IN-SITU SCOUR TESTING DEVICE (ISTD), STATE DEMONSTRATIONS OF FIELD SOIL TESTS, BUTTE CITY, CA

Emerging in-situ scour testing device (ISTD) technology uses an innovative erosion head that more accurately measures soil erosion resistance, resulting in cost-effective foundation designs and increased reliability and resiliency in bridge performance.

An aerial view of the Butte City 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. The device 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 in terms of 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) NextScour research initiative for improving the accuracy of future bridge scour estimates.

BACKGROUND

The California Department of Transportation (Caltrans) hosted the 12th ISTD field demonstration on State Route 162 at the Butte City Bridge over the Sacramento River. The demonstration was held in a field near the east abutment. Caltrans planned to replace the aging through-truss structure, originally built in the 1940s, with a cast-in-place prestressed box girder. The new bridge will feature wider lanes and shoulders to better accommodate the large farm vehicle traffic in the area.

Caltrans drilled a soil boring at the site in 2015, which showed a clay layer from 12.5 to 26 ft deep. The clay was categorized as a lean clay, moist, hard, reddish brown, with traces of fine sand. Standard penetration tests (SPTs) produced *N*-values of 17 blows-per-foot (bpf) at depths of 16 ft and 21 ft. However, whether this clay layer was beneath the groundwater elevation was not apparent.

Due to having limited soil information, Caltrans conducted a cone penetration test (CPT) at the site the morning of the demonstration to obtain a detailed soil profile to a depth of 40 ft. The CPT data revealed a very stiff layer of material around 22–23 ft and clay material more suitable for erosion testing from 25–30 ft. A continuous SPT test from 25–29.5 ft produced *N*-values of 11, 8, and 13 bpf. The SPT also found groundwater around 25–26 ft. The clay layer starting around 25 ft was selected as the targeted testing layer for the ISTD.

TEST PROCEDURE

The demonstration occurred on June 26, 2019, but the drill crew and the hydraulics team arrived a day earlier to conduct as much ISTD field testing as possible in the two-day span. After the CPT and SPT tests were completed, the drillers augered to 25 ft and the hydraulics team assembled the remaining equipment, including the water tank, pump, piping, hoses, linear drive, and laptop, to prepare for the first test.

During the initial tests, the distance sensors produced erratic data. All four sensors were equally displaced, simultaneously, even after stopping and starting the pump. The test was halted, and the casing and Shelby tube were recovered. The tip of the Shelby tube was damaged, but more importantly, a 3-inch layer of loose cemented soil was moving freely up and down in the Shelby tube. This soil was very hard and would never be eroded by the water flow. The hydraulics team determined that the soil must have been related to the stiff layer found by the CPT test earlier that morning. Fortunately, beneath the cemented soil was clay material. The plan for the second day of testing was for the drillers to auger 1 ft past the current location and attempt the erosion test again in the desired testing layer.

The ISTD equipment assembled in front of the drill rig.

Source: FHWA.

RESULTS

Over the course of the testing, the hydraulics team collected more than 4 h of erosion data, captured in five test runs ranging between 15–90 min in length. The team tested about 2.5 ft of soil with nine flow rates ranging from 0.151 to 0.325 ft³/s.

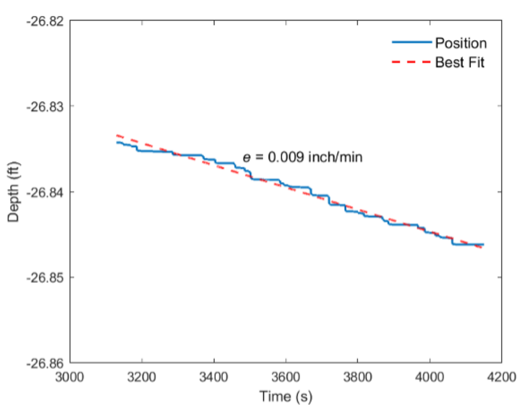
Despite some early difficulties with a loose, stiff section of soil, the testing was successful, obtaining numerous data points. With this data, FHWA identified 11 different segments, extracted erosion rates using a best-fit line through each set of data, and calculated the corresponding mean flow rates for each segment. The Summary of Results table shows the 11 data points. The accompanying graph presents erosion rates plotted against flow rates, revealing the correlation between the two values. With more data points, a nonlinear power curve can be fit to the data to extract the critical flow rate.

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

Summary of Results

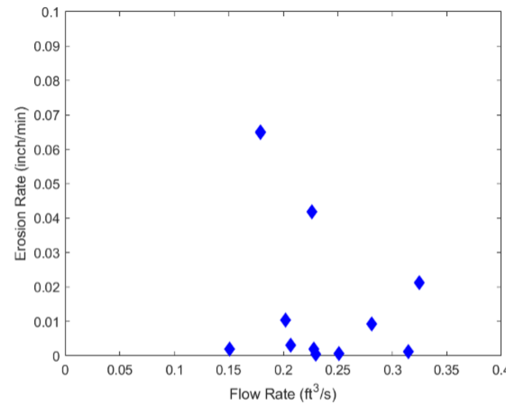
Depth (ft)	Duration (min)	Flow Rate (ft³/s)	Erosion Rate (inch/min)
24.55*	33:10	0.179	0.0650
24.68*	12:55	0.226	0.0418
26.64	5:50	0.151	0.0019
26.64	15:05	0.202	0.0103
26.67	16:10	0.228	0.0020
26.80	25:05	0.325	0.0212
26.82	18:30	0.207	0.0030
26.83	17:20	0.230	0.0005
26.83	14:25	0.251	0.0006
26.83	17:00	0.281	0.0093
26.85	12:30	0.315	0.0013

Note: Potential disturbed soil in auger; initial test was intended to start at 25.5 ft.



Source: FHWA.

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



Source: FHWA.

Erosion rate versus flow rate for the Butte City 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)	26.75
Water content (%)	21.4
Liquid limit (%)	35.0
Plasticity index (%)	16.0
Clay fraction (%)	36.1
Percent fines (%)	86.6
Soil classification (USCS)	ML
Soil classification (AASHTO)	A-6(13)

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

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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For additional information, please contact:

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

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

U.S. Department of Transportation
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https://highways.dot.gov/laboratories/hydraulics-research-laboratory/hydraulics-research-laboratory-overview

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