Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 7, Issue 06, June -2020

Offshore Platform Analysis for Nonlinear Loading Condition

Yash M. Mehta[1], Mohit Vachhani[2]

[1]Student, M.E. Structural Engineering, Darshan Institute of Engineering & Technology, Rajkot
[2]Assistant Professor, Department of Civil Engineering, Darshan Institute of Engineering & Technology, Rajkot

Abstract —*The structural design requirements of an offshore platform subjected wave interacted forces and moments in the jacket can play an important role in the analysis of the offshore platform structures. A nonlinear static analysis of a steel offshore platform under wave loading is shown, the structure is generalised using the finite element method in SAP2000. Hydrodynamic loading condition on horizontal and inclined tubular members and the dynamic response of fixed offshore platform structure together with the parameters as displacement, shear and bending moment along the leg are analysed for moderate and sever conditions, where the structure should not stop production capacity in conditions of the 1 year return period wave and must be able to survive the 100 year return period storm wave conditions. The result of the analysis shows that the nonlinear response study is quite critical for not to hard design and operation of offshore platform.*

Keywords- Offshore Structures, Sea waves, Nonlinear Static analysis, SAP2000, Soil-interaction.

I. INTRODUCTION:

- Offshore structures have extraordinary attributes from monetary and specialized perspectives, where offshore structure stages more rely upon oil and gas creation which will legitimately, through the oil value, influences overall venture.
- From a specialized perspective the seaward structure stage plan and development is a scaffold between steel structure plan and harbour structure, and there are as yet set number of staff building territories concentrating on seaward auxiliary designing, for example, the plan of fixed seaward stages, in the case of skimming or different sorts.
- The use of these platforms is generally specified to a water depth of about 150-180 m in the North Sea ecology. Platform were among the very first structures to be used in the offshore industry, as stable platforms mainly for oil and gas production facilities
- In the study of fixed offshore platform structures many non-linear structural quantity and mechanism exist that are not easy to calculate and interpret in relation to hydro-dynamic loading. The calculation of the wave loading on inclined tubular members is always of serious concern to engineers, especially now when such studies are encouraged by the need to build solid offshore platform structures in consideration with oil and natural gas productions. The impact of various wave patterns on offshore structures has been studied by numerous researchers in long time.
- This research gives brief idea about non-linear dynamic analysis of a 3-D model of a typical Jacket-Type offshore platform, which will be in Gulf of Kutch. Wave loading condition is assigned to a full jacket platform structure by Stokes 5th order wave methods with gravity and environmental loads also there. The analysis takes various nonlinearities generated due to change in the non-linear hydrodynamic force. Natural time periods, displacement, and base moment of the system are calculated. The results of this analysis highlight the importance of precisely considering non-linear effects in fixed offshore platform structures.

II. CODES OF PRACTICE:

- American Petroleum Institute (API) RP2A-LRFD, 1993 provisions provides description of environmental load and design requirement for fixed offshore platform for use in analysis, describe logical methods to determine the forces persuaded in the platform system by ground motions, and give direction for sizing and arranging steel elements for the design forces. The consideration of environmental loads is included earthquake loads in terms of earthquake ground motions, wind, wave and current loads.

III. DIFFERENT TYPES OF LOAD:

- Water force can be categorized as forces due to waves and forces due to current. Wind gusting over the ocean's surface drags water along with it, thus forming current and generating waves. The forces encourage by ocean waves on platform are dynamic in nature.

3.1 Waves and Hydrodynamic Loads

- Several theories for the explanation of the shape and kinematics of regular waves exist. Regular wave concepts used for calculation of wave forces on fixed offshore structures are based on the three considerations water depth (d), wave height (*h*) and wave period (*T*) as obtained from wave dimensions adapted to different statistical model. Wave forces on discrete structural elements can be calculated, based on hydro-dynamic drag and mass co-efficients (*Cd*, *Cm*) and particle velocity and acceleration gained by the chosen wave theory. Water particle kinematic is evaluated using linear wave theory. This description assumes the waveform whose wave height; *h*, is small in comparison to its wavelength; *L*, and water depth; *d*.

- The analysis is performed in time field to solve the dynamic behaviour of jacket platform as an integrated system using the iterative incremental approach. Stokes 5th order wave is distinct by providing wave height and period in the contribution data with the wave type specified as Stokes in the Sap2000 options. Stokes waves were applied as distributed loads to the submerged members of the offshore structure using normal offshore analysis procedures.

