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Review of Finite Element Analysis of Berthing Structures

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Abstract— Berthing structures are integral part of ports and harbors. They provide facilities for berthing and mooring of vessels, loading and unloading of cargo and for embarking and disembarking of passengers and vehicles. The main components of berthing structure are piles, diaphragm wall, anchor rod and rigid deck. Berthing structures are subjected to lateral forces caused by impact of berthing ships, pull from mooring ropes, pressure of wind, waves and floating ice, seismic force, active earth pressure, differential water pressure and live load on the structure. The berthing structure must be analyzed and designed properly, in order to avoid the failure due to these loads. The analysis can be done using various software such as STAAD.Pro, PLAXIS, ANSYS, StruCAD 3D etc. In this paper, the various work on berthing structure using software, available in the literature, have been reviewed.

Index Terms— Berthing structure, diaphragm wall, anchor rod, displacement, shear force, bending moment.

1 Introduction

Berth is a designated location in ports and harbors to provide facilities for berthing and mooring of vessels, embarking and disembarking of passengers and vehicles and for loading and unloading of cargo. Berths are designed depending on the types of vessel that are to use them. For a small boat, the size of the berths varies from 5 to10 m and it is over 400 m for the largest tankers. The thumb rule is that the length of a berth should be roughly 10% longer than the longest vessel to be moored at the berth. In berthing structures, lateral forces are caused by impact of berthing ships, pull from mooring ropes, pressure of wind, waves and floating ice, seismic force, active earth pressure, differential water pressure and live load on the structure. A berthing structure can be classified as an open type structure and a vertical face type structure. A rigid deck is supported over vertical piles or combination of vertical and raker piles, in an open type structure. Sheet pile walls, block wall, caissons and diaphragm walls are used in vertical type structures. The active earth pressure is resisted by the diaphragm walls and the tie rods anchored to the diaphragm walls or raker piles absorb the load.

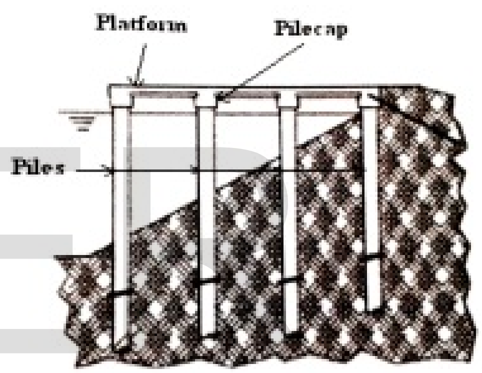

Fig 1: Open type berthing structure

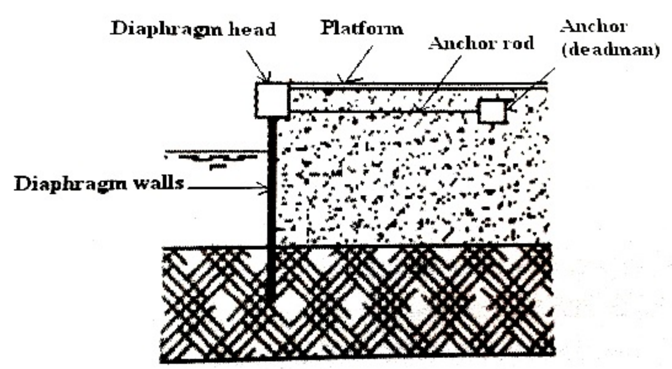

Fig 2: Vertical face type berthing structure

A diaphragm wall is a reinforced concrete wall that is made in situ. The wall is characterized by high bearing capacity and stiffness; hence the deformations are minimal. However, since the width of the panels is limited, problems regarding the sealing of the joints between the panels arise.

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Another important consideration is the need for good cover of the reinforcement. The design depth of quay walls has increased dramatically due to the development in transshipment the last decades (bigger vessels), resulting in sheet pile walls with heavy profiles. Diaphragm walls is a cast in-situ reinforced concrete retaining wall created using the slurry supported trench method. As such, they are often known as slurry walls. Diaphragm walls are considered to be very stiff with respect to ground movement control, compared to other wall types. Diaphragm walls are often attractive in granular soils with a high groundwater level, especially when a low permeability layer underlies the granular soils. They are typically terminated in the underlying low permeability layer which can consist of soil or rock. The diaphragm walls are subjected to loads due to the soil layer on one side of the structure. Additional lateral loads are derived from landside earth pressure in case of dredging. At the time of earthquake additional seismic force also acts on the structure.

