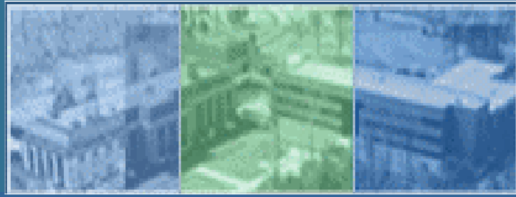


Scour in Cohesive Soils

presented

by

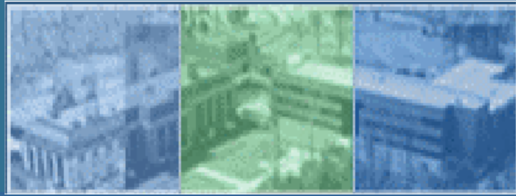
Haoyin Shan and Kornel Kerenyi

at the

National Hydraulics Engineering Conference

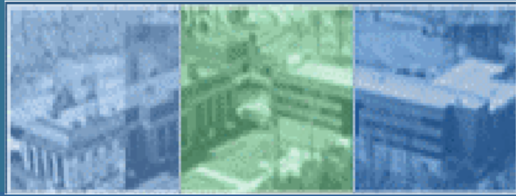
Thursday, August 21st, 2014

Iowa City, IA

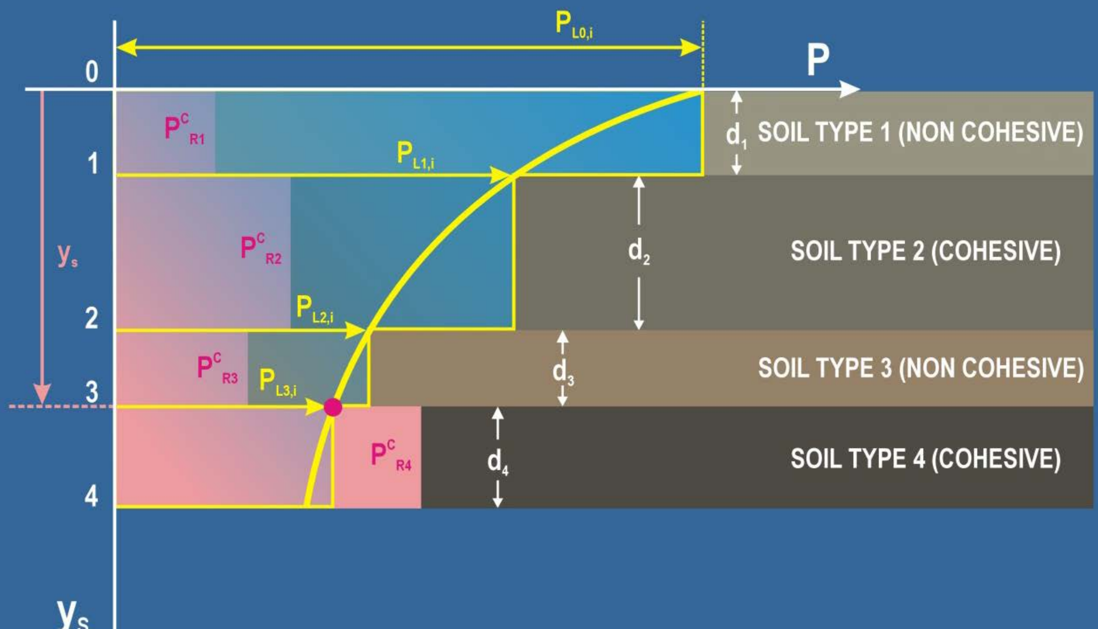


Outline

- Background
- Ex Situ Scour Testing Device
- Flow Condition: Log-law Velocity Profile
- Soil Preparation & Geotechnical Tests
- Erosion Results
- Conclusions



