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Project TPF 5(341)Update: Permeability of Base Aggregate and Sand

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NRRA National Road Research Alliance
STRATEGIC IMPLEMENTATION THROUGH COOPERATIVE PAVEMENT RESEARCH

Statement of Problem

- Lack of proper pore water drainage is one of the main causes geosystem failure (e.g., roadway base course, retaining wall backfills).
- Proper drainage required to minimize elevated pore pressure, minimize freeze-thaw damage.
- A simple and reliable tool capable of estimating drainability values for common aggregate types will aid in material selection and design
  - Saturated hydraulic conductivity, K_{sat}
  - SWCC parameters
- It's not just about D10!
  - Grain size distribution, crushing percentage, fines content, angularity, material type, others.....

Project Objectives

- Assess permeability of a wide range of coarse materials from base course (2” minus) to sand size (less than 20% finer than sieve #200).
- Conduct laboratory permeability tests on aggregates of different types, gradations, angularity, fine contents, and crushing percentages.
- Develop simple predictive tool that may be used to assess permeability from gradation, crushing percentage, fines content, aggregate angularity, and material type.

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Summary of Testing Progress

Sample	Sample Number	Particle-Size Distribution Curve (PSD)	Permeability	Soil-Water Characteristic Curve (SWCC)
3149 Super Sand (MnDOT)	1	X	X	X
MN Class 5 (MnDOT)	2	X	X	X
1007 Type 5 DGB (MoDOT)	3	X	X	
1007 Type 7 DGB (MoDOT)	4	X	X	
1010 Man. Sand (MoDOT)	5	X	X	
MCC Freeborn West Quarry Crushed Stone (WisDOT)	6	X	X	
Lannon Lisbon Pit (North Ave.) Structural Backfill (WisDOT)	7	X	X	
Lannon Lisbon Pit (Mukwonago) Structural Backfill (WisDOT)	8	X	X	
Lannon Stone Product Chips (WisDOT)	9	X	X	
Super Aggregate Pit Granular Backfill (WisDOT)	10	X	X	
Beige Gravel (Large) (WisDOT)	11			
Beige Gravel (Small) (WisDOT)	12			
Gray Gravel, Rounded (WisDOT)	13			
Yellowish Brown Gravels with Fines (WisDOT)	14			
Brown Sandy Soil with Gravel (MnDOT)	15	X	X	
Brown Sandy Soil (MnDOT)	16	X	X	

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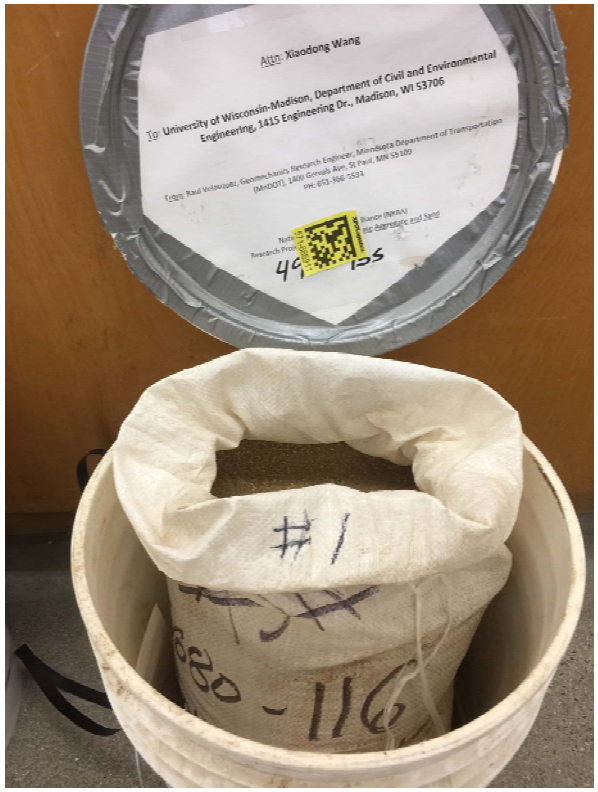
MnDOT

