International Journal of Applied Engineering Research
ISSN 0973- 4562 Volume 10, Number 12 (2015) pp.32159-32174

http://www.ripublication.com

Behaviour Of Berthing Structure Subjected To Stack, Crane And Mooring Load

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Abstract

The demand for oil and gas has grown significantly over the past 4 decades. In the near future this growth is expected to continue so larger volumes of oil, gases and bulk cargo are to be transported; an important part thereof by shipping over the high seas. The transportation costs can be reduced by using larger vessels with, among other things, a larger draft; new ports will be constructed in more environmentally challenging conditions, so the loads working on the marine constructions and berthed vessels will be higher. Berthing structure is a general term used to describe a marine structure consists of Deck slab and Substructure for the mooring of vessels for loading and unloading the cargo, for embarking and disembarking passengers. Damage to port/harbour structure was primarily due to Stack, Crane and Mooring load. The literature on the adequacy of the STAAD.Pro modelling of Berthing structure to analyze their behaviour under varying Stack, Crane & Mooring forces is limited. Piles & Diaphragm wall supported Deck slab berthing structure on marine soils are subjected to different loading conditions i.e., BGML, Crane load, Stack load, Concentrated load & IRC 70R loadings. This paper describes the behaviour of varying Stack, Crane and Mooring forces on bending moment of Main Cross Head beam of Deck Slab, "T" Shaped Diaphragm wall and the axial forces of vertical & racker piles.

Key Words: Berthing Structure, Stack Load, Crane Load and Mooring Load

1. INTRODUCTION

1. Introduction

Rapid growth in the water transport system demands the construction of more port and harbour structures. Berthing structures are 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. Quays, wharfs, piers, jetties and dolphins are the most widely used berthing structures.

The demand for oil and gas has grown significantly over the past 40 years. In the near future this growth is expected to continue so larger volumes of oil and gases are to be transported; an important part thereof by shipping over the high seas. To obtain a safe and secure berth for the vessel, there are limits to the acceptable motion and required strength, especially while transferring fluids such as oil, gas and other petrochemical products. For safe maneuvering of vessels and transfer of goods, it is important to predict all these forces and the required strength of the structures, as accurately as possible.

Fig.1.Berthing Structure

1.1 Sub Structure

Generally the piles of a berthing structure on marine soils are subjected to both axial and lateral loads. The lateral loads are not equally distributed among the piles of such structures. The load shared by each pile varies with respect to the slope of the ground, the location of piles in the sloping or horizontal ground, the length, diameter and spacing of the pile. Anchors are provided in order to strengthen the structure and to resist lateral loads thereby reducing the deflection.

Fig2.Sub Structure

1.2 Role of Fenders in Berthing structure:

Marine fenders are used at ports and docks on quay walls and other berthing structures. They absorb the kinetic energy of a berthing vessel and thus prevent damage to the vessel or the berthing structure. Many types of marine fenders include: Cell fenders, Cone fenders, Arch fenders, Pneumatic fenders used to protect the berthing structures from impact forces.

Fig3.Fender

2.METHODOLOGY

The entire berth of 255 metres length is divided into 5 units each 51 metres long. Each unit consists of 17 Nos. "T" shaped diaphragm wall (T.D.W) panels,17 Nos. vertical piles and 19 racker piles. The diaphragm wall is connected at the top through a cellular deck 2.8 metres deep to a series of vertical piles (V.P) 850 mm dia and raker piles (R.P) 700 mm dia. All the substructure elements are socketed in hard rock.

2.1 Material Properties

The material used for analysis Reinforced concrete with M-30 grade concrete and Fe-415 grade reinforcing steel.
The Stress-Strain relationship used is as per IS 456:2000. The basic material properties used are as follows:
Modulus of Elasticity of steel, Es = 21,0000 MPa
Ultimate strain in bending, cu =0.0035
Characteristic strength of concrete, fck = 30 MPa
Yield stress for steel, fy = 415 MPa

2.2 Modelling of Structure

The overall plan dimension of Deck slab of the Berthing structures of one unit is 51m x 17.2m and comprises 5 units with overall length of 255mts. Berthing structure is assumed to be rigid at junction of diaphragm wall/pile and Main Cross Head beam (M.C.H.B) and overall depth of the deck was taken as 2.8m. All the members of the structure are assumed to be homogeneous, isotropic and having elastic modulus same in compression as well as in tension, details are shown in Table 2.1.

