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Reliability Based Analysis of Berthing Structure Subjected to Variable Crane Load

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Abstract
The Indian peninsula is also strategically located between the Atlantic Ocean in the west and the Pacific Ocean in the east and Indian Ocean in south, with a 7,517 km-long coastline. During the last decades ships have grown larger in number, as a result consequence berthing facilities have to be adopted for larger units. Over the years, cargo handling capacity of Major Ports has steadily increased. Due to this, Berthing facilities for ships has increased and new berthing structures have to be constructed. Berthing structures are subjected to large lateral forces due to berthing and mooring vessels. The lateral forces are to be resisted by the vertical pile, raker pile and diaphragm wall. The construction and maintenance of Berthing structures are very expensive and therefore the safest and most economical design should be adopted. Many studies have been reported previously on the loading mechanism of laterally loaded pile group on horizontal ground. The Berth is subjected to moving crawler crane load perpendicular to the direction of berth with its designed capacity. This paper aims to study the behavior 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.

Keywords: Berthing Structure, Varying Crane, Crane Load, Reliability

INTRODUCTION

India has one of the largest merchant shipping fleets among developing countries and is ranked 16th in the world in terms of gross tonnage. Due to this, many new ports are constructed over the past few years. Today, India has 12 Major Ports and 200 notified Non-Major Ports along the coastline and islands. Major Ports are administered by the Union Government under the Major Port Trusts Act of 1963, with one exception, Ennore Port, which is administered under the provisions of the Companies Act, 1956. Non-Major Ports are administered by nine maritime states and three union territories within their respective coastlines. Over the years, cargo handling capacity of Major Ports has steadily increased. Due to this, structures on the port are constructed. These structures are known as Berthing structures. Berthing structure is shown in figure 1 below

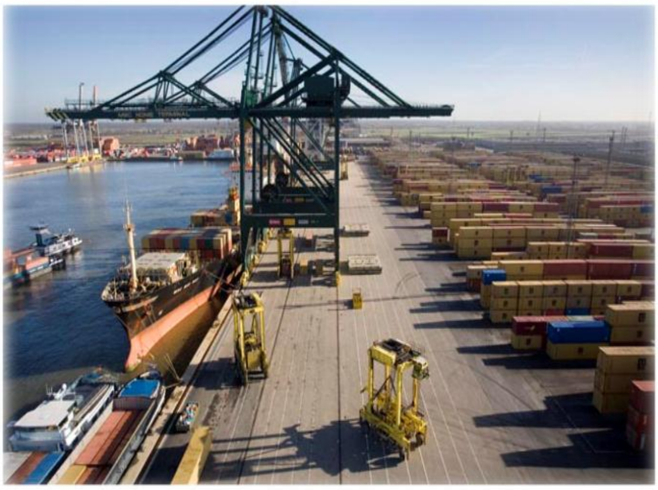

Figure 1: Berthing structure

LITERATURE REVIEW

Past studies show the various characteristics of Berthing structures. The following are some of the available literatures.
M. Gokul Krishnan et al., [2009] [1] studied the Behaviour of an open type berthing structure under earthquake condition. Piles and diaphragm wall supported berthing structure on marine soils are loaded laterally from horizontal soil movements. A maximum of 7.3 mm lateral deflection was observed under seismic condition. However, under seismic condition the lateral displacement of ground was observed to 700mm. and the bending moment behaviour also changed significantly under the seismic condition. A maximum bending moment of 230kNm was observed under seismic condition.
Y.L. Young a et al., [2010] [2] studied the Reliability-based design and optimization of adaptive marine structures. A first order reliability method is used to evaluate the influence of uncertainties in material. Reliability-based design and optimization is a common practice for many rigid and/or non-adaptive structural engineering systems. The results show that a probabilistic approach is more appropriate than a deterministic approach for the design and optimization of adaptive composite structures

Yili Barbara J. Lence et al., [2011] [3] studied the marine structures subjected to long-term cyclic environmental and operational loadings and gives an experimental investigation has been carried the linear elastic fracture mechanics (LEFM)-based fatigue reliability method provides straightforward information regarding the effect of fatigue crack.

Daniel Straub et al., [2015] [4] studied the Bayesian Updating with Structural Reliability Methods. That is particularly effective for updating mechanical and other computational models, termed Bayesian updating with structural reliability methods (BUS). In his paper, subset simulation was used to obtain samples of the posterior distribution. Three application examples were included to demonstrate the versatility and efficiency of BUS.