#1: 3149 Super Sand (MnDOT)



#2: MN Class 5 (MnDOT)

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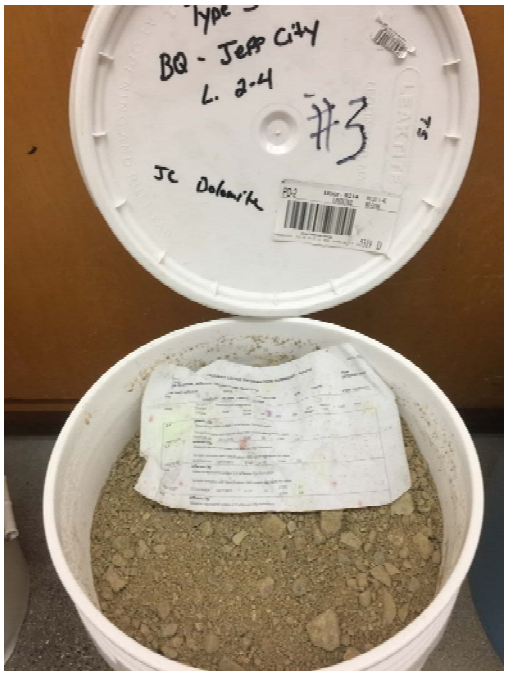
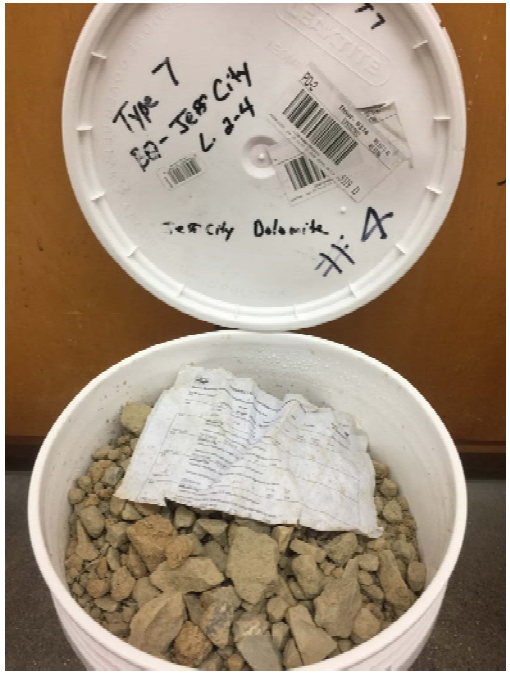
MoDOT

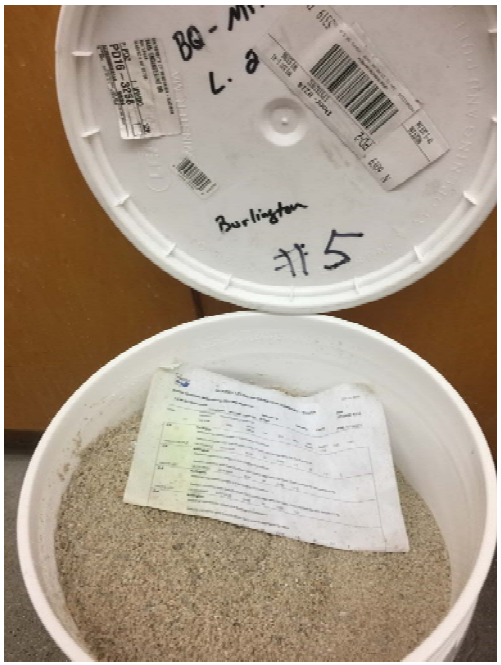
#3: 1007 Type 5 DGB (MoDOT)



#4: 1007 Type 7 DGB (MoDOT)



#5: 1010 Man. Sand (MoDOT)