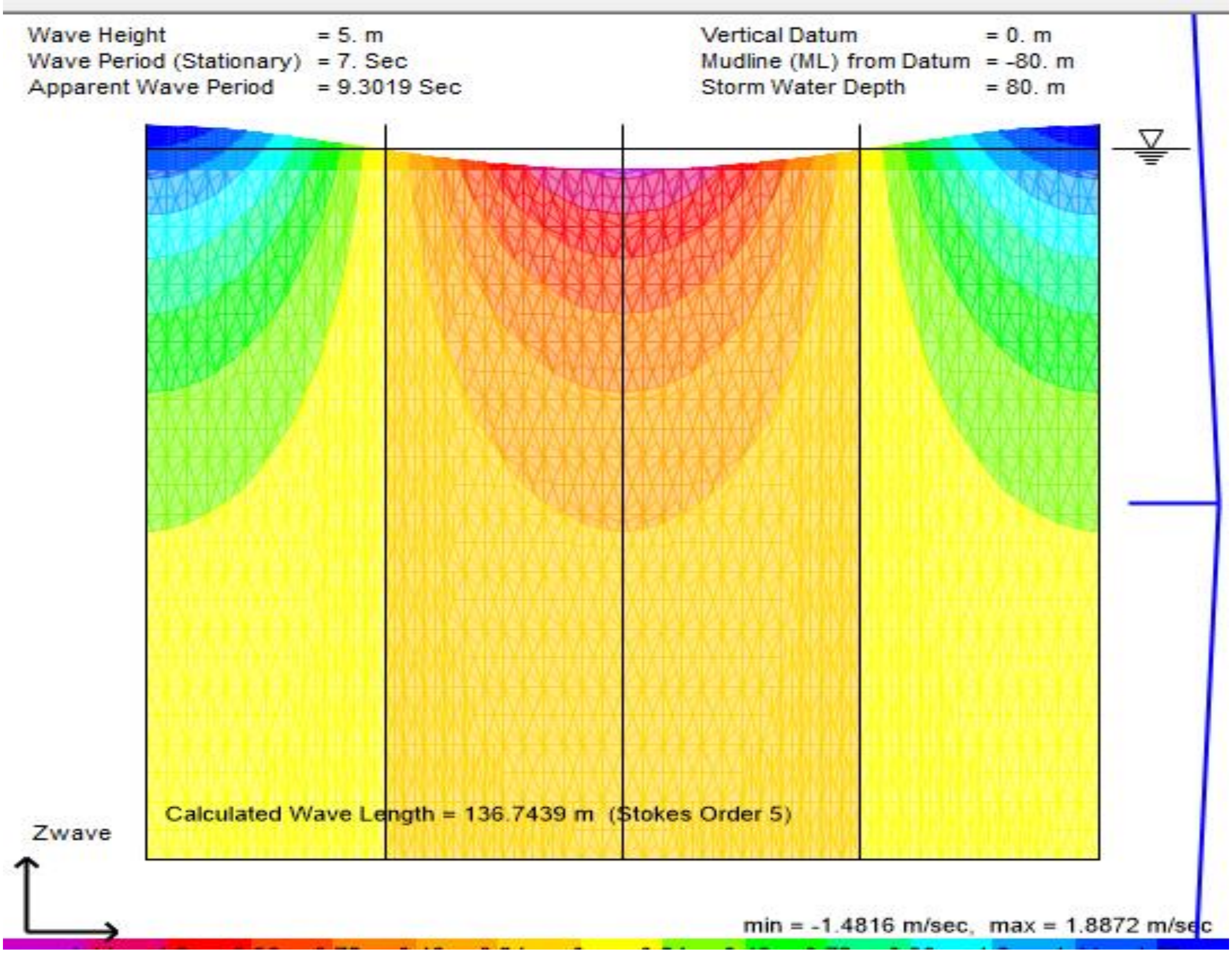


Figure 1: Wave Parameters:

3.2 Current Loads

- The wave induce an orbital motion in the water in which they pass, and these orbits are closed but involvement a slight drift forward to wind surface effects. The current is actually persuaded by wave. A current in the wave track tends to stretch the wavelength. (API Recommended practice 2A-LRFD, 1993)

3.3 Wind Loads

- When a structure is put in the path of the travelling air so that wind is stopped or is deflects from its way, then all or some part of the kinetic energy is altered into the potential energy pressure. Wind forces on any structure accordingly result from the differential pressure produced by the obstruction to the free flow of the wind. These forces are functions of the wind velocity, alignment, area, and shape of the structural elements. Wind forces on a structure are a dynamic cause, but for analysis purposes, it is sufficient to study these forces as an equivalent static pressure.

