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EQUIVALENT STATIC ANALYSIS OF OFFSHORE STRUCTURE USING SAP 2000

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Abstract: The structural design requirements of an offshore platform subjected to wave induced forces and moments in steel jacket can play a major role in the design of the offshore structures. For an economic and reliable design, good estimation of wave loadings is essential. A linear static analysis of an offshore platform under wave loading is presented the structures discretised using the finite element method. The offshore steel structure, four legged jacket platform is considered. For this study structure consists of four legs, four piles and topside platform. The jacket is supported on pile. The wave and current forces acting on the structure are computed by using stoke 5th order equation, which decomposes the total force into an inertia component and a drag component. The structure is nearly 136 ft deep and three different configurations of models with lateral bracing are use for offshore structure. The equivalent static load analysis done in this study, using the SAP2000 V20 software helps to analyze and predict the performance of structure , when subjected to various load cases which will help in future to design it properly and accurately. The various loads such as wave load for using stokes 5th order law and also dead load, live load, wind load both have been used to calculate the Natural time period , Mode shape and Displacement due to wave loading.

Keywords: Offshore Structure, Nonlinear Analysis, Finite Element Analysis, Wave Structure Interaction, Wave Loading, Wind Loading.

1 INTRODUCTION

1.1 General

Offshore platform are used for oil exploration and production, navigation, ship loading and unloading, and to support bridges and causeways. Analysis and design of such structures are challenging as these structures are subjected to extreme environment conditions. Offshore platforms are generally constructed using steel and concrete. It consists of pile as a foundation, jacket as a supporting structure and a top side structure to accommodate the equipment. Offshore structures are among the tallest and heaviest structure on earth. Depending upon different types of materials used and the height of sub structure there are classified into three categories i.e. Gravity based, Jacket platform and Tension Leg Platform. In gravity based structure, a concrete caisson is bought to site and placed on sea bed then after it is filled by sand or gravel (Sadeghi & Sadeghi, 2007) .This structure is most efficient for shallow depth up to 50-60m, as depth increases the construction of this kind of structure become uneconomical because of huge weight. For deeper construction i.e. up to 100-140m Jacket Platforms are most cost efficient. This Jacket Platform is made up of Legs and bracing system. If the site is deeper generally greater than 500m, Tension Leg Platform can be used. In Tension Leg Platform the pontoon kind of structure is supported by cables, these cables are always remains in tension that's why it is called Tension Leg Platform. Offshore structure is subjected to extreme environment condition due to wind and wave loadings. Analysis and design of these kinds of structure are challenging. 25 to 30 percent of total project cost is involved in the construction (Martens, 2014).Hence little bit saving in construction will led to more economical design. Hence optimization plays significant role in design.

Fig 1.1: Gas explosion on an offshore platform

1.2 Load Considerations

The following loads and any dynamic effects resulting from them should be considered in the development of the design loading conditions:

1. Dead Loads
2. Live Loads
3. Environmental Loads
4. Removal and Reinstallation Loads
5. Dynamic Loads

Design Methods

Design of offshore structures includes two methods namely:

1. Working Stress Design Method (WSD)
2. Limit State Method or Load and Resistance Factor Design (LRFD)

3. METHODOLOGY

Environmental Loads Environmental loads are loads imposed on the platform by natural phenomena including wind, current, wave, earthquake, snow, and ice and earth movement. Environmental loads also include the variation in hydrostatic pressure and buoyancy on members caused by changes in the water level due to waves and tides. Environmental loads should be anticipated from any direction unless knowledge of specific conditions makes a different assumption more reasonable

2.1 Waves

(API WSD 2000 Cl. no 3.6.4) The wave loads on a platform are dynamic in nature. For most design water depths presently encountered, these loads may be adequately represented by their static equivalents. For deeper waters or where platforms tend to be more flexible, the static analysis may not adequately describe the true dynamic loads induced in the platform. Correct analysis of such platforms requires a load analysis involving the dynamic action of the structure.

2.2 Wave kinematics factor

The two-dimensional regular wave kinematics from Stream Function or Stokes 5th wave theory do not account for wave directional spreading or irregularity in wave profile shape. These "real world" wave characteristics can be approximately modelled in deterministic wave analyses by multiplying the horizontal velocities and accelerations from the two-dimensional regular wave solution by a wave kinematics factor. Wave kinematics measurements support a factor in the range 0.85 to 0.95 for tropical storms and 0.95 to 1.00 for extra-tropical storms. Particular values within these ranges that should be used for calculating guide-line wave forces are specified for the Gulf of Mexico in 2.3.4d.1 and for other U.S. waters in 2.3.4f.1. The Commentary provides additional guidance for calculating the wave kinematics factor for particular sea states whose directional spreading characteristics are known from measurements or hind casts

2.3 Current blockage factor

The current speed in the vicinity of the platform is reduced from the specified "free stream" value by blockage. In other words, the presence of the structure causes the incident flow to diverge; some of the incident flow goes around the structure rather than through it, and the current speed within the structure is reduced. Since global platform loads are determined by summing local loads from Morison's equation, the appropriate local current speed should be used. Approximate current blockage factors for typical Gulf of Mexico jacket-type structures are as follows:

2.4 Marine growth

All structural members, conductors, risers, and appurtenances should be increased in cross-sectional area to account for marine growth thickness. Also, elements with circular cross-sections should be classified as either "smooth" or "rough" depending on the Amount of marine growth expected to have accumulated on them at the time of the loading event. Specific marine growth profiles are provided for U.S. waters

2.5 Drag and mass coefficients

For typical design situations, global platform wave forces can be calculated using the following values for unshielded circular cylinders:

Smooth Cd = 0.65, Cm = 1.6
Rough Cd = 1.05, Cm = 1.2

These values are appropriate for the case of a steady current with negligible waves or the case of large waves with

Umo Tapp/D > 30. Here, U_{mo} is the maximum horizontal particle velocity at storm mean water level under the wave crest

From the two-dimensional wave kinematics theory, T_{app} is the apparent wave period, and D is platform leg diameter at storm mean water level.

