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STUDY OF RIVER PORT WITH REFERENCE TO SEISMIC VERSION OF IS 1893:2016

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ABSTRACT

There are a large number of rivers in the country which widens the scope of inland waterways. The ports and harbours are major structural engineering aspect of inland waterway. This study mainly deals with analysis of berthing structure and multi storeyed building located in a river port with reference to seismic version of IS 1893:2016. Six different models of berthing structure are considered for analytical comparison using SAP 2000 (i) berthing structure supported on vertical piles (ii) berthing structure with diaphragm wall and tie rod (iii) berthing structure with front diaphragm wall and supported on vertical piles (iv)berthing structure with front diaphragm wall and supported on vertical and raker piles (v) berthing structure with rear diaphragm wall and supported on vertical piles (vi) berthing structure with rear diaphragm wall and supported on vertical piles. The static analysis and dynamic analysis including response spectrum were carried out. The results show that model 1 is the most efficient in terms of deflection, moments acting, base shear and the seismic performance. The analysis of building is done by using response spectrum analysis in ETABS 2015. The new version of seismic code IS 1893:2016 is used for the seismic analysis of building.

Keywords: river por, berthing structure, pushover analysis, multi storeyed building, IS 1893:2016.

INTRODUCTION

India is a peninsular country, with a large number of rivers. The scope for the development of inland waterways is widely open in the country. To improve the economy of the country and to promote the development, the rivers are converted into national waterways, thus making it possible for navigation. This mode of transportation is economical and eco-friendly. The inland water way terminals are to be developed in certain locations in the form of ports and harbours. There are several forces acting on the structure, among that earthquakes are one of the deadliest and highly unpredictable dynamic forces acting on a structure. The structures which appeared to be strong enough, may crumble like house of cards during an earthquake and deficiencies may be exposed. Experiences from the past earthquakes demonstrate that most of the buildings collapsed were found to be seismically deficient because of lack of awareness regarding seismic behaviour of structures. Also, earthquakes are unpredictable and unpreventable major natural disasters. The ground motion causes the structures to vibrate and induce internal forces on them. Hence, structure in such an earthquake prone zones need to be suitably designed and detailed for ductility. The building should have minimum design requirement to establish the unified design basis that will form the overall design philosophy to be adopted in the structural design of the proposed building.

In the proposed structure, it will have

- Structural & well functional integrity.
- Structural performance under characteristic service design loads which will be desirable.
- Resistance to loads due to natural phenomena i.e. wind, earthquakes.
- Structural durability & maintainability will be maintained.
- Structural Safety, Performance during Fire & Fire Safety measures will take into consideration.

The planning, analysis and designing of ports is a challenge that arises for a structural engineer. The ports consist of berthing structure and associated administrative as well as operative buildings. The berthing structures are broadly classified into two: solid type berthing structure and open type berthing structure. The selection of the type of berthing structure depends on the geotechnical and topographical factors and the impact due to vessels. Both open type berthing structures and solid type berthing structures are considered in this work.

The objective of this research paper is to analyse berthing structure and multi storeyed building located in a river port. The six different structural options for berthing structure are compared considering the conditions of river Ganges for handling 9 million tonnes per annum of cargo using 3000-ton barges. The best one from the above is sorted out from the study. The study consists of how the berthing structure and the multi-storeyed building respond to the seismic forces. This is carried out analytically using finite element software by considering the moments acting on the structural components, deflection, base shear, modal participation factors and push over analysis.

LITERATURE REVIEW

Sudarsana and Ramanujan [1] made a comparative study on horizontal forces which are found out as per the provisions of IS 1893: 1984 & IS 1893:2002. Base shear of a particular building was calculated using both codes. They concluded that forces calculated as per IS 1893-2002 yielded higher values than the previous version for building in Zone I upgraded to Zone II & the base shear calculated as per revised IS 1893 -2002 is higher for structures in Zone II.

