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Critical Shear Stress from Varied Method of Analysis of a Submerged Circular Impinging Jet Test for Determining Erosion Resistance of Cohesive Soils

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Purpose of Work

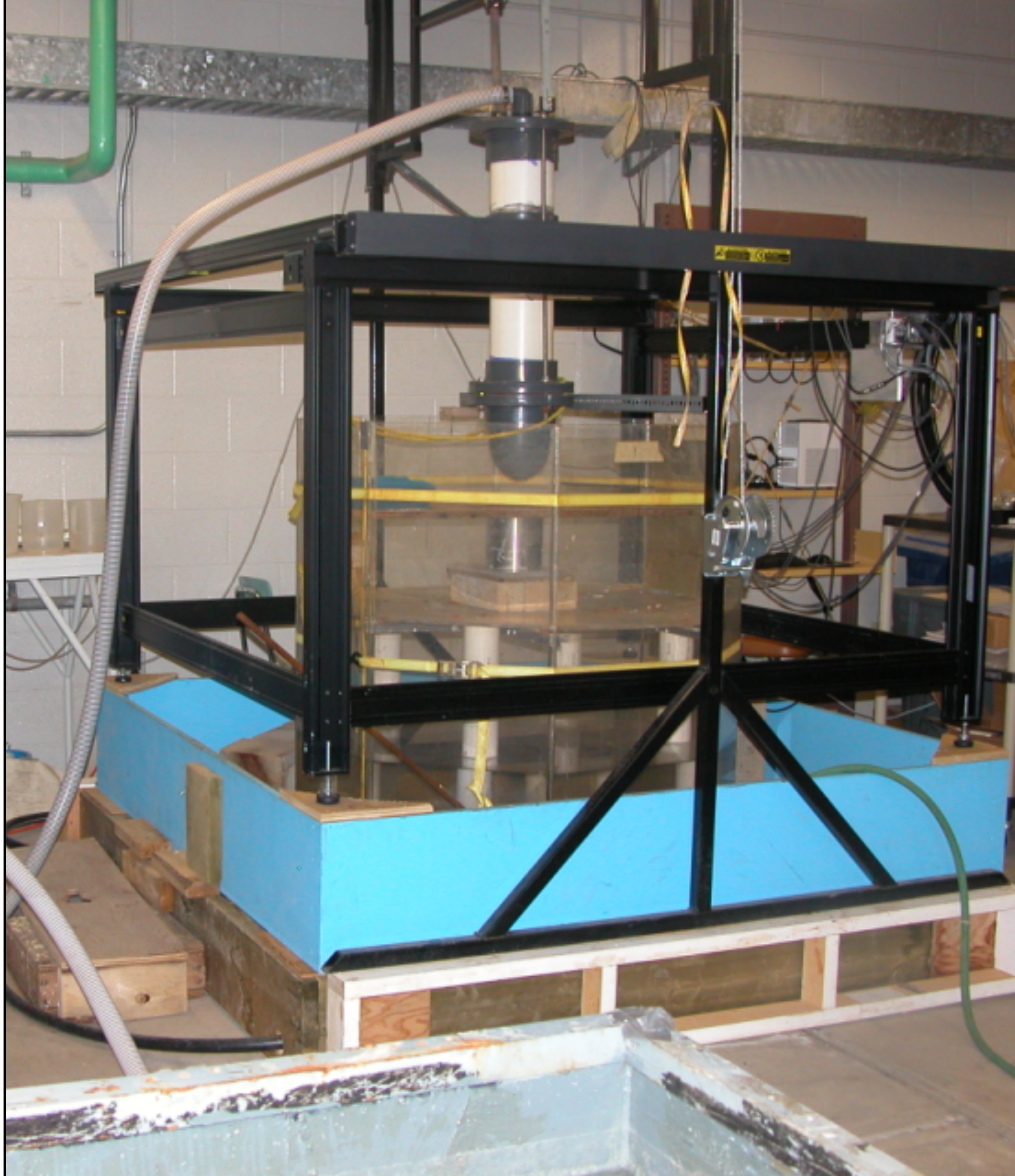
- Seeking to determine critical shear stress, τ_c, of several clayey soils.
- Using circular impinging jet apparatus similar to that of jet erodibility test (ASTM standard).
- Can evaluate τ_c in several ways from scour data, how much does it vary amongst methods?

Soil Samples

- Two natural and three pottery clay samples.

