O 145. UNDERPASS DESIGN WITH TOP-DOWN CONSTRUCTION TECHNIQUE ON RAILWAY AND HIGHWAY INTERSECTION LINES

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ABSTRACT: In this study, the definition, construction stages, advantages and disadvantages of top-down construction technique were mentioned. Within the scope of Karaman - Ulukışla high-speed train project infrastructure works, the solution of the problem encountered in the railway - highway intersection route between 201 + 900 km and 202 + 000 km was discussed with the top - down method and the numerical analysis related to this problem was performed in PLAXIS 2D computer program. Material parameters to be used in the analysis were selected according to the literature and obtained data in the field. As a result of the analysis carried out in PLAXIS 2D computer program, deformations and cross-sectional effects of the structural system were obtained. The static and dynamic safety factor of the designed system have been obtained and controlled according to permissible limits.

Keywords: Top-down, Karaman-Ulukışla high-speed train project, excavation method, top-down construction, underpass construction

1. INTRODUCTION

Top-down construction method is a method used in our country for the last 30 years. It is preferred especially in deep and very basement buildings with limited working area. This method is the opposite of the traditional excavation methods and constructions are completed from top to down. In this way, both the basements and the upper floors of the structure can be constructed in the same time. In addition, if there is not enough slope distance for the excavation and the construction of the superstructure should be continued, the top-down method becomes reasonable. This method is preferred especially in underground subways, underpasses, car parks and hotel constructions. Top-down construction technique can be applied on all soil condition.

Top-down method was constructed in 1993 at Kızılay station of the Ankara metro line. Being quite intense pedestrian and vehicle traffic in Kızılay and due to excavation in order to minimize the environmental negative effects primarily, it is decided to construct the station and construction methods as a top-down, one of the first practices in Turkey that has been preferred construction method from top to bottom. In the period of the excavations, urban transportation and vehicle traffic, which will be very difficult during the construction period, is needed to ensure that the traffic flow should be provided in the shortest time in order to prevent the encounter of bigger problems.

In previous studies on the subject, top-down construction method was preferred to support excavation in places where anchorage support system could not be applied. In the designed anchor shoring system, depending on the environmental conditions and ground conditions, anchors in some levels could not be constructed. Moreover, it is determined that the manufactured anchors do not carry enough load as a result of performance tests. Due to the large size of the construction area, the excavation surfaces with steel struts could not be supported. As a result of this situation, half-top-down construction method was used in the fronts. In the study, the deformations that would occur in the excavation pit of 25,00 m depth and in the case of semi-top-down were determined and compared with the PLAXIS 8.2 computer program. [5]

Excavation should be done from the ground to the foundation bottom level within the scope of underpass construction. Excavations are usually carried out as slope excavation depends on soil and working conditions. Considering that the planned underpasses will be built in the city, the slope distances of the deep excavations are not enough and may correspond to the structures or the road - railways where the traffic should work. Hence, deep excavations may be required by means of shoring systems. With top-down method, the underpass reinforced walls can be constructed with secant piles, soldier piles or diaphragm walls. It is aimed that the railway beams are connected to the pile heads and the railways can operate continuously and to limit the deformations.

2. TOP-DOWN CONSTRUCTION TECHNIQUE

During excavation of the foundation made with classical excavation techniques, the excavation process is continued until the final excavation level. After the excavation is completed, the foundation plate is constructed and the construction of the structure is continued to the upper floors. In other words, the construction of structure is done from bottom to top. [5]

In the top-down construction method, the building's curtain and carrier columns are constructed. Shoring curtain and concrete slabs connected to the carrier columns are constructed, then a space is left in the floor and excavation is done for the production of plaques in the lower levels. Following the completion of each excavation stage, the building floors are constructed from the top to the bottom level respectively. In this process, upper floors can be continued to construct.

