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Research Article

CONTROLLING INCOMING WATER OF DEEP EXCAVATION WALL RESULTED FROM INCREASE IN GROUNDWATER LEVEL

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ABSTRACT
Today, because of increase in population and increasing need for optimal use of available spaces and as a result of development of underground spaces, implementation of deep excavations and stabilizing them has become a common issue. While excavation and with the increase in height of walls, stabilization of excavations becomes important. Nailing, Anchorage, concrete pile and metal pile implementation systems or a combination of these systems are common methods for stabilizing excavation walls. It should be noted that each method have their specific advantages and disadvantages. Hence, due to specifications of the project and existing needs, one of the mentioned methods with the aim of reducing cost and time should be selected. At the present study, case study on behavior of retaining structure system implemented using hybrid system of pile-anchorage in project of Daneshgah Tower in Mashhad has been conducted according to 27-month interval from completion of retaining structure system, lack of implementation of the main structure and also increase in groundwater level to height of 3.1m from concrete floor balance. Taking a suitable method for purpose of preventing horizontal displacements of excavation wall, subsidence of adjacent and preventing occurrence of piping phenomenon were important issues existed in this project, which have been explained in this study. Finally, desirable consistence was observed between obtained results from monitoring of excavation wall and results of finite element modeling through comparing them using PLAXIS software

Keywords: *Controlling, Incoming, Deep Excavation, Increase, Groundwater*

INTRODUCTION
Through increase in construction of tall buildings, due to needs of the growing population of Mashhad City and its tourism status, implementation of deep excavations and stabilizing them can be considered one of the most important challenges for the current age engineers for purpose of optimized use of available spaces. Rise of groundwater level of Mashhad Plain over the years has made many problems for implementation of deep excavations and stabilizing them. At the present study, stabilization and control of incoming water of excavation walls in Daneshgah Tower Project has been studied in details.
Excavation of the project, which its plan has been illustrated in figure 1, has been started in a land with area of 4300m^2 including administrative, commercial floors and lower floors for purpose of constructing parking lot and facilities in center of Mashhad City by 2007.

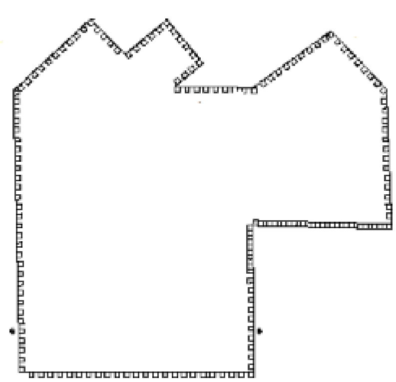

Figure 1: Plan of Daneshgah Tower Project

After short time, construction operations were stopped and again in 2009, the operations were restarted. By the same year, implementation operation of the excavation with depth of 22.5m from ground surface balance was ended and stabilization of the excavation wall was conducted using hybrid system of pile-anchor. In obtained results from previous geotechnical studies before beginning of project excavation operations, value of groundwater level balance was reported to 26m depth from land surface. However, by 2011 and after completion of retaining structure implementation, incoming of water from walls and bottom of the excavation was observed. Gradual increase in groundwater level balance after completion of the project after 27 months till Nov of 2013 with height of 3.10m from the concrete floor of the project as it is illustrated in figure 2.

Figure 2: Lake constructed in location of the project

Existence of this lake with volume of 13330m^3 in center of Mashhad City caused many concerns for residents around the project. Fear of landslides, destruction of adjacent buildings, filling wells of houses with no geed reason, bad smell and prevalence of diseases resulted from mere caused concern and dissatisfaction of residents. Hence, a group of experienced engineers and counselors were gathered together to solve the current problem in the best manner. After programming, modeling and exact designations of decision on water pumping and draining were conducted at the same time with complete caulk of excavation walls over the 4 steps. By late 2013 and after 2 months continuous working, the water was controlled and drained completely and then, bottom of the excavation was caulked as it is illustrated in figure 3.

Figure 3: A schema of the Daneshgah Tower project after 2 months continuous working

Properties of Soil in Studied Place

According to importance and sensitivity created in the project, geotechnical investigations were conducted in 2 steps. The first step was conducted before beginning excavation operations and rise of groundwater level balance. In this step, 4 mechanical bores were excavated with maximum depth of 80m.

