Top-Down Construction Alongside Of Bosphorus – A Case Study

Construction en « Top-Down » le long du Bosphore – Une étude de cas

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ABSTRACT: Hatice Sultan and Fehime Sultan Residences are two historical Ottoman waterfront mansions placed on the European shore of Bosphorus in Istanbul. Within the restoration campaign of these mansions, it is planned to add four basement levels under the complete plot with the exception of preserved two corners where Hatice Sultan Residence and an old and large tree exist. The depth of the excavation needed for the basements is about 24 m below ground surface of which 21.20 m will be below groundwater level. The excavation should take place just 75 m far from the southwest pylon of the Bosphorus Suspension Bridge. Soil profile consists of uncontrolled fill, marine alluvium layer and bedrock which is sloped towards the seaside with a varying inclination. Steel propping system was set forth by the geotechnical design group of the Client, though this method was eliminated later during the bidding stage, because it was found impractical due to their obstacle in basement construction. The method of top-down construction of the basement levels with permanent diaphragm wall and bored piles socketed into bedrock was agreed to be realized by the Client based on the alternative proposal given by the foundation subcontractor during the bidding stage. THY -Do&Co JV Ortakoy Hotel Project is an interesting case-study where a challenging supporting system is being implemented near the Bosphorus in very poor soil conditions, under high seismicity.

RÉSUMÉ : Les Résidences de Hatice Sultan et de Fehime Sultan sont deux yalis Ottomanes historiques situées sur la côte Européenne du Bosphore, à Istanbul. Le projet de rénovation de ces yalis prévoit d'ajouter quatre étages en sous-sol sous l'ensemble du terrain, à l'exception de deux zones préservées où sont situés la Résidence de Hatice Sultan et un arbre centenaire. Une excavation de 24m sous le niveau du terrain naturel est requise pour la réalisation des sous-sols dont environ 21,20 m sous le niveau de la nappe phréatique. L'excavation aura lieu à tout juste 75 m du pylône sud-ouest du Pont sur le Bosphore. Le profil du sol est constitué de remblais non contrôlés, de couches d'alluvions marins reposant sur un substratum rocheux s'enfonçant avec une inclinaison variable en allant vers le Bosphore. Cependant, le design initial du client basé sur la mise en œuvre d'un système de soutènement en acier a été plus tard écarté car ne permettant pas la réalisation ultérieure des niveaux de sous-sol. La méthode de construction en « top-down » utilisant une paroi moulée et des pieux forés ancrés dans le substratum rocheux a finalement été sélectionnée par le Client, sur la base de la proposition alternative remise par le sous-traitant lors de l'appel d'offres. Le Projet de THY - Do&Co JV Ortakoy Hôtel est une étude de cas intéressante pour lequel un soutènement a dû être mis en œuvre à proximité du Bosphore, avec des conditions de sol très difficiles et en prenant en compte de forts risques sismiques.

KEYWORDS: Top-Down Construction

1 INTRODUCTION

Fehime Sultan and Hatice Sultan Residences are one of the historical Ottoman waterfront mansions constructed alongside the Bosphorus. These residences were constructed in the second half of the 19th the Century by Sultan Abdulhamid II as a wedding present for two daughters of Sultan Murat V. Later on, Fehime Sultan Residence was given as a gift to Gazi Osman Pasha for his success in Plevne Defense against Russian Army. During the Turkish Republic period this mansion served as a primary school and unfortunately was seriously damaged in a recent fire in 2002. On the other hand Hatice Sultan Residence served as an orphanage and then as private swimmers club in the later periods. The plot has been recently purchased by Turkish Airlines - Do&Co JV on BOT basis and is planned to be restored and developed to serve as a boutique hotel. Ruins of the Fehime Sultan Residence have been transferred to the restoration workshop. This beautiful and historical mansion is planned to be re-constructed using its original fragments. Within this restoration campaign, it is also planned to add four basement levels under the complete plot with the exception of two corners where Hatice Sultan Residence and an old and large tree exist. This deep excavation is agreed to be implemented with the Top-Down construction method because of the poor soil conditions, high ground water table and important neighboring infrastructures. On the date of the paper submission, the diaphragm wall construction was just finalized. Therefore, only findings and implications of design and methodology together with diaphragm wall construction are presented within this paper.

