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General Report - Session 8

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Commemorate the Legacy of Ralph B. Peck
April 29 - May 4, 2013 CHICAGO
Seventh International Conference on
Case Histories in Geotechnical Engineering
and Symposium in Honor of Clyde Baker

GENERAL REPORT - SESSION 8

8a. Case Histories on Forensic Geotechnical Engineering

8b. Case Histories on Health Monitoring and Retrofit of Infrastructure

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INTRODUCTION

This General Report presents a summary of the eleven (11) papers accepted for the session 8 focused on Case History of Forensic-Geotechnical Engineering and Case Histories on Health Monitoring and Retrofit of Infrastructure. The session includes discussion of Reliability of Codes; Risk Analysis Pertaining to Public Structures, Non-Destructive Evaluation and Load Testing of Drilled Shafts, Auger Cast Piles and Driven Piles, and Damage Evaluation; Advance Information, Systems in the Geotechnical Risk Predication and Assessment.

The papers originate from eight countries and cover an array of important topics in the area of forensic and geotechnical engineering. These include case histories; geotechnical-forensic engineering investigation of structures; probabilistic three dimensional modeling; behavior of laterally loaded piles; failure of helical anchors; working pile load tests; refurbished used of timber piles; and vibration effects on historic buildings. A list of the papers is assimilated in Table 1 by topic. The summary illustrated below will give the reader(s) a general overview of the focus of those papers and is intended to direct the reader to their area of interest. The activities of Session 8 also include case histories on health monitoring and retrofit of infrastructure, including bridges, tunnels, and other transportation and geotechnical structures, and their effects on existing facilities and buildings, and remediation. The Session 8 organizers greatly appreciate the efforts of the authors and commend the quality of the accepted papers.

Topic	Paper	Author(s)
Case Histories	8.05a	Petr Koudelka
Geotechnical Forensic Investigation	8.08a	Joshi, Badu-Tweneboah, Riotte, Klinger, and Cohen
Three-Dimensional Modeling	8.09a	Vahdatirad, Anderson, Ibsen, Clausen and Sorensen
Case History	8.10a	Ali, Khan, Zafar, Shehryar
Pile Load Tests	8.12a	Teymur and Sekerer
Geotechnical Forensic Investigation	8.13a	Labuda, Corley, and Murphy
Pile Load Tests	8.15a	Carroll, Hardy, and Ting
Case History	8.02b	Yang, Dai and Gong
Vibration Effects by Pile Driving	8.03b	Fernandez and Park
Forensic Investigation	8.04b	Singh
A Fast-Track Bridge Project	8.05b	Rinkel and Naida

Table 1. Session 8 papers presented in the order of topic, paper number, and author(s)

SUMMARY OF RESEARCH PAPERS

Paper 8.05a, CASE OF ULTIMATE LIMIT STATE DESIGN AND EUROCODE 7-1, by Koudelka: This paper describes the history of slow adoption of the Eurocode 7-1 Ultimate Limit State Design (ULSD) in Europe and especially in Czech Republic. The paper highlights problems in selecting parameters in view of the stress dependent properties of soils. Examples regarding analyses for slope stability, shallow foundation and pile foundations are presented. It is shown that slopes designed by the Eurocode (EC 7-1) are milder than the allowable stress method for a Factor of Safety of 1.5. The author appreciates the EC 7-1 design concept for piles as it encourages the use of pile tests. It is pointed out that for shallow foundations both the methods of design are based on geometrically dimensionless solutions and absolute size of foundation is not taken into account. This is not the state of practice as empirical methods used for design take into account the design of the foundations for allowable settlements. Recommendations for ULSD improvement in the EC 7-1 are presented. An interesting Fig-7 is included in the paper recommending Factor of safety (partial factor for slope resistance) as a function of the slope angle. The experience of the author is not much different than the adoption of the Load and Resistance Factor Method (LRFD) method in the United States (see Paper No. 8.05b of this conference). We, geotechnical engineers, want to retain the allowable stress method (ASD) approach.

Paper No. 8.08a, GEOTECHNICAL FORENSIC INVESTIGATION OF OBSERVED CRACKS ON A BUILDING IN TALLAHASSEE, FLORIDA, by Joshi, Badu-Tweneboah, Riotte, Klinger, Cohen: This paper presents the installation of vapor extraction wells in the immediate vicinity of a single-story structure and the alleged distress caused due to the same. Two (2) wells were installed 15 ft away from the existing structure at a 50 degree angle using rotosonic drilling for the purposes of vapor extraction as a part of Florida Department of Environmental Protection (FDEP) Dry Cleaning Solvent Cleanup Program. The structure's owner raised a concern about the drilling activities being a cause of the observed distress in the structure and needed assurance against further distress due to future similar activities. The authors present a detailed forensic-geotechnical evaluation of the site subsurface conditions in addition to pictorial documentation and crack monitoring to address the concerns raised by the owner. Finally the authors recommend continued monitoring as well as recommendations for alleviating the various causes of distress in the structure.

