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Support of extended foundation pit in urban area

Support de l'extension d'un puits de fondation en zone urbaine

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ABSTRACT: This paper deals with engineering solution for stabilization of existing foundation pit intended for construction of new hotel. The foundation pit is excavated up to 6,5 m depth and supported by reinforced concrete cantilever retaining walls. It was left for several years without any construction activities but in 2017 it was decided to proceed with the construction of the hotel but according to updated, modified design. In order to comply with the Client's requirement for extension of the foundation pit for one extra underground level a new design for support of foundation pit was developed. Considering the fact that the existing retaining walls are design to support the foundation pit to the depth of 6,5 m additional support structure was needed to be designed and constructed to provide support of the extended foundation pit (one extra underground level). The new excavation depth was set to 10,65 m which means it is approximately 4,0 m more that the depth of existing foundation pit. The new underground level which actually will be the third underground level of the hotel will have smaller area than the other two underground levels. This will provide more space for construction of separate support structure for support of the extended part of the foundation pit. The new design proposes construction of new anchored pile walls and installation of passive anchors on the existing and new retaining structures.

RÉSUMÉ: ce document traite des solutions d'ingénierie pour stabiliser des fondations existantes dans le cadre de la construction d'un nouvel hôtel. Les fondations sont creusées jusqu'à une profondeur de 6,5m. Elles sont renforcées par des murs de soutènement en béton armé. Le chantier est resté sans activité durant plusieurs années jusqu'en 2017, lorsqu'on à décidé de reprendre la construction de l'hôtel mais selon un nouveau plan. Afin de satisfaire la demande du client quant à l'extension des fondations en vue de créer un niveau souterrain supplémentaire, un nouveau plan des supports de fondations a été établi. Etant donné que les murs de soutènement existants sont calculés pour des fondations de 6,5m, une nouvelle structure est nécessaire pour supporter les nouvelles fondations (+ un niveau souterrain). La nouvelle excavation est arrêtée à 10,65m soit environ 4m de plus que les fondations actuelles. Le niveau souterrain supplémentaire – le niveau -3 en fait – devra avoir une surface moindre que les deux autres niveaux inférieurs. Ceci procurera plus d'espace pour la construction d'un support indépendant destiné à soutenir l'extension des fondations. Ce nouveau plan préconise la construction de nouveaux puits d'ancrage et la mise en place d'ancrages passifs sur les nouvelles et les anciennes structures.

Keywords: foundation pit, support structures, passive anchors, pile wall

1. INTRODUCTION

The main objective of the particular design is support of extended foundation pit. For the design purposes the foundation pit was divided in 6 sections and each section has a different engineering solution for support. Major differences in the proposed stability measures can be noticed in the section 1 and section 4. The sections 2, 2', 3 and 3' has similar engineering solutions.

Figure 1 Demolishing of the existing foundation pad at level -6,5 m

The proposed design for support of section 1 involves construction of pile wall and installation of anchors to restrain excessive displacement of the structure. The pile wall was planned to be constructed behind the existing cantilever wall. According to the Client's requirements the stem of the existing wall should be kept attached to the pile wall in order to provide smooth surface for installation of hydro-insulation before construction of the hotel. The foundation of the existing wall was cut off.

Adopted design option for section 2 and 3 are involving stabilization of the existing cantilever wall using passive anchors and construction of reinforced concrete pile wall in front of the existing wall. In order to prevent excessive displacement pile wall will be restrained with one row of passive anchors installed through the capping beam and spaced at 2,4 m.

Section 4 of the foundation pit are the north and east side of foundation pit. On both sides there is large space which enables forming of cut slopes without any need for construction of support structures.

Section 2' is a very short section and originally the design involved construction of five 600 mm in diameter, reinforced concrete piles. The piles will be exposed approximately 5 m and according to the calculations the displacements are less than maximum allowable displacement and therefore anchors are not proposed for this section. Later, the design for this section was modified and 3 piles of 800 mm in diameter are introduced.