2 PROJECT DESCRIPTION

Fehime Sultan and Hatice Sultan residences are located in district of Ortakoy alongside of Bosphorus and approximately 75 m away the southwest pylon of the Bosphorus Suspension Bridge in Istanbul (Figures 1a and 1b). Within the restoration campaign of these residences four basement floors are planned to be constructed in the entire plot. The periphery of the basement floors encloses the plot limit, except two corners on where Hatice Sultan residence and a historical tree exist (Figure 2). Basement excavation will be realized under Fehime Sultan residence location at the left in Figure 2 because ruins of this residence as a result of fire have been removed to restoration workshop area before the commencement of the works. The perimeter of the excavation plot is about 372 m and the area of the plot is approx. 6064 m². Site elevations are varying between +1.00 m to +3.00 m. Excavation elevation is 21.20 m below the sea level and maximum excavation depth is approximately 24 m.

Figure 1a and 1b. General View of the Site Figure and Location of the Site in Istanbul

Figure 2. Periphery of the Excavation (photo after the fire of 2002 and before the start of the restoration campaign)

During the bidding stage, top-down construction proposed by the foundation subcontractor was considered as a suitable method under the existing conditions. Typical cross section of the basement structures through the perpendicular direction to the seashore is given in Figure 3. It is planned to use the diaphragm walls as permanent periphery walls of the basement floors, construct the bored piles as permanent columns of the underground structure and integrate the foundation and slabs with the permanent wall and columns during the top-down construction method. This choice resulted in the necessity to develop special details for ground water isolation and continuity of the structural elements.

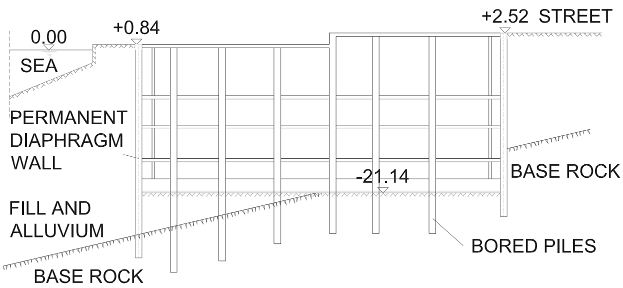


Figure 3. Section of the Basement Structure in Perpendicular to the Seashore

3 GEOTECHNICAL MODELLING

Within the soil investigations ten boreholes were implemented with a maximum length of 50 m. Two of the boreholes adjacent to the seaside were implemented with 45° inclination and length of these boreholes was 100 m. Also within the geophysical measurements, MASW and microtremor studies are implemented in the site to obtain the geodynamic modeling of subsoils.

Soil profile consists in sequence from top to down as of uncontrolled fill, marine alluvium and bedrock. Dyke, sandstone and shale are the commonly encountered rock types at the site. According to the results of vertical boreholes at the site bedrock is located between 13.50 m and 27.20 m under the sea level. Therefore length of the diaphragm wall and bored piles are chosen variable from one location to another in accordance to encountered bedrock elevations. Typical soil profile is given in Figure 4.