IV. PLATFORM STRUCTURAL MODEL:

- The analysis platform is a fixed Jacket-Type platform is considered in region of Gulf of Kutch shown in **Fig. 2**, The offshore platform structure is a four legs jacket platform, contains of a steel tubular-space frame. There are diagonal

brace elements in both vertical and horizontal planes in the units to increase the structural stiffness. The Platform is originally designed as a 4-pile platform installed in 262.46 feet
(262.46' = 80 *m*) water depth.

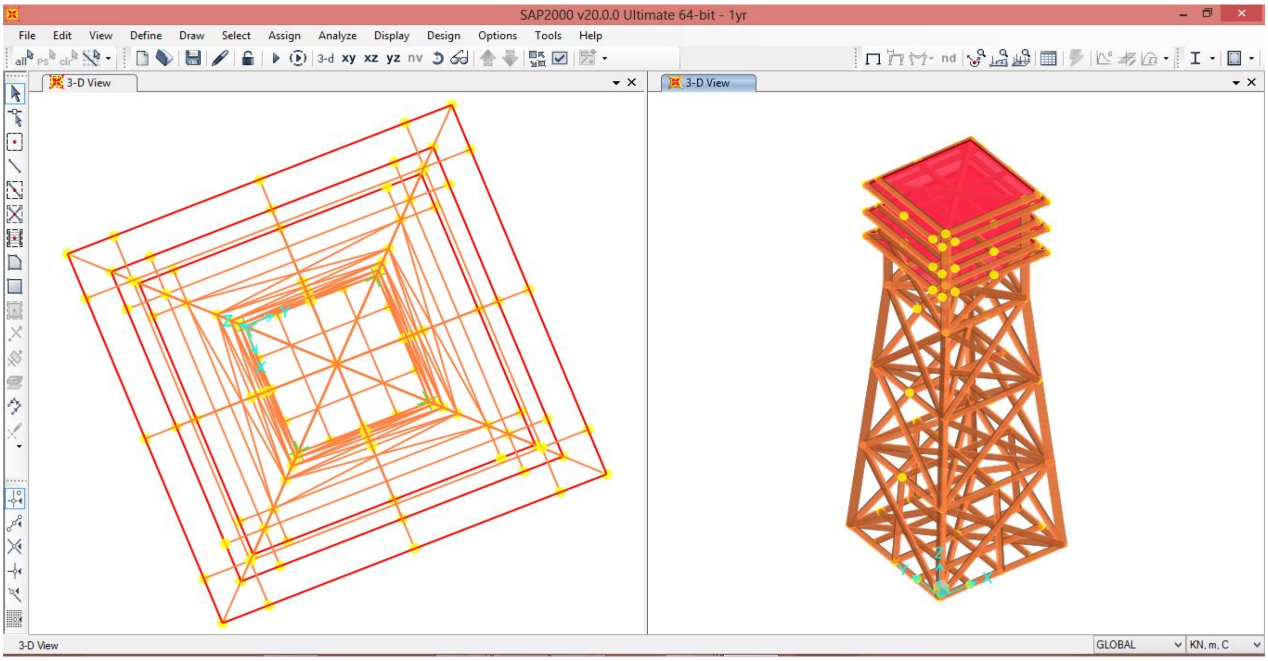


Figure 2: Sap Model:

- **The geometry of offshore platform structure is divided in 3 parts:**

1. Steel Jacket with bracing
2. Steel Plane area (DECK)
3. Steel Pile.

1. Steel Jacket Properties:

Table 1: Steel Jacket Properties:

Member	Diameter	Thickness
Horizontal and diagonal bracing	1.52m	0.01m
Vertical bracing	1.60m	0.02m
Legs	2.2m	0.08m

2. Deck Properties:

Table 2: Deck Properties:

Structure	Dimensions	Elevation (z) above MSL
Main deck	22x22m	+21m
Heli-Deck	22x22m	+13m
Cellar deck	22x22m	+6m

- The deck is always above the wave height minimum 4m plus, deck is assigned with live load of 5kn/m2 on each deck.

