同济大学交通运输工程学院
COLLEGE OF TRANSPORTATION ENGINEERING
TONGJI UNIVERSITY

Study on the pores characteristics and permeability simulation of pervious concrete based on 2D/3D CT images

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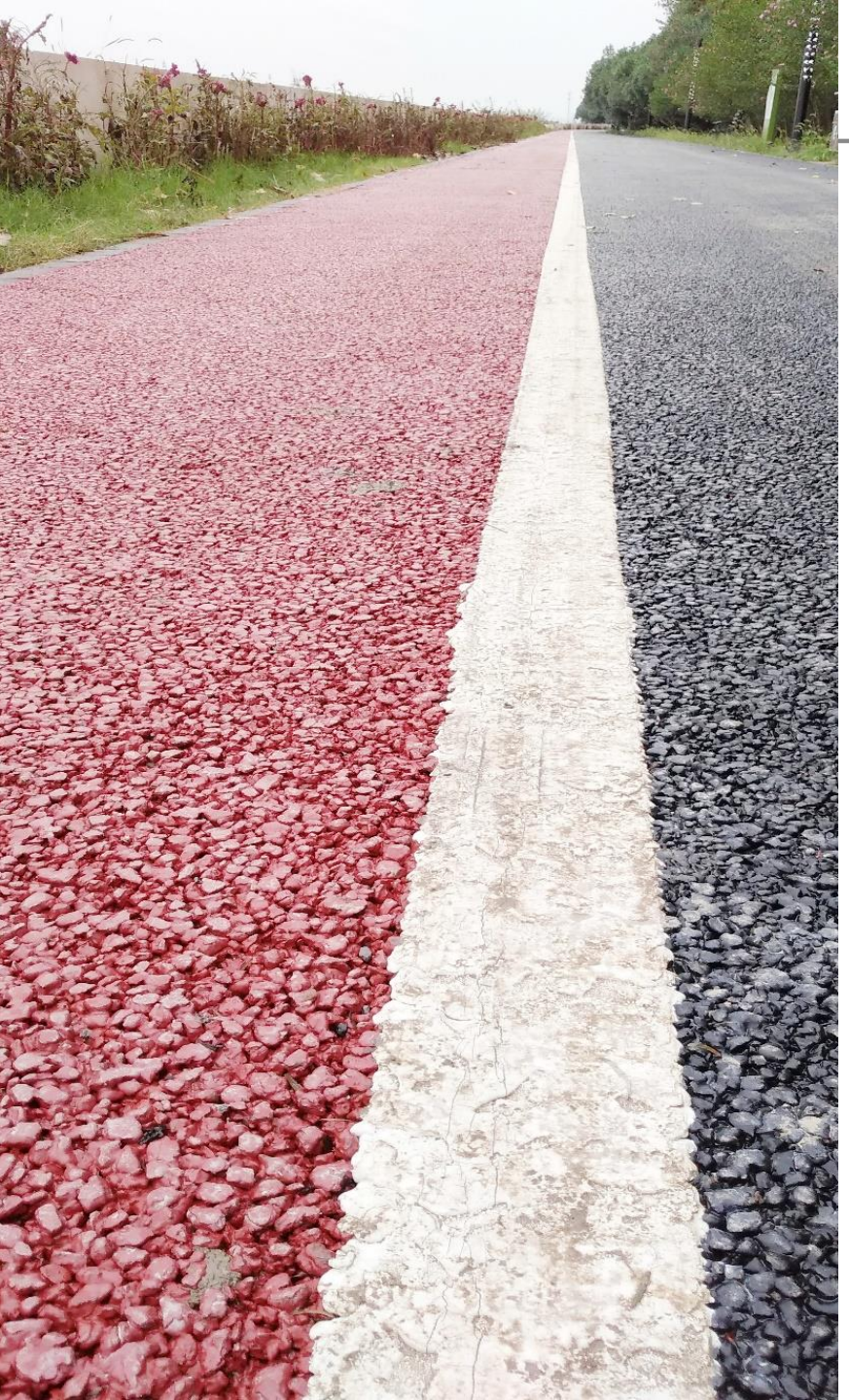

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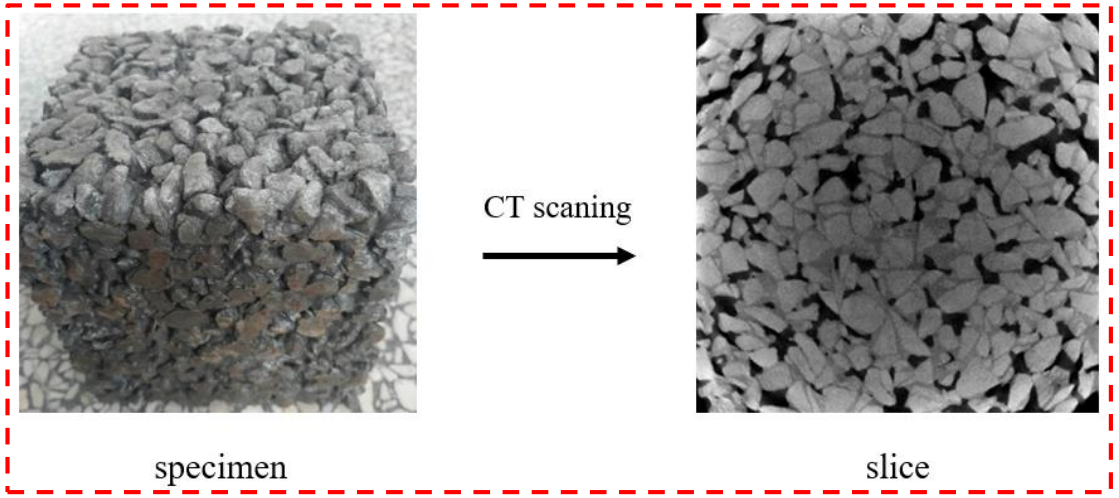
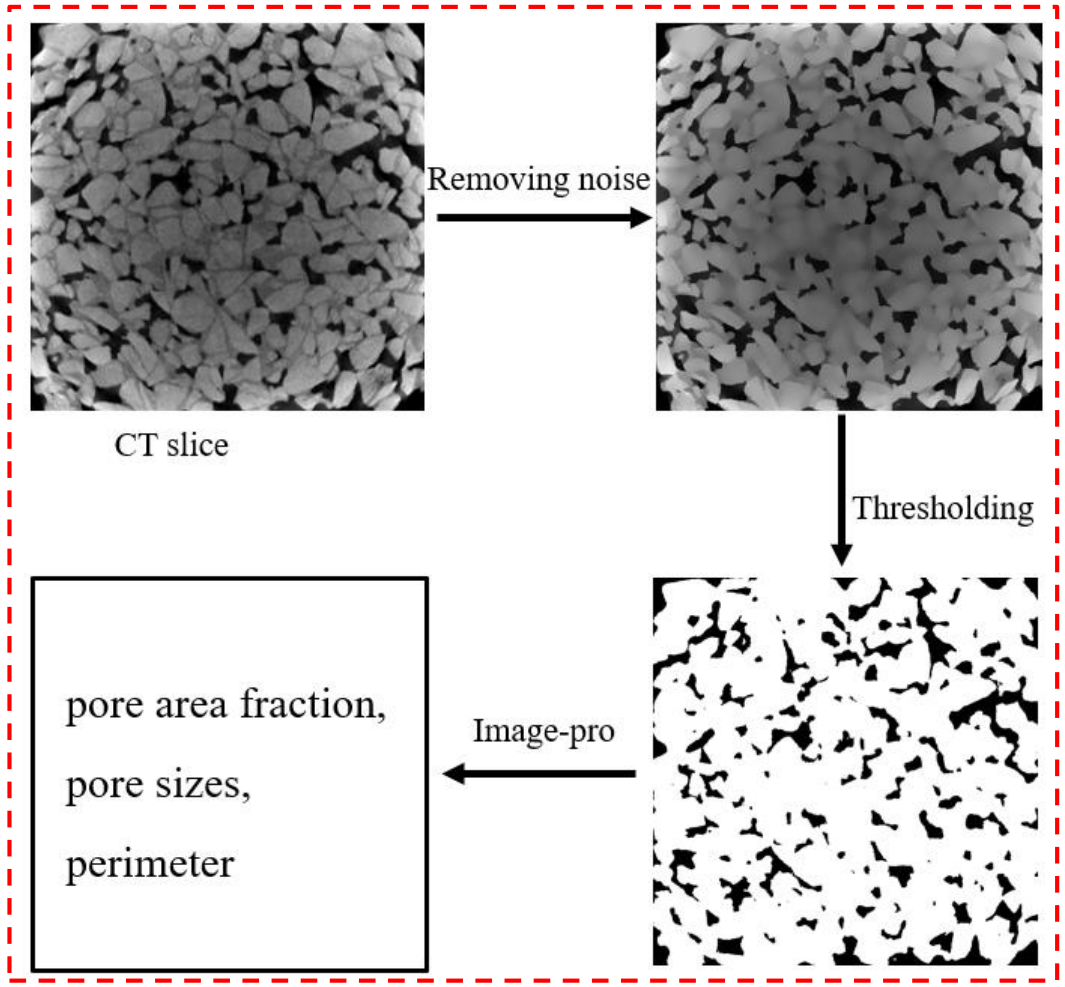
1. Experiment method

Sample code	Aggregate size (mm)	Target porosity (%)	Measured porosity (%)	Permeability coefficient (mm/s)
A	2.36~4.75	20	21.03	2.90
B	4.75~6		21.11	6.03
C	6~8		20.89	7.05
D	8~9.5		20.50	8.98
E	4.75~9.5		21.25	6.28
F	10~12.5		20.78	13.30
G	12.5~15		21.16	13.53
H	10~15		20.56	12.01

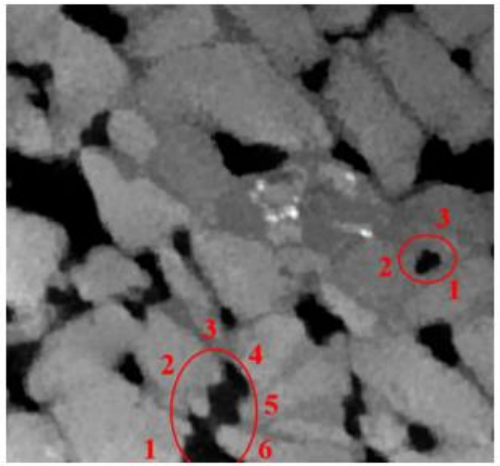
2. 2D pore structure analysis

Method

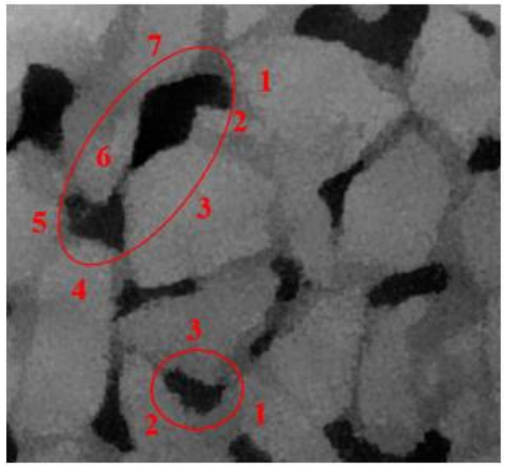




Pores shape



2.36-4.75



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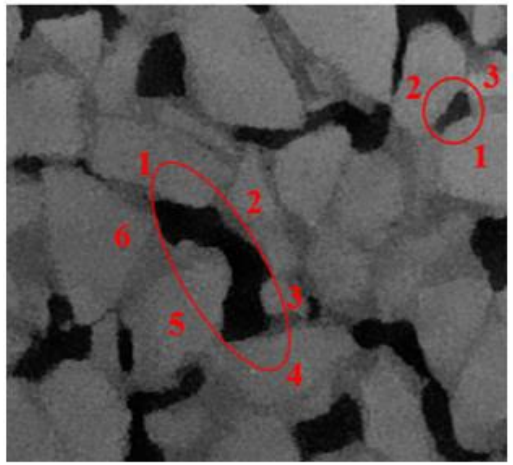
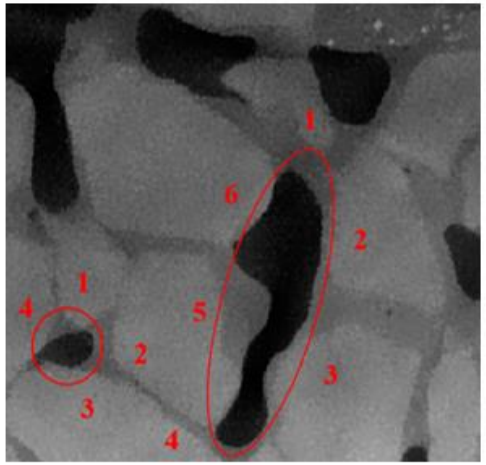
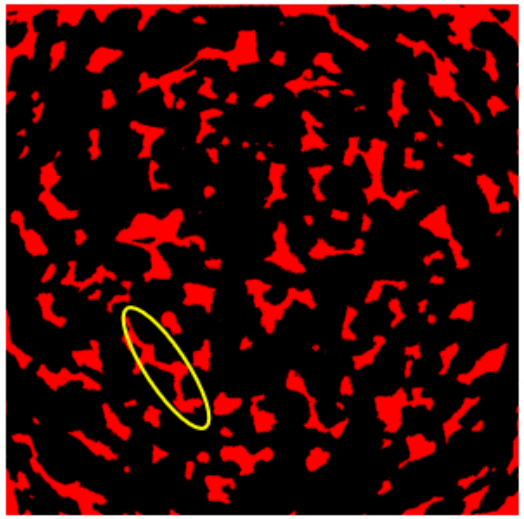


