IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Analysis Of Jetty Structure For Coastal Resilience

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Abstract: Coastal structure engineering and design encounters with specific challenges in marine environments, which demand for careful planning and innovative solutions. For concrete jetties to remain durable, safe, and functional, a thorough understanding of the structural behavior is necessary due to the dynamic interaction of maritime factors, such as tides, waves, and currents. The study's conclusions have consequences for design guidelines, engineering procedures, and the larger field of coastal infrastructure development. The goal of the research is to provide useful information that advances the development of durable and sustainable concrete jetty structures by fusing environmental factors and structural engineering concepts. It is expected that the comprehensive methodology used in this study will influence future advances in coastal engineering by providing a framework for optimal design and construction techniques in the constantly changing marine environment.

***Index Terms* - Jetty Structure, Berthing forces, Mooring forces, Tidal forces.**

I. INTRODUCTION

The design and engineering of coastal structures encounter specific obstacles in marine environments, which require for thorough research and creative design solutions. A jetty is typically a platform built from a shoreline into the water, extending beyond the shallow waters to accommodate ships and boats. In India, jetties are essential components of ports, harbours, and coastal areas where maritime activities are concentrated. They serve as berthing points for cargo vessels, fishing boats, and passenger ferries, allowing for safe and efficient movement of goods and people between land and sea. Jetties also support various coastal industries such as fisheries, aquaculture and tourism. Jetties in India are vital for coastal defence and protection against natural forces like waves and currents. They act as barriers, mitigating erosion and protecting coastal areas from the impacts of cyclones and storm surges. Among these essential constructions, concrete jetties are crucial for supporting marine activities since they operate as berthing locations for ships and offer vital land-sea connectivity. For concrete jetties to remain long-lasting, safe, and functional, a thorough understanding of the structural behaviour is necessary due to the dynamic interaction of coastal factors, such as tides, waves, and currents. The research aims to investigate in detail the environmental pressures acting on concrete jetties, the dynamic responses of the structures, and the creation of design criteria that strike a balance between sustainability objectives and structural strength. The main objective of this research is to identify critical points of jetty by analysing the structure in software by referring load combination as per is code4651:2014 for normal and severe conditions and comparing those results with the design performed as per IS 4651:1989.

II. Literature Review

Application of Forces Acting on Jetty Structure Studied by Himesh B Chopra et.al which shows wind forces are generally applied above mean sea level (MSL). The level can experience a drop or rise with the passage of time and hence the real scenario regarding the action of forces cannot be derived. The average MSL is obtained and the forces are assigned above the average MSL. – In case of wave forces, loads are assigned as nodal forces. Analysis and Design of a Quay Berthing Structure presented by S.Nagarjuna ,S.Shamshad Begum .Different factors were considered while analyzing and designing the berthing structure. Lateral loads on the berthing structures are more noteworthy than those on land–based structures. Suitable environmental data, traffic forecasting and soil data ought to be received from the proposed site location, typical load distribution is induced on the shore line structures. The structure was analyzed and designed satisfying various loading conditions and dimension analysis for economical aspect was also taken care of without exceeding the structural safety. Analysis and Design of Marine Berthing Structure performed by T.Vivek, R.Durga.. After going for designing or orchestrating a berthing structure, all the present and future optimistic conditions regarding traffic data, hinterland expansion and industrialization of that particular hinterland are to be studied, which additionally play a major role in shaping the project inception at the first place.

The review study on Structural Health Monitoring of Existing Reinforced Concrete Jetty Structure conducted by Mohit M Patil and Dr.S.A.Rasal**.** The review found that concrete mixed with blast furnace slag and volcanic ash deteriorated less after sixty years of exposure to the marine environment. The durability of the RC members in the splash zone and atmosphere zone was discovered to be low. The RC member's durability in the tidal zone and undersea water zone is excellent. One of the most corrosive atmospheres in which chloride penetration and chloride induced reinforcement corrosion lead to a reduction in structure service life, structures below low water were in good condition but deterioration was slowly occurring in the tidal zone and above high water deck beams were severely affected by corrosion in steel and proper attention was not given to the maintenance of beams and deck slabs. In zones of alternate soaking and drying, the deterioration rate is higher.