Ahirwar *et al* [2] explained seismic load estimation for high rise structures as per IS 1893: 1984 & IS 1893:2002. The analysis of four multi-storey RC framed buildings with different number of storeys are considered. The seismic forces computed by IS 1893: 2002 are found to be much higher than that calculated as per IS 1893:1984.

Azhar *et al* [3] have done design of Industrial structure. The structure consists of roof trusses, purlins, rafters. The analysis was carried out as per new IS 800-2007 and the earthquake loading was applied as per IS 1893-1984. Then this was compared with the code IS 1893-2005. The software used was STAADPro. The necessary loads such as dead load, live load, wind loads, earthquake loads and al combinations are calculated and applied in STAADPro and importing all analysis result value from STAADPro. It is found from the analysis results that the displacement in the new IS code is less than the old version of IS code. Also, it is concluded that the performance of seismic load as per IS 1893-1984 is inferior to IS 1893-2005

Sudarsana & Ramanujan [4] made a study to understand the lateral forces based on static as well as dynamic analysis. To compare the base shear two case studies were done. They concluded base shear values obtained by Static Analysis (Seismic Coefficient Method) are comparable with values obtained by Dynamic Analysis (Response Spectrum Method) in Zone II. The base shear values obtained by Static Analysis (Seismic Coefficient Method) are less than the values obtained by Dynamic Analysis (Response Spectrum Method) in Zone II

Kavitha [5] *et al* in the paper explains that it is very expensive to maintain and construct. For an economical design the structural engineer has to optimise the structure which is a time-consuming process. As a solution for this software BESTDESIGN has been developed. The new berthing structure can be analysed and designed using BESTDESIGN software and also for reconstructing a structure which is existing. The software developed was made a trial attempt with the requirements at cochin port.

Naidu [6] *et al* aims to study the behaviour of berthing structure by using reliability-based analysis when subjected to variable crane load and to determine the member characteristics of each structural component. The software's used are STAAD Pro for modelling of structure and MATLAB for reliability analysis. From the study, it was concluded that the influence of variable crane load has effect on the bending moment of main cross head beam & T shaped diaphragm walls and axial force of vertical pile & raker pile of the berthing structure. From the study, it is also concluded that due to variable crane load with and without mooring force conditions, the variation of results of load effects in case of T-Shaped Diaphragm wall, vertical pile and raker pile were minimal, but have found significant variation in the case of main cross head beam.

Gokul Krishnan [7] *et al* studied on the behaviour of an open type berthing structure due to seismic loads. It is explained through numerical approach. The berthing structure is supported by piles and has diaphragm wall too. The dredging generates horizontal movements in the marine soil. These structural elements are laterally loaded due to these movements. The finite element analysis for the lateral response of pile and diaphragm wall while dredging as well as seismic loading is explained in this study. Piles are represented by equivalent sheet pile walls. The plain strain analysis using the finite element approach is carried out. The comparison of static and dynamic analysis is described.

MODELLING OF BERTHING STRUCTURE

The various structural options for berthing structure is given in Figure-1. The modelling and analysis was carried out using SAP 2000 software.

