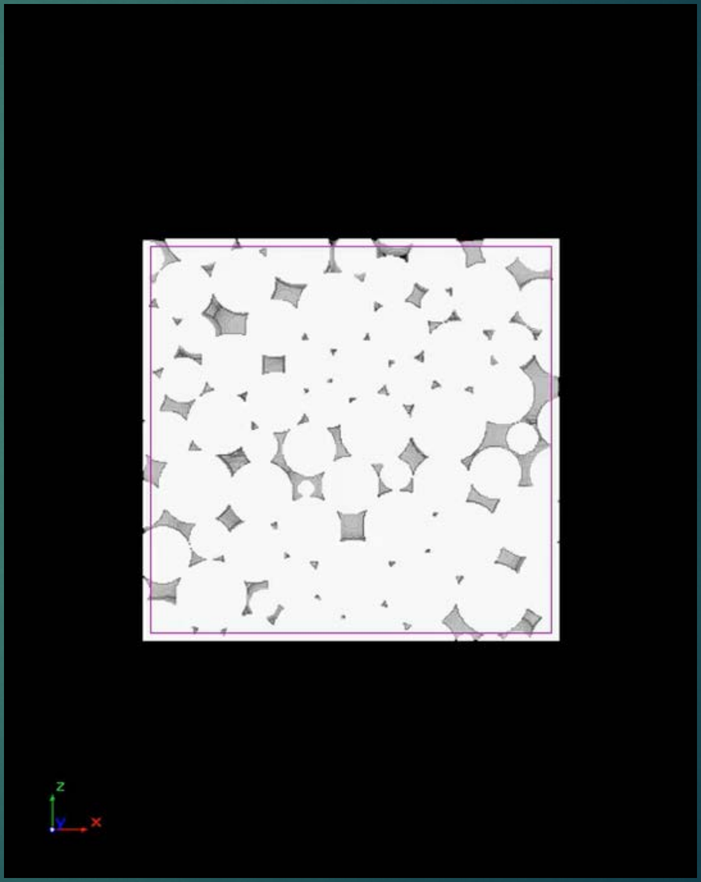
- **Based on Molecular Dynamics (MD) method**
- **Model parameters:**
  - **Medium size, range of grain size**
  - **Number of grains**