III. METHODOLOGY

DETAILS OF JETTY STRUCTURE

Jetty size: 56 m × 32 m
Slab Thickness: 600 mm
Longitudinal Beams: 1400 mm × 2200 mm
Transverse Beams: 1500 mm × 1850 mm
Crane Beams: 2500 mm × 1950 mm
Sea-face Beam and Landside beam: 2200 mm × 1950 mm
Right edge and left edge Beam: 1800 mm × 2000 mm
Deck Slab Top: (+) 7.10 m RL
Sea bed level: General (–) 13.0 m
Rock encountered at: (-) 20 m
Founding Level of Piles: (-) 26 m

LOADS ACTING ON JETTY SRUCTURE

Dead Load:

Weight of Deck slab =15 KN/m2
Wearing coat weight =5 KN/m2
Beams:
Longitudinal beams =77 KN/m
Transverse beams =70 KN/m
Sea-face beam & Landside Beam =108 KN/m
Right edge & Left Edge beam = 90 KN/m
Crane beam =122 KN/m
Marine growth =1.5 KN/m2 (IS 4651, Part 4:2014)

Live Load:

Live load is based functioning of berth and truck loading on berth as per IS 4651 (Part 3)-2020. The function of berth is related to truck.

Loading A or AA or 70R (Heavy cargo Berth) so we are adopted 50 KN/m2

Berthing Load:

When a ship or other vessel comes into contact with a jetty structure in order to dock, forces and loads are applied to the structure. This is known as the berthing load. Several dynamic forces are at work when a ship approaches the jetty to dock; in order to guarantee safe and secure berthing, the jetty needs to be built to bear these loads.

Design vessel size	=	2,00,000	DWT
Length of Ship	=	235	M
Width of Ship	=	32.5	M
Height	=	16.2	M
Draft/laden weight D	=	15.2	M
Unit weight of sea water γ	=	1.03	T/m3
Angle of approach θ	=	10	Degrees
Velocity of approach	=	0.2	m/s
Factor of safety	=	1.4	
DT/DWT factor	=	1.26	
Mass co-efficient Cm,	=	1.385	
Eccentricity coefficient, Ce,	=	0.51	
Softness co-efficient, Cs	=	0.9	
Berthing Energy, E	=	85	Tm
Design Berthing Energy, Ed	=	120	Tm

$E = W_D.V^2/2g.(Cm)(Cs)(Ce)$

Mooring Load:

The lateral masses that the mooring lines create as they draw the ship into or onto the dock or stabilize it against the forces of wind or current are referred to as the mooring masses.

Adopted Design load for Mooring is 900KN.

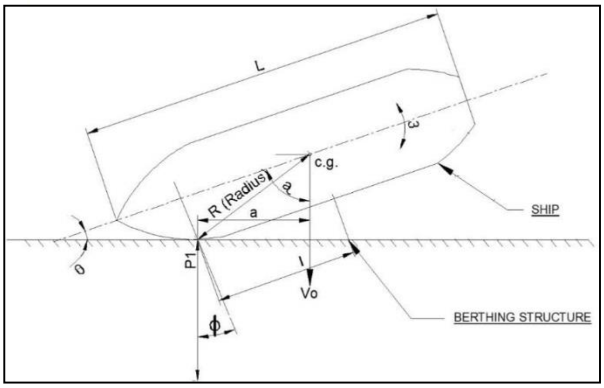

Fig 1: Vessel approaching Berth at an angle

Wind load:

Wind Contributes primarily to the lateral loading on a pier. It Blows from many directions and can change without notice.IS 875 (Part 3):2015.

Design wind speed, Vz = Vb x k1 x k2 x k3

Vb = 44 m/s

k1 = 1.07
k2 = 1
k3 = 1.3
Vz = 2.247 KN/m2 = 0.6 (Vz)2
P = 2.247 KN/M2
Now the design wind pressure is resolved as nodal loads on structure = 9 KN

Seismic load:
The forces and vibrations that a jetty structure experiences during an earthquake are referred to as seismic loading. Jetties and other waterfront constructions are susceptible to ground changes and dynamic forces during earthquakes, which could jeopardize their stability. It is essential to design jetty constructions to withstand seismic loads in areas where earthquakes are common.
Design seismic base shear Vb = Ah W
Ah = (Z/2) x (Sa/g) x (I/R)
Zone factor Z = 0.24
Importance factor I = 1.75
Sa/g = 2.5 Hard soil
Ah = 0.105

