GEOTECHNICAL PRACTICE PUBLICATION NO. 13

Rocky Mountain Geo-Conference 2021

Proceedings of the Rocky Mountain Geo-Conference 2021

Westminster, Colorado
April 16, 2021

Edited by
Jere A. Strickland, P.E.
Richard L. Wiltshire, P.E.

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SPONSORED BY
The Geo-Institute of the American Society of Civil Engineers

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Front cover: Mount Carmel retaining wall, Zion National Park. Photograph by James Arthur, Federal Highway Administration. Used with permission.

Preface

Since 1984, the ASCE Geo-Institute Chapter of the Colorado Section, in collaboration with the Mile High Chapter of the Association of Environmental and Engineering Geologists and the Colorado Association of Geotechnical Engineers, has organized a biennial series of conferences on a wide variety of geotechnical and geologic themes that are attended by civil/geotechnical engineers, geologists, and other geo-professionals. The geotechnical conferences are held at area universities or hotels and offer the opportunity for sharing ideas and experiences among Colorado's diverse geo-disciplines. Since 2004, ASCE's Geo-Institute has published the papers of these conferences in a total of nine Geotechnical Practice Publications, allowing the experiences to be shared with a worldwide audience.

The Steering Committee convened in September 2019 and held monthly meetings to plan for the 2020 Biennial Rocky Mountain Geo-Conference. The Steering Committee convened in September 2019 and held monthly meetings to plan for the 2020 Biennial Rocky Mountain Geo-Conference. Although originally planned for November of 2020, the Covid-19 virus caused a delay in the conference which was ultimately presented as a hybrid virtual and in person conference in April of 2021. The Steering Committee will still plan on presenting another conference in 2022. The Steering Committee members included Christoph Goss (Conference Chair), Lindsay Tita (Vice Conference Chair), James Arthurs, Joel Jackson, Evan Lindenbach, Joels Malama, Cameron Mang, Ryan Marsters, James Olsen, Nicolas Potter, Will Rausch, Becky Roland, Jere Strickland, Tom Szynakiewicz, Tom Terry, Nathan Thompson, Mark Vessely, Chris Wienecke and Richard Wiltshire.

Jere Strickland, Richard Wiltshire, and Joels Malama

Acknowledgments

The Steering Committee wishes to take this opportunity to thank all of the authors and reviewers of our papers, which are herein presented as Geotechnical Practice Publication No. 13. The authors have spent many hours in preparing and finalizing their papers, which will be presented at the 2021 biennial Rocky Mountain Geo-Conference on April 16, 2021. These papers have been reviewed by a volunteer group of Denver area geo-professionals who put in their valuable time and helped make these papers even better. The Geo-Institute's Committee on Technical Publications completed its review of our papers in a very timely manner and their adherence to our aggressive publication schedule is greatly appreciated. We would also like to acknowledge the assistance of Donna Dickert, ASCE Acquisitions Editor and Corinne Addison, Manager ASCE Book Productions, and Kenneth Fishman, Technical Publications Committee Geo-Institute of ASCE, for putting this publication together. Last but not least, we would like to thank and acknowledge the sponsors and exhibitors of this year's conference. Without their support, we would not be able to offer the incredible experience that the Rocky Mountain Geo-Conference has become known for.

Contents

U.S. 36 Emergency Project—Geofoam Fill to Support Urban Roadway Traffic

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ABSTRACT

An approximately 35-foot-high retaining wall supporting eastbound U.S. Highway 36 near Milepost 49.8 experienced a failure of the foundation materials below the wall system, resulting in closure of eastbound U.S. 36 on July 12, 2019. Vertical downward movement of the wall system was in excess of 8 ft by the end of July 2019. To assist the Colorado Department of Transportation (CDOT) in designing a repair option and to facilitate rebuilding the wall system, RJ Engineering and Consulting, Inc. (RJ) worked as a geotechnical sub-consultant designer to restore traffic within 12 weeks of the initial failure. This paper presents our evaluation, analysis, design, and monitoring for the rebuild of the wall system that utilized more than 23,000 cy of geofoam also known as expanded polystyrene (EPS) and drilled shafts (caissons) for global stability support. Peak and residual shear strength parameters used in the stability evaluation and analysis including the use of both phi (internal friction angle) and cohesion shear strength parameters are described and discussed.

