Comparison of High Pressure Pressuremeter (HyperPac) and Pre-Bored Pressuremeter Test Results - A Case Study

Comparaison des résultats d'essai du pressiomètre haute-pression de type HyperPac et du pressiomètre avec pré-forage – Cas d'étude

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ABSTRACT : The foundation of the high rise tower is planned to be constructed in sandstone, mudstone intercalation with intrusive dyke (diabasic, basaltic, andesitic, dasitic) and thick fracture zones with clay interfiling of Ordovician Aged Bakacak Member. According to performed boreholes, high plasticity clay interfilings are encountered under high rise tower foundation with thickness between 0.01m to 2.0m. For determining of geotechnical parameters of those units, towards settlement estimation several high pressure pressuremeter (HyperPAC) and pre-bored pressuremeter tests are carried out in addition to other in-situ tests and laboratory tests. Comparison of high pressure pressuremeter (HyperPAC) and pre-bored pressuremeter test results are discussed within this paper.

RESUME : Les fondations de la tour ont été prévues dans du grès avec des horizons de roche argileuse intercalées et contenant des intrusions magmatiques (diabasique, basaltiques, andésitiques, dacitique) et d'épaisses zones de fractures avec de l'argile infiltrée d'éléments de Bakacak de l'Ordovicien. D'après les forages exécutés, des inclusions d'argile hautement plastique ont été localisées sous les fondations de la tour, d'une épaisseur de 0,01 à 2,00m. Afin de déterminer les paramètres géotechniques de cette partie du sol, plusieurs tests avec un pressiomètre de haute capacité (HyperPAC) et un pressiomètre avec pré-forage furent réalisés conjointement avec d'autres tests insitu et de laboratoire. La comparaison des résultats obtenus entre le pressiomètre haute capacité (HyperPAC) et le pressiomètre avec pré-forage est abordée dans cette étude.

KEYWORDS: Pressuremeter, high pressure pressuremeter

1 INTRODUCTION

Turkey is located in the Alpine Belt and it shows high seismic activity. In the country, the North Anatolian Seismic Zone, Graben systems of West Anatolia (Aegean Region), and the East Anatolian Fault System are quite active. Subject site is located at the Asian part of İstanbul, within the first degree (the highest risk) earthquake zone at a distance of approximately 15 km's to the north of the North Anatolian Fault Line. The planned project for the subject site comprises a podium and high rise tower. High rise tower (6 basements + ground floor + 58 floors) has distinction of asymmetric architecture features. Foundation base area is approximately 1800m2. Because of the importance of the project and high seismicity of the region; several boreholes with maximum 150.0m length, in-situ tests (pre-bored pressuremeter and high pressure pressuremeter HyperPAC) and geophysical investigations (subsurface and within borings) are performed within the scope of soil investigation studies.

High plasticity clay interfilings are encountered under high rise tower foundation with thickness between 0.01m to 2.0m. For determination of geotechnical parameters below the foundation tower both high pressure pressuremeter tests (HyperPAC) and pre-bored pressuremeter tests are conducted. Comparison of high pressure pressuremeter test (HyperPAC) and pre-bored pressuremeter test results are discussed within the paper.

2 SEISMICITY AND GEOLOGY OF INVESTIGATION SITE

Turkey is located on the Anatolian plate, which is at the confluence of the Arabian, Eurasian and African plates. The Arabian and the African plates are moving north relative to Eurasia at a rate of about 25 mm/year and 10 mm/year, respectively (Lettis et al., 2000). This 15 mm/year differential motion is mostly accommodated by the left-lateral Dead Sea transform fault (see Figure 1).