In the top-down method, the lateral supports of the retaining walls consist of basement floors or steel beams. In other words, the use of horizontal elements such as anchoring and pipe support, which are used in conventional methods, undertakes slab and beams.

In the dimensioning of the slabs and beams, the structural loads and lateral loads that occur during the excavation are taken into consideration. [3]

It is planned to add four basement floors to the project within the scope of the restoration works of two Ottoman mansions, Hatice and Fehime Sultan built in the late 19th century on the shores of the Bosphorus. Due to the lack of sufficient distance for the excavation and its proximity to the surrounding structures, it was found appropriate to build the basements with the top down method. The curtain wall of the building was formed with 5,00m socketed diaphragm walls and the carrier columns with bored piles. Considering the challenging ground and environmental conditions, it was determined that the top-down construction method is a safe, economical solution and can save time for the project. [1]

2.1. Elements Used in Top-Down Systems

The top-down construction method utilizes secant piles, intermittent piles, diaphragm wall, steel profiled piles for the surroundings of the excavation area, and structural slabs to provide lateral support to them.

In the selection of the vertical elements used in top-down method, the determinants can be listed as geological unit of the ground, ground water condition, cost status, vertical and horizontal forces acting on the shoring system.

In case the ground water level is high, the diaphragm walls are more favorable than the intersecting walls as the retaining wall. Because the diaphragm wall width is larger than the piles, labor defects will be less. Diaphragm walls have a more rigid geometry than piles, so they are safer than piles in terms of stability. However, in addition to all these advantages, it is a more expensive solution compared to piled shoring systems.

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The top-down construction method stages are given below;

- The shoring wall surrounding the boundary of the area to be excavated is constructed,
- Carrier columns of the structure are constructed as a barette piles or bored piles,
- The ground floor slab is attached to carrier columns and shoring wall. In addition, the slab plate for excavation of the lower stages of machinery and excavation is provided with sufficient space to exit and entrance.
- After the construction of the ground floor, the excavation equipment excavates from the space left in the floor to the floor bottom level to be made at the lower level and the excavation from the excavation is taken out from the left space.
- The first basement floor slab is the constructed after the excavation
- The operations listed above are followed up to the lowest level of the building and finally the structure of the building at the lowest level is constructed.

2.2. Top-Down Application in Underpass Construction

Considering that the underpasses will be built in the city, the slope distances required for the excavations are generally not enough. In this case, pedestrian, vehicle and railway traffic disruptions occur. As a result, it is necessary to carry out the top down construction technique in excavations for the completion of the construction. The construction of the structures to be constructed by the top - down construction method is important in terms of minimizing the negative effects that traffic and environmental structures will be exposed to during the construction period. Underpass walls are designed with bored piles. It is the primary goal that the railway beams can be connected to the constructed pile heads and that the railway can operate continuously during the underpass production.

During the construction phase, the land is leveled up to the upper elevation and then piles are produced with sufficient reinforcement and length. After the piles have reached sufficient strength, the railway beams are construction in the with sufficient moment, shear and axial load capacity to ensure that the system works as a whole. The rail beam is an important factor in reducing the lateral deformations because it will serve as the pile cap between the piles.

Examples of the top-down method of excavation method preferred for the construction of Ankara Metro are given in Figure 1.

Figure 1. Kızılay station constructed by top-down construction method [2]

3. CASE STUDY

3.1. The Solution of Problem encountered in Karaman - Ulukışla Railway Line Structures by Top-Down Construction Technique

In this study, the solution of the problem encountered in the railway - highway intersection route between the railway line 201 + 900 km - 202 + 000 km within the scope of Karaman - Ulukışla high speed train project infrastructure project was discussed.

It is aimed that the railway and highway transportation will continue uninterruptedly by constructing underpasses, overpasses, bridges at railway and highway intersections.

