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Monitoring Lateral Deflections of a Berthing Structure During Dredging — A Case Study

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MONITORING LATERAL DEFLECTIONS OF A BERTHING STRUCTURE DURING DREDGING-A CASE STUDY

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ABSTRACT

For one of the major ports in India, a shallow water berth is recently constructed comprising of a diaphragm wall and pile rows to support the deck structure. The soil strata are essentially very soft clay extending to a large depth. Reclaiming land behind this structure created number of problems including mud flow. The structure was constructed after placement of fill required for reclamation. After completion of the structure, when dredging work was undertaken, it was decided to monitor the lateral movements of berths, as the dredging depth increases. For this purpose inclinometer tubes were installed in one of the diaphragm wall panels and another in one of the piles of the structure. The structure is analysed using PLAXIS finite element software and results are compare with field measurements which are in good agreements.

INTRODUCTION

The development of port structures has necessitated in depth study on the behaviour of berthing structure under dredging. The soil found in some of the coastal region is soft marine clay and during dredging, it may create lot of problem to the existing structure due to slope instability. The clay strata may cause mud flow and transfer heavy lateral forces on the structure which may get damaged. In order to study problem, a berth was monitored in Jawaharlal Nehru Port Trust, Mumbai.

DETAILS OF THE STRUCTURE

The general layout of the berthing structure is shown in Fig.1. The total length of the berth is 252m and width is 33m. 1100 mm thick diaphragm wall was adopted and it was terminated at a depth of -27 m level and 1400mm diameter piles were adopted. The natural ground level is +0.0m. To satisfy the berthing facility of the vessel the ground level is required to be dredged up to -9.5 m level. After completion of the structure when dredging work was under taken it was decided to monitor the behavior of the berth, particular in the lateral deflection, as the dredge depth increases. The inclinometer readings were taken when the water depth in front of the structure was – 3 m (with out dredging) and -9 m (after -9 dredging). Two readings were taken at – 9 m level, one immediately after reaching -9 m depth and another 3 months after completion of dredging up to – 9 m level.

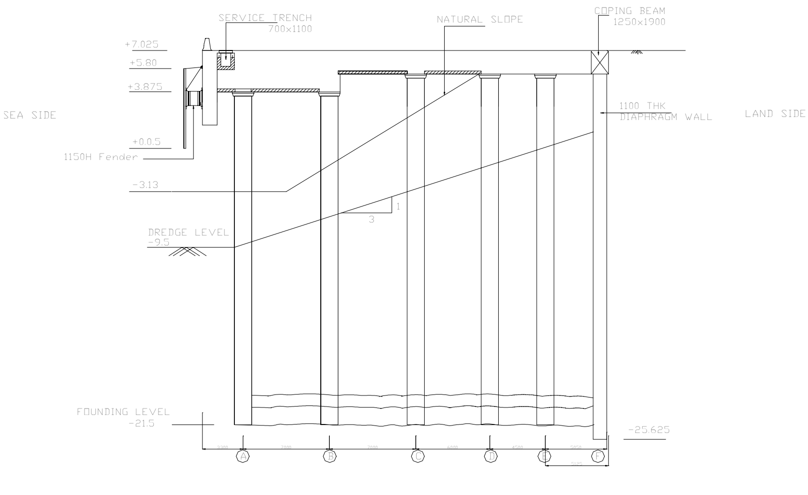

Fig. 1. Cross Section of Berth

GEOTECHNICAL DATA

Soil investigation were carried out in the site in several locations and one of the typical bore hole details is given in Fig 2. Nearly depth of 6m below ground level the soil strata is soft marine silty clay of $20kN/m^2$ cohesion and followed by 2m medium stiff clay of $50kN/m^2$ cohesion values. Below 15m level the soil strata is hard marine silty clay and followed by basalt rock. The actual dredge level of -9m is fall in the soft marine silty clay and medium stiff clay of low shear strength layers. While during dredging this soft strata will not be stable and this will create lot of problems to the existing structure, especially in lateral movement of the structure due to unstable slope.