INTRODUCTION

An approximately 35-foot-high retaining wall along eastbound US 36 experienced a foundation failure, which resulted in the closure of the eastbound lanes on July 12, 2019. Vertical movement of the retaining wall system was in excess of eight feet by the end of July 2019. To assist CDOT in designing a repair solution and to facilitate rebuilding the retaining wall system, RJ worked as the geotechnical engineering sub-consultant with David Evans and Associates, Inc. to provide the mitigation design for the emergency repair.

Through ongoing progress meetings and input from the CDOT Chief Engineer, the design team was directed to provide an expedited mitigation design and a proposed construction schedule with the goal of providing a safe, long-term solution that could be implemented quickly to restore all lanes of eastbound US 36 to service. Mitigation or wall-rebuild options, such as bridges, mechanically stabilized earth (MSE) structural foundations systems, closure of the entire US 36 for construction, etc. were not considered because those options would require more than a few months to construct.

RJ suggested a geofoam-fill retaining wall option to address the stability issues at the site and to provide for an expedited method of construction based on previous project experience that RJ personnel had with geofoam projects for embankment and landslide failures in Colorado. The geofoam sites were located along US 160 at Mileposts (MP) 69.8,74.1, and 75.1; US 50 at Mileposts 104.6 and 108; and SH 13 at MP 15.9 (Arndt, 2016 and Arndt, 2009).

DISCLAIMER AND INTENT OF THE PAPER

The intent of the paper is to provide an overview of the emergency geotechnical response design mitigation that was undertaken by RJ and CDOT to rebuild US 36 in an expedited manner. The paper discusses observations by RJ from July 13, 2019 forward.

The goal of the paper is to provide a case history which utilized lightweight geofoam fill as a mitigation option that was undertaken and proposed to CDOT to begin rebuilding the roadway in a matter of days. Subsequent geotechnical investigations and laboratory testing was conducted by others to verify our initial design assumptions but are not the focus of this paper.

Furthermore, one of the basic reasons we undertook writing this paper is to discuss how reasonable shear strength results can be integrated into slope stability modeling. The evaluation and analysis method should be straightforward and not overly complex. Our intent is to show a reasonable, no-nonsense, approach to using basic direct shear data and incorporating it into what we consider "useful" stability modeling. We believe that in many cases it is possible to perform direct shear testing and global stability analysis ad nauseum and still have models and parameters that we do not consider reasonable for the site conditions.

As stated by George Box, a British statistician, "…all models are approximations. Essentially, all models are wrong, but some are useful. However, the approximate nature of the model must always be borne in mind." (Box, 1987).

Site Geology

The wall system was founded in the overburden and fill materials above the Arapahoe Formation (Ka) as shown in Figure 1. The Arapahoe is an olive-gray to bluish-gray claystone and siltstone, and a light gray to light-orange-brown (weathered) fine-grained sandstone with a thickness about 400 feet (Machette, 1977). Reported montmorillonite or mixed-layered illite-montmorillonite is the main clay mineral in the claystone along with minor amounts of illite and kaolinite (Shroba, 1996).

DISCUSSION OF MSE WALL GLOBAL STABILITY AND SOIL PROPERTIES USED FOR DESIGN

On July 13, 2019, observations by CDOT indicated that the retaining wall near MP 49.8 was experiencing a global failure of the underlying overburden and fill soil materials. Photographs 1 2, and 3 depict the failing retaining wall system.

Discussion on Geotechnical Investigation and Laboratory Testing

Initially, CDOT Geotechnical drilled one boring at the toe of the failing wall on July 13, 2019. CDOT Geotechnical completed the boring and moved off site due to safety concerns as the MSE wall was actively failing from above the drilling location. CDOT Geotechnical was able to install a PVC standpipe in the borehole. The standpipe sheared off slightly above the bedrock surface by the following day (July 14, 2019). Laboratory testing (Unified Soil Classification System) from CDOT's initial boring suggested the subsurface materials underlying the wall consisted of high plasticity clays (CH) with a plasticity index ranging from 36 to 44 and liquid limits ranging

from 51 to 58. Due to the time constraints of the project this boring and laboratory data was used as the basis for the preliminary design.