In order to increase the stability of the retaining wall, a tieback which is a horizontal wire or rod, or a helical anchor is used for reinforcement. One end of the tieback is secured to the wall and the other end is anchored to a stable structure, such as a concrete deadman which has been driven into the ground or anchored into earth with sufficient resistance. The forces that cause the wall to lean is resisted by the tieback-deadman structure. Tie rod anchors are provided in order to strengthen the structure, to resist the lateral loads and reduce the deflection to a large extent. The use of tie rod anchors in berthing structures will lead to an economical design of the structure since it reduces the bending moment and lateral deflection and thus the required cross-sectional area of the pile and the amount of reinforcement.

The berthing structure is subjected to various kinds of loads. If not properly designed, the structure may fail due to these loads. Hence, the study of berthing structure subjected to various loads is necessary to check the adequacy of the structure.

2 ANALYSIS OF BERTHING STRUCTURE

Berthing structures are analyzed using software such as STAAD.Pro, PLAXIS, ANSYS, StruCAD 3D etc. These software are based on finite element approach. These software have their own advantages and disadvantages. From the analysis, shear force, bending moment and deflection corresponding to the components of the berthing structure can be found out and these results can be used for the design of various components of berthing structure. Similarly, the designed structures can be analyzed to check their performance.

Muthukkumaran et al., (2007) studied the numerical modeling of dredging effect on berthing structure. Finite element program, PLAXIS, was used for analyzing the lateral response of pile and diaphragm wall during dredging. In order to measure the lateral deflection on pile and diaphragm wall for their full length, a full-scale field test was conducted on a bearing structure using inclinometer during dredging in sequence. The results of the finite element method and full-scale field test data were compared and it was found that the finite element method results were in good agreement with full-scale field results.

Muthukkumaran et al., (2007) studied the effect of dredging and axial load on a berthing structure. Field study was conducted on a berthing structure to estimate the actual axial load distribution during axial loading and the lateral displacement during dredging. A full scale axial load test was done on a single pile and the lateral movements of the berth during and after dredging was monitored.

Premalatha (2009) analyzed the optimum length of tie rod anchors required for a berthing structure. The behavior of laterally loaded piles considering the effect of anchors was studied and various analyses were performed by varying the location of anchors.

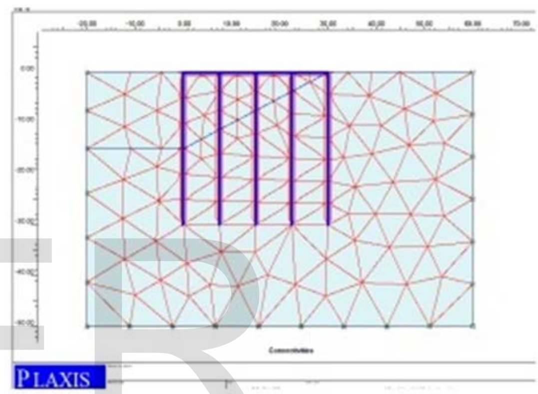

Fig 3: 2D mesh for a single frame of a berthing structure [3]

Premalatha et al., (2011) studied the behaviour of piles supported berthing structure under lateral loads. They designed a series of laboratory experimental setup with single row of instrumented piles in a berthing structure reduced to a model scale. The experiments were carried out by applying both berthing and mooring forces, with and without considering the seabed slope angle. Tie rods were introduced in the frame of the berthing structure and its effect was also studied. The load vs. deflection behavior of piles, distribution of load among the piles and tie rod, and the behavior of the structure with the effect of tie rod on the structure were studied.