Table1. Section details

MEMBER	SIZE (m)
longitudinal Beams	2.25 X 0.25 & 2.25 X 0.30
Cross Beams	2.25 X 0.6 & 2.25 X 0.25
Top Slab	0.30
Bottom Slab	0.25
T.D.W	3X3, t_w = 0.6, t_f = 0.6
Vertical pile	0.85
Racker pile	0.70

The soil is idealized as a classical Winkler foundation - beam on elastic springs. The soil passive resistance is considered to be offered by linear elastic springs. Spring constants for the Sub - structure elements - retaining diaphragm wall and the anchor piles are calculated using the elastic module of the soil strata. (Ref Soil profile). The supports at the end of the retaining diaphragm wall are considered to be effectively restrained against translation in the Y - direction. The supports at the end of the anchor piles are considered to be effectively restrained against translation in the X and Y directions. Supports for the retaining diaphragm wall and anchor piles are taken to be at level -28.00 m. Each of the other joints (node) have three degrees of freedom (DOF'S). The joint between the deck and the retaining diaphragm wall and that between the deck and the anchor piles are considered to be very rigid. Mobilisation of the soil's passive resistance is effected through linear elastic soil springs,(-17m) neglected due to soft marine clay. Structural analysis package, "STAAD.Pro" is used for the analysis. A Typical model of Berthing structure as shown in fig 4.

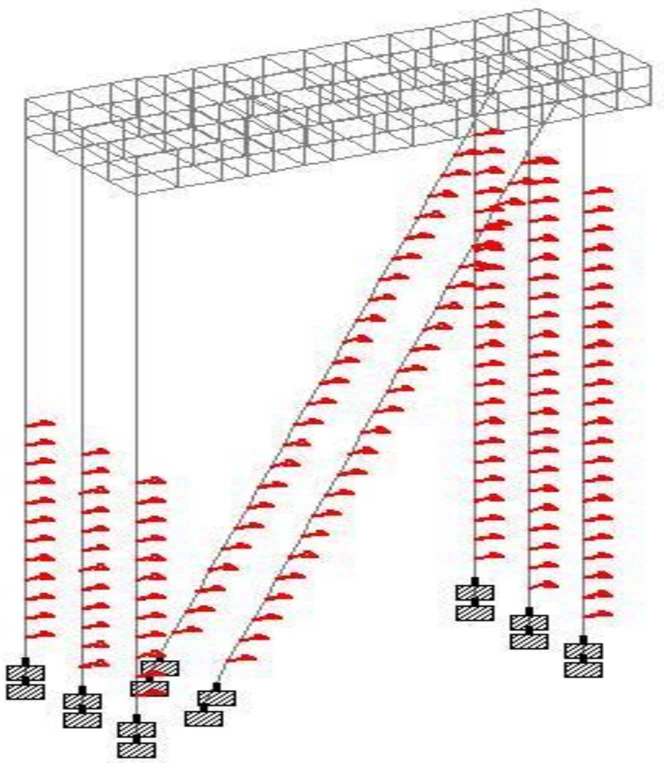

Fig 4. View of Berthing structure

2.3 Load combination consider for Berthing structure

From among the various live loads indicated the following live combinations are considered in the design of the Berthing structure.

Dead Load+ Live Load (Stack load+ Crane Load+ BGML +Concentrated load 20 T+IRC 70R+Bottom slab Load+ Earth pressure+ lateral pressure due to surcharge+ Mooring+ Lateral)

3. RESULTS AND DISCUSSIONS

Analysis done for Berthing structure by using STAAD.Pro. Studied the Influence of varying Crane, Stack& Mooring forces on Bending moment of Main Cross Head beam of Deck Slab &"T" Shaped Diaphragm wall and the axial forces of vertical & racker piles.