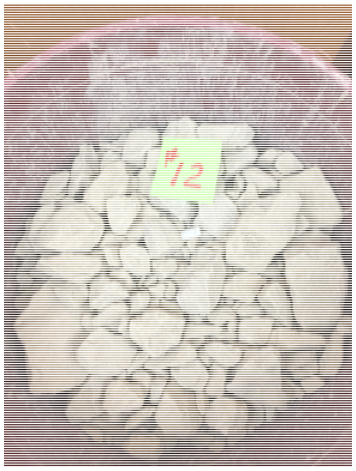


WisDOT

Spec 209	Granular Backfill	Horsfall	Grade 1 and Grade 2
Spec 305	Dense Graded Base	Horsfall	3", 1 1/4" and 3/4"
	MSE Wall Backfill	Horsfall	current WHRP project 0092-18-07
	Limestone Chips	Horsfall	Substitiute for structural backfill

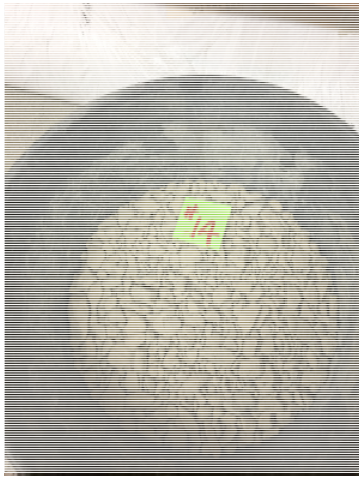
#11: Beige Gravel (Large) (WisDOT)

#12: Beige Gravel (Small) (WisDOT)



#13: Gray Gravel, Rounded (WisDOT)

#14: Yellowish Brown Gravels with Fines (WisDOT)