Hydraulic Loading Decay Function and Critical Soil Resistance



$\rightarrow P_{L0,i} >< P^C_{R1,i}$

$\rightarrow P_{L1,i} >< P^C_{R2,i}$

$\rightarrow P_{L2,i} >< P^C_{R3,i}$

$\rightarrow P_{L3,i} >< P^C_{R4,i}$

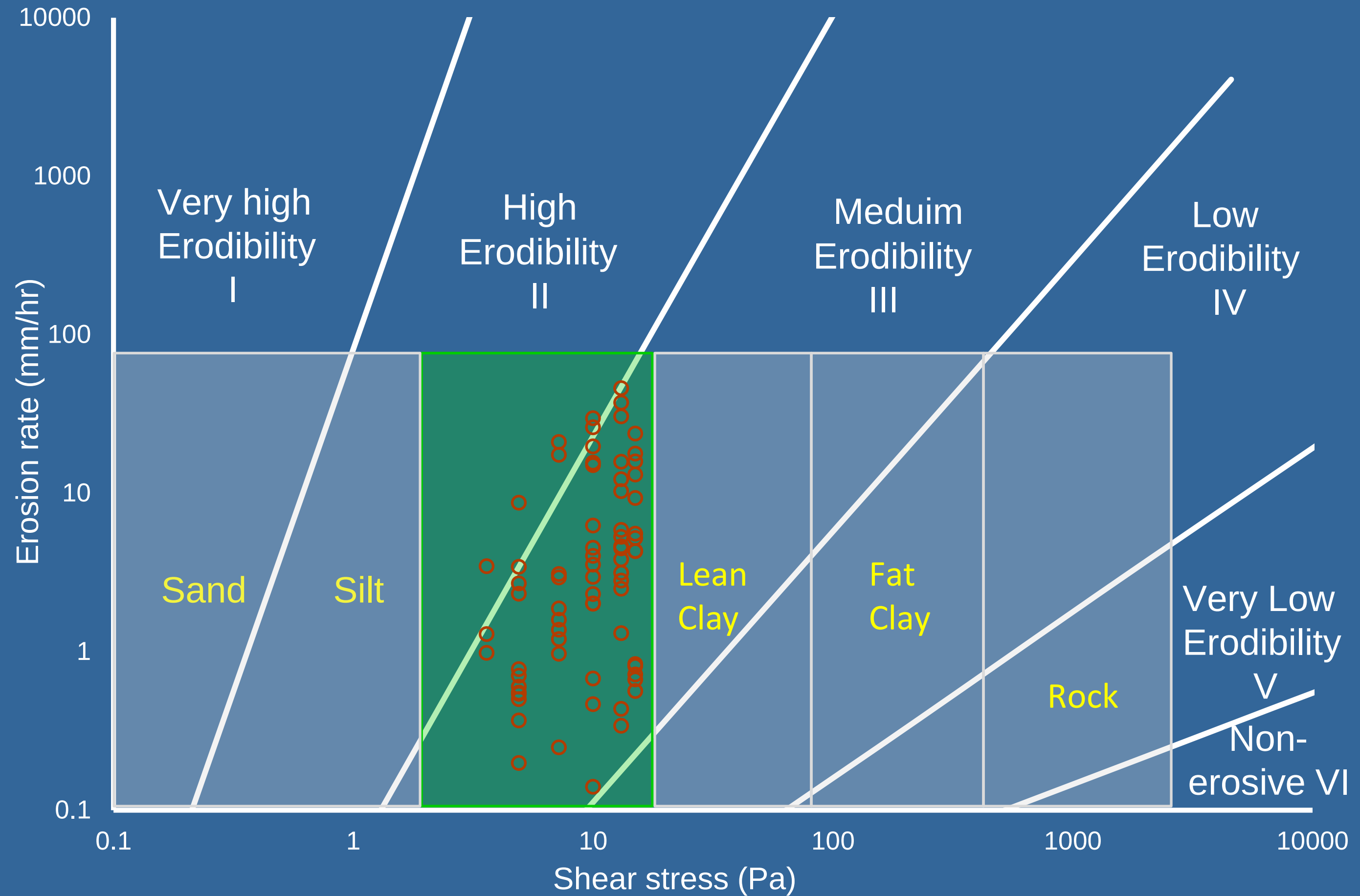
$P_{L,i}$ = HYDRAULIC LOAD BASED ON Q_{100}