# Simulation



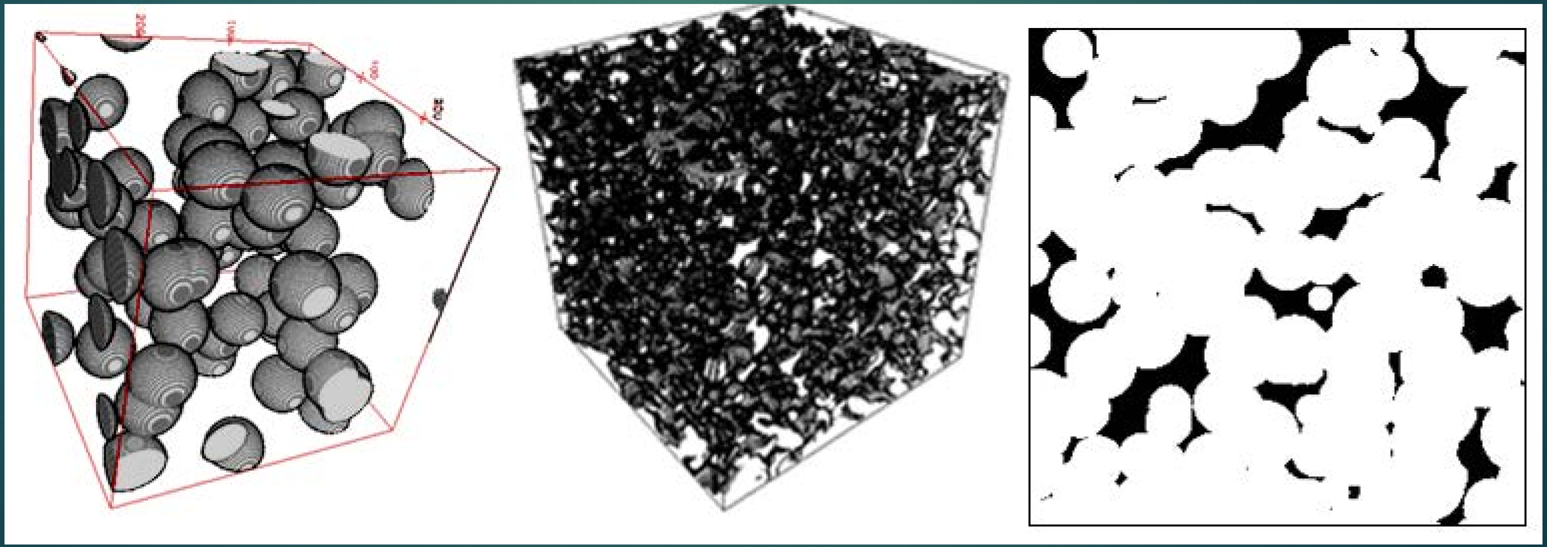




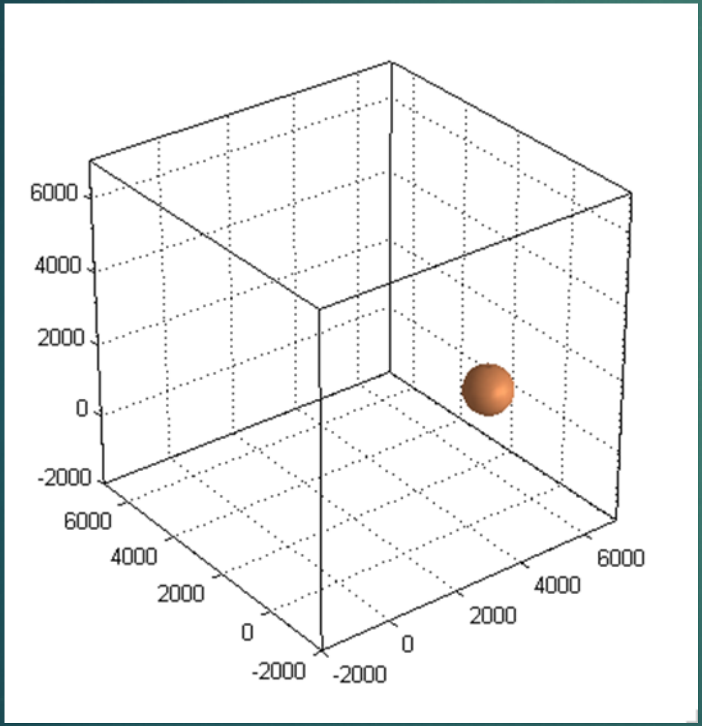
# Random Penetrable Grain Model (Rnd)



- Evenly distributed random deposition
- Model parameters:
  - Medium size, range of grain size
  - Target porosity



# Simulation


6000
4000
2000
0
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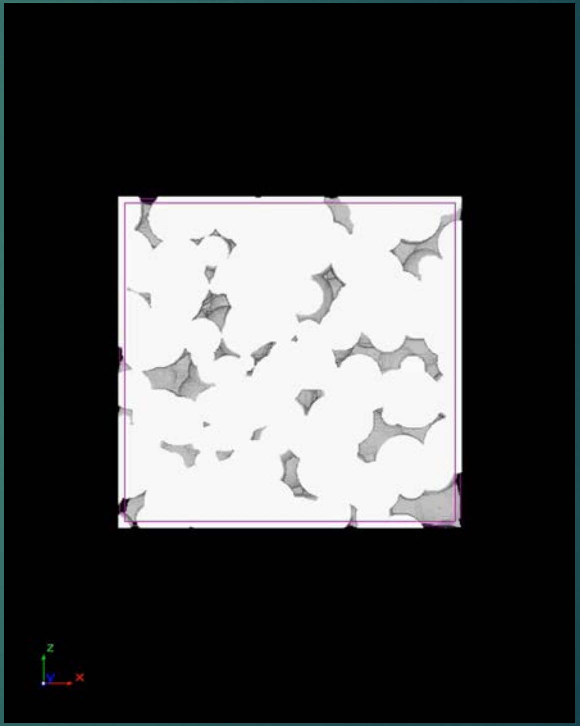
6000