Earth pressure:
A crucial factor in the design and analysis of the jetty's structural stability is the ground pressure exerted on the piles supporting its superstructure. The jetty's foundation is supported by piles, which are susceptible to a number of factors, including lateral earth pressure. The force that the soil applies to a pile or other retaining structure is known as lateral earth pressure.
Design Active Earth pressure,
Pa = K ɣ h Pa = 171.6 KN/m2
Uniform Load, Pa = 686.4 KN/m

WATER PRESSURE/HYDROSTATIC PRESSURE:

Water pressure affects jetties that reach out into bodies of water. Loads that are vertical and lateral may be influenced by the water's hydrostatic pressure. The pressure rises with depth and is inversely related to the water's density and gravitational acceleration. An RCC jetty structure experiences an increase in hydrostatic pressure that is linear in depth. The pressure is constant at whatever depth and perpendicular to the jetty's surface in all directions.

Design Water Pressure
P = ɣ h P = 260 KN/m2
Load on each Pile P = 390 KN/m

Crane loads:
The forces and loads applied by cranes that are attached to or utilized in connection with jetty structures are referred to as crane
loads on jetty structures. Cranes are frequently installed on jetties to help with cargo handling, ship loading and unloading, and
other marine tasks. Dynamic motions occur during crane operations, so dynamic impacts need to be taken into account.
Wide-span Crane
Gantry span 40 - 50 m
Outreach 30 – 40 m
Back-reach 15 – 20 m
Crane weight Capacity (A) 40 T
Crane weight Capacity (B) 30 T

LOADS COMBINATIONS

Load Combinations for Extreme/Severe Condition (IS 4651, Part 4:2014)
1.2 (DL+ DyL+ LL) +1.0 EP + 1.0 (HyF + CL) + 1.0 BF
1.2 (DL+ DyL+ LL) +1.0 EP + 1.0 (HyF + CL) + 1.0 EL
1.2 (DL+ DyL+ LL) +1.0 EP + 1.0 (HyF + CL) + 1.0 TL

1.2 (DL+ DyL+ LL) +1.0 EP + 1.0 (HyF + CL) + 1.0 E-WiF

Load Combinations for Normal Condition (IS 4651, Part 4:2014)

1.5 (DL+ DYL+ LL) +1.0 EP + 1.0 (HYF) + 1.2(WL + CL) + 1.5 BF + 1.0 (WWIF)
1.5 (DL+ DYL+ LL) +1.0 EP + 1.0 (HYF) + 1.2 (WL + CL) + 1.5 MF + 1.0 (WIF)

DL – Dead Load
LL – Live Load
EP – Earth Pressure
WL – Wave Force
CL – Current Force
BF – Berthing Force
MF – Mooring Force
WWIF – Working Wind Force
EWIF – Extreme Wind Force
HYF – Hydrostatic Force
DYL – Dynamic Load
TL – Tsunami Load
EL – Seismic Force

Load combinations for Normal Condition (IS 4651, 1989)

1.5DL + 1.5LL + 1EP + 1HYD PRESSURE + 1.5B + 1.5M
1.2DL + 1.2LL + 1.0 EP + 1.2 HYD PRESSURE
0.9DL + 0.9LL + 1.0 EP + 1.0 HYD PRESSURE
1.2DL + 1.2LL + 1EP + 1HYD PRESSURE + 1.5WL
0.9DL + 0.9LL + 1EP + 1HYD PRESSURE + 1.5WL
1.2DL+1.2LL+1.0EP+1.0HYD PRESSURE + 1.5 EQ
0.9DL+0.9LL+1.0EP+1.0HYD PRESSURE + 1.5 EQ
1.2DL+1.2LL+1.0EP+1.0HYD PRESSURE + 1.5 DQ
0.9DL+0.9LL+1.0EP+1.0HYD PRESSURE + 1.5 DQ

RESULTS:

