RECLAMATION

Managing Water in the West

Improving Reclamation's Field Investigations with the Rock Borehole Shear Test

Research and Development Office
Science and Technology Program
(Final Report) ST-2019-1805-01

U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

September 2019

Mission Statements

The U.S. Department of the Interior protects America’s natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

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14. ABSTRACT **The goal of this feasibility level study was to investigate the possible uses of a rock borehole shear test (RBST) device to determine shear strengths of difficult-to-sample materials in-situ. Materials that lie on the border between rock and soil (transition materials) can be difficult to sample but critical for design strengths. Many of Reclamation's projects are founded on these transition materials (shale, claystone, weak sandstone etc.) resulting in uncertainty in field and laboratory determined engineering parameters. Testing the materials in place while drilling during a field investigation program can be an effective method of characterizing the material and reducing uncertainty in strength parameters. This type of equipment could also be used to test concrete in-situ. Reclamation already uses similar field equipment (i.e. the vane-shear device or a cone penetrometer) to characterize weak/soft clay or sands in place. The use of down-hole equipment to test difficult to sample rock/soil transition materials is a logical extension. This work is on-going at the time of this report; continuing work to construct the device is being funded by the Dam Safety Technology Development Program.**		
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Acronyms and Abbreviations

RBST – Rock Borehole Shear Test Device

Executive Summary

The goal of this scoping level study was to investigate the possible uses of a rock borehole shear test (RBST) device to determine shear strengths of difficult-to-sample materials in-situ. Materials that lie on the border between rock and soil (transition materials) can be difficult to sample but critical for design strengths. Many of Reclamation's projects are founded on these transition materials (shale, claystone, weak sandstone, etc.) resulting in uncertainty in field and laboratory determined engineering parameters. Testing the materials in place while drilling during a field investigation program can be an effective method of characterizing the material and reducing uncertainty in strength parameters. This type of equipment could also be used to test concrete in-situ.

Reclamation already uses similar field equipment (i.e. the vane-shear device or a cone penetrometer) to characterize weak/soft clay or sands in place. The use of down-hole equipment to test difficult to sample rock/soil transition materials is a logical extension.

The Dam Safety Technology Development Program is funding the construction and laboratory-scale commissioning of this device during FY19 and FY20. The S&T and Dam Safety funds have been used to develop preliminary design drawings and purchase components to construct the device. At this time, the intent is to have a functioning device early in FY20 and use the remainder of FY20 for laboratory scale commissioning tests.

Additional funds will be sought from the Research and Development Office and the Dam Safety Technology Development Program to further this work if results are promising.

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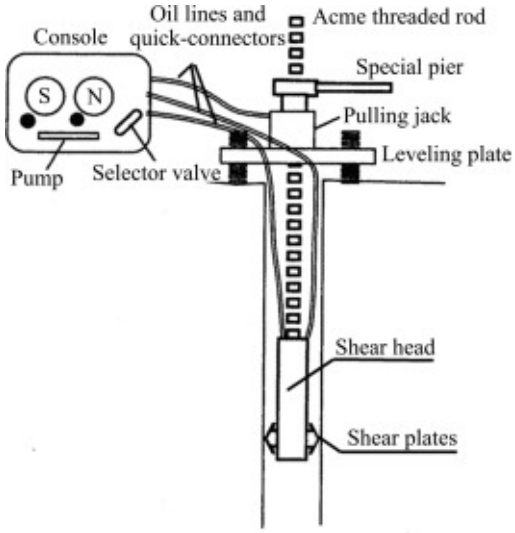
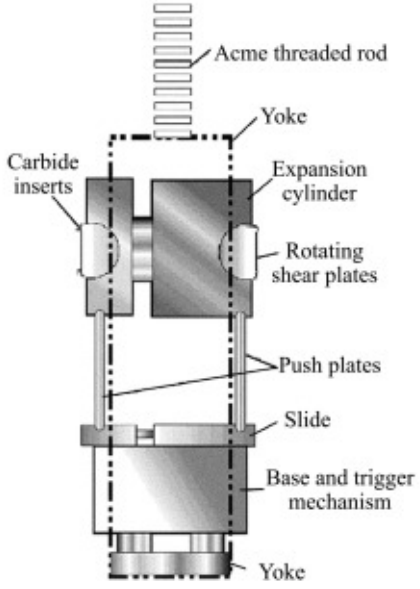
Background

The rock borehole shear test (RBST) device generates shear strength parameters in a boring by applying a normal stress to the boring walls with shearing induced by "pulling" the device along the boring axis. The test is performed at a number of normal stresses and a failure envelope is developed. The example RBST shown in Figure 1 uses hardened saw teeth to develop shear resistance along the boring walls (Zhao et al., 2012). Note that the shearing resistance is generated by the saw teeth or other pins which are pressed into the soft rock surrounding the borehole so the actual shearing is taking place between the teeth or pins.