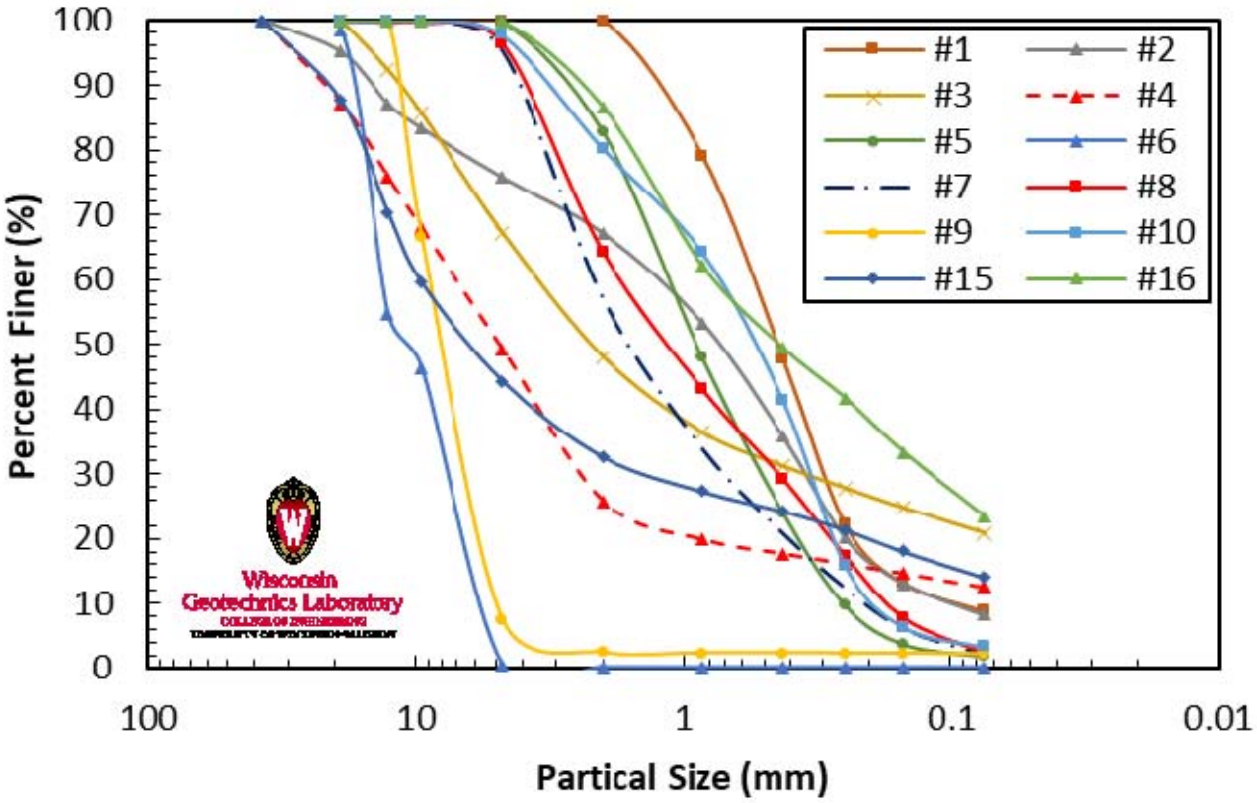


MnDOT

#15: Brown Sandy Soil with Gravel (MnDOT)

#16: Brown Sandy Soil (MnDOT)

Particle Size Distribution Curves



Sample #	Sample
1	3149 Super Sand (MnDOT)
2	MN Class 5 (MnDOT)
3	1007 Type 5 DGB (MoDOT)
4	1007 Type 7 DGB (MoDOT)
5	1010 Man. Sand (MoDOT)
6	MCC Freeborn West Quarry Crushed Stone
7	Lannon Lisbon Pit (N. Ave.) Backfill
8	Lannon Lisbon Pit (Mukwonago) Backfill
9	Lannon Stone Product Chips
10	Super Aggregate Pit Granular Backfill
11	Beige Gravel (Large)
12	Beige Gravel (Small)
13	Gray Gravel, Rounded
14	Yellowish Brown Gravels with Fines
15	Brown Sandy Soil with Gravels
16	Brown Sandy Soil

- Sieve tests for 12 soils were completed.
- Hydrometer tests are needed for fines of four soils among the 12 soils (#3, #4, #15, #16).

