

# Non-Linear Analysis of Off-Shore Structures

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**Abstract:** -- Performance-based design requires consideration of environmental conditions at recurrence periods well beyond those of current practice when structural damage is expected and connections are likely to behave in-elastically. The performance-based design considers both the occurrence and consequence of structural damage caused by extreme conditions and could improve the performance of offshore structures. This paper assesses the post-elastic behavior and ductility of common connection details for offshore jacket structures based on a survey of experiments and empirical joint models and on nonlinear finite element analyses. The assessment includes common connection details under tension, compression, and bending. The prediction of the inelastic load-deformation response, based on MSL and API, two empirical joint models in the structural analysis program, USFOS, is compared to experiments. As an illustrative example to demonstrate the performance assessment capabilities of this approach, a pushover analysis is carried out for an offshore jacket structure supporting a wind turbine and subjected to extreme wind and wave loading.

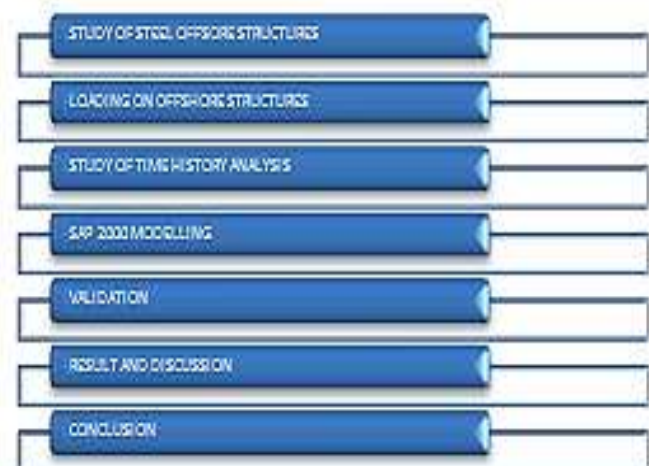
**Index terms:** Sap 2000, nonlinear analysis, Off-shore structure

## I. INTRODUCTION

The total number of offshore platform in various bays, gulf and oceans of the world is increasing year by year, most of which are of fixed jacket-type platforms located in 30 m to 200 m depth for oil and gas exploration purposes. Fixed offshore platforms are subjected to different environmental loads during their lifetime. These loads are imposed on platforms through natural phenomena such as wind, current, wave, earthquake, snow and earth movement. Among various types of environmental loading, wave forces loading is dominated loads. The results of these investigations highlight the importance of accurately simulating nonlinear effects in fixed offshore structures from the point of view of safe design and operation of such systems. It is necessary to design an offshore structure such that it can respond to moderate environmental loads without damage and is capable of resisting severe environmental loads without seriously endangering the occupants. The standard design of the structure is carried out using the allowable stress method. However, it is important to clarify the effects on nonlinear responses for an offshore structure under the severe wave conditions. Offshore structures may be analyzed using static or dynamic analysis methods. Static analysis methods are sufficient for structures, which are rigid enough to neglect the dynamic forces associated with the motion under the time-dependent environmental

loadings. On the other hand, structures which are flexible due to their particular form and which are to be used in deep sea must be checked for dynamic loads.

## II. METHODOLOGY



**2.1 Ground Motions and Linear Time History Analysis:** Dynamic analysis using the time history analysis calculates the building responses at discrete time steps using discretized record of synthetic time history as base motion. If three or more time history analyses are performed, only the maximum responses of the parameter of interest are selected.

### 2.2 Response Spectrum Method:

Response spectrum analysis is a procedure for computing the statistical maximum response of a structure to a base excitation. Each of the vibration modes that are considered may be assumed to respond independently as a single-degree-of-freedom system. Spectra which determine the base acceleration applied to each mode according to its period (the number of seconds required for a cycle of vibration).

## II. PROBLEM STATEMENT

The studied platform is a fixed Jacket-Type platform currently installed in the Suez gulf, Red sea, 1988 shown in Figure 3, The offshore structure is a four legs jacket platform, consists of a steel tubular-space frame. There are diagonal brace members in both vertical and horizontal planes in the units to enhance the structural stiffness. The Platform was originally designed as a 4-pile platform installed in 110 feet (110' = 33.5 m) water depth.

