GEOTECHNICAL PRACTICE PUBLICATION NO. 12

Rocky Mountain Geo-Conference 2018

Proceedings of the Rocky Mountain Geo-Conference 2018

Golden, Colorado
November 2, 2018

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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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 eight Geotechnical Practice Publications, allowing the experiences to be shared with a worldwide audience.

The Steering Committee convened in August 2017 and held monthly meetings to plan for the 2018 Biennial Rocky Mountain Geo-Conference. The Steering Committee members included Christoph Goss (Conference Chair), Lindsay Tita (Vice Conference Chair), James Arthurs, Eric Bergstrom, Mark Brooks, Robin Dornfest, Darin Duran, Evan Lindenbach, Joels Malama, Cameron Mang, Ryan Marsters, Minal Parekh, Nicolas Potter, Will Rausch, Robert Redd, Becky Roland, Jere Strickland, Tom Terry, Nate 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. 12. The authors have spent many hours in preparing and finalizing their papers, which will be presented at the 2018 biennial Rocky Mountain Geo-Conference on November 2, 2018. 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's Acquisitions Editor and Diane Swecker, Senior Technical Manager, 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

Pikes Peak: Subsurface Conditions and New Summit Visitor Center Foundation Design

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ABSTRACT

Standing at 14,115 ft above sea level, Pikes Peak is the 31st highest of Colorado's 54 fourteeners and is one of the most visited mountains in North America. Subsurface conditions at the summit consist of an active soil layer of in-place weathered Pikes Peak granite subject to seasonal freeze/thaw cycles, underlain by an intermediate and unstable ice-rich permafrost zone, followed by bedrock with subfreezing temperatures. The current summit house was constructed in the early 1960s with a shallow foundation bottomed in the active overburden layer and has suffered from differential heave and settlement associated with freezing and thawing. Pikes Peak—America's Mountain is planning a new summit visitor center to replace the current facility which will be founded on spread footings bottomed on the lower, massive Pikes Peak granite. Micro-pile foundations, isolated from the active and ice-rich permafrost zones will support a series of designated walkways throughout the summit. The purpose of this paper is to present the subsurface conditions determined by a series of geotechnical investigations in preparation for the new summit visitor center, document some of the geotechnical challenges associated with construction on Pikes Peak, and describe the proposed geotechnical solutions to be incorporated in the summit complex design.

INTRODUCTION

Standing at 14,115 ft above sea level, Pikes Peak is the 31st highest of Colorado's 54 fourteeners. Pikes Peak is one of the most visited mountains in North America and is a top tourist destination in Colorado with an estimated 750,000 visitors annually. A paved road to the summit makes the mountain accessible to both young and old, to those in good health and to many with disabilities. The Broadmoor Pikes Peak Cog Railway began service to the peak from Manitou Springs in 1891 and is also a convenient way for many to visit the peak.

The land at the summit above the 14,000 ft contour is part of Pike National Forest under the administration of the US Forest Service (USFS) and is listed as a National Historic Landmark. The Pikes Peak Highway, the Summit House, and other summit infrastructure is operated and maintained by Pikes Peak – America's Mountain (PPAM), an enterprise of the City of Colorado Springs, via a special use permit from the USFS.

The top of the peak is relatively level but has been graded at various points in its history to accommodate access roads, parking areas, and facility construction. The existing Summit House is located in the northeast quadrant of the developed area and consists of a one-story building. There are also three other small one-story structures, the Overlook/Plant building in the southeast quadrant, the Colorado Springs Utilities building in the south-central area and the US Army High Altitude Research Lab (HARL) in the west-central portion of the developed mountain top. The tracks for the Cog Railway traverse the east crest, terminating at the existing Summit House. Undeveloped boulder fields exist in the central portions of the mountain top and to the west of the loop access road. Figure 1 shows the locations of these features.

