Time Development of Scour by Circular by Wall Jets in Cohesive Soils at Varied Scale

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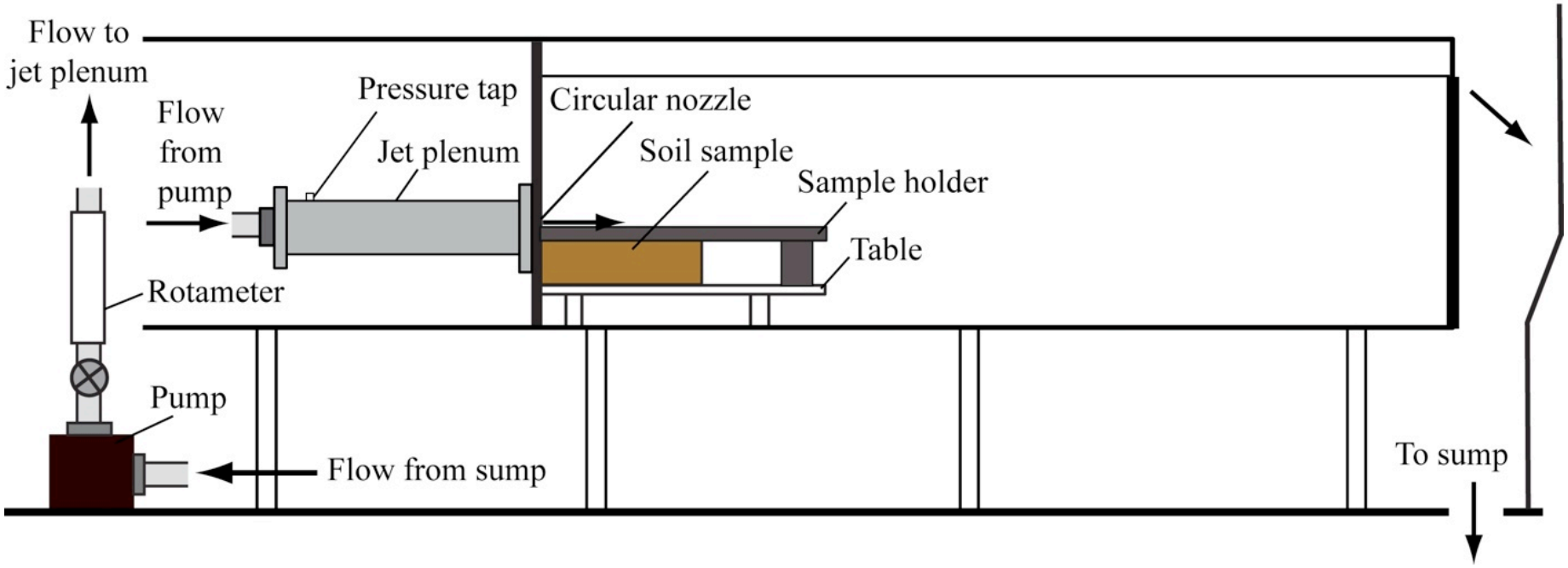
Background

- Stream boundaries in Canada typically a thin layer of alluvial material overlying highly consolidated, clayey sediments.
- Seeking to better understand time development of scour below culverts in clayey soils.
- Modelled as scour by circular wall jets.

Past Work - Abt (1980)

- Large scale experiments in 30.5 m long, 6.1 m wide, 2.4 m deep flume.
- One soil (58 % sand, 28 % clay, 14 % silt).
- Three culvert diameters (273, 356, or 457 mm).
- Tailwater at 45 % of diameter.
- Measure scour hole at 31.6, 100, 316, and 1000 min.