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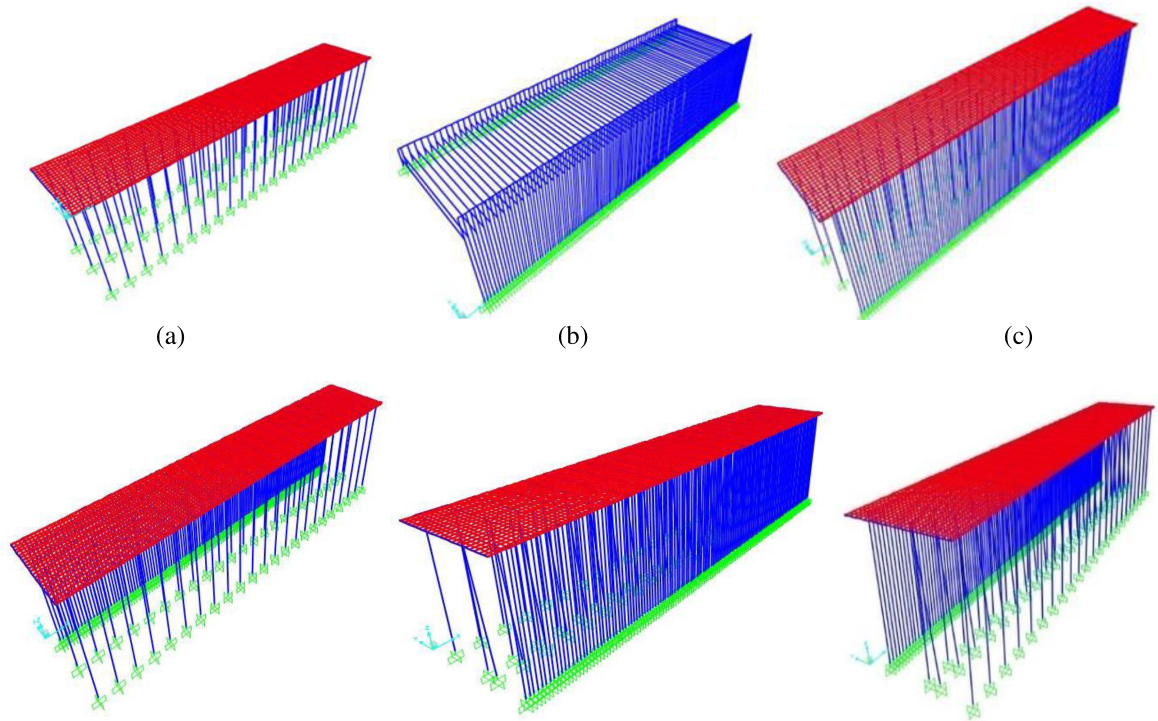


(a) (b) (c)

(d) (e) (f)

Figure-1. Model of the structures using SAP 2000 (a) Model 1- berthing structure supported on vertical piles (b) Model 2- berthing structure with diaphragm wall and tie rod (c) Model 3- berthing structure with front diaphragm wall supported on vertical piles (d) Model 4- berthing structure with front diaphragm wall supported on raker piles and vertical piles. (e) Model 5- berthing structure with rear diaphragm wall supported on vertical piles (f) Model 6- berthing structure with rear diaphragm wall supported on raker piles and vertical piles

