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Analysis and Design of Berthing Structure

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***Abstract** - The structures which are constructed for the intention of berthing and mooring of vessels to facilitate loading and unloading of cargo and also for embarking and disembarking of passengers or vehicles etc. is called berthing structure. Various factors influence the analysis and design of the berthing structures. The berthing structures are designed for dead load, live load, berthing force, mooring force, earthquake load and other environmental loading due to winds, waves, currents etc. In the present study, a proposed berthing structure in Belekeri port is taken for analysis and design. All suitable data are collected like geotechnical data, environmental data, and traffic forecasting data from the Karwar region. By using all these data, we planned and modelled a structure. After that we calculated various loads induced on structure and we analyzed the modelled structure in STAAD Pro V8i software. The present study is an attempt to observe the changes in design for five different cases in which pile founding level are varied with respect to assumed model in which the pile founding level is same for all the piles. Also the design variations are tabulated for each case. The results are shown in tables and graphical forms in the discussions.*

***Key Words**: Berthing structure, Cargo, Load, Earthquake, STAAD-Pro.*

1. INTRODUCTION

The transportation part is an strong aspect in terms of financial and regional balanced development, as well as also having a excessive influence on national integration to the global financial market. A seaport is a facility consisting one or more harbour's where ships can dock and people or cargo are transport to or from land. Thus, sea ports form vital sub system of the entire transportation firm. Harbours are handling almost 82% of an world's occupation, thus its size and capability will influence in accession and also financial potential of any seaside country. India have an long seashore of length across seven thousand six hundred kilometres making one of the large peninsulas throughout the world. It has long sea shore of about 6000km on main land, out of which 3300km is on east coast and 2700km on west coast.

Berth is an structure which helps for landing of ships and to anchor of ships for allowing loading and unloading of freight, these structures also helps to boarding and debarking of travellers, vehicles ,etc., The planning and design of berth is depend upon several aspects suchlike soil features in projected location, atmosphere circumstances and amount of circulation. An establishment of new berth structure is an principal importunate project. Thus, optimal usage as well as the investment turn into crucial. That means appropriate planning of all components of the berth for the contemporary and expectant forthcoming requirement is necessary. In this current work of project, we explain a appropriate method to design a new berth.

1.1 Study Area

In this contest the present work on Karwar region, the belekeri seaport be situated 26kms from south direction of Karwar on the river bank of Hattikeri river. This port has a magnificent weather conditions and is a minor seaport having a normal traffic range in all seasons. This port is situated in 14^0 42' 50" latitude and 74^0 16' longitude.

2. OBJECTIVE OF THE PROJECTE

A. To Analyse and design the berthing structure as per the guidelines provided by the bureau of Indian Standards and followed by the bye laws of International Maritime Organization.

B. The Objective of this project is to analyse a berth structure for a capacity of 1,250,00 DWT.

C. To analyse the structure using the STAAD. Pro.

D. To design all the components in the berthing structure as per the codal provisions.

3. MODELLING OF BERTH STRUCTURE

Berth was generally designed as all piles founding in same level. But at site they may change based on the soil strata and the founding level for piles may not be same. There are totally 5 different case has been selected for the study in comparison with the actual model. Each model is of size 35m X 65m. All models are have 54 number of pile with a diameter of 1.2m arranged in 6 rows at distance of 2.50m, 9.50m, 15.50m, 22.50m, 28.5m and 33.50m from berth face. All models have same dimensions of beam as shown in Table-1. Only the changes in between models in pile height. Actual model have all piles length of 20m as shown in Fig.1, case-1 model have piles length varied from 6m to 22m as shown in Fig.2, case-2 model have piles length varied from 18m to 20m as shown in Fig.3, case-3 model have piles length varied from 16m to 20m as shown in Fig.4, case-4 model have piles length varied from 19m to 21m as shown in Fig.5, case-5 model have all piles length of 30m as shown in Fig.6. Cross section of berth structure is showed in Fig.7.