$P^C_{R,i}$ = CRITICAL SOIL RESISTANCE

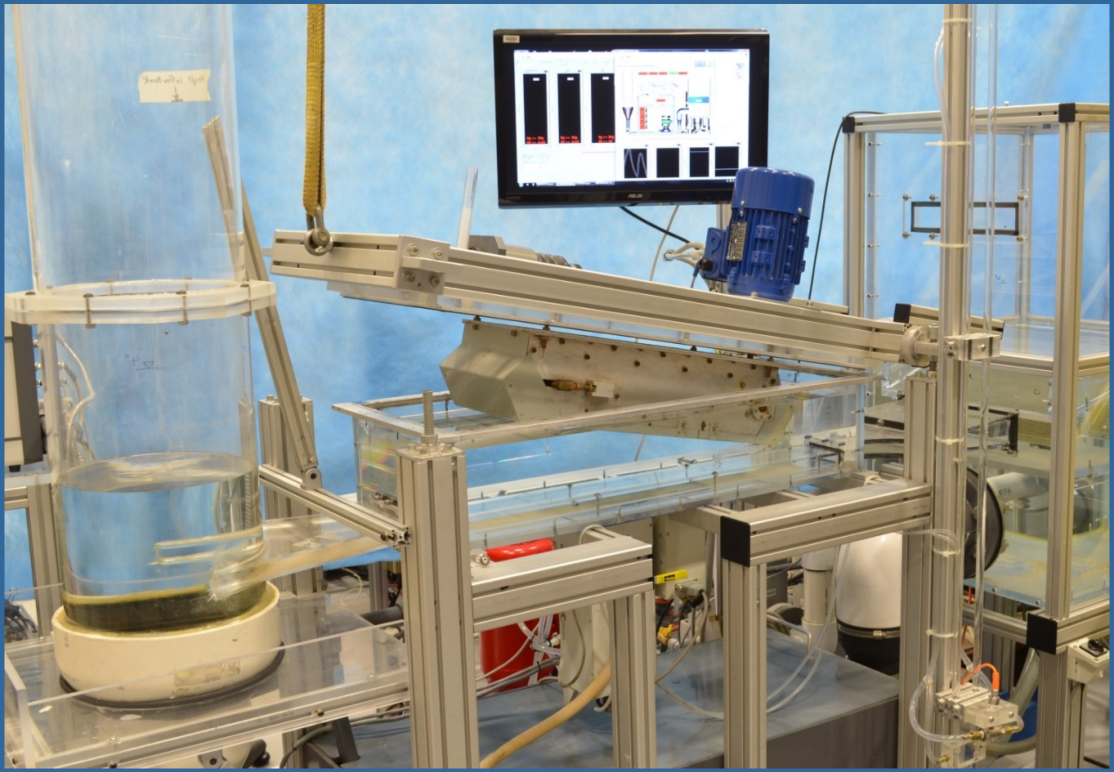
y_S = SCOUR DEPTH

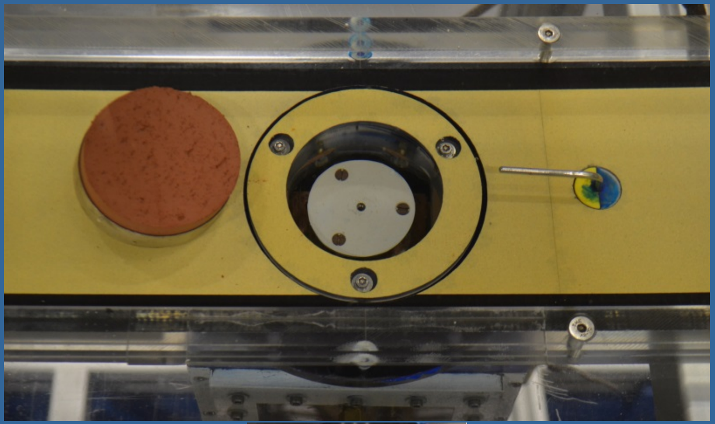
$$y_{S\,MAX} \rightarrow P_{Lj,i} < P^C_{Rj+1,i}$$

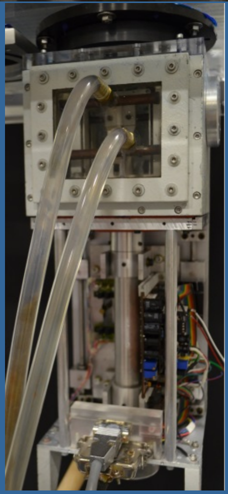
Background


10000
1000
100
10
1
0.1
Erosion rate (mm/hr)
0.1
1
10
100
1000
10000
Shear stress (Pa)
Very high Erodibility I
High Erodibility II
Meduim Erodibility III
Low Erodibility IV
Very Low Erodibility V
Non-erosive VI
Sand
Silt
Lean Clay
Fat Clay
Rock