Note: The Crane and Stack load are originally point loads but in the design considered as uniformly distributed load by converting point load in the equivalent uniformly distributed load.

3.1Berthing structure with different loading conditions as follows:

The structure was analyzed for linear static analysis for the following
Loads. Stack load
Crane load
BGML
load IRC
70R load
Concentrated load
Mooring force of
90Tons

The results obtained are shown in Table No.2, 3 and 4 for variable stack, crane and mooring load.

3.2VARIABLE STACK LOAD

Table No.2.Details of Bending Moment of Main Cross Head beam of Deck Slab,"T" Shaped Diaphragm wall and the axial forces of vertical & racker piles for Stack load, keeping other loads constant.

Table.2

S. No	Stack Load (Tons/m^2)	Max. B.M of M.C.H.B(Tons-m)	Max. B.M of T.D.W (Tons- m)	Axial Force (R.P) (Tons)	Axial Force (V.P) (Tons)
1	5	2071	4901	644	1612
2	5.25	2082	4967	650	1627
3	5.5	2093	5007	654	1636
4	5.75	2105	5039	657	1644
5	6	2116	5069	659	1651

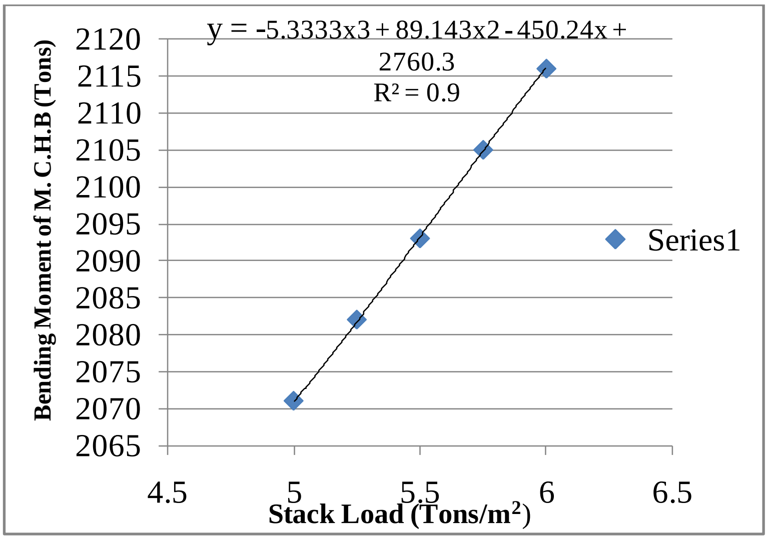

Fig5. Stack Load v/s BM of M.C.H.B

Bending moment of M.C.H.B variation was in the polynomial of order 3 with respect to Stack load.

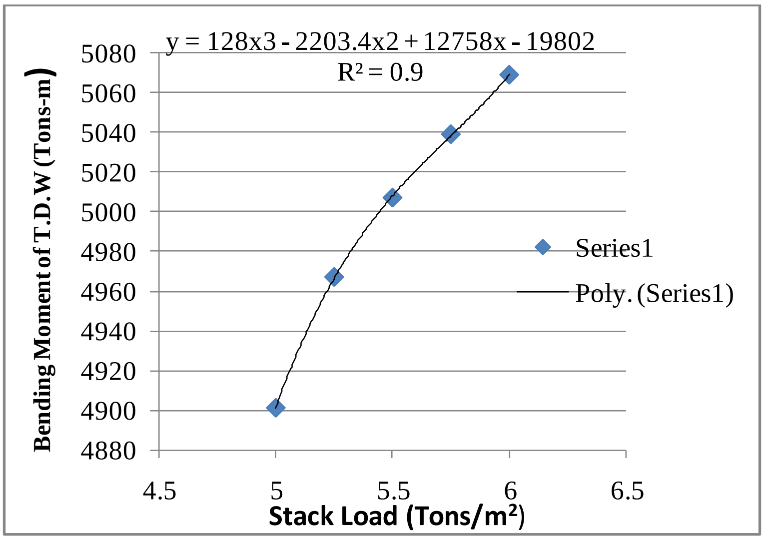

Fig6. Stack Load v/s BM of T.D.W

Bending moment of T.D.W variation was in the polynomial of order 3 with respect to Stack load.

