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# Optimized design of coastal observatory for Indian gulf conditions

**[1]N.PREETHAM RAJAN,**
Masters Student,
Structural Engineering with (Spl.) in Offshore
Department of Civil Engineering,
University of Petroleum and Energy Studies,
Dehradun, Uttarakhand-248007
preethamrajan0@gmail.com

**[2]SATYA KIRAN RAJU,**
Scientist-C,
Offshore Structures,
National Institute of Ocean Technology,
Pallikaranai, Chennai,
Tamil Nadu, India- 600100.
raju@niot.res.in,

**[3]VIJAY RAJ,**
Senior Professor,
Structural Engineering with (Spl.) in Offshore
Department of Civil Engineering,
University of Petroleum and Energy Studies,
Dehradun, Uttarakhand, India248007
vraj@upes.ddn.ac.in

**ABSTRACT : The design of offshore structure are mainly governed by environmental conditions at proposed location and also meta-ocean parameter like waves, water level, currents, wind etc.., which are need to be collected for longer duration by deploying instruments. These instruments are support by floating system in deep waters and fixed platform in shallower waters. The present study aims at identifying optimum three legged and four legged jacket configuration for coastal observatories in shallower waters. Different configuration of jacket platform with varied batter angle are modelled using finite element method subjected to suitable environment loading in water depth of 20m. All structural member of each configuration are sized considering a utilization factor of 0.75 and its structural weights are estimated. It is observed that the optimum structural configuration with minimal weight for 3legged jacket is 10.5 tonnes and 4legged jacket is 11.25 tonnes. Thus the paper concludes in providing optimized design methodology for jacket platform using Finite element methods.**

**Keywords: (jacket platform, optimisation, braces, utilisation factor, coastal observatory)**

## I INTRODUCTION

Preliminary assessment by various institutions and organizations indicate huge potential for energy in terms of crude oil, wind and tide in Gulf of Khambhat and Gulf of Kutch along Gujarat coast. For exploitation of these resources, detailed numerical studies of waves, currents and winds need to be carried out. For validation and calibration of these numerical models, it is essential for measurement of met-ocean parameters along Gujarat coast. A suitable coastal observatory scheme needs to be developed considering high tidal currents and soft soil conditions along Gujarat coast.

Coastal observatories require data collection platforms either fixed or floating type in the near shores to monitor met-ocean parameters. They collect data for years which help in understanding variation processes in the ocean environment. In the initial stages these parameters were collected by deploying instruments on vessels either in moored or sailing state. In later stages, by realising the importance of ocean data dedicated systems were developed for data collection.

Coastal observatory structure are not massive structure like oil platforms and they are small fixed platform or floating buoys. Usually floating structures are deployed in deep water, jacket structures in intermediate waters with weak soil condition and monopole structure in shallow waters with medium soil condition. As Gujarat coast has shallow to intermediate waters with poor soil conditions, Jacket would be an ideal substructure concept. Three and four legged jacket platforms are studied with variable configurations for 20m water depth to obtain an optimum structural configuration.

## II DESIGN METHODOLOGY:

Jacket platform with three and four legs is modelled by considering fixed condition at seabed. Environmental loads like wind, wave, and current are applied as per site conditions. The member's utilization factors for all the members are obtained as per API standards. Now, the members are optimized through an iterative process by varying the sizes for a utilization factor of 0.75. The base reactional and the material quantities are estimated for final configuration. Similar process is repeated by varying the batter angle for legs and optimum configurations are arrived for three legged and four legged jacket platform.

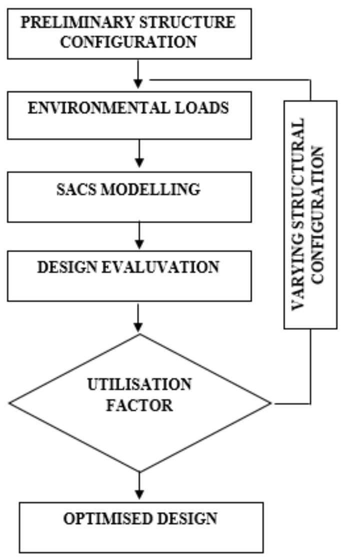



**Figure 1: Methodology for substructure Optimization**

## III ENVIRONMENTAL CONDITIONS

The environmental conditions that influence the coastal structures include wind, wave and current. The methodology for estimation of these loads based on suitable standards is detailed below:

**A. Wave Loads:** In this paper design is based on [1] API RP 2A WSD in this the load is arrived by categorising the wave based on wave theory which is done by calculating $H/gT^2$ and $d/gT^2$. Here 'H' is the height of the wave, 'T' is the wave period, and'd' is depth of water, 'g' acceleration due to gravity. These factors are obtained by field data collection process and they are substituted in the region of applicability graph which decides on what wave theory it falls on.

