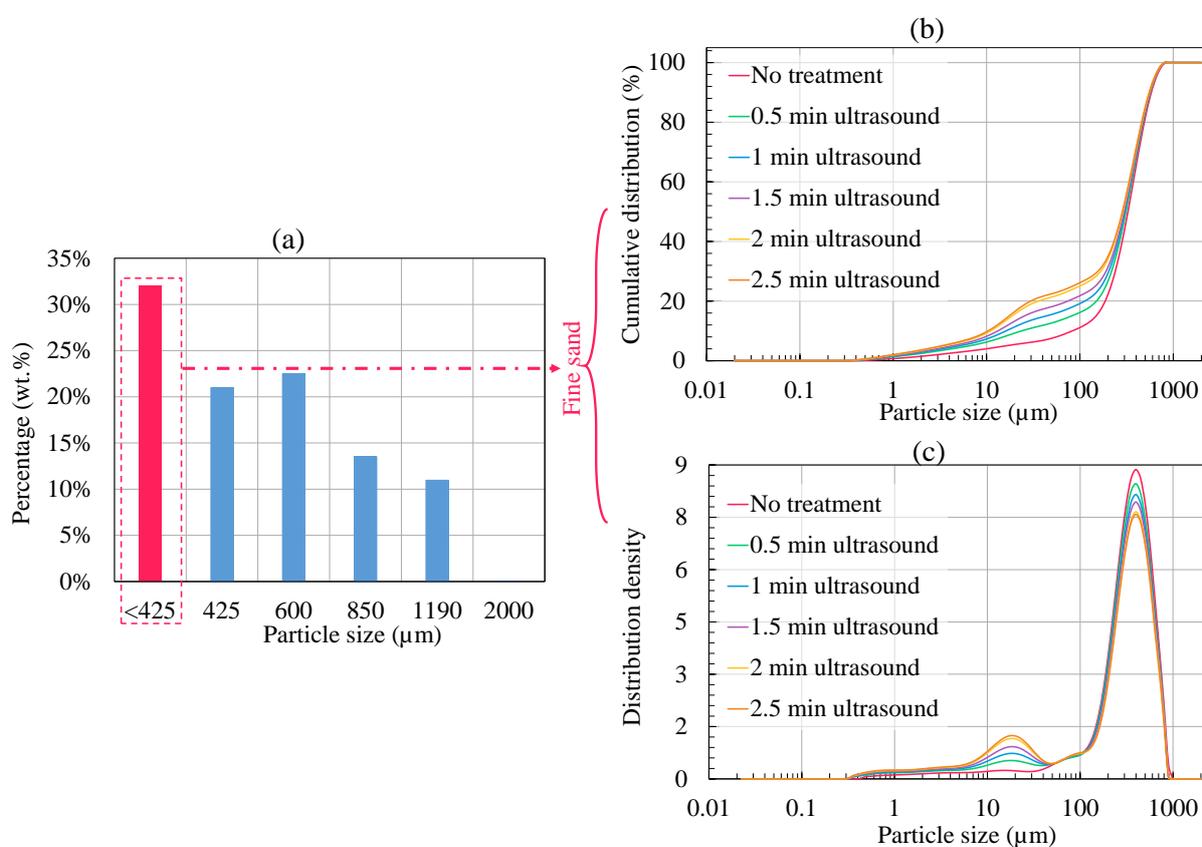


## Supplementary Materials:

### Material Characterization

First, the CS was manually sieved to determine the PSD, and the particles below 425  $\mu\text{m}$  (FS) were separated for further analysis. The particle size of the FS was analysed using a Malvern Mastersizer 2000 Laser Diffraction Particle Size Analyser. To do this, a 5% solid suspension was made by combining a representative sample of the sand with deionized water. Before drawing an aliquot for particle size analysis, the suspension was stirred for 10 minutes. To disaggregate particle clusters, treatment with ultrasonic waves (at 0 min, 0.5 min, 1 min, 1.5 min, etc.). The effect of the ultrasonic treatment time on the particle size (e.g.,  $d_{50}$ ) was investigated. Increasing the ultrasonic treatment time from 2 minutes to 2.5 minutes did not result in a notable change in the value of  $d_{50}$ . So, further ultrasonic treatment was not considered necessary. The cumulative distribution and the distribution density of the FS, along with the particle size analysis for the CS, are presented in Figure S1.



**Figure S1.** (a) Particle size analysis of the CS, (b) Cumulative distribution (%), and (c) distribution density of the FS used in the experiment.