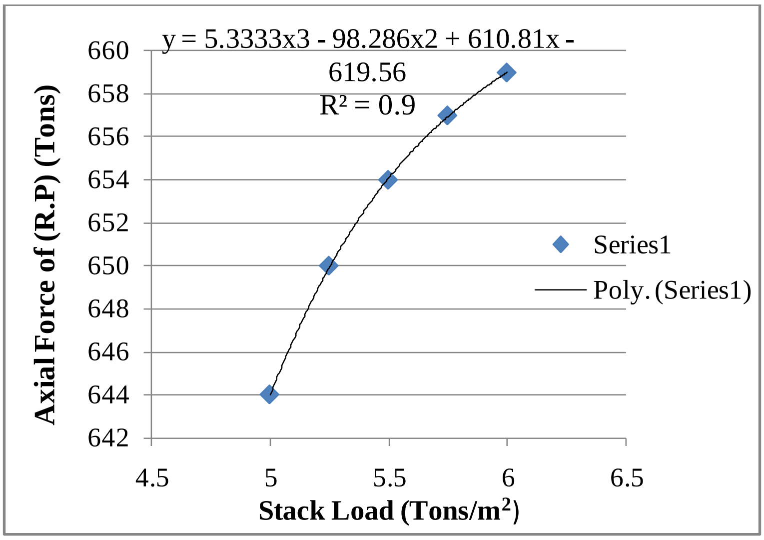

Fig7. Stack Load v/s Axial force of (R.P)

Axial force of raker pile was in the polynomial of order 3 with respect to stack load.

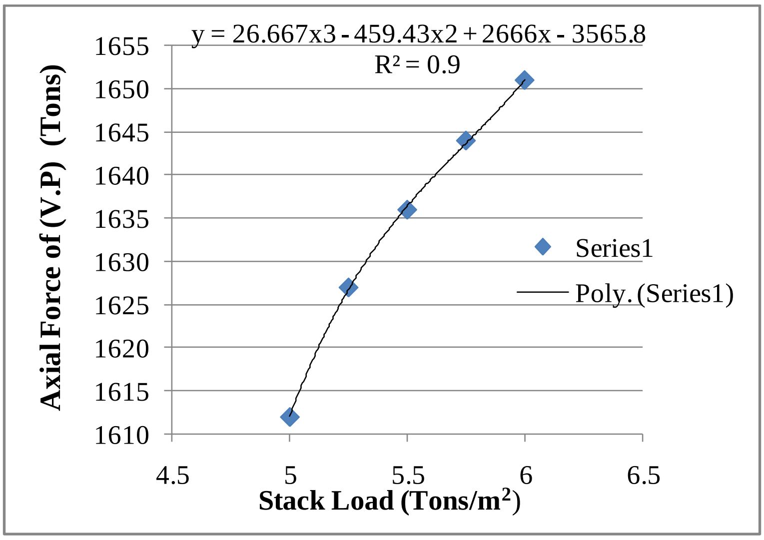

Fig8. Stack Load v/s Axial force of (V.P)

Axial force of vertical pile was in the polynomial of order 3 with respect to stack load.

3.3 VARIABLE CRANE LOAD

Table No3.Details of Bending Moment of Main Cross Head beam of Deck Slab,"T" Shaped Diaphragm wall and the axial forces of vertical & racker piles for Crane load, keeping other loads constant.