Premalatha et al., (2011) studied the effect of dredging and tie-rod anchor on the behavior of berthing structure. They conducted a numerical study on pile group supporting the berthing structures subjected to berthing or mooring forces and the forces arised due to dredging operations. 2D Finite Element Model was developed using the geotechnical software Plaxis and was validated using the theoretical solution. Using the developed FE model, a real time berthing structure located in India was analyzed as a case study. The case study was used to assess the optimum tie-rod length required for the actual installation.

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Shanthala et al., (2011) performed the analysis of berthing structures for wave induced forces. The layout of jetty for berthing 5000 DWT ship at NMPT was modeled using the ship dimensions from IS code and analyzed for the available environmental data from NMPT using StruCAD 3D software. For the significant wave height of 3.2m, a detailed analysis of the berthing structure was carried out for a full cycle of wave. The variation of deflection, forces and moments for perpendicular wave directions and different pile diameters were done by Static and Dynamic analysis. By comparing static and dynamic analysis results, Dynamic Amplification Factor was calculated. Time history analysis was also carried out for the wave loading and deflection, forces and moments of the structure were calculated. From the results, it was observed that the forces and moments increase with the increase in the diameter of pile but the deflection reduces. From the time history analysis, it was observed that, as the pile diameter increases the maximum deflection occurs at the larger time period. It was found that at time period of 8.611seconds peak response occurs.

Subha (2012) analyzed an open type berthing structure using the finite element software, PLAXIS, to study the lateral response of pile and diaphragm wall during dredging and seismic loading on the dredged soil. The static and earthquake analysis results were compared and it was observed that the lateral response of the berthing structure is significantly affected by dredging and under earthquake conditions.

Yajnheswaran et al., (2014) studied the performance of berthing structure under static and dynamic Loading. The analysis was carried out using the finite element software PLAXIS 2D with absence of anchor and varying locations of anchor of diaphragm wall. In the case of static loading, the extreme displacement, and bending moment of the diaphragm wall were found to be about 0.07342 m and 24936.03kNm/m respectively, in absence of anchor. In the case of seismic loading of the structure, the maximum displacement and bending moment of the diaphragm wall were around 0.0749m and 28263.68kNm/m respectively, in absence of anchor condition. When anchor was provided the maximum displacement and bending moment were reduced to 0.00642m and 11830kNm/m respectively. The variation of bending moment was 13.34% more in dynamic analysis than static analysis. The variation of displacement was 2% more in dynamic analysis than static analysis.

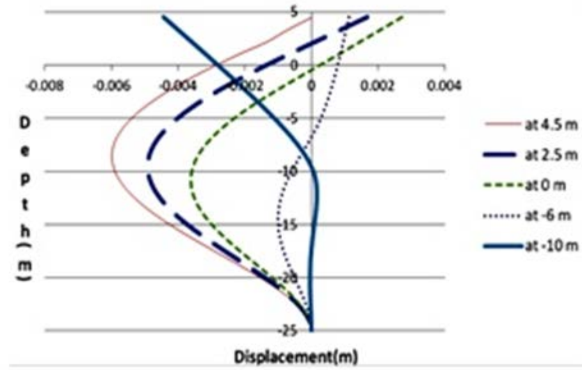

Fig 4: Depth Vs displacement graph of diaphragm wall in static analysis for varying locations of anchor rod [8]

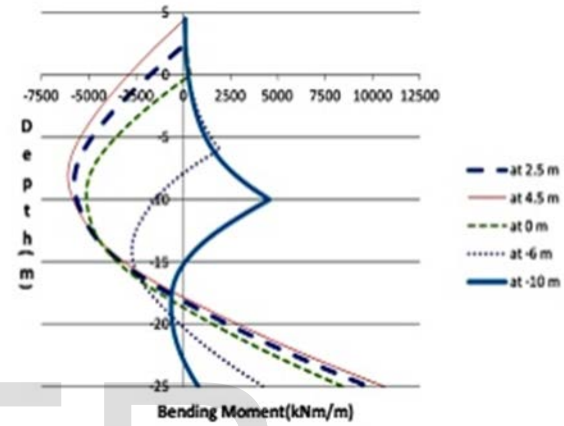

Fig 5: Depth Vs Bending Moment of diaphragm wall in static analysis for varying locations of anchor rod [8]