G.T. Naidu et al., [2015] [5] their study 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 & raker piles. The variation in Stack load, Crane load, Mooring load plays a major role in influencing the bending moment of Main Cross Head beam, "T" Shaped Diaphragm wall, Axial forces of vertical and raker piles**.**

BERTHING STRUCTURE

Berthing structure is a general term used to describe a marine structure for the mooring of vessels, loading and unloading cargo, and embarking and disembarking passengers. Berthing structures should be located in the most sheltered part of the harbor or along the lee side of the breakwaters. Also, wherever possible the berth can be oriented so that, the ship headed alongside as nearly into the wind and waves.

The structure is idealized as a plane frame. In order to idealize the soil, a Winkler foundation system with passive soil resistance is offered by the equivalent linear elastic springs. The passive soil resistance between EL-12.00 m and EL 17.00 m on the diaphragm wall is neglected. Spring forces on the vertical and raker piles are limited to the passive resistance as per safety factor. The original design slope of 1V:4 H was stable by itself and hence no failure of slope was expected. All the structural elements were socketed in hard rock. The crawler crane load acts perpendicular to the direction of berth with designed capacity of 200T.

SCOPE OF WORK

- STAAD.Pro was used to model the Structure and MATLAB was used for generation of random numbers by using Monte Carlo simulation technique.
- This thesis was restricted to study the member characteristics of each structural component.
- Size of beams & diameters of piles were kept constant throughout the study.

MATERIAL PROPERTIES

The materials used for analysis are Reinforced concrete with M-30 grade and Reinforcing steel with Fe-415 grade. The Stress-Strain relationship used is as per IS 456:2000. The basic material properties used are as follows:

- Modulus of Elasticity of steel, $E_s = 2.1\text{x}10^5$ N/mm^2
- Characteristic strength of concrete, $f_{ck} = 30$ N/mm^2
- Yield stress for steel, $f_y = 415$ N/mm^2

LOADS CONSIDERED ON STRUCTURE

- Dead Load of the structure
- Live Loads on deck
- Crane Load (Expressed as intensity of load per unit floor area on deck slab)
- Broad Gauge Main Line Load
- IRC 70R tracked and wheeled vehicle.
- Concentrated Load

Loads on Substructure

- Earth pressure
- Lateral pressure due to surcharge
- Mooring Load

LOAD COMBINATIONS ON BERTHING STRUCTURE

Case-1: Without Mooring Force
Dead Load + Live load +Hydrostatic Force + Surcharge + Earth Pressure
Case-2: With Mooring Force
Dead Load + Live Load +Hydrostatic Force + Surcharge + Earth Pressure + Mooring Force

MODELING OF THE STRUCTURE

The structure was analyzed in STAAD Pro software in order to obtain the bending moment values of Main Cross Head Beam (MCHB), T shaped Diaphragm wall (TDW) and Axial force values of Vertical Pile (VP) & Raker Pile (RP). The total analysis was carried out in two conditions: with and without mooring force**.** Berthing Structures are considered with different loading conditions such as: BGML, Crane load, Stack load, Concentrated load and IRC-70R loadings. In this paper, Stack load is kept constant and Cane load is varied for with mooring and with-out mooring force conditions. Berthing structure is assumed to be fixed at junction of diaphragm wall/pile and Main Cross Head beam. Overall depth of the deck was taken as 2.8m.

Table 1 Structural details of the components

MEMBER	SIZE (m)
I section	3 X 0.3 X 0.86 X 0.25X 2.8
T Diaphragm wall	3 X 0.6 X 0.6
Vertical pile	0.85
Raker pile	0.70

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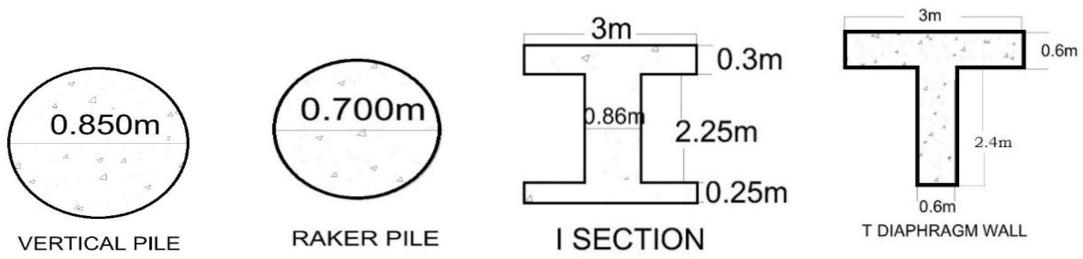