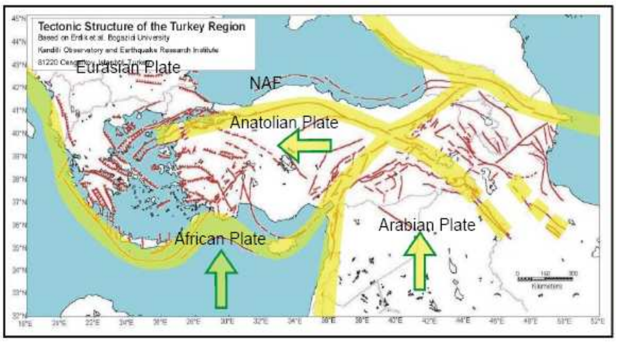

Figure 1. Tectonic Structure of Turkey (Erdik et al., Bogazici University)

Recent seismic sections complemented with the interpretation of focal mechanisms have helped to elucidate the configuration and geometry of the underwater basins Figure 2 after Okay et al. 1999, shows a proposed configuration, which consists of a series of pull apart basins bounded by a system of relatively short strike-slip and normal faults. As can be noted in Figure 2, according to this proposed fault configuration, the closest distance from the site to the fault line is approximately 15 km.

The subject area is at the north of the North Anatolian Fault line. An earthquake having an epicenter at Gölcük with a magnitude of M=7.4 and another one having an epicenter at

Bolu with a magnitude of M=7.2 had occurred on the North Anatolian Seismic Zone in August 17th, 1999, and November 12th, 1999.

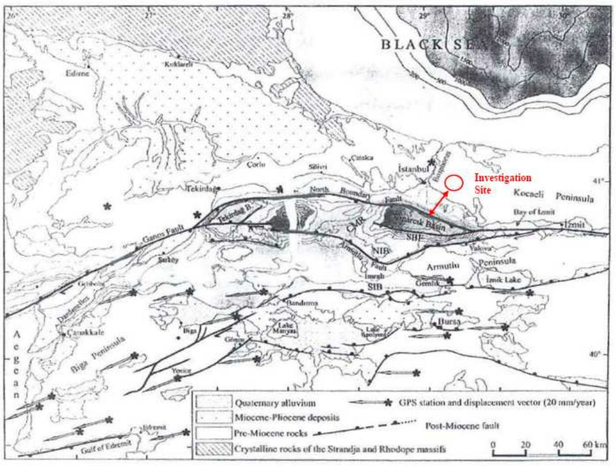

Figure 2. Active Tectonic Map of The Marmara Sea (Okay et al, 1999)

Subject site is located within the 1st degree (the first highest risk) earthquake zone as indicated below in Figure 3 according to the Specification for Structures to be built in Disaster Areas by the Ministry of Public Works and Settlement of the Republic of Turkey effective from 2007.

This critical seismic conditions increase the importance of the local geology and soil-rock conditions.

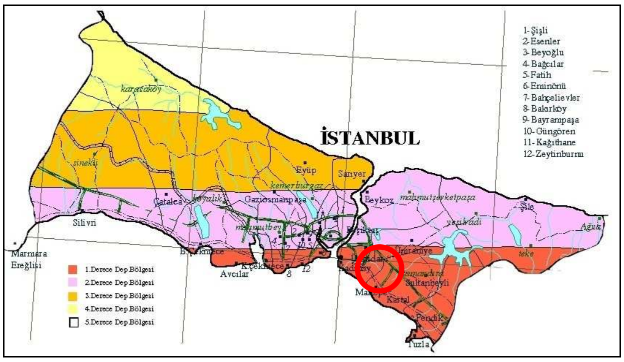

Figure 3. Earthquake Zoning Map of Istanbul (Ministry of Public Works and Settlement of the Republic of Turkey, 2007)

Main geological units of Ordovician aged Bakacak Member of Kurtköy Formation are encountered. Light and dark purple, sandstone and intercalated laminated siltstone dominate the lower part of the Kurtköy Formation, and is denoted as the Bakacak Member.

Within the soil investigation studies more than hundred boreholes with length of 30m to 150m, sandstone, mudstone intercalation with intrusive dyke (diabasic, basaltic, andesitic, dasitic) and thick fracture zones with clay interfilings are encountered. According to performed boreholes high plasticity clay interfilings are encountered under high rise tower foundation with thickness between 0.01m to 2.0m.

Thick clay layers from the cross section (Figure 4) are indicated based on the classification according to weathering level and spacing frequency of Bakacak Member units.

As given in Figure 5; extremely closely fractured/plastic clay interfiled thick zone is encountered between 0.0m to 11.5m depth located at the centre of the high rise tower.