- The Top side structure consists of Helideck 50'x50' at Elevation, EL. (+54') & Production deck 50'x50' at EL. (+26'); Top of jacket at EL (+12.5').
- The Jacket consists of 4 legs with 33 inch Outer Diameter (33" O.D.) & 1 inch Wall Thickness (1" W.T.) between EL. (+10') and EL. (-23') and (33" O.D. x 0.5" W.T.) between EL. (-23') and EL. (-110').
- In the splash zone area that is assumed to extend from EL. (-6') to EL. (+6') LAT. (Lowest Astronomical Tide).
- The jacket legs are horizontally braced with tubular members (8.625" O.D. x 0.322" W.T.) at elevations (+10'); (10.75" O.D. x 0.365" W.T.) at elevations (-23'); (12.75" O.D. x 0.375" W.T.) at elevations (-62') and (14" O.D. X 0.375" W.T.) at elevations (-110').
- In the vertical direction, the jacket is X-braced with tubular members (12.75" O.D. x 0.844" W.T.) from EL. (+10') to EL. (-23') and (12.75" O.D. x 0.375" W.T.) from EL. (-23') to EL. (-110'). The platform is supported by 4 piles (30" O.D. x 1.25" W.T.)

### 3.1 Description of loading:

Density of various materials considered for design,

Concrete – 25kN/m<sup>3</sup>

Insulation – 1kN/m<sup>3</sup>

Structural steel – 78.5kN/m<sup>3</sup>

Live load – 5kN/m<sup>3</sup>

Wind load:

The following wind parameters are followed in accessing the wind loads on the structure

Basic wind speed – 55m/s

Terrain category -2

Class of structure – c

Risk coefficient k1 – 1

Topography factor k3– 1

K2 factor taken from Draft Code CED 38(7892):2013 (third revision of IS 4998(part 1):1992)

Earthquake force data:

Earthquake load for the chimney has been calculated as per IS 1893(par 4): 2005

Zone factor – 0.16

Seismic zone – III

Importance factor (I) – 1.5

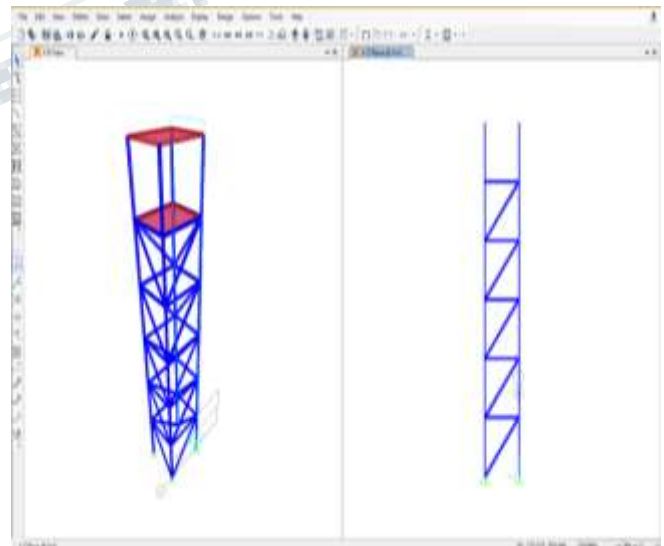
Reduction factor (R) – 3

Idealization of above problem statement is modeled in finite element analysis tool SAP 2000. Following models are prepared for comparative analysis of offshore steel structures

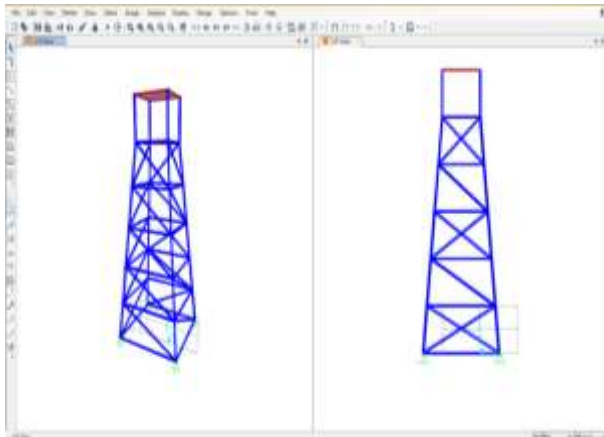
<b>MODEL NO. 1</b>	OFFSHORE PLATFORM WITH SINGLE BRACING 0 DEGREE
<b>MODEL NO. 2</b>	OFFSHORE PLATFORM WITH SINGLE BRACING 20 DEGREE
<b>MODEL NO. 3</b>	OFFSHORE PLATFORM WITH SINGLE BRACING 20 DEGREE

