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NON-LINEAR STATIC ANALYSIS OF A BERTHING STRUCTURE SUBJECTED TO VARIOUS CRANE LOADS

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Abstract - *In this project, non-linear static analysis berthing structure is studied for various crane loads. The basic data influence factors which affected the berthing structure were taken from Visakhapatnam port. The entire Berth length is 506.4m which is divided into 11 modules and each module length is 50.640m and width of the berth is 33.450m. By using all these data various loads induced on structure was calculated and then structure is modelled and analyzed using STAAD Pro V8i software. The berthing structure was analyzed for various loads and load combinations and also for various crane loads (such 20t,22t,24t,26t and 28t). Pushover analysis is done for all cases. After performing the non-linear static analysis of the berthing structure module, the behavior of the structural elements is compared by various parameters deflection, bending moments, shear forces of cross beam, and also for the different piles.*

Key Words: Berthing structure, FEA, STAAD Pro, Non-linear static analysis, Pushover analysis,

1. INTRODUCTION

Countries surrounded by ocean can easily achieve tremendous progress in trade and industry provided proper planning of ports and harbours is made for transportation of goods and materials through sea transport. And also, Marine transportation system is very important and cheapest way of transportation. The transportation of men and material is increasing day by day. So, to reduce the marine traffic there is a need to construct many new ports with a vision to ensure ecofriendly environment in spite of challenging conditions.

Berthing structures is a term general term used to describe marine structure constructed in ports and harbours to provide facilities such as berthing and mooring of vessels, loading and unloading of cargo and embarking and disembarking of passengers. Berthing structures are vary widely from port to port. The number of berths will be depended upon the number of ships used in the port and time it will take to discharge. These berthing structures are to be designed for stack, crane, berthing force, mooring force, seismic force, active earth pressure and differential water pressure, in addition to self-weight of the structure and live load.

1.1 Port and Harbour Structures

A port is constructed to provide facilities for the transshipment of ship cargo, transported to and from the inland locations by rail, road, inland waterways and pipeline. The basic requirement is to accommodate the ships safely along the berths or anchor. Mechanical handling equipment's have to be provided for the efficient handling of cargo. Also, storage facilities have to be provided at the port. A port facility essentially consists of pier, wharfs, quays, bulkheads, dolphins and platform of structure, trestle and access bridge or catwalk and buildings. They are classified depending upon the type of service they provide as follows;

- Harbour protection facilities.
- Berthing, mooring and repair facilities.
- Storage facilities.

1.2 Objectives of the Present

Following particular objectives are decided for the existing study:

1. To Analysis of berthing structure as per guidelines provided by the bureau of Indian Standards.

2. The Objective of this project is to analyze a berth structure for a capacity of 80,000 DWT.

3. To know how to model and analyzing of berthing structure by using STAAD PRO.

4. To study the behavior of berthing structure for various loads and load combinations.

5. To study the behavior of berthing structure during pushover analysis by using STAAD Pro Software.

6. To compare the nonlinear static analysis results with various crane loads (such 20t, 22t, 24t, 26t and 28t).

2. LITERATURE REVIEW

B. Santosh Kumar:

In the project described a suitable way to design a new berthing structure with example of one of the proposed berthing structures in Visakhapatnam port. So, the factors which effected on the structure were taken into consideration of before analyzing and designing, the influence such as soil characteristics of the proposed location, environmental conditions and range of traffic.

All the basic Data is taken from Visakhapatnam port which were supposed to be used in the project such as geotechnical data, environmental data, and traffic forecasting data. The entire length of berth is 100m and is divided into 3 units of each 33.33 in length with an expansion joint of 40mm between successive units and proposed in the inner harbour, meant for handling liquid cargo like Sulphuric acid, Phosphoric acid, phosphoric acid, edible oils etc.