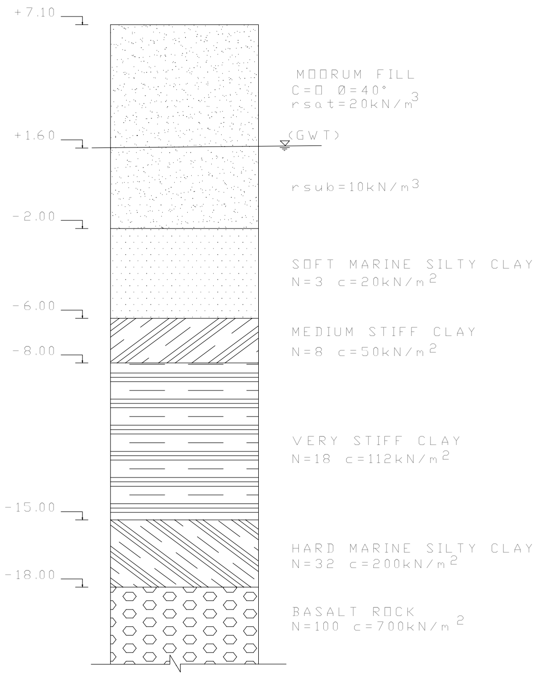

Fig. 2. Bore Hole Details

INSTALLATION OF INCLINOMETER TUBE

The inclinometer tube was made of PVC, which has very flexibility and can easily deform along with the deformation in the diaphragm wall and pile. During casting of diaphragm wall panel and pile, inclinometer tube was placed with reinforcement gauge. The location of inclinometer tube was chosen such that it was away from the tremie pipe location. The length of inclinometer tube above out off lever was closed and protected by rubber hose of 150 mm diameter. The annular gap between the rubber hose and inclinometer tube was filled with bentonite mud to ensure that no concrete enters the hose pipe during concreting

INSTRUMENTATION DETAILS

<u>Technical Data of Probe</u>

Weight 2.2 kgs
Probe can be used in tubes with i.d of max 70 mm and not less than 35 mm
Measuring length each 500 mm
Total length of the sound: 700 mm
Working temperature: -5 degree centigrade to 60 degree centigrade

ANALYTICAL STUDY

Several forms of finite element analysis have been proposed to assess the response of piles influenced by lateral soil movements. The finite element approaches are three dimensional finite element analysis, plain strain analysis and axis symmetric finite element analysis. In the present study, plain strain finite element approach is adopted.

<u>Plane Strain</u>

Randolph (1981) performed a site specific plane-strain analysis, where the piles were replaced by an equivalent sheet-pile wall with flexibility equal to the average of the piles and soil it replaced is shown in Fig 3. The sheet pile wall was modeled with stiffer elements within the finite element mesh. Springman (1984) continued analyses of this type, with the embankment represented by the self-weight of linear elastic

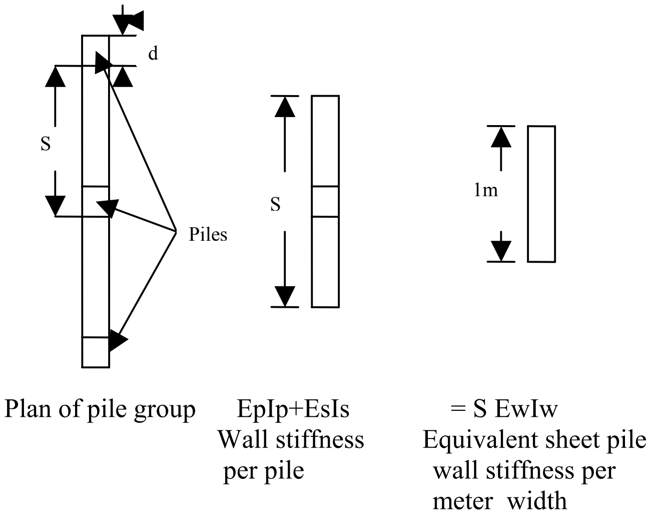

Fig. 3. Equivalent sheet pile wall representation of piles for plane strain finite element analysis

elements and the soft clay represented by either linear elastic or modified cam-clay models. This form of analysis allows pile groups to be analysis directly by incorporating them into the finite element mesh, although single piles can be adequately represented, since the equivalent sheet-pile wall models a row of equally spaced piles.