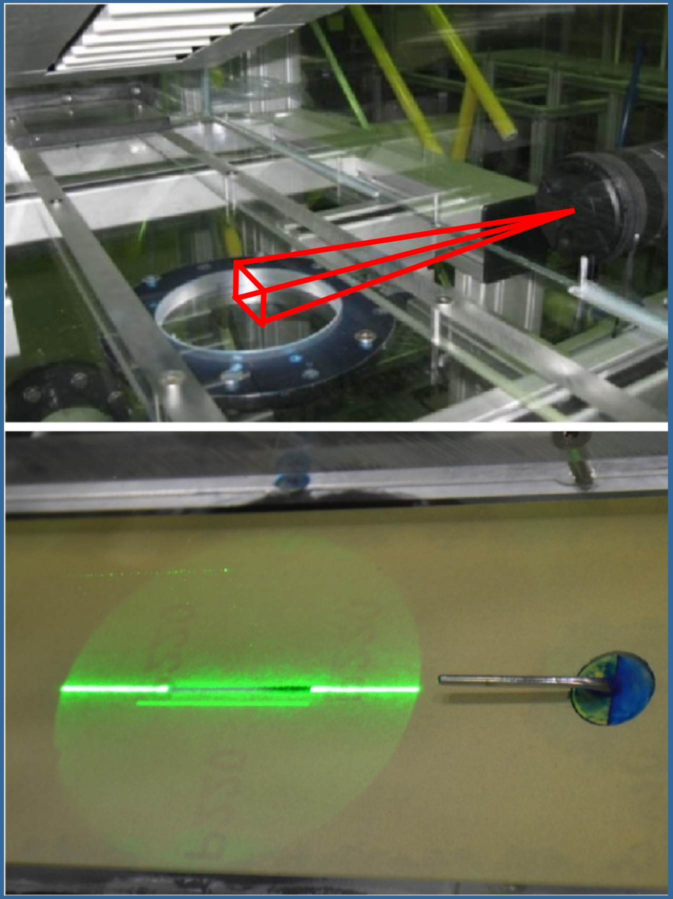
Ex situ Scour Testing Device

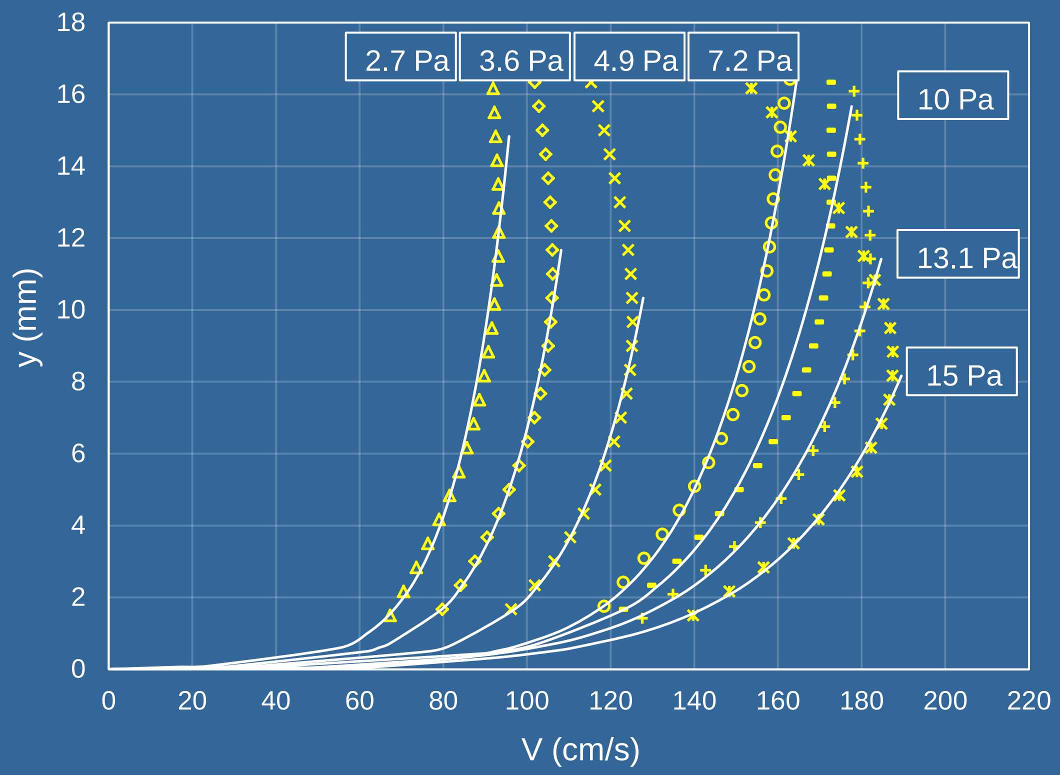




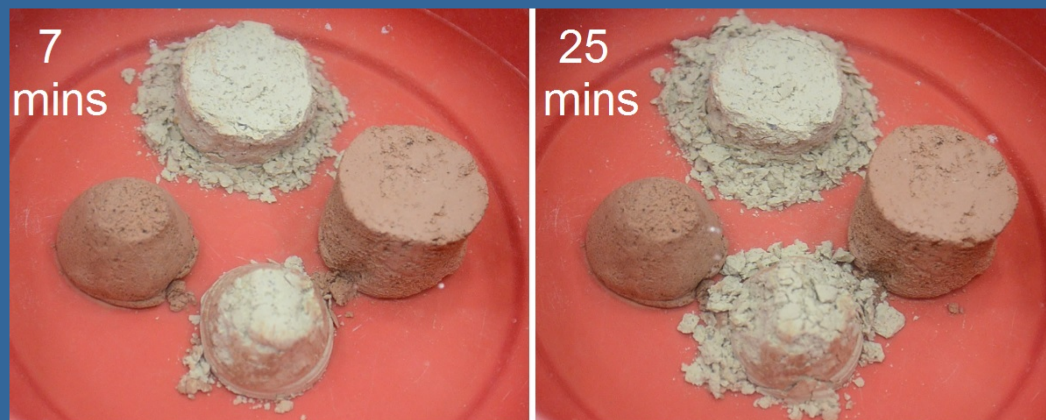


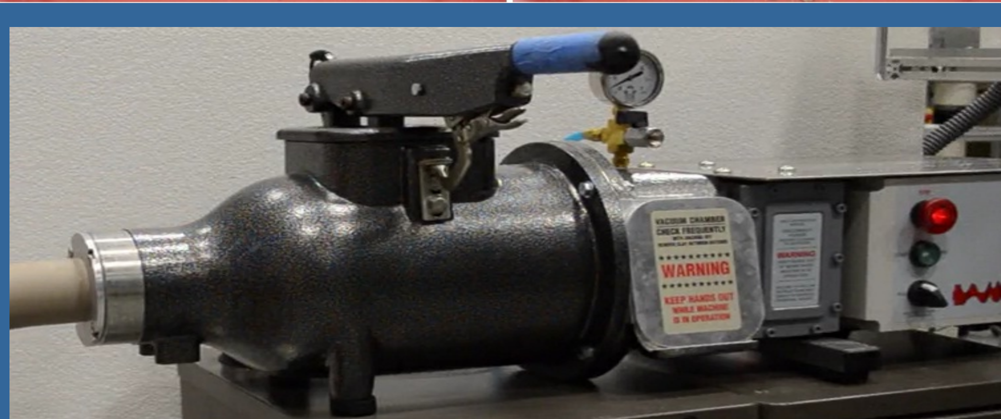
Flow Condition: Log-law Velocity Profile





Pugger Mixer: Preparing Slaking-free Soils



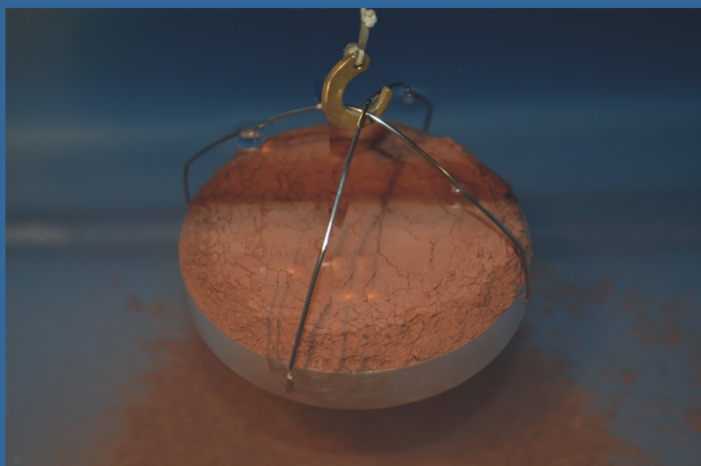


Tested Soil Characteristics

Index	Soil type	Materials (%)			SG	PL	LL	PI	F(<75 μm)	# of WC
		Clay	Silt	Sands		%	%	%	%	
1	CL-ML: sandy silty clay	20	40	40	2.69	16.7	21.0	4.3	60.6	3
2	CL: sandy lean clay	30	20	50	2.71	14.3	21.3	7.0	50.7	3
3	CL: sandy lean clay	40	10	50	2.73	14.4	21.1	6.7	50.7	2
4	CL-ML: Silty clay with sand	25	45	30	2.72	17.4	22.5	5.1	70.4	3
5	CL: Lean clay with sand	40	40	20	2.69	17.7	26.4	8.7	80.3	3
6	CL: Lean clay with sand	40	30	30	2.71	16.6	25.5	8.9	70.4	3