Table.3

S. No	Crane Load (Tons)	Max. B.M of M.C.H.B (Tons- m)	Max. B.M of T.D.W (Tons- m)	Axial Force (R.P) (Tons)	Axial Force (V.P) (Tons)
1	20	2071	4901	644	1612
2	21	2103	4933	647	1619
3	22	2136	4972	650	1628
4	23	2163	5004	653	1635
5	24	2190	5035	656	1643

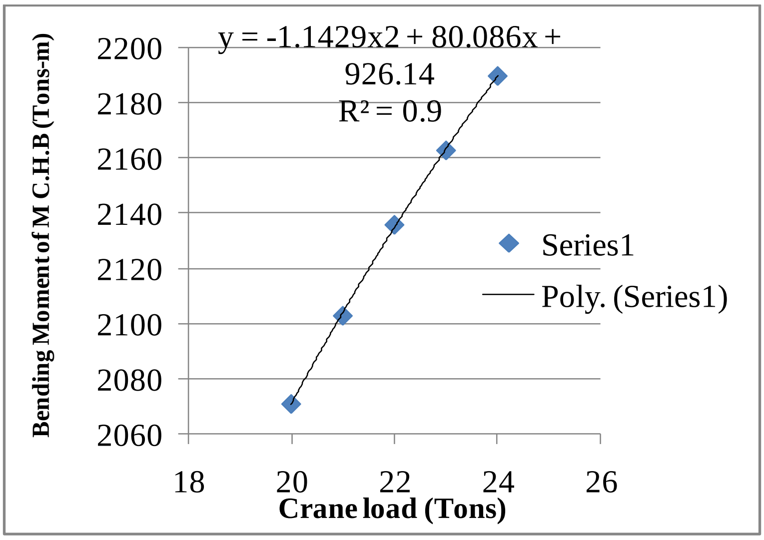

Fig9. Crane Load v/s BM of M.C.H.B

Bending moment of M.C.H.B variation was in the polynomial of order 2 with respect to Crane Load.

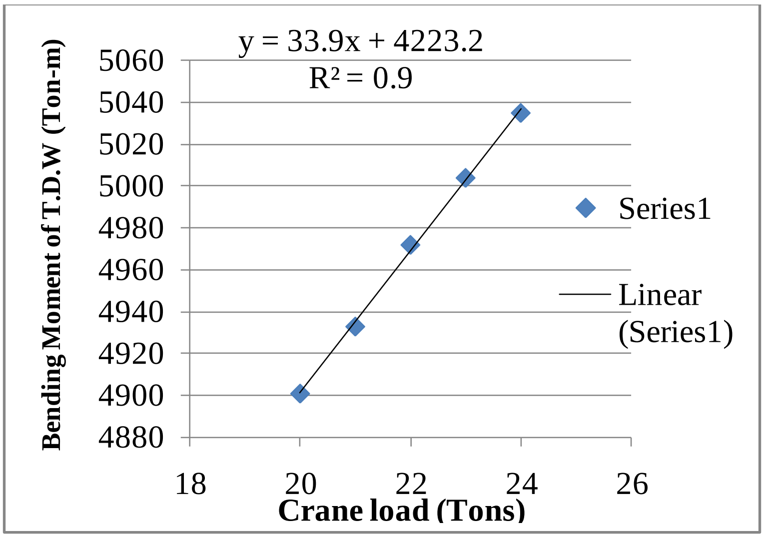

Fig10. Crane Load v/s BM of T.D.W

Bending moment of T.D.W variation was linear with respect to Crane Load.