**Table 1. Wave parameter.**

| Type | Sea State | H m | T s | d m | $d/gT^2$ | $H/gT^2$ |
|---|---|---|---|---|---|---|
| Jacket platform | Severe | 6 | 10 | 20 | 0.02 | 0.006 |

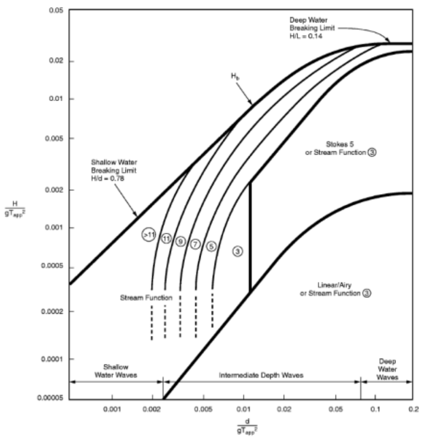



**Fig 1. Region of applicabity graph**

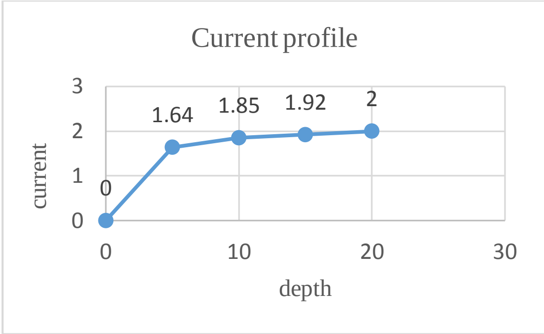
From the graph for the given wave parameter the wave theory arrived is Stroke's V order wave theory. Later the wave load is found using Morison's equation

**B. Current load:** The current load for the design is also arrived using [1] API RP 2A WSD. For calculation of current the current profile is analysed the current profile is obtained by power law.

$$V = V_{ot} * \left[\frac{y}{h}\right]^{1/7}$$

Here 'V' is the current velocity, '$V_{ot}$' is current velocity at water surface. 'y' is required depth and 'h' is the water depth.

From this formula the current velocity for required depth can be calculated.




**Graph 1. Current profile**

By this graph it can be seen that the load increases as the depth increases and the calculation is based on mud line elevation. However both current and wave are hydrodynamic parameter which calculated using Morisons equation.

$$F = C_D\ (\rho/2)\ D\ V^2 + (\pi/4)\ D^2\ \ \rho\ C_m\ U^2$$

Where F is Force per unit length, ρ is mass density of water (1025 kg/m3), CD is Drag Coefficient for Tubular Section (0.65 – smooth surface), Cm is Inertia Coefficient for Tubular Section (1.6 – smooth surface), U =Acceleration of water particle, V =Velocity of water particle .This is a semi empirical equation which equation which assume the total force as a sum of inertia component to the fluid acceleration and a drag component of velocity due to fluid velocity.
The formula is applicable only when current and wave are in same direction. So the wave and current direction is varied for every 30° for 3legged and every 22.5° for 4legged platform

**C. Wind load:** Wind load in this design is calculated using IS 875 PART III in which wind velocity is obtained by [2]

$$V_z = K_1 * K_2 * K_3 * V_b$$

Where $V_b$ is the basic wind speed taken from the standard provision, $V_z$ is the design wind speed to be calculated, $K_1$ factor for life span, $K_2$ factor for type of structure, $K_3$ factor for topography. These factor are computed with respect to condition prevailing in Gujarat region. The reference height for calculation is taken to 10m. The wind load varied in different direction (i.e.) every 30° for 3legged and every 22.5° for 4legged platform

.

**Table 3. Wind velocity**

| $V_z$ (m/s) | $K_1$ | $K_2$ | $K_3$ | $V_b$(m/s) |
|---|---|---|---|---|
| 51.22 | 0.91 | 1.13 | 1 | 50 |

## IV SUBSTRUCTURE CONFIGURATION AND DESIGN.

The jacket platform is a substructure in this design which supports the monitoring equipments and recording device. Basically jacket are welded tubular space structure consisting of structural components as leg, horizontal braces, vertical braces, diagonal braces. Each component in a jacket has its own purpose which provides structural integrity for the platform.

- **A. Leg**: These are primary member of a jacket platform which are vertical and takes care of the axial forces coming onto the structure.
- **B. Horizontal braces**: these are secondary member which spans in horizontal direction. They connect the legs together and resist any torsion or twist coming on to the structure
- **C. Diagonal braces**: these are also secondary member which are inclined to an angle of 45° from the horizontal and leg member junction, they take care of the lateral loads coming on to the structure.

Here the jacket platform are designed as three legged and four legged structures to support a topside load of 7000kg. Two different configuration are taken to see which one of it will be more efficient for the provided condition. The jackets are design for a height of 25m and are deployed into a water depth of 20m. For structural integrity the leg of the platform is divide into 5base at an interval of 5m from mudline up till 4th base and 5th base 3m from the top. . In jacket structure by creation of base point in leg nodes are assigned in each base and the load is transferred through these nodal points**.** The structural orientation of jacket is in such a way to avoid large spanning of members. The jacket platform designed in this paper are sleek in appearance as they are small monitoring structures and so the loads coming on the structure are not so heavy. These platform uses leg member which are heavy at the bottom and light at the top, the horizontal braces adopted in each design are almost same at every base for the particular structure. The slant braces used in this structure is zigzag braces as the lateral load will be transferred to leg member efficiently. X- Braces are avoid in this design as the dead weight of the member will increases. After modelling the jacket in SACS the member of the jacket are assigned sections. Generally in offshore structures the section assigned are hollow tubular as the compute minimum dead weight and hydrodynamic properties. Once the member are created they are assigned to the structure, later the load application is done. The load applied to the structure are wind wave current which computed based on the environmental parameters and assigned to the member. Later the member are checked for failure and unity check then redesigned if any accordingly.