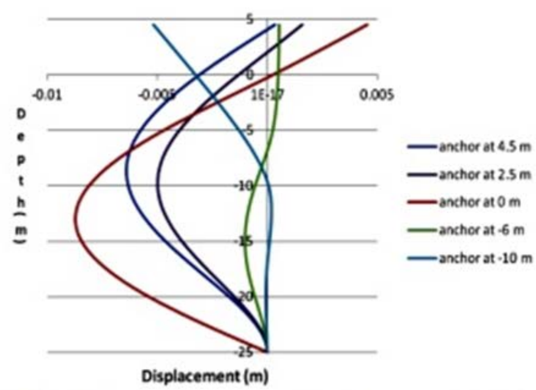

Fig 6: Depth Vs displacement of diaphragm wall in dynamic analysis for varying locations of anchor rod [8]

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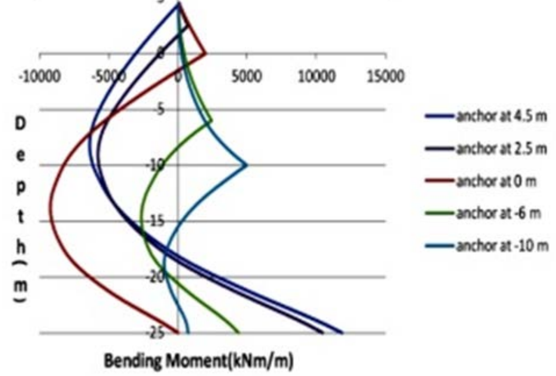

Fig 7: Depth Vs bending moment of diaphragm wall in dynamic analysis for varying locations of anchor rod [8]

Vivek et al., (2016) analyzed and designed a berthing structure using different load conditions and described the best possible way to construct a new berthing structure. All the suitable and useful data were adopted from the proposed site location at Visakhapatnam Port. The proposed berthing structure was modeled with suitable geometry using STAAD.Pro, after which all considerable loads on the structure were induced and analyzed carefully. During the analysis, different sectional dimensions were trialed and the most acceptable structure was designed by providing all structural members with suitable reinforcement and satisfying all marine safety conditions.

Naidu et al., (2016) studied the structural behavior of berthing structure due to variable stack load. Linear static analysis was performed on the berthing structure subjected to variable stack load with and without mooring effects. Equations related to bending moment and axial forces of structural members of berthing structure were obtained, based on this study. A Monte Carlo simulation method was adopted for generation of random numbers using MATLAB software. In order to obtain characteristics of load effects on the components of the berthing structure, analysis was performed from the obtained results. It was observed that the influence of variable stack load has an effect on the bending moment and axial force of structural components of the berthing structure. It was also found that there was a significant variation of results of load effects between with and without mooring force condition in case of vertical pile but there was no significant variation of results of load effects on main cross head beam, T-shaped diaphragm wall and raker pile due to stack load.

Yajnheswaran et al., (2016) studied the non-linear analysis of 3D interaction of soil- diaphragm wall structure with different cross-sections. Using PLAXIS 3D software, they performed the static analysis of diaphragm wall sections having different stiffness for the load condition existing in deep draft berth of New Mangalore Port, India. The displacement and bending moment were found out for diaphragm wall sections and results were compared with the actual diaphragm wall section having 1.1m thick. A single panel diaphragm wall section having 5m length with 2.5m center to center spaced anchors was modeled for the analysis. Soil properties were considered as per the boreholes data obtained from New Mangalore Port. The results were validated with values derived from the design chart.