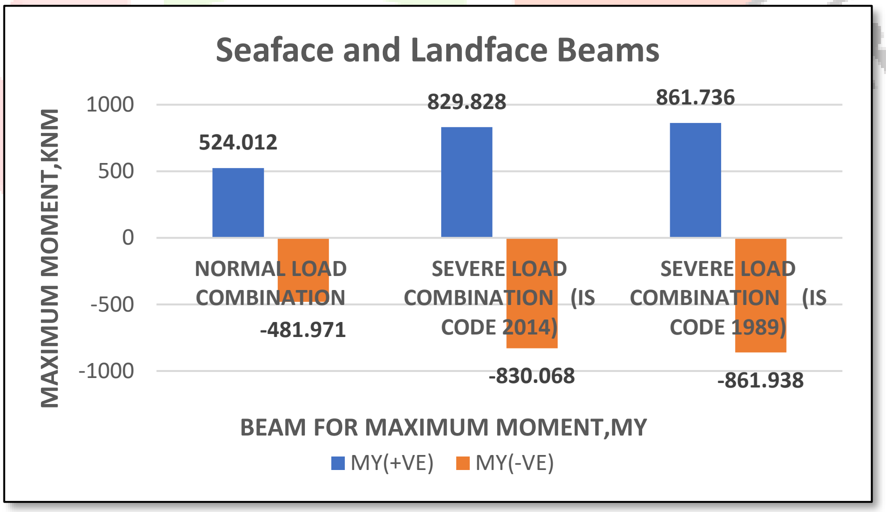

Fig 2: Comparison of Sea-Face and Land-Face Beam for Normal, Severe Condition as Per IS 4651:2014 and Worst Condition as Per IS 4651 1989

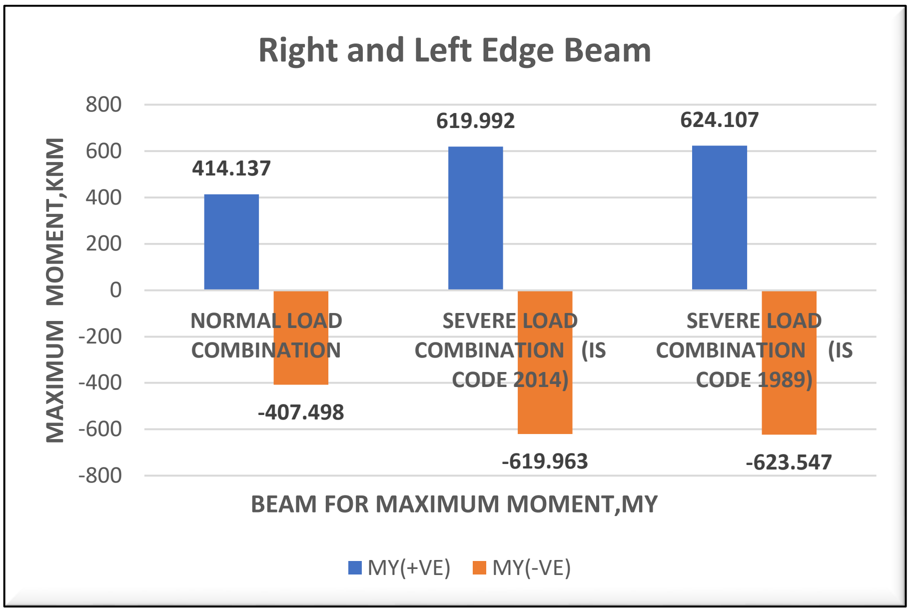

Fig 3: Comparison of Right and Left Edge Beam for Normal, Severe Condition as Per IS 4651:2014 and Worst Condition as Per IS 4651 1989

