In-Situ Scour Testing Device (ISTD), State Demonstrations of Field Soil Tests, Columbus, OH

Emerging ISTD technology uses an innovative erosion head that more accurately measures soil erosion resistance, resulting in more cost-effective foundation designs and greater reliability and resiliency in bridge performance.

The demonstration group observes the Columbus ISTD field test.

INTRODUCTION

The ISTD is an advanced system designed by the hydraulics research team at the Turner-Fairbank Highway Research Center to measure the erosion resistance of fine-grained, cohesive soils directly in the field. It features an innovative erosion head that, when inserted into a standard drill casing, can direct a horizontal radial water flow across the surface of the soil, resulting in erosion. The erosion resistance is measured in terms of a critical shear stress, which, when coupled with the decay of hydraulic shear forces (water loads) with scour depth, is the basis of the Federal Highway Administration's (FHWA's) NextScour program for improving the accuracy of future bridge scour estimates.

BACKGROUND

The third ISTD field demonstration was held in conjunction with the 2018 National Hydraulic Engineering Conference (NHEC) in Columbus, OH. The Ohio Department of Transportation (ODOT) worked with FHWA to select a test site near the conference that had an appropriate soil testing profile and could safely accommodate a large number of conference participants interested in attending the demonstration. They eventually selected a field adjacent to a rest area off Interstate 70 located roughly 30 mi west of Columbus.

The subsurface soil profile of the site was initially determined from boring logs taken in 2017 at the rest area and an additional boring log taken in the vicinity of the test site several months in advance. The day before the demonstration, a new borehole was drilled to confirm the exact soil profile at the site using a continuous standard penetration test (SPT), which revealed a layer of stiff, brown, silty clay featuring low plasticity from 7–17.5 ft. At around 11 ft, the clay transitioned from brown to an olive-green color. The SPT revealed that the clay had N-values ranging from 10–18, with the material increasing in stiffness with depth. The groundwater table settled in at 9.5 ft, which became the initial starting test depth for the ISTD. Trace amounts of gravel were found at the site, which is typical for clay deposits throughout Ohio.

TEST PROCEDURE

The demonstration took place on Thursday, August 30, 2018. The drill crew augered to a depth of 9 ft and then lowered the Shelby tube and casing into the borehole and pushed 14 inches. The hydraulics team then assembled their equipment, including the linear drive, water tank, hoses, pump, control box, and laptop. The first test only lasted 12 min before the erosion head became stuck. The head was removed and, as expected, excessive amounts of gravel fragments had become lodged in the passages. The recovery of the Shelby tube revealed it had been damaged during the push because of the gravel. The decision was made to switch from the thin-walled Shelby tube to a casing shoe, which is a 1-ft-long segment of casing with a tapered edge that can be directly pushed into the soil. The gravel still damaged the tapered edge of the casing shoe during each push, but its thicker walls prevented it from collapsing. The disadvantage of using the shoe was that the soil in the casing became more compressed and disturbed compared to a sample in the thin-walled Shelby tube.

RESULTS

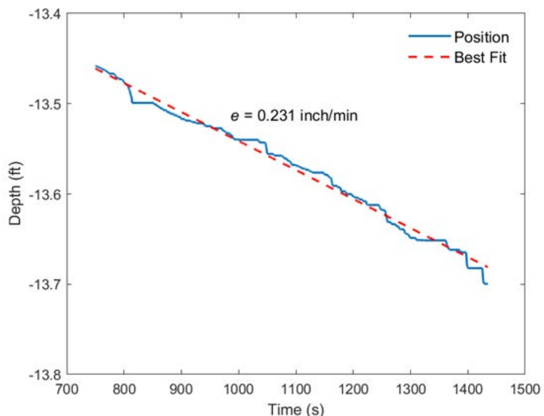
Over the course of the testing, the hydraulics team collected a total of 3 hr of erosion data, captured in seven separate test runs ranging from 10 to 40 min per run. They tested roughly 24 inches of soil with 11 different flow rates ranging from 0.145 to 0.373 ft^3/s.

Even after switching to the casing shoe, gravel fragments continued to pose issues during testing. Pieces would often get lodged in the outlet of the erosion head, interfering with the water flow. Tests had to be interrupted repeatedly to

The ISTD equipment assembled in the field.

clear out the clogged passageways. Additionally, because the clay was very stiff, the higher flow rates required for erosion occasionally forced the linear drive's motor to reach its maximum torque limit. Despite these issues, the team collected enough data to extract erosion rates from 11 different segments by calculating a best-fit line through each set of data. The corresponding mean flow rates were also calculated for each segment. The 11 data points are detailed in the Summary of Results table. With enough data points, a nonlinear power curve can be fitted to the data to determine the critical flow rate of the soil, which can be correlated to the shear stress. The plot shows the data points from testing, but more points are needed to extract the curve confidently.

Due to the presence of low erosion rates during testing, this ISTD demonstration revealed that this location could potentially have a clay layer with significant erosion resistance. However, additional testing is needed to confirm that result and produce more consistent data.

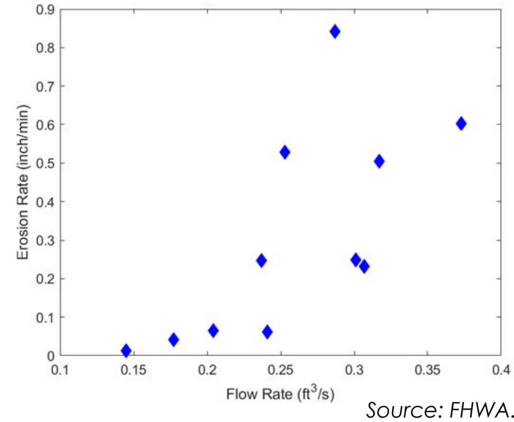


Source: FHWA.

Soil layer's erosion rate (e) calculated from the slope of the best-fit line.

Summary of Results

Depth (ft)	Duration (min)	Flow Rate (ft^3/s)	Erosion Rate (inch/min)
9.44	13:10	0.241	0.061
10.42	8:45	0.317	0.505
13.21	12:10	0.237	0.247
13.46	11:25	0.307	0.231
13.72	3:10	0.373	0.602
13.97	2:20	0.301	0.249
14.08	33:50	0.145	0.013
13.99	22:20	0.177	0.041
14.09	4:10	0.253	0.529
15.17	3:00	0.287	0.482
15.78	12:00	0.204	0.065



Source: FHWA.

Erosion rate versus flow rate for the Columbus ISTD demonstration. With more data points, a nonlinear fitted power curve could be used to extract the critical flow rate where erosion begins.

Soil Properties

Parameter	Value
Depth (ft)	15-17
Water content (%)	12
Liquid limit (%)	22
Plasticity index (%)	8
Clay faction (%)	30
Percent fines (%)	69
Soil classification (USCS)	CL
Soil classification (AASHTO)	A-4(3)
Unconfined compressive strength (psi)	39.17

USCS = Unified Soil Classification System; AASHTO = American Association of State Highway and Transportation Officials.

ADDITIONAL RESOURCES

ISTD Field Demonstration Webinar:
https://connectdot.connectsolutions.com/ph8wgrf8erz7/

AASHTO Hydrolink Newsletter:
https://design.transportation.org/wp-content/uploads/sites/21/2018/02/Hydrolink-Issue-16.pdf

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