Deekshith Shetty:

The present investigation is an attempt to observe the changes in design for different cases with respect to assumed model in which the pile founding level is same for all the piles. Three different cases are taken for which pile founding level has been varied which may arrive at site while construction and compared with the assumed model which has same founding level for all the piles. Case 1 model has only 25% of the pile founding in (-) 19.0m level and rest founding in (-) 24.0m level. Case 2 model has 50% of the pile founding in (-) 19.0m level and rest founding in (-) 24.0m level. Case 3 model has 75% of the pile founding in (-) 19.0m level and rest founding in (-) 24.0m level. From above cases the forces and design has been compared with the basic assumed model in which all the piles are founded at (-)24.0m level. In this work the analysis and design is carried out by using SAP 2000 (Ver.14.1.0) application

G. Tirupathi Naidu:

In this construction the type of berthing structure is two types they are Open type and Closed/Solid type of berthing structure. While designing the berthing structure there are different type of live loads, they are stack load, crane load, BGML load, truck load, Mooring force etc.., are acting on the deck slab of berthing structure. To resist the all the load there is need to provide different structural elements they T-Shaped Diaphragm Wall, Main Cross head Beam, Vertical pile, Raker pile/ Anchored Wall/ Tie Rod. Especially to resist the horizontal force the structural elements like Raker Pile or Anchored Wall or Tie Rod are used. In construction type of berthing structure there are two types they are Open type and Closed/Solid type of berthing structure. While designing the berthing structure there are different type of live loads they are stack load, crane load, BGML load, truck load, Mooring force etc.., are acting on the deck slab of berthing structure. To resist the all the load there is need to provide different structural elements they T-Shaped Diaphragm Wall, Main Cross head Beam, Vertical pile, Raker pile/ Anchored Wall/ Tie Rod. Especially to resist the horizontal force the structural elements like Raker Pile or Anchored Wall or Tie Rod are used.

The entire berth of 225m length divided into 5units each 51m long. The plan dimensions of deck slab berthing structure of each unit were 51m (17 panels of 3m width) x 17.2m. Each unit consists of T-Shaped diaphragm wall (TDW) of 17 No's. The T-shaped diaphragm wall was connected at the top through a cellular deck Main Cross Head Beam (MCHB) of 2.80 meters depth to a series of vertical pile and racker pile on rear side. Berthing structure was assumed to be fixed at junction of diaphragm wall/pile and Main Cross Head Beam. All the members of the structure were assumed to be homogenous, isotropic and having the same Elastic modulus both in compression and tension.

G. T. Naidu:

In this study the structural behavior of the components of berthing structure subjected to variable stack load with and without mooring force conditions. Methods/Statistical Analysis: Linear static analysis was performed on the berthing structure subjected to variable stack load with and without mooring effects.

From this study, equations related to bending moment and axial force of structural members of berthing structure has been obtained. A Monte Carlo simulation method was adopted for generation of random numbers using MATLAB software.

The entire berth of 255m length is divided into 5 units of 51m long. Each unit consists of T- Shaped Diaphragm walls (TDW) of 17 Nos, Raker piles (RP) of 700 mm (diameter) of 19 Nos and Vertical Piles (VP) of 850 mm (diameter) of 17 Nos. The T-shaped diaphragm wall was connected at the top through a cellular deck Main Cross Head Beam (MCHB) of 2.80 meters deep to series of vertical piles and raker piles on rear side.

S Augustina:

This design project is focusing on analysis and design of 2nd passenger berth at Beypore port, Kozhikode. It's an open piled bored cast-insitu structure and lying in the seismic zone III. The berth is to be designed for a vessel having capacity of 5000DWT. The structure is subjected to various forces and combinations such as, High tide, Earthquake, High winds, heavy live loads as per IS: 4651-1983. A model was generated using STAADPro software and analysis was conducted with appropriate loads acting on the structure. It was observed that seismic force was nominal since Beypore being located in seismic zone III. This research is an attempt to understand the concept of design and analysis of berthing structures under different conditions of loading.