Paper No. 8.09a, PROBABILISTIC THREE-DIMENSIONAL MODEL OF AB OFFSHORE MONOPILE FOUNDATION: RELIABILITY BASED APPROACH, by Vahdatirad, Andersen, Ibsen, Clausen and Sorensen: This paper presents a probabilistic model for an offshore wind turbine monopole foundation. For the allowable stress design (ASD) typically 5 percent quintile measured strength parameters is used in design of these foundations The in-situ tests conducted offshore are costly and only limited amount of testing can be done. With the ASD method the foundation is expensive but at the same time its reliability is unknown. The authors have presented the case history of a monopole foundation in undrained overconsolidated clay. A three dimensional fine element model was established and a stochastic model for the undrained shear strength of soil is proposed using random field theory. An elastic perfect plastic Mohr-Coulomb constitutive model was used for soil response. The Undrained shear strength of the clay was modeled by a lognormal distribution. A linear correlation between shear strength and the elastic modulus was assumed as an approximation. Three levels of rotation i.e., 0.25 degree, 3 degrees and failure limit state respectively were considered. Reliability indices of the monopole are obtained through a reliability method and a probabilistic model is proposed regarding the 3-D design of the foundations. The paper concludes that reliability procedure can be used to calibrate / modify the partial safety factor for the soil properties such that a given target reliability is obtained thus resulting in an optimized design.

Paper 8.10a, FORENSIC GEOTECHNICAL DISTRESS EVALUATION OF DAMAGED BUILDINGS IN ALLUVIAL-LOESSIC SOILS; A CASE HISTORY, by Ali, Khan, Zafar, Shehryar: This paper describes the forensic geotechnical distress evaluations performed by the authors for structures on soils of alluvial-loessic nature in the city of Hyderabad, Pakistan. Large number of buildings in the northern part of the city experienced cracks, tilts and excessive settlements. The authors reviewed and evaluated the existing geotechnical investigation reports, design parameters and construction materials for the distressed buildings. Geotechnical field and lab investigations using conventional and geophysical techniques were carried out. Index, performance and chemical properties of the soils were analyzed. Geological site conditions indicated presence of 1-2 m alluvial-loessic deposits consisting of clayey and silty material with carbonates. The soil exhibited bearing capacity of 1-2 tsf under normal conditions, however less than 0.5 tsf in wet conditions. This upper layer was underlain by high compressibility clay of about 1-2 m. Tests indicated presence of clay mineral Montmorillonite which exhibits very high swelling potential. Based on the case history the authors suggest stabilization of foundation soils using soil mix columns around the building walls, underpinning of existing foundation and retrofitting damaged parts of existing damaged buildings. For future buildings in the area, the authors suggest to build foundations on bedrock, and using soil mix columns in case of deeper bedrock.

8.12a, BEHAVIOUR OF LATERALLY LOADED PILES, by Teymur and Sekerer: This paper focuses on pile deflection,

bending moment and rotation of laterally loaded piles in tuff soils in Izmir, Turkey. The authors used a three dimensional finite element program OpenSeesPL to model the properties of the laterally loaded piles embedded in tuff. A field test pile was drilled at a location next to a tank foundation area through upper fill material and was socketed 5 m in tuff. Lateral load tests were performed at two different locations using hydraulic jacks and deformations were measured using dial gauges. The displacement of 2.25 mm calculated within OpenSeesPL was close to the measured displacement of 2.5 mm under 80 ton loading. Within the program, lateral displacements of a single pile in various soil types were analyzed. The authors determined that in all types of soils, as the pile length decreases, the pile displacement increases. It was observed by the authors that as the pile length increased, the movement, the displacement and the rotation of the pile decreased. Further, the paper presents the results for pile displacement in loose and dense sands, and soft and stiff clays.