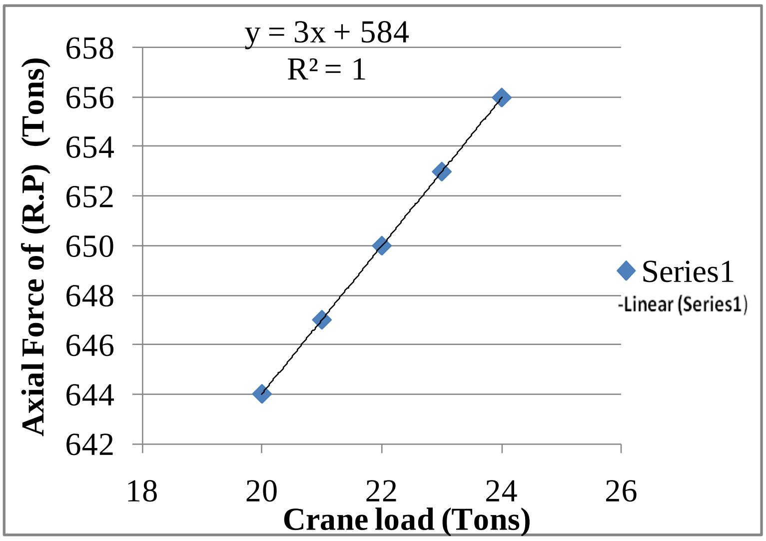

Fig11. Crane Load v/s Axial force of (R.P)

Axial force of raker pile was linear with respect to crane load.

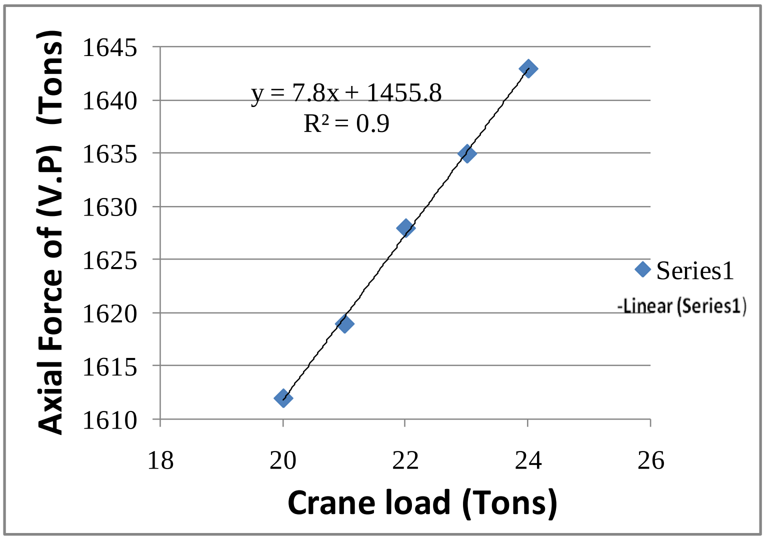

Fig12. Crane Load v/s Axial force of (V.P)

Axial force of vertical pile was linear with respect to stack load.

3.4VARIABLE MOORING LOAD

Table No4.Details of Bending Moment of Main Cross Head beam of Deck Slab,"T" Shaped Diaphragm wall and the axial forces of vertical & racker piles for Mooring load, keeping other loads constant.

Table.4

S. No	Mooring Load (Tons)	Max. B.M of M.C.H.B (Tons- m)	Max. B.M of T.D.W (Tons- m)	Axial Force (R.P) (Tons)	Axial Force (V.P) (Tons)
1	90	2071	4901	644	1612
2	100	2083	4930	645	1615
3	120	2105	5005	647	1620
4	150	2132	5105	650	1627