Section 3' is also a short section which is to be supported by construction of pile wall restrained by passive anchors. This section is at the corner between section 3 and section 4 and construction of the pile wall was needed to avoid forming of cut slopes due to lack of space in this corner of the foundation pit.

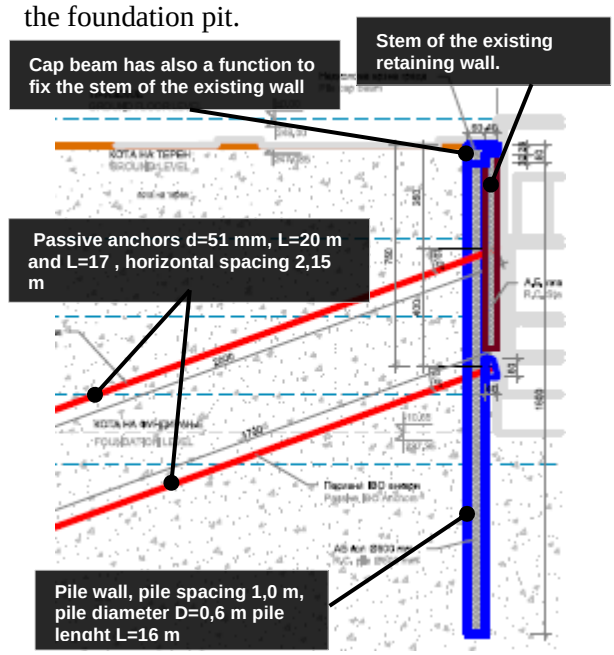

Figure 2 Anchored pile wall – section 1 of the foundation pit

2. Ground profile

The ground profile is consisted of soil materials, rock formations are not encountered at the site.

The surficial layer up to 3,5 m depth is predominantly consisted of silts with low to intermediate plasticity. Under the layers of silts alluvium (gravel) deposits are detected. The gravel is extended from 3,5 m to 6,0 m from the ground surface and they are underlaid by marl. The established ground profile is typical for the valley of Skopje. The ground water table is detected in the alluvium deposits.

3. STABILIZATION OF THE EXISTING SUPPORT STRUCTURES

Having in mind that the existing foundation pit will be extended (the excavation will be deeper) stability of the existing support structure should be reconsidered and verified. The existing support structure is consisted of reinforced concrete retaining walls which have construction joints spaced at 2,15 m along the perimeter of the retaining structure. The construction joints are intentionally left in order to comply with the method of construction of the retaining wall. Precast reinforced concrete thin segments were used for construction of the facing of the retaining wall. The precast segments are 2,15 m wide and they are separated by construction joints. Later, they were concreted with the rest of the wall stem and the wall foundation. The existing retaining wall is constructed along entire perimeter of the foundation pit with exception of the east side where cut slopes were formed. Behind the retaining wall extraction wells are constructed at approximate spacing of 20 m which were used and will be used for lowering of the ground water level. It is important to emphasize that the existing retaining wall is not designed to withstand the hydrostatic pressure from the ground water level. Therefore, the extraction wells should be used all the time until underground levels of the hotel are constructed. Considering all this, the first step was to stabilize the existing retaining wall. In order to achieve this objective passive anchors were introduced for each 2,15 m wide segments of the retaining wall. The bearing capacity of each anchor is estimated at 400 kN. The anchors were installed in the middle of each wall segment at 5,5 m vertical distance from the wall crest.