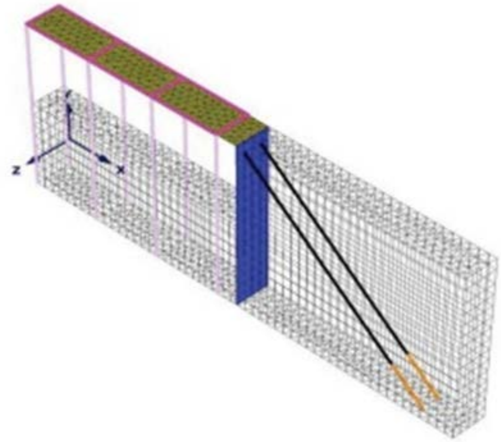

Fig 8: Model of diaphragm wall with anchors [11]

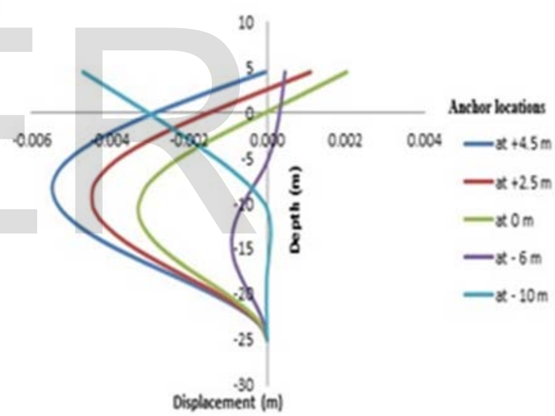

Fig 9: Variation of maximum displacement with depth for the diaphragm wall with 1.1m thick section, for different anchor rod location [11]

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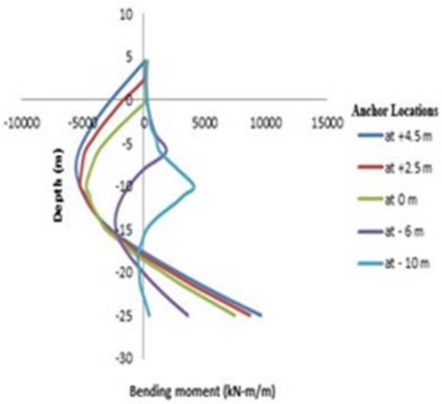

Fig 10: Variation of maximum bending moment with depth for the diaphragm wall with 1.1m thick section, for different anchor rod location [11]

Rajesh et al., (2017) performed cost benefit analysis on different configurations of berthing structure. Detailed load calculations conforming to the various codal provisions and design of the structure were included in the analysis. STAAD. Pro was used for the analysis and design of the three types of configuration of berthing structure for different combination of loads as per IS 4651.Bill of Quantities were prepared and final cost of construction was calculated. Factors affecting the construction and maintenance such as land availability, soil conditions, hydrodynamics of the site, dredging requirements, design ship size etc. were considered to finalize the configuration of the berthing structure. It was observed that the cost of Diaphragm wall berthing structure is lower than that of piled structures but the amount of land available on the land side and the soil condition are the major criteria in deciding the use of diaphragm wall type of berthing structure. Result of the study showed that Diaphragm wall type of berthing structure is economic for Ennore port in India.

Naidu et al., (2017) studied and compared the behaviour of structural elements of berthing structure with raker pile and anchored wall. This comparison was made in order to know the best model of the berthing structure which can resist all type of loads. The software used for modeling and analysis of the Berthing structure was STAAD.Pro. From the study, it was observed that the berthing structure with raker pile system performed well when compared to the berthing structure with anchored wall system under same loads and soil strata.

Kavitha et al., (2017) studied the influence of soil structure interaction in the structural behaviour of a berthing structure in sloping ground using the software PLAXIS 3D. They performed numerical investigations of a typical 2D berthing structure for various diameter of pile, soil modulus and bed slope. It was observed that an increase in pile diameter and soil modulus causes an increase in bending moment on piles. Also, the studies regarding the change in the bed slope revealed that the results depend on the phenomena of change in slope, whether by deposition on the berthing side or by erosion on the shore side.

