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FIELD PERFORMANCE AND NUMERICAL EVALUATION OF DIAPHRAGM WALL AT MULTI-LANE ROAD TUNNEL UNDER THE RIVER KARNAPHULI IN BANGLADESH

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ABSTRACT

The first-ever tunnel construction is going on under the River Karnaphuli in Chattogram, Bangladesh, to bridge between two banks of the River Karnaphuli, keeping an aim to be a future business hub of the country. Diaphragm walls have been constructed at two sides of the tunnel to allow deep excavation for road construction. However, the primary concern is to evaluate the sub-soil condition as the proposed tunnel is running through the soft sedimentary deposition. Highlighting this real scenario, an attempt has been made in this research to evaluate the performance of the diaphragm wall. A set of numerical simulations at different segments of the diaphragm wall have been conducted. Geotechnical parameters of the sub-soils have been extracted from prior investigation reports, and an identical Finite Element Model has been developed to determine the calculated maximum deflection of the wall. Stage construction has been considered in the numerical model to reflect the actual scenario. It has been seen that the calculated maximum deflection of the wall corresponds to the field monitored maximum deflection after the construction of the wall. The variation of the sub-soil profile has been considered by considering different sections of diaphragm walls on both sides of the tunnel. Overall, the performance of the constructed diaphragm wall is acceptable, and the developed model can be a plausible option for the prediction of necessary parameters of future constructions works, especially for deep excavation.

Keywords: *Diaphragm wall; BSMRT; Deflection; FEM; Validation*

1. INTRODUCTION

Diaphragm wall is typically used to facilitate underground construction, a cut-off option for deep excavation and sometimes act as a basement. With the rapid urbanization, there is an intense increase in complex and high-rise constructions, which require excavating soils to a greater depth; eventually, the necessity of a permanent and rigid retaining system is obligatory. Compared with other wall types, the diaphragm walls are considered very stiff with respect to ground movement control. Research has been conducted to explore different aspects of the diaphragm wall under different loading conditions (Pan and Fu 2020; SaravanaPrabhu and Vidjeapriya 2021; Xie et al. 2021; Zhang et al. 2021). Besides that, constitutive models for different diaphragm wall-soil interactions have been incorporated in numerical modeling (Kawa et al. 2021) . Recently, statistical modeling, to be exact, Machine Learning algorithm has been adopted in many cases to precisely predict the behavior of diaphragm wall under different loading conditions (Zhao et al. 2021).

Bangladesh, a developing country situated along the downstream end of the Himalayan Belt, has experienced significant infrastructural development. In line with such development projects, the country's first-ever underground tunnel named Bangabandhu Sheikh Mujibur Rahman Tunnel (BSMRT) is now under construction and, hopefully, will be opened at the end of 2022, as stated by the concerned officials. To facilitate the construction of the approach road on both sides, diaphragm walls were constructed to retain near-vertical cut soils. The major challenge associated with the project was to retain soft clayey soils, which pose a major threat to the stability of the soils. However, the contractor successfully installed diaphragm walls on both sides of the tunnel and completed the necessary road without having any distress. Continuous monitoring of deflection was done at different sections to check the stability of the wall. All the same, the validity of the diaphragm wall movement with respect to a hands-on numerical approach has high potential to check the accuracy of measurement and provide a guideline for future construction of such deep diaphragm wall in the country. Summing up the preceding points, this research aims to numerically analyze the response of a section of the diaphragm wall. The subsequent section describes in detail the calculation procedure.

2. METHODOLOGY

Several approaches have been used to predict the response of diaphragm wall under different conditions. For simplified analysis, some analytical methods are available , which provide better result for small vertical cut. However, the deep excavation, and to the extreme case, deep excavation with soft soil problems cannot be solved using simplified analytical model. Experimental investigation may provide better interpretation in this case, however, scaled experimental model lacks the actual prediction in many instances. Besides that, numerical modeling is a plaussible option to carry out such type of complicated simulations. Among many available numerical tools, PLAXIS, which is a famous FEM package specially developed for geotechnical problem analysis are used in this research. The steps for construction, such as soil excavation and strut installation, were simulated in the FEM analysis. Furthermore, steps for casting the base slab and strut installation must also be designed and combined. The PLAXIS 2D program was used to predict diaphragm wall behavior for these projects. The Mohr-coulomb soil model was employed in the FEM analysis. Diaphragm wall was modeled using two-dimensional model PLAXIS model to analyze the response of soil adjacent to the wall. The numerically estimated deflections were validated with measured data of the BSMRT project. A layout of the model is shown in the Figure 1.