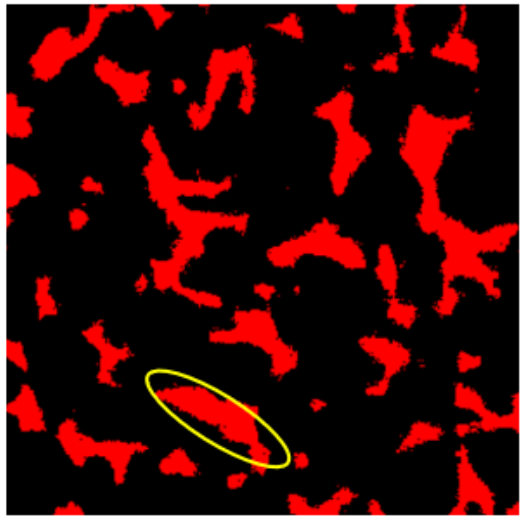
4.75-9.5



10-12.5



2.36-4.75



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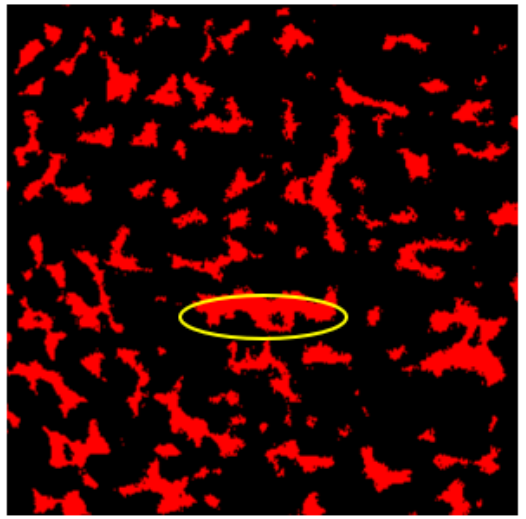
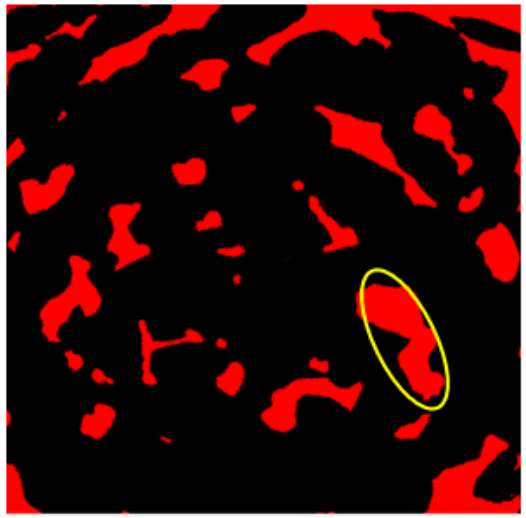
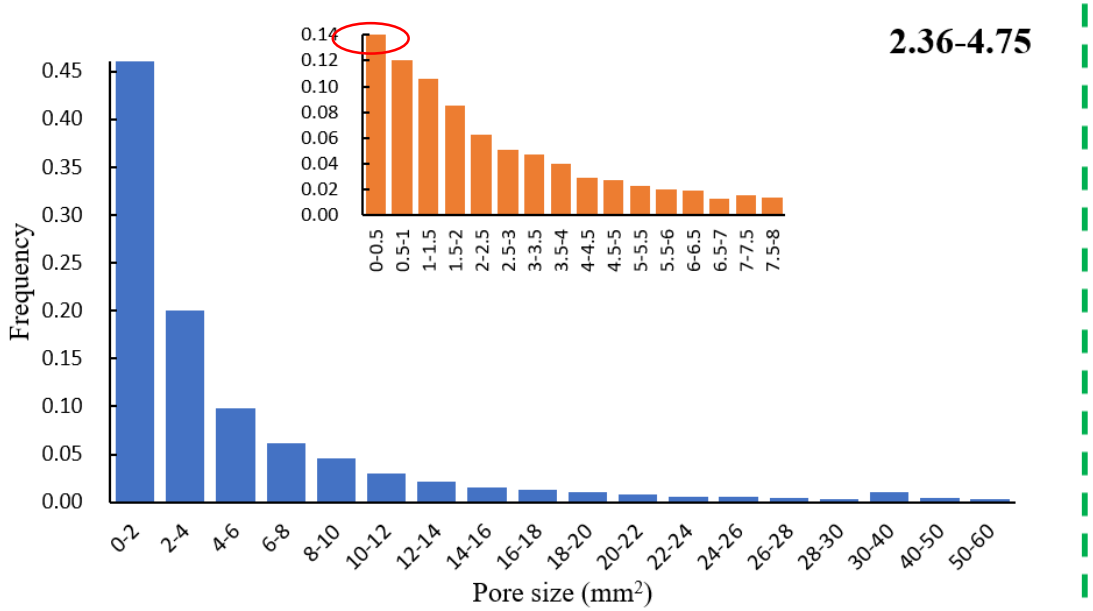