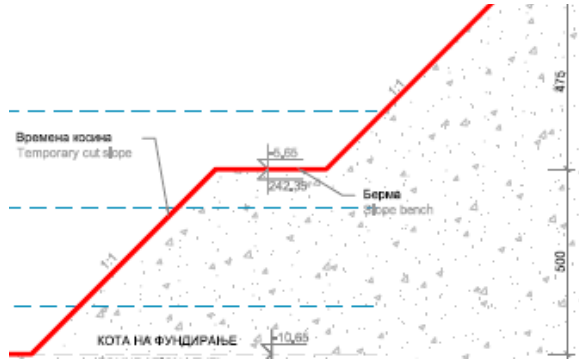

Figure 3 Slopes of the foundation pit – section 4 of the foundation pit

4. SITE ANCHOR TESTING

The considered design for support of the foundation pit involves installation of many passive anchors intended to prevent excessive displacements of the existing and newly designed support structures. In order to have proper design and evaluation of the anchor bearing capacity site testing was performed. According European norms EN 1537 three site tests are proposed investigation test, suitability test and acceptance test. Before developing of the design on this particular project site investigation test was not performed. Having this fact in mind the bearing capacity of the anchors in the design was calculated but also the experience gained from work on one adjacent foundation pit was taken into account. The passive anchors in this design are considered as temporary, so their design life is 2 years. Following the requirements from EN 1537 in case the investigations tests are not performed then the results from suitability test can be considered for design purposes. It was obvious that the suitability test will be conducted upon construction of all designed support structures and installation of all proposed anchors. Considering this fact it was

agreed with the Client that modification of the design concerning the length and location of the passive anchors are possible upon establishing the results from suitability tests. The design proposes installation of 143 temporary passive anchors and 8 anchors were put on suitability site test. The results of site testing were satisfactory i.e. 7 anchors passed the test and only one failed, hence it was decided not to do any modification of the designed anchors.

During the construction works there were not any problems regarding the installation of the passive anchors.

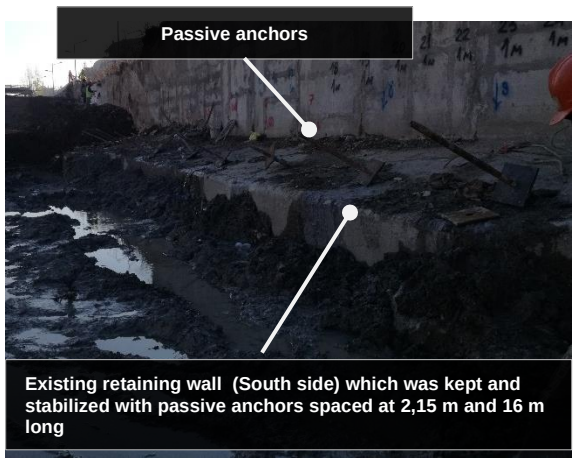

Figure 4 Installed anchors (before locking off) on the existing retaining structure on south side of the foundation pit

During the site testing the anchors were subjected to maximum axial force of 285 kN (depending of the design requirement). As noted before one anchor failed the test. One of the tested anchors experienced approximately 2,4 cm displacements at 285 kN axial load which was a little bid higher than the estimated anchor displacement of 1,6 cm. All other anchors showed satisfactory results and they experienced displacements lower than 1,6 cm.

5. MONITORING OF THE EXISTING AND NEW STRUCTURES

Monitoring of the retaining structures either existing or new ones on this project site was highly important. Having in mind that the site is located in the central area of the city of Skopje surrounded by highly trafficked boulevards and streets any excessive displacement of the retaining structures can cause damages on the adjacent infrastructure. Also, considering the fact that excessive deformations can negatively affect the cost, construction schedule and safety performance the timely detection of excessive deformations of the structures has even greater importance. The estimated deformations of the structures listed in the design were used as reference values for checking if any excessive deformations have occurred.