Geotechnical Tests

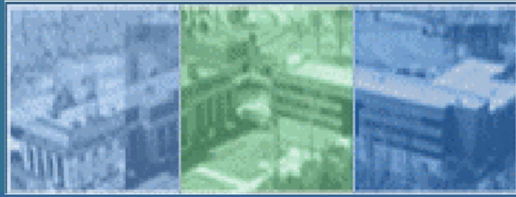
1. Slaking test



2. Unconfined compression test (q_u) / Field vane tester

www.humboldtmfg.com

3. WC, SG and bulk density
4. Particle size distribution
5. Atterberg limits
6. Direct shear



Soil Erosion Video

Soil 4$_{WC=19.8\%}$

CL-ML: silty clay

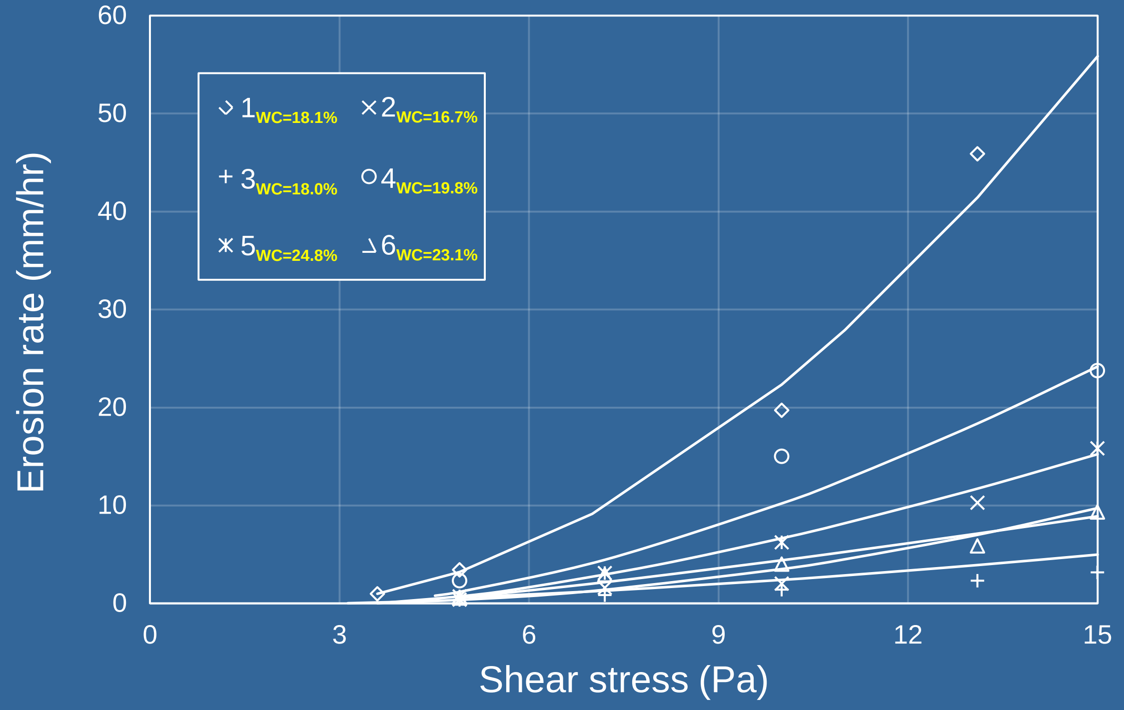
25% clay + 45% silt + 30% sands

PI=5%, q_u=1242 lbf (59 KPa)

Erosion Curve of Tested Soils

Index	Soil type	Materials (%)			SG	PL	LL	PI	>75 µm	WC (%)
		Clay	Silt	Sands		%	%	%	%	
1	CL-ML-sandy silty clay	20	40	40	2.69	16.7	21.0	4.3	39.4	3: 15.6, 16.5, **18.1**
2	CL-sandy lean clay	30	20	50	2.71	14.3	21.3	7.0	49.3	3: 14.7, **16.7**, 17.7
3	CL-sandy lean clay	40	10	50	2.73	14.4	21.1	6.7	49.3	2: 16.0, **18.0**
4	CL-ML-Silty clay with sand	25	45	30	2.72	17.4	22.5	5.1	29.6	3: 18.9, **19.8**, 21.7
5	CL-Lean clay with sand	40	40	20	2.69	17.7	26.4	8.7	19.7	3: 21.5, 23.1, **24.8**
6	CL-Lean clay with sand	40	30	30	2.71	16.6	25.5	8.9	29.6	3: 19.2, 20.0, **23.1**