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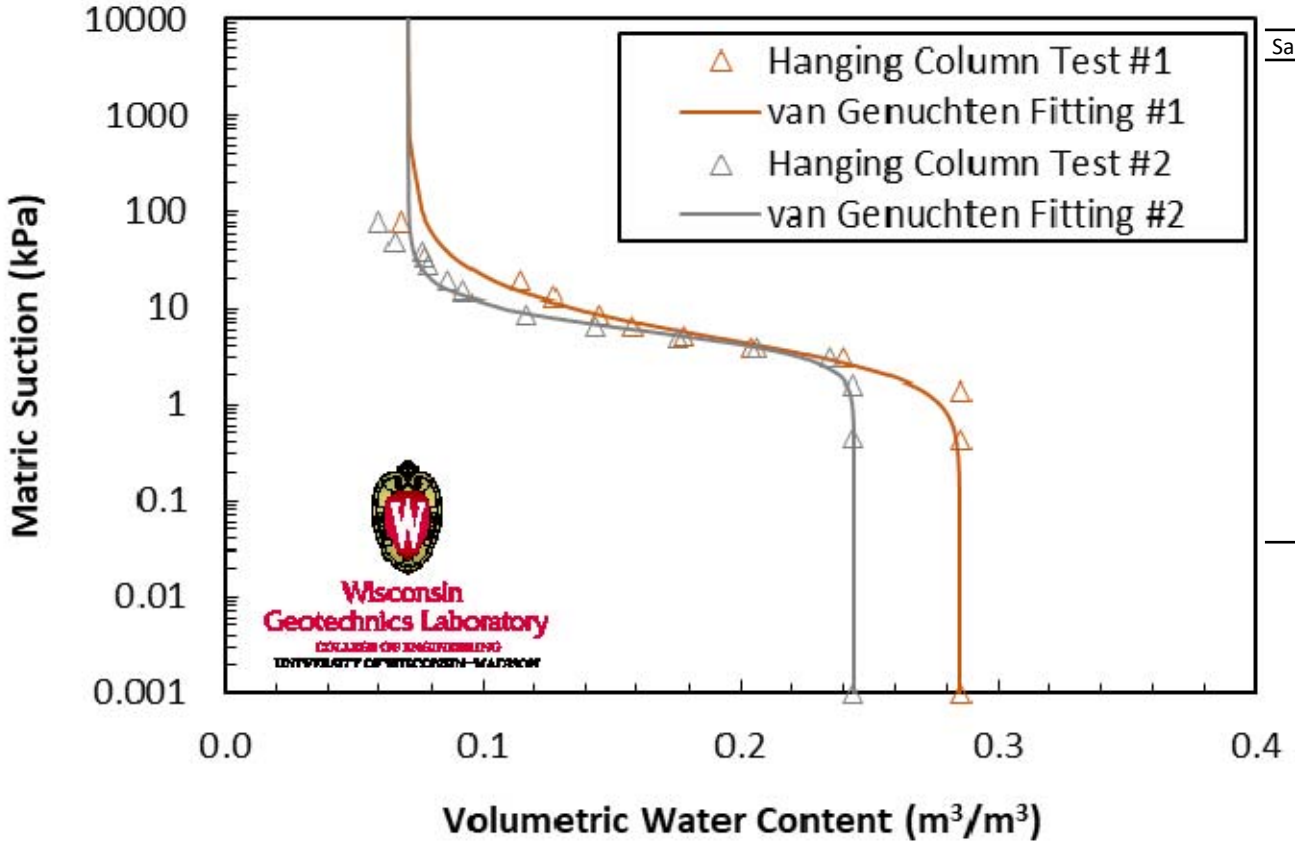
Particle Size Parameters

Specimen	Particle Size Parameters						USCS
	D_{10} (mm)	D_{30} (mm)	D_{50} (mm)	D_{60} (mm)	C_u	C_c	
#1	0.093	0.3	0.46	0.55	5.91	1.76	SP-SM
#2	0.102	0.36	0.72	1.38	13.53	0.92	SP-SM
#3	-	0.36	2.28	3.65			
#4	-	2.5	4.9	7.09			
#5	0.265	0.518	0.9	1.26	4.75	0.80	SP
#6	5.85	7.7	10.9	14	2.39	0.72	GP
#7	0.218	0.715	1.7	2.2	10.09	1.07	SW
#8	0.18	0.45	1.3	1.82	10.11	0.62	SP
#9	5	6.6	8.05	8.95	1.79	0.97	GP
#10	0.2	0.33	0.53	0.72	3.60	0.76	SP
#15	-	1.58	6.35	9.5			
#16	-	0.13	0.44	0.788			

Note: D_{10}, D_{30}, D_{50}, D_{60} = particle sizes corresponding to 10%, 30%, 50%, 60% finer, respectively, in PSD; C_u = coefficient of uniformity; C_c = coefficient of curvature; USCS = unified soil classification system

Soil-Water Characteristic Curves



Sample #	Sample
1	3149 Super Sand (MnDOT)
2	MN Class 5 (MnDOT)

- Hanging column tests (ASTM D6836) for two soils were completed (#1, #2).