3. METHODOLOGY

The conceptual layout should include the length, width, dredge level, top level, location of beams for handling equipment, spacing of bollards and fenders and configuration of the structure. The configuration includes the arrangement of piles, deck system and dimensions of various structural members. The size of berthing structure depends on the principal dimension of the large vessel to be handled, area required for transit shed, number of rail tracks, truck lines, crane rail and width of apron required to accommodate mooring facilities and utility service.

3.1. Forces Acting on Berthing Structure

Once the dimensional requirement for a structure has been defined, it becomes necessary to determine loads of the structure. Because Loads are the primary consideration in any structure design because they define the nature and magnitude of hazards are external forces that a structure must resist providing a reasonable performance throughout its lifetime.

- Dead load: [IS 875-1987 Part I]
- Live loads [IS 4651(Part III)-1974]:
- Truck loading and uniform loading [IS 4651 (Part III) – 1974]:
- Berthing Load [IS 4651(Part III) – 1974]:
- Mooring Load [IS 4651 (Part III) -1974]:
- Seismic load [IS 1893 - Part (1)]:
- Earth Pressure [IS 4651(Part III)-1974]:
- Hydrostatic Pressure [IS 4651(Part III)-1974]:

3.2. Load Combinations

Partial Safety Factors for Loads in Limit State Design

Loading	Partial Safety Factor					
	Limit State of serviceability		Limit State of Collapse			
Dead Load	1.0	1.0	1.5	1.2 (or 0.9)	1.2 (or 0.9)	1.2 (or 0.9)
Vertical live load	1.0	1.0	1.5	1.2 (or 0.9)	1.2 (or 0.9)	1.2 (or 0.9)
Earth pressure	1.0	1.0	1.0	1.0	1.0	1.0
Hydrostatic and hydrodynamic forces	1.0	1.0	1.0	1.2	1.0	1.0
Berthing and mooring forces	-	1.0	1.5	-	-	-
Secondary stress	1.0	-	-	-	-	-
Wind forces	-	-	-	-	1.5	-
Seismic forces	-	-	-	-	-	1.5

Fig.3.1 Load Combinations

3.3. Modeling Of the Structure

The structural models must allow considering the effects of movements and deformations in those structures or part thereof, where second-order effects increase the effects of the actions significantly. The modeling of the entire structure is done in STAAD PRO software.

4. ANALYSIS OF BERTHING STRUCTURE

The following cases are considered in the structural analysis of berthing structure, they are:

Case 1: Berthing structure with 20t crane load.

Case 2: Berthing structure with 22t crane load.

Case 3: Berthing structure with 24t crane load.

Case 4: Berthing structure with 26t crane load.

Case 5: Berthing structure with 28t crane load.

Table -1: Primary Data of Berthing Structure Analysis

Length of The Berthing Structure =	560 m
Width of The Berthing Structure =	33.45
Number of Modules =	11
Module Dimensions =	50.6 x 33.45 (m)
Draft =	28m
DWT =	80,000
Seismic Zone =	II
Response Reduction Factor =	3
Importance Factor	1.5

Soil Type =	II
Cross Beams =	1600 x1800 (mm)
Retaining Beam=	1600 x 2000 (mm)
Diaphragm wall=	1000 x 4000
Diameter of Piles (A, B) =	1250 (mm)
Diameter of Piles (C,D) =	1400 (mm)