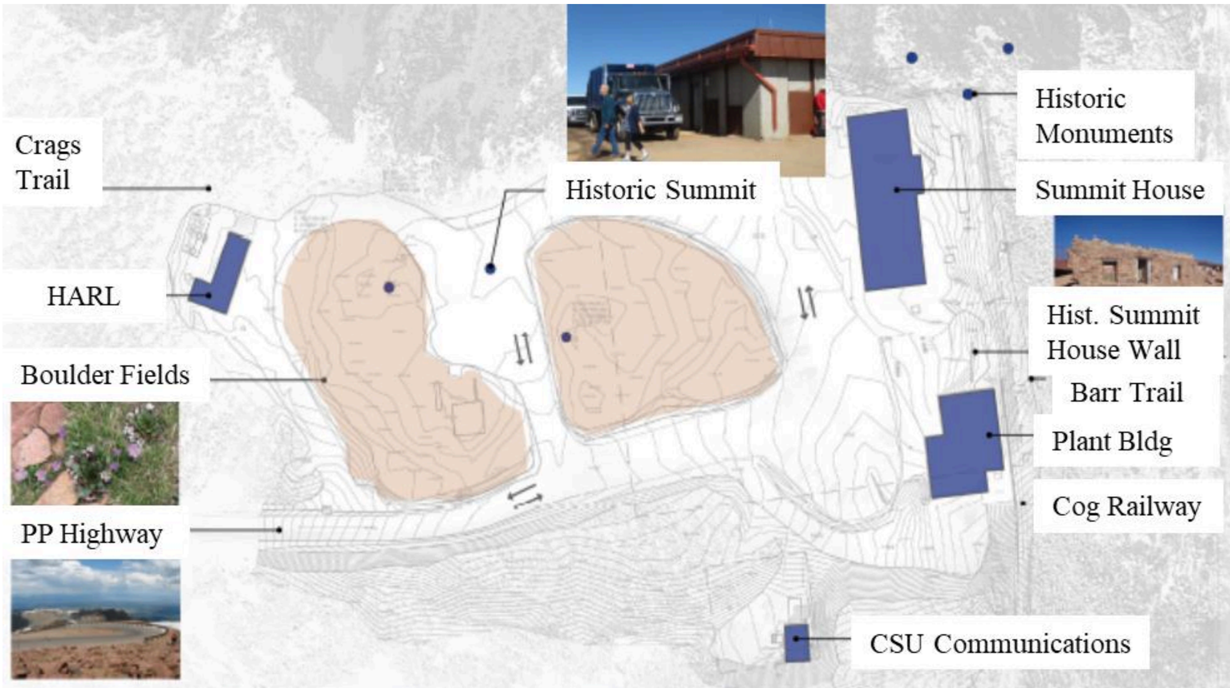

FIGURE 1. Current Development on Pikes Peak (Colorado Springs 2018)

Subsurface conditions generally consist of alpine permafrost over bedrock, the specific details of which will be discussed in significant detail later in this paper. The conditions are similar to Arctic or Antarctic permafrost over bedrock situations (CRREL 2017) although they are somewhat unique in Colorado due to the presence of permafrost only at high altitudes.

The existing Summit House was constructed in the early 1960's using a reinforced concrete mat over a steel beam grid supported by a fill pad that consisted of 3 ft of densely compacted sand and gravel. The building began experiencing differential settlements early in its life due to the heat within the structure melting the permafrost below. Some of the settlements over time were extensive enough that the structure could not be occupied temporarily until repairs were made.

Due to the age and foundation problems of the current facility, coupled with the desire to provide an improved visitor experience at the summit, PPAM is planning a new 39,180 square foot Summit Visitor Center to replace the current facility. The stated goal of the design team is to "find the perfect balance between a dynamic building that presents a clear destination to visitors and a minimalist structure deferential to the Peak and its majestic views" (Colorado Springs 2018).

GEOLOGIC SETTING

The summit of Pikes Peak is approximately 15 miles west of Colorado Springs. Pikes Peak is part of the Pikes Peak Granite batholith with an exposed area of approximately 1,200 square miles (3,100 km^2) (Tweto 1980). The batholith is bounded on the east by the Rampart Range and Ute Pass faults and intrudes into older granites and metamorphic rock on its other boundaries

(Smith et al. 1999, Carroll and Crawford 2000, Thorson et al. 2001, Keller et al. 2005). It extends from southern Colorado Springs up to the latitude of Castle Rock in the north, and extends approximately 40 miles west of the fault zones on its eastern boundary. Based on the results of aeromagnetic mapping, as much as half of the batholith area may be unexposed beneath the ground surface (Noblett et al. 1987).