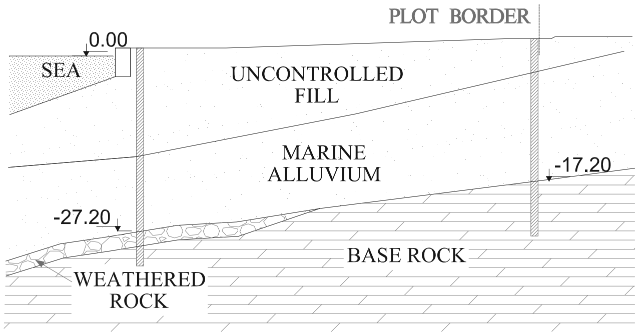


Figure 4. Typical Soil Profile

Simplified average drained shear parameters of the alluvial soil layers based on the field and laboratory testings are given in Table 1. Ground water table is located within 1.0m to 3.0m below the ground surface.

Table 1. Soil Properties

Layer	*γ(kN/m³)*	*Ø' (°)*	*c' (kN/m²)*
Uncontrolled Fill and Marine Alluvium	*18*	*28*	*1*
Weathered Rock	*22*	*33*	*20*
Bedrock	*24*	*33*	*50*

4 PRELIMINARY DESIGN

The preliminary retaining system has been proposed by a geotechnical design group employed by the Client prior to the tender, which consisting a peripheral diaphragm wall and tubular steel struts. Diaphragm wall thickness was considered as 800 mm and planned to be used only temporarily during the excavation. To support the diaphragm wall, four rows of steel struts are proposed to be implemented. The spacing between the struts was 5.0 m in vertical and 8.20 m in horizontal directions. Typical cross section of the tender design is given in Figure 5.

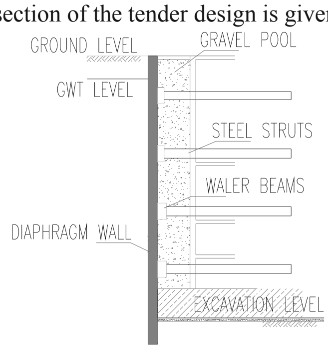


Figure 5. Tender Design Typical Cross Section

Complete underground structure were planned to be constructed 21.20 m below the water table. As a result, the uplift of the underground structure is one of the critical issues for the design.

5 PROPOSED ALTERNATIVE DESIGN

During the bidding stage the applicability towards the construction of underground structure and the cost of the tender design was examined. One of the drawbacks realized was that the space between the steel tubular struts was very limited to implement the excavation works in a safe and efficient manner. As a result, alternative top-down construction method was proposed to eliminate the implications of steel struts. Further, in order to eliminate the gravel filled between the walls; namely gravel pool, proposed in the preliminary design, uplift loads are proposed to be taken by tension piles under the foundation.

As described in the previous sections, the site is located in a densely populated urban zone and there are important neighboring infrastructures around the plot. In order to minimize the lateral displacements to be realized during excavation implication of the proposed top down procedure was very effective and superior compare to strutted excavation.

In the proposed top down method permanent diaphragm walls and piles are to be constructed prior to excavation works. Later ground level r. c. floor will be constructed except the part behind the Hatice Sultan residence (Figure 6).

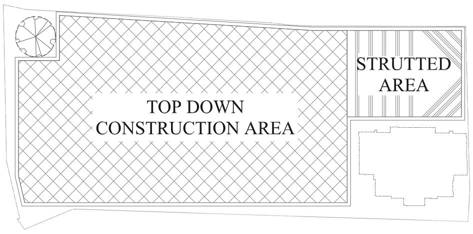


Figure 6. Top Down Construction Area

Soil under the ground level floor will be excavated phase by phase until the bottom elevation of foundation. In parallel to excavation works 1st basement r. c. floor will be constructed. The part of limited excavation plot behind the Hatice Sultan Residence will be supported with steel struts to provide space for ramps which will be used for the transportation of the excavated material. Top down construction steps will continue similarly as 2nd basement floor 3rd basement floor and foundation respectively (Figure 7).