z
x

# Characteristics of the Models

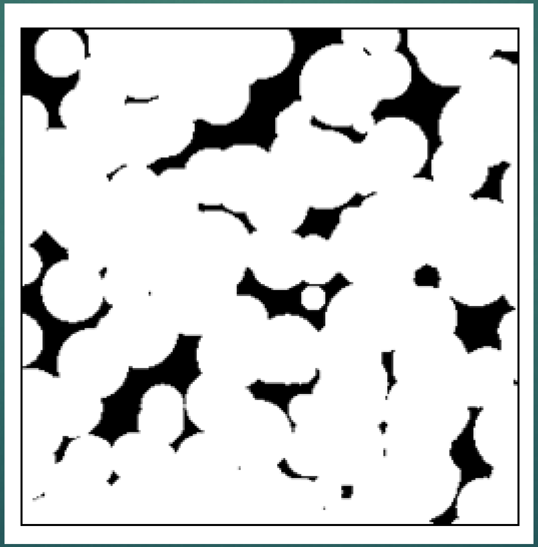
# Porosity



- Fraction of the pore volume per unit (total) volume

$$\phi = \frac{V_p}{V_T} \times 100\% = \frac{\text{pore volume}}{\text{total volume}}$$

- "Counting the black pixels"



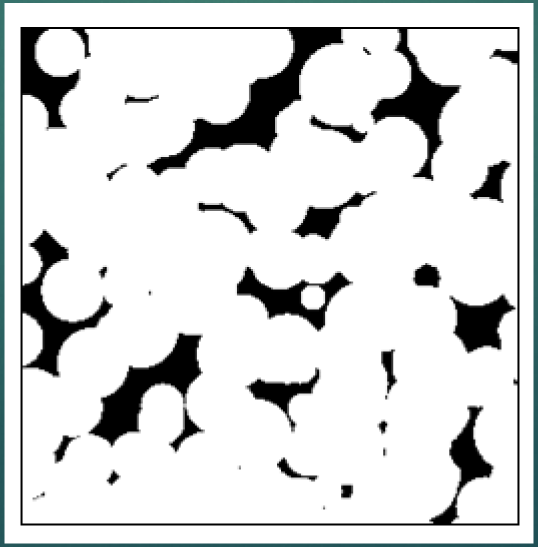
# Specific Surface Area



- Fraction of the pore surface area per unit (total) volume

$$S_v = \frac{Obj.S}{V_T} = \frac{\text{pore surface area}}{\text{total volume}}$$

- "Edge detection" (using marching cubes method) of the pore walls

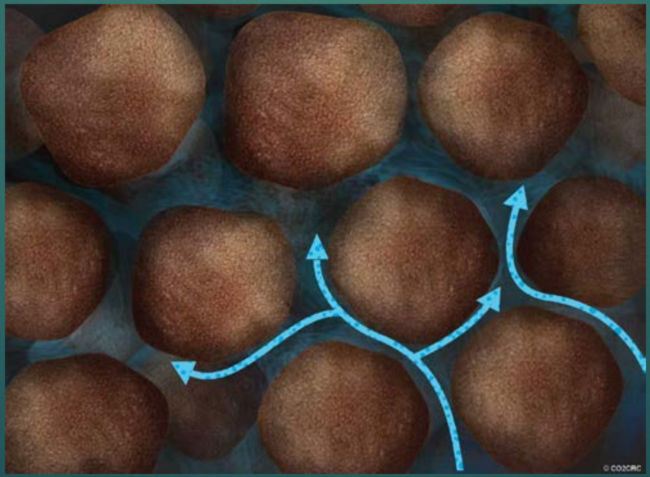


# Permeability



- Measure of the ability of a porous material (often, a rock or unconsolidated material) to allow fluids to pass through it.
- Calculated using Kozeny-Carman equation:

