LIQUEFACTION POTENTIAL & POST EARTHQUAKE STABILITY ASSESSMENT 50% REPORT

Project ID: CEEn_2016CPST_013

by

H2J Engineering

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Executive Summary

Currently the factor of safety calculations and cross sections are on the verge of completion. Parameters concerning the general soil characteristics have been gathered and tabulated. What remains is to determine characteristics of the seismic activity in the region. Analysis is being done using principles from studies done by Idriss and Boulanger on a deterministic level. Later on performance analysis will be applied if time permits. Several cross sections have been completed and the rest are on schedule to be finished for the final analysis and report. Details left to be completed include the presentation material, the final analysis for factors of safety, and the completion of the report.

Introduction

PROJECT TITLE: Post-Liquefaction & Earthquake Stability Assessment

PROJECT ID: CEEn-2016CPST-013

PROJECT SPONSOR: AECOM

TEAM NAME: H2J Engineering

This Project has proved to be a very straightforward example of earthquake liquefaction potential. The boring logs that were presented for the analysis provide sufficient information to determine the general soil characteristics. Using data from the USGS on earthquake intensities and these soil profiles this information can then be used to make an accurate summary of the soil strength and expected loading. This is basic soil mechanics and was not too difficult to perform. Most of the researching was centered on how to take this data and make an accurate prediction of the factor of safety under an average earthquake. The tools that were researched and built to help with this prediction are featured in the body of this report.

Report

To get an accurate picture and to make an effective presentation of the ground underneath the BRT project it was necessary to draw AutoCAD representations of the expected soil layers. Figure 1. displays one of the completed AutoCAD pictures. The general layout of the soil can be seen in the figure and can be used to visualize what a potential liquefaction scenario might cause and what surface displacements might result. Later versions of these soil profiles will be written in color to more easily distinguish the layers. Layers were generally taken to be continuous and changed linearly throughout the span of the sampling area. Very few abrupt changes were necessary to make an adequate picture.

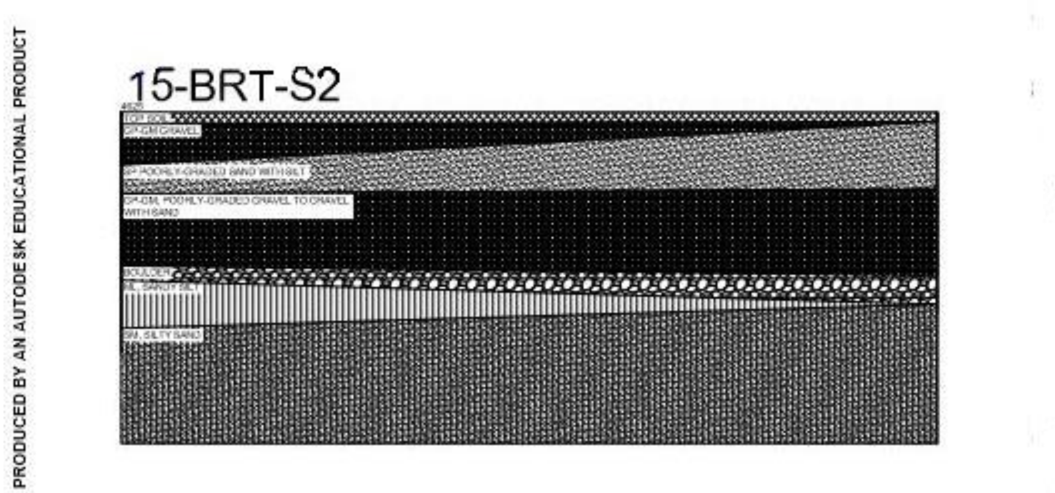

Figure 1. AutoCAD cross section of soil sample for are around sampling location 15-BRT-S2

The three profiles for all the boring holes are on schedule for completion. These three profiles will show an overall view of all the data collected and give a 3-dimensional perspective to this analysis. A diagram showing the layout of these profiles superimposed on the map provided by AECOM of the boring logs is shown below in Figure 2. These locations were chosen because the provide cross sections at both ends and down the center of the highway. This way soil behavior can be accounted for in multiple directions.