3 METHODOLOGIES OF PRE-BORED PRESSUREMETER AND HIGH PRESSURE PRESSUREMETER (HYPERPAC)

Louis Menard in 1955 invented the pressuremeter. Pressuremeter probe is a cylindrical device. A pressuremeter test in a vertical borehole gives a ground response curve in the horizontal direction.

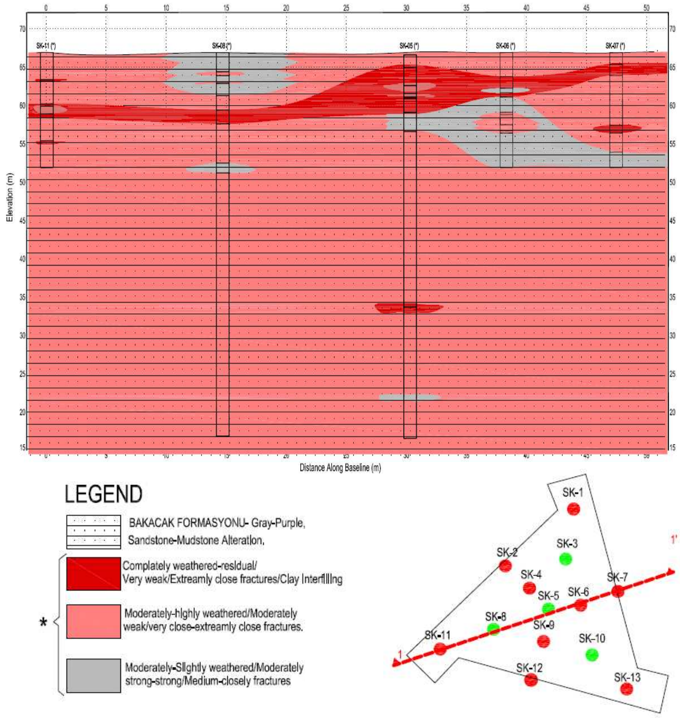

Figure 4. Representative Geotechnical-Geological Cross-Section

Figure 5. Core Box Photo Between 0.0m to 11.5m Depth Extremely Closely Spacing/clay Interfilled Zones.

Thus, the derived parameters represent the horizontal stress, stiffness and strength. As the pressure increases and the membrane expand, the walls of the borehole begin to deform. The pressure inside the probe is held constant for a specific period of time and the increase in volume required maintaining the pressure is recorded. For increasing pressure both water and gas are used.

The pressuremeter has a slightly smaller outside diameter than the diameter of the hole. In the original Ménard system the probe contains a measuring cell which is fluid-filled. The radial expansion of the probe when pressurized is inferred from measurements of volume take made at the ground surface, using the control/measuring unit. A guard cell is incorporated into each end of the probe, in order to ensure, as far as possible, that the measuring cell expands only radially.

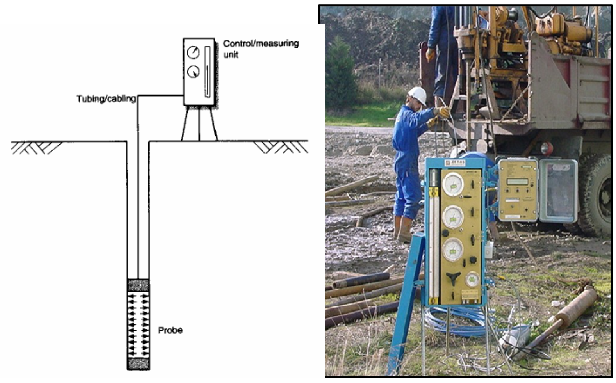

Figure 6. Application of pre-bored pressuremeter in investigation site.

Pre-bored pressuremeter tests can be carried out in hard clays, dense sands and weathered rock. The maximum capacity of pre-bored pressuremeter is 100bar. The aim of a pressuremeter test is to obtain information on the stiffness, and in weaker materials on the strength of the ground, by measuring the relationship between radially applied pressure and the resulting deformation.

For hard soils or rocks; higher pressure devices are designed. HyperPAC is one of a high pressure pressuremeter. Its probe has only one outer membrane. The main box can increase the water pressure up to 250bar. Thus the fluid-filled probe inflates. The radial expansion of the probe in volume and the applied pressure is recorded by geobox.

