Engineering
UPDATE©

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FOUNDATION RECOMMENDATIONS RESULT IN UNNECESSARY LARGE COST

This update concerns a case where a more well thought out geotechnical investigation which would have cost a little more could have saved millions of dollars and a significant amount of lost time. This project involves an assessment of the swell potential of weathered to fresh rock, the foundation system chosen, and the repair of mushroomed piers (see Figure 1). Mushroomed concrete piers are the result of pouring against the naturally formed widening of the drill hole made to install the pier.

FIGURE 1 TYPICAL PICTURE SHOWING THE MUSHROOMING OF THE PIER TOP

The contract for this project involved the construction of 7 structures and a total of 705 drilled piers. After a preliminary geotechnical investigation of several sites, this location was chosen for construction. Through analyzing laboratory tests of the soil and rock samples, the geotechnical engineer recommended pier foundations to be used at this site. The design and guidelines for execution were presented with clearly assigned responsibilities of each party within the project. Everything seemed to be in order until the work started. The grading of the surface and drilling for pier installation was found to be more difficult than expected. This caused delays and deviations from the specifications. It was not until after completion and payment for the work that the owner, the structural engineer, and the construction manager insisted the drilled pier installations were defective and had to be corrected.

What went wrong? Was it the design of the foundation or its execution? Was it the subsurface conditions or wrong choice of the equipment used? An investigation was requested to resolve these questions. MEA was asked to investigate the reasons behind the resulting construction difficulties. After a thorough forensic geotechnical investigation, MEA was able to shed light on the shortcomings of the project.

MEA made field visits to do geotechnical reconnaissance. Literature survey and laboratory tests conducted on the samples revealed that the actual rocks at the site are limestone and micrite of the Niobara Formation, contrary to the geotechnical engineers' classification as Pierre Shale Formation. The latter formation is notoriously known in Colorado by its swell or heave potential. Based on this fault classification and a few anomalous swell tests, the geotechnical engineer considered the ground to be highly expansive and rather than using regular spread foundations, an expensive drilled pier-structural floor system was chosen for all the structures. This foundation system caused the cost to increase significantly. Later on the structural engineer raised concern over the execution of the piers as some of these piers were mushroomed near the top (the diameter was bigger at the top). This can cause significant stresses in the piers upon swelling of the ground as shown in Figure 2. There was no provision in the contract to use cylindrical carton "Sondex" near the top section of the pier to prevent mushrooming. To relieve this concern the owner decided to chip off the mushrooms of a significant number of piers. This costly action was based on an unfounded fear of high swelling pressure induced by the shale. The fact that the typical weathered rock foundation was not this shale and exhibited lower swell pressures resulted in overestimating the design forces and caused the owner to choose the wrong foundation type and later on to carry out costly and unnecessary remediation actions. Figure 3 below shows the range of swell pressure as determined in the lab on many weathered rock samples collected at different locations at the site. The figure shows that 90% of the samples showed a swell pressure of 3000 psf or less. This is 30% of the design swell pressure value of 10,000 psf.

At some locations, the contractor encountered harder than expected rock, and the use of a bucket or helical auger resulted in construction delays and significant changes in the original pier specifications. The use of either method of drilling would render the basic intent to avoid mushrooming at the tops of the piers futile as drilling in hard rock using either method caused the drill bit to wander. The action of the drill bit and gravity

movement of soil and weathered rock into the hole resulted in instability at the upper portion of the drill holes and S-shaped piers. Better choice and planning of equipment would have prevented this. The S-shaped piers typically develop in the hard rock areas, where the bit would tend to wander during drilling through alternate hard and weathered horizons. Some of the piers ended up with mushroomed tops, which could be detrimental in expansive soils as shown below, but this was not the case for this site.

This case study shows that a poor geotechnical investigation program caused several problems which included:

- The choice of a very expensive foundation system
- Construction delays due to encountering unexpected hard rock
- Carrying out unnecessary costly remedial measures
- More inspection and administrative man hours and testing costs charged to the client.

The client should be aware of the fact that some firms offer low-ball investigation and design prices so they can be in a good position to provide the engineering inspection and testing services of the construction materials. The lack of a thorough geotechnical investigation leaves the designer no option other than to be conservative and this can be very costly.