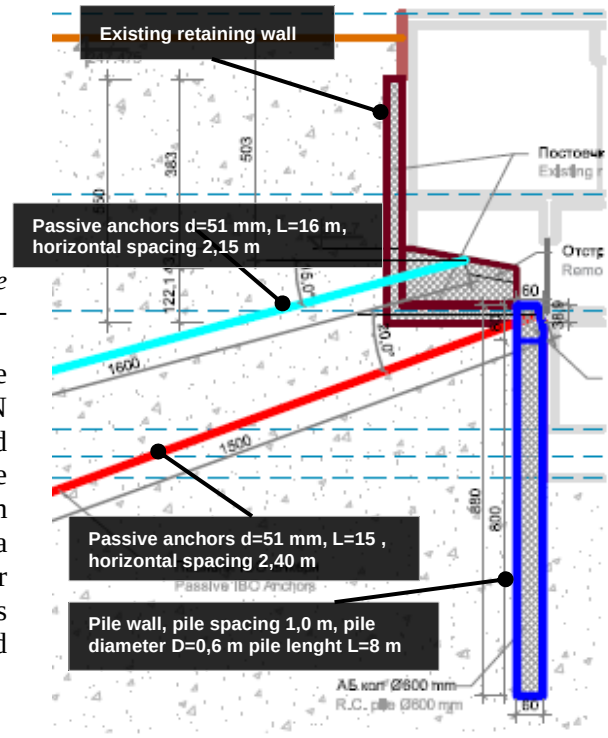

Figure 5 Anchored pile wall – section 2 of the foundation pit

Monitoring of the structures was carried out on every 2-3 days for each phase of excavation. The survey started upon construction of the structures and before the start of the excavation works. Fourteen survey points were established and all of them were positioned at the pile cap beams. The monitoring of the structures was conducted from 4.12.2017 to 4.01.2018. The zero measurement was carried out on 4.12.2017 when all support structures were constructed but the additional excavation of foundation pit from -6,5 m to -10,65 m was not started yet. After the zero measurement the following measurement sessions were conducted on every 2-3 days depending on the progress of excavation works. The general idea was that each excavation phase should be monitored with measurement of the displacement of the structures. The calculated displacement of the structure from section 1 were approximately 7,0 cm and for other sections the estimated structure displacements were approximately 5,0 cm. The maximum measured displacement was 2,2 cm which is far below the estimated displacement.

Figure 6 Existing foundation pit (before proceeding of the construction works), August 2017

6. CONCLUDING REMARKS

From designer's point of view working on a design for support on this particular foundation pit was a challenging task. Moreover, the need for additional stabilization of the existing retaining structure was a tricky issue. The stability of the existing structure raise a lot of concerns having in mind that the informations regarding existing retaining structures were limited and there is no "As build" design. Also the foundation pit had to be extended for additional 4 meters below the original excavation level.

Probably the greatest benefit was gained from the monitoring results and site testing of the anchors. The monitoring results were later used to recalibrate the calculation model and to rerun the

stress-strain analysis. Considering the monitoring results for each excavation phase a fine tuning of the soil material properties was done and more realistic behavior of the designed structures in the calculation model was provided.

	Geo 5	Plaxis 2D AE
Вкупни деформации [cm]	≈0,50	≈5,00
Аксијални сили во кол [kN/m']	/	52.29
Трансверзални сили во кол [kN/m']	22.53	26.99
Нападни моменти во кол [kNm/m']	38.88	24.87
Сила во анкер (горен ред) [kN]		206.28
Сила во анкер (долен ред) [kN]	59.55	66.50

Figure 7 Estimated displacement and forces of the structures – section 2 and 3

The site anchor testing showed that the estimation of the anchor's bearing capacity was satisfactory and very close to the calculated capacity of the anchors. Eight anchors were tested on site and only one failed i.e. it was not pulled out but the displacements were greater than required.

Probably the most valuable experience for the designers was the adjustment of the newly designed support structures during the construction works. In order to simplify the execution of the works and according to the contractor's requests minor modifications of the structures were done. Most of them were related to the structures of section 1. On this section modifications were done on the pile cap beam and short steel anchors which were introduced to hold the stem of the existing wall to the newly constructed piles. Namely, in the original design short steel anchors are proposed to be installed on 0,5 m spacing in vertical direction and 1,05 cm spacing in horizontal direction. To install the anchors holes had to be drilled through the existing wall stem and the new piles and then the anchors should been installed. Instead of installation of many short steel anchors (made of reinforcement bars) additional 3 m long self-drilling anchors were installed and the number of short steel anchors were significantly reduced. This facilitated the works and reduced the construction time which was very important in order to meet the construction deadline.

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