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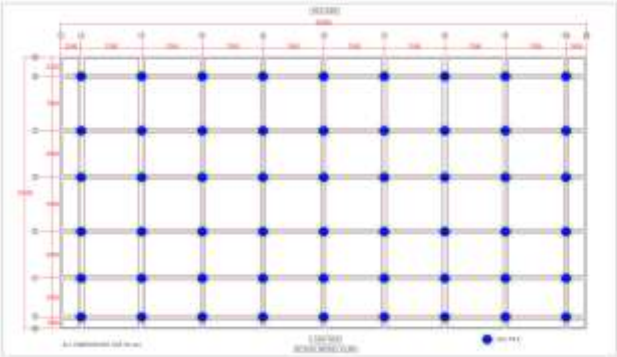

Fig -1: Typical plan of actual model

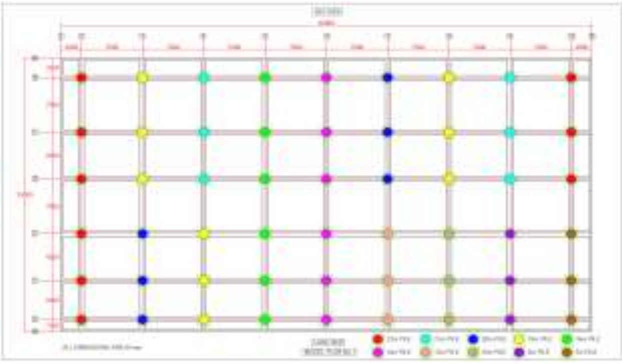

Fig -2: Typical plan of case-1 model

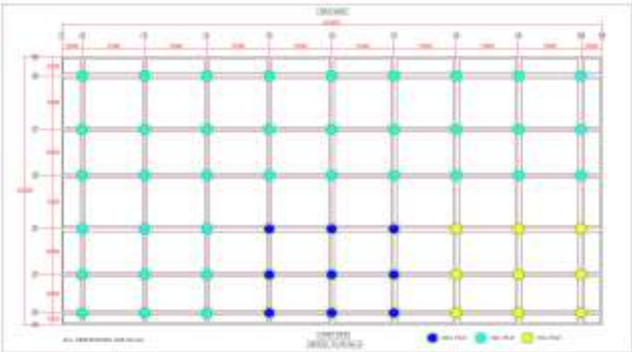

Fig -3: Typical plan of case-2 model

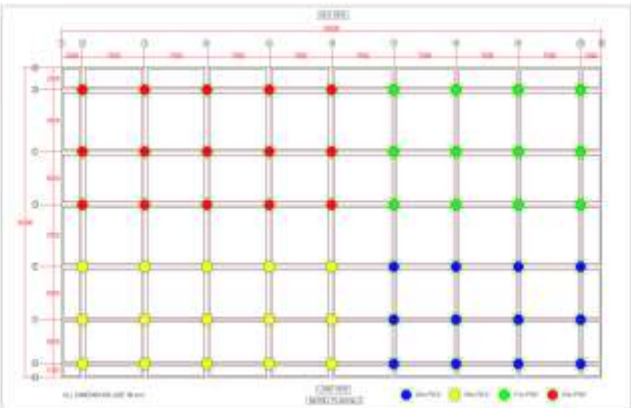

Fig -4: Typical plan of case-3 model

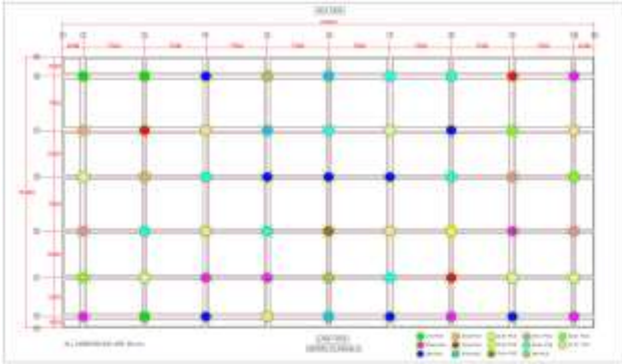

Fig -5: Typical plan of case-4 model

Fig -6: Typical plan of case-5 model

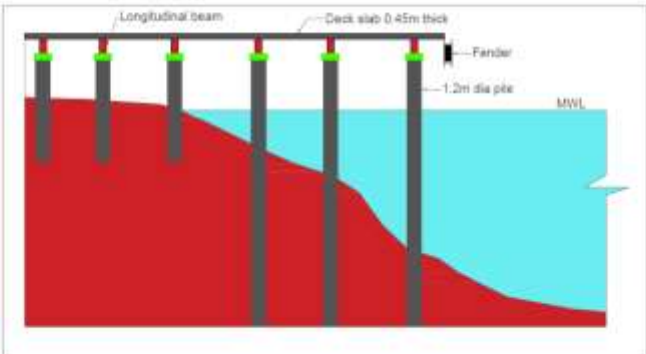

Fig -7: Cross section of Berth structure

Table -1: Dimensions of beam

Beam type	Beam size (m × m)
Longitudinal beams	0.6 × 1.1
Longitudinal edge beams	0.2 × 0.65
Cross beams	0.6 × 0.8
Cross edge beams	0.2 × 0.65

The structure has modelled using STAAD.Pro software with X and Z direction are primary horizontal directions, Y direction was primary vertical direction. Berthing structure was principally modelled as an 3 D assembly. While creating a models all supports of piles are consider as fixed.

4. LOADS ON BERTH STRUCTURE

4.1 Dead load: Self weight of all beam and pile should be assigned. Self weight of slab is assigned as floor load of 11.25kN/m^2. Dead load is assigned to the model is as showed in Fig-8.

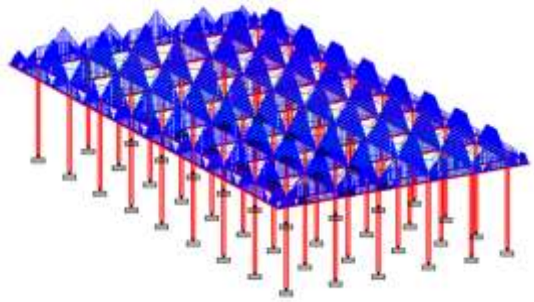

Fig -8: Figure showing dead load on structure.

4.2 Live load: The berth structure should be designed for an uniform live load of 55kN/m^2 as per code IS 4651. Live load is assigned to the model is as showed in Fig-9.