From investigation of log of the bores, it could be observed that groundwater level balance before beginning of the operations was in depth of 29.5m from street level balance. In addition, it was found based on the studies that the soil of studied zone has been mainly sand and cohesionless silt. According to the time gap since completion of excavation stabilization, complementary geotechnical studies were conducted for purpose of removing problems such as probability of destruction of pre-stressing force of anchorage strands; lack of construction of barrier walls and foundation and also rise of groundwater level balance as an important problem. Two manual bores with depths of 15 and 22.5m were excavated in north and northeast zones of the excavated place. In field tests and in experimental examinations were conducted on disturbed and undisturbed samples. Conducted tests included classification of soil based on ASTM-D421 standard; mechanical aggregation; hydrometer; determining Atterberg limits; determining density of materials; permeability test; triaxial test; direct shear test; and chemical soil and water examination.
According to geotechnical studies conducted on soil samples collected from bores and as it is indicated in table 1, dominant texture of soil has been mainly in SM group; silt sand with gravel and ML silt. In addition, presence of rigid and impermeable clay layers in depth of 40-50m could indicate existence of groundwater in the region.

Table 1: Geotechnical features of soil

Row	Depth (m)	Unit weight (KN/m^3)	Cohesion (KN/m^2)	Internal friction angle (□)
1	0-17	19	20.1	16.8
2	17-19	19.3	8.1	32.7
3	19-30	19	19.3	26.7
4	30-80	19.38	33.6	2

Excavation Stabilization System
According to centrality and latitude of the Daneshgah Tower Project to $4300m^2$ and also due to difference and diversity of surrounding overloads like 20-storey commercial-administrative tower, 7-storey hotel and tall residential buildings, selection of retaining structure system of the project was so important. According to the mentioned issues and high sensitivity of the project, hybrid system of pile-anchor was selected as retaining structure for purpose of better control of displacements. 200 concrete square piles with diameter of 1m were embedded in zones with high stress concentration in tangent mode and in other zones with axis to axis space of 2m from each other with length of 24.5m around the project. They were then embedded to the soil behind the wall in 4 different balances by pre-stressed control system with variables number of strands from 3 to 5 strands. Details of the pre-stressed control system of excavation wall near the 20-storey tower and adjacency of 7-storey hotel have been presented in table 2.

Table 2: Details of pre-stressed control system of excavation wall in the most critical excavation wall

Row	Anchor position from ground surface level (m)	Anchor length (m)	Bond length (m)	Horizontal space (m)	Pre-stress force (ton)	Angel of drilling (^{o})
1	-6.50	21.2	5.7	4	50	10
2	-9.00	21.2	7	4	75	10
3	-13.50	19.2	9.1	2	100	10
4	-18.00	15.2	7.5	2	125	10

Stepwise Water Control System of Excavation Wall
As it was mentioned, after completion of the retaining structure due to the 27-month time gap and gradual rise up of groundwater level in Mashhad Plain, a lake was created in the excavation place with depth of 3.10m. Presence of the lake and continuity of inundation and adjacent buildings like 20-storey

administrative-commercial tower and 7-storey hotel could cause many dangers for the zone such as subsidence, landslide and destruction of stability of the foundation because of rinse. Due to the concerns and sensitivities created, drainage operation was conducted in Dec of 2013 and water control from excavation walls was considered as a priority for implementation process. Firstly, decision was made for drainage of water by pumping it inside the containers of green space irrigation. However, using the method was not useful based on the reduction of water volume and the water replaced immediately. On the other hand in this method, existing soil in spaces among piles was removed by water pumping and caused instability of excavation wall and increased risk of collapse of adjacent buildings. Hence, more advanced method should be applied. For purpose of preventing scour of walls and due to entrance of water from the bottom and walls in the project, the water influence should be prevented step by step. As a result, firstly the water was controlled in excavation walls. Concentrated water inside the project was drained to a canal near the project through two pumps that were designed for working day and night through transfer network based on head, discharge, water influence velocity and conditions of the project. At the same time, reduction in static level of the water, excavation wall was stabilized from two meters above the primary level of water through 4 steps.
At the first step (according to figure 4), installation of drainage system in wall was conducted based on discharge of incoming water for purpose of transferring water from walls to the bottom. Then in the next step, implementation of reinforced waterproof concrete in walls was conducted for purpose of preventing scour of soil in spaces among piles and also preventing water influence as it is illustrated in figure 5. At the third step, impermeable 2-layer implementation in cross from on reinforced waterproof concrete was conducted as it is depicted in figure 5. Finally, secondary geo-membrane layer was installed on back of the retaining wall.