3. Pile dimensions:

- The dimensions of pile are:
- **Diameter** D = 2.1m, **Thickness** T = .07m and **Length**: L= 15m
- Piles are bettered at 1 in 12 in both side broad and framing.

V. ANALYSIS PROCEDURES

- A finite element analysis is carried out in SAP2000 under different types of wave loading. The exterior of jack up is relatively stiff compared to legs, so the structural model focuses on the accurate explanation of load deformation characteristics of the legs. The legs are assigned by equivalent beam elements. Focus has been on the primary mechanisms of the global structural response. For the current analysis, dead loads contain all fixed items in the platform deck, jacket, and bridge structures. Live loads are defined as portable loads and will be temporary in nature. A uniformly distributed live load strength of $5kn/m^2$ is applied to Helideck area; $5kn/m^2$ is applied to production deck area and cellar deck area. The water depth in the location of installed platform is 80m

- About to the information of waves height with the returning period of one year for zone, a fifth order stokes wave theory with the height of 5m and the period of 7 sec used. A 100-years return wave with the height of 6.2m and the period of 8.3 sec was selected for the type of analysis that is usually used for safety checks.
- The design force of most platforms is subject by waves. A wave height of 1 or 100 years return period is the usually used design criterion, which was stretched by employing the combination of the 100-year wave with the 100-year wind. American Petroleum Institute (API RP 2A) mentions the following formula to calculate wind force on offshore structures, the 100 year return period constant wind at 30 feet above LAT (lowest astronomical tide) shall be 32 mph (mile per hour), the wind may act in multi direction.

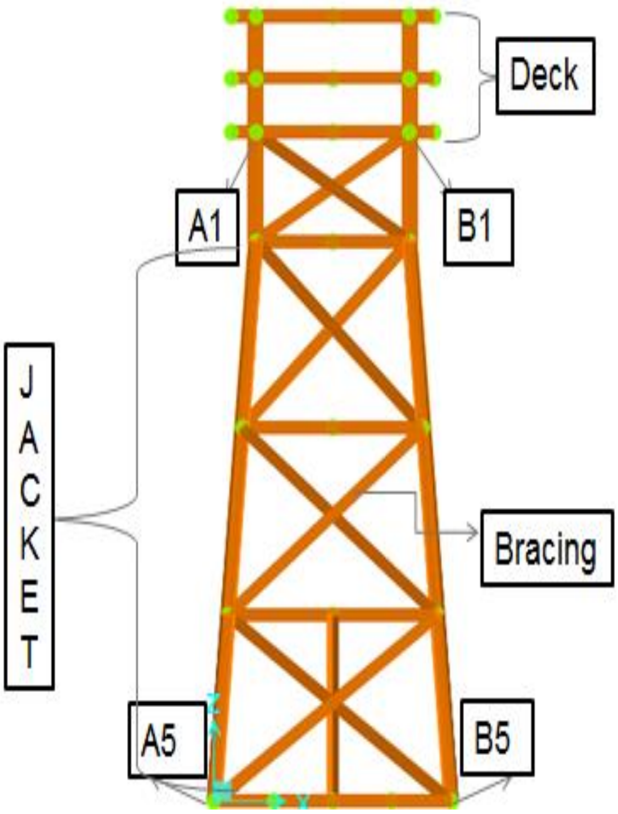


Fig. 3 Finite element model

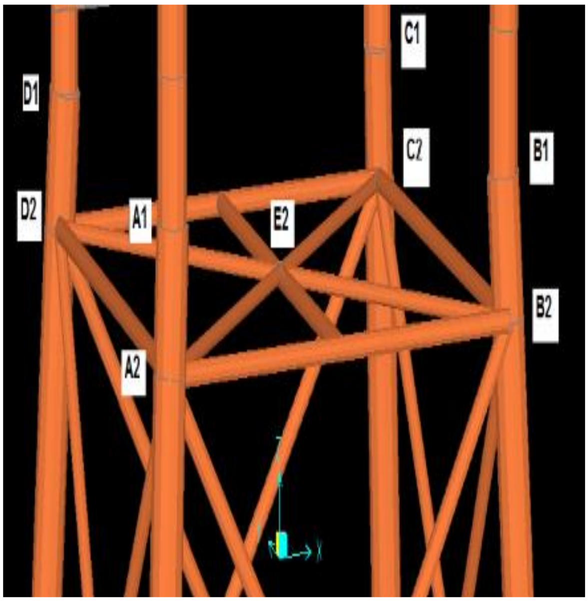


Fig.4: Jacket - deck connection nodes at level (+10 ft)