Figure 7. Application of High Pressure Pressuremeter (HyperPAC) in Investigation Site.

As pre-bored pressuremeter, the aim of the HyperPAC is to determine geotechnical parameters and modules of soil and rock units by measuring the relationship between radial applied pressure and the resulting volume change.

4 SITE INVESTIGATIONS

At the first stage, in the scope of the site investigation eighteen (18) boreholes between between 30.0m and 150.0m length, sixty-three (63) pre-bored pressuremeters at every five meter depth in eight boreholes, 83 high pressure dilatometer tests (HPDT) in two (2) boreholes, and surface geophysical tests consist of eleven (11) Multi-Channel Analysis of Surface Waves (MASW), two (2) Electrical Resistivity Tests, three (3) Microtremor Tests, five (5) P&S Logging Tests and one (1) Cross-Hole Test are performed under the high rise tower location in 2011. Subsoil investigation layout plan is given in Figure 8.

The second stage of soil investigation is needed because of the encountered clay interbeds and fractured zones in the boreholes under the foundation of high rise tower locations in order to assess their influence in resulting vertical settlement of foundations.

At the second stage, in the scope of the site investigation nine (9) boreholes with length of 15.0m, four (4) boreholes having 50.0m length with total 335.0m length drilling, thirty-three (33) high pressure pressuremeter (HyperPac) tests in one (1) borehole for each 1.5m depth are performed under the high rise tower location in 2013. Subsoil investigation layout plan is given in Figure 9. Excavation down to foundation base level was completed; at the time of the second stage. Boreholes and high pressure pressuremeter tests were performed within the excavated area where the high rise tower foundation will be located. For that reason, elevation difference between the first stage boreholes and second stage boreholes is approximately 24.0m.

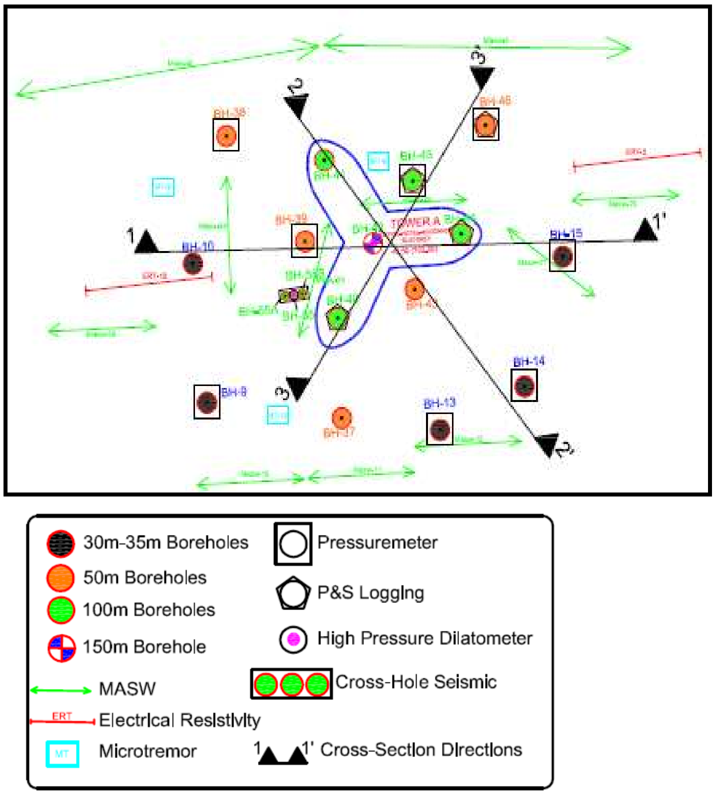

Figure 8. Soil Investigation Layout Plan of the First Stage

5 PRE-BORED MENARD PRESSUREMETER AND HIGH PRESSUREMETER TEST RESULTS

Engineering parameters (Menard Modulus) are given in Table 1 as determined from the results of Menard pre-bored pressuremeter test results.