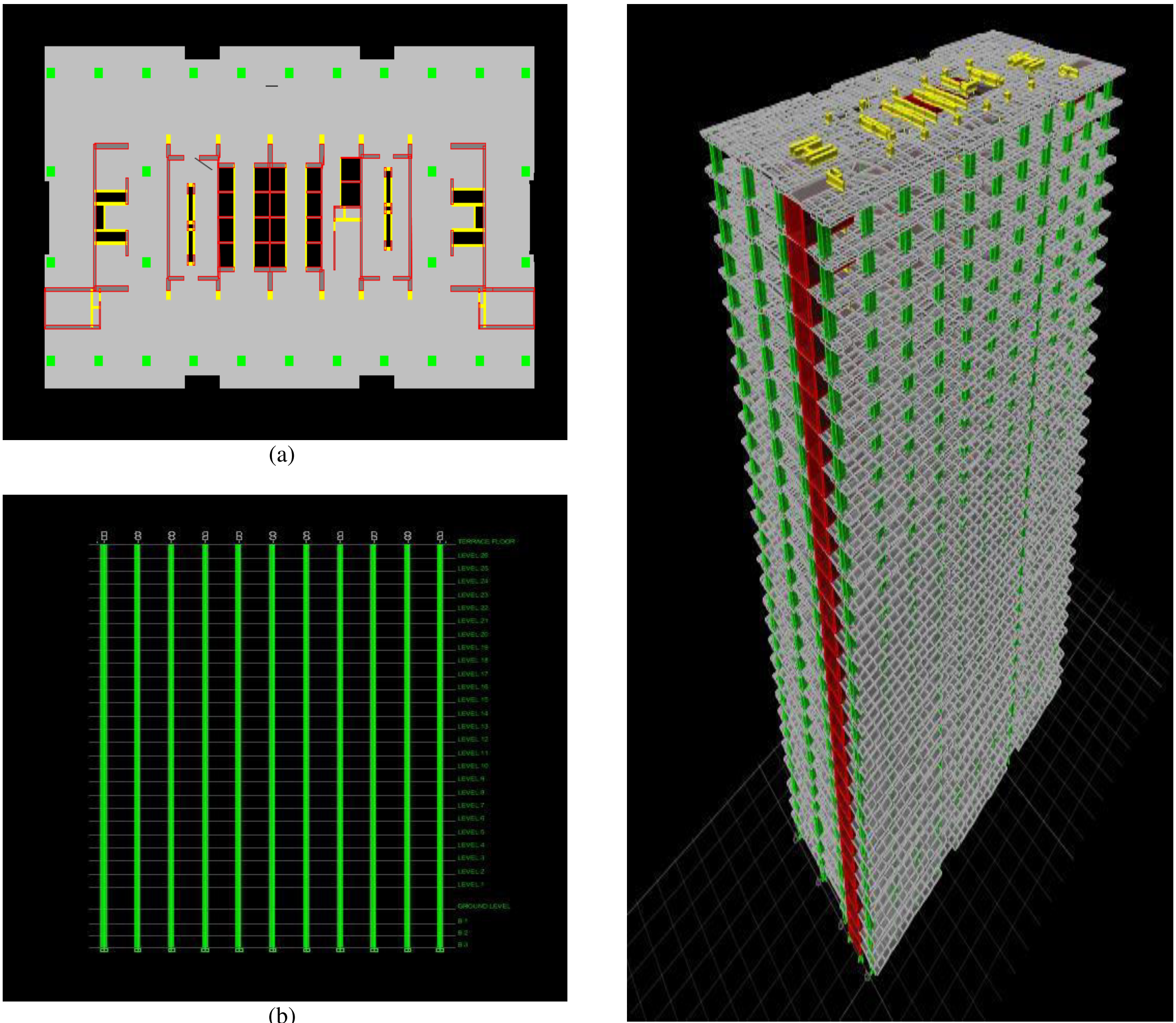
The below given table shows the structural components considered

Superstructural components	
Slab	200 mm thick
Rectangular beam 1	350 x 800 mm
T beam	1190 mm flange, 350 mm web
Rectangular beam II	1200 x 800 mm
Main beam	1200 x 800 mm
Substructural components	
Pile muff	2.4 x 2 m, 0.5 m thickness
Pile	1 m diameter
Fender pile	1.5 m diameter
Diaphragm wall	1.5 m thickness

MODELLING OF BUILDING

The modelling and analysis of the multi storeyed buiding in the river port was carried out using ETABS Building configuration:

- Commercial Multi-storey Building having 3 Basements + Ground floor + 26 floors + Terrace + LMR
- Three Basements (B1, B2 and B3) are used for Parking & Services
- Plan Dimensions – 86.205 m x 41.4 m
- Height of building above Ground floor - 112.2 m
- Floor to Floor heights - 3.9 m
- Typical Floor height – 3.9 m
- Basement Floor height – 3.5 m.



(a)

(b)

(c)

Figure-2. Model of multi-storeyed building (a) plan (b) elevation (c) 3D view.

ANALYSIS OF BERTHING STRUCTURES

The analysis of six different structural options for berthing structure was carried out using SAP 2000.The loads and load combinations are considered as per IS 4651:1989 . The response spectrum analysis and push over analysis were carried out as per IS 1893:2016, from which the base shear and seismic performance point were calculated.