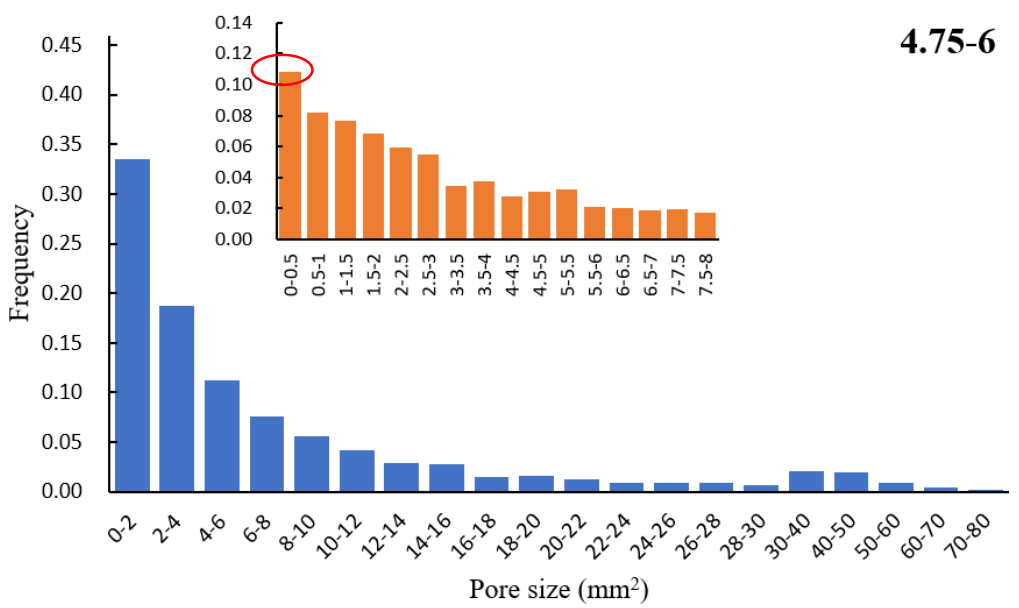
4.75-9.5

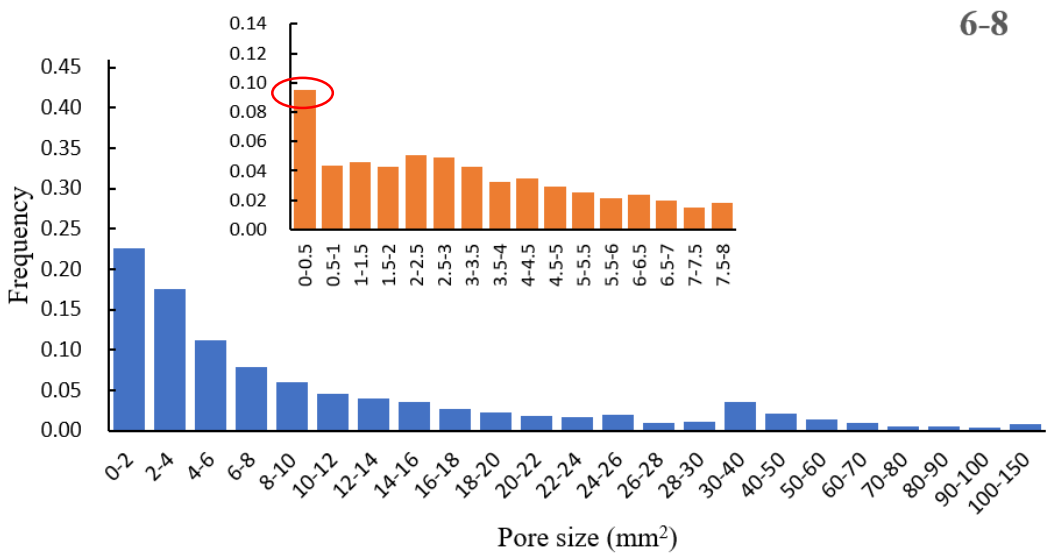


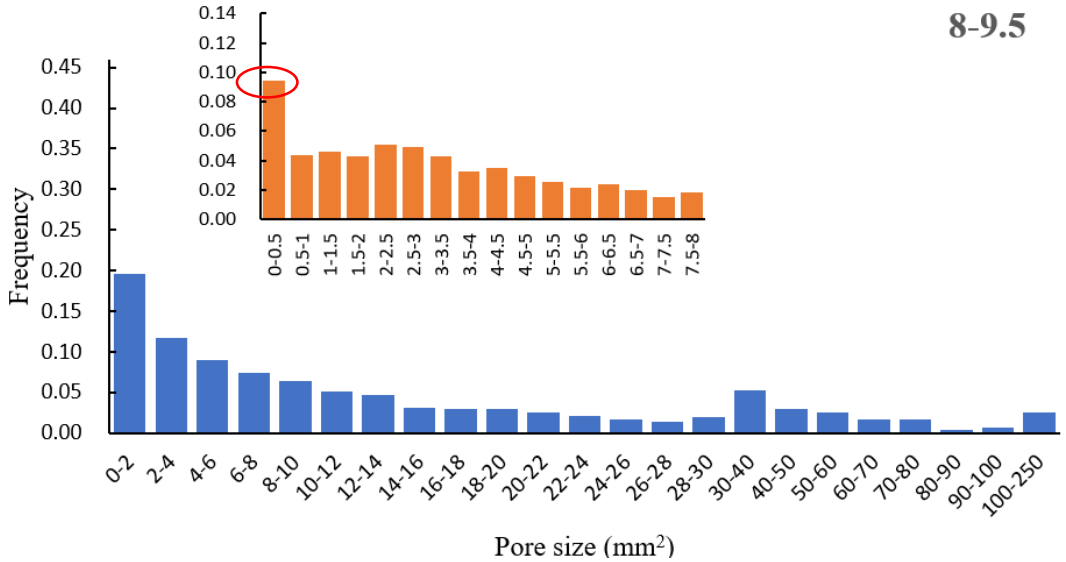
10-12.5

2D pores size distribution

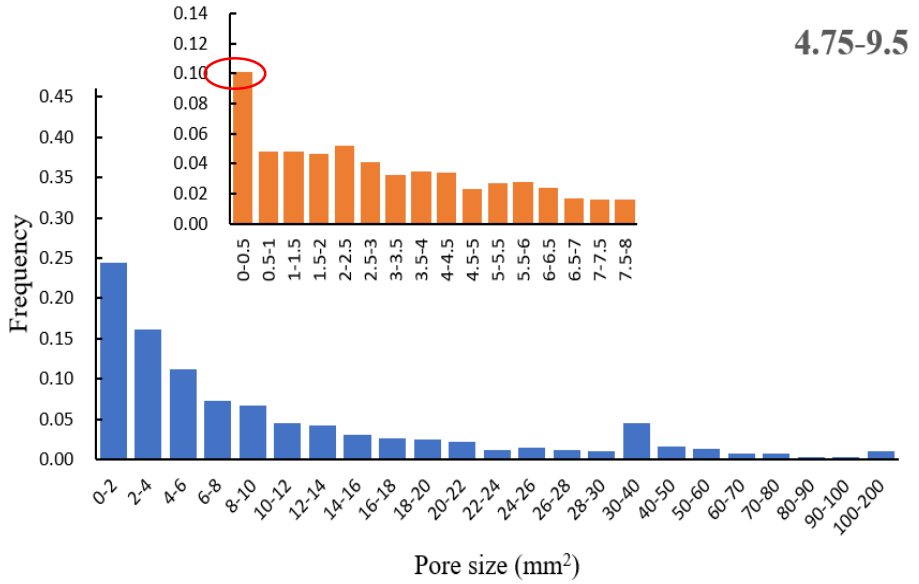


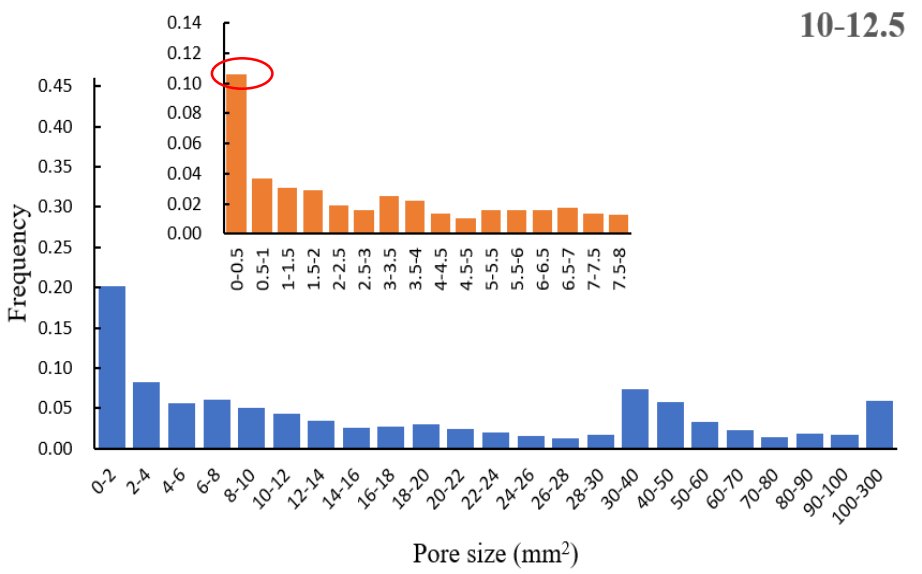


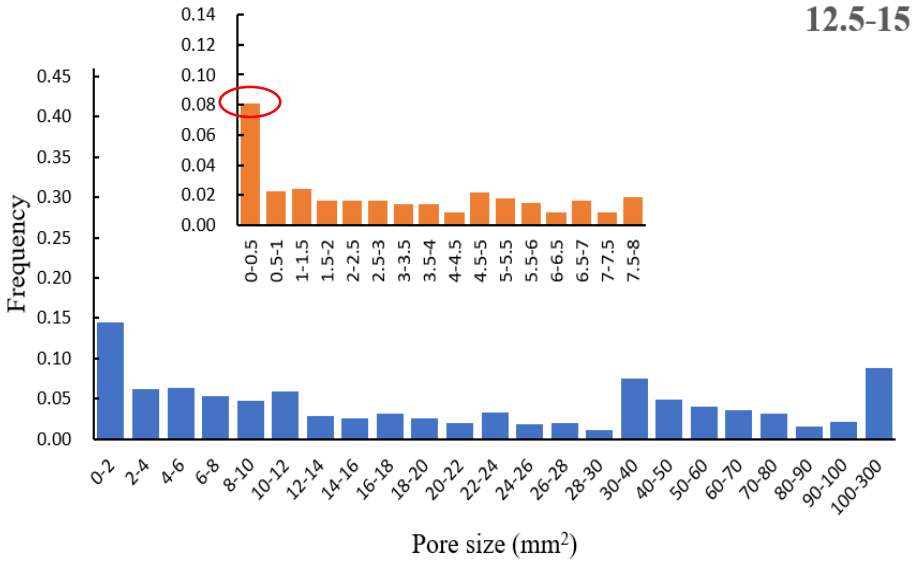


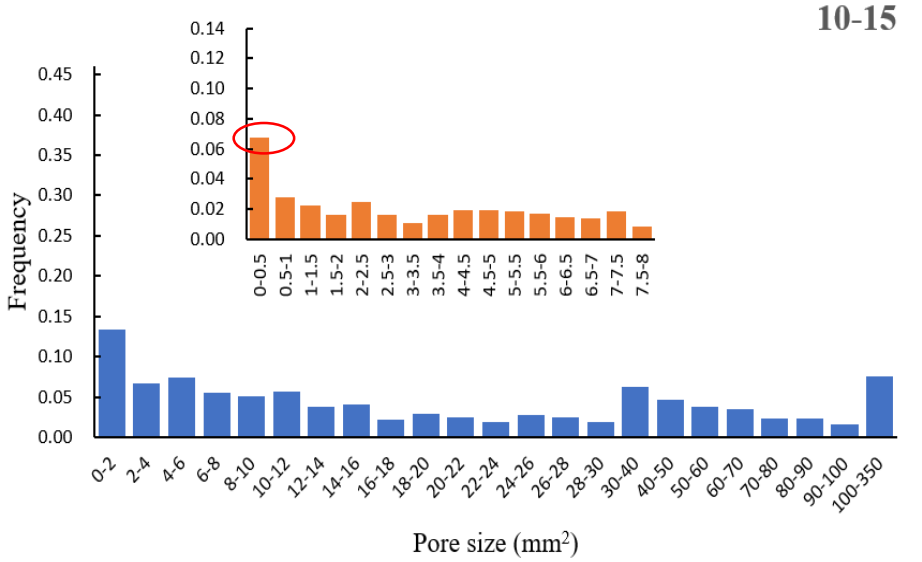


2D pores size distribution



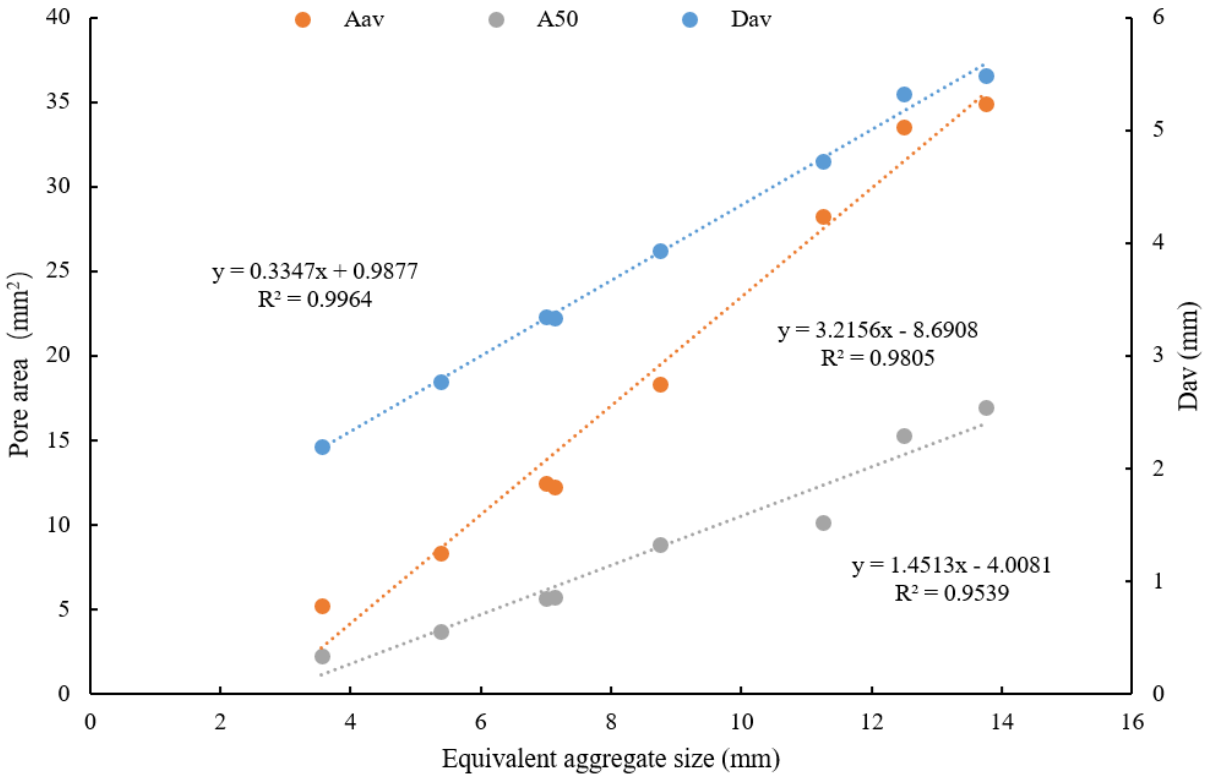




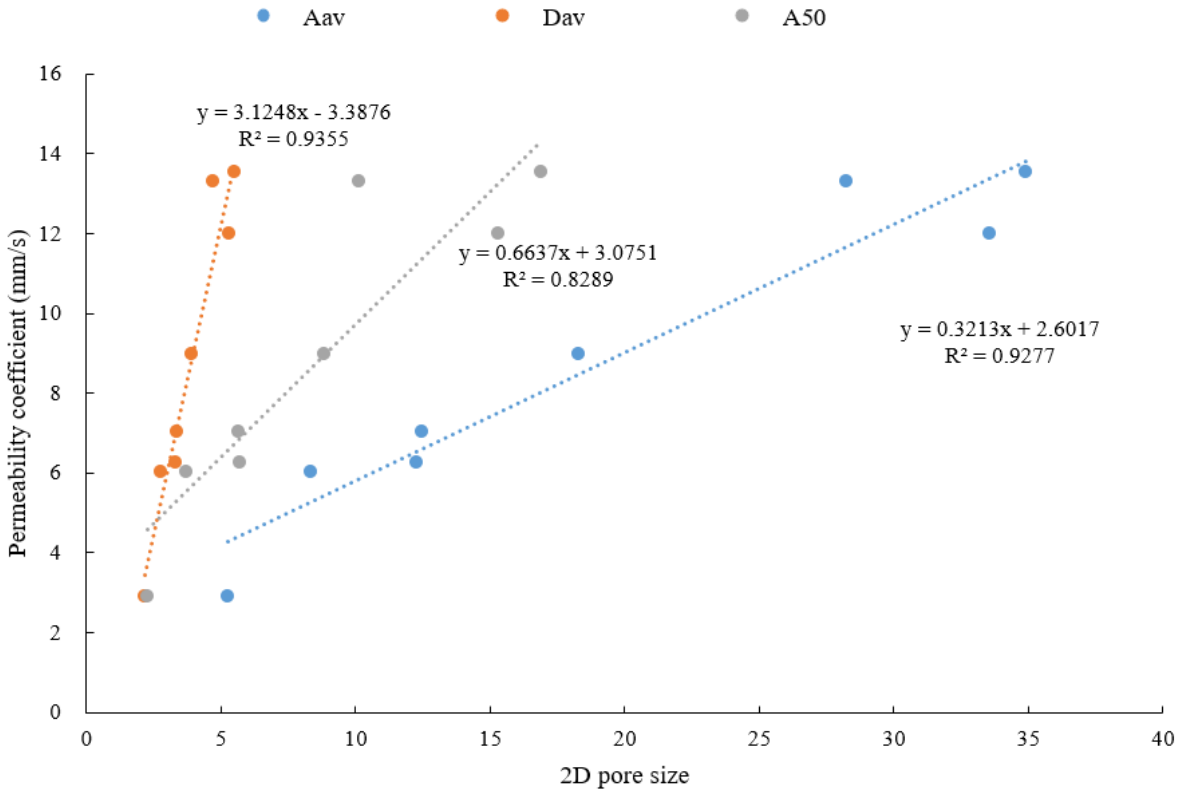


Aggregate (mm)	Equivalent aggregate size (mm)	Average 2D porosity (%)	Number of pores per slice	Range of pore area (mm^2)	A_{av} (mm^2)	A_{50} (mm^2)	D_{av} (mm)
2.36-4.75	3.555	0.191	354	0~60	5.23	2.28	2.19
4.75-6	5.375	0.192	227	0~80	8.34	3.70	2.77
6-8	7.000	0.186	141	0~150	12.48	5.67	3.35