TABLE 1. Annual Weather Summary at Pikes Peak, 1874 to 1888, After HLA (1987)

Parameter	Mean	Max	Min
Total precipitation (in.)	29.7	44.6	9.4
Average maximum temperature (°F)	26	29	25
Average temperature (°F)	20	22	18
Average minimum temperature (°F)	13	16	11
Average wind speed (mph)	21	22	19
Average barometric pressure (in. mercury)	17.75	17.79	17.72

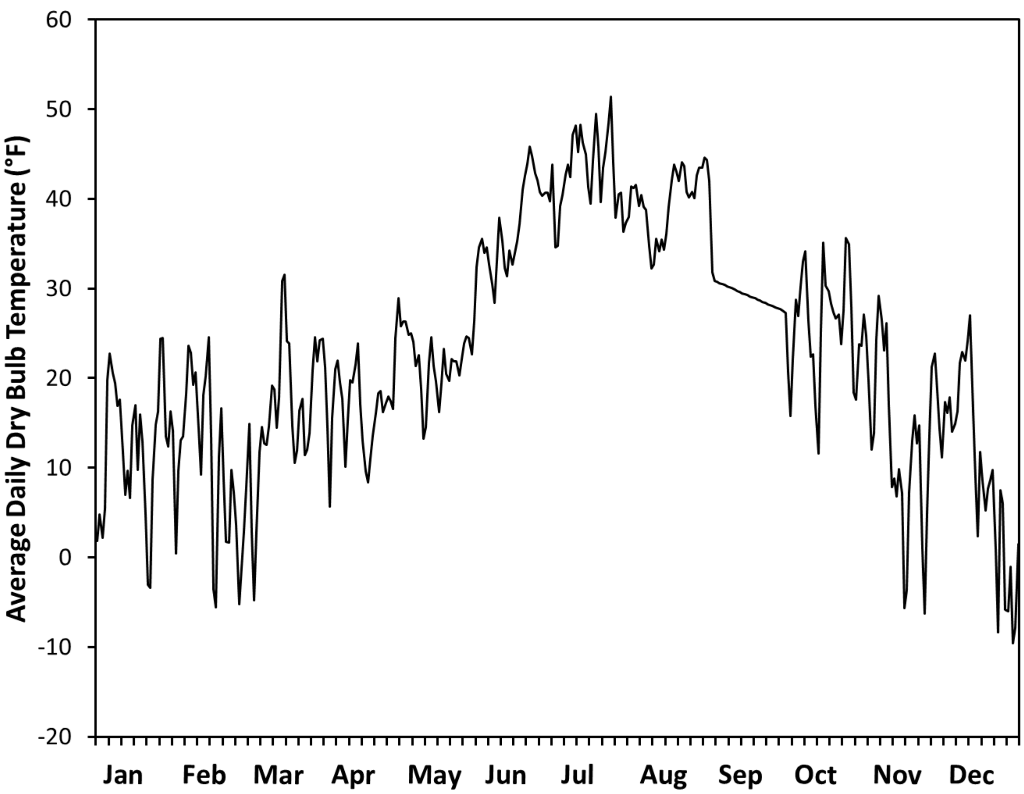

FIGURE 2. Pikes Peak Average Daily Temperature

Finlay (1916) was one of the first to describe and map the geology of the Pikes Peak region. He described the Pikes Peak Granite as “remarkably uniform in texture and composition throughout large areas,” noting that the “mesh of coarse interlocking grains is easily ruptured by frost, and the rock goes to pieces by disintegration, forming a characteristic angular gravel that is widely distributed as a mantle on long, low divides.” Pikes Peak granite is a coarse-grained granite composed of alkalic feldspar, quartz and biotite; its color, mostly light pink, is due to the abundance of the feldspar (Finlay 1916). Noblett et al. (1987) described the granite as a coarse-