The different loads acting on the structure are (i) Live load (ii) Dead load (iii) Wind load (iv) Seismic load (v) Temperature load (vi) Current load (vii) Earth pressure (viii) Crane load (ix) Berthing load (x)Mooring load. The same loading conditions were given to all models, except in model 1. The model 1 is an open type berthing structure in which the earth pressure is absent. The analytical comparison of the six different berthing structures are given below:

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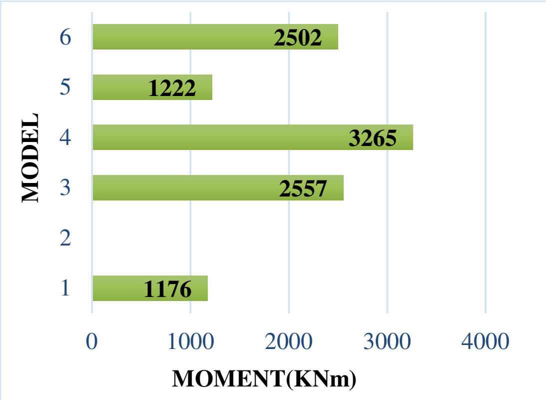

Figure-3. Comparison of moments in vertical pile.

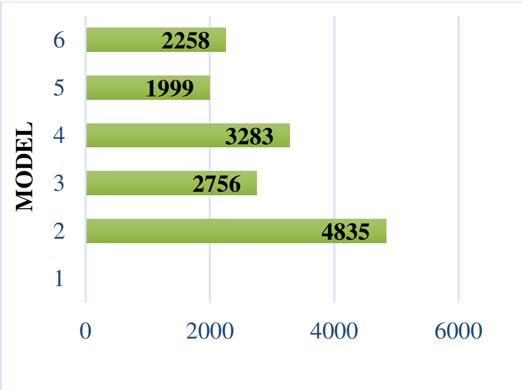

Figure-4. Comparison of moment in diaphragm wall.

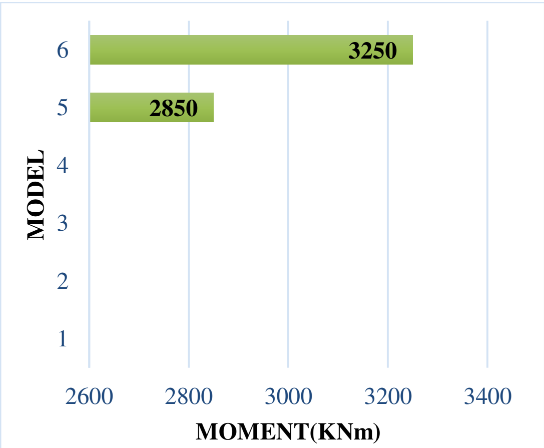

Figure-5. Comparison of moments in raker pile.

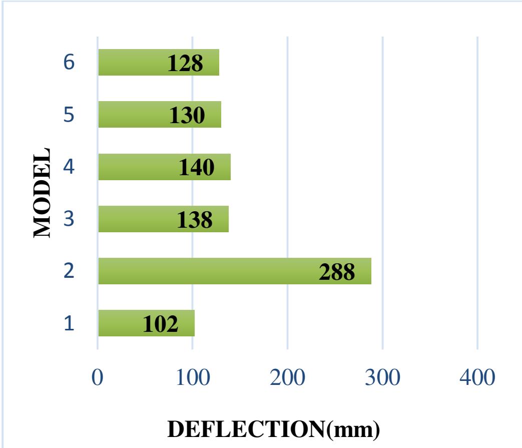

Figure-6. Comparison of deflection.