Underpasses that are planned to be built generally correspond to the city. Considering the thickness of the gabarite and reinforced concrete structures at the underpasses, excavations should be carried out at depths ranging from about 6-8 m. Excavations cannot be carried out in slope excavation and endangers the safety of environmental structures. In addition, the train running on the current line during construction must continue to serve. For this purpose, it was considered appropriate to apply the underpass construction with top down method.

Karaman - Ulukışla 135 km 2. Line Infrastructure and Superstructure Construction work at the intersection of railway and highway underpass is planned to be constructed with the Top-down method. The underpass is projected as shown in Figure 2 and Figure 3.

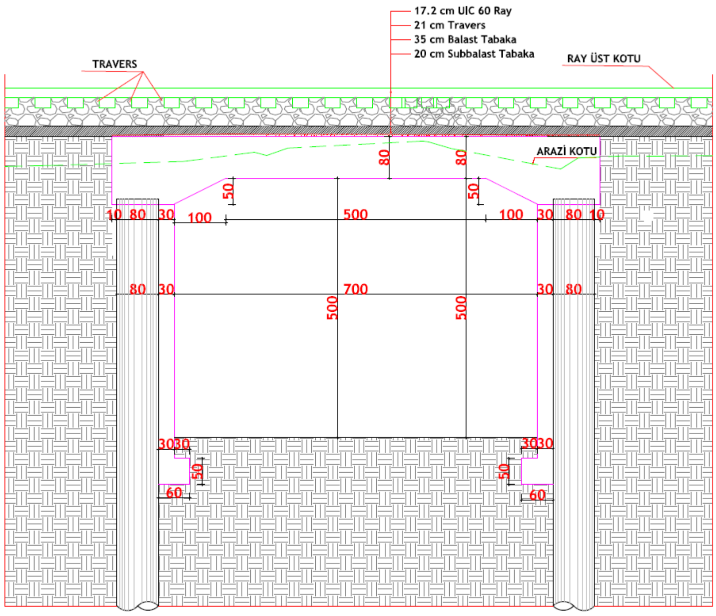

Figure 2. Underpass design with top-down method

In Figure 2 given the longitudinal section of 5m x 7m, there are 80cm diameter bored piles, 80cm high pile cap connecting the bored piles and rail fill on the header beam.

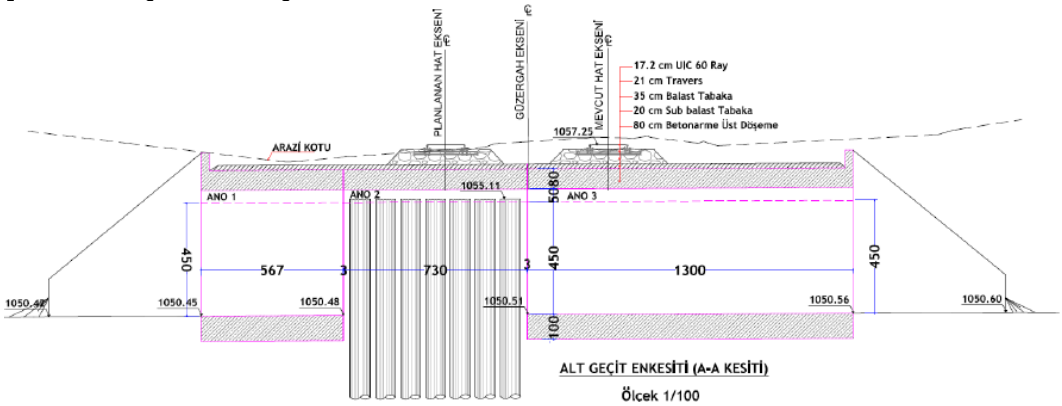

Figure 3. Underpass top-down longitudinal section

The analysis of top-down construction was done in PLAXIS 2D computer program, deformations of the structure and forces on the bearing elements were determined.

3.1.1. Underpass Load Acceptance and Determination of Stress

The load model Eurocode LM 71, which represents the static effect of the vertical load under normal railway traffic, is shown in Figure 4.