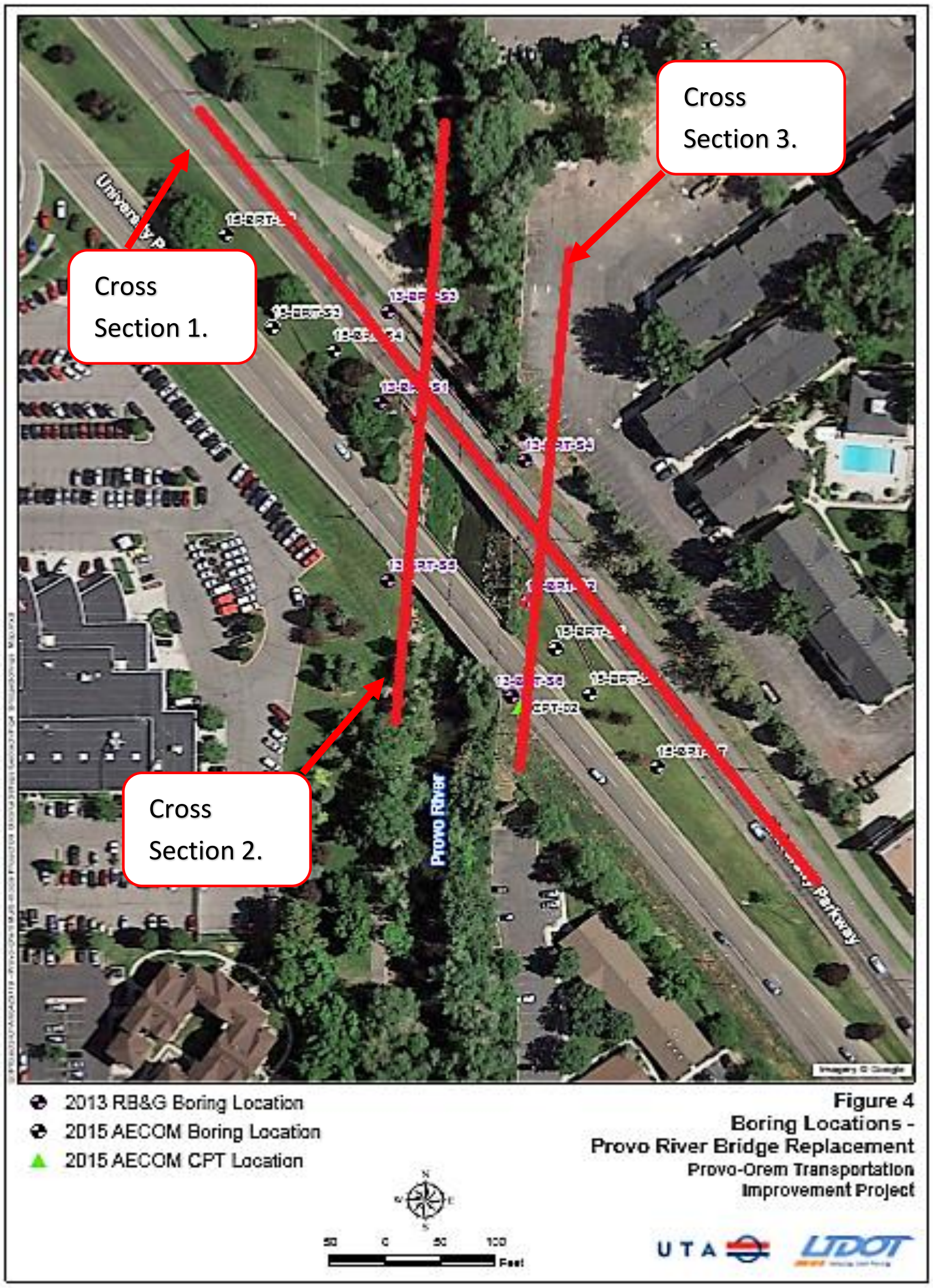

Figure 2. Aerial view of cross sections layouts for final report.

Most the research that has been done on this project centers around the calculations for factors of safety against liquefaction. These factors of safety allow us to know exactly how likely it is that a specific layer in the soil will undergo liquefaction during a given earthquake. To better understand the process necessary to predict the behavior of soil under earthquake conditions a deterministic approach was used. This means that all parameters for earthquake intensity are assumed to be for the average earthquake and then from that we find the factors of safety for each soil layer. To perform this analysis equations developed by Idriss and Boulanger were used as well as a series of commonly used correlations.