## V DESIGN OPTIMISATION

Optimisation of jacket platforms are done to decrease the cost to weight ratio. In general optimisation research work are carried by many researcher and their study provides ideas on various perspective with respect to which optimisation can be done. To do optimisation researcher adopt different methodology and technique having the cause of optimisation as objective function which varies from structure to structure. [6]Kleiber performed optimisation of jacket structure with respect to stability oriented and reliability based technique having volume of the structure as an objective function. [8] Nasseri proceeded optimisation by using generic algorithm with weight as a parameter.[7] Desert and Deleuil proposed optimisation having geometry of the structure as objective function. Here this paper provides optimisation of jacket with respect weight and mudline reaction by placing batter as a varying function.

Initially before starting optimisation of the jacket certain boundary condition are set like unity check and D/T ratio of member. These conditions are assigned by hit trail method and fixed to be 0.75 and 7 as they are found optimum for the design. Optimisation is carried for both three legged and four legged platform by varying the batter scale from 5 to 15 with a variance of 2.5. The optimisation response of the structure with respect to batter is varied with self-weight of the structure and the mudline reaction are plotted in a graph as shown below for three legged and four legged.

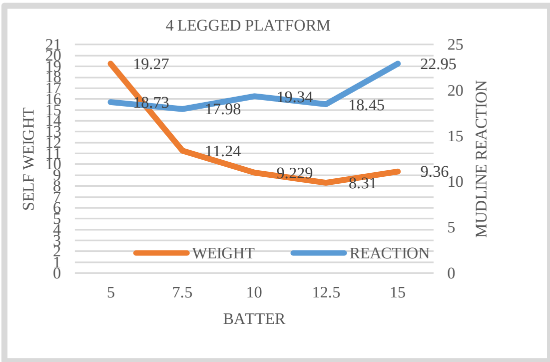



**Chart 1. Four legged**

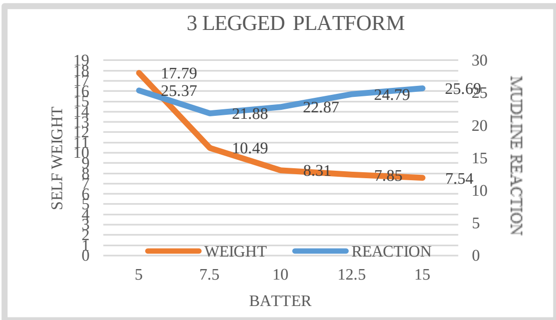



**Chart 2. Three legged**

From the graph it is clear that at batter of 5 the legs are widely spread so spanning of member are high hence the section are heavy. So when further the batter is increased self-weight decreases by 41.6% and reaction to 13.7% with respect to three legged were as in four legged the self-weight and reaction decreases by 4% and 41.6%. So on further increasing the value on a scale of 2.5 self-weight decrease and gets normalised but the reaction starts increasing so the batter value should be chosen from 7.5 to 10. Further it can be observed from the graph that when we compare the structure with respect to self-weight then 3legged is suitable on the other hand comparing with respect to mudline reaction 4 legged is viable. On closer observation with respect to both parameter at batter 7.5 the self-weight and mudline reaction for 3legged is considered optimum when comparing to 4legged as the mudline reaction is only few tonnes more that it and also designing a foundation for an extra leg can be avoided by choosing 3legged over 4 legged.

## VI CONCLUSION

Coastal observatories are monitoring structure deployed in open oceans for long term collection of met-ocean parameters. The gulfs in Gujarat experience a high tidal current of 4m/s with highest tidal range of 12m near Bhavnagar. These gulfs are also associated with soft soil conditions and dynamic sea bed movement. So, use of conventional monopile platforms will be expensive as larger fixity depths will be required and are not commercially viable.

Three and four legged Jacket structures are studied for these Gulf condition in Gujarat to arrive at an optimum configuration. The Jacket structures are light in weight and are stable for lateral loads in weak soil conditions. In the present study optimisation is achieved with respect to cost (i.e. weight) by varying batter angle. It is observed that adopting a batter of 7.5 will result in an optimum structure with minimum self-weight and optimal mud line reaction. Further, choosing a three legged platform would be ideal as the weight and base reaction variation compared to four legged are minimal and when compared to efforts for driving and additional. So, it can be concluded from the present study that a three legged coastal observatory platform with a batter of 7.5 and member diameter to thickness ratio of 7 will provide an optimised jacket structure for the Gulf condition in Gujarat.

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