Naylor (1982) extended this type of approach by connecting the sheet-pile wall to the soil with link elements, thus allowing relative displacement of the soil and the wall, and more closely approximating the true three dimensional behaviour around the piles. However, limiting soil pressure between the soil and wall was not allowed for, since the soft stratum, embankment and link elements were represented by linear elastic models. The conclusions arising from that study were that link elements were not required in cases where the piles were quite flexible, or the soft layer was deep. A similar approach was adopted by Rowe and Poulos (1979) for the analysis of stabilizing piles installed at the crest of a slope, although an elastic-plastic soil model was used and limiting soil pressure on the piles were specified to allow plastic flow of the soil past the piles.

Description of Approach

For this study, the model tests were analyzed using a plane strain finite element approach, with the piles represented as equivalent sheet- pile wall (Fig.3). Plane strain analysis is the most straightforward of the finite element approaches described above, and allows good representation of the pile group configuration and geometry, without being unduly complicated. The equivalent sheet-pile walls were modeled with beam-column elements and the soil strata were represented by 6 nodded triangular elements of elastic-plastic Mohr- Coulomb models. Soil structure interaction was specified by the use of elastic-plastic Mohr-Coulomb model. The finite element program PLAXIS was used for this work. The dimensions of the full berth were represented by a typical finite element discretization is shown in Fig 4 and 5 and the deflected shape of the structure is shown in Fig. 6 and Fig. 7 has shown the shading of shear stress distribution after completion of -9m dredging.