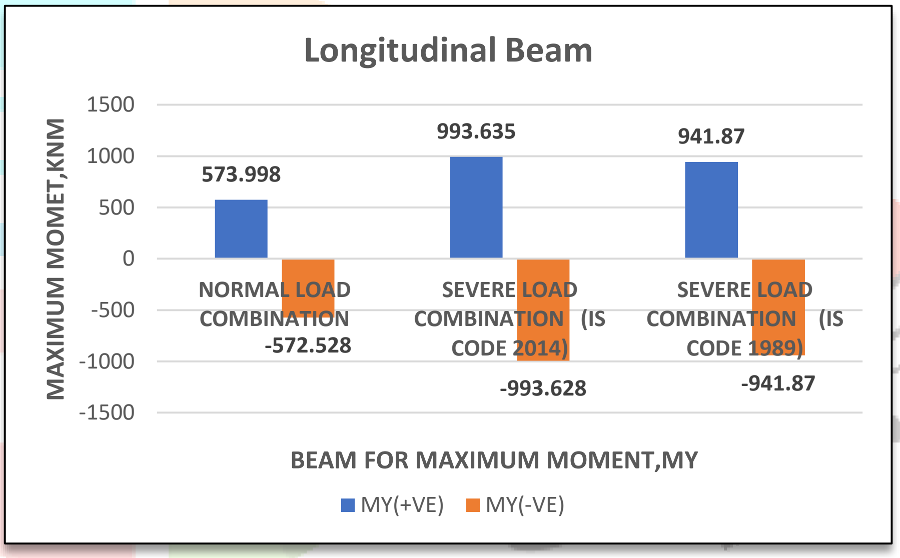

Fig 4: Comparison of Longitudinal Beam for Normal ,Severe Condition as Per IS 4651:2014 and Worst Condition as Per IS 4651 1989

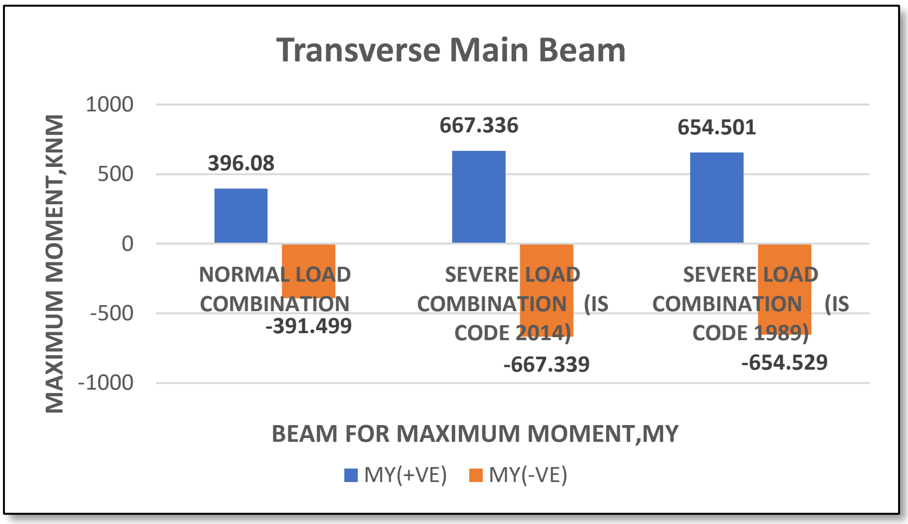

Fig 5: Comparison of Transverse Beam for Normal, Severe Condition as Per IS 4651:2014 and Worst Condition as Per IS Code 4651 1989