4.1 Non-Linear Static Analysis By Using Staad Pro

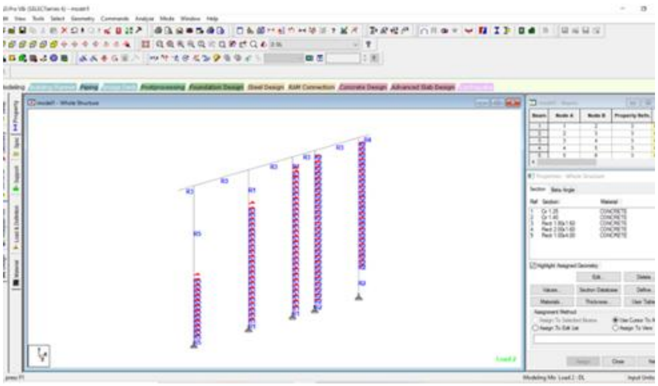

Fig.4.1 Berthing Structure

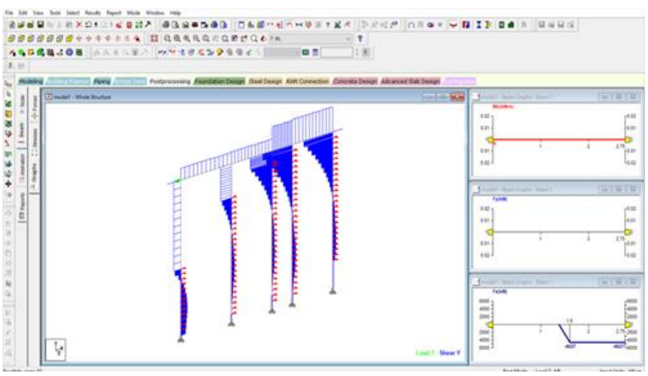

Fig.4.2 Bending Moment Results

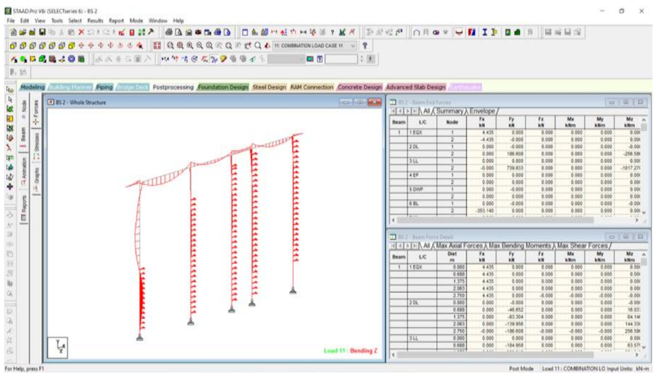

Fig.4.3 Shear Force Results

5. RESULTS AND DISCUSSION

In this present chapter, the results acquired for distinct berthing structure module for various crane load cases are presented. The evaluation is carried out in STAAD Pro software. After performing the Nonlinear static analysis of structure is taken into consideration, their behavior is analyzed and compared in phrases of following parameters.