The limit pressure could not be determined by pre-bored pressuremeter due limitation of applied pressure by 100 bars to the lithological units of the investigation site. This means that limit pressure values are in fact higher than 100bars and it could not be reached with the classical test (Figure 10). Further, because of the varying rock conditions of the project site, the deformation modulus Em (Menard Modulus) values obtained from the pressuremeter tests have a wide range. This means that, the test values obtained from intact rock were on the high side, and the test values obtained from clay interbeds and fractured/weathered rock were on the low side.

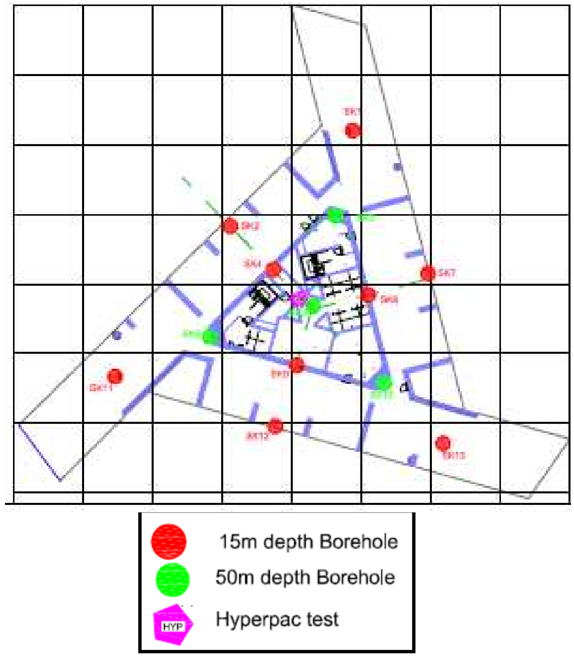

Figure 9. Soil Investigation Layout Plan of the Second Stage

Table 1. Summary of Pre-Bored Pressuremeter Test Results

Menard Modulus, E_m (MPa)	Elevation/Depth (m)
Minimum=67.0 Maximum=8422.0	75.0/21.0 55.0/33.0

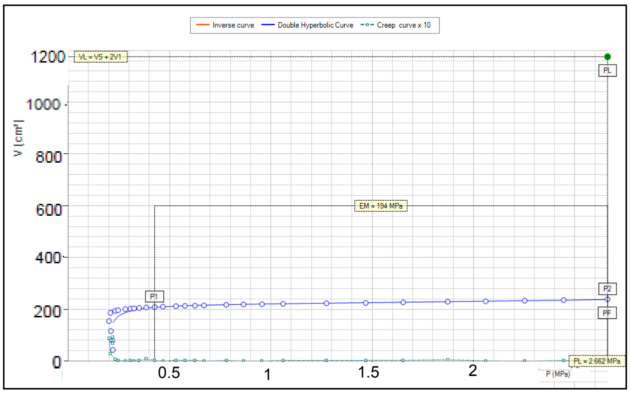

Figure 10. Pre-bored Pressuremeter Test Result Obtained From Related Software Program

The range of the results (Em and Pl* Net Limit Pressure) obtained from the high pressure pressuremeter (HyperPAC) test performed encountered formations are shown in Table 2. From the test readings (volume variation based on controlled pressure), a stress- strain curve can be obtained for the rock or hard soil at hand in the case of plane deformation (see Figure 11). The deformation modulus Em and the net limit pressure Pl*, Creep pressure Pf values were calculated for each test elevation.

The results obtained from both tests are shown in Figure 12. Although, net limit pressure could not be determined by pre-bored pressuremeter tests, the results are given in the graph for comparison with high pressure pressuremeter (HyperPAC) test results (Pl*). It is known that net limit pressure values that are obtained from pre-bored pressuremeter given in the graph are lower than the real value for rock formation.