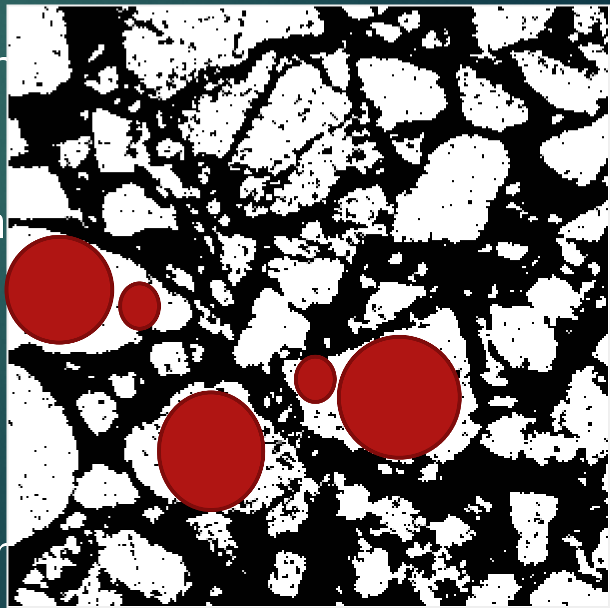
$$k = 10^{2\phi_c} \frac{(\phi_c)^3}{c\tau^2 S_v^2}$$



# Structural Properties



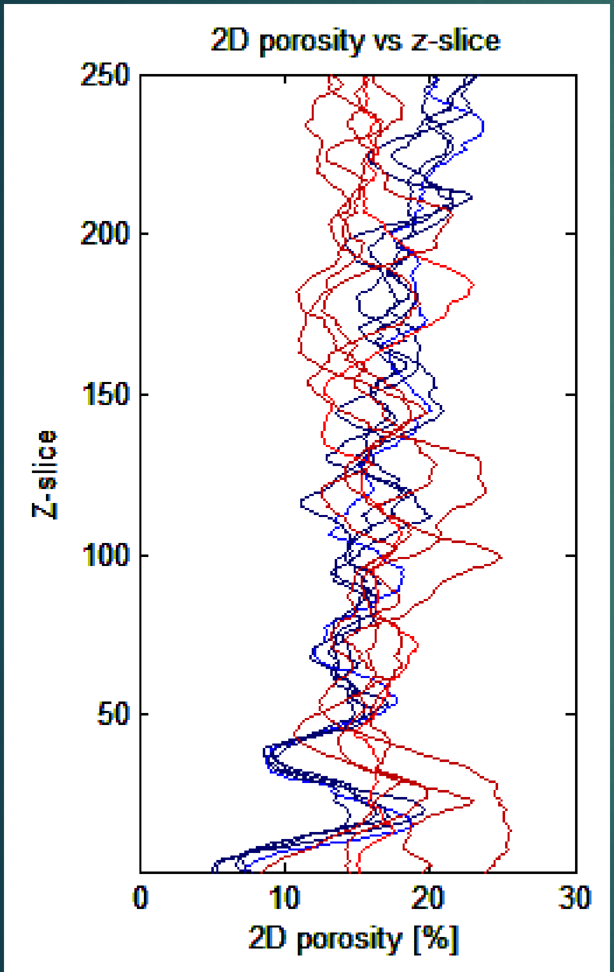
- Structure Thickness (St.Th)
  - ~ grain size
  - diameter of the largest sphere of a point inside the solid space
  - Starts with a "skeletonization" (identifying the medial axes of the solid structure) → "sphere-fitting" local thickness measurement
- Structure Separation (St.Sp)
  - ~ pore size
  - diameter of the largest sphere of a point inside th
  - space
  - Starts with a "skeletonization" (identifying the me the pore structure) → "sphere-fitting" local thickn measurement
- Fractal Dimension
  - ~ surface complexity
  - how that object's surface fills space
  - calculated using the Kolmogorov or "box countir