Experimental Setup



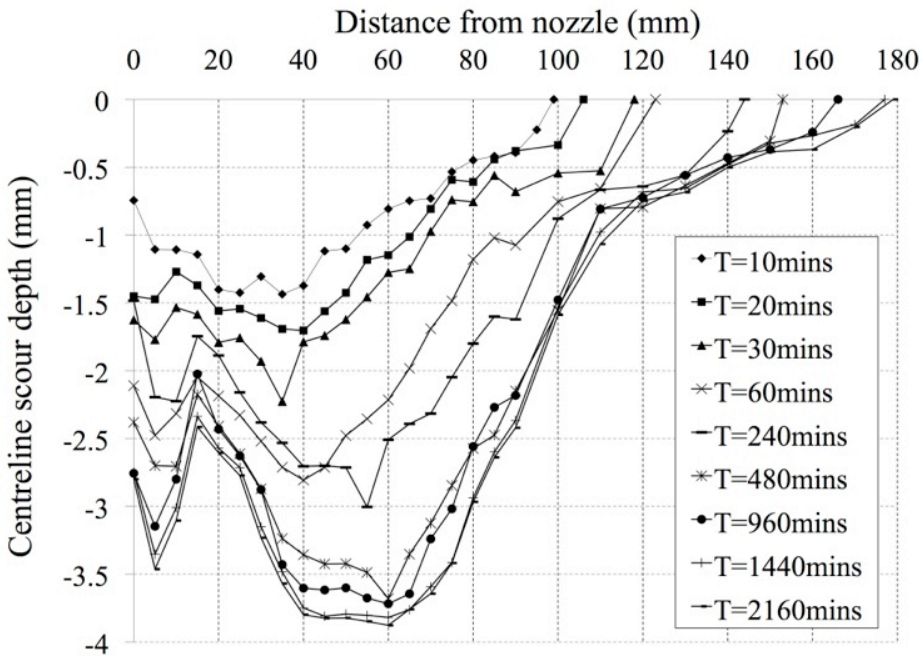
Measurements

- Stopped test at times of 10 min, 20 min, 30 min, 1 h, 2 h, 4 h, 8 h then at 8 h intervals.
- Tests run for 36 to 84 h.
- Cross-sections of scour hole taken using laser displacement meter at every interval.

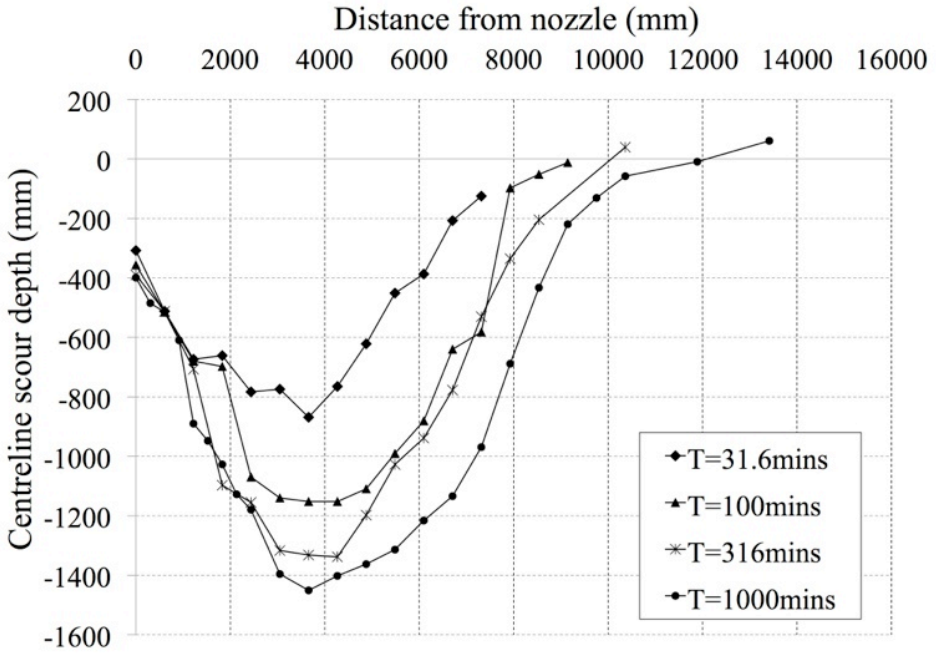
Details of Experiments

Test No.	Jet Velocity (m/s)	Test Duration (h)	Clay	Dry Density (kg/m^3)	Sand (%)	Silt (%)	Clay (%)	PL (%)	LL (%)	τ_c (Pa)
1	5.3	84	M370	1610	0	68	32	13	33	26.1
2	8.3	36	M370							
3	8.9	60	M370							
4	7.0	60	BSC	1560	6.5	69	24.5	14	33	19.9
5	5.3	84	BSC							