VI. NUMERICAL RESULTS AND DISCUSSIONS

- The natural frequencies and vibration mode shapes are calculated by eigenvalue analysis. The values of natural frequencies are shown in **Table 3** for up to the six mode of vibration. The stress circulation within such a large structure is a leading factor in the design procedure of an offshore structure. To provide a more precise and effective design, a finite element model in SAP2000 is employed herein to determine the internal forces and displacements in an offshore leg under combined structural and wave loadings. The vertical structural load is basically a static load, while the lateral wave loading varies in time domain and is directly exaggerated by the incident wave angle.
- The module in this study is classical steel platform is considered in Gulf of Kutch, **Fig. 2**. A 3D model had been generated for the platform using SAP 2000 computer software package. Secondary members that are not estimated to
- contribute much to the structure strength are not involved in the model imitation (i.e. ladders, grating, etc.) but their loads were reflected to the model. The right hand Cartesian system is used with the Z-axis vertically upwards and the origin is located at the bottom of grid lines in **Figs. 3** and **4. Table 4** lists the properties of the studied. Different load and load combinations are applied to platform as shown in **Table 5**.
- The straining actions and deflection results are examined for jacket only because the key important part in platform, which is supported under sea, water and exposed to all environmental load.
- A parametric study of changing certain parameters of the wave, current loads to study their properties on the internal forces circulation and platform displacement under various combinations of structural and wave loadings is investigated. The *Cd* and *Cm* values are taken as per API (2000) to be 0.65 and 1.6, respectively. The same values of wave constraints are applied in three directions ±0o, ±45o and ±90, with the associated current parameters requiring the same direction of wave application, Table 5.

Table 3 Natural period and vibration mode

Modes	Mode1	Mode2	Mode3	Mode4	Mode5	Mode6	Mode7
Natural Period (sec)	0.838528	0.838528	0.466347	0.271777	0.234831	0.234831	0.212884

Table 4 wave loading parameter values

Wave return period	Water depth	H. maximum	Tp.
1-yr return	80m	5	7sec
100-yr return		6.2m	8.3sec

a. Displacement Response of the Structure

- To have a better understanding of the behaviour over -all height of the platform jacket, the analysis was conducted for a 80m water depth for the maximum wind and wave forces. Even though time series deflection of the platform were projected, only maximum deflection to each wave and wind forces are take out. The deflection responses along the platform jacket height to the wave loading parameter of 1 year and 100 year return period are shown in **Figs. 5 and 6**. It should be noted that the response taken are deflection in global X- direction; U1.
- The maximum platform deflection in the wave direction is 11mm and 18mm at jacket –deck level for 1 year and 100 year return period wave and wind loadings, correspondingly. The displacement responses achieve its peak values for the accident of the wave; current and wind directions, decrease as the current direction deviate from that from the wave incidence direction.

Table5: Load Combinations:

1	Dead Loads
2	Comb1 " Dead Load + Live load "
3	Comb1+ (Wind + wave) 1 year+ currents hitting 00.0 deg.
4	Comb1+ (Wind + wave) 1 year + currents hitting 45.0 deg.
5	Comb1+ (Wind + wave) 100 year + currents hitting 00.0 deg.
6	Comb1+ (Wind + wave) 100 year + currents hitting 45.0 deg.
7	Comb1 + Earthquake load

- Large inter-story drift of the jacket leg is not permissible for the jacket platform to satisfy the drilling and production requirements. Both the maximum deck acceleration and the maximum Deck to top of jacket displacement were significant response parameters affecting the behavior of equipment, vessels, and pipelines.

- From analysis results, it can be stated that the critical nodes for displacement responses are at jacket - deck connection and at jacket level (+6m).