Table 2. Summary of High Pressure Pressuremeter (HyperPAC) Test Results

Menard Modulus, E_m (MPa)	Net Limit Pressure, Pl^* (kPa)	Elevation/Depth (m)
Minumum=15 Maximum=3602	Minumum=1950 Maksimum= 40920	59.4/7.5 27.9/39.0

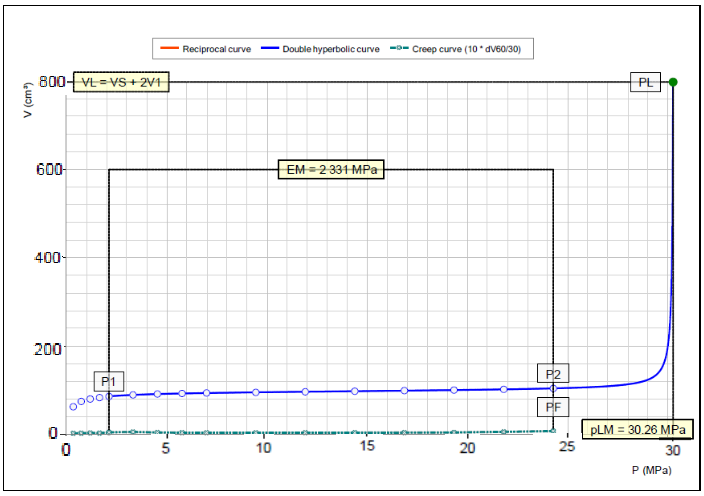

Figure 11. High Pressure Pressuremeter (HyperPAC) Test Result Obtained From Related Software Program

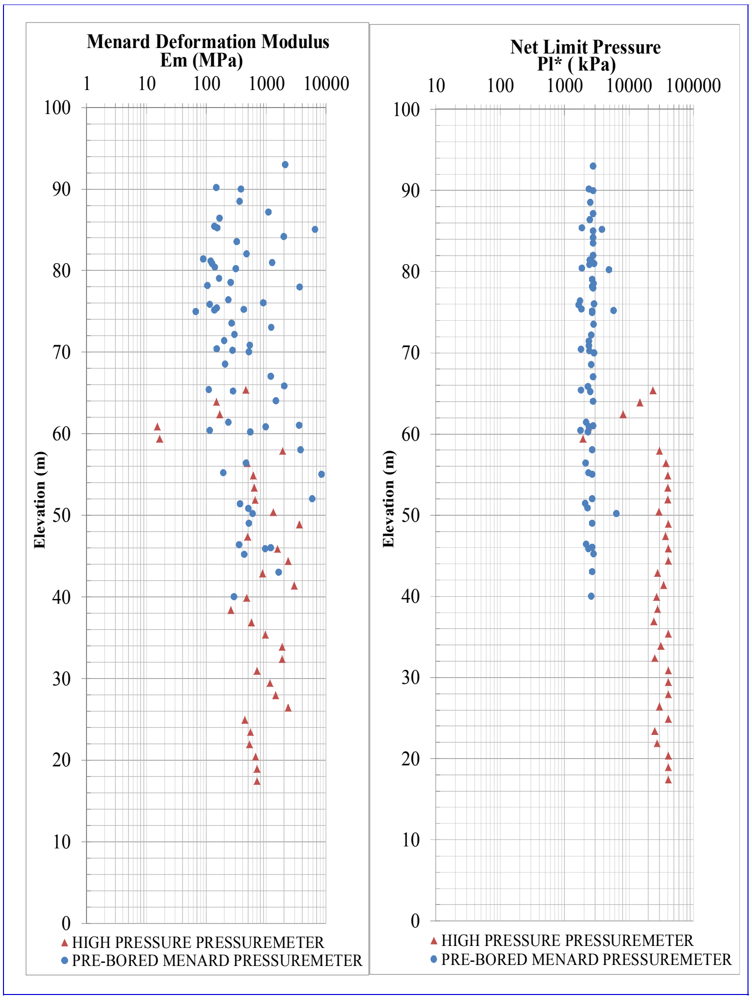

Figure 12. Pressuremeter Modulus (E_m and Pl*) values vs. Elevation Obtained from Both of The Tests

6 CONCLUSION

In the soil investigation scope of the high rise tower project, performed pre-bored pressuremeter and high pressure pressuremeter tests results are summarized and compared within the paper. According to pressuremeter test results (both Menard pressuremeter and HyperPAC) values of Menard modulus seem to be in similar range. However, net limit pressure values that could be reached in the HyperPAC test are higher than the values that can be reached by Menard Pressuremeter. Therefore, wider range of results could be determined by HyperPAC pressuremeter for the rock unit. Therefore results using HyperPAC pressurmeter is more appropriate for rock unit.

7 REFERENCES

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