Erosion Curve of Tested Soils



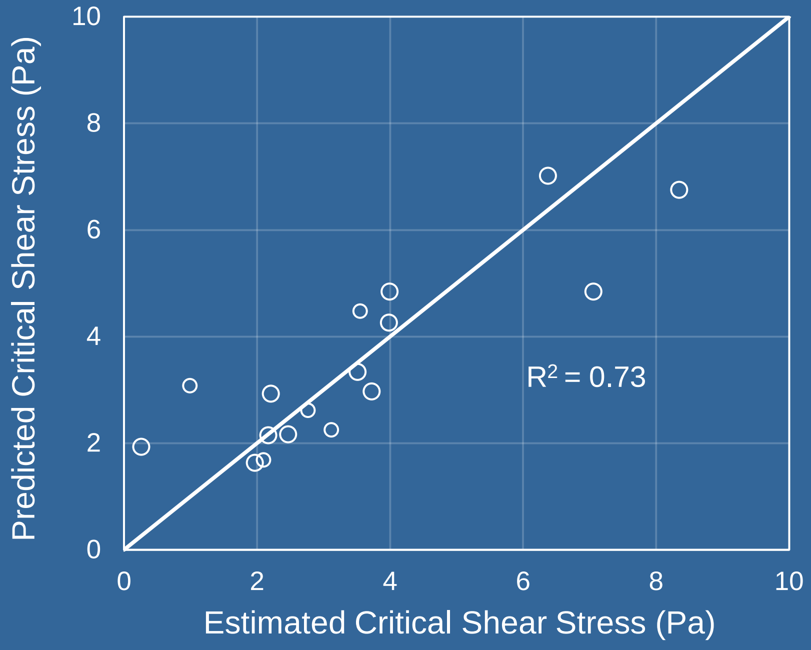
Estimated critical shear stress deduced by fitting data:

