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ABSTRACT

The case histories of Beirut geotechnical practice is an important teaching example concerning deep and specialty foundations. Micro-piles, tie-back retaining structures, and sheet pile-walls are common practices around Beirut. The city, having reached its saturation potential and real estate prices escalating, is moving vertically to optimize investments and toward deeper exploration of underground space. The diverse geology poses also real challenges to the geotechnical practicing engineers with karstic terrains and cavities, liquefiable sandy zones and high salt water table. The geographical constraints are pushing the city toward a better exploration of land reclamation solution over a large surface of the sea.

In front of this challenge, geotechnical companies have reached a high level of know-how. Their expertise, skills, equipment and laboratories positioned them at a very good standard of professionalism in the Middle East. University laboratories are working hand in hand with industry in creating many opportunities to expose students to existing case studies. Therefore, geotechnical instruction is illustrated by several case histories on interesting projects around Beirut. Field trips, laboratory testing, and guest speakers are complementing traditional classroom instruction. This paper exposes the geotechnical case histories of Beirut and its impact on students' instruction and early experience. For the past three years, it was found that as a result of continuous exposure to specialty courses, field trips, guest speakers, laboratories and case history analysis in geotechnical engineering, more than 30 % of students selected their profession either through graduate school or industry, in geotechnical engineering.

INTRODUCTION

The discipline of geotechnical engineering, being a "state-of-the-art" science, implies that students have to be trained to use their judgment by analyzing case studies. Cases from Beirut geotechnical projects are perfect illustrating examples. Many sites in construction present ideal case studies for analysis, as a result of their complexity as well as soil challenges. Faculty members involved in instructing geotechnical engineering courses have to complement their instruction material by collecting case history data through their interaction with industry. Relationship between the covered topic and engineering practice will then be strengthened significantly.

Initially, with basic teaching topics of soil mechanics followed by laboratory experiments, it becomes more valuable to involve case studies in the advanced courses. This gradual approach will eventually culminate in the discussion of cases of failures and their interpretation.

Students can benefit from a wide variety of case studies found around the Beirut area. The geotechnical discipline is significantly improving as a result of the market's need to employ qualified companies and laboratories. Challenging projects are widely available with increasing investments in the Middle East. In this paper, an overview of the geotechnical case histories of Beirut based on the urban expansion, deeper foundations, specialty foundations, geological hazards and the trend toward land reclamation is presented. This situation strongly influences teaching approaches of geotechnical case histories with the diversity of projects, laboratory and commercial testing, interaction of consultants with academia, field trips and documented references. The impact on students is highly visible with students' motivation, their choice in selecting summer training with geotechnical engineering companies, and their orientation for graduate school toward this field, or selection of their careers within geotechnical firms.

GEOTECHNICAL CASE HISTORY OF BEIRUT

Urban expansion

The city of Beirut is close to reaching its saturation in land occupancy. The evidence is an inflated real estate market, with prices rocketing in front of the scarcity of available land. Reasons are diverse, from migration into urban living, to the improvement of investments on real estate projects, passing by the natural population increase. It is also evidenced by the invasion of surrounding suburb hills. The reconstruction and restoration of downtown Beirut as mainly a business district played also an important role in the increase of property value. Added to the above, is the chaotic picture of land use (Harb J. N., 2006), amplified by many years of trouble as well as the lack of regulation and implementation (Ruppert H. (1969)).

Deeper foundations

With the high value of property land and limitation in heights of structures, scarcity of parking spots as well as storage areas, developers are investing more on exploiting the underground. Deeper excavations and specialty foundations are part of the project investment. The close proximity of adjacent structures implies careful implementation of special retaining system.

Photo 1 Excavation showing a shoring system in sand dune area

Specialty foundations

Shoring consisting of tieback system or soldier piles is very common. In the presence of friable sand layers, shotcrete and tieback are used with deeper excavations. Also, cellular cofferdam techniques are seen in loose sandy areas. Micro-piles are often used to strengthen a structure. Pier foundations are seen in the construction of bridges.

Geologic hazards

Cases of failure as a result of geologic hazards are most commonly related to the presence of cavities in karstic areas that collapse under loading. Also the hydrogeology contributed to many cases of settlement as a result of water table fluctuation. High saltwater table also contributed to the degradation of structural foundations. Beirut geology is mainly sandy and rocky in the surface. Marly Limestone rocks are often seen with the presence of loose sand. Several zones of liquefiable sand have been identified across the Greater Beirut area. In a previous publication (Harb J. N., 2003), liquefaction hazard assessment for the Greater Beirut area analysis has shown a probability of more than 80% in certain zones. The area is classified under a high seismic zone due to the proximity of major faults. They are known as the Yammouneh fault along the Bekaa valley and the "Chevauchement de Saida- Tripoli" that runs in the Mediterranean Sea in front of Beirut. The record of earthquake case histories is large (Observatoire de Géophysique, CNRS, Décembre (2006)). Earthquake events of small magnitudes are recorded on a daily basis. Magnitude 5.5 and above occur intermittently, but major events of magnitude larger than 7 have been recorded with a recurrence of approximately 250 years.