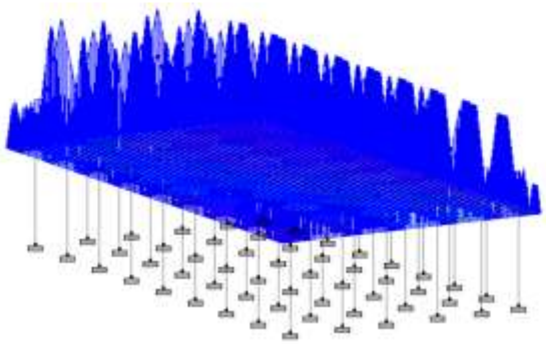

Fig -9: Figure showing live load on structure.

4.3 Berthing force: As showed in IS: 4651 code of practice for Planning and Design of ports and harbour (part-III loadings) for moderate wind and swell site condition and moderate berthing condition for bulk carrier vessel of 1,25,000 DWT (Dead weight tonnage). Kinetic energy transmit to the fenders is calculated by using following formula

$$\mathbf{E = ((W_D \times V^2) / 2g) \times C_m \times C_e \times C_s}$$

Where,

W_D = Displacement Tonnage of the vessel in tones

V = Velocity of vessel in m/s, normal to the berth

g = Acceleration due to gravity (9.81m/s^2)

C_m = Mass coefficient

C_e = Eccentricity coefficient

C_s = Softness coefficient

W_D/DWT = 1.17 Therefore, W_D = 1,17,000 tonnes

Velocity = 0.15 m/s^2 (from table:2 IS 4651 for DT > 1,00,000)

The mass coefficient C_m should be calculated as

For WD > 20,000 Tonne

$$\mathbf{C_m = 1 + [(\pi/4 \times D^2 \times L \times w) / W_D]}$$

Considering unit weight of water as 1.03 tonnes/m^2,

$C_m = 1 + ((\pi/4 \times 15.6^2 \times 285 \times 1.03) / 117000) = 1.48$

The eccentricity coefficient C_e should be calculated as

$$\mathbf{C_e = [\{1 + (l/r)^2 \times \sin^2\Theta\} / \{1+ (l/r)^2\}]}$$

Here considered: l = L/4, r = 0.2L, $\Theta = 10^0$

l = 285/4 = 71.25m, r = 0.2 × 285 = 57m, l/r = 1.25

$C_e = ((1 + (1.25^2 \times \sin 10^0) / (1 + (1.25)^2)) = 0.41$

Consider C_s = 0.9

$E = ((117000 \times 0.15^2) / 2 \times 9.81) \times 1.48 \times 0.41 \times 0.9$