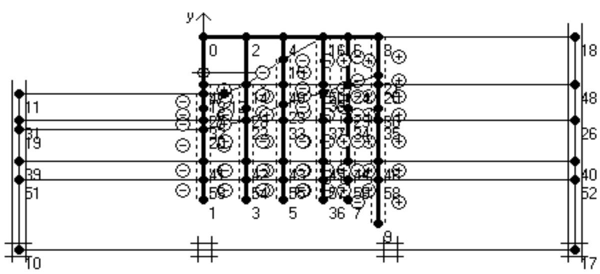

Fig. 4. Discretization of the structure

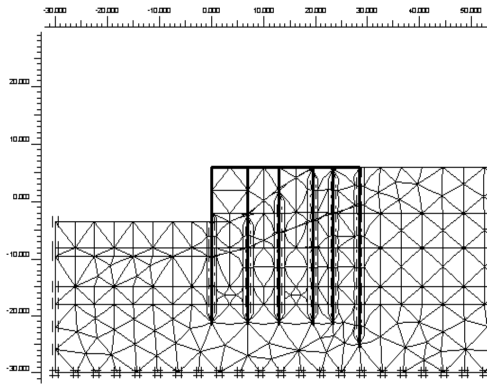

Fig. 5. Discretization of the finite element mesh

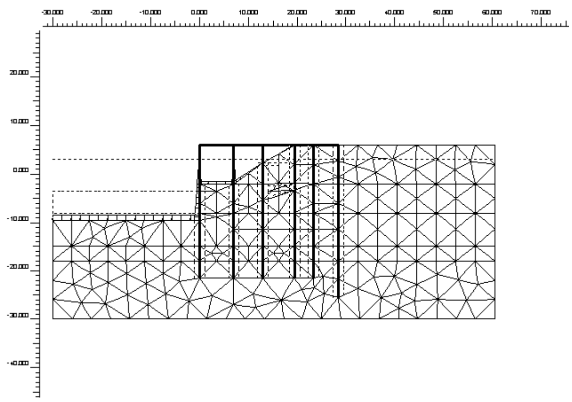

Fig. 6. Deformed mesh

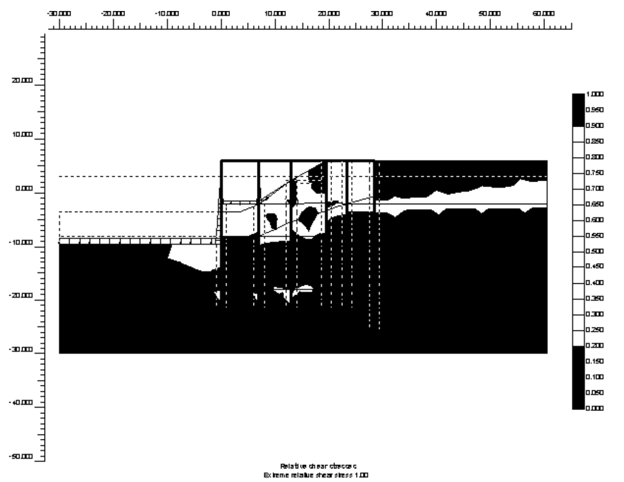

Fig. 7. Distribution of shear stress

RESULTS AND DISCUSSION

After construction of the full berth, the inclinometer readings were taken in 3 stages. First readings were taken after construction of the berth and before starting dredging, these represent the initial position of the diaphragm wall and pile The dredging was carried out in frond of the structure. During dredging the nature ground level was distrusted as the top soil is very soft clay of low shear strength. It may create slip failure of the ground and the soil movement can exact lateral load to the piles and finally the structure may get deflected towards sea side.

The second readings were taken immediately after dredging of -9 m depth, the difference between second readings and first readings will give the deflected shape of the diaphragm wall panel and pile. The third readings were taken after 3 months of – 9 m dredging, the difference between third and second readings will give the further deflected shape of the diaphragm wall panel and pile which is shown in Fig 8 and 9.

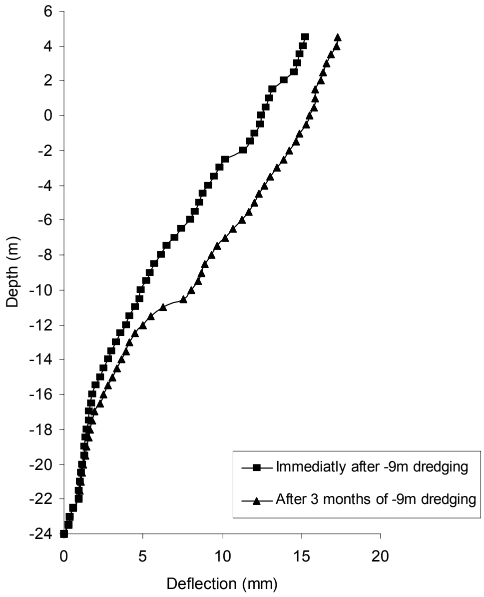

Fig. 8. Deflected shape of diaphragm wall

From the measurements, it is seen that immediately after -9m dredging the maximum deflection is 15.2mm at the level of +4m, in the same level after 3 months of -9m dredging maximum deflection is 17.3mm. in diaphragm wall The increase deflection is due to creep behaviour of soft clayey soil. The same behaviour was observed in pile also. From the deflection shape of diaphragm wall and pile, the overall observation is the variation of deflection from -16m and below is very small compared to the top layers; this is due to the hard layer of marine silty clay and basalt rock. In addition to that the top soil is very soft clay of low shear strength, due to that the defection is more in the top layers. Figure.10 and 11 has shown the comparison of both measured and PLAXIS deflection. In diaphragm wall deflected shape is almost same as PLAXIS result for immediately after-9m dredging.