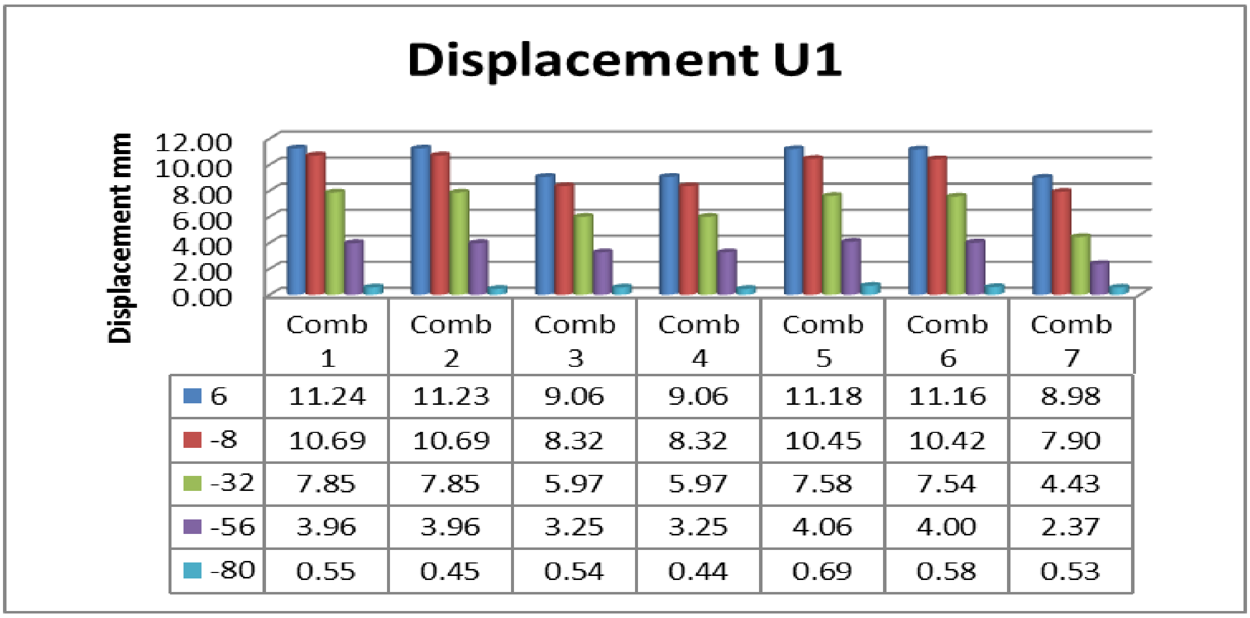


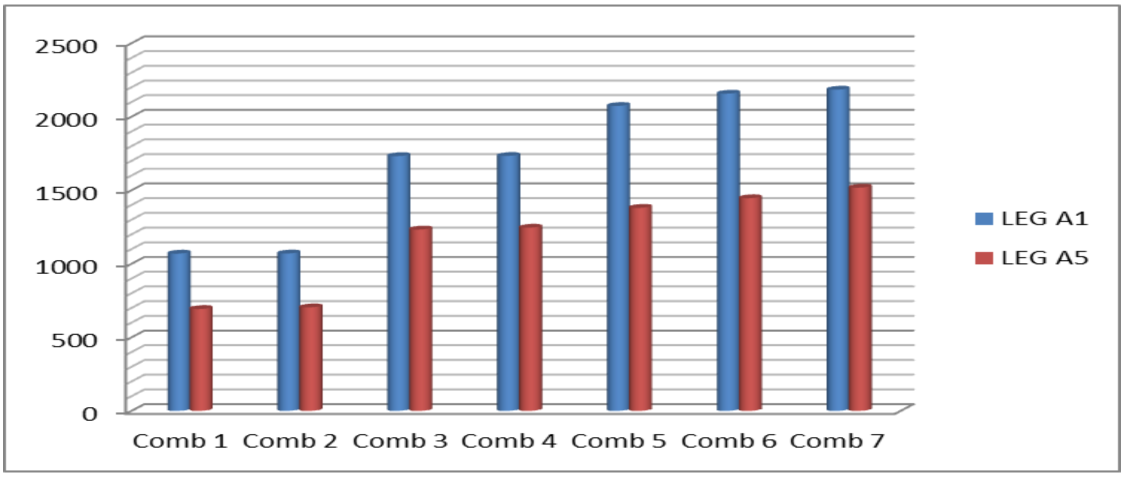
Fig. 5 Displacement with respect to jacket levels for 1-year operating conditions.