E = 73.3Tonne

Factor of safety = 1.5

Ultimate Kinetic energy imparted to fendering system E = 73.3 × 1.5 = 110Tonne = 1100kN

The berthing force shall be applied directly on the pile at the fender location in the model, as showed in Fig-10.

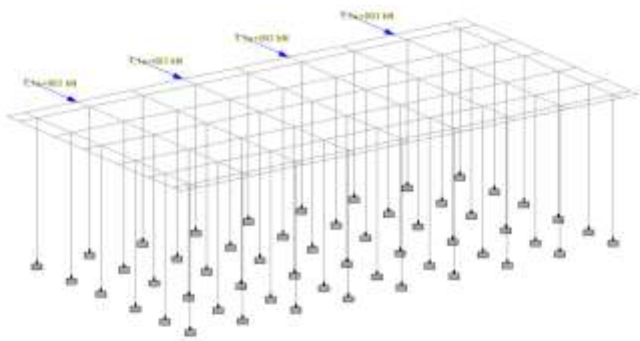

Fig -10: Figure showing berthing force on structure.

4.4 Mooring force: These loads are induced by bollards while the vessels are pulled towards berth using ropes against wind and current forces. This force is taken according to IS: 4561-1974 (Part 3 loadings). Mooring force due to wind is calculated as

$$\mathbf{F_w = C_w \times A_w \times P}$$

Where,

C_w - Shape Factor = 1.3

A_w - Windage Area in sq.m

P - Wind Pressure for design wind speed in kg/sq.m

Wind speed is considered as 39 m/sec for Mangalore (As per IS: 875-III)

Therefore, $P = 0.6 \times 39^2 = 912.6$ kg/m^2

$$\mathbf{A_w = 1.175 \times L_s \times (DM - DL)}$$

Where,

L_s = Length between perpendiculars

DM= Mould depth in meters

DL = Average light draft in meters

$A_w = 1.175 \times 285 \times (1.82\text{-}14.6) = 4279.7m^2$

$F_w = 1.3 \times 4279.7 \times 653.4 = 363.53$Tonne=3622.21kN.

Mooring Force due to current:

$$\mathbf{F_c = L_{pp} \times D_r \times P_c}$$

Where,

L_{pp} = Length between perpendicular in m

D_r = Loaded draft of vessel in m

P_c = Pressure due to current in kg/m^2

$P_c = w \times v^2/2g$

Where,

w = Unit weight of water is 103 kg/m^2

v = Velocity of current is 0.3m/s

g = acceleration due to gravity m/s^2

Therefore, $P_c = 0.6 \times 39^2 = 912.6$ kg/m^2

$F_c = 285 \times 14.6 \times 0.47 = 19.6$Tonne = 195.29kN.

Assuming that mooring force due to wind and current act simultaneously in the same direction, total mooring force = 3635.3 + 196 = 3831.3kN

There are four bollards in each model there by total force will be divided by four. Hence force on individual bollard is = 3831.3 / 4 = 957.8kN.

The mooring force shall be applied directly on the pile at the bollard location as showed in Fig-11.

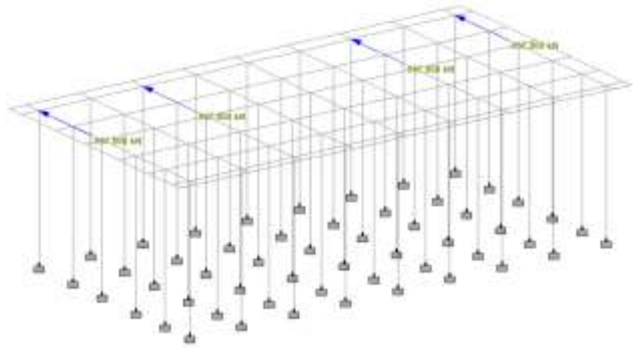

Fig -11: Figure showing mooring force on structure.