Figure 2. Various Cross sections of the structural components

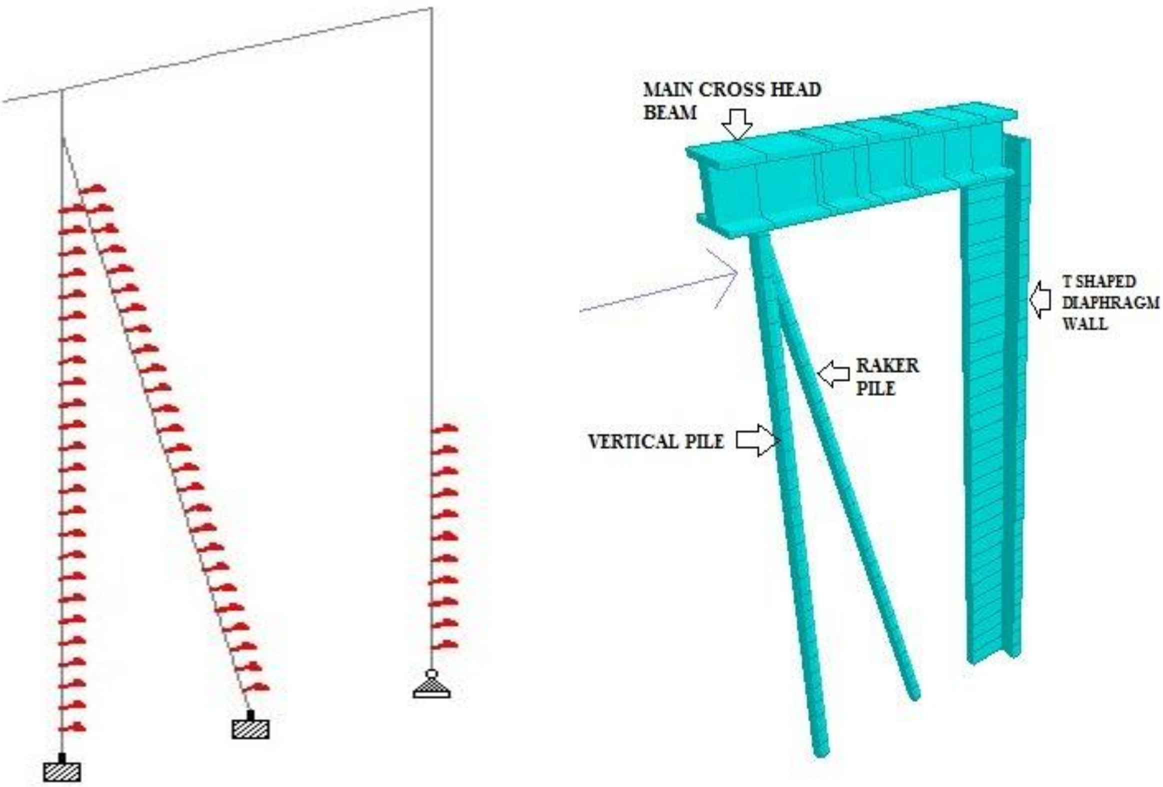

Fig 3. 2-D and 3-D rendered view of structure modeled in Staad pro

RELIABILITY ANALYSIS

Reliability Analysis is a mathematical tool to enhance performance of component of a structure. In the reliability analysis, the variables are characterized by their mean and coefficient of variations. Monte Carlo technique is a simulation technique used to estimate the probability distributions of random numbers. It says that, the probability of failure provides the basis for quantifying the structural reliability. By using this technique, probability distributions of random numbers can be estimated and those values depend up on the interactions with random variables whose probability distributions are specified. This technique is used to study the distribution of random variables, to simulate the performance of or behavior of the system and to determine the reliability or probability of failure of system or a component. MATLAB software is used for the generation of random numbers by their values of mean, standard deviation and coefficient of variation are obtained for each structural component.

RESULTS and DISCUSSIONS

Following figures shows the variations of COV in with mooring and without mooring conditions