*Table no: 1*

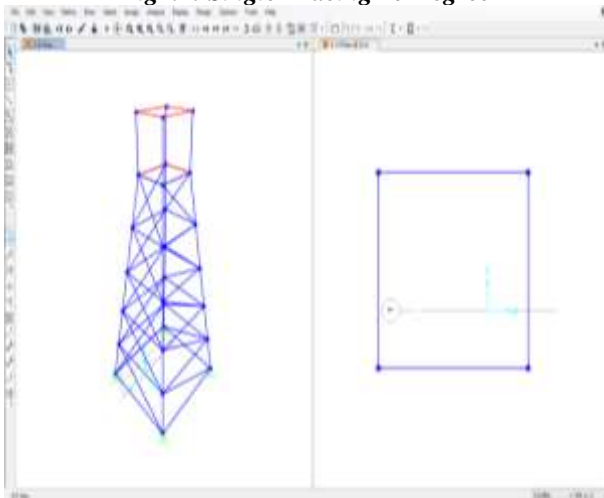
## IV. SAP MODEL SOFTWARE



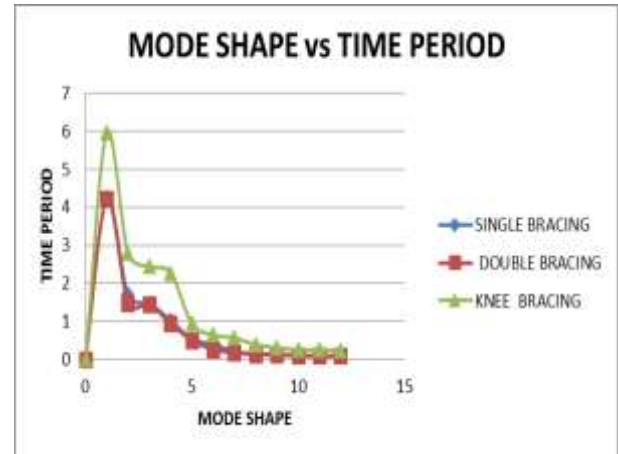
**Fig4.1: Single Bracing 0 Degree**



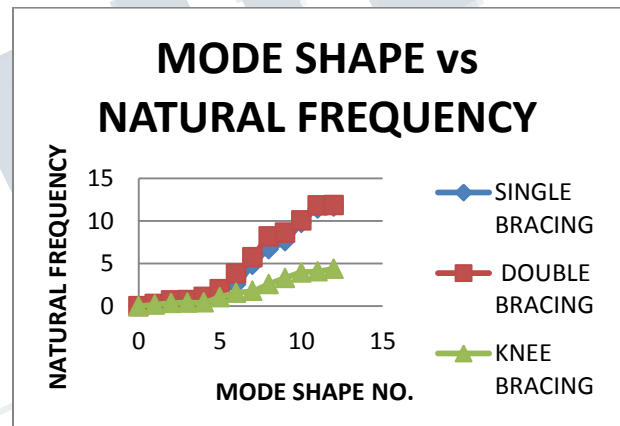
**Fig4.2: Single Bracing 20 Degree**



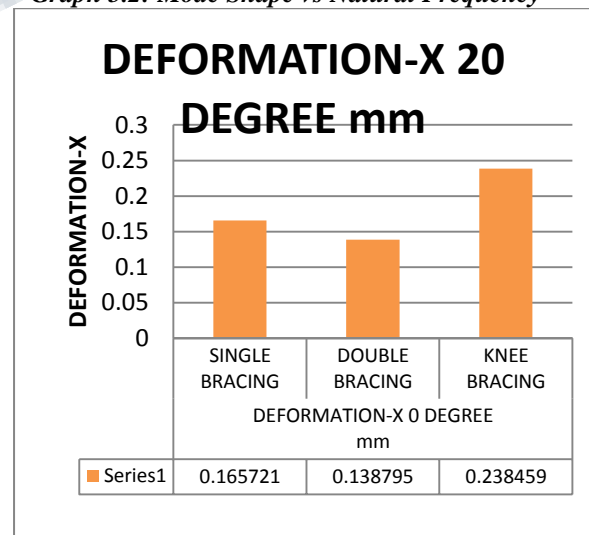
**Fig4.3: Single Bracing 20 Degree**



**Graph 5.1: Mode Shape vs Time Period**



**Graph 5.2: Mode Shape vs Natural Frequency**



**Graph 5.3: Deformation-x20 Degree**

**V. RESULT AND DISCUSSION**

The results are compared discuss in between;

- In graph 5.1 of Mode Shape v/s Time Period of knee bracing the highest time period is observed.
- In graph 5.2 of Mode Shape v/s Natural Frequency, highest natural frequency is observed for double bracing.
- From graph 5.3 for Deformation in x-direction 20 Degree, the highest deformation is observed for single bracing.
- From graph 5.4 for Deformation in y-direction 20 Degree, highest deformation is observed for single bracing.



**Graph 5.4: Deformation-y20 Degree**

## VI. CONCLUSION

In this paper various types of bracings are studied subjected to dynamic load and it is observed that deformation in y direction is 25% less in double bracing and 15% less in knee bracing. But deformation in X direction is observed more in knee bracings. In addition to this natural frequency is observed more in knee bracings. So from the study double bracing system should prefer to off-shore structure.

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