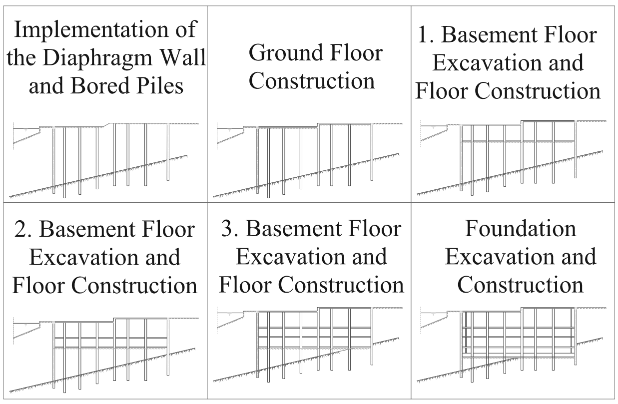


Figure 7. Top Down Construction Steps

Groundwater seepage into the excavation site is evaluated by seepage analysis and optimum socket length in to the bedrock is determined as 5.0 m. Also settlements due to the lowering groundwater table are estimated and found to be less than 18 mm which is considered as tolerable for the existing structures.

Bored piles are designed to be used as compression and tension members depending on the loading conditions. Therefore, piles which will act as permanent columns of the underground structure are extended into the bedrock having minimum socket length of 6.0 m basedon the result of pile tension test conducted at the site in order to satisfy the most critical tension loading condition under the uplift forces. Tension capacity of the piles are estimated and taken into account against uplift forces.

In the top down construction, floor and foundation reinforcements will be integrated into the permanent diaphragm wall and piles with the aid of additional link reinforcements which are already placed in these elements. Details of these link reinforcements are given in the next section.

After the top down construction steps the limited area behind the Hatice Sultan Residence will be constructed with conventional method from bottom to top in parallel to dissembling the steel struts. Special water-proofing works will also be implemented under the foundation and on the constructive inner wall during the down to top construction steps.

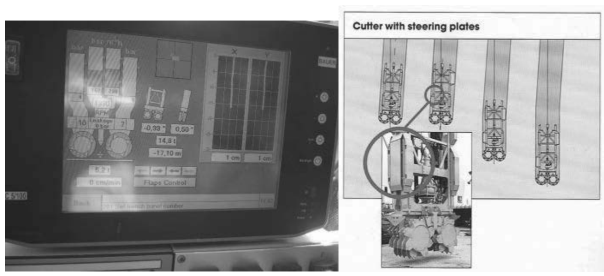
6 CONSTRUCTION STAGE OF DIAPHRAGM WALLS

At the time of paper submission, diaphragm wall construction was just completed and preparations have been realized to initiate the piling works. Therefore only diaphragm wall construction stage would be covered within the paper.

To implement the diaphragm wall in required socket lengths in the bedrock formation, hydrofraise machine was mobilized for this project having 81 kNm max. torque per gear box, and 25 rpm max. revolution, with a max cutting depth capacity of 70m (Figure 8).

Figure 8. Diaphragm Wall Machine, Hydrofraise-Cutter

Another reason of implementing the hydrofraise-cutter machine was to provide a better verticality control during the construction of the permanent diaphragm walls. The verticality was monitored parallel to diaphragm wall excavation and direction of the cutter controlled with the help of the flaps on the edges (Figures 9a and 9b).



Figures 9a and 9b. Verticality Control System

During the soil investigations encountered maximum UCS values of the bedrock are given at the Table 2 below.

Table 2. Unconfined Compression Strength (UCS) values- Mpa

	Intrusive Dyke		*Sandstone*		*Shale Sandstone*	
UCS	*Min.*	*Max.*	*Min.*	*Max.*	*Min.*	*Max.*
Value	*0.7*	*65*	*3.6*	*160*	*1.0*	*67*

The distribution of the UCS values with the depth is given in Figure 10.

