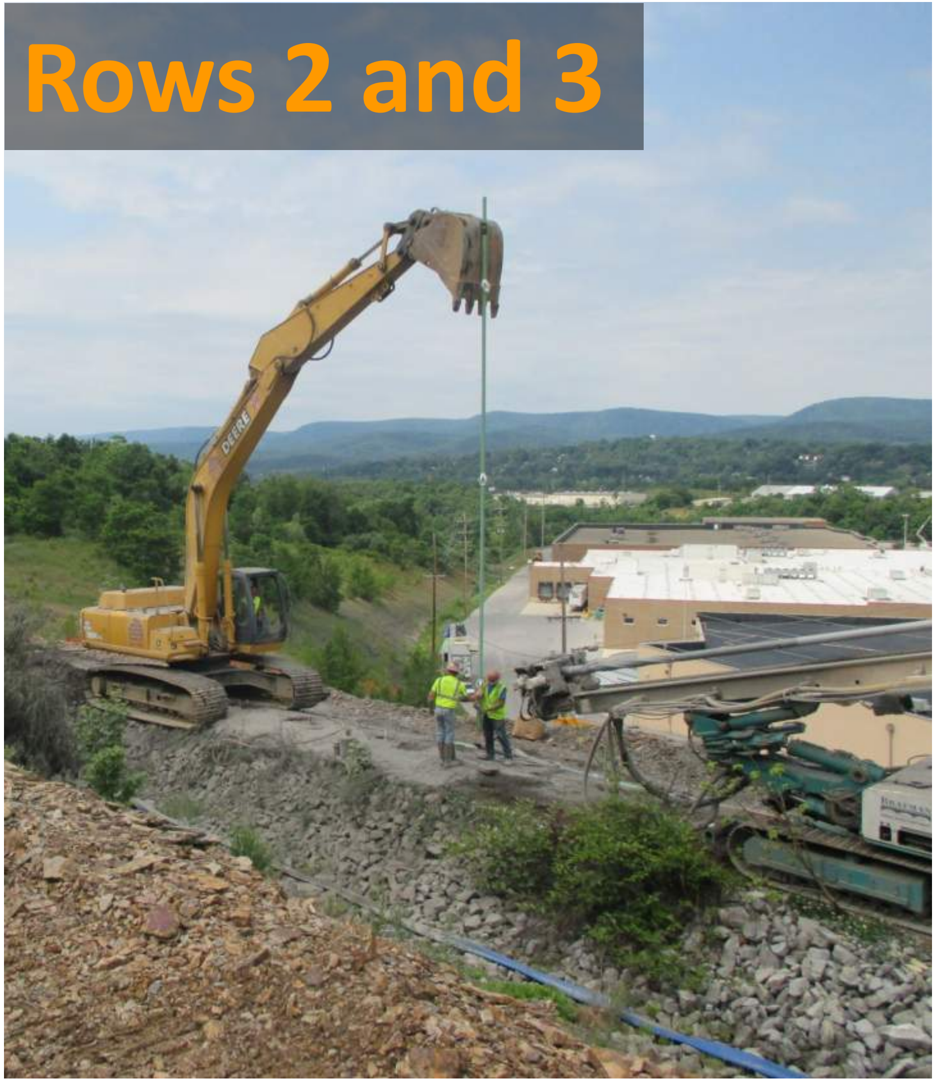
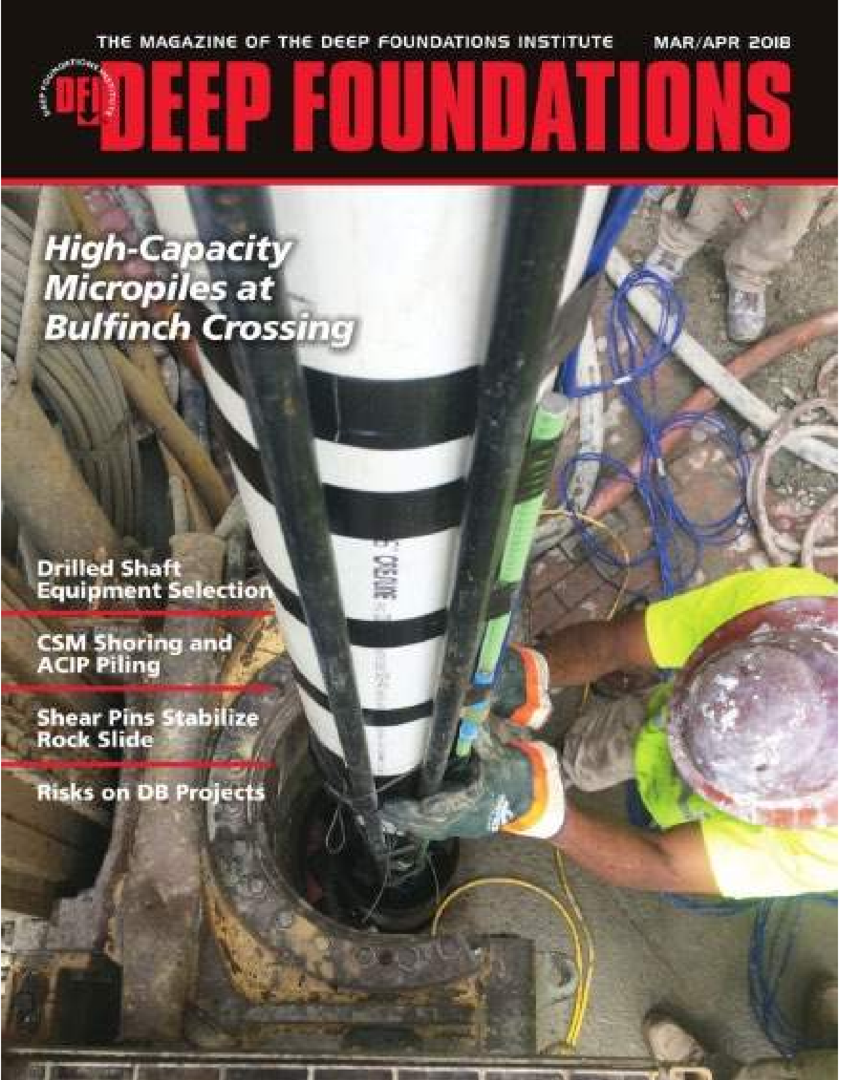
Row 1, micropile 1