8-9.5	8.750	0.189	100	0~250	18.29	8.82	3.93
4.75-9.5	7.125	0.191	142	0~200	12.27	5.72	3.33
10-12.5	11.250	0.198	62	0~300	28.25	10.11	4.72
12.5-15	13.750	0.193	46	0~350	34.92	16.92	5.49
10-15	12.500	0.195	52	0~350	33.55	15.30	5.32

A_{av} ——the average pore area; A_{50} ——the pores size corresponding to 50% of the cumulative frequency distribution; D_{av} ——the average pore diameter.

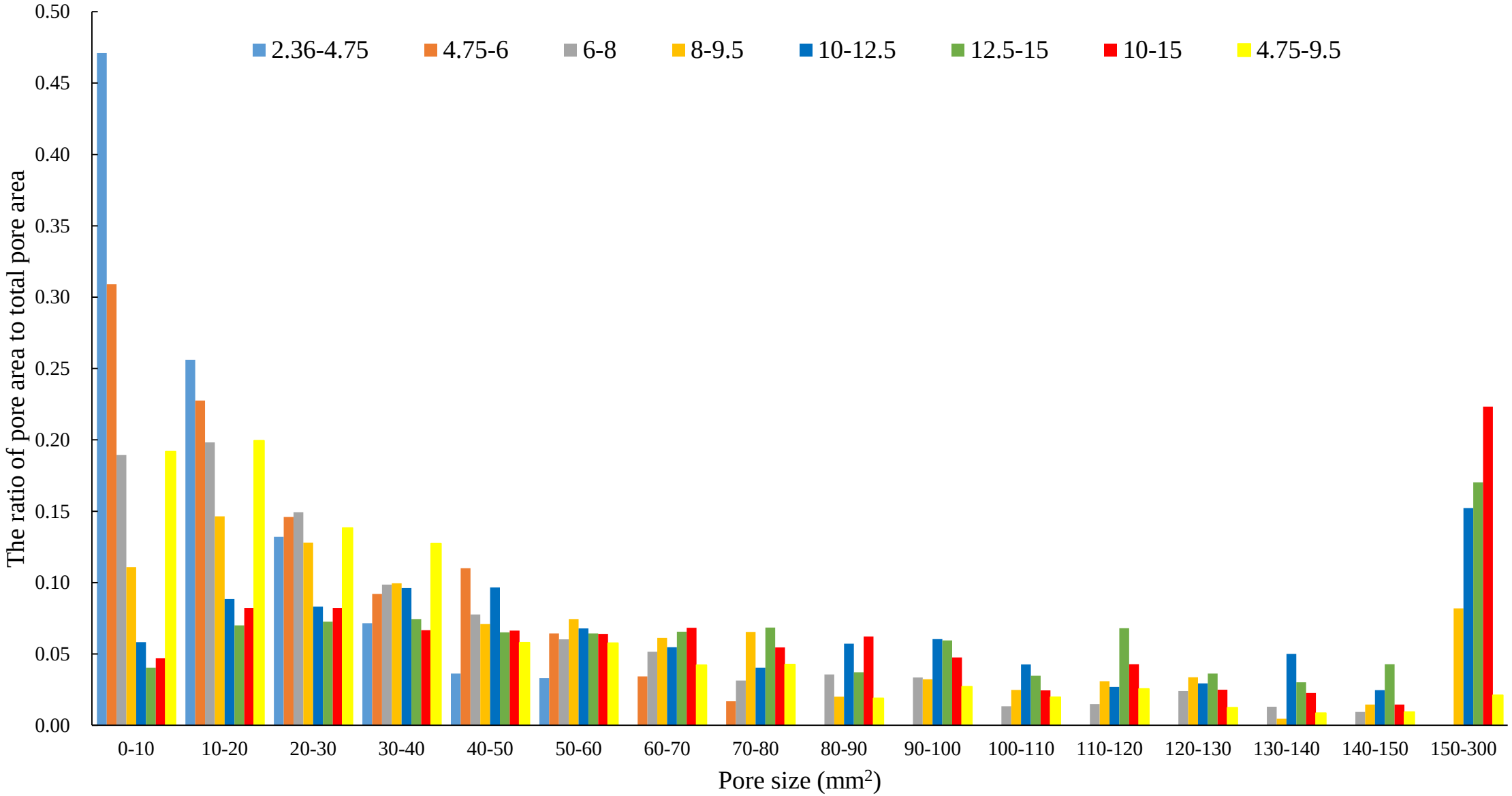


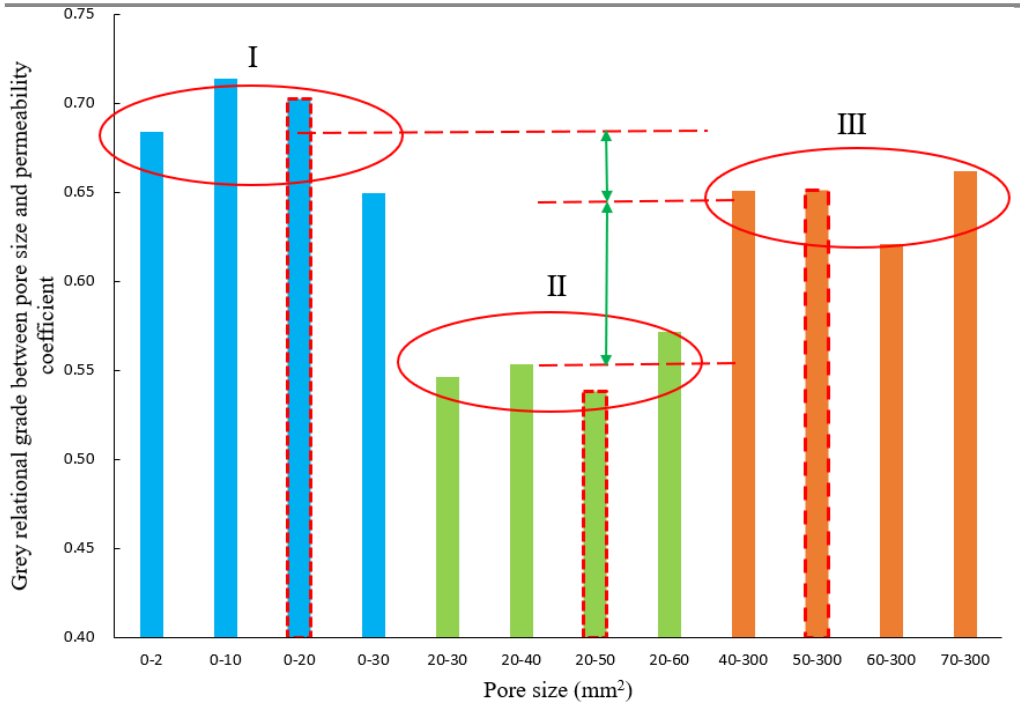
The 2D pores size is linearly related to the equivalent aggregate size.

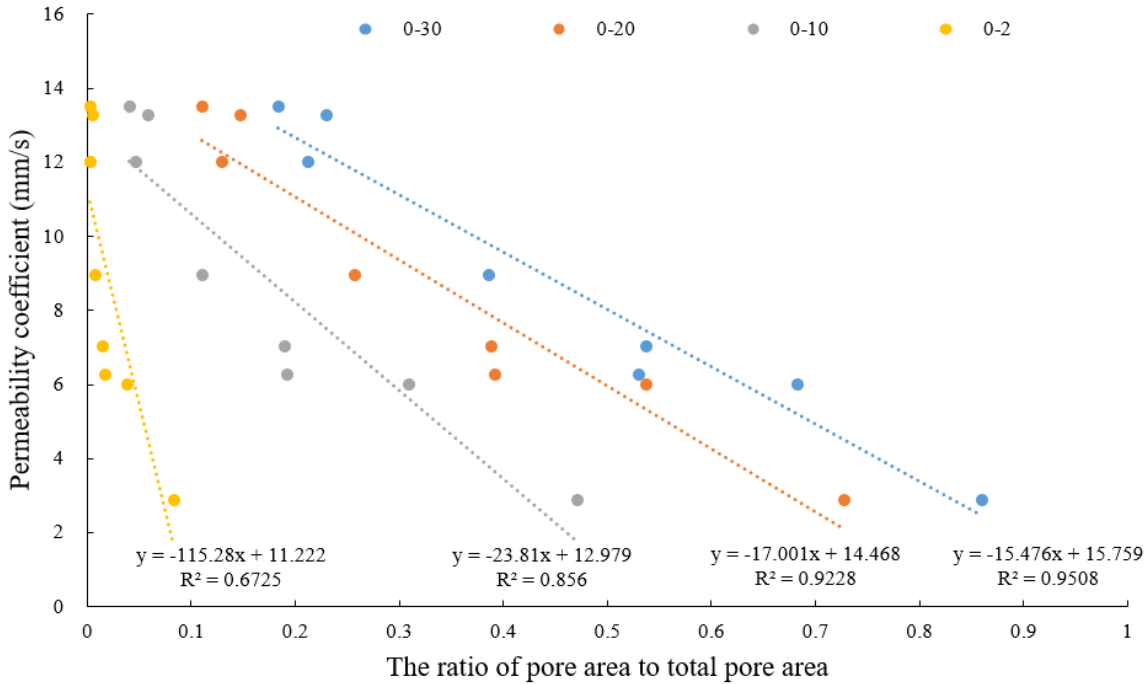


The permeability coefficient is linearly related to 2D pores size. The value of R^2 of average pore area and average pores size is close to each other, and obviously larger than that of A_{50}.