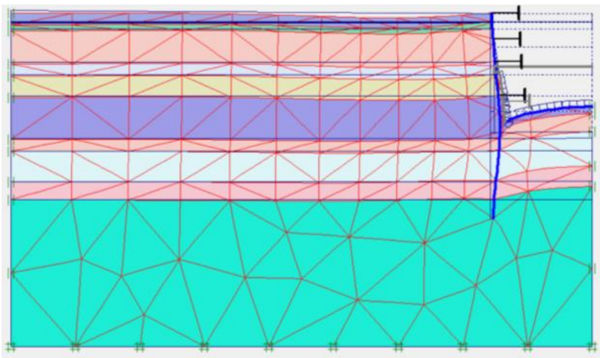

Figure 1: Numerical model of WJD-11 section (Deformed shape)

Plate elements were used to define the wall, lining wall and based slab. For the wall, modulus of elasticity was estimated as

$$Ec= 57000\sqrt{f_c'} \quad lb/in^2 \text{ in USCS units}$$

where f_c' (MPa) is the standard compressive strength of the concrete.

Flexural rigidity plays an important role on the response of diaphragm wall. An equivalent plate thickness was estimated using the following equation:

$$d_{eq} = \sqrt{12(EI/EA)}$$

3. DIAPHRAGM WALL MODEL OF BSMRTP

Sequential construction was simulated in the model. Simplified Mohr-Coulomb failure criteria was used to define the soil characteristics. The displacement of diaphragm wall in lateral direction was not significant owing to the high rigidity of basement slab in case top-down construction method. In the FEM simulation, the bending moment and shear force developed in all simulation steps were extracted to understand the mechanics of the diaphragm wall. The estimated peak values were found compatible with in-situ observations.

3.1 Case 1-(Segment WJD-11-West Bank):

Lateral wall movement of diaphragm wall were recorded by a set of inclinometer and compared with the FEM simulations, and shown in Figure 2. At the very first step, soil was excavated up to the bottom of the wall. It was found that both the field estimations and numerical results agreed quite well.

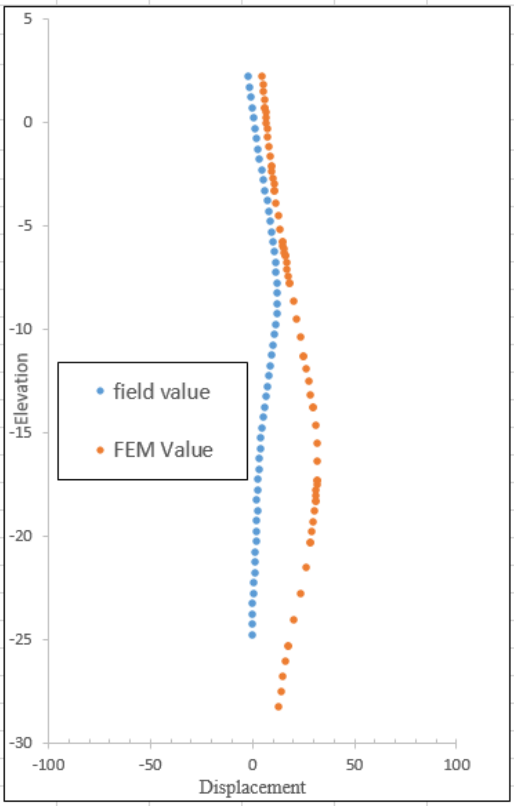

Figure 2: Comparison between field and predicted value at WJD-11 section

3.2 Case 2-(Segment EJD-02, East bank)

In the first step of construction, the soil was excavated up from the ground level to the bottom level of the diaphragm wall. This section was located at the EAST bank side of tunnel. It can be seen that the field measurements of the diaphragm wall movement agreed well with the results predicted by the FEM analysis.