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Hydraulic Conductivity

Hydraulic Gradent	Hydraulic Conductivity (cm/sec)											
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#15	#16
0.25	0.00203	0.00299	0.007468	0.195988	0.049869	1.207203	0.020621	0.004739	1.049892	0.01078	0.014664	0.000394
0.50	0.00228	0.00264	0.00751	0.185112	0.047947	0.826853	0.022571	0.004766	0.727531	0.01052	0.017281	0.000436
1.00	0.00216	0.00257	0.007327	0.160374	0.048299	0.592718	0.024441	0.004977	0.505423	0.010461	0.016472	0.000437
1.50	0.00217	0.00260	0.007299	0.155355	0.048996	0.464726	0.025294	0.0052	0.426079	0.01025	0.015782	0.000462
2.00	0.00195	0.00262	0.006765	0.149759	0.049529	0.386866	0.025182	0.00522	0.388865	0.010095	0.015397	0.000449
Dry Unit Weight (kN/m^3)	18.57	19.63	17.76	17.80	15.91	16.22	18.65	20.10	16.57	18.26	18.66	17.69

- Hydraulic conductivity tests for 12 soils were completed.
- Hydraulic conductivity values for each soil were similar under five hydraulic gradients.

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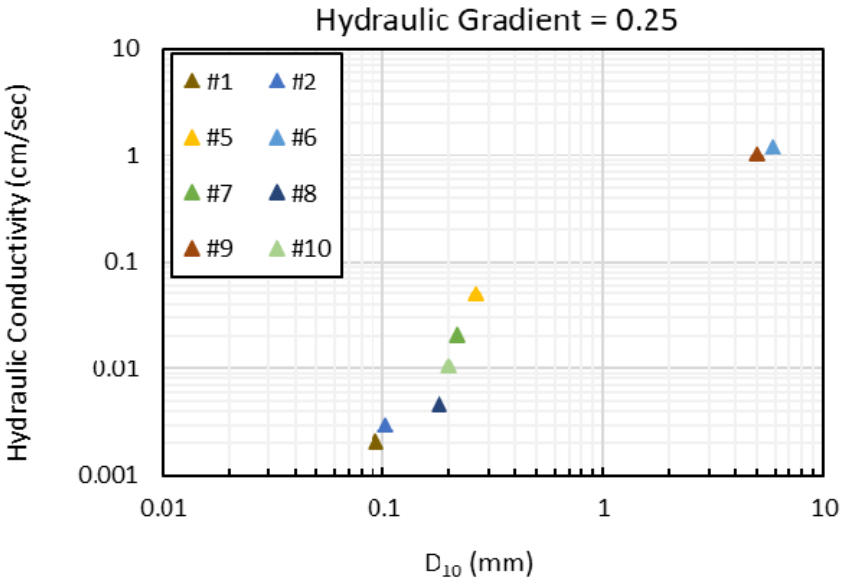
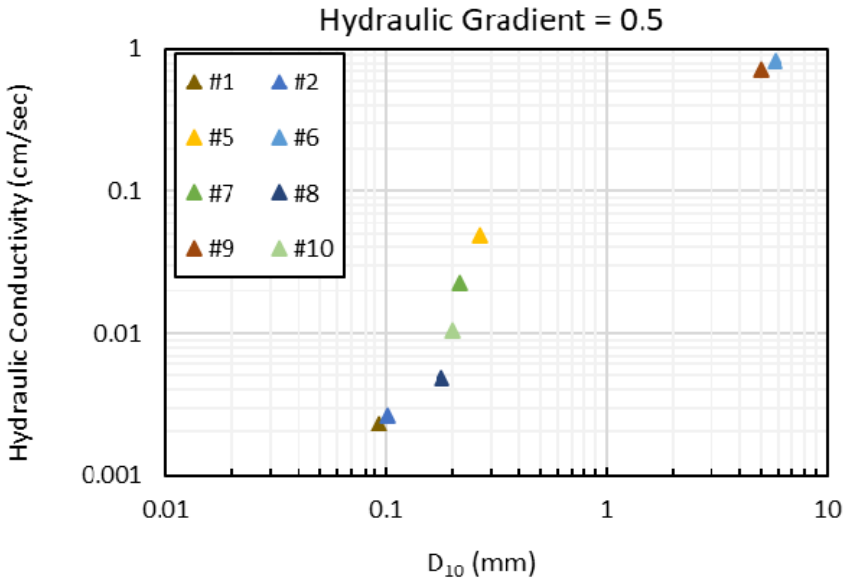
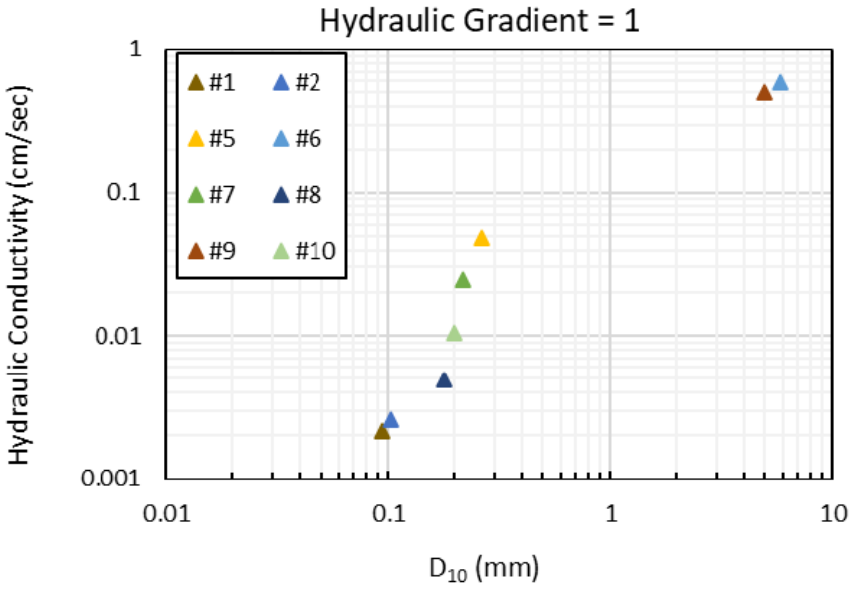
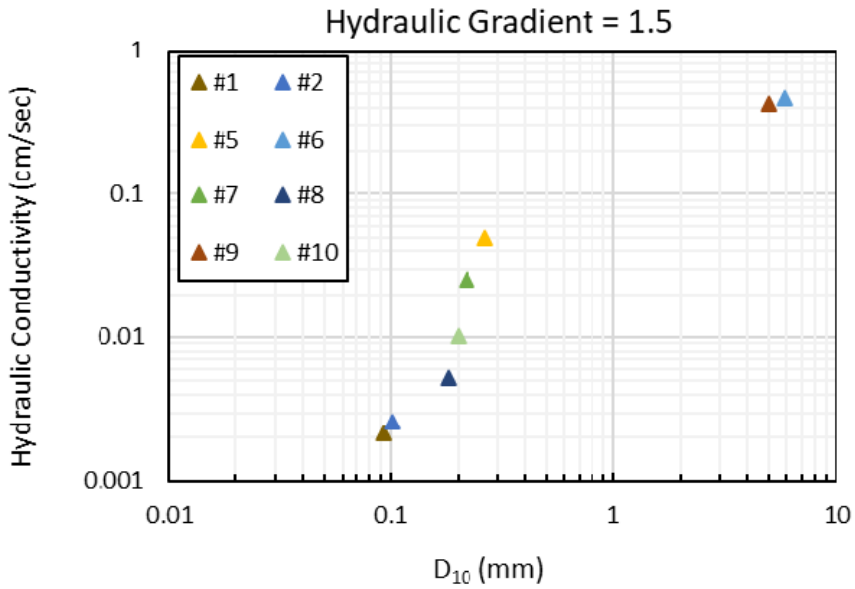
Hydraulic Conductivity vs. Particle Size Corresponding to 10% Finer in PSD (D_{10})





Hydraulic Conductivity vs. Particle Size Corresponding to 10% Finer in PSD (D_{10})





Hydraulic Conductivity vs. Particle Size Corresponding to 10% Finer in PSD (D_{10})