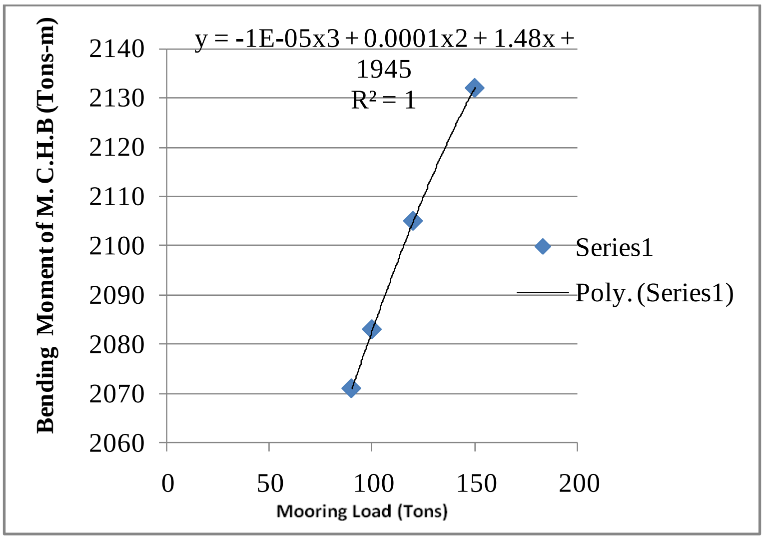

Fig13. Mooring Load v/s BM of M.C.H.B

Bending moment of M.C.H.B variation was in the polynomial of order 4 with respect to Mooring Load.

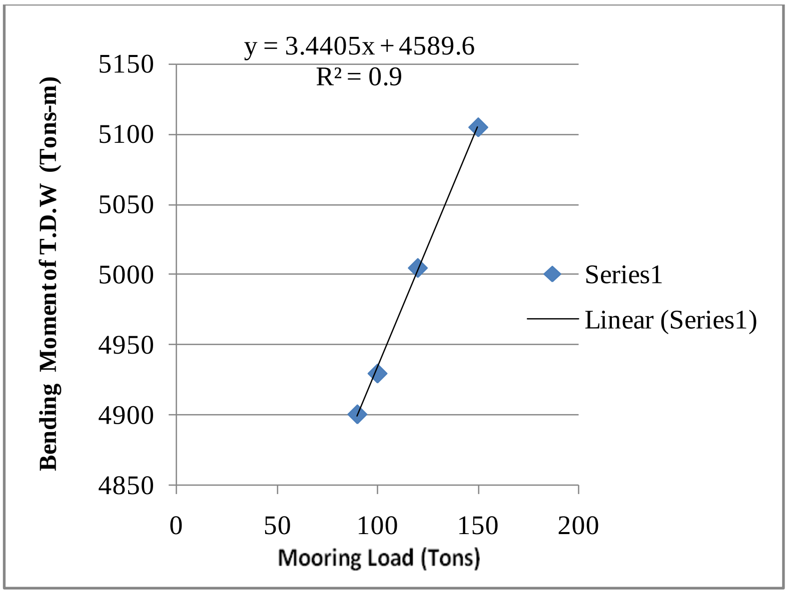

Fig14. Mooring Load v/s BM of T.D.W

Bending moment of T.D.W variation was Linear with respect to Mooring Load.

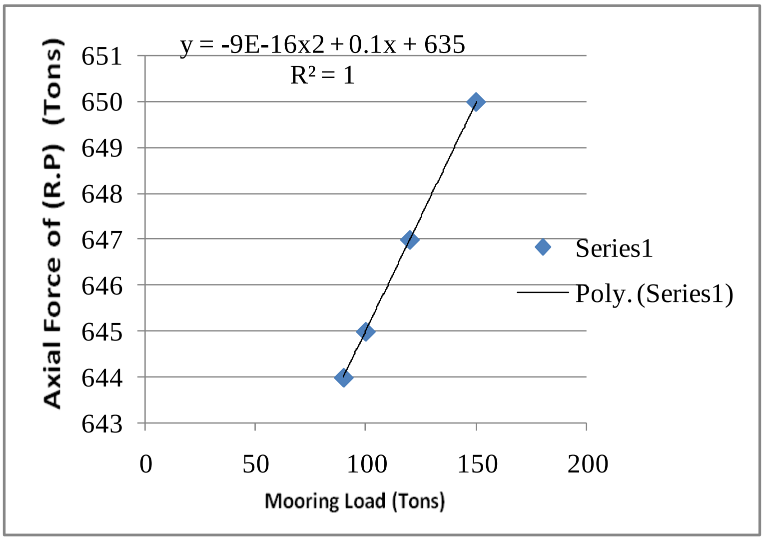

Fig15. Mooring Load v/s Axial force of (R.P)

Axial force of raker pile was in the polynomial of order 3 with respect to Mooring Force.