The following figure shows the loads transferred from the train axles. In the analysis, the rail load was taken as 80 kN / m. Rail transport structures should be designed to carry the vertical static load given in Figure 4.

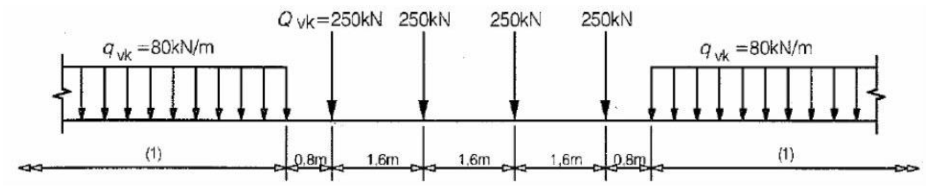

Figure 4. Characteristic values for load model LM 71 and vertical loads [4]

3.1.2. Field and Laboratory Studies

In order to obtain geological and geotechnical data related to the project, drilling wells with depth of 15.00 meters were opened in the region.

In the borehole drilled from 0.00 to 3.00m, brown colored, coarse-medium gravel, high plasticity, sandy clay (CH), between 3.00 and 15.00 m brownish-pinkish-beige, extremely weak strength, decomposed, completely degraded, very cracked sandstone-Marn was passed. Groundwater levels were not found in the soundings.

The soil profile formed in accordance with the ground units determined as a result of the drillings is given in Figure 5.

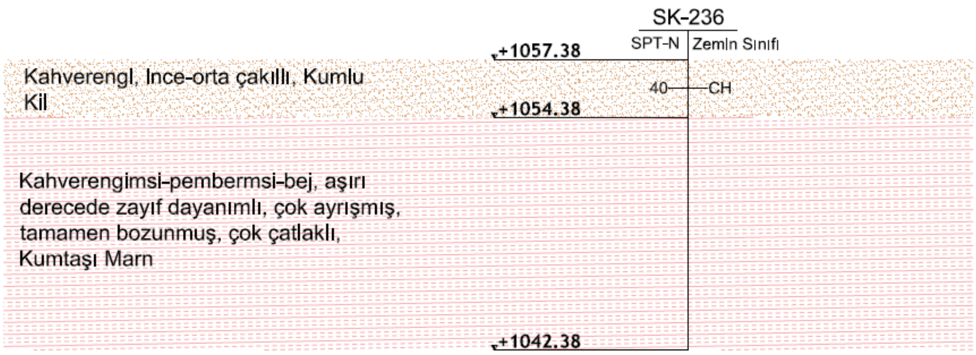

Figure 5. Ground profile determined in the borehole

Pressuremeter test was performed in the borehole. The results of the pressuremeter test are given in Table 1.

Table 1. Results of the pressure test of the drilling well

Depth (m)	Net Limit Pressure P_{LN} (kg/cm^2)	Menard Modul E_M (kg/cm^2)
2,00	13,90	167,00
4,00	14,80	180,00

There are various correlations between PLN value and undrained shear strength (cu) in the literature and between the Menard module and Elasticity module. Net limit pressure and Menard module values given in Table 1 were used to determine the engineering parameters of the clay unit determined in the drillings.

3.1.3. Determination of soil parameters and idealized soil profile

SPT-N values, Atterberg limits and pressuremeter test result were used to determine the soil parameters and profile. While determining the modulus of elasticity for the clay units, the safe side remained within the limits specified in the literature.

The idealized soil profile and parameters used in the analysis were determined by using the field and laboratory tests and also within the limits specified in the literature, cu (undrained shear strength), c (cohesion), ϕ (internal friction angle) and Es (Elasticity module) parameters of the soil units are shown in Table 2.