Sample	> 2 mm	Med. Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	PL (%)	LL (%)	Dry density (kg/m^3)
M370-1	0	0	0	68	32	20	33	1570
BSC-1	0	0	7	71	22	19	32	1576
BSC-2	0	0	6	67	27	19	33	1549
Wilton Creek 1/2	0	0	21	65	13	18	28	1488
Wilton Creek 2/2	2	2	41	50	5	18	24	1500

Experimental Setup



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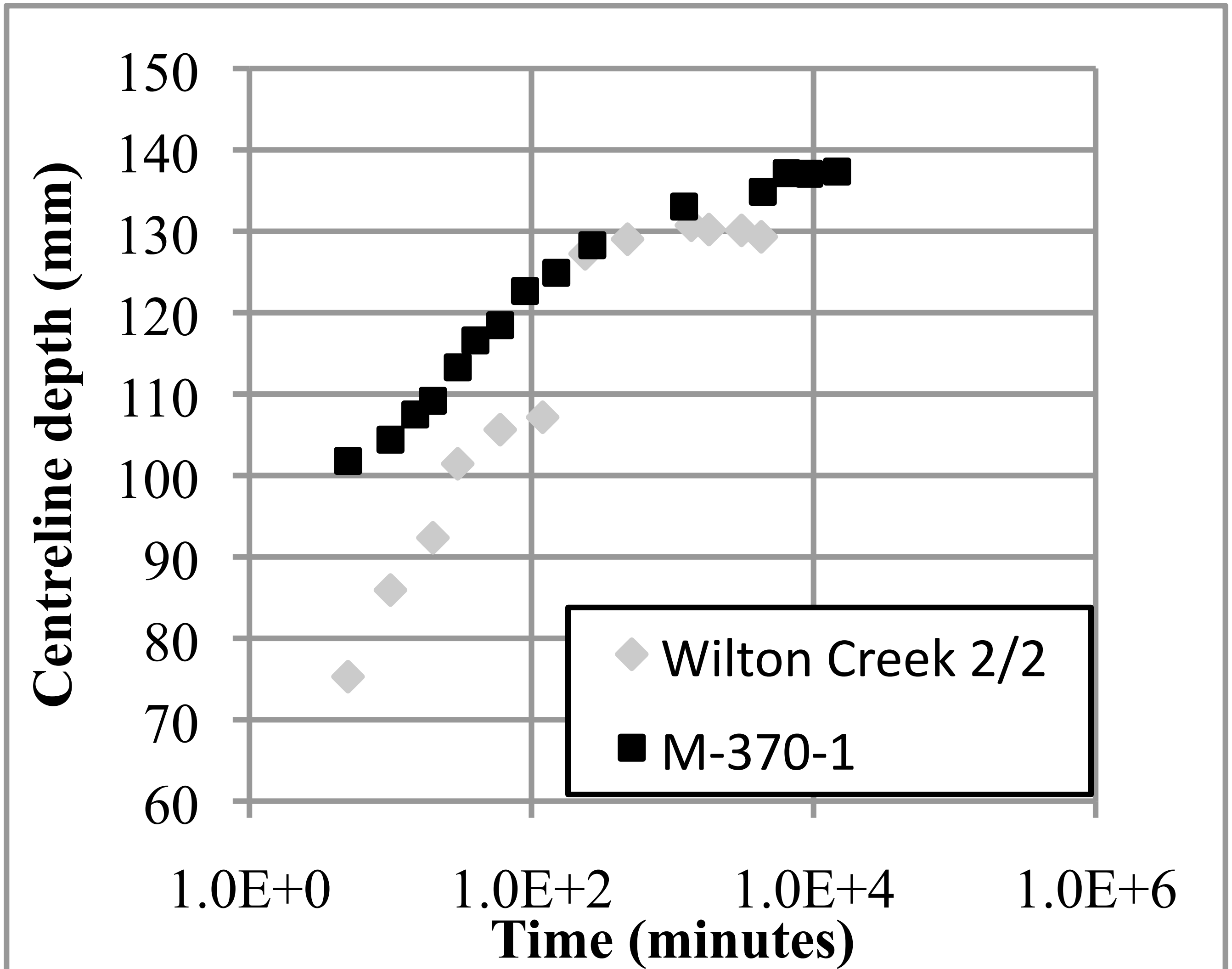
Test Operation

- Prepare samples by inserting into a steel cylinder and cutting surface with a wire.
- Submerge sample in jet tank.
- Start jet at low flow, increase flow in small increments until mass erosion observed.
- Increase flow to start scouring sample.
- Measure centreline scour depth until equilibrium scour reached.