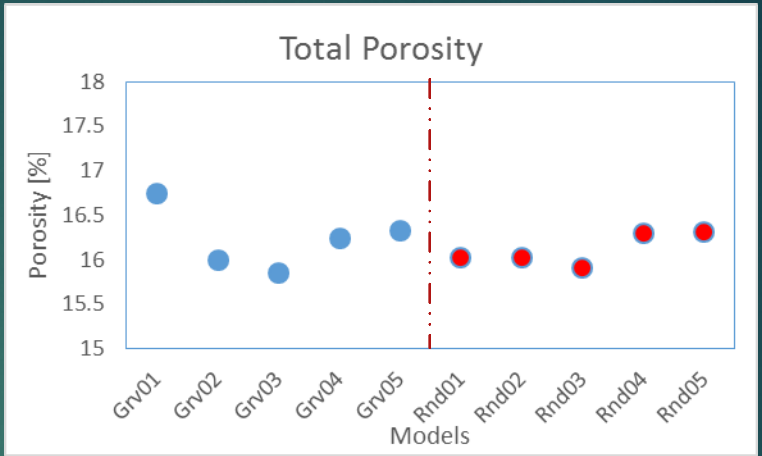


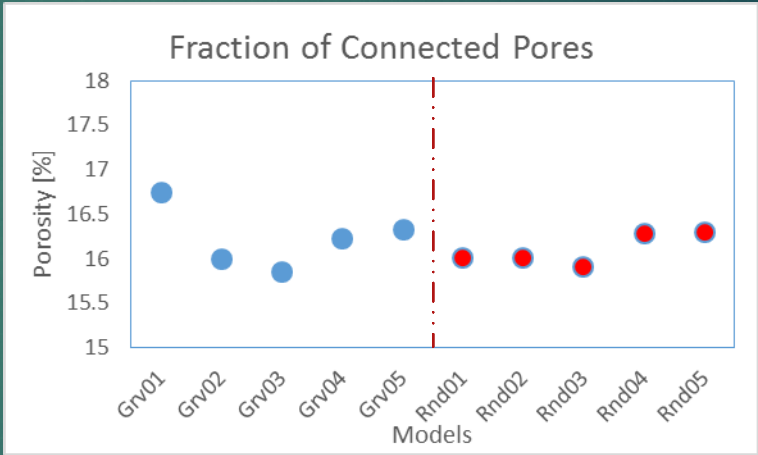
# Result and Discussion

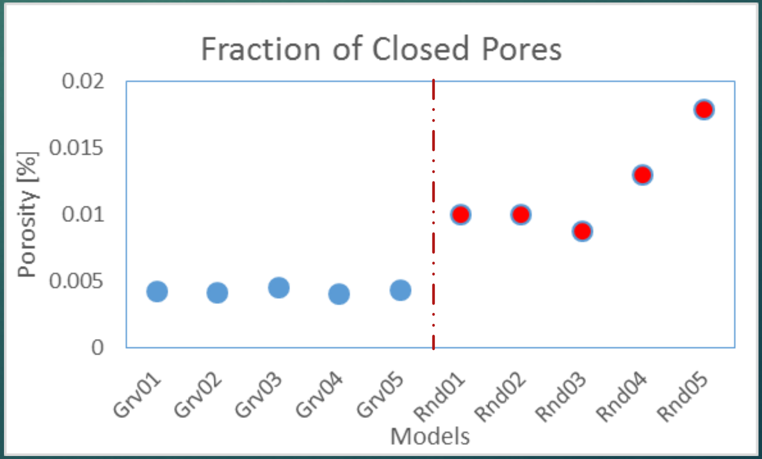
# Porosity




2D porosity vs z-slice