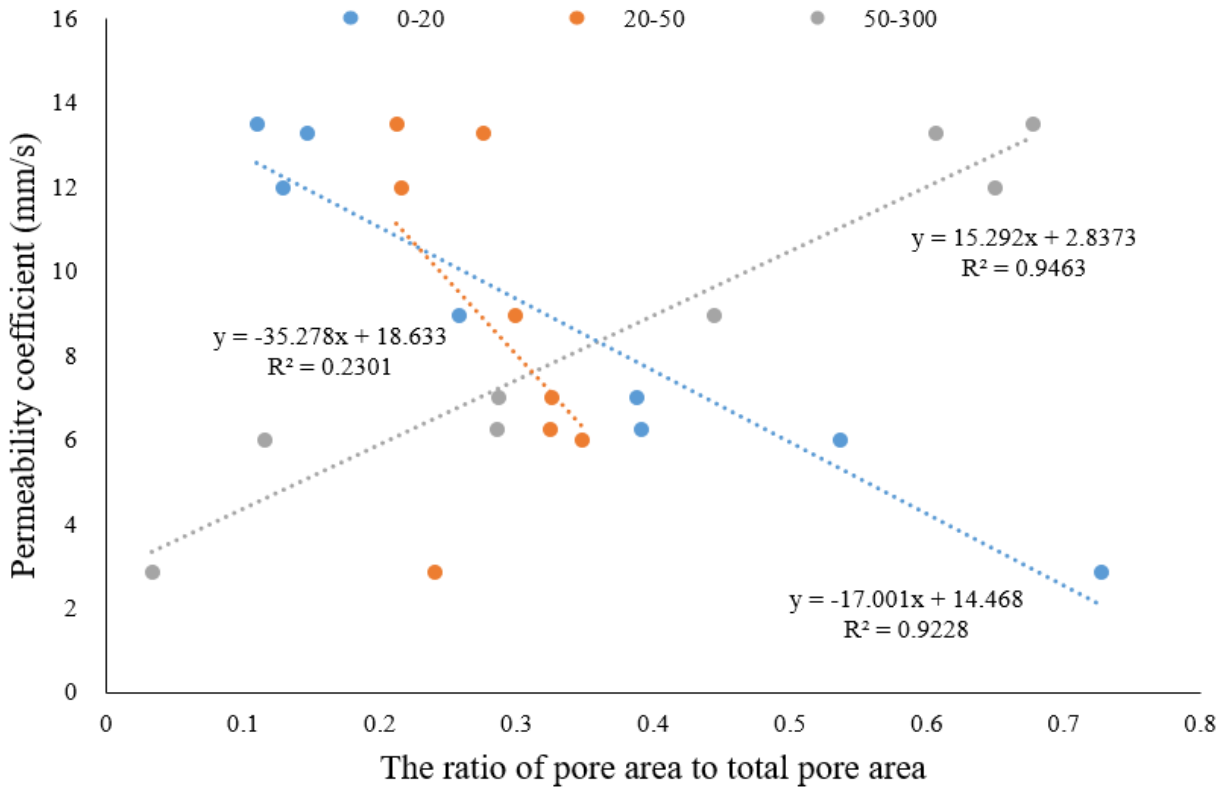
The distribution of the content of different size of pores



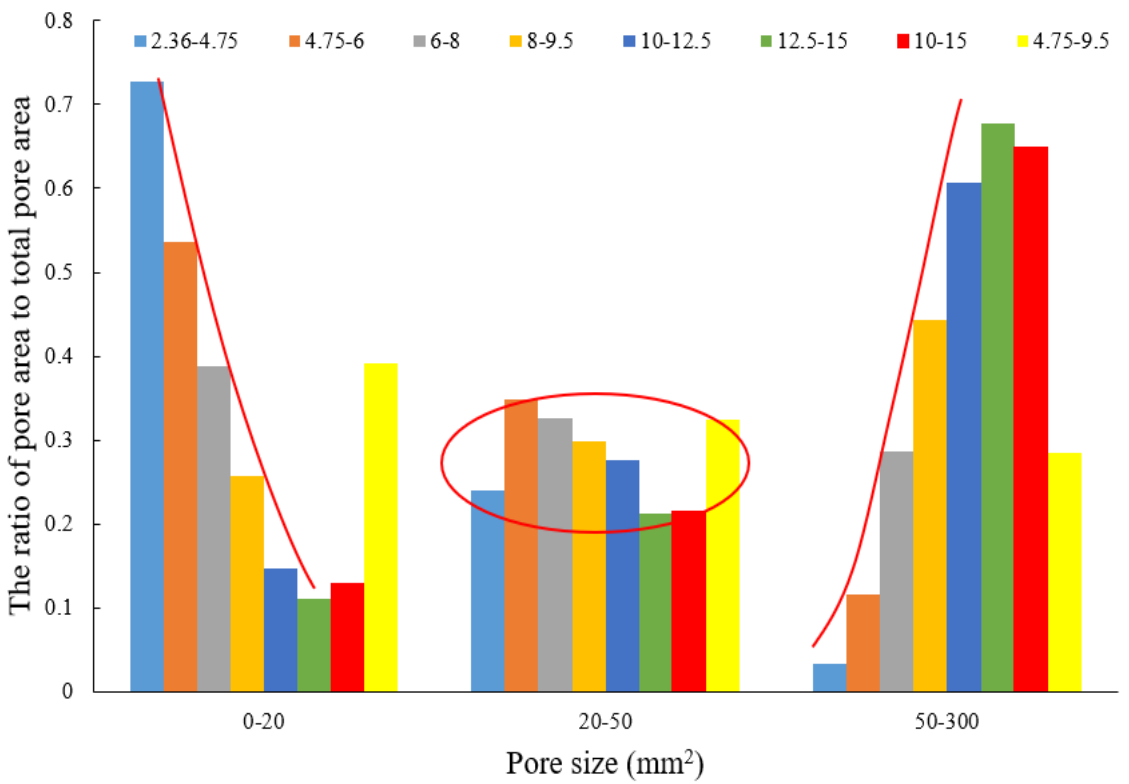




- Assume that the pores in the permeable concrete can be divided into three types: large, medium and small pores. It is not difficult to imagine that the larger the proportion of small pores, the lower the water permeability. In order to classify pores accurately into three types, the methods of regression analysis and grey relational analysis were used.
- small pores (0mm^2-20mm^2); medium pores (20mm^2-50mm^2); large pores (> 50 mm^2).
- Permeability is most sensitive to the content of small pores, followed by large pores content, and is less sensitive to the content of medium pores.



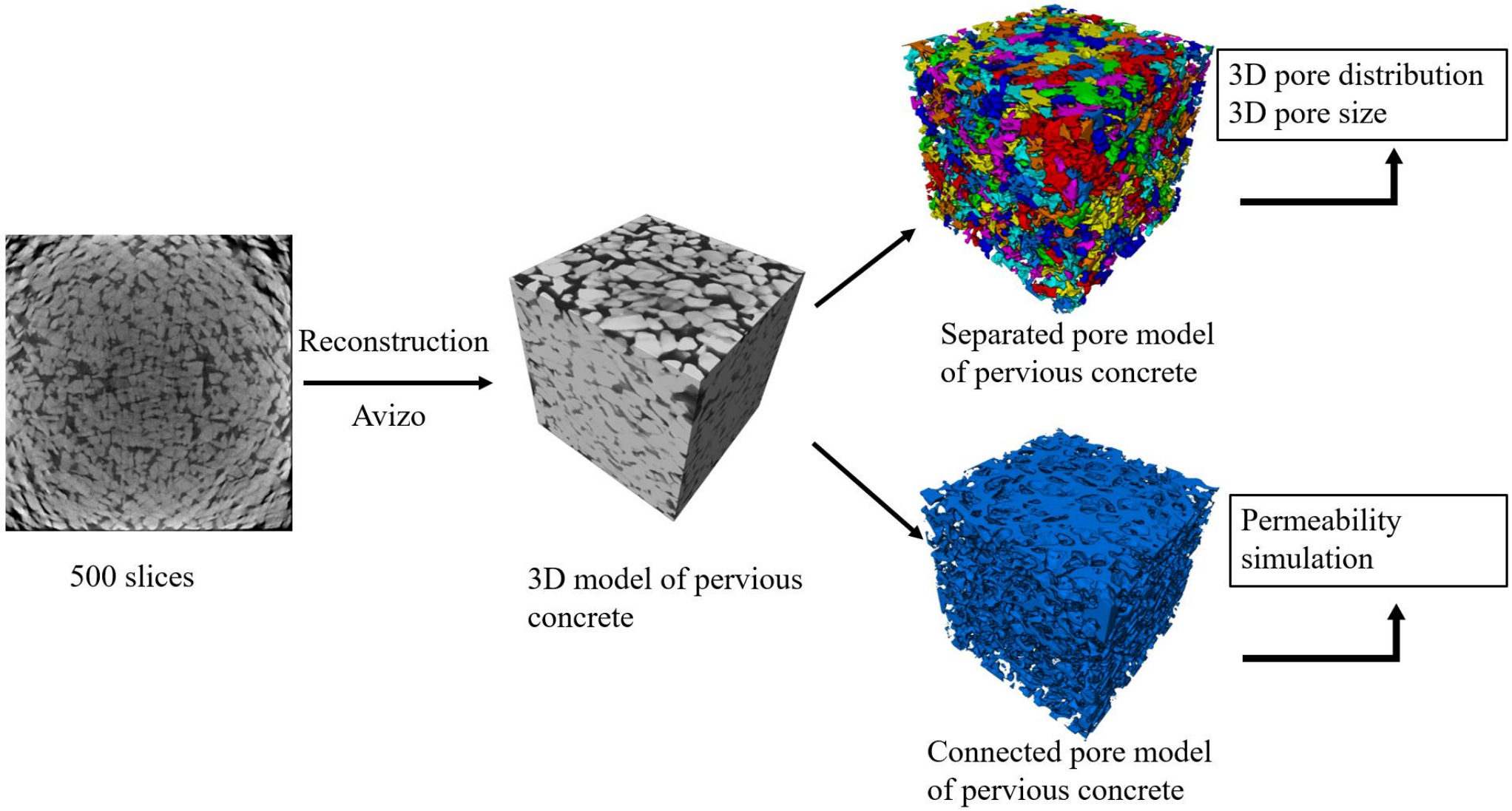
The permeability coefficient is linearly related to the content of small pores or large pores.



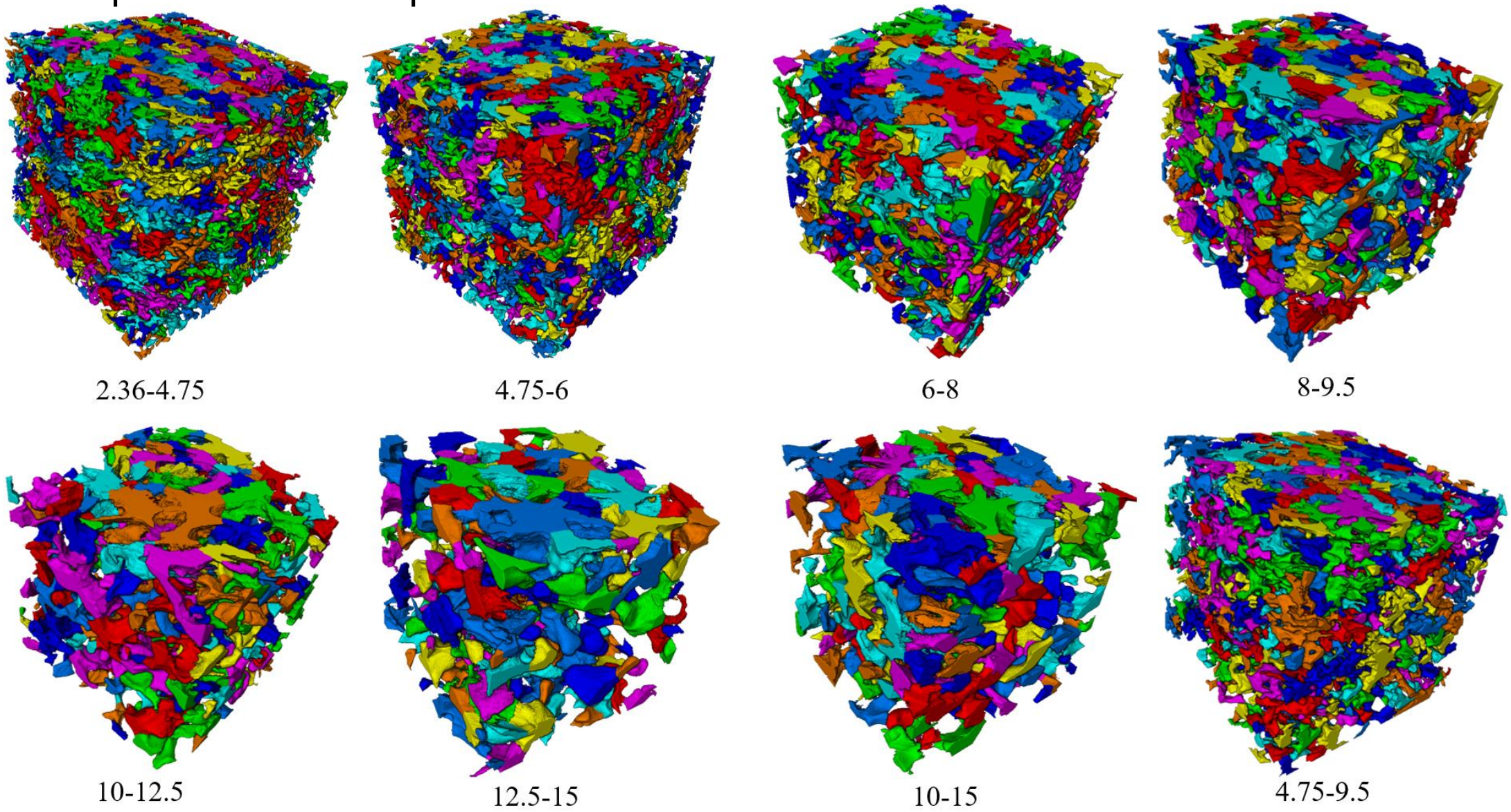
With the increase of aggregate size, the content of small pores decreases, while the content of large pores increases. The content of medium pores varies not particularly noticeable compared to small pores and large pores.