Paper No. 8.13a, FAILURE INVESTIGATION OF A HELICAL ANCHOR TIE-DOWN SYSTEM SUPPORTING AN OLYMPIC SIZE SWIMMING POOL, by Labuda, Corley and Murphy: This Paper presents the forensic analysis related to the failure of helical anchors used as tie-backs for an Olympic size swimming pool subjected to uplift. The failure resulted in expensive rebuild of the pool. The helical anchors provided significant initial cost savings as compared to the use of tie-down piles. The pool was constructed below water table and was subjected to hydrostatic uplift. The worst condition will be when the pool is empty and the groundwater at the highest level. For the case study presented the groundwater fluctuated seasonally up to 4 feet. The site has static groundwater about 5 feet below grade. Bottom of the pool was about 12 feet below the highest potential groundwater. Uplift forces calculated for the original design were found to be non-conservative. The pile design load of 27 kips also was higher than 20 kips capacity of pile connection provided in the literature of the manufacturer. For this case study structural details were found to be deficient in addition to underestimate of the uplift forces. The paper is an interesting case study where the local geology was ignored as far as the groundwater fluctuations were concerned. The local rainfall, drainage, and activities of man influence the groundwater elevation fluctuations. The deficiency of connection details in the paper may not be of much interest to geotechnical engineers.

Paper No. 8.15a, PRELIMINARY AND WORKING PILE LOAD TESTS IN SIMSIMA LIMESTONE, by Carroll, Hardy, and Ting: This paper describes the results of an extensive load testing program on a series of drilled shafts instrumented with Osterberg-cell , conventional load tests, and high strain dynamic load tests in the Simsima Limestone formation in Doha , Qatar. This limestone formation is the founding stratum for many important structures in Doha. Prior to construction 10 sacrificial piles were tested in order to confirm the basis of design. During construction 13 load tests were conducted to confirm the design. After the construction high strain dynamic tests (PDA) were performed on 11 drilled shafts which were concreted after the allowable time of 12 hours after excavation to quantify effects of any softening due to exposure to weather. Groundwater elevation at the site is not available in the paper. The testing program was designed to separate the side shear and end bearing by providing soft toe comprising of 300 mm of expanded polystyrene (EPS) at the bottom of the rebar cage. The paper presents mobilized side friction distribution, base resistance and load-deformation for the shafts tested. A cumulative distribution of mobilized side friction values for the three grades of limestone based on degree of weathering is presented. The maximum capacity of the Simsima Limestone was not mobilized despite loading it up to three times the design values. The authors attribute it to the roughness of the side walls as confirmed by caliper survey. The paper is a good source of information for how to conduct a comprehensive load testing program of deep foundation elements. No factors of safety applied to estimate design capacity of piles is given.

Paper No. 8.02b. A CASE HISTORY OF SUPER-LARGE SCALE BRIDGE PILE FOUNDATION IN SOFT SOIL, by Yang, Dai and Gong: This paper describes geotechnical investigation for the longest cable-stayed bridge in the world over river Sutong Yangtze with a 1088 meter main span. The foundation for each pylon consisted of 131 drilled piles with a length of 114 to 117 meters and diameters varying from 2.5 to 2.8 meters. Bed rock at the site is deep at over 270 m and is overlain by soft to stiff silt and dense to very dense silty sands and subject to scour. Good bearing layer is below -80 m. The investigation included static loading tests on single piles, finite element method (FEM) analysis, centrifugal model tests on pile groups, cap model tests and field monitoring for the super-large scale pile foundation. For the FEM Duncan-Chang model was used for soil behavior. Osterberg-cell was used for the 16 pile load tests in addition to one anchor-pile method. The paper provides lots of information in a concise manner. Results of the investigation indicated that the long piles are mainly friction piles with 10 to 20 percent of ultimate load being resisted in end bearing. Post grouting response was much stiffer. Compression of the long piles accounted for 30-40 percent of total displacement at pile top. A pile group efficiency of about 0.82 was estimated for pile spacing of 2.5 diameters. Values near to 1.0 were observed for spacing of 4.0 to 6.0. The paper presents results of theoretical analyses, lab simulations and field observation data. The data is voluminous and makes this paper an important reference for behavior of long deep foundations. However, no construction procedure details or difficulties, if any, are described. Drilling of shafts more than 100 meters will obviously pose many problems. The authors should present details of this important investigation in a series of papers.

Paper No. 8.03b, ELLIS ISLAND: VIBRATION EFFECTS ON HISTORIC BUILDINGS CAUSED BY PILE DRIVING, by Fernandez and Park: This paper presents the data for vibration attenuation with distance for driven H-Piles obtained at the historic Ellis Island in the Upper New York Harbor. Pile lengths varied from 50 to 100 feet. A plot showing PPV values and distance to pile driving is presented. The PPV used in the analysis is the vector sum of the measured velocity in the three directions and the distance is calculated as between the seismograph and pile tip. The paper also presents the data in terms of scaled distance. The recorded PPV exceeded the limits established value of 0.08 inch / second. The paper identifies the response of pile driving mainly on the pile impedance and less so on the soil. The paper states that for the type of buildings at Ellis Island the criterion of 0.50 inch/second proposed by Dowding is best suited. However the project specified a very low value of 0.08 in/second. This is a good example where a stringent project criterion results in significant added project costs. If Dowding criterion was adopted, no monitoring of vibrations for the project would have been needed. It is noted that there is a typographical error in Equation 1.