To begin with, for each layer of soil the number of $(N_1)_{60}$ blow counts, the type of soil, and any other information were tabulated. Using the blow counts both the cyclic resistance ratio and the average density for each soil type was correlated, again using work by Idriss and Boulanger. Using the density of the soil and the water table level the effective normal stress on the soil could then be calculated throughout the area of interest. These numbers give an idea of the strength of the soil in resisting an earthquake. Data concerning an actual earthquake that might occur can be obtained from the USGS hazards web site. Assuming a 50 year event the peak ground acceleration for the area could then be determined. This gives the strength of the earthquake that is expected to happen every 50 years. After understanding both the strength of the soil as well as the strength of the earthquake a factor of safety can then be correlated using the following equation.

$$FS_{Liq} = \frac{CRR_{M,\sigma\prime v}}{CSR} = \frac{CRR \cdot MSF \cdot K_\sigma \cdot K_\alpha}{0.65 \frac{a_{\max}}{g} \frac{\sigma_v}{\sigma_v'} (r_d)}$$

In this equation FS = factor of safety, CRR = cyclic resistance of the soil, CSR = cyclic stress caused by the earthquake, MSF = magnitude of the earthquake, a_{max} = the peak acceleration caused by the earthquake, σ'_v = effective stress in the soil, σ_v = normal stress in the soil, g = acceleration of gravity, r_d = distance below the surface of each soil layer, and K_σ and K_α are the initial stress states of the soil. For the two K values K_α is assumed to be 1 and K_σ can be correlated from the effective stress in the soil and the number of blows necessary to penetrate it.

Figure 3. shows an example of the spreadsheets that were designed to perform the calculations for this analysis. Generally, layers that have a factor of safety greater than 2 are considered to be safe while factors of safety between 2 and 1 indicate that the soil is close to liquefying and factors below 1 show that the soil has already liquefied. Soils that have generally been known never to liquefy are discounted in the analysis since they generally produce extremely high values that do not necessarily reflect the strength of the soil. The USGS reported a peak ground acceleration of almost 5 ft/s^2 for a magnitude 7.5 earthquake in the Provo area. This would cause significant damage in the area and may even cause damage to the road and the bridge spanning the area of interest.

Material	Depth (ft)	$(N_1)_{60}$	CRR	ρ	C_σ	K_σ	σ_v	$\sigma_{v'}$	FS
Gravel	4	24.7	0.283	129	0.161	1.10	516	516	6.8
SP(Sand)	6	43.2	13.7	104	0.300	1.10	749	749	219
Gravel	9	36.6	1.59	103	0.288	1.10	1060	1060	16.9
Gravel	11	47.4	113	128	0.300	1.10	1291	1291	989
Gravel	14	57.1	373544	132	-2.71	0.37	1681	1681	873288
Boulders	16	100	2.7332E+73	1	-0.152	0.98	1945	1820	NA
Sandy Silt	19	15.6	0.161	88	0.113	1.01	2275	1963	0.65
Sandy Silt	21	13.7	0.146	86	0.106	1.01	2449	2012	0.50
Silty Sand	23	25.1	0.292	100	0.163	1.00	2635	2073	0.88
Silt	26	10.2	0.119	85	0.093	1.00	2912	2163	0.30
Silt	29	21.0	0.219	91	0.139	0.99	3176	2240	0.46
Silt	31	7.5	0.101	84	0.084	0.99	3351	2290	0.19
Silt	34	38.5	2.61	94	0.300	0.97	3618	2370	4.25

Figure 4. Calculated values to arrive at factor of safety for soil layers at sample area 15-BRT-S2

We can see that the upper half of the soil is resistant to liquefaction while the sands and silts below the water table have a much higher susceptibility. One adjustment that will be made later is that the $(N_1)_{60}$ values need to be adjusted to their clean sand equivalents to give the best estimate possible for the correlations. This is among the final issues that still need to be resolved.

The type of deterministic analysis shown above is limited because it does not provide a range of data but instead gives engineers a view of how a structure would react under a single set of earthquake conditions. A more effective approach would be to perform a performance based analysis of the soil. Certain computer programs exist that allow for engineers to model the behavior of soil under a wide range of loadings and conditions. This allows for trends in the results to be identified and for optimization of any design improvements.

Conclusion

The project is progressing well up to this point. Most the research has been completed and all that is necessary to complete the analysis is to finish running the calculations and then complete the report. If time remains there will be an opportunity to perform a performance based analysis of the soil and to create an in-depth study of the soil under different loading conditions. From the results obtained so far there appears to be a layer below the water table that could be subject to liquefaction given a moderate intensity earthquake in the area. Overall the project is on schedule for completion and a complete picture will be available for the assessment of liquefaction potential.