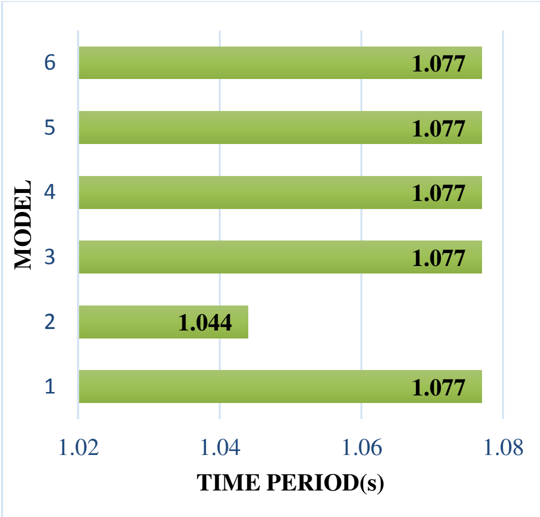

Figure-7. Time period of the berthing structures.

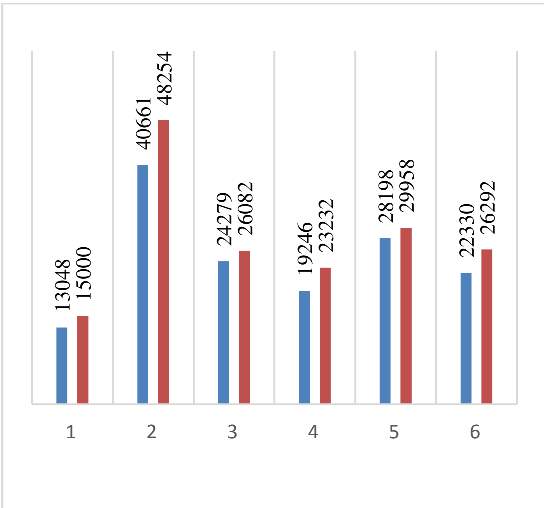

Figure-8. Comparison of base shear (KN).