$$\dot{z} = C_1(\tau - \tau_c)^{C_2}$$

Proposed Models for Critical Shear Stress

$$\tau_c = \alpha_1 \left(\frac{W}{F}\right)^{-2.0} PI^{1.3} q_u^{0.4}$$

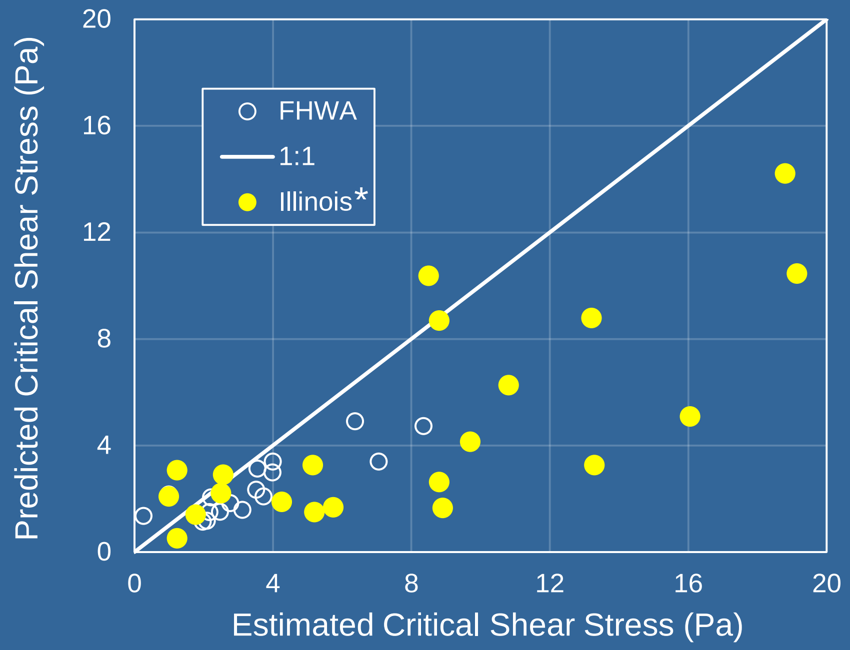
For best fit, $\alpha_1 = 0.1$



Proposed Models for Critical Shear Stress

$$\tau_c = \alpha_1 \left(\frac{W}{F}\right)^{-2.0} PI^{1.3} q_u^{0.4}$$

For design, $\alpha_1 = 0.07$



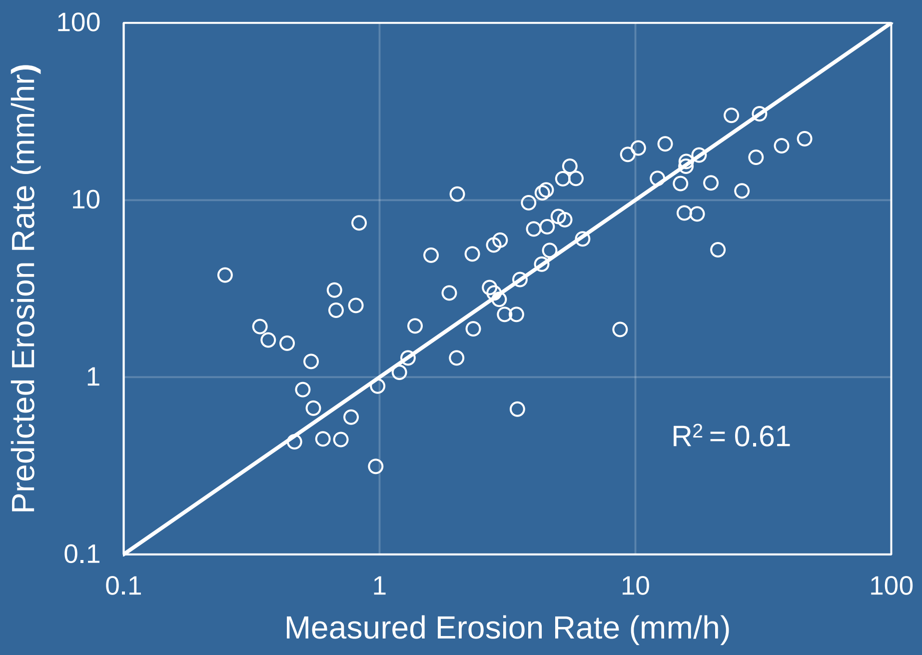
* Straub, T., and Over, T. (2010). Pier and Contraction Scour Prediction in Cohesive Soils at Selected Bridges in Illinois. Research Report ICT-10-074.

Proposed Models for Erosion Rate

$$\dot{z} = C_1(\tau - \tau_c)^{1.8}$$

$$C_1 = \alpha_2 q_u^{-1.0} PI^{-1.1}$$

For best fit, $\alpha_2 = 680$

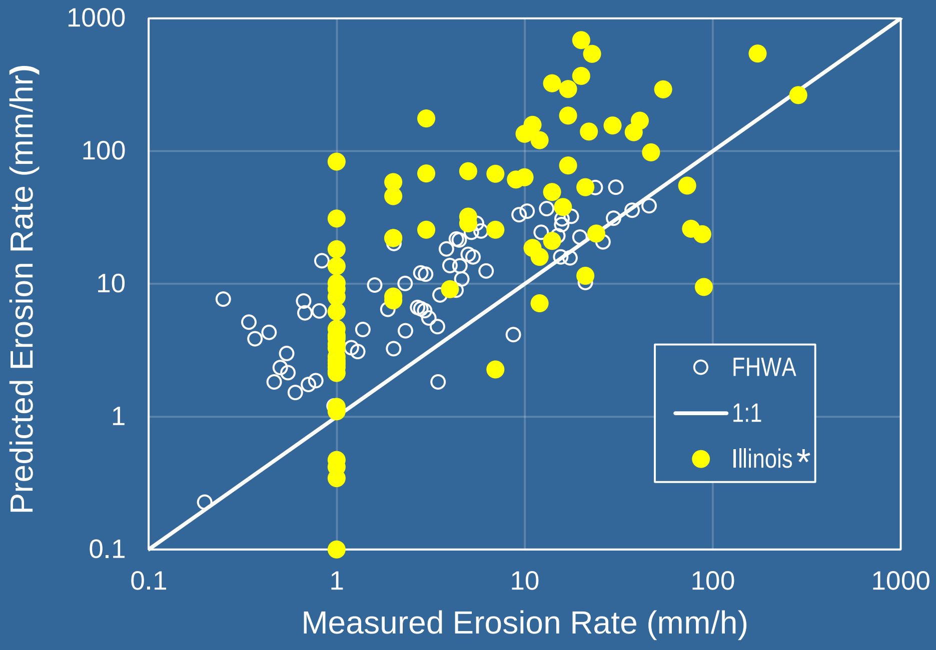


Proposed Models for Erosion Rate

$$\dot{z} = C_1(\tau - \tau_c)^{1.8}$$

$$C_1 = \alpha_2 q_u^{-1.0} PI^{-1.1}$$

For design, $\alpha_2 = 1100$



Conclusions

- ESTD mimics erosion in open channel flows
- The shear sensor directly measure the shear stress
- Critical shear stress is formulated with soil properties
- Erosion rate is a function of soil properties and excess shear stress
- Slaking should be excluded from an erosion test