Table 2. Idealized soil profile and parameters

Depth (m)	Geological Unit	c_u (kPa)	c (kPa)	ϕ	E_s (kN/m²)
0,00 – 3,00	Sandy Clay	100,00	5	26	40.000
3,00 – 25,00	Weathered Sandstone-Marn	150,00	10	28	60.000

3.1.4. Engineering Analysis and Evaluations

Ø80cm bored piles are designed with 100cm spacing. All details of the top-down system are given in Figure 2 and Figure 3. 80cm header on the pile made of the pile to work together. After the construction of the beam, excavation was done at both side. While determining the load of the current route; the rail surcharge load is taken as 80,00 kN/m.

3.1.4.1. Cross Section Details

Details of the planned underpass construction, top-down system to be constructed in 201- 934 km are given in Table 3.

Table 3. Km: 201 + 934 underpass retaining system details

Diameter of pile (cm)	Pile Length (m)	Pile Spacing (cm)	Excavation Depth (m)
80,00	13,80	100,00	≅6,00

3.1.4.2. PLAXIS 2D Analysis

The underpass planned to be constructed within the scope of the project was analysis in PLAXIS 2D computer program and deformations and forces on piles were observed in the system under top-down construction method.

In PLAXIS 2D program, all stages, from the beginning of the underpass construction to the opening of the train services, are modeled respectively. The stages of construction are given below.

- Stage 1: Slope excavation up to the upper of the pile elevation in the existing land.
- Stage 2: Construction of the designed size and diameter bored piles.
- Stage 3: Construction the railway beams on the cap of the piles and ensuring that the piles work together.
- Stage 4: Filling up to the upper elevation of the rail after the production of the head beam.
- Stage 5: Opening of the railway line to transportation.
- Stage 6: Excavation up to the road level.
- Stage 7: Determination of cross-section effects by applying earthquake forces to the system.
- Stage 8: Determination of safety factors for static and dynamic analysis.

Progressive solutions of the top-down excavation method in PLAXIS 2D computer program and the results are given below.

Figure 6 shows the PLAXIS 2D model in case of underpass excavation under railway traffic. According to the results of the analysis, the maximum deformation that will occur under railway approach fillings is determined as 3.25 cm.

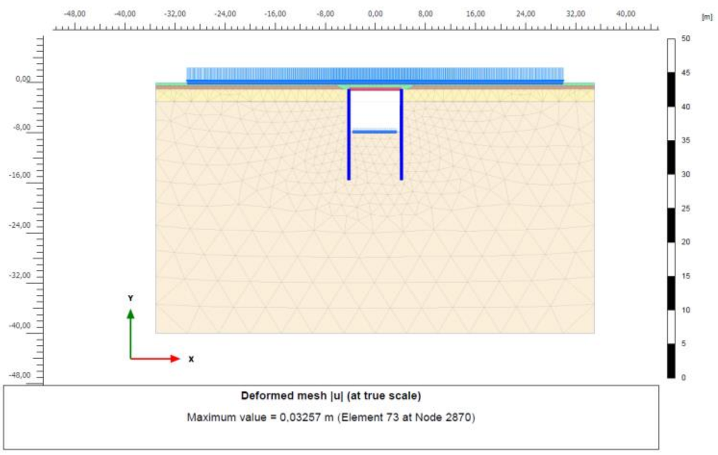

Figure 6. Total deformations in the static state in PLAXIS 2D analysis

Figure 7 shows the vertical deformations in the system in case of underpass excavation under railway traffic. According to the results of the analysis, the vertical deformation will be 3.25 cm.