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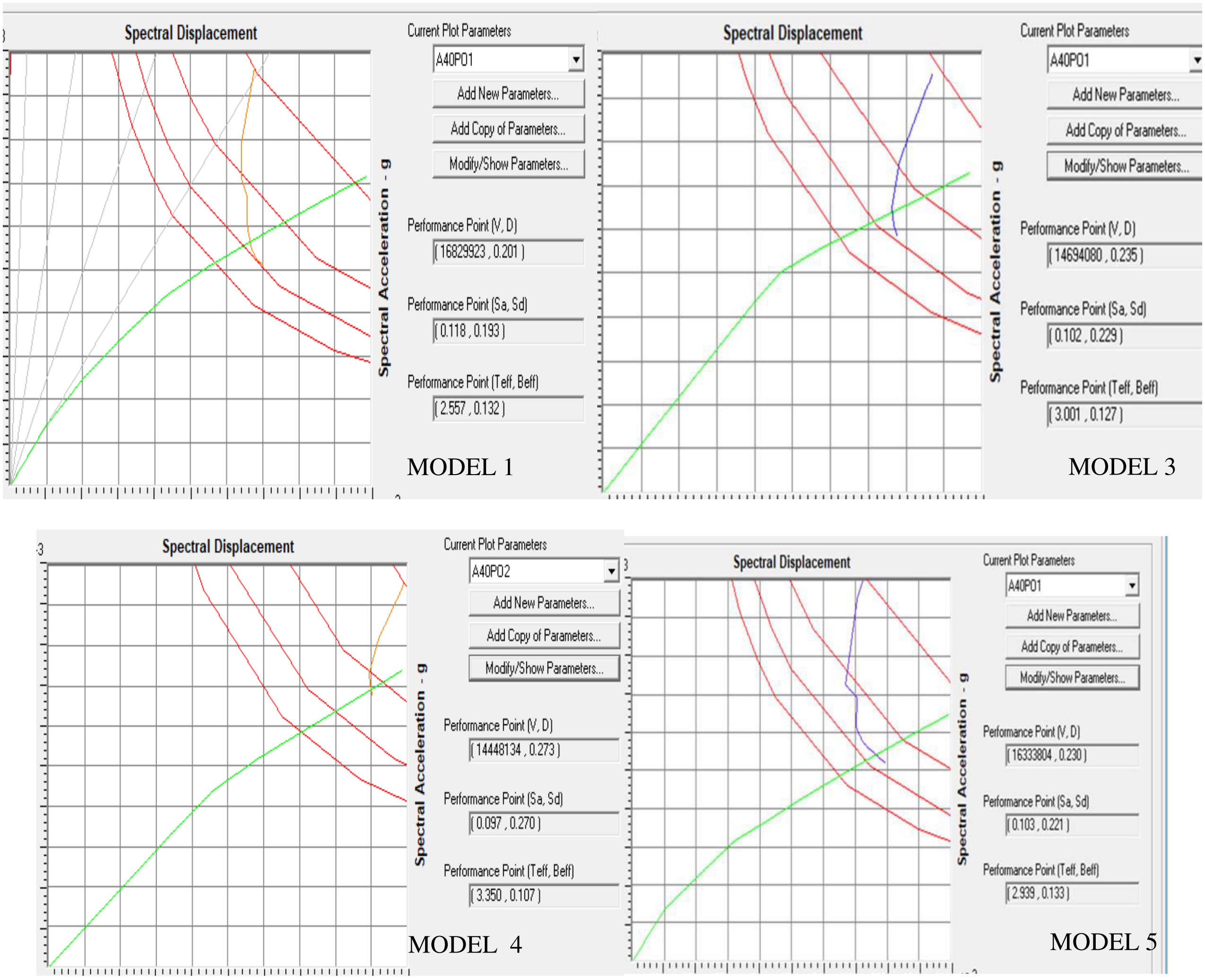
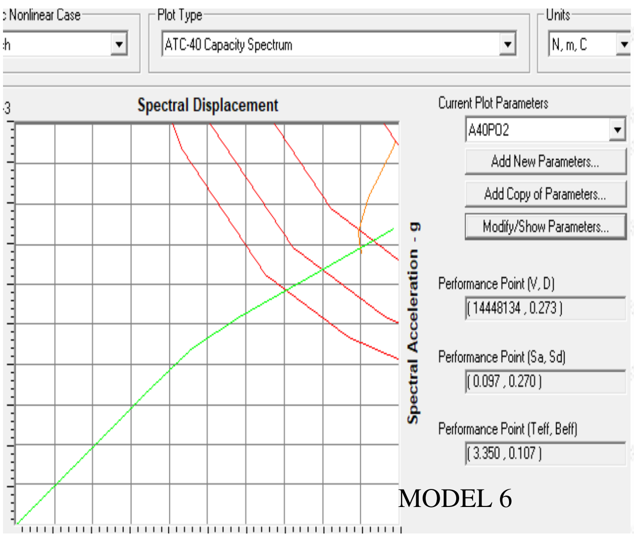
PUSH OVER ANALYSIS OF BERTHING STRUCTURES





MODEL	Performance point T_{eff}	Category
1	2.557	Life safety
2		Performance point not obtained
3	3.001	Intermediate occupancy
4	3.350	Intermediate occupancy
5	2.939	Intermediate occupancy
6	3.150	Intermediate occupancy

Figure-9. Performance point for different models.

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ANALYTICAL RESULTS FOR PORT SIDE BUILDING ACCORDING TO IS 1893 Part 1:2016

The analysis of port side building is carried out by using ETABS 2015. Response spectrum analysis is used for analysis.

The different loads acting on the structure are (i) Live load (ii) Dead load (iii) Wind load (iv) Seismic load

1. Seismic weight of building 1991200 kN

Load case	**Base shear** (kN)	**% with Bldg. Weight**
EQX	49004.2626	2.46
EQY	39772.842	1.99
SPECX	53894.7937	2.71
SPECY	44940.4788	2.25
WX	7236.7439	0.36
WY	16404.1682	0.82

2. Acceleration values at top-moststory

Mode	**Ux** (mm/sec^2)	**Uy** (mm/sec^2)	**Uz** (mm/sec^2)
SPECX	471.77	203.1	194.54
SPECY	29.31	570.18	248.23