Figure 4: Implementation of horizontal drainage

Figure 5: Implementation of Waterproofing concrete

Figure 6: Implementation of impermeable 2-layer

Hence, the water level was declined during 4 steps gradually and the method was applied for purpose of controlling incoming water from the excavation wall and it was stopped from the body completely.
Based on status of soil saturation around the excavation wall, with the beginning of pumping operations and reduction of water level balance, stress has been removed and resistant force against reversal has been decreased. Hence, excavation walls have faced risk of downfall. Therefore, before starting the operations and while performing the operations, excavation walls have been monitored by 10 monitoring gauges, which used to give weekly reports as it is illustrated in figure 7. The most critical results of the monitoring indicated horizontal displacement to 9mm. As a result, displacement of excavation walls has been investigated based on maximum overload. Obtained results from the monitoring would be compared with each other using finite element software.

Figure 7: Weekly monitoring operations

Finite Element Modeling
In order to clarify results of excavation wall monitoring, behavior of retaining structure system was numerically modeled through considering new status of groundwater level balance by PLAXIS finite element software. In the mentioned numerical modeling, some geotechnical parameters have been considered including soil profile, excavation adjacent overloads, status of implemented controls, bending anchors in concrete piles, status of groundwater level balance, effect of pumping and other relevant parameters for the project. In this study, corrosion of excavation wall was occurred near the 20-storey tower and 7-storey hotel as it is illustrated in figure 8. After each step of wall water control and pumping it, horizontal displacements of the wall were measured and obtained results were compared with the results of monitoring operations. The most horizontal displacement obtained from finite element modeling in the most critical mode was equal to 12mm.

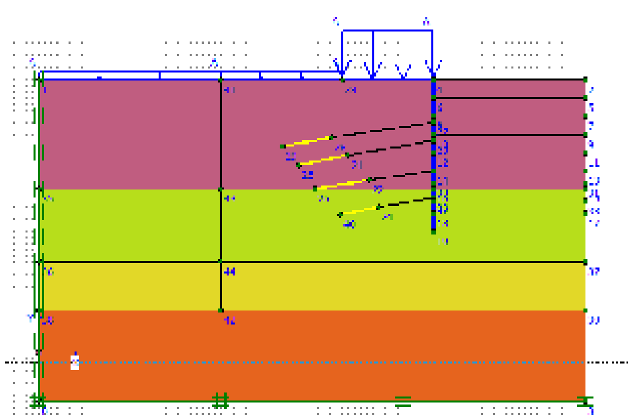

Figure 8: Numerical modeling using finite element software PLAXIS

CONCLUSION

Operation of water incoming control from excavation walls and water drainage of Daneshgah Project was conducted using an advanced method and through a perfect planning in short time of 2 months successfully. According to concrete pile retaining structure system and anchorage in the mentioned project, for purpose of controlling influence of water from the walls, drainage system was embedded on the right wall adjusted with water discharge to transfer the water from walls to the bottom. Then in the next step, reinforced waterproof concrete was implemented in walls for purpose of preventing soil scour in spaces among piles and also preventing influence of water. At the third step, impermeable 2-layer implementation in cross from on reinforced waterproof concrete was conducted as it is depicted in figure 5. Finally, secondary geo-membrane layer was installed on back of the retaining wall. According to applying conditions of plane strain in modeling with 2-D software of PLAXIS, the obtained results are conservative. Comparison of value of horizontal displacements in the monitoring reports with obtained results from numerical modeling has confirmed the applied method in this study and has also confirmed that obtained results have high consistency and unity.

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