On the other hand, slope stability is a major concern with the invasion of neighboring hills surrounding the Beirut suburbs. Sand and clay layers are found on those hills. With the galloping deforestation, slope stability becomes recurrent especially in winter time with incidence of mud flows during heavy rain season.

Photo 2 Excavation showing high water table in a red sandy area

Land Reclamation

The land scarcity implies high demand as well as overpricing. This situation has induced several land reclamation projects. The first large investment project north of Beirut was a perfect example. In front of this successful experience, several harbor expansion plans are being accomplished. Also, the presence of two major dumps on the ocean has initiated dismantling of the first and the rehabilitation of the second as a first phase. The "Normandie" dump is now completely dismantled using an extensive recycling, disinfection and rehabilitation techniques. During the operations, many geotechnical challenges in the presence of high water table have been encountered. The land will be used for the construction of hotels and a recreation area. As for the second dump of "Karantina" north of Beirut, a degasification system has been installed. However, the dump experienced several slope stability problems. It is not clear if the funding will be available for dismantling it.

It is believed that the model of Hong Kong to expand on the ocean after reaching land saturation, will be initiated once peace and stability return to this country. The natural expansion using land reclamation on the Mediterranean presents several advantages on the exploitation of the suburbs hills. On the other hand, it presents a significant constraint on the ecosystem.

APPROACH OF GEOTECHNICAL CASE HISTORY

Addressing case history as a major tool

Case Histories of major projects as well as cases of failure are a major supporting tool and food for thought in classroom teaching. Geotechnical courses are taught by practitioners and consultants in the area. Addressing them in correlation with the corresponding section incites strong interest among students, develops their analytical skills in geotechnical engineering and facilitates the assimilation of basic theories.

Laboratories and commercial testing

Geotechnical engineering laboratories are equipped not only for teaching purposes, but also to serve the local community. Students are exposed to the same laboratory procedure requested by clients. Equipment is state of the art with a data acquisition system installed. Besides, in-situ testing is an important part of the Soil Mechanics laboratory course.

Guest speakers

Guest speakers from the local geotechnical firms are continuously invited for presenting a case history, either within a geotechnical course instruction, or invited by the Society of Civil Engineers. It is the first encounter of students with the professional applications. Interaction between a practitioner and students offers diversity in presenting and explaining geotechnical issues.

Field trips

Students are often sent on-site to visit a major geotechnical project around Beirut in coordination with local firms. Field trips events are either organized by the instructor or by the Society of Civil Engineers. The magnitude of the projects varies from major dam construction to simple foundation casting.

IMPACT ON STUDENTS

Students motivation

Students are motivated to deepen their knowledge in geotechnical engineering, due to the stimulating requirements in this field. Once exposed to solving problems in specialty foundations, guest speakers' opinion, laboratory work and field trips, the geotechnical profession becomes a challenge on students. The evidence is seen from their number joining geotechnical firms or selecting graduate studies in geotechnical engineering after graduation. The Figure below shows some data on the number of students moving to geotechnical engineering after graduation for the past five years. It is estimated that around 30% of the graduating students select this path.

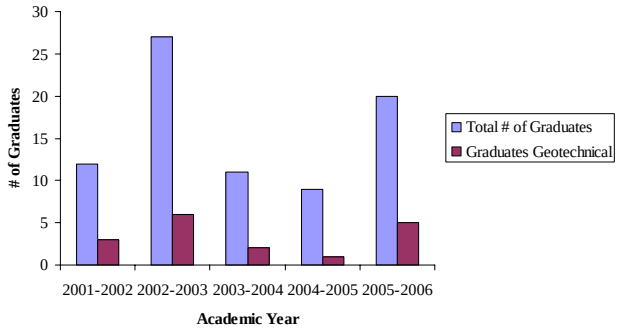

Fig. 1 Total number of civil engineering graduates compared to the number of students selecting geotechnical engineering after graduation.

Practical summer training in geotechnical engineering

Prior to graduation, students are required to perform a two-month summer training. As a result of their exposure on live

projects, a special attention is placed on the geotechnical components. This is evidenced by their feedbacks, reports and their enthusiasm in relating their experience.

CONCLUSION

Addressing geotechnical case histories from the Beirut area is an excellent illustration in geotechnical engineering. The city poses many challenges to the profession due to its subsurface heterogeneity and multiple geological hazards. With the saturation in land occupancy, the trend to excavate deeper implies more complex situations to be resolved. When professional geotechnical engineers contribute in sharing their experience among students and interact with the teaching methods, the result is a strong motivation among them to be oriented toward geotechnical careers. Statistics show that around 30% of the graduating students select either graduate school or companies in the geotechnical engineering field.

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