5.1. Comparison Of Analysis Results of structural components

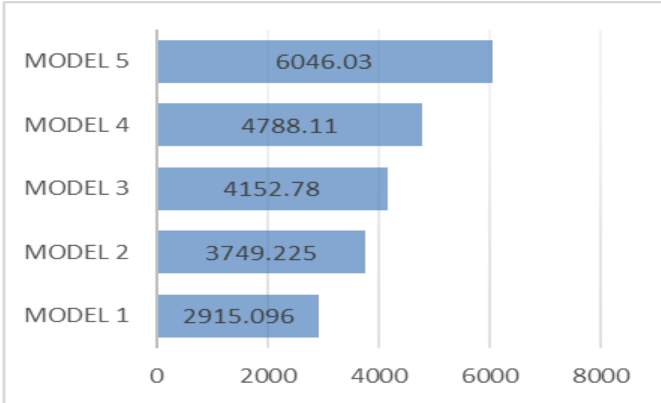

Fig.5.1 Bending Moment Results of a Cross Beam

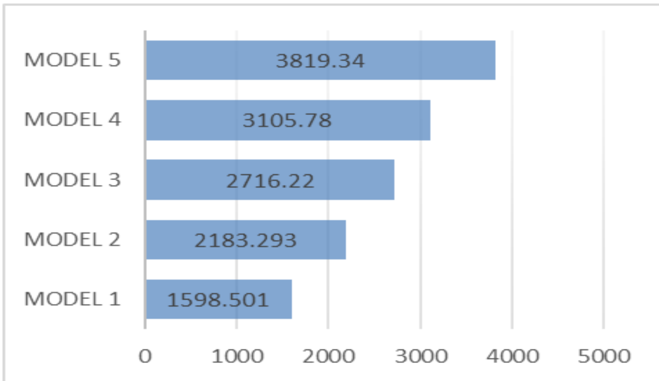

Fig.5.2 Shear Force Results of a Cross Beam

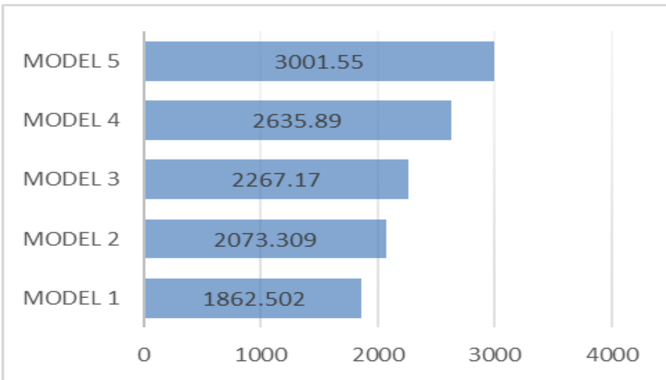

Fig.5.3 Bending Moment Results of a Diaphragm Wall

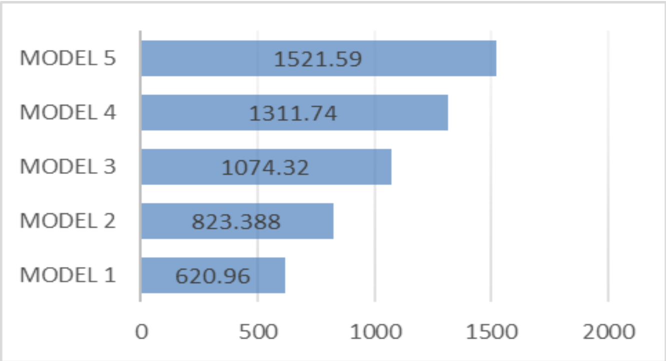

Fig.5.4 Shear Force Results of a Diaphragm Wall

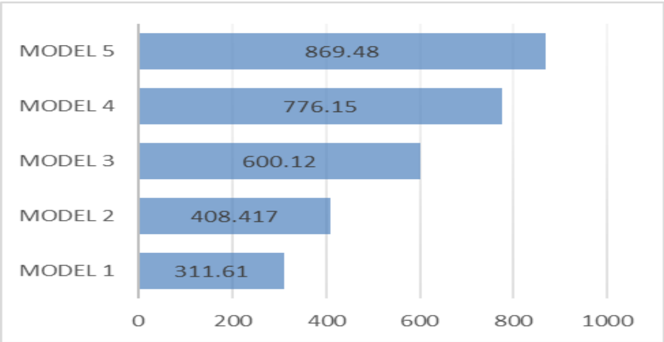

Fig.5.5 Bending Results of A Row Pile

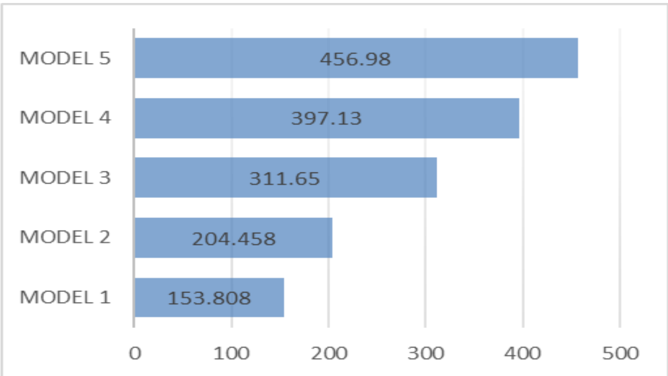

Fig.5.6 Shear Results of A Row Pile

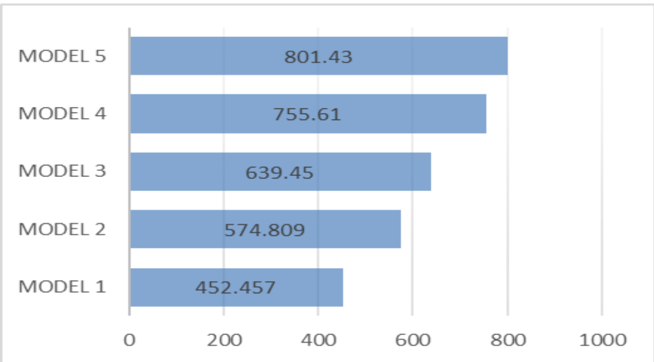

Fig.5.7 Bending Results of B Row Pile

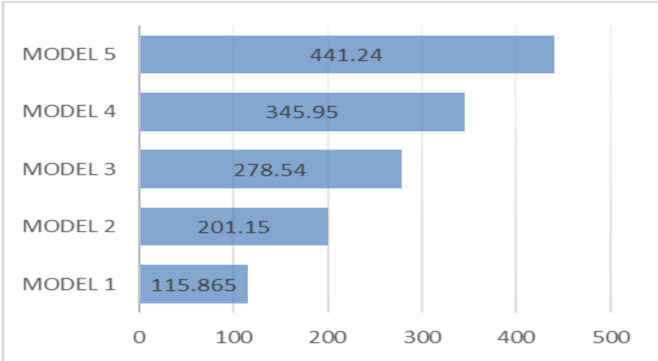

Fig.5.8 Shear Results of B Row Pile

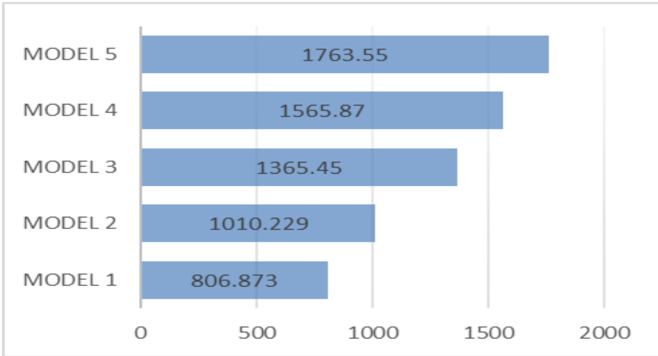

Fig.5.9 Bending Results of C Row Pile

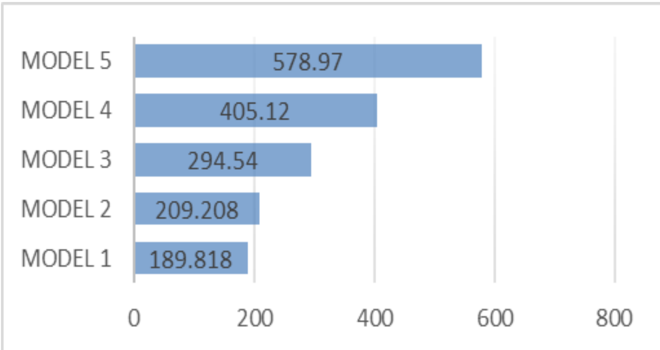

Fig 5.10 Shear Results of C Row Pile

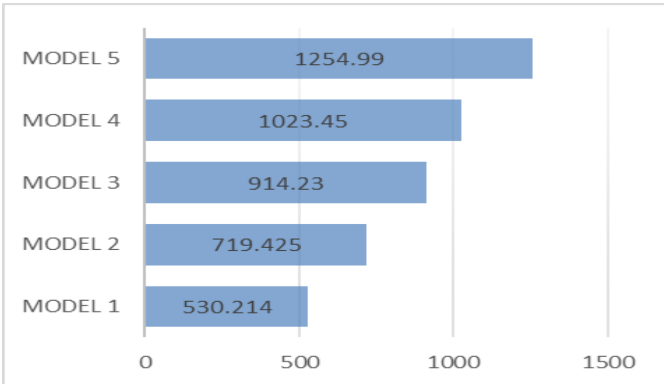

Fig.5.11 Bending Results of D Row Pile

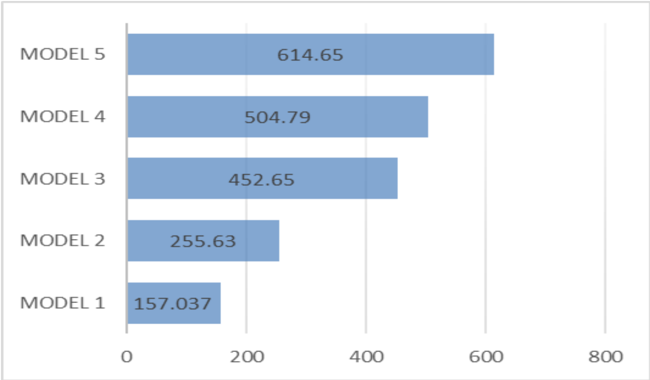

Fig.5.12 Shear Results of D Row Pile

6. CONCLUSIONS

In this project, non-linear static analysis berthing structure module is studied. For the purpose of the study the basic data influence factors which affected the berthing structure were taken into consideration, before analyzing and designing, such as soil characteristics of the proposed location, environmental conditions