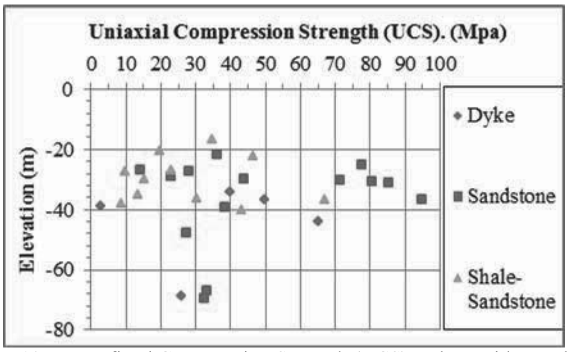


Figure 10. Unconfined Compression Strength (UCS) Values with Depth

The socket length of the diaphragm wall is variable due to the variability of the lithology of bedrock. It is estimated that the minimum 5.0 m socket length in the rock formation will be required. With the utilized hydrofraise cutter diaphragm wall machine, it was possible to construct approximately 2.65 m/day on plan (equals to 60 m² diaphragm wall per day) in average.

To integrate the slabs and foundation with the diaphragm walls additional link reinforcements are placed in the reinforcement cage (Figure 11). It is planned to chip the concrete on these elevations to bend the additional reinforcement into the slab and foundation elements.

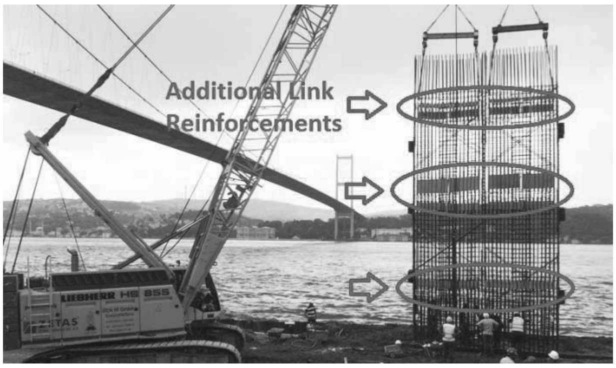


Figure 11. Additional Link Reinforcements on the Slab Elevations

Prior to diaphragm wall construction on the seaside, it was planned to implement sheet piles at the shore to remove the large quay stones at the back side and to prevent the negative fluctuation effect of the sea during the diaphragm wall construction. Sheet piles also contribute to the overall stability of the quay under the weight of heavy diaphragm wall machine. Sheet piling application is presented in the Figures 12a and 12b.

Figures 12a and 12b Sheet Piling

7 CONCLUSIONS

Within the restoration campaign of two beautiful historical mansions from Ottomans alongside the Bosphorus namely Hatice Sultan and Fehime Sultan, four basement floors was planned to be constructed with a maximum excavation depth of 24 m. Tender design for the retaining system of this excavation was temporary diaphragm walls supported with steel tubular struts. Due to the lack of enough spacing between the struts, applicability of the excavation works to achieve the desired speed was found to be questionable. Therefore an alternative system of top down construction method was proposed during the bidding stage. Prior to the excavation, it is proposed to construct the diaphragm wall and bored piles which will be also part of permanent structure of the basement so a remarkable saving and speed together with additional safety could be provided to the project. Another benefit of this system was also allowing extension of bored piles which are also columns of the basement into the bedrock to have desired tension resistance against uplift. This design gave a chance to eliminate the gravel pool proposed in preliminary design and provided additional space in basement floors. Integration of diaphragm wall, slabs and foundation is realized with additional link reinforcements and these reinforcements are placed in their for seen locations during the cage preparation. Sheet piles implemented also successfully prior to the seaside diaphragm wall construction in order to eliminate the negative effect of sea. In spite of the high UCS values it was possible to construct the diaphragm walls socketing 5.0 m deep into the bedrock with high capacity hydrofraise – cutter diaphragm wall machine at a reasonable rate. It is concluded that with the implication of top down construction method, part of this challenging project is completed successfully in economical, safe and timely manner.

8 ACKNOWLEDGMENT

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