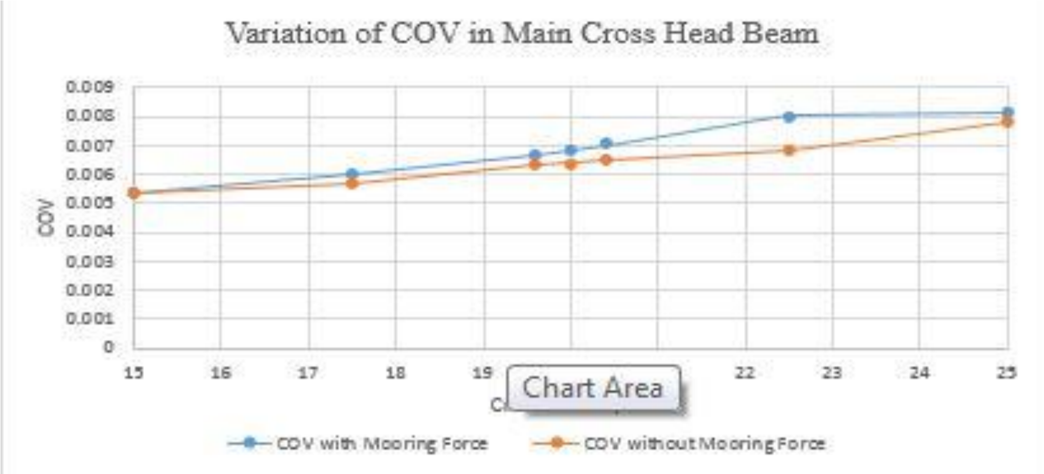

Fig 4 Intensity of crane load vs COV of Bending Moment in Main Cross Head Beam

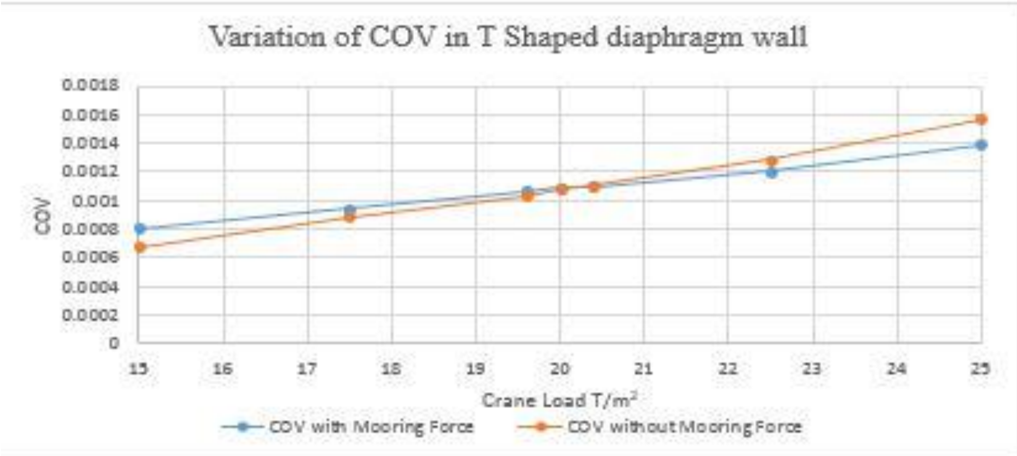

Fig 5 Intensity of crane load vs COV of Bending Moment in T Shaped Diaphragm wall