	Comb 1	Comb 2	Comb 3	Comb 4	Comb 5	Comb 6	Comb 7
6	18.1	18.1	14.2	14.2	17.3	17.3	14.1
-8	16.7	16.7	13.0	13.0	16.2	16.2	12.4
-32	12.3	12.3	9.3	9.3	11.8	11.7	7.6
-56	6.1	6.1	5.0	5.0	6.3	6.3	3.7
-80	0.7	0.6	0.7	0.5	1.0	0.8	0.7

Fig. 6 Displacement with respect to jacket levels for 100-year safety conditions.

b. Bending Moment Response:

- **In Figure7** it shows an evaluation of the maximum bending moments at critical nodal points. As the bending moment is generally focused at the connection points between the different structural systems, the biggest value can be expected to occur at the top of the structure. Bending moment at A1 is maximum due to jacket deck connection and wave impact at that point.



VII. CONCLUSIONS

- The offshore structural analysis is used to find platform displacement response under changing external loadings. The deflection of the platform is considered for individual and combined wind and wave forces. Offshore platform jacket displacement, bending moments, and natural time period are assessed.
- An evaluation of the maximum displacement at nodal points for various current incidence angles is presented. The results designate a significant effect of the current incidence direction. The displacement response, U1 increases nonlinearly with the height of the platform jacket.
- Large inter-story drift of the jacket leg is not permissible for the jacket platform to satisfy the drilling and production requirements. Both the maximum deck acceleration and the maximum Deck to top of jacket displacement were significant response constraints affecting the performance of equipment, vessels, and pipelines. Nonlinear analysis is required for a realistic determination of the behaviour of structures and to obtain a rational structural design.

REFERENCES:

1) API RP 2A – WSD, "Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress Design, 21TH Edition, 2000".

2) ***Shehata e. Abdel raheem1, elsayed m. A. Abdel aal 2, aly g. A. Abdel shafy3 and fayez k. Abdel seed 3"*** **nonlinear analysis of offshore structures under wave loadings"** *journal of engineering sciences, assiut university, vol. 40, no. 3, pp.673- 687, may 2012.*

3) Duy-duan nguyen1, chana sinsabvarodom2 "nonlinear behavior of a typical oil and gas fixed-jacket offshore platform with different bracing systems subjected to seismic loading" the 20th national convention on civil engineering july2016

4) Selection of environmental parameters for offshore jacket platform design in Malaysia B. Idrus1, n. S. Potty1, m. F. A. Hamid2, z. Nizamani1, n. J. Cossa1

5) CIRIA (1977), "Dynamics of Fixed Marine Structures", methods of calculating the dynamic response of fixed structures subjected to wave and current action, Underwater Engineering Group report, UR8, U.K.

6) ***Neeta chavhan1*, prof.p.s.bhalge2, n.s.vaidkar3 "*** **analysis of offshore structure having different bracing pattern using sap2000"** journal of structural engineering, its applications and analysis volume 2 issue 2

7) Offshore engineering: an overview of types and loadings on structures A s kharade1* and s v kapadiya2

8) Bipasha das1, dr. Prashanth janardhan2 "**model development and load analysis of offshore jacket structure using sap2000" international journal for research in applied science & engineering technology (ijraset)** *volume 5 issue iv, april 2017*

9) Martin Bjerre Nielsen*,A, Jacob Fisker Jensena, Christopher Harpera, Lennart Skovbjerg Knudsenb, Ronnie Refstrup Pedersenb " **State-Of-The-Art Framework For Structural Design Of Offshore Wind Jacket Foundations "** The 14th Nordic Steel Construction Conference, September 18–20, 2019, Copenhagen, Denmark.

10) Sensitivity analysis of jacket-type offshore platforms under extreme waves Mona hezarjaribi a, m.r. Bahaari a, vahid bagheri b,⁎, hossein ebrahimian b

VIII. BIOGRAPHIES

	❖ **Yash M. Mehta** ❖ **Post Graduate Student at Civil Engineering Department** ❖ **Darshan Institute of Engineering and Technology, Rajkot, -** ❖ **363650 & Gujrat** **Technological University, Gujrat, India.**
	❖ **Prof. Mohit Vachhani.** ❖ **Assistant Professor, Civil Engineering Department** ❖ **Darshan Institute of Engineering and Technology, Rajkot, -** ❖ **363650 Gujrat** **Technological University, Gujrat, India.**