*Sand Permeability Variability Testing*

A series of tests were conducted to identify the necessary conditions to achieve certain permeabilities with both CS and FS. All these tests were conducted with the experimental setup introduced in Figure 3. The following table contains a summary of the results.

**Table S1.** Summary results of different tests conducted to measure the sand permeability at various conditions.

Sand type	Moisture Content (Wt. %)	Bulk Density (kg/m <sup>3</sup> )	Length (m)	Flow rate (m <sup>3</sup> /s)	Permeability (m <sup>2</sup> )	Average Permeability (m <sup>2</sup> )
CS	3	1.58 × 10 <sup>3</sup>	0.151	6.7 × 10 <sup>-5</sup>	1.28 × 10 <sup>-10</sup>	1.27 × 10 <sup>-10</sup>
				1.0 × 10 <sup>-4</sup>	1.27 × 10 <sup>-10</sup>	
				1.3 × 10 <sup>-4</sup>	1.26 × 10 <sup>-10</sup>	
	3	1.51 × 10 <sup>3</sup>	0.134	3.3 × 10 <sup>-5</sup>	2.05 × 10 <sup>-10</sup>	1.99 × 10 <sup>-10</sup>
				1.0 × 10 <sup>-4</sup>	1.86 × 10 <sup>-10</sup>	
				6.7 × 10 <sup>-5</sup>	2.05 × 10 <sup>-10</sup>	
	2	1.46 × 10 <sup>3</sup>	0.127	3.3 × 10 <sup>-5</sup>	2.85 × 10 <sup>-10</sup>	2.71 × 10 <sup>-10</sup>
				1.0 × 10 <sup>-4</sup>	2.56 × 10 <sup>-10</sup>	
				6.7 × 10 <sup>-5</sup>	2.73 × 10 <sup>-10</sup>	
	2	1.52 × 10 <sup>3</sup>	0.135	3.3 × 10 <sup>-5</sup>	1.50 × 10 <sup>-10</sup>	1.43 × 10 <sup>-10</sup>
1.0 × 10 <sup>-4</sup>				1.37 × 10 <sup>-10</sup>		
6.7 × 10 <sup>-5</sup>				1.43 × 10 <sup>-10</sup>		
3	1.39 × 10 <sup>3</sup>	0.165	3.3 × 10 <sup>-5</sup>	3.40 × 10 <sup>-10</sup>	3.79 × 10 <sup>-10</sup>	
			1.0 × 10 <sup>-4</sup>	4.13 × 10 <sup>-10</sup>		
			6.7 × 10 <sup>-5</sup>	3.84 × 10 <sup>-10</sup>		
FS	5	1.70 × 10 <sup>3</sup>	0.128	3.3 × 10 <sup>-5</sup>	1.71 × 10 <sup>-11</sup>	1.71 × 10 <sup>-11</sup>
				5.0 × 10 <sup>-5</sup>	1.70 × 10 <sup>-11</sup>	
				1.7 × 10 <sup>-5</sup>	1.73 × 10 <sup>-11</sup>	
	5	1.75 × 10 <sup>3</sup>	0.119	1.7 × 10 <sup>-5</sup>	1.28 × 10 <sup>-11</sup>	1.28 × 10 <sup>-11</sup>
				2.5 × 10 <sup>-5</sup>	1.28 × 10 <sup>-11</sup>	
				1.3 × 10 <sup>-5</sup>	1.27 × 10 <sup>-11</sup>	
	5	1.73 × 10 <sup>3</sup>	0.127	8.3 × 10 <sup>-6</sup>	1.45 × 10 <sup>-11</sup>	1.44 × 10 <sup>-11</sup>
				3.3 × 10 <sup>-5</sup>	1.43 × 10 <sup>-11</sup>	
				2.5 × 10 <sup>-5</sup>	1.44 × 10 <sup>-11</sup>	
	5	1.47 × 10 <sup>3</sup>	0.132	1.7 × 10 <sup>-5</sup>	5.95 × 10 <sup>-11</sup>	5.78 × 10 <sup>-11</sup>
5.0 × 10 <sup>-5</sup>				5.66 × 10 <sup>-11</sup>		
3.3 × 10 <sup>-5</sup>				5.73 × 10 <sup>-11</sup>		
2	1.64 × 10 <sup>3</sup>	0.124	1.7 × 10 <sup>-5</sup>	1.61 × 10 <sup>-11</sup>	1.61 × 10 <sup>-11</sup>	
			5.0 × 10 <sup>-5</sup>	1.61 × 10 <sup>-11</sup>		
			3.3 × 10 <sup>-5</sup>	1.62 × 10 <sup>-11</sup>		