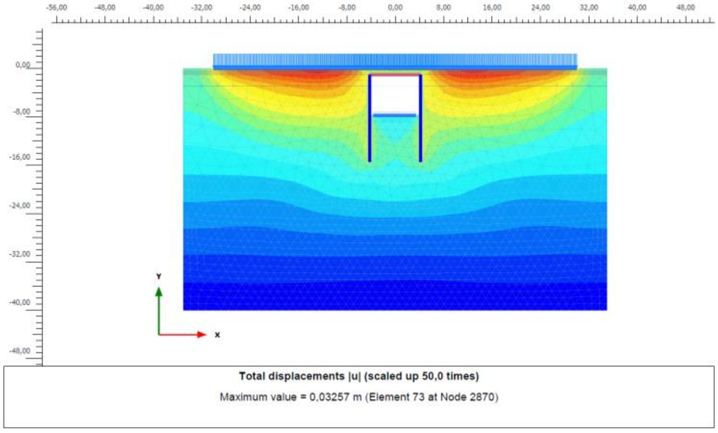

Figure 7. Vertical deformations in the static state in PLAXIS 2D analysis

Figure 8 shows the horizontal deformations in the system in case of underpass excavation under railway traffic. According to the results of the analysis, the resulting horizontal deformation will be 0.47 cm.

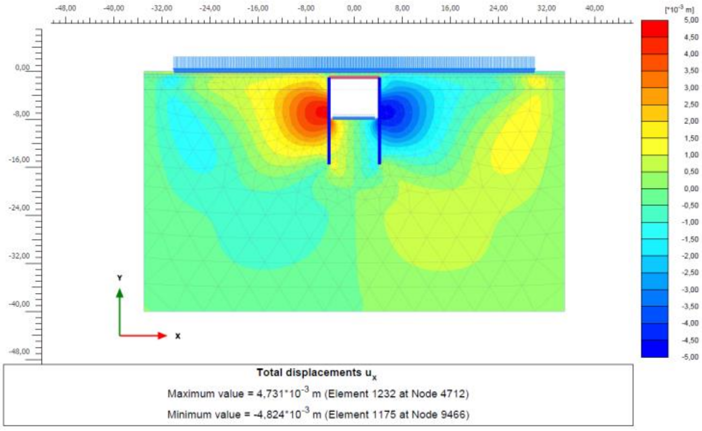

Figure 8. Horizontal deformations in the static state in PLAXIS 2D analysis

Figure 9 shows the horizontal deformations in the bored piles in case of underpass excavation under railway traffic. Maximum horizontal deformation in the bored piles designed according to the results of the analysis is 0.47 cm.