Z-slice
2D porosity [%]
0
10
20
30
50
100
150
200
250

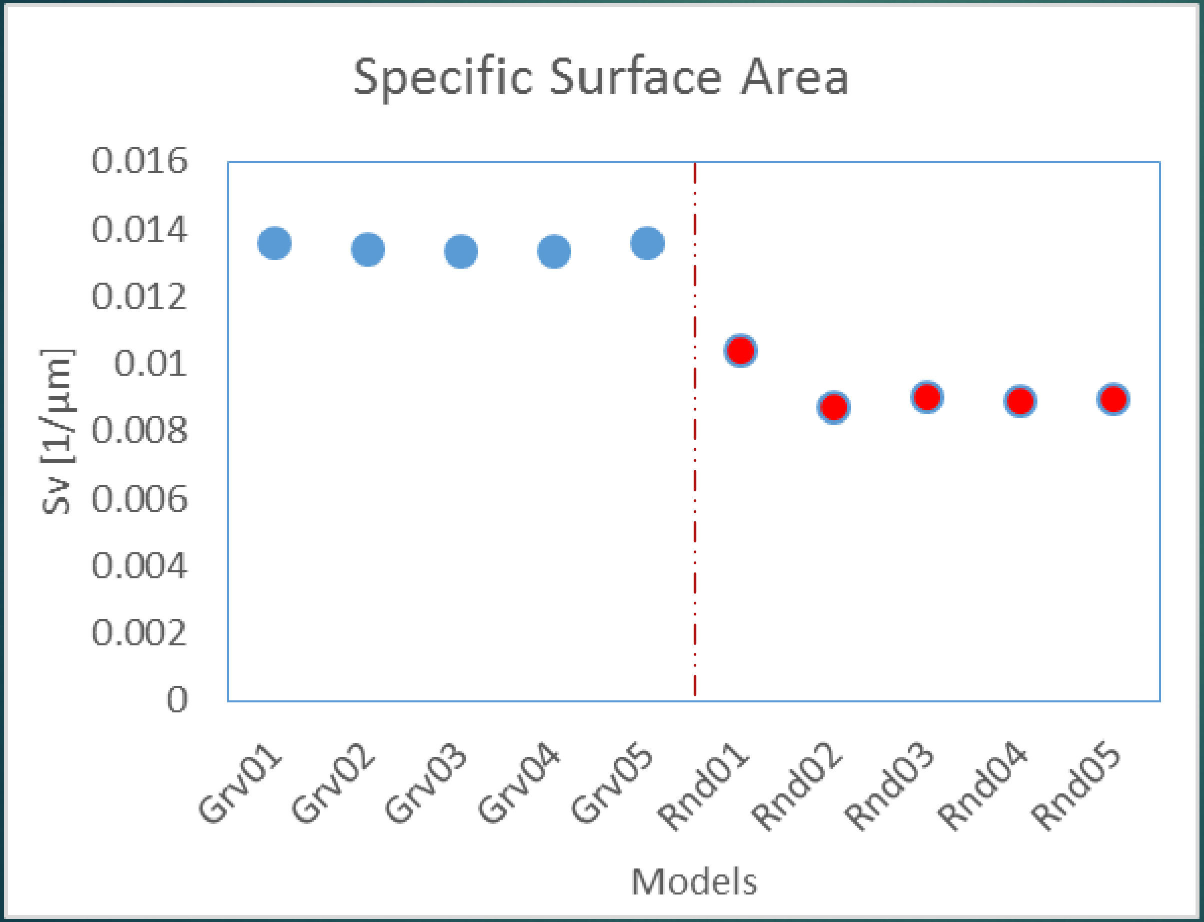

Total Porosity
Porosity [%]
Models
Grv01
Grv02
Grv03
Grv04
Grv05
Rnd01
Rnd02
Rnd03
Rnd04
Rnd05