For wave-dominant cases with Umo Tapp/D < 30, guidance on how C_d and Cm for nearly vertical members are modified by "wake encounter" is provided in the Commentary. Such situations may arise with large-diameter caissons in extreme seas or ordinary platform members in lower sea states considered in fatigue analyses.
For members that are not circular cylinders, appropriate coefficients can be found in Det norske Veritas' "Rules for the Design, Construction, and Inspection of Offshore Structures.

2.6 Design Wind Loading

Use code for wind loading API4F 2013
Wind Velocity = 93 ft. /sec
SS Multiplier = 1
Shielding Coefficient = 0.85
Wind Direction Angle = 0
4.5.1 Wind speed and force relationship
The wind drag force on an object should be calculated equation in 4.1
F = (ρ 2) × u2A Cs 4.1
Where,
F = wind force,
ρ = mass density of air, ($slugs/ft$3, 0.0023668 $slugs/ft$3 for standard temperature and pressure),
u = wind speed (ft/sec)
Cs = shape coefficient,
A = area of object (ft2)

3.7 Structure Details

Steel material
AISC code use for selection of steel section Grade of steel section is A36

2.8 Section parameter

1. The top side structure consists of helideck 50'x50' at elevation, EL (+110 ft.) & Production deck 50'x50' at EL. (+26'); top

of jacket at EL (+12.5'). And also I section is used for as a girder (ISMB 300).

2. The jacket consists of 4 legs with (33”) outer diameter & (1”) wall thickness and EL. (-110’).
3. In the splash zone area that is assumed to extend from EL. (-6') to EL. (+6') lowest astronomical tide.
4. The jacket legs are horizontally braced with tubular members 8.625" outer diameter and 0.322" thickness of section at elevations (-110’).
5. In the vertical direction, the jacket is X-braced with tubular members (12.75" outer diameter and 0.844’’ thickness of section from EL. (-23’) to EL. (-110’). The platform is supported by 4 piles, 30" outer diameter and 1.25" thickness of section.

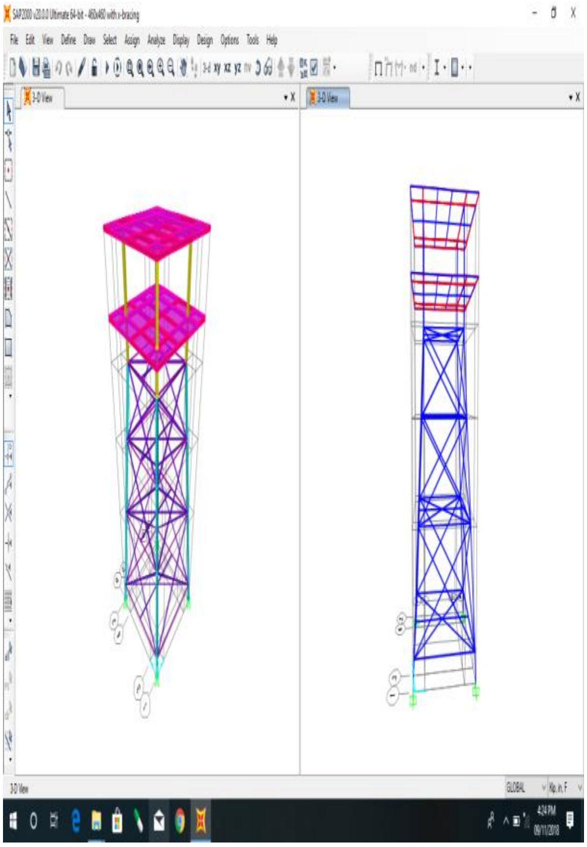
2.9 Design wave loading

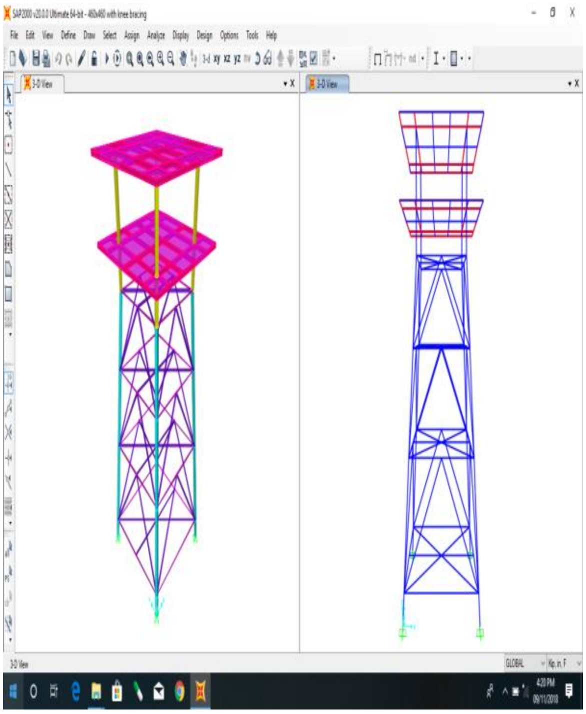
Use code for wave loading API WSD 2000
Mud line from datum = 110 ft.
High tide from datum = 36 ft.
Sea water density = 0.064
Wave height = 35.2 ft.
Wave period = 8 sec
Apparent wave period = 8 sec
Strom water depth = 132 ft.
Idealization of above problem statement is modeled in finite element analysis tool SAP 2000 v20. Following models are prepared for comparative analysis of offshore steel structure.