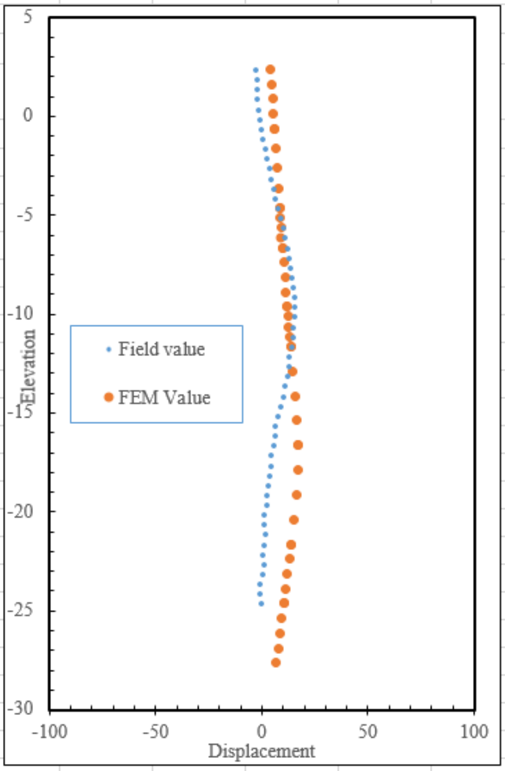

Figure 3: Comparison between field and predicted value at EJD-02 section

4. PARAMETRIC STUDY

The previous section derived the compatibility between numerical and field results, and it was seen that a comprehensive adjustment was evident. To further investigate the aspects of diaphragm walls in a broader aspect, a sensitivity analysis considering different properties was conducted in this research works. Among many parameters, the effect of drawdown and strength parameter for cohesive soils influenced the response of diaphragm walls under different conditions. Therefore, this research conducted a parametric study on the same numerical model used for BSMRT for an observed water table variation and cohesion. Figure 4 shows the relation between the elevation of the water table to the displacement of the diaphragm wall. This graph clearly indicates a minimal difference among different levels of water level.

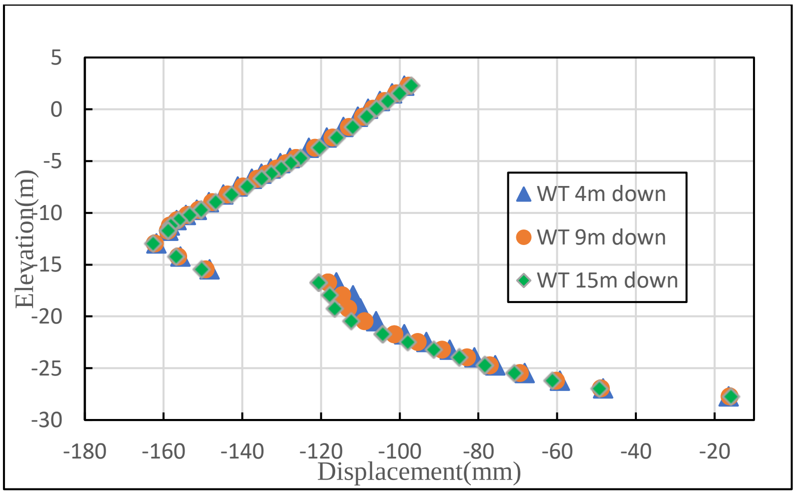

Figure 4 Relation between Max displacement and depth of water table of the soil profile

Figure 5 shows the relation between the maximum displacement of diaphragm wall to the depth of water table. This graph indicates that the displacement of the diaphragm wall gradually increases with the increase of water table depth. So, water table depth is a one of the major factors for diaphragm wall displacement.

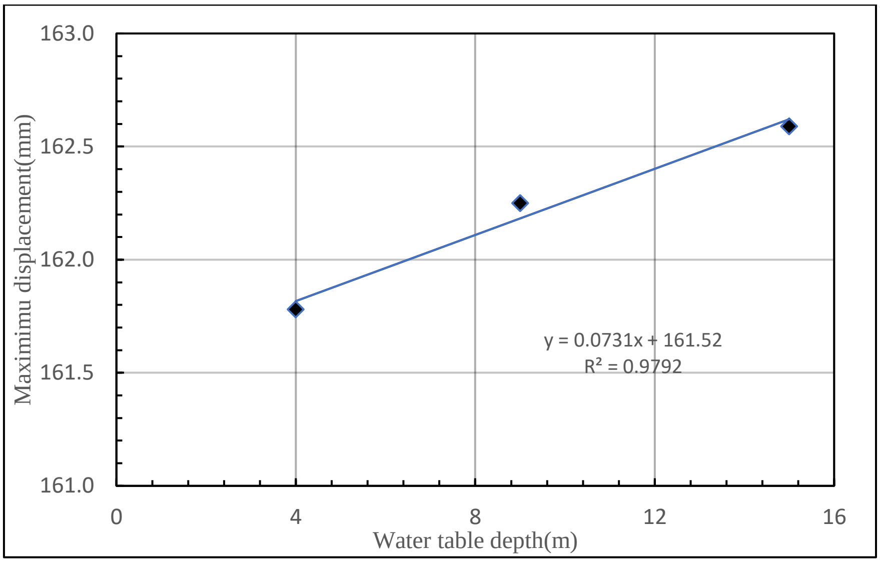

Figure 5 Relation between maximum displacement and depth of water table of the soil profile