3. 3D pore structure analysis

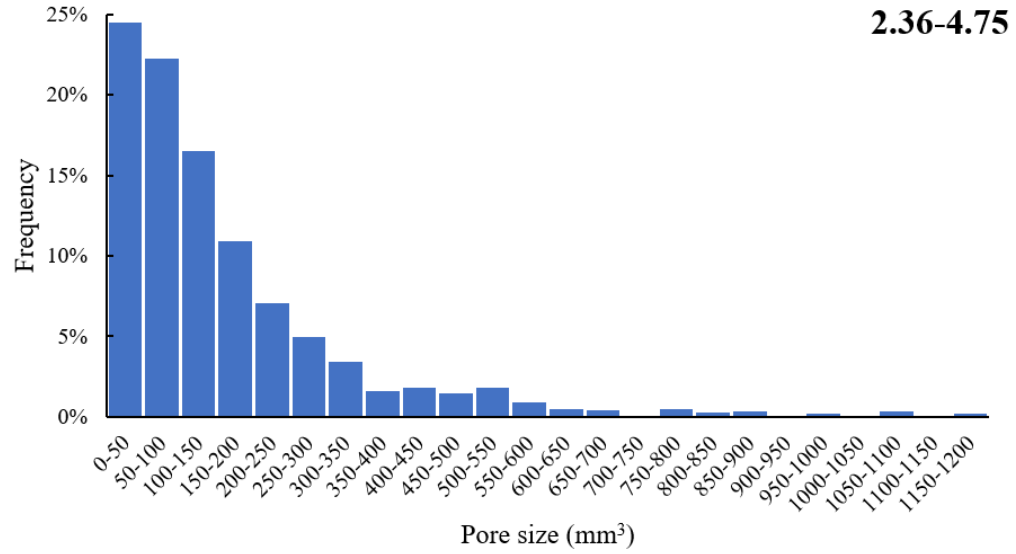
Method

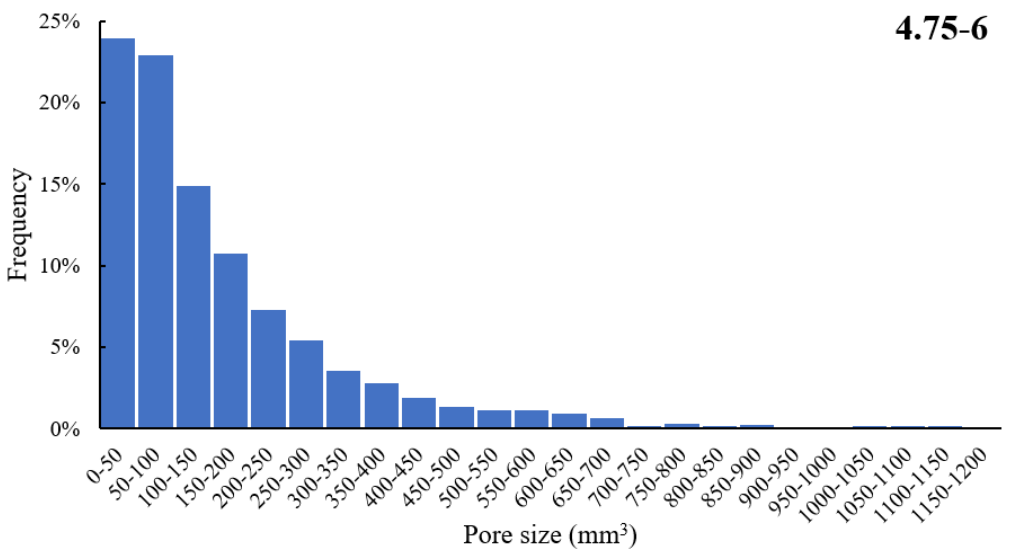


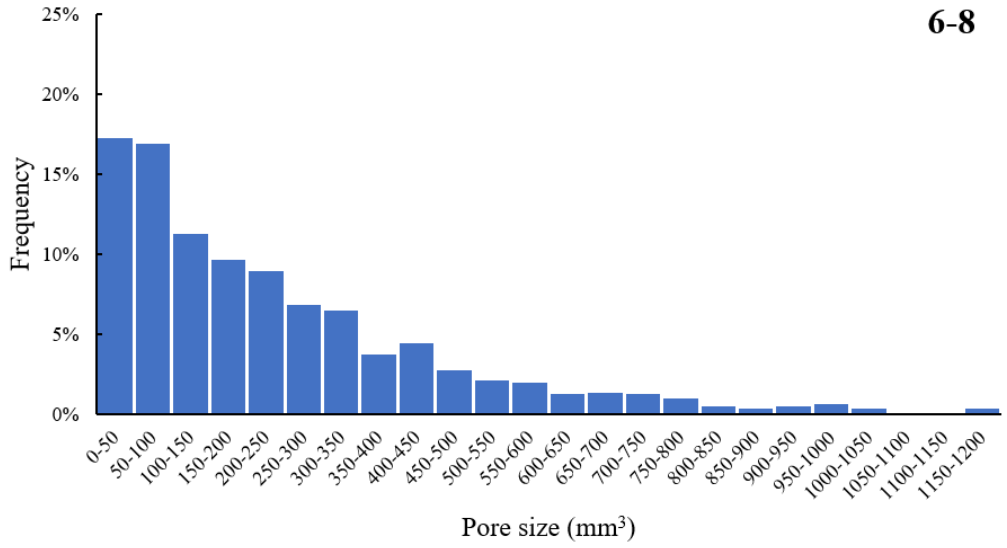
Separated pores models of pervious concrete