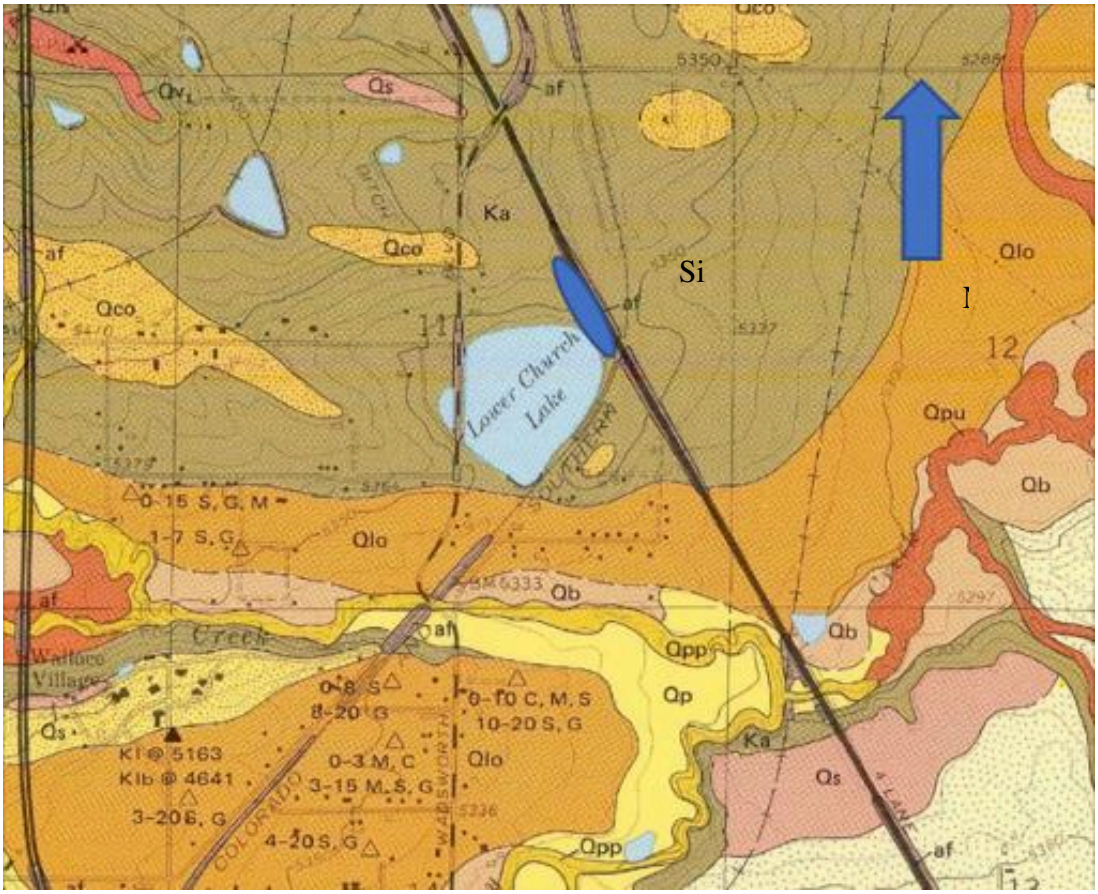

FIGURE 1. Geology Map in the Vicinity of US 36 - MP 50
The area of the wall failure is approximated by the blue oval.

Further geotechnical drilling occurred (by others) after the failed section of the wall had been removed as part of the emergency rebuild, which was used to verify the initial design assumptions. In general, the additional testing in the vicinity below the wall foundation suggested similar CH materials in the range of the initial CDOT boring as described above.

As part of the laboratory testing, three California samples were selected for direct shear testing in general accordance with ASTM D3080. Rather than describing a long and lengthy dissertation on direct shear testing, suffice to say we were provided with results from three direct shear tests from materials near the base of the wall. The individual samples were run at three different load scenarios ranging from 3,000 to 8,000 psf confining pressures with initial saturation ranging from 80 percent to 92 percent and at-test saturation of 100 percent. Water contents of the samples ranged from 16 percent to 20 percent during testing. The test results were reported as a peak shear strength and residual shear strength. Peak shear strength was reported after the initial shear run. Residual shear was reported after shearing the sample two more times. Table 1 is a summary of the reported cohesion and phi values.

PHOTOGRAPH 1. US 36 Looking East along Eastbound Lanes on July 18, 2019 Wall supporting US 36 has dropped vertically more than 5 feet and moved laterally to the right more than 3 feet.

PHOTOGRAPH 2. US 36 Looking West along Eastbound Lanes on July 16, 2019 Note the lateral offset of the pedestrian guard rail barrier to the left.