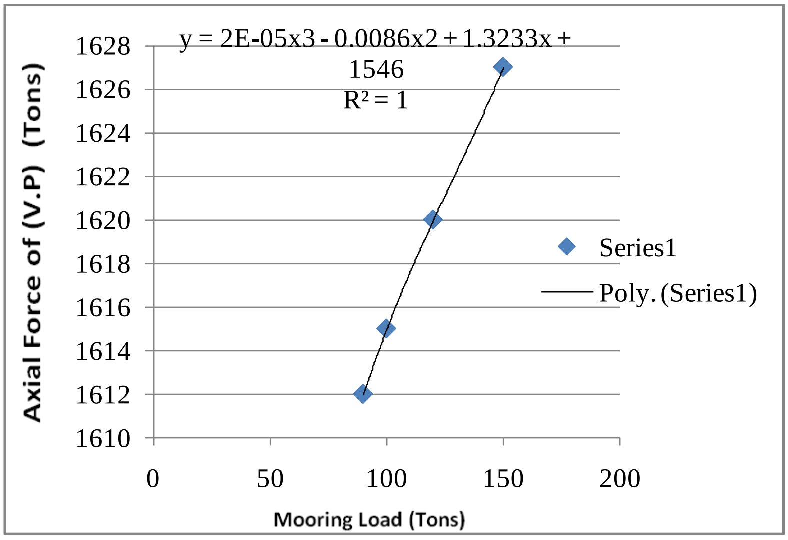

Fig16. Mooring Load v/s Axial force of (V.P)

Axial force of vertical pile was in the polynomial of order 4 with respect to Mooring Force.

4. CONCLUSIONS

The following conclusions are obtained from the STADD.Pro analysis for variable stack, crane and mooring loads.

4.1. STACK LOAD

On increasing the stack load of 5%, 10%,15%, 20% and 25% on $5T/m^2$

a) The percentage of increase in the bending moment of M.C.H.B 0.52, 1.05, 1.61, 2.12 and 2.68 respectively.
b) The percentage of increase in the bending moment of T.D.W were 1.32, 2.11, 2.73, 3.31 and3.89 respectively.
c) The percentage of increase in the Axial force of racker pile were 0.92,1.52,1.97,2.27 and2.72 respectively.
d) The percentage of increase in the Axial force of vertical pile were0.92,1.46,1.94,2.36 and 2.84 respectively.

4.2.CRANE LOAD

On increasing the Crane load 5%, 10%,15%, 20% and 25% on 20T

a) The percentage of increase in the bending moment of M.C.H.B were 1.52, 3.04, 4.25, 5.43, and6.64 respectively.
b) The percentage of increase in the bending moment of T.D. were 0.64, 1.42, 2.05, 2.64 and 3.27 respectively.
c) The percentage of increase in the Axial force of racker pile were 0.46,0.92,1.37,1.82, and2.27 respectively.
d) The percentage of increase in the Axial force of vertical pile were 0.43,0.98,1.40,1.88 and 2.32 respectively.

4.3. MOORING LOAD

On increasing 90T mooring load to 100T, 120T and 150T

a) The percentage of increase in the bending moment of M.C.H.B were 0.57,1.61and 2.86 respectively.
b) The percentage of increase in the bending moment of T.D.W were 0.58, 2.07 and 3.99 respectively.
c) The percentage of increase in the Axial force of racker pile were 0.15,0.46 and 0.92 respectively.
d) The percentage of increase in the Axial force of vertical pile were 0.18, 0.49 and 0.92 respectively.

The variation in Stack load plays a major role in influencing the Axial forces of vertical and racker piles when compared to Crane load and Mooring Load.

The variation in Crane load plays a major role in influencing the bending moment of Main Cross Head beam when compared to Stack load and Mooring Load.

The variation in Mooring load plays a major role in influencing the bending moment of “T” Shaped Diaphragm wall when compared to Stack load and Crane Load.

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