The variation of cohesion also play a significant role on the bending response of a diaphragm wall, and the response is shown in Figure 6. It was found the cohesion significantly reduce the induced moment, eventually responsible for more stiff diaphragm wall.

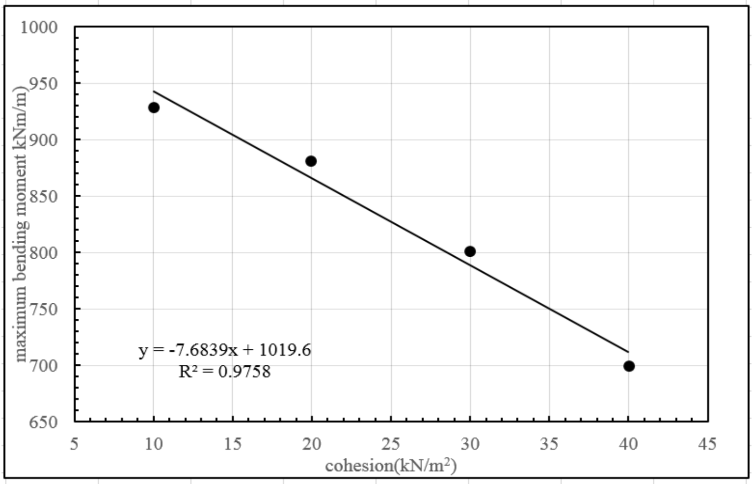

Figure 6 Relation between cohesion and maximum bending moment of diaphragm wall

The variation of shear force in the diaphragm wall to different cohesive soil is shown in Figure 7. The maximum value was obtained at less cohesive soil. Shear force is 233.05 kN/m for C-10 and 196 kN/m for C-40 respectively. Here it was shown that, shear force of diaphragm wall is decreases with the increase of cohesion of soil.

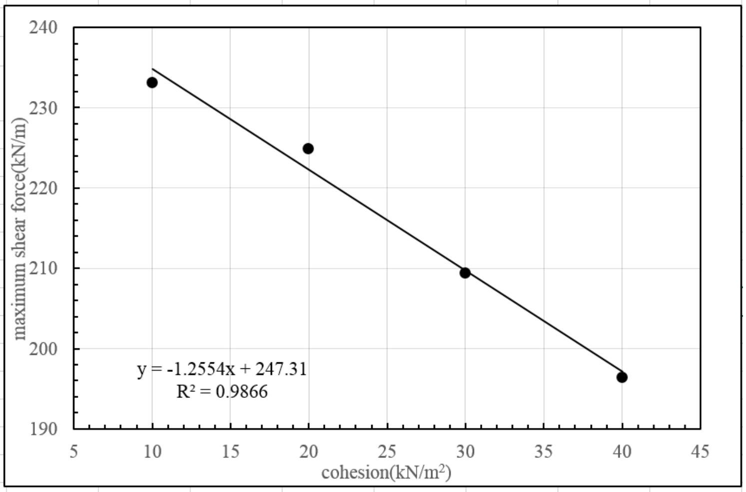

Figure 7 Relation between cohesion and maximum shear force of diaphragm wall

5. CONCLUSIONS

In this paper,we have obtained the relation between the displacement of diaphragm wall for the maximum depth of water table. So,the water table depth is a major factor during diaphragm wall design for the displacement of diaphragm wall.The maximum bending moment and shear force of diaphragm wall analysed in this paper were greatly dependent on cohesion of soil. Here we found that, the maximum shear force and maximum bending moment gradually decreased with the increasing of cohesion of soil.So,the relation between cohesion and maximum bending moment and shear force are inversely propotional . This thesis paper will be fruitful in near future for the design of diaphragm walls in different soil conditions. For different soil properties, anyone can predict the maximum deformation of the diaphragm wall before design and construction.

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