Assessment of Equilibrium Scour



Critical Shear Stress Evaluation

- **Method 1 - Hanson and Cook (2004)**
  - Uses velocity decay of circular free jet:

$$\frac{u_m}{U_o} = C_d\left(\frac{d}{x}\right)$$

  - Relates shear stress to velocity using skin friction coefficient c_f:

$$\tau_{om} = c_f \rho u_m^2$$

- Then find the shear stress on the soil bed at a distance H from the jet origin:

$$\tau_{om} = c_f \rho \left(C_d U_o \frac{d}{H} \right)^2$$

- Assumes that the shear stresses are at critical when at equilibrium scour, H_e:

$$\tau_c = c_f \rho \left(C_d U_o \frac{d}{H_e} \right)^2$$

- Equilibrium scour depth H_e determined from curve fitting approach of Blaisdell et al. (1981).
- Tests run for about 2 hours.

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- **Method 2 - Visual Assessment**
  - From determined flow rate when erosion first observed, determine maximum shear stress on bed.
  - Calculate shear stress assuming bed is rigid, non-porous, smooth and flat.
  - Shear stress equation that of Hanson and Cook (2004).

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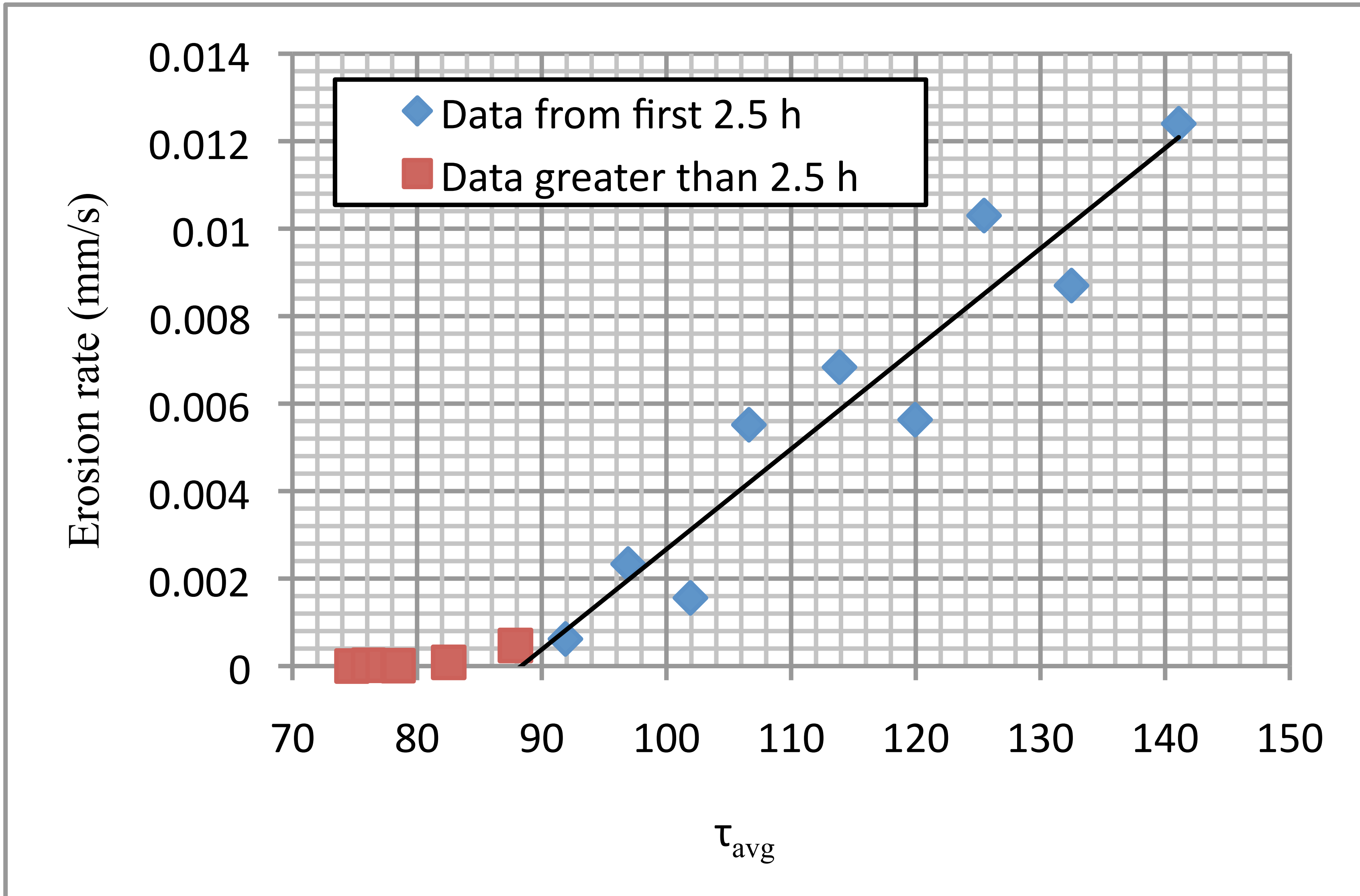
- **Method 3 - Measured Equilibrium State**
  - Uses the measured value of the equilibrium scour depth instead of the estimated value.
  - Assumes stress on sample is critical shear stress at equilibrium.
  - Shear stress equation that of Hanson and Cook (2004).