Growth of Scour Hole Profile along Jet Centreline



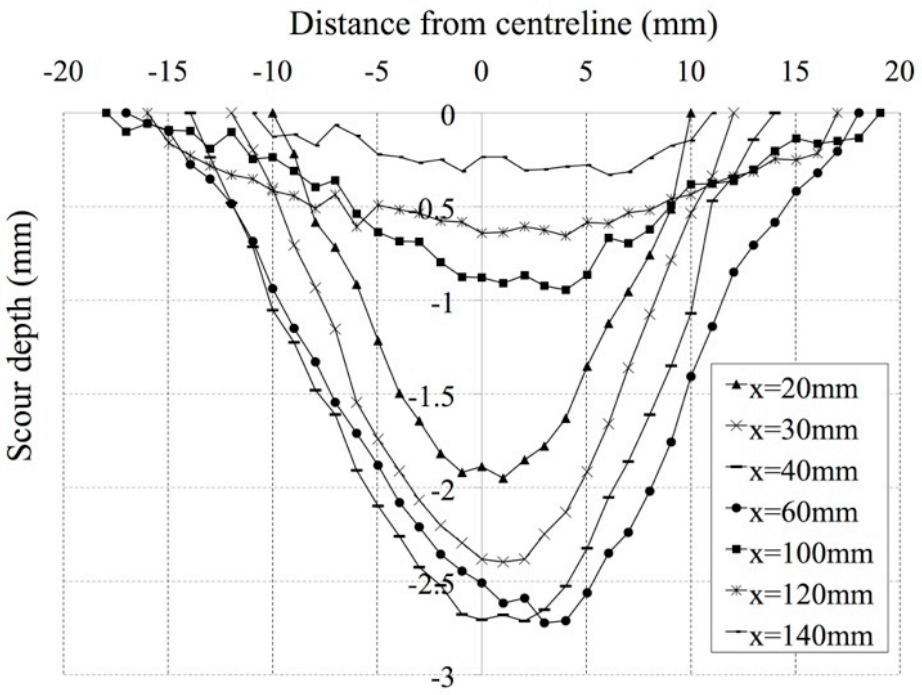
Test 2



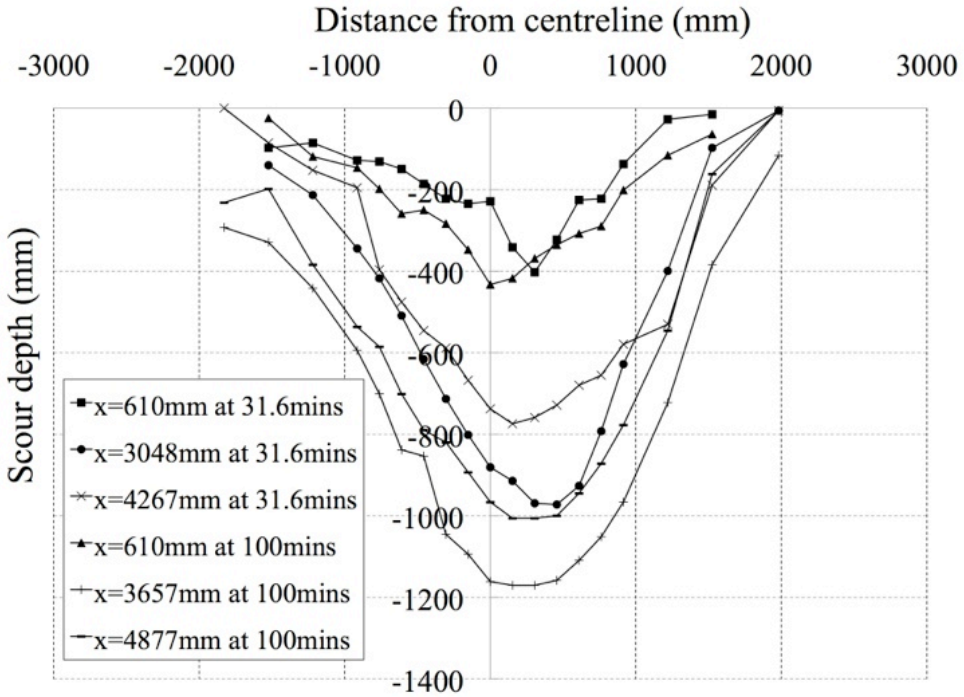
Abt (1980)

*Eroded by mass erosion.