4.5 Seismic force: The seismic force has been calculated as per IS: 1893-2002 (Part I). The design horizontal seismic coefficient Ah for a structure has been determined by the following expression:

$$\mathbf{A_h = (Z / 2) \times (I / R) \times (S_a / g)}$$

Where,

Z - Zone factor given in Table 2 of IS: 1893 – 2002, Mangalore falls in Zone – III. Therefore it is adopted as 0.16

I -Importance factor = 1.5 has been used.

R - Response reduction factor has been taken as 5.0 for RCC Structures as per Table 7 of IS: 1893 – 2002.

Sa/g - Average response acceleration coefficient depends upon time period of structure and soil conditions and has been taken according to IS: 1893 – 2002 (Part I).

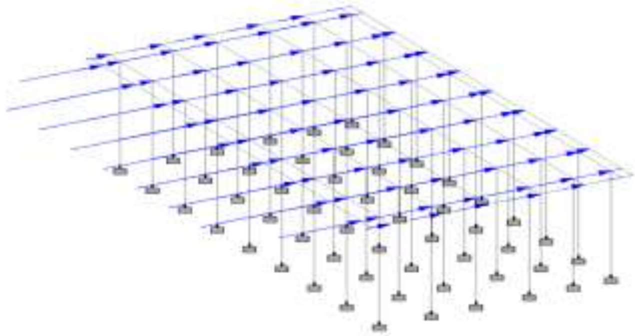

Fig -12: Figure showing seismic load along X-direction

The seismic force has been applied in X and Z directions at each pile joint as shown in Fig-12 & Fig-13 . The seismic force calculation is built in STAAD.Pro.

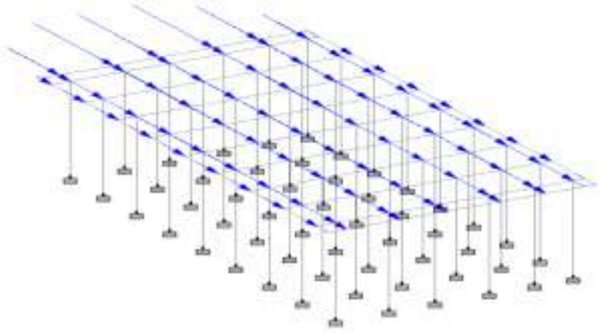

Fig -13: Figure showing seismic load along Z-direction

4.6 Load combinations: All loads are to be multiplied with partial safety factors as per limit state method for serviceability condition, collapsibility-normal, collapsibility-survival and reversal conditions as per IS: 4651-2007 (Draft copy) as shown in tables-2, 3, 4, 5 respectively.

Table-2: Limit state of serviceability

1	1DL + 1LL + 1BL + 1ML
2	1DL + 1LL + 1ML
3	1DL + 1LL + 1BL
4	1DL + 1LL + 1BL + 1ML + 1EQ-X
5	1DL + 1LL + 1BL + 1ML + 1EQ-Z
6	1DL + 1LL + 1BL + 1ML - 1EQ-X
7	1DL + 1LL + 1BL + 1ML - 1EQ-Z

Table-3: Limit state of collapsibility - normal

8	1.5DL + 1.5LL + 1.5BL + 1.5ML
9	1.5DL + 1.5LL + 1.5BL
10	1.5DL + 1.5LL + 1.5ML

Table-4: Limit state of collapsibility - survival

11	1.2DL + 1.2LL + 1.2BL + 1.2EQX
12	1.2DL + 1.2LL + 1.2BL + 1.2EQZ
13	1.2DL + 1.2LL + 1.2BL – 1.2EQX
14	1.2DL + 1.2LL + 1.2BL – 1.2EQZ
15	1.2DL + 1.2LL + 1.2ML + 1.2EQX
16	1.2DL + 1.2LL+ 1.2ML + 1.2EQZ
17	1.2DL + 1.2LL + 1.2ML – 1.2EQX
18	1.2DL + 1.2LL + 1.2ML – 1.2EQZ