- **Method 4 - Erosion rate vs. Shear Stress Plot**
    - Suggested by Thomas (unpublished)
    - For each measurement interval from scour data, determine:
        - Erosion rate from change in scour depth at jet centreline.
        - Average shear stress on the soil surface at the jet centreline during interval.
    - Determine critical shear stress from plot of erosion rate and shear stress.

Erosion Rate vs. Shear Stress (M370-1)



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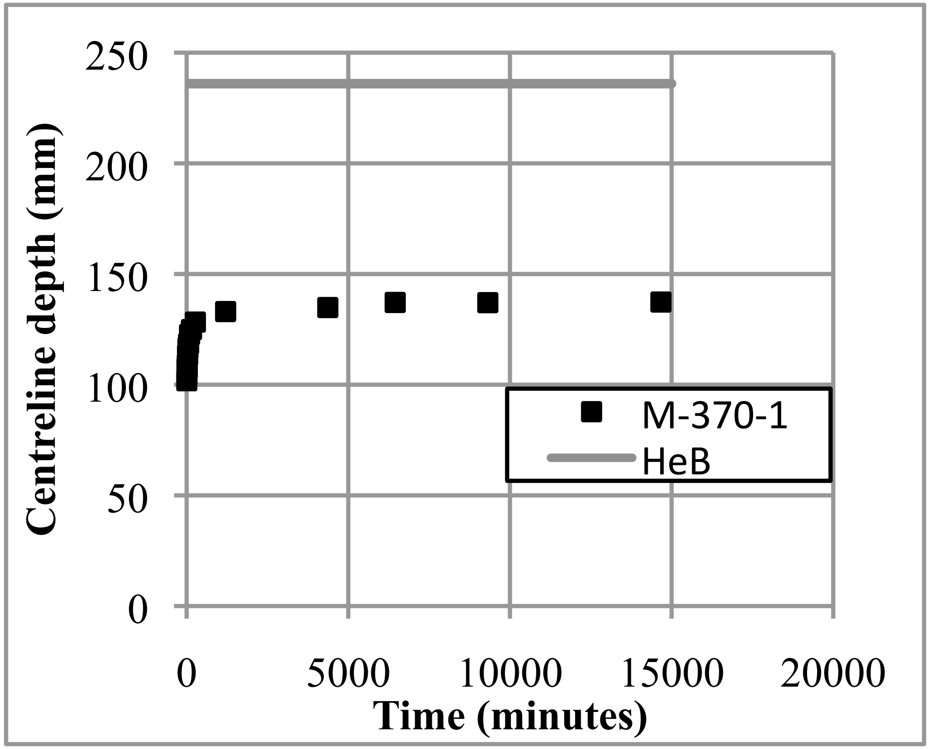
Results

Sample	Hanson and Cook (2004) τ_c (Pa)	Visual Assessment τ_c (Pa)	Equilibrium Depth τ_c (Pa)	Plot of Erosion Rate τ_c (Pa)
M370-1	26.1	60.1	74.8	88.4
BSC-1	20.6	88.1	71.7	107.0
BSC-2	19.1	44.9	52.5	62.0
Wilton Creek 1/2	1.4	1.6	3.4	3.9
Wilton Creek 2/2	0.1	0.4	1.0	1.3

Results

- Hanson and Cook’s (2004) values much lower than other methods.



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- Hanson and Cook (2004) most closely matched critical shear stress values from flume tests.

Discussion and Conclusions

- Different test analyses with the same data can give wide ranging results.
- Likely problems with theoretical underpinnings of analysis procedures of jet test.
- More careful analysis of standard jet test procedures need to be undertaken.