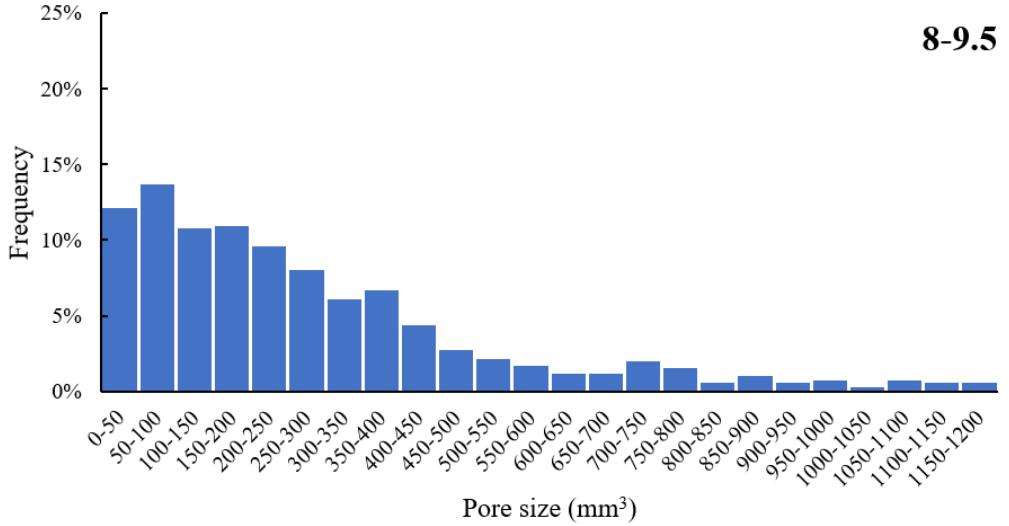


3D pores size distribution

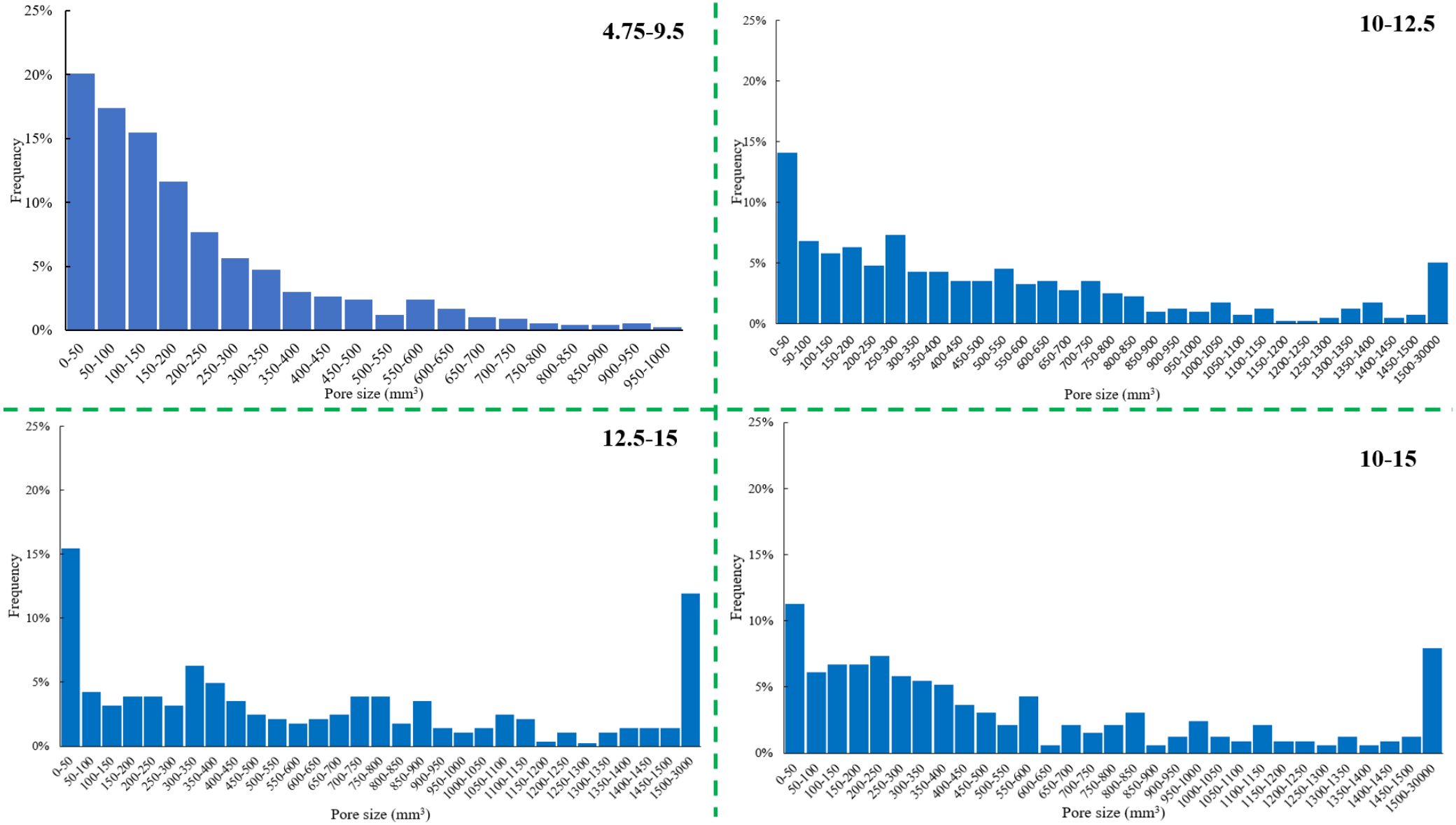






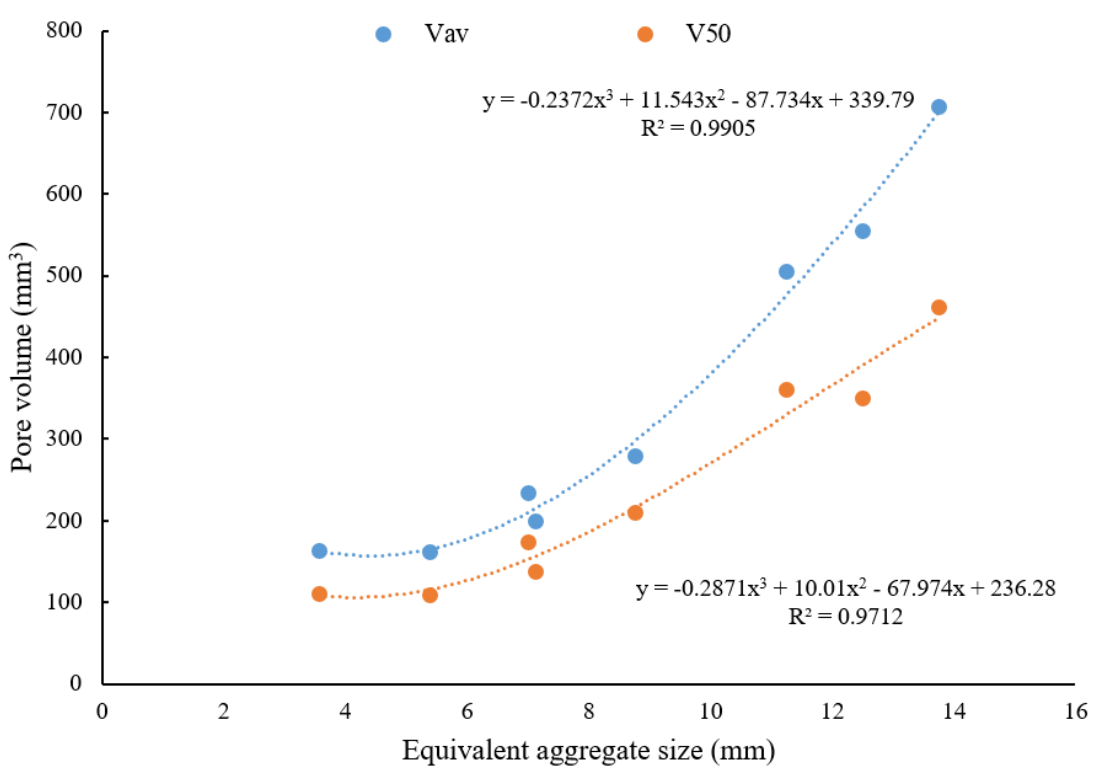


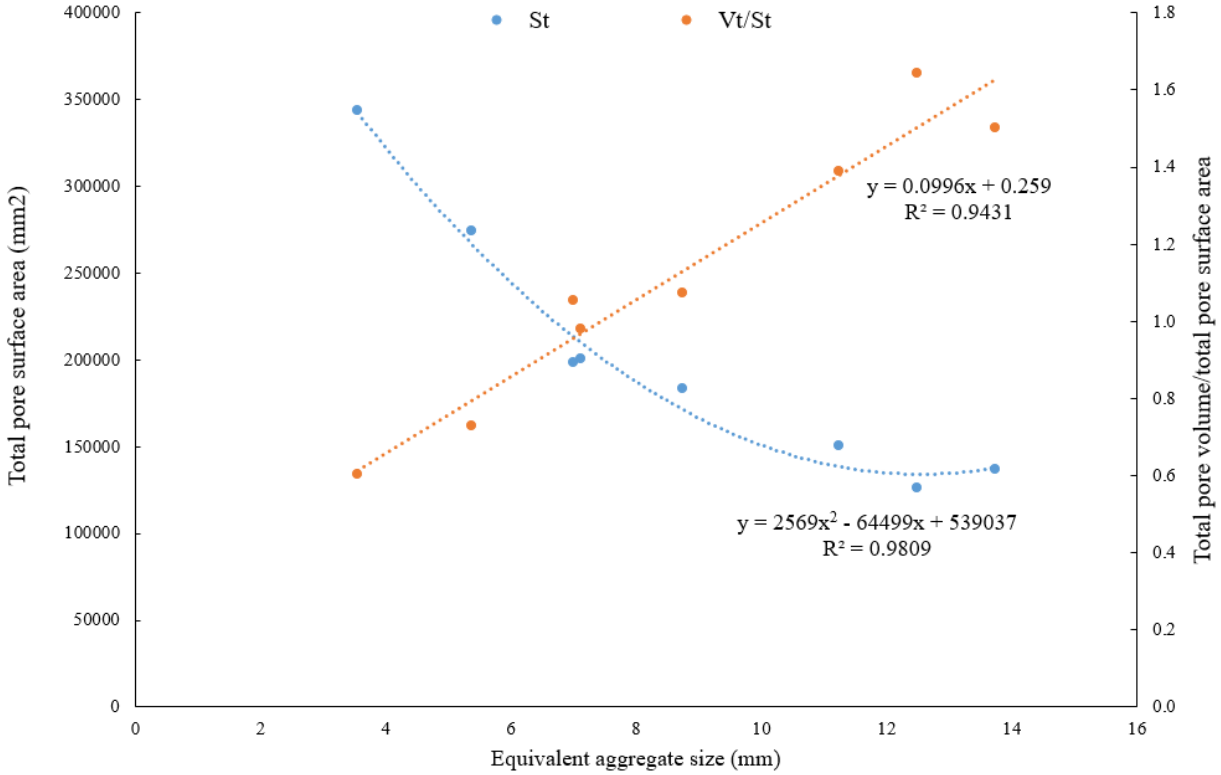
3D pores size distribution



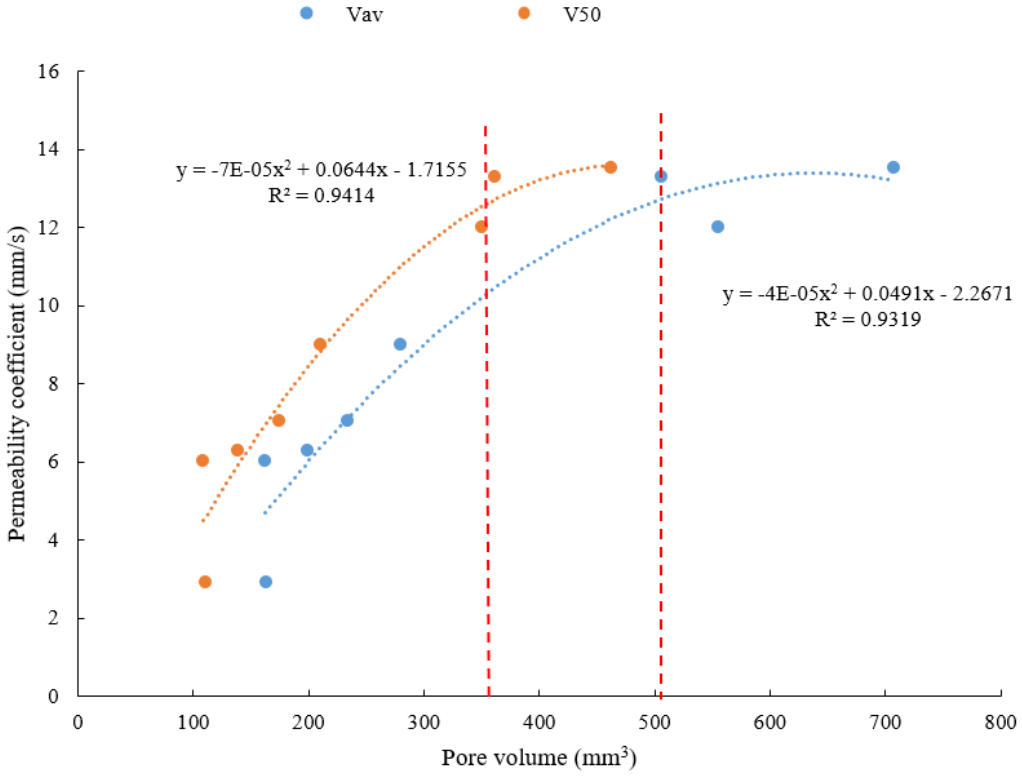
Aggregate (mm)	Number of pores	3D porosity (%)	3D connected porosity (%)	3D connected porosity / 3D porosity	V_{av} (mm^3)	V_{50} (mm^3)	S_t (mm^2)	V_t/S_t
2.36-4.75	354	20.74	20.50	0.988	163.2	110.8	343936	0.603
4.75-6	227	19.97	19.83	0.993	162.4	108.9	274533	0.728
6-8	141	20.23	20.18	0.997	234.4	174	198402	1.055
8-9.5	100	19.67	19.42	0.987	280.3	210.1	183404	1.073
4.75-9.5	142	20.90	20.61	0.986	506.2	361.2	150437	1.390
10-12.5	62	20.48	19.88	0.971	707.1	461.8	136752	1.501
12.5-15	46	20.74	20.22	0.975	555.3	350.4	126244	1.643
10-15	52	19.64	19.33	0.984	199.4	138.6	200435	0.980

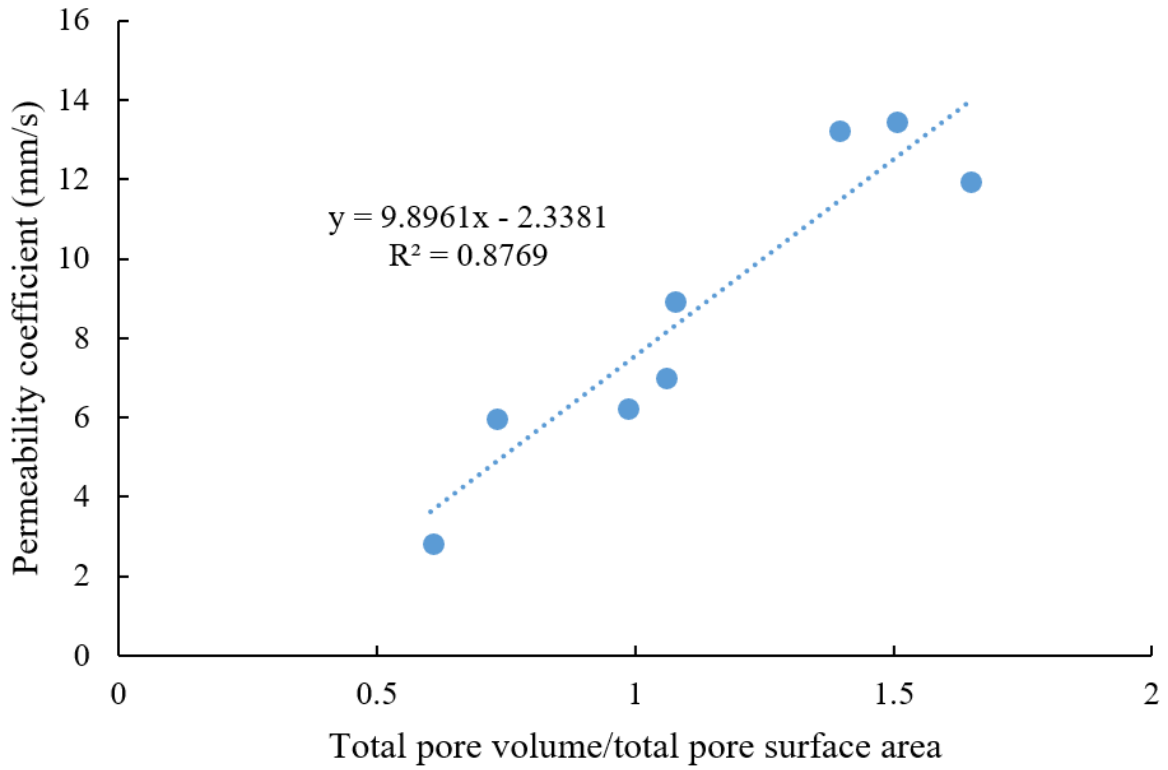
Average pore volume (V_{av}), V_{50} (defined as the pore volume corresponding to 50% of the cumulative frequency distribution.), total pore surface area (S_t), and the ratio of total pore volume to total pore surface area (V_t/S_t)





- The 3D pores size is well related to equivalent aggregate size.
- With the increase of aggregate size, V_{av}, V_{50} and the value of V_t/S_t, increase, while S_t decreases gradually.