Fraction of Connected Pores
Porosity [%]
Models


Fraction of Closed Pores
Porosity [%]
Models

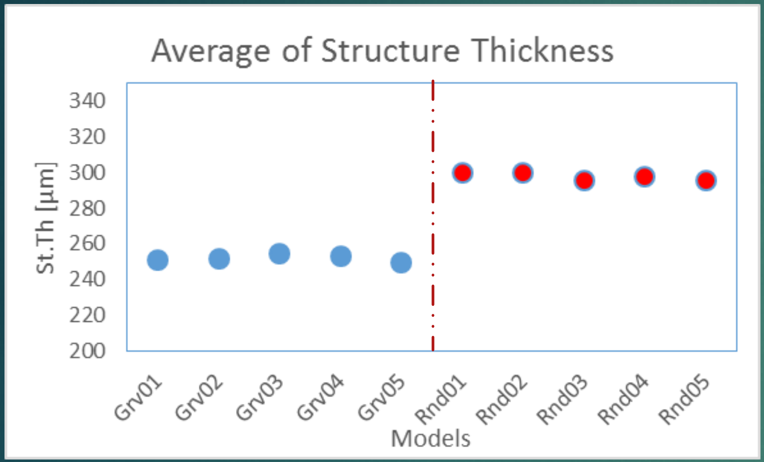
# Specific Surface Area

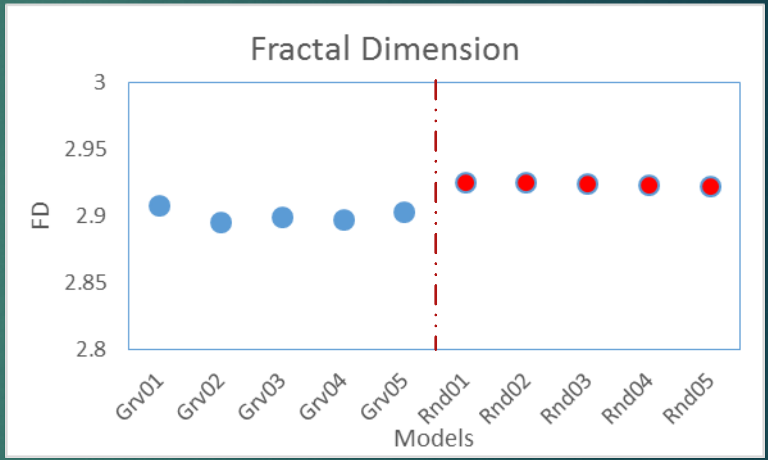


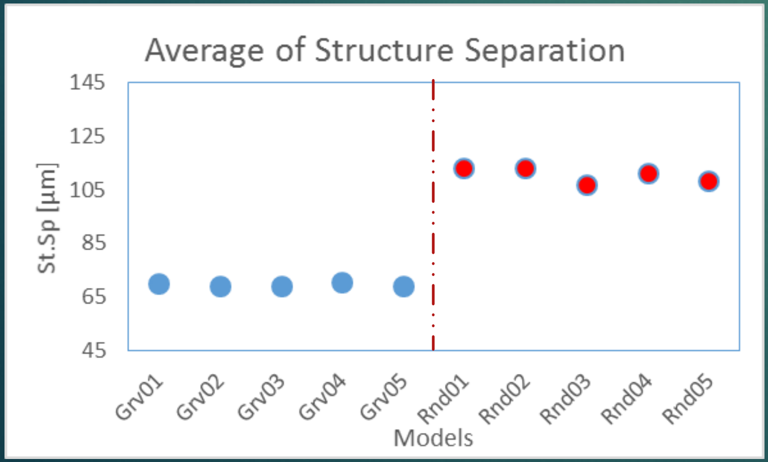


# Structure Thickness
# Structure Separation
# Fractal Dimension



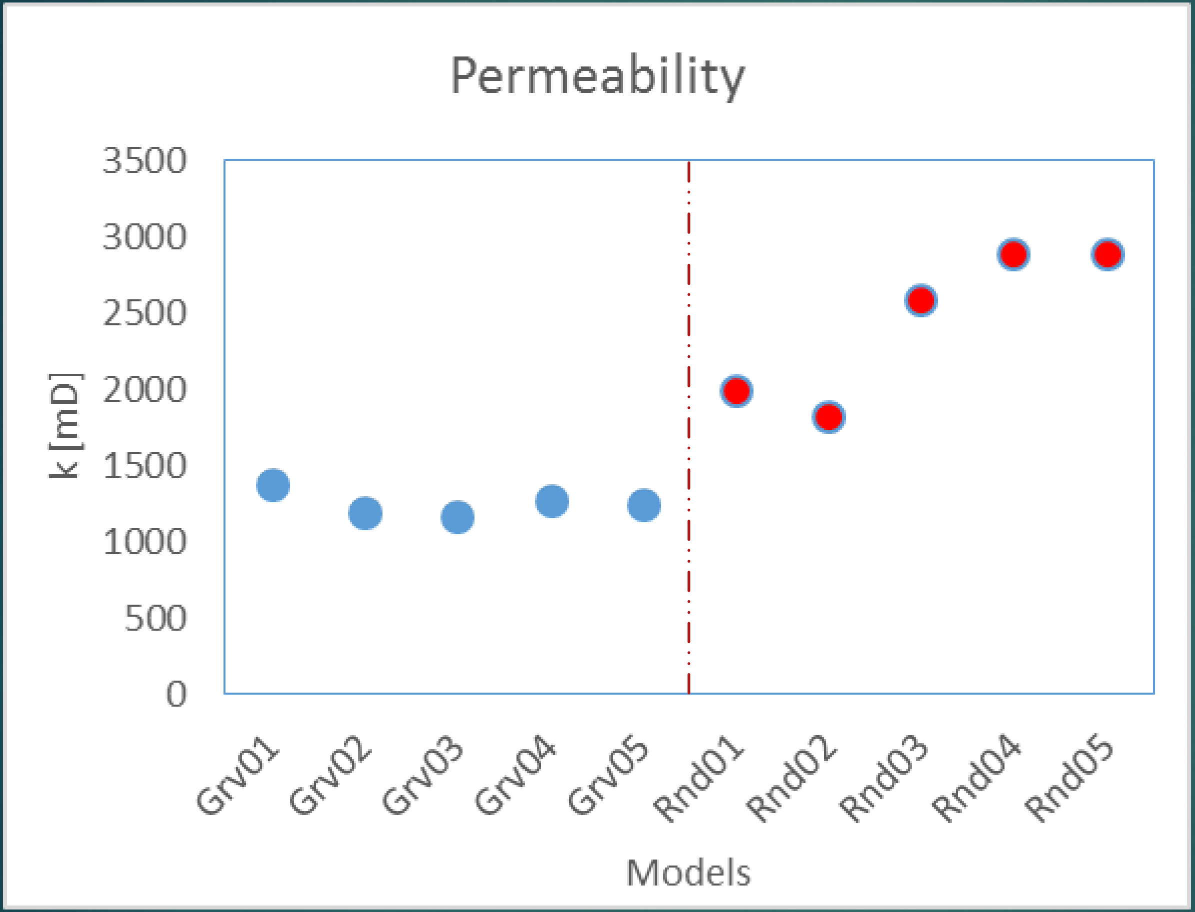


# Permeability





# Conclusion

# Conclusion



- Gravity driven sedimentation model (Grv) have varying particle density (in vertical direction)
  - the effect of overburden pressure due to gravity,
- Random penetrable grain model (Rnd) have more uniform distribution of particle density
  - Very slow deposition
- Permeability along the vertical direction of the Grv models are also smaller compared to that of the Rnd models.
  - caused by smaller surface area of the Rnd models.

# Publication




1. Fourier Dzar Eljabbar Latief, Umar Fauzi, Characterization of Gravity Driven Sedimentation Model and Random Penetrable Model of Sedimentary Rock, PROCEEDINGS HAGI-IAGI Joint Convention Medan 2013, 28 – 31 October 2013.
2. Firmansyah, Selly Feranie, Fourier D. E. Latief, Prana F.L. Tobing, Tortuositas Pada Model 3D Batuan Berpori, Poceedings of Seminar Nasional Fisika (SNF) III, Universitas Nasional Jakarta, 7 Juni 2014.

# Future Work



- “Decorated” grain (polygonal) models based on both sedimentation models.
- Analysis of Kozeny-Carman equation and the Kozeny constant using both models.