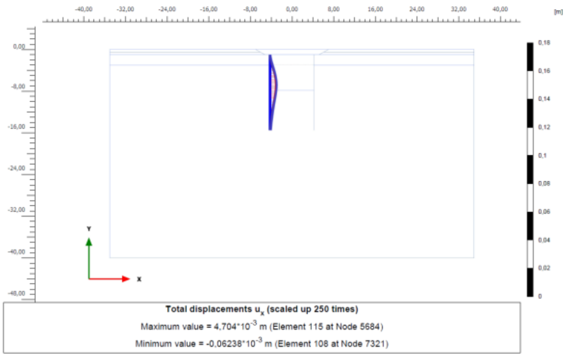

Figure 9. Horizontal deformations in piles in static state

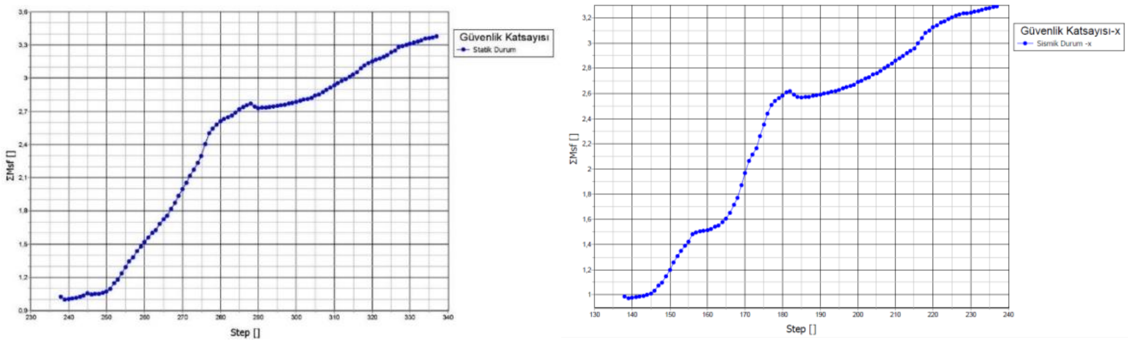

Figure 10. Static and dynamic factor of safety in PLAXIS 2D analysis

In the analysis, 0,47cm horizontal deformation was measured in the static situation. The system was designed in a static condition and exposed to a seismic effect by subjecting to a 0.05 g earthquake acceleration and the safety coefficients were measured. The static and dynamic safety parameters of the designed system were determined as 3.33 and 3.23, respectively (Figure 10). Deformations and safety coefficients determined as a result of the analysis remain within the allowable limits. The section effects to be formed in the piles are given in Figure 11.

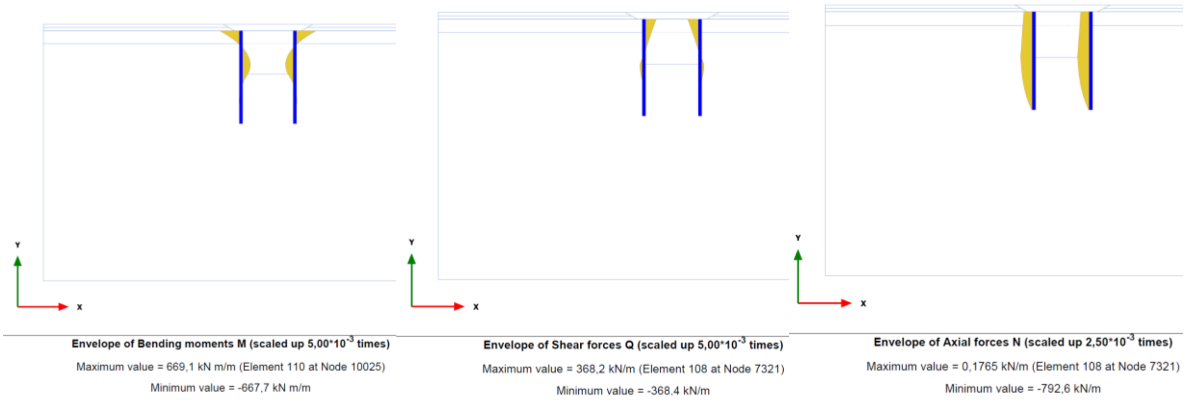

Figure 11. Sectional effects on piles in static state

4. CONCLUSION AND DISCUSSION

In this study, the solution of the problem encountered in the railway - highway intersection route between the railway line 201 + 900 km - 202 + 000 km within the scope of Karaman - Ulukışla high speed train project infrastructure project was discussed. It is aimed to continue the railway and highway transportation uninterruptedly by under passing the railway and highway intersection points.

In the determination of the soil parameters used in the analysis, drillings, laboratory test results and pressuremeter test results were used.

Top-down construction method, designed for underpass construction was modeled and analysis in PLAXIS 2D computer program. Retaining system Ø80cm L = 13,80m bored piles are designed at interval 100cm. 80cm height header beams on the top of the piles were provided to work together.

As a result of the analysis, the horizontal deformation occurred in the system in static condition was 0.47cm and vertical deformation was measured as 3.25cm. Figure 7 shows that when investigated carefully, vertical deformation of 3.25cm is found in underpass approach fillings. The vertical deformation of the constructed beam will be less. The static and dynamic safety coefficients of the designed system were determined as 3.33 and 3.23, respectively. The calculated factors of safety are above the permissible limits in the literature.

As a result of the analysis, the determined cross section effects are multiplied by the pile interval of 1,00m. As a result of this process, the moment force of the stakes was 669.1 kNm, the shear force was 368.4 kN and the axial force was 792.6 kN.

In case the structure is constructed with the designed system, the underpass excavation can be performed safely while the railway line is working.

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