Table-5: Limit state of reversal

19	0.9DL + 0.9LL + 1.5BL + 1.5EQX
20	0.9DL + 0.9LL + 1.5BL + 1.5EQZ
21	0.9DL + 0.9LL + 1.5BL – 1.5EQX
22	0.9DL + 0.9LL + 1.5BL – 1.5EQZ
23	0.9DL + 0.9LL + 1.5ML + 1.5EQX
24	0.9DL + 0.9LL + 1.5ML + 1.5EQZ
25	0.9DL + 0.9LL + 1.5ML – 1.5EQX
26	0.9DL + 0.9LL + 1.5ML – 1.5EQZ

5. DESIGN OF BERTH STRUCTURE

The Important levels and design parameters are as shown in Table-6.

Table-6: Design parameters of berth

1	Deck level of berth	4.662	m
2	Top level of pile	3.187	m
3	Diameter of piles	1.2	m
4	Required dredged level	-15.6	m
5	Mean higher low water level (MHLWL)	0.03	m
6	Mean higher high water level (MHHWL)	1.89	m
7	Grade of concrete	40.0	N/mm^2
8	Unit weight of concrete	25.0	kN/m^3
9	Spacing between expansion joints	65	m
10	Depth of scour below dredged level	1	m
11	Scour depth level	-16.6	m
12	Founding level of pile	-20	m

5.1 Beam design

Concrete grade : $40N/mm^2$

Steel grade : $500N/mm^2$

Length of beam : 7000mm

Beam dimension : 600mm × 800mm

Effective cover : 50mm

Effective depth : 750mm

Main reinforcement : 6 bars of 32mm diameter

Shear reinforcement :12mm stirrups at 300mm centres

5.2 Slab design

Concrete grade : $40N/mm^2$

Steel grade : $500N/mm^2$

Overall depth of slab : 450mm

Short span length (L_X) : 7000mm

Long span length (L_Y) : 7500mm

Effective cover : 40mm

Effective depth : 410mm

Effective span : 7000mm

Short span reinforcement: 20mm bars at 250mm centres

Long span reinforcement: 20mm bars at 300mm centres

5.3 Pile design

Concrete grade : $40N/mm^2$

Steel grade : $500N/mm^2$

Service load on pile : 800kN

Design ultimate load : 1200kN

Length of pile : 20000mm

Effective cover : 75mm

Main reinforcement : 12 bars of 40mm diameter

Lateral reinforcement(middle):12mm ties at 165mm centres

Lateral reinforcement(top): 12mm diameter of spiral at a pitch of 53mm for 3600mm length

Lateral reinforcement(bottom): 12mm diameter of ties at a pitch of 55mm for 3600mm length

6. RESULTS AND DISCUSSIONS

This work which is to be carried out comprises primarily of static analysis for different site cases system configuration by the method of static analysis presented in IS: 1893-2000, using Staad.Pro V8i. software. Typical cases chosen in this contemporary work and also area of steel of berth are studied.

Comparison of variations in bending moment, shear force, axial force, displacement and area of steel in piles for the actual model and typical site case considered are as shown in Chart-1.

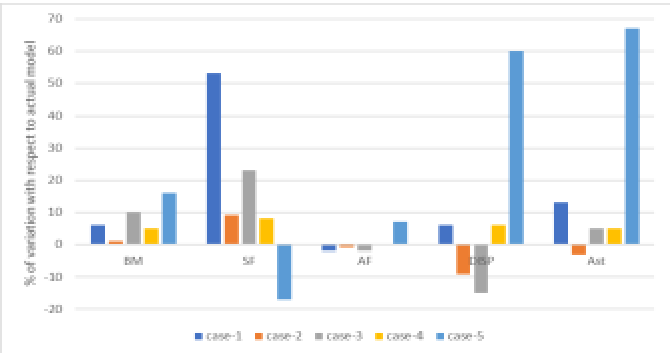

Chart -1: percentage of variation in piles of different cases with respect to actual model