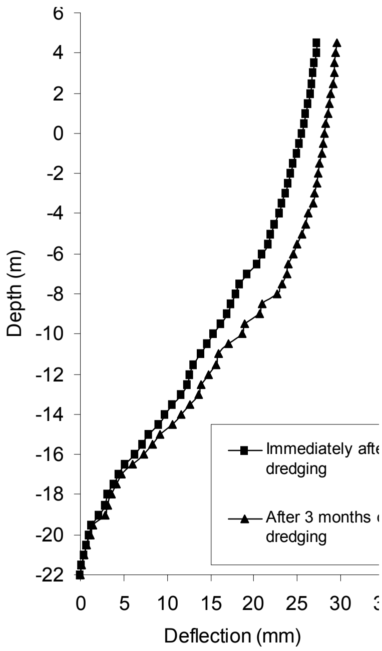

Fig. 9. Deflected shape of pile

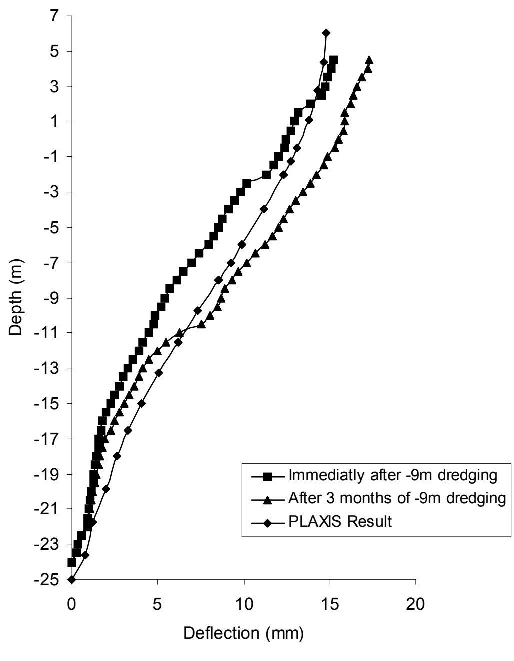

Fig. 10. Comparison of measured deflection with

PLAXIS result in diaphragm wall

In case of after 3 months -9m dredging the field measured deflection is more than PLAXIS results, this is due to the creep effect of clay in the field condition. The PLAXIS result the creep effect is not considered. The same type of behaviour is observed in pile also.

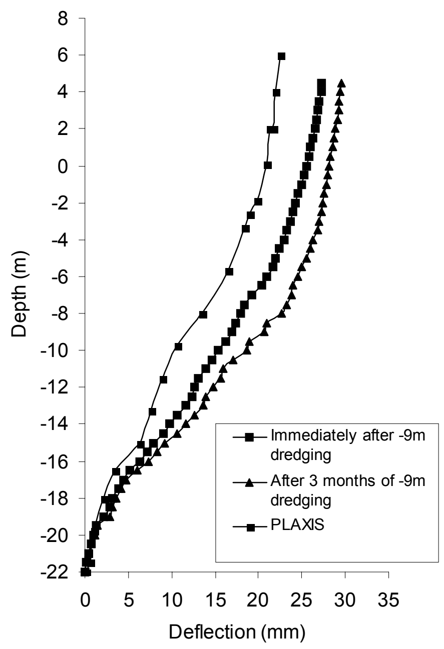

Fig. 11. Comparison of measured deflection with PLAXIS result in pile

CONCLUSIONS

The inclinometer measurement is one of the best field monitoring method to know the lateral movement of structure.

Based on the field observation and PLAXIS analysis, it is seen that the maximum deflection in diaphragm wall is 18mm and pile is 30mm, the maximum deflections were observed in weak layers than good soil strata. The total deflection of 87% will be mobilized in top layers of low shear strength; remaining 13% deflection was mobilized in hard strata. Generally in berthing structures the total defection may allow to 150mm, in the present case the deflection is with in the limit and the structure is functioning safely.

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