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

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 ISTD data collection.

Source: FHWA.

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 Kansas Department of Transportation (KDOT) hosted the fifth ISTD field demonstration on the floodplain south of the west abutment of the bridge that transports US 73 traffic over Walnut Creek near Reserve, KS. This bridge was scheduled for replacement, and a Kansas State University team had already conducted some preliminary geotechnical work and alternative erosion testing for a research project.

There were no boring logs from the site to review before the demonstration was conducted. However, according to KDOT engineers, soils in northeast Kansas tend to be a silt and clay combination with little or no gravel, and they are typically categorized as loess soils down to 30–50 ft. On the day before the demonstration, the drill crew performed a cone penetration test (CPT) to a depth of 23 ft to obtain detailed information about the soil profile. They then conducted a series of standard penetration tests (SPTs) from 9 to 20 ft. The tests revealed gray to dark brown clay with a medium plasticity in the upper layer that transitioned to dark brown, very fine, moist sandy silt. All SPTs recorded zero blow counts, indicating that the clay and silt were very soft. FHWA selected the clay layer that began around 11 ft as the targeted testing layer for the ISTD.

TEST PROCEDURE

The demonstration took place on September 19, 2018. After the drill crew conducted the CPT and the SPTs, they took soil samples from two new boreholes to ship back to FHWA's hydraulics lab. The hydraulics team then prepared to assemble the ISTD equipment to conduct some practice tests the day before the demonstration. However, they discovered that the inner diameter of the hollow stem augers was too narrow by one-half of an inch, and the casings would not fit inside. The drill crew augered to 11 ft, and then they carefully removed the augers from the ground. Fortunately, the borehole remained open and stable. The crew then lowered the Shelby tube and casings into the open borehole until they touched the clay layer below. To conduct additional tests, the Shelby tube and casings would need to be continuously pushed into the ground after each run. However, because the clay was soft, the hydraulics team did not anticipate any issues with subsequent testing. With the casing inserted and clamped to the drill rig, the hydraulics team then assembled the ISTD equipment—including the linear drive, water tank, hoses, and pump—and successfully performed a test run. The hydraulics team conducted the demonstration, which included performing three field tests for the group of KDOT engineers, on the following day.

RESULTS

Over the course of the testing, the hydraulics team collected more than 3 hr of erosion data, captured in four separate test runs ranging from 15 to 70 min per run. They tested roughly 5 ft of soil with eight different flow rates ranging from 0.115 to 0.266 ft^3/s.

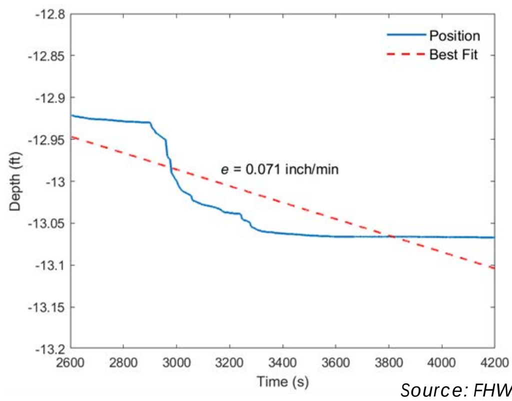
This site was different than the other early demonstration sites because it had very soft clay. The start of each test featured

The ISTD equipment assembled in front of the drill rig.

Source: FHWA.

a substantial drop of the erosion head in the first 3–5 min, sometimes eroding up to 8–10 inches, before settling into a more typical erosion curve. The cause of this behavior remains unclear. During analysis, these initial drops were discarded, and only the stabilized portion of the curve was considered. However, there could still be relevant erosion information in those data. From the remaining data, eight different segments were identified, and erosion rates were extracted by using a best-fit line through each set of data. The corresponding mean flow rates were also calculated for each segment. The eight 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 cloud of data points beginning to form, but more points are needed to confidently calculate the curve.

Due to the presence of some low erosion rates during testing, this ISTD demonstration revealed that this location could potentially have a clay layer with erosion resistance. However, because of those large initial periods of fast erosion, additional tests must be run to produce more consistent data.

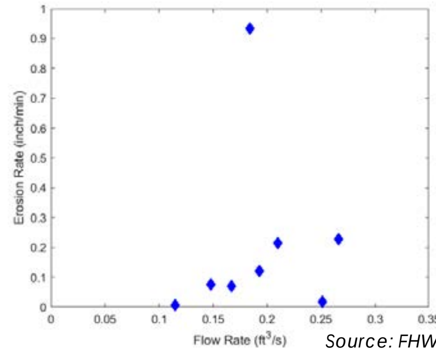


Source: FHWA.

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)
11.24	21:00	0.148	0.076
11.45	2:45	0.184	0.933
12.87	40:50	0.115	0.007
12.92	27:20	0.167	0.071
14.59	39:20	0.193	0.121
14.94	27:45	0.251	0.017
15.89	7:45	0.210	0.215
16.12	6:55	0.266	0.228



Source: FHWA.

Erosion rate versus flow rate for the Reserve 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)	10–13
Water content (%)	31
Liquid limit (%)	37
Plasticity index (%)	17
Clay faction (%)	27
Percent fines (%)	97
Soil classification (USCS)	CL
Soil classification (AASHTO)	A-6(17)
Unconfined compressive strength (psi)	1.53

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

NextScour Journal Paper: https://doi.org/10.1680/jfoen.20.00017

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Federal Highway Administration

https://highways.dot.gov/laboratories/hydraulics-research-laboratory/hydraulics-research-laboratory-overview

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