8.04b, EVALUATION OF TIMBER PILE SUPPORTED MARINE PIERS, by Singh: This paper summarizes the methodology of a comprehensive investigation of evaluating structural strength of existing timber pier piles, typical results and experience of the author in the Philadelphia area. The field investigations included video survey, retrieval of representative core samples from the timber deck and foundation piling as well as laboratory testing to evaluate their condition and changes in strength characteristics. Laboratory compression strength tests on core samples are compared with both tests on new piles as well as test data obtained from case histories. Several parameters including environment, salinity, age, treatment, and source of timber are considered. A risk mitigation program in addition to strength reduction parameters are provided in the summary.

Paper No. 8.05b, GEOTECHNICAL OPPORTUNITY ON A FAST-TRACK BRIDGE PROJECT, by Rinkel and Naida: This paper presents results of a fast-track geotechnical investigation of the bridge for Nine Mile Road over Interstate 75 in Hazel Park, Michigan destroyed by tanker fire. A fuel tanker burst into flames underneath the bridge and damaged it beyond repairs. A replacement bridge was designed and constructed. The new bridge design was based on Bridge Design Specifications from the current American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD). The authors had access to the design documents of the old bridge designed on Allowable Stress design (ASD). The paper presents a summary comparing the foundation types, design parameters, and sizes using the two methods. Comparisons on this project between the two methods indicated that the shallow foundations using LRFD method were, in general, about 5 to 15 percent larger than using ASD. The paper also describes use of LRFD method using a Pile Driving Analyzer (PDA) for the H-Piles for the center pier. For H-Piles the LRFD method coupled with PDA increased the capacity of H-Piles by about 33 percent. Light weight fill consisting of relatively expensive expanded polystyrene (EPS) blocks was used behind the new abutments reducing the size of the abutment foundations as well as resulting in time savings for the fast- track construction project.

FINAL REMARKS AND TOPICS FOR DISCUSSION

Papers in this session cover a wide spectrum of important topics in the area of Forensic-Geotechnical engineering. They range from distress evaluation of damaged buildings to behavior of laterally loaded piles to investigation of helical anchor tie-down system to pile load tests in Simsima Limestone to super large scale bridge pile foundation in soft soil to ultimate limit state design and Eurocode 7-1 to building distress investigation. Case history to reliability based approach to vibration damage to historic buildings caused by pile driving and timber pile supported marine piers. The papers indicate a high level of technical expertise among the international geo-engineering community. Some investigations originating in less developed countries, where resources are sometimes limited, demonstrate the highly creative and resourceful nature of our engineering colleagues. Several papers described initial/incomplete stages of ongoing case histories that will result in very useful data, which should then be disseminated. The purpose of the discussion topics below, is to establish a communication venue between the authors and the delegates of this Conference to foster what we expect to be a lively and vigorous dialogue.

SUGGESTED LIST OF SESSION 8 DISCUSSION TOPICS

8.05a – Foundation design is performance oriented depending upon allowable settlement (total and differential). How does USDL address this in application?

8.08a – Are the vibrations from rotosonic drilling comparable to the vibrations from an impact hammer used in SPT drilling?

8.09a – There is a large range for the probability if failure. Which model should be used in making the decision?

Undrained behavior for over-consolidated clays may not be the worst condition. Was any drained analysis done?

8.10a – Discussion about typical costs associated with the proposed stabilization of foundation soils– composite

columns. Applicability/suitability of the proposed solution for structures with variable serviceability.

8.12a – What is the reason for shorter piles to show increased pile displacement and increased rotation?

8.13a – Need for tensile (in conjunction with compression) tests in helical anchors

8.15a – Proper development of appropriate factors of safety for estimating design capacity.

8.02b – APILE computer program accounts for the compression of the pile in load deformation analyses. Was any prelimina5ry analysis done?

8.03b - The paper states that pile impedance rather soil conditions controls the vibration attenuation. This is too simplistic and other studies have established a strong correlation between stiffness of soil and attenuation.

8.04b - How does the percent reduction or variation in compressive strength (parallel and perpendicular to the wood grain) of timber piles (below and above the mud line) correlate to the previously performed and available industry research in timber engineering.?

8.05b - LRFD method was supposed to result in smaller sized footings. That did not happen on this project. However, for piles this method coupled with PDA increased usable capacity of H-Piles by a third. Any comments and recommendations?

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General Report – Session 8

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