Typical Cross-Sections

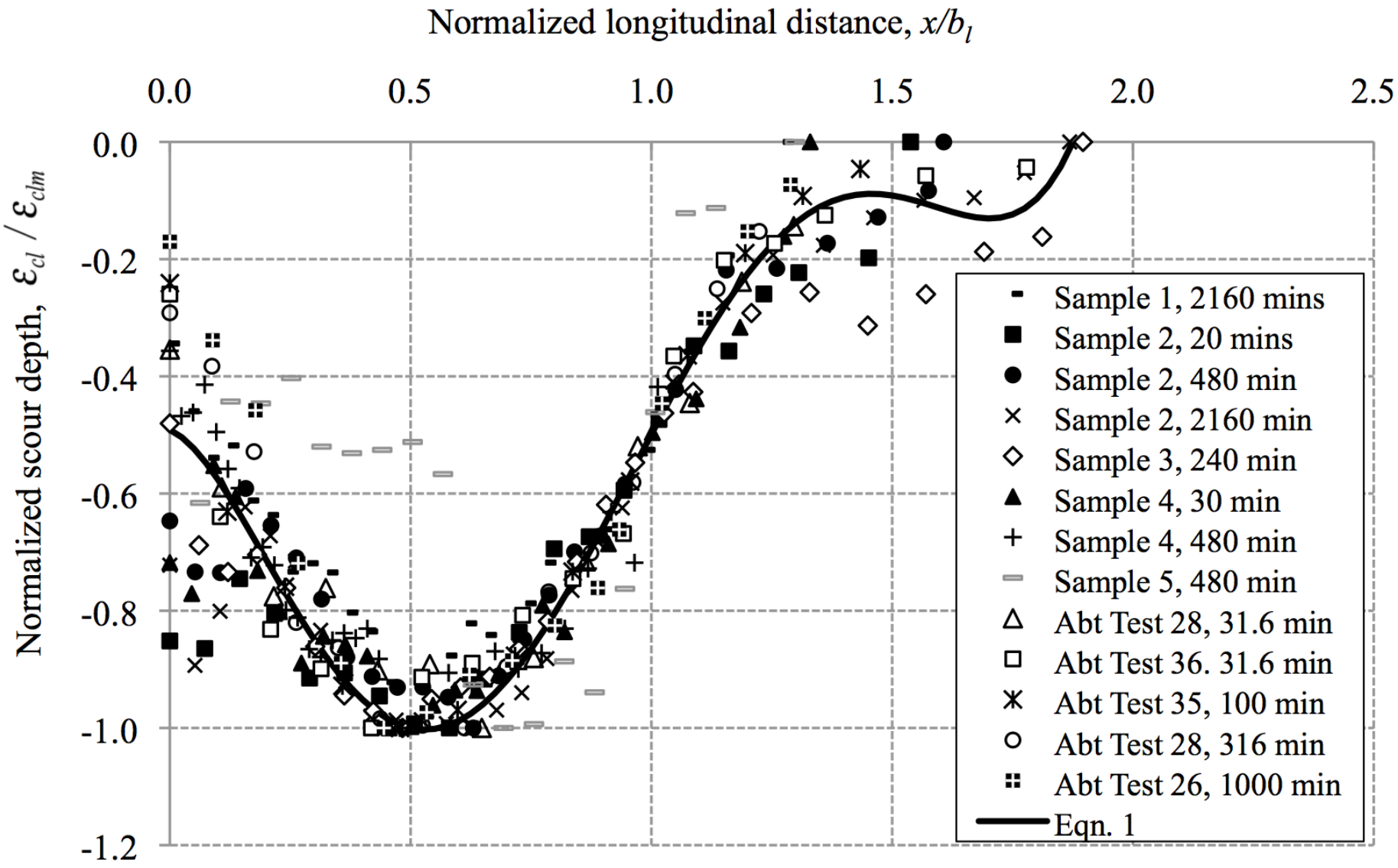


Test 2
(after 240 min)