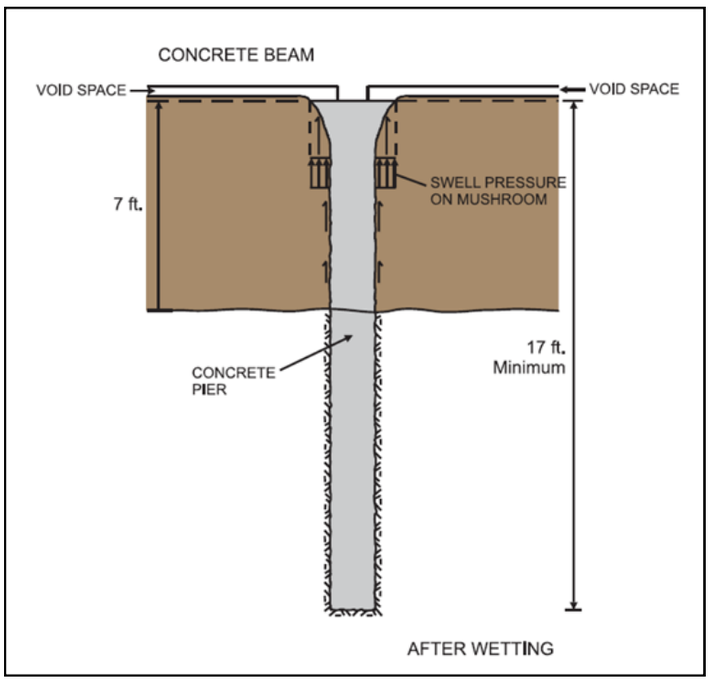

FIGURE 2 MUSHROOM STRESS ANALYSIS

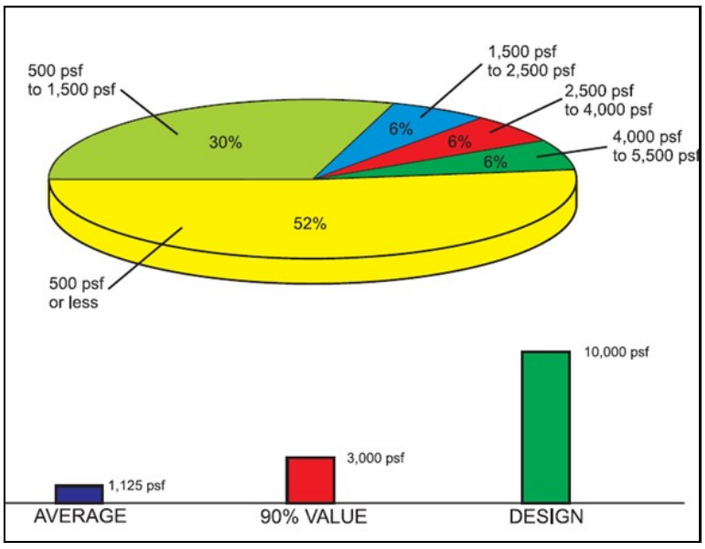

FIGURE 3 DISTRIBUTION OF SWELL PRESSURE RESULTS FOR WEATHERED ROCK

Other Engineering UPDATES of Interest:

UPDATE 8: Geotechnical Investigation of Building Damage

UPDATE 7: Soil Provides Poor Road Construction Support

UPDATE 9: Hard Excavation Dispute

ABOUT MEA: Marino Engineering Associates, Inc. focuses on engineering research, practice and expert evaluations and is licensed in 24 states in the U.S. Our projects primarily have an emphasis on Geotechnical Engineering, however, we also have significant experience in projects involving transportation, subsidence engineering, laboratory testing, training, and geophysical exploration. Gennaro G. Marino, Ph.D., P.E., D.GE is president and principal engineer of Marino Engineering Associates, Inc., and has been a licensed professional engineer since 1984. To obtain additional information on MEA, one can also visit our website at www.meacorporation.com.

FOR MORE INFORMATION: There is a significant amount of additional information that is available on the above subject. For more information, please contact Dr. Marino at the address listed below.

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