3. TorsionalIr regularity

Load case	**Corner-1** (mm)	**Corner-2** (mm)	**Corner-3.** (mm)	**Corner-4** (mm)	**Maximum**	**Minimum**	**Maximum / Minimum**
EQX	82.8	82.8	106.2	106.2	106.2	82.8	1.28
WX	8.8	8.8	11.1	11.1	11.1	8.8	1.26
EQY	57.4	56.3	56.3	57.4	57.4	56.3	1.01
WY	15.9	15.4	15.4	15.9	15.9	15.4	1.03
SPECX	25.6	25.6	36.8	36.8	36.8	25.6	1.43
SPECY	26.3	26.4	26.4	26.3	26.4	26.3	1.003

4. Modal participation mass ratios

Mode	**Time period** (sec)	**Ux** (%)	**Uy** (%)	**Uz** (%)	**Rx** (%)	**Ry** (%)	**Rz** (%)
Mode 1	2.926	64.03	0.01	0	0.01	24.32	8.29
Mode 2	2.208	0.12	67.38	0	32.42	0.04	0.31
Mode 3	2.172	9.2	0.39	0	0.19	2.82	60.72
Mode 4	0.81	11.93	0.00118	0	0.001455	35.93	0.73
Mode 5	0.542	0.59	0.29	0	0.5	1.66	16.48
Mode 6	0.535	0.004485	18.37	0	31.78	0.01	0.26
Mode 7	0.389	4.58	0.000324	0	0.00074	8.33	0.21
Mode 8	0.245	0.000591	5.43	0	11.69	0.001423	0.001248
Mode 9	0.233	2.7	0.001091	0	0.002318	7.24	0.11
Mode 10	0.149	0.004996	2.91	0	7.77	0.01	0.03
Mode 11	0.119	4.41	0.01	0	0.04	12.03	0.08
Mode 12	0.077	0.01	3.99	0	11.76	0.03	0.04

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5. Seismic base shears

Load case	**Static base shear** (kN)	**Dynamic base shear** (kN)	**Scale factor**
EQX / SPECX	49004.2626	53984.7937	1962
EQY / SPECY	39772.842	44940.4788	1962

6. Maximum lateral deflection at the topstory

Load Case	**Deflection in X-Dir** (mm)	**H/Δx**	**Drift X-Dir**	**Deflection in Y-Dir** (mm)	**H/Δy**	**Drift Y-Dir**
DL	0.6	179500	8E-06	6.4	16828.125	8.1E-05
Live+LIVE1+RLIVE	1	107700	1.2E-05	3.8	28342.105	4.7E-05
DL+(Live+LIVE1+RLIVE)	1.6	67312.5	2E-05	10.4	10355.769	1.28E-04
EQX	106.2	1014.124	0.000713	25	4308	0.000226
EQY	0.7	153857.142	6E-06	57.4	1876.306	0.00056
WX	11.1	9702.702	5.8E-05	2.5	43080	1.9E-05
WY	0.3	359000	2E-06	15.9	6773.584	0.00014
SPECX	36.8	2926.630	0.000281	21.5	5009.302	0.000191
SPECY	0.6	179500	5E-06	26.4	4079.545	0.000271

7. Lateral deflections in only DL +LLcases Xdir 1.6 mm Ydir 10.4 mm

8. $A_h = \frac{Z \times I \times Sa}{2 \times R \times g} =$ X dir = 0.02377 Y dir = 0.02124

CONCLUSIONS

The analysis of the river side port was carried out and following conclusions were made:

a) Out of the six berthing structures analyzed, Model 1 was concluded as the most efficient in the structural aspects.
b) The deflection, moments in the structural elements was found to be minimum and within the limits of IS Codes for Model 1.
c) By performing push over analysis, the seismic performance was understood and model 1 falls under the intermediate occupancy category and others in life safety category which is comparatively critical.
d) The building doesn’t have torsional irregularity.
e) As per the analytical results of building the building is well seismic resistant.

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