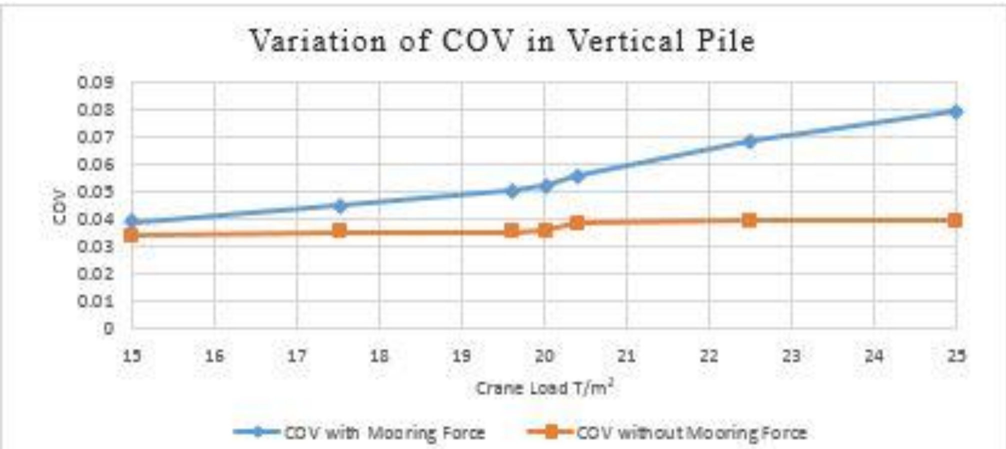

Fig 6 Intensity of crane load vs COV of Axial Force in Vertical Pile

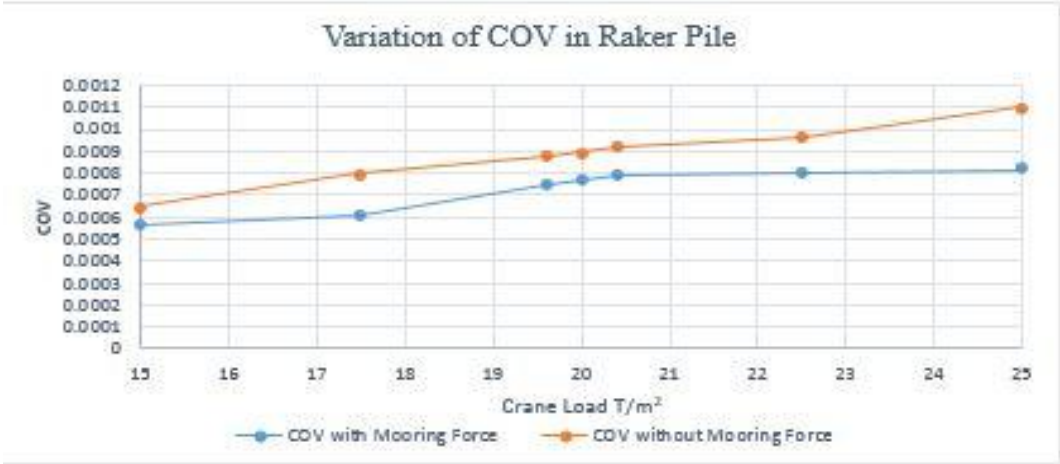

Fig 7 Intensity of crane load vs COV of Axial Force in Raker Pile

The member characteristics obtained from the Reliability analysis for Bending Moment and axial force was tabulated below

Table 2 Member characteristics of each component with Mooring force condition

MEMBER	MEAN [μ]	STANDARD DEVIATION [σ]	COEFFICIENT OF VARIATION [COV]
MCHB [Bending Moment]	1501.79	10.28	0.00684
'T' Diaphragm wall [Bending Moment]	1323.66	1.43	0.001086
Vertical Pile [Axial Force]	31.75	1.68	0.05253
Raker Pile [Axial Force]	413.55	0.32	0.000769

Table 3 Member characteristics of each component without Mooring force condition

MEMBER	MEAN [μ]	STANDARD DEVIATION [σ]	COEFFICIENT OF VARIATION [COV]
MCHB [Bending Moment]	1582.82	10.09	0.00638
'T' Diaphragm wall [Bending Moment]	1276.17	1.38	0.001079
Vertical Pile [Axial Force]	43.55	1.58	0.03630
Raker Pile [Axial Force]	390.12	0.35	0.000898

CONCLUSIONS

From the Analysis, for variable Crane load of 15 T/m^2 and $25T/m^2$ when compared to service Crane load of $20T/m^2$ with and without mooring force condition, observed variation of results of load effects in Main Cross Head Beam (MCHB), T-shaped Diaphragm Wall (TDW) and Raker Piles (RP) and the following conclusions were drawn.

1. Main Cross Head Beam (MCHB): For Crane load of $15T/m^2$, the COV for Bending Moment was decreased by 26 % and 16% for conditions with and without mooring forces respectively. In case of Crane load of 25 T/m^2, the COV for Bending Moment was increased by 6% and 23% for conditions with and without mooring forces respectively.
2. 'T'-Shaped Diaphragm Wall (TDW): For $15T/m^2$ Crane load, the COV for Bending Moment was decreased by 37% for both conditions with and without mooring force. For 25 T/m^2 Crane load, the COV for Bending Moment was increased by 46% for both conditions with and without mooring force.
3. Vertical Pile (VP): In case of $15T/m^2$ Crane load, the COV for Axial force was decreased by 7% for both conditions of with and without mooring force. In case of Crane load of 25 T/m^2, the COV for Axial force was increased by 9% for both conditions of with and without mooring force.
4. For Raker Pile (RP): For Crane load with $15T/m^2$ intensity, the COV for Axial force was decreased by 28% for both conditions of with and without mooring force. For 25 T/m^2 Crane load, the COV for Axial force was increased by 22% for both conditions of with and without mooring force.

5. From the study, it was concluded that the influence of variable Crane load has effect on the Bending Moment of MCHB & TDW and Axial Force of VP & RP of the berthing structure.
6. 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 (TDW), Vertical Pile (VP) and Raker Pile (RP) were minimal, but have found significant variation in the case of Main Cross Head Beam (MCHB).

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AUTHOR'S PROFILE

G.T.Naidu, The author presently working as Associate Professor and Head of the department in Sanketika Vidya Parishad Engineering College, PM Palem, Visakhapatnam doing his Research at GITAM College of Engineering, GITAM University and having 26 years of industrial experience, guiding the students at Graduate and Post Graduate level. He is with service many years in industry and as Head of the Department enriched the knowledge to hundreds of students. He is member in various professional bodies like FIV, MIE.

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