Rows 2 and 3




Final Product

http://dfi.dcatalog.com/v/March-April-2018/?page=83



Tension crack along top of the cut

FEATURE ARTICLE

Emergency Rock Slide Stabilization with Shear Pins

On Easter Sunday, March 27, 2016, a landslide initiated in an existing rock cut located uphill from a shopping plaza in Altoona, Pa. The landslide created tension cracking along the existing rock cut, and during a period of weeks the tension cracks expanded from inches to feet (mm to meters). Survey readings indicated that portions of the slide were moving at a rate of approximately 2 in/day (5 cm/day). In addition to the shopping plaza, high voltage electric lines and an underground gas line ran along the base of the rock cut, further prioritizing the need to mitigate the failure as quickly as possible. Due to the rate at which the rock mass was sliding and the associated potential danger below, a plan was rapidly implemented to secure the hillside. The plan involved constructing a temporary rock buttress, removing most of the slide mass, securing the bedrock upslope of the tension crack with shear pins, and final reconstruction and grading of the slope. The inherent danger that quickly developed from the slide failure led to intense media coverage, with some positive and negative impacts.

Slope Failure and Preliminary Investigation

The failure of the slope was first observed when tension cracks were discovered along the top of the rock cut, which was constructed more than a decade before the failure. Once the failure was identified, the site owner quickly began an investigation and contacted The EADS Group for engineering services (slide monitoring and project coordination) and A.G.E.S. for geotechnical design of the slide remediation. The site investigation was performed as quickly as possible, and revealed that bedrock along the cut consisted of sandstone with interbedded shale with a bedding dip of about 16 degrees. The orientation of the dip was downslope along and toward the cut.

A drainage ditch was present upslope of the failure scarp, and was intended to divert water from wetlands upslope. It was noted that trees were growing along the drainage ditch. Water flow within the ditch seemed to "disappear" in the region closer to the scarp. It was believed that surface runoff had been flowing into the slide rather than following the path of the constructed drainage ditch. Water could be heard flowing within the tension cracks of the slope failure, and seepage was observed along the slope. In an effort to reduce future movement, the water in the ditch (region of groundwater infiltration) was temporarily diverted by pumping until the ditch and slide could be repaired.