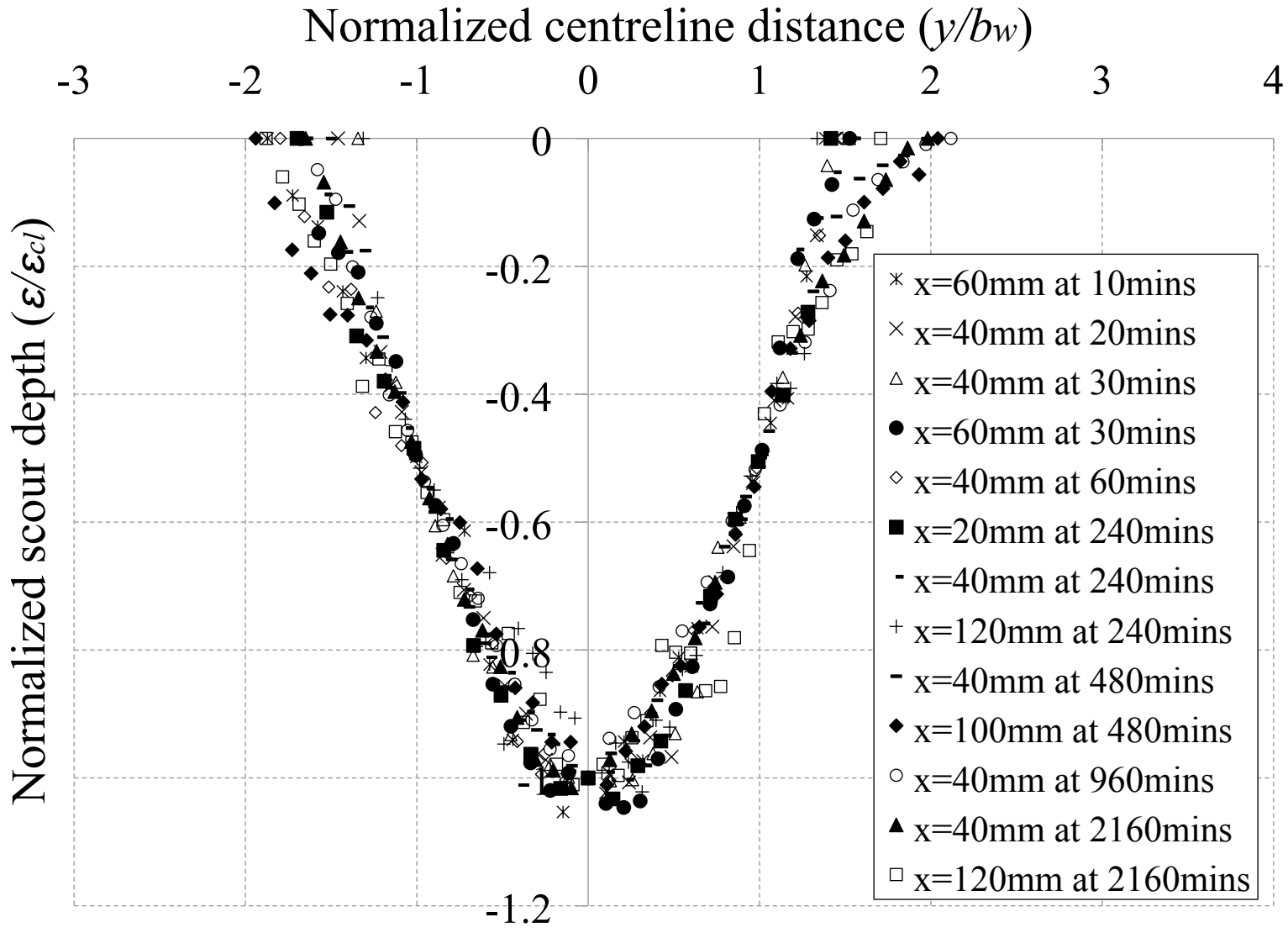


Abt (1980)
(after 31.6 min
and 100 min)

Dimensionless Longitudinal Scour Profile



Dimensionless Cross-Sections



Prediction of Scales

- To use dimensionless profiles need to predict at a particular time:
  - maximum depth of scour hole along centreline.
  - half-width of scour hole at a given location.
- Assume:

$$\varepsilon_{clm} = f\left\{U_o, d, \rho, \mu, \tau_c, t\right\}$$

- Using dimensional analysis:

$$\frac{\varepsilon_{clm}}{d} = f\left\{\frac{\rho U_o^2}{\tau_c}, \frac{\rho U_o d}{\mu}, \frac{U_o t}{d}\right\}$$

$$\tau_o = c_f \rho \frac{U_o^2}{2}$$

- Rewrite as using excess stress:

$$\frac{\varepsilon_{clm}}{d} = f\left\{\frac{\tau_o - \tau_c}{\tau_c}, \frac{U_o t}{d}\right\}$$

- Using multiple linear regression, find:

$$\frac{\varepsilon_{clm}}{d} = 0.201\left(\frac{\tau_o - \tau_c}{\tau_c}\right)^{0.613}\left(\frac{U_o t}{d}\right)^{0.0145}$$

Adjusted r^2=0.77:

Conclusions

- Shape of scour hole in cohesive materials appears to similar at small and large scales.
- Developed a reasonably good relationship for maximum scour depth based on excess shear stress and dimensionless time.
- Prediction of half-width of scour hole more problematic for small scale tests in clay due to mass erosion.

Acknowledgments

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