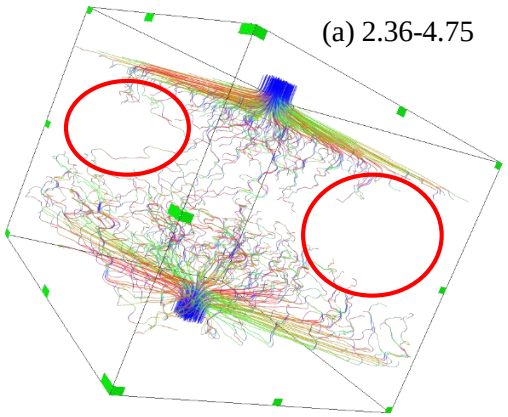


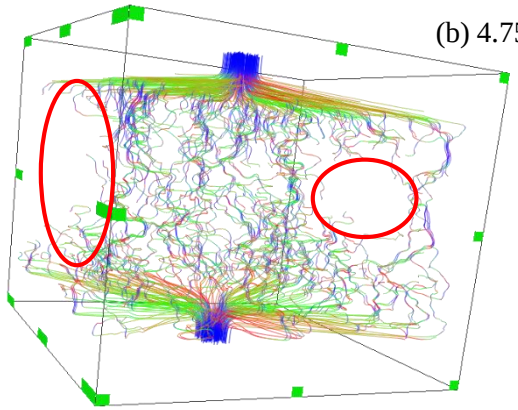


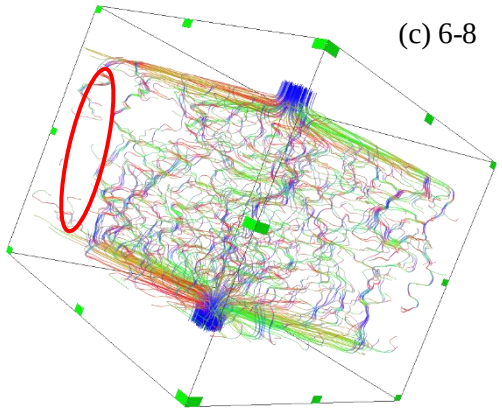
As the pore volume increases, the permeability coefficient increases rapidly at first, and then increases slowly after the pore volume is beyond 500mm^3.

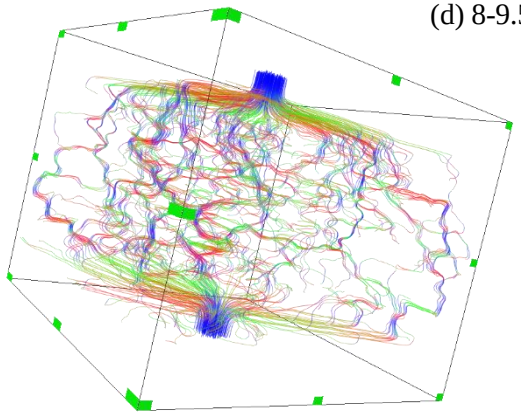
Permeability is positively correlated with the ratio of total pore volume to total pore surface area.

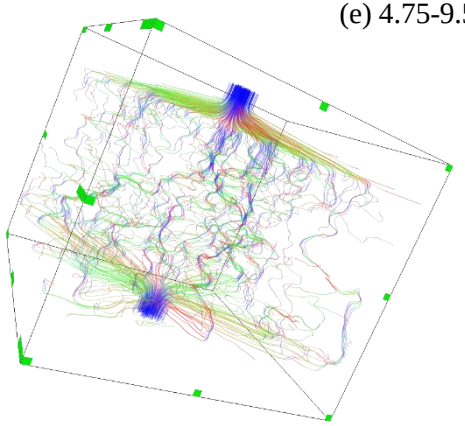
4. Absolute permeability experiment simulation


(a) 2.36-4.75


(b) 4.75-6


(c) 6-8


(d) 8-9.5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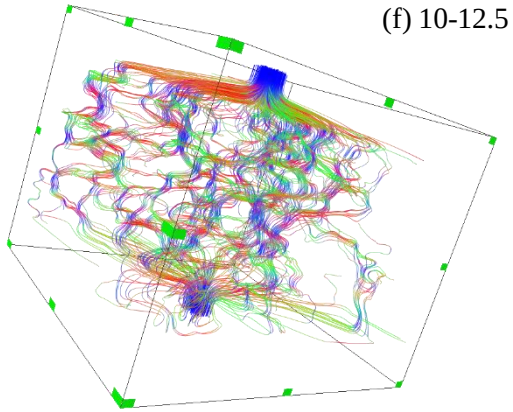
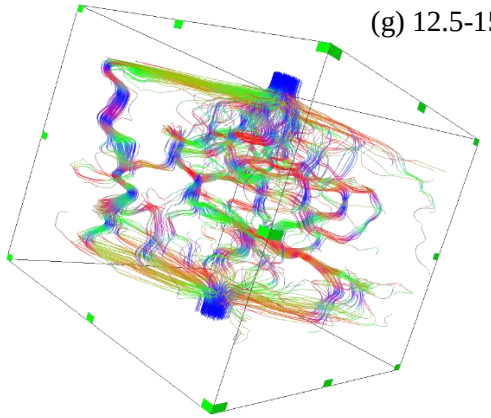
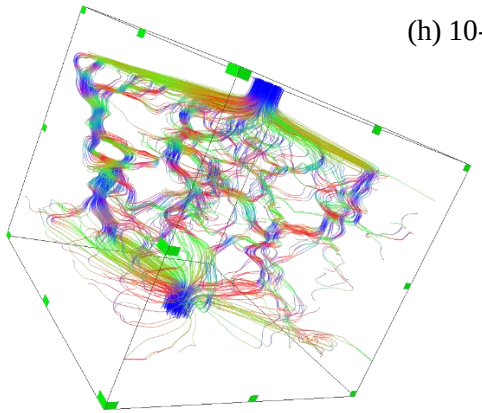

(f) 10-12.5


(g) 12.5-15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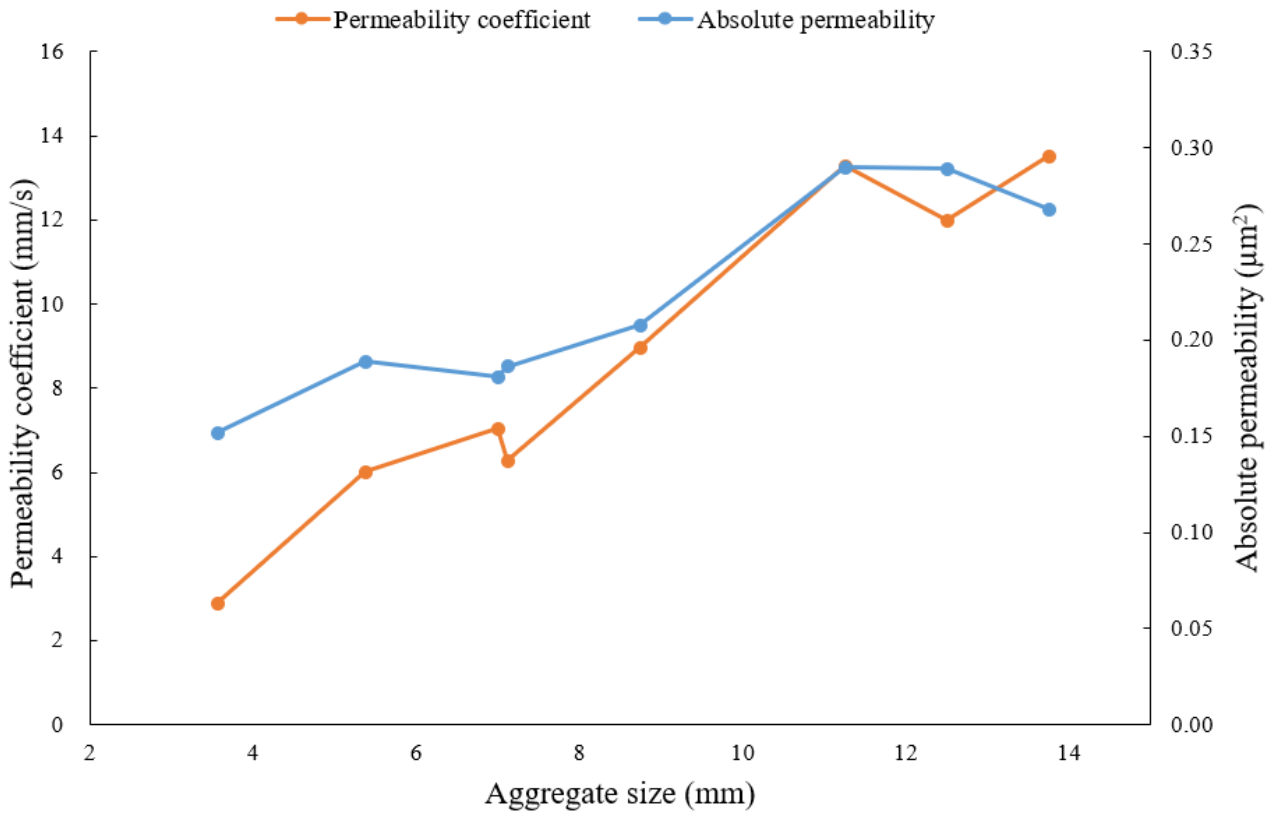

Although the absolute values of the test results and simulation results are different, their changing tend on aggregate size is quite similar. Therefore, this simulation method can be used as an effective tool to describe the permeability of pervious concrete.

5. Conclusions

- (1) No matter what size of aggregate the pervious concrete is prepared by, there will always be a considerable part of "small pores ($<2mm^2$)".

- (2) With aggregate size increases, the content of small pores decreases, the proportion of large pores increases, while the content of medium pores varies not particularly noticeable. The 2D/3D pores size is well related to equivalent aggregate size. With the increase of aggregate size, the 2D/3D pores size increases, while the total pore surface area decreases gradually.

- (3) The permeability increases with the increase of 2D/3D pores size and decreases with the increase of the total pore surface area. Average pore area or average pores size is more accurate than A_{50} in permeability prediction.

- (4) Permeability is positively correlated with the content of large pores, but negatively correlated with the content of small pores. Permeability is most sensitive to the content of small pores, followed by large pores content, and is less sensitive to the content of medium pores.

- (5) The simulation result based on Avizo indicates that with aggregate size increases, the number of seepage flow lines increases and the seepage flow paths become thicker, which promotes water permeating.

Thanks for your listening!

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