(a) Structure of RBST apparatus.



(b) Structure of shear head.

Figure 1 - Typical rock borehole shear device (from Zhao et al., 2012).

Hay (Hay, 2007) designed and tested a unique variation on this design where the shear plates were replaced with a series of metal studs to develop shear resistance. The original design by Handy (Lutenegger and Hallberg, 1981) used saw-toothed shear plates; adjustment of the type of shear plate versus metal studs could be useful for different types of materials, although the shear plates have more historical use. Zhao et al (Zhao et al., 2012) found that the small shear teeth posed a limitation for the RBST device.

Close agreement between the friction angle found from laboratory triaxial testing or core samples and testing in-situ with the RBST was found for soft rocks (coal and shale) with some loss of cohesion likely due to the drilling and installation (Lutenegger and Hallberg, 1981). Zhao et al. (2012) found shear strength parameters from the RBST to be similar to those recommended for the site by geological engineers. The frictional coefficient was found only to be slightly less than that obtained from conventional tests, but the cohesion was generally 25% to 50% less than that obtained from conventional tests (Zhao et al., 2012). Yang et al. (2006) found the RBST device extremely useful in weathered shale to develop a range of shear strength parameters for a site under consideration for a costly repair.

The primary advantages of the device are how quickly data can be generated, and the ability to perform testing in weak or fractured rock where sample recovery is typically poor (Lutenegger and Hallberg, 1981). Hay (2007) found that knowing the uniaxial compressive strength of the rock prior to starting the RBST limited jamming of the equipment and reduced excess penetration of the shear studs into the boring walls. Zhao et al. (2012) found that the RBST equipment can be buried during testing if the borehole walls collapse and recommend only using this equipment in the top and middle portion of a boring.

The borehole shear equipment could be used by Reclamation at soft rock sites to help develop a range of shear strength parameters at a relatively low cost. Devices are commercially available and could be acquired and modified to meet project needs. While the RBST would not replace laboratory testing, it could be a valuable addition to Reclamation's site investigation tool box.

Purpose

Reclamation strives to operate on the cutting edge of site investigation, a critical component of any geotechnical design or evaluation of operational performance. We are also in the business of ensuring public safety, and our facilities and infrastructure are some of the largest in the world. In order to both continue to operate at the state-of-the-art and to accomplish the mission to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public, Reclamation needs to be at the forefront of subsurface data acquisition and analysis.

Reclamation projects are founded on a variety of materials, from soft soils to hard rock. The materials between "soil" and "rock" are considered to be transition materials that are known to be difficult to sample and characterize. These difficulties result in greater uncertainty in designs of both existing and new structures. Transition materials are often encountered during Reclamation's field investigations and represent significant challenges in terms of sampling and lab testing. Significant resources are often expended to achieve less than ideal results.

Given Reclamation's vast and aging geotechnical infrastructure, how we determine material strengths underlying that infrastructure, and the large costs and uncertainties associated with those investigations, each investigation must determine material properties as accurately, reliably and efficiently as possible. RBSTs are a critical technological component in that process and their use for Reclamation projects should be investigated.

Sampling concrete for laboratory testing can be difficult due to the large diameter of specimens required, and the difficulty in obtaining high quality samples at the depths of interest. This device will allow testing of materials in a boring to better target depths for laboratory testing.

The RBST device can be used to determine shear strengths of transition materials in-situ. Sites underlain by transition materials are located in all of Reclamation's regions. At this time, the only way to characterize the transition materials is laboratory testing, which may not provide accurate results about field performance, leading to epistemic uncertainty.

The S&T funds were used to perform a background review of the RBST device, and fund some initial conceptual designs. A small portion was used to make purchases of components to guide the preliminary design stages.

Next Steps

The Dam Safety Technology Development Program is funding the construction and laboratory-scale commissioning of this device during FY19 and FY20. The S&T and Dam Safety funds have been used to develop preliminary design drawings and purchase components to construct the device. At this time, the intent is to have a functioning device early in FY20 and use the remainder of FY20 for laboratory scale commissioning tests.

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