and range of traffic which will be used in the project is generally taken from Visakhapatnam port. The entire Berth length of 50.640m and width of the berth is 33.450m. The Berth has been modeled analyzed by using STAAD Pro Software. From the comparison of non-linear static analysis results for various crane loads the following conclusions were drawn.

- From the study, it was concluded that the influence of variable Crane load has effect on the Bending Moment and shear force results of the cross beam, diaphragm wall and vertical piles of the berthing structure.
- Based on study here load combinations of (0.9DL + 0.9LL + 1.2DWP + 1EP), (1.2DL + 1.2LL + 1.2DWP + 1EP) got the maximum results.
- The Percentage of variation of bending moment and shear force results due to various crane loads are 22.24%, 9.71%,13.71% and 20.85% and26.78%, 19.62%,12.54%, and 18.68% respectively for cross beam.
- The Percentage of variation of bending moment and shear force results due to various crane loads are 10.16%, 8.55 %, 13.98% and 12.18 % and 24.58%, 23.35%, 18.09%, and 13.79%respectively for diaphragm wall.
- The Percentage of variation of bending moment and shear force results due to various crane loads are 23.70%,31.94 %, 22.67% and 10.73 % and 24.77%, 34.39%, 21.52%, and 13.09%respectively for A pile.
- The Percentage of variation of bending moment and shear force results due to various crane loads are 21.28%,10.10 %,15.37% and 5.71 % and 42.77%, 27.78%, 19.48%, and 21.59%respectively for B pile.
- The Percentage of variation of bending moment and shear force results due to various crane loads are 20.12%,26.01 %, 12.79% and 11.20 % and 9.26%, 28.97%, 27.29%, and 30.02%respectively for C pile.
- The Percentage of variation of bending moment and shear force results due to various crane loads are 26.30%,21.30%, 10.67% and 18.44 % and 38.56%, 43.52%, 10.32%, and 17.87%respectively for D pile.
- Pushover analysis is contemplated as an effective tool to assess the capability of structure for seismic forces and for this reason it is expected the actual behavior of the structure during earthquake.
- This proves that the analysis carried out using Pushover method is more effective as it studies the real time behavior of the structure and brings efficiency in terms of cost too.
- It is found that the results of analysis of the berthing structure using STAAD Pro. software are very useful in the design of the structures as well as to undertake the performance analysis of the constructed structures.

6.1. Scope Of Further Study

- Extension of this work needs to be considered for various stack and mooring loads.
- And influence of raker pile on berthing structure performance.

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BIOGRAPHIES

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