College of Engineering
UNIVERSITY OF WISCONSIN-MADISON

Permeability of Base Aggregate and Sand [TPF-5(341)]

Kickoff Meeting

February 19, 2020

DEPARTMENT OF TRANSPORTATION

Research Team

- Bill Likos (PI) – University of Wisconsin-Madison
- Tuncer Edil (Co-I) – University of Wisconsin-Madison
- Jie Yin – Visiting Scholar (Jiangsu University)
- Tyler Klink - Graduate Research Assistant
- Lamin Moore – Undergraduate Research Assistant

- Benjamin Worel – MnDOT Technical Liaison

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.

Project Approach

- Task 1 - Memorandum on Expected Research Benefits and Potential Implementation Steps
- Task 2 – Literature Review
  - Tremendous amount of information on empirical relations for permeability and water retention characteristics of coarse materials
- Task 3 – Laboratory Tests and Data Analysis
  - Sources: (i) literature, (ii) UW Archives, (iii) New tests
  - Index testing (GSD, crushing, fines content, compaction, angularity
  - Rigid/Flex wall permeability testing
  - SWCC testing
  - Statistical analysis to develop empirical relations

Preliminary Literature Review

Agus, S. S., Leong, E.-C., & Rahardjo, H. (2005). Estimating permeability functions of Singapore residual soils. Engineering Geology, 78(1-2), 119–133. doi:10.1016/j.enggeo.2004.12.001

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Hong-yuan, F. U., Sheng-jun, W. U., & Gui-yao, W. A. N. G. (2009). Experimental study of influence of compressive stress on water permeability of sands soils. Rock and Soil Mechanics, 30(12), 3677-3681.(in chinese)

Mokwa, R. L., & Trimble, N. R. (2008). Permeability of Coarse-Grain Soil from Void Space and Pore Distribution. GeoCongress 2008. doi:10.1061/40972(311)54

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Onur, E. M., & Shakoor, A. (2014). Relationships Between Grain Size Distribution Indexes and Permeability of Sands. Engineering Geology for Society and Territory - Volume 3, 287–290. doi:10.1007/978-3-319-09054-2_59

Rosas, J., Lopez, O., Missimer, T. M., Coulibaly, K. M., Dehwah, A. H. A., Sesler, K., Mantilla, D. (2014). "Determination of Hydraulic Conductivity from Grain-Size Distribution for Different Depositional Environments,." Groundwater, 52(6), 824–825. doi:10.1111/gwat.12279

Su, L. J., Zhang, Y. J., & Wang, T. X. (2014). Investigation on permeability of sands with different particle sizes. Yantu Lixue/Rock and Soil Mechanics, 35(5), 1289-1294.(in chinese)

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Zhai, Q., & Rahardjo, H. (2015). Estimation of permeability function from the soil–water characteristic curve. Engineering Geology, 199, 148–156. doi:10.1016/j.enggeo.2015.11.001

Zhang, G. L., & Wang, Y. J. (2014). Experimental investigation of hydraulic conductivity of sand under high confining pressure. Rock and Soil Mechanics, 35(10), 2748-2754. (in chinese)

Method	Equation	Variable and Unit Definition	β	Use
Alyamani and Sen (1993)	$K\left[\frac{m}{d}\right] = \beta[I_0 + 0.025(d_{50-}d_{10})]^2$	I_0 is the intercept in mm of the line formed by d_{50} [mm] and d_{10} [mm] with the grain-size axis	1300	Well-distributed sample
Barr (2000)	$K\left[\frac{m}{s}\right] = \beta\frac{\rho g}{\mu}nm^2$ $m = \frac{n}{s}$ $S = C_s S_0(1-n)$ $S_0 = \sum_i S_{oi}$ $S_{oi} = \frac{3}{r_i}wf_i$	m is the hydraulic radius S is the surface area C_s is a surface area adjusting parameter S_{oi} is the surface area per unit mass of solid material r is the radius of the sphere representing the grain (sieve size),in meters wf_i is the weight fraction retained in sieve i	1/5	1<Cs<1.35
Beyer (1964)	$K\left[\frac{m}{s}\right] = \beta\frac{g}{v}\log\frac{500}{C}d_{10}^2$ $C = \frac{d_{60}}{d_{10}}$	C is the coefficient of uniformity	6×10–4	$0.64\ mm < d_{10} < 0.6\ mm$ $1 < C < 20$
Chapuis et al. (2005)	$K\left[\frac{cm}{s}\right] = \beta\left(\frac{d_{10}^2 e^3}{1+e}\right)^{0.7825}$ $e = \frac{n}{1-n}$	e is the void ratio d_{10} is in mm	2.4622	$0.03\ mm < d_{10} < 3\ mm$ $0.3 < e < 0.7$
Fair and Hatch (1933)	$K\left[\frac{m}{s}\right] = \beta\frac{\rho g}{\mu}\frac{n^3}{(1-n)^2}\frac{1}{m\left(\frac{\theta}{100}\sum_i\frac{P_i}{d_{mi}}\right)}$ $P_i = 100 \cdot wf_i$ $d_{mi} = \sqrt{d_{s_i} \cdot d_{s_{i+1}}}$	m is a packing factor θ is a sand shape factor P is the percentage of sand held between adjacent sieves d_m is the geometric mean d_{s_i} is the size of the i sieve	1	$m = 5$ $6 < \theta < 7.7$, spherical to angular respectively

Schedule

FY20 (7/1/ 19– 6/30/20)													
Month of Contract													**Budget**
Calendar Month	J	A	S	O	N	D	J	F	M	A	M	J	
Task #1			X	X	X	R	R						$1,000
Task #2			X	X	X	R	R						$1,000
Task #3				X	X	X	X	X	X	R	R		$22,000
Task #4											X	X	
Task #5													
												FY20 Total:	$24,000

"R" in the schedule indicates the review/revision period

FY21 (7/1/ 20– 6/30/21)													
Month of Contract													**Budget**
Calendar Month	J	A	S	O	N	D	J	F	M	A	M	J	
Task #1													
Task #2													
Task #3													
Task #4	R	R											$4,500
Task #5	R	R											$1,500
												FY 21 Total	$6,000
												Project Total:	$30,000

- All start and end dates pushed back 6 months
- Project start = March 31, 2020
- Project end = Feb 28, 2021

Items for Discussion

- Alignment with NRRA Members goals
- Materials for permeability testing
  - Need robust dataset for statistical analysis
  - Sources: (i) literature, (ii) UW Archives, (iii) New tests
- UW-Madison staffing issues