Tension crack at the back of the slide mass

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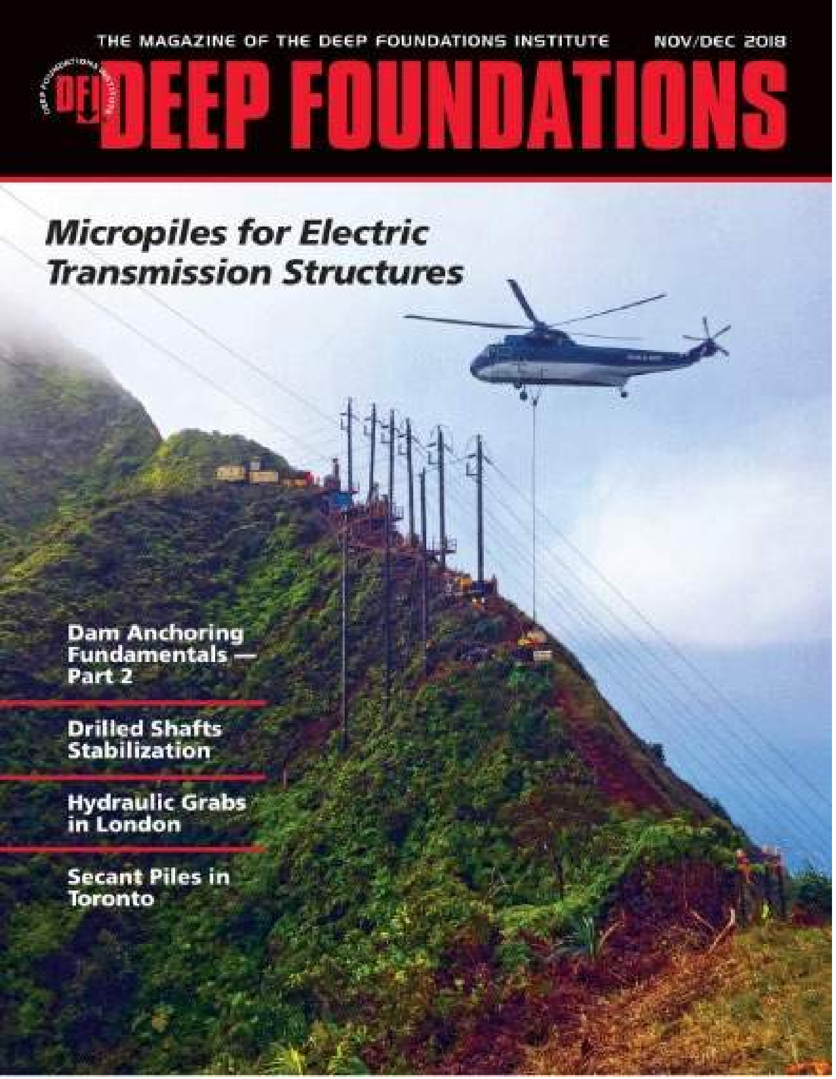

http://dfi.dcatalog.com/v/November-December-2018/?page=83

Embankment Stabilization with Drilled Shafts

There are many different alternatives to stabilizing large-scale slopes that are commonly utilized on geotechnical engineering related projects in both the private and public sector, including:

- Remove and replace – over-excavate unsuitable material and backfill with competent material (e.g., competent soil, rock or slope reconstruction with a geosynthetic reinforced soil slope)
- Buttressing – rock toes and soil berms
- Retaining walls, with and without ground anchors – soldier pile-and-lagging and sheetpiling
- Ground anchors – soil nailing and rock anchors

However, these techniques are sometimes impractical from both a constructability and stability point of view.

While effective, slope stabilization with deep foundations, such as drilled shafts or micropiles, has not been used widely used due to a lack of published design procedures and familiarity. Generally, micropiles are limited to smaller capacities than drilled shafts, and may have longer installation times due to the larger number of elements. The design procedures of the drilled shafts for this application are not as standardized as for other techniques. Very few procedures or design methodologies have been published for stabilization of slopes using drilled shafts.

Published Design Procedures

The Federal Highway Administration (FHWA) *Drilled Shafts: Construction Procedures and LRFD Design Methods* circular (GEC-10, FHWA-NHI-10-016, 2010) is one of the most comprehensive design manuals regarding the design of drilled shafts for geotechnical applications. However, this document provides little insight into slope stabilization using drilled shafts and was prepared with specific focus on transportation structures and applications. The publication describes the mechanism of stabilization and common advantages of using drilled shafts, but does not include a step-by-step design procedure. Specifically, it is noted that drilled shafts are beneficial due to the flexibility of installation techniques and the fact that drilled shafts can be installed with less soil disturbance than other alternatives, such as driving sheetpiles, reconstructing slopes, etc. Limited slope disturbance is particularly important when stabilizing large scale slopes or slopes that have previously failed.