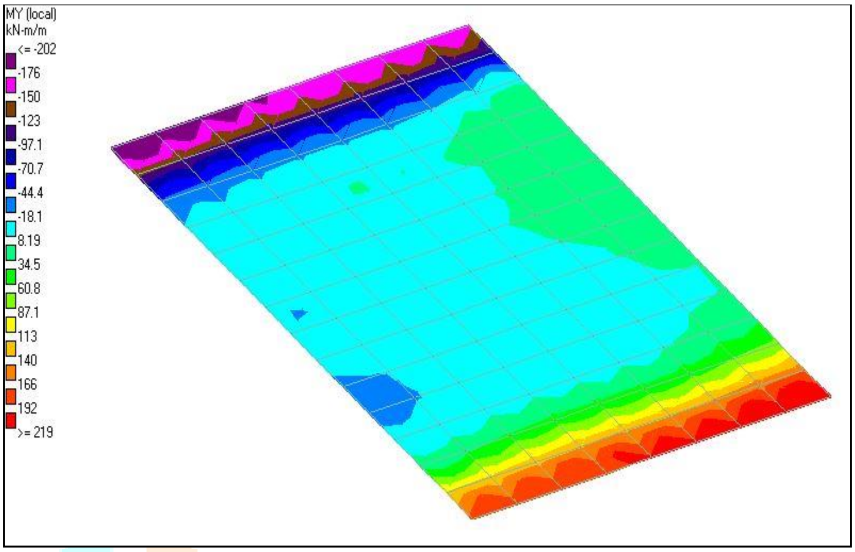

Fig 6: Plate Stress Diagram for Normal Load Combination

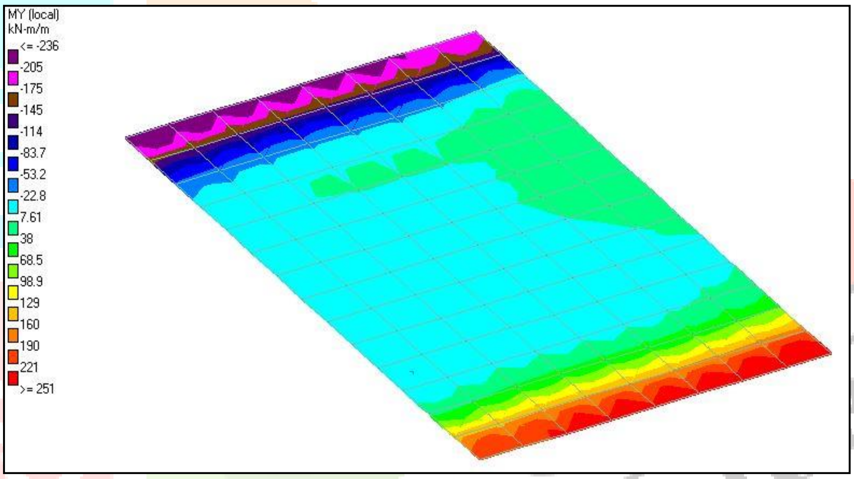

Fig 7: Plate Stress Diagram for Severe Load Combination

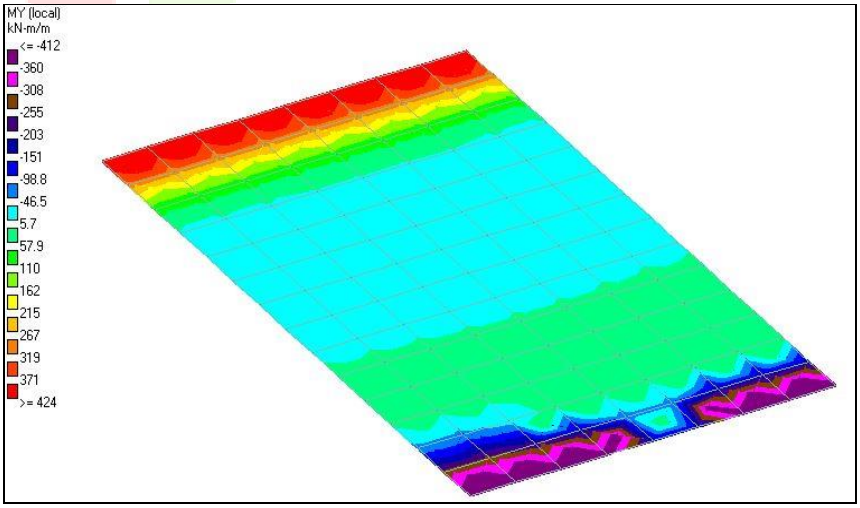

Fig 8: Plate Stress Diagram for Worst Load Combination (IS 4651:1989)

The above Plate Stress diagram shows that Sea-face and land-face experience maximum moment values due to action of Crane movement and Tidal forces acting on sea-face beam.

CONCLUSION

[1] This research study performed for several load combinations and critical load cases were taken into consideration for analysis of beams and deck slab as per loading suggested by Indian code IS 4651:PART 4 :2014 and compared those results with the loading and load combinations given as per IS 4651:1989 to identify the difference in the analytical results for particular jetty structure and to undergo better performance of jetty structure, worst load combinations are adopted

[2] As per Clause 5.1 and 7..1 from IS 4651:Part4:2014,Load combination for Normal Conditions and severe condition were introduced, which represent performance of jetty structure in worst scenario.

[3] The Result show the difference of 3.6%, 0.6%, 2.8% decrease in maximum moment for sea-face and land face beam, Right and Left edge beam and for Crane Beams, and decrease in 2%, 5% for Transverse Beam and Longitudinal Beam. The difference is less than 5% for structure analysed by referring both the IS codes

[4] The Normal load combination and Severe Load combination for strength analysis of beam shows 37%, 33%, 41%, 40.6%, 42.25% increase in moment for severe condition in sea-face & Land-face beam, Right & Land edge beams, Crane Beams, Transverse Main Beam, Longitudinal Main Beam.

[5] The Berthing Forces, Crane load Dynamic loading and Seismic effects shows the Maximum moment values for worst load combination considered for Design of Jetty structures.

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