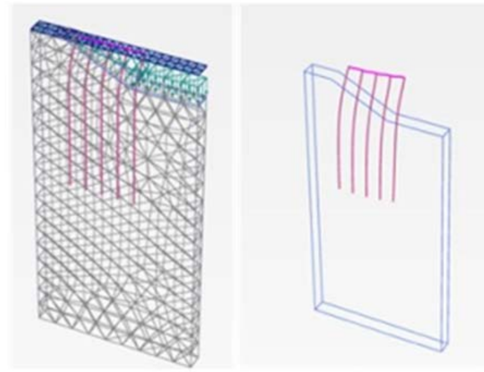

Fig 11: Meshed model and deflection pattern of the typical berthing structure considered [14]

3 Summary

In this paper an attempt is made to summarize the previous work carried on the berthing structures. Berthing structures are analyzed using software such as STAAD.Pro, PLAXIS, ANSYS, StruCAD 3D etc. It is found that the variation of bending moment and displacement is more in dynamic analysis than in static analysis. Dynamic analysis is more critical and should be considered during the design of the structure. It is found that the results of analysis of the berthing structure using these software are very useful in the design of the structures as well as to undertake the performance analysis of the constructed structures. A review on finite element analysis of berthing structures has been presented.

References

[1] Kasinathan Muthukkumaran and Ranganathan Sundaravadivelu (2007), “Numerical Modeling of Dredging Effect on Berthing Structure”, Acta Geotechnica, pp.249–259, DOI 10.1007/s11440-007-0040-1

[2] Muthukkumaran K, Sundaravadivelu R. and Gandhi S. R. (2007), “Effect of Dredging and Axial Load on a Berthing Structure”, International Journal of Geo-Engineering Case histories, Vol.1, Issue 2, pp.73-88

[3] Premalatha P. V. (2009), “Analyzing the Optimum Length of Tie Rod Anchors for a Berthing Structure”, Indian Geotechnical Society, chapter 5.

[4] Premalatha P. V, Muthukkumaran K. & Jayabalan P. (2011), “Behaviour of piles supported berthing structure under lateral loads”, Pan-Am CGS Geotechnical Conference.

[5] Premalatha P.V., Muthukkumaran K. & Jayabalan P. (2011), “Effect of dredging and tie-rod anchor on the behavior of berthing structure”, IJEST, Vol. 3, No. 6.

[6] Shanthala. B, Subba Rao, Katta Venkatramana & Harish (2011), “Analysis of Berthing Structures for Wave Induced Forces”, International Journal of Earth Sciences and Engineering, Vol. 04, No. 01, pp. 112-121

[7] I.P. Subha (2012), “Behaviour of an Open Type Berthing Structure under Earthquake Condition - A Numerical Approach”, International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 1, pp.036-040

[8] Yajnheswaran & Subba Rao (2014), “Performance of Berthing Structure under Static and Dynamic Loading”, International Journal of Earth Sciences and Engineering, Volume 07, No. 04, pp.1727-1732

[9] T. Vivek & R. Durga Prasad (2016), “Analysis and Design of Marine Berthing

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Structure", International Journal of Engineering Research and Application, Vol. 6, Issue 12, (Part -3), pp.46-56

[10] G. T. Naidu, K. V. G. D. Balaji, M. Pavan Kumar & B. Siddharth Rao (2016), "Study on the Structural Behaviour of Berthing Structure due to Variable Stack Load", Indian Journal of Science and Technology, Volume 9, DOI: 10.17485/ijst/2016/v9i45/100261.

[11] Yajnheswaran B & Subba Rao (2016), "Non-Linear Analysis of 3D Interaction of Soil - diaphragm wall structure with Different Cross-Sections", International Journal of Ecology & Development, Volume 31, Issue No. 4

[12] G Rajesh, R Saravanan, Vijaya Ravichandran, S Parameswara Pandian & EvangelinRamani Sujatha (2017), "Cost benefit analysis on different configurations of berthing structure", IOP Conference Series: Earth and Environmental Science, DOI:10.1088/1755-1315/80/1/012048

[13] G. Tirupathi Naidu, Dr. Balaji. K.V.G.D, M. Pavan Kumar & L. Manikanta (2017), "A Study on Behaviour of Structural Elements of Berthing Structure with Raker Pile and Anchored Wall", International Journal of Civil Engineering and Technology (IJCIET), Volume 8, Issue 7, pp. 1111–1124.

[14] P. E. Kavitha, K. S. Beena & K. P. Narayanan (2017), "Influence of Soil Structure Interaction in the Structural Behaviour of a Berthing Structure in Sloping Ground", J. Inst. Eng. India Ser. A, pp.469–476, DOI 10.1007/s40030-017-0254-7

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