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

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.

An aerial view of the Farwell demonstration site.

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 Nebraska Department of Transportation (NDOT) hosted the fourth ISTD field demonstration at the northwest corner of the Farwell West Bridge. The bridge is located about 2.5 miles west of the town of Farwell, NE, and carries SR 92 over Turkey Creek. The bridge had received a poor scour critical rating in a 2013 scour assessment report and NDOT scheduled to replace the structure with a 145-ft-long concrete girder bridge.

Unlike previous demonstration sites, there were no recent boring logs for determining the subsurface soil profile. However, borings from 1938 indicated a 12-ft layer of yellow clay situated above a 25-ft layer of brown clay. Two days before the demonstration, the drill crew performed a cone penetration test (CPT) to obtain more detailed information about the soil profile. The next day with FHWA on-site, the crew performed a continuous standard penetration test (SPT) between 11 and 22.5 ft. These tests revealed a moist, lean clay of medium stiffness, with trace sands, with N-values ranging from 6 to 8. The clay layer beginning around 11 ft was selected as the targeted testing layer for the ISTD.

TEST PROCEDURE

The demonstration took place off the shoulder of SR 92 on September 13, 2018. The bridge's guardrail protected the drill rig, pump, and ISTD equipment. The drill crew augered to a depth of 11 ft and then used a Shelby tube to clean out 14 inches of material. They then mounted a new Shelby tube onto the casing and lowered it into the borehole. The hydraulics team then assembled the remaining ISTD equipment. The initial run of the equipment resulted in two different issues that caused some lengthy delays. First, the connection between the motor and the linear drive failed, causing the linear drive to shoot up from the water pressure. The team noticed that a hydraulic part on the rig mast had slowly slid down onto the motor. The weight of the hydraulic part then tilted the motor at an angle. This weakened the connection to the linear drive. Second, the team also noticed an oil film coating the piping, hoses, and water tank, which they believed came from the rental pump. Significant time was lost while the team cleaned as much of the oil out of the equipment as possible. Eventually, the drill crew augered past the previous attempt and the hydraulics team started a new test in fresh clay. This time the ISTD successfully collected erosion data.

RESULTS

Over the course of the testing, the hydraulics team collected more than 3 hours of erosion data, captured in three separate test runs ranging from 50 to 100 min per run. They tested roughly 20 inches of soil with 11 different flow rates ranging from 0.145 to 0.296 ft^3/s.

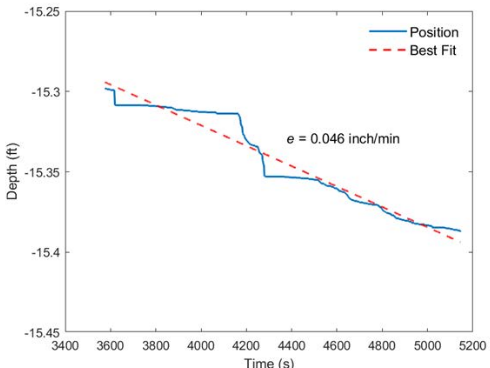
Despite the unforeseen difficulties encountered during the initial test, the next two tests proved successful and provided most of the data points for this site. From the data, 11

The ISTD equipment assembled in front of the drill rig.

Source: FHWA.

different segments were identified, and erosion rates were then extracted by using 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 cloud of data points beginning to form, but more points are needed to confidently calculate the curve. Almost all the data points featured very slow erosion, but there were a few moments where the clay washed out several inches in a few seconds. In one instance, the clay eroded almost 10 inches in a span of 15 minutes. It is unclear why the clay eroded suddenly in this manner.

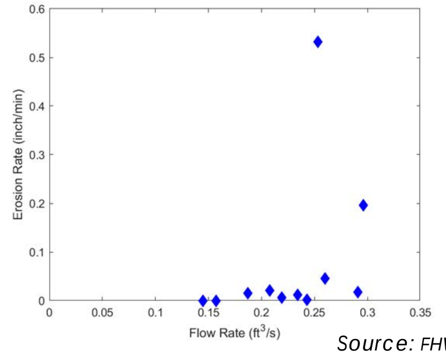
Due to the presence of low erosion rates during testing, the ISTD demonstration revealed that the location could potentially have a clay layer with significant erosion resistance. However, additional testing would be needed to confirm that result and produce more consistent data.



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 (ft³/s)	Erosion Rate (inch/min)
12.14	3.83	0.145	0.000
12.15	12.67	0.234	0.012
12.39	21.08	0.291	0.017
14.46	11.58	0.253	0.532
15.25	26.33	0.187	0.015
15.29	18.75	0.219	0.006
15.30	26.17	0.260	0.046
15.74	2.58	0.157	0.000
15.74	34.08	0.208	0.021
16.01	13.92	0.243	0.002
16.01	9.75	0.296	0.196



Source: FHWA.

Erosion rate versus flow rate for the Farwell 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)	11-14
Water content (%)	31
Liquid limit (%)	51
Plasticity index (%)	31
Clay faction (%)	40
Percent fines (%)	97
Soil classification (USCS)	CH
Soil classification (AASHTO)	A-7-6(33)
Unconfined compressive strength (psi)	2.71

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

For additional information, please contact:

Daniel Alzamora
Senior Geotechnical Engineer
FHWA Resource Center
720-963-3214
daniel.alzamora@dot.gov

James Pagenkopf
Hydraulics Research Engineer
FHWA Hydraulics Laboratory
202-493-7080
james.pagenkopf@dot.gov

U.S. Department of Transportation
Federal Highway Administration

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

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