Ohio Department of Transportation (ODOT) developed a general procedure for landslide stabilization using drilled shafts: *Geotechnical Bulletin GB-7 Drilled Shaft Landslide Stabilization Design* (Nov. 20, 2014). This document is specific to landslide stabilization and provides significant detail in determining the location of the slide surface and designing the drilled shafts based on the subsurface

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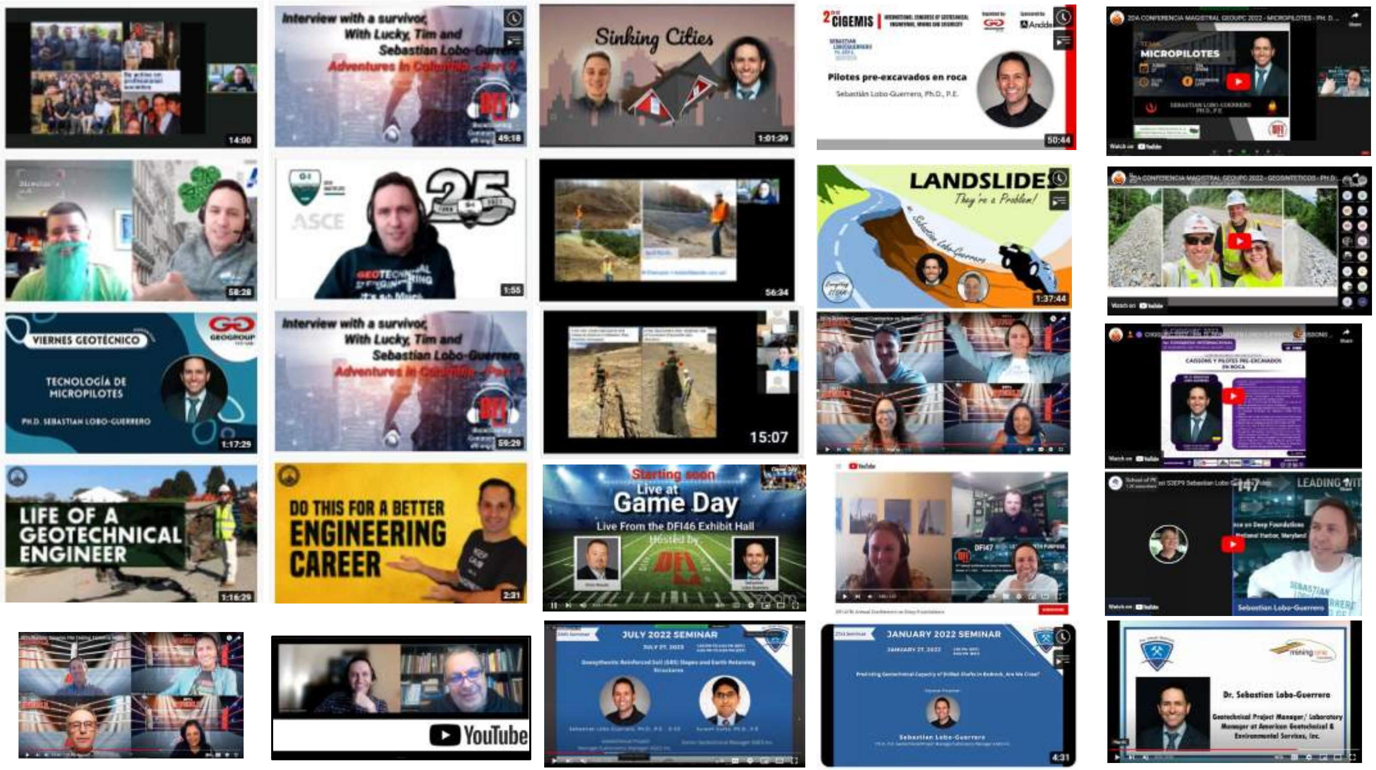
Additional Examples


HOWARD
HOWARD

Conclusions

- Cost effective
- Structural design controls. Shear in rock, bending on soils. FS independent
- Geotech: global stability → unbalanced force. Embedment below failure plane. FS independent
- Spacing along a row 3 x D / between rows 6 x D

YouTube: Sebastian Lobo-Guerrero



Also available at: www.agescup.wordpress.

Thanks! LinkedIn: Sebastian Lobo-Guerrero