From results observed that,

- The bending moment in piles of case-5 is 16.04% more than bending moment in piles of actual model.
- The shear force in piles of case-1 is 53.47% more than shear force in piles of actual model.
- The axial force in piles of case-5 is 6.82% more than axial force in piles of actual model.
- The displacement in piles of case-5 is 59.604% more than displacement in piles of actual model.
- The area of steel in piles of case-5 is 67.114% more than area of steel in piles of actual model.
- The maximum bending moment in piles is 2930.68kN-m and is find in pile case-5 for a load combination (0.9DL + 0.9LL + 1.5BL + 1.5EQX).
- The maximum shear force in piles is 645.576kN and is find in pile case-1 for load combination (0.9DL + 0.9LL + 1.5ML - 1.5EQX).
- The maximum axial force in piles is 6477.27kN and is find in pile case-5 for load combination (1.5DL + 1.5LL + 1.5ML).
- The maximum displacement in piles is 217.052mm and is find in case-5 for load combination (0.9DL + 0.9LL + 1.5BL + 1.5EQX).
- The maximum area of steel in piles is 34921.09mm^2 and is find in case-5.

Comparison of variations in bending moment, shear force, axial force, displacement and area of steel in beams for the actual model and typical site case considered are as shown in Chart-2.

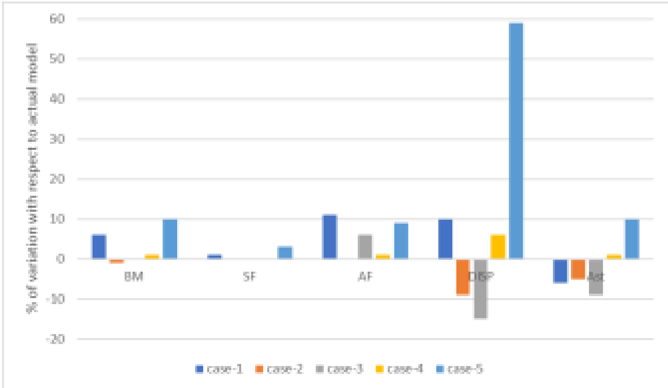

Chart -2: percentage of variation in Beams of different cases with respect to actual model

From results observed that,

- The bending moment in beams of case-5 is 9.77% more than bending moment in beams of actual model.
- The shear force in beams of case-5 is 3.91% more than shear force in beams of actual model.
- The axial force in beams of case-1 is 10.94% more than axial force in beams of actual model.
- The Displacement in beams of case-5 is 58.81% more than displacement in beams of actual model.
- The area of steel in beams of case-5 is 9.996% more than area of steel in beams of actual model.
- The maximum bending moment in beams is 3431.41kN-m and is find in case-5 for load combination (1.5DL + 1.5LL + 1.5ML).
- The maximum shear force in beams is 1686.104kN and is find in case-5 for load combination (1.5DL + 1.5LL + 1.5ML).
- The maximum axial force in beams is 1664.420kN and is find in case-1 for load combination (0.9DL + 0.9LL + 1.5BL + 1.5EQX).
- The maximum displacement in beams is 217.426mm and is find in case-5 for load combination (0.9DL + 0.9LL + 1.5BL + 1.5EQX).

- The maximum area of steel in beams is 18882.44mm^2 and is find in case-5.

7. CONCLUSIONS

This project study build the accomplishment to evaluate Berth structure with various structural configurations, which are resting on basically fixed type of pile foundation. The work conducted will give the following conclusions:

1. The comparison with case-1 shows that bending moment, shear force, displacement, and also area of steel are increased in case-1. Hence here considering actual model is very economical and safe.
2. The comparison with case-2 shows that bending moment, shear force, axial force, displacement, and also area of steel are decreased in case-2. Hence here considering model of case-2 is economical and safe.
3. The comparison with case-3 shows that bending moment, shear force, axial force, displacement, and also area of steel are decreased in case-3. Hence here considering model of case-3 is economical and safe.
4. The comparison with case-4 shows that bending moment, shear force, displacement, axial force also area of steel are increased in case-4. Hence here considering actual model is economical and safe.
5. The comparison with case-5 shows that bending moment, shear force, displacement, axial force also area of steel are increased in case-5. Hence here considering actual model is very economical and safe.
6. Based on study here load combinations of (1.5 DL + 1.5LL + 1.5ML), (0.9DL + 0.9LL + 1.5BL + 1.5EQX), (0.9D L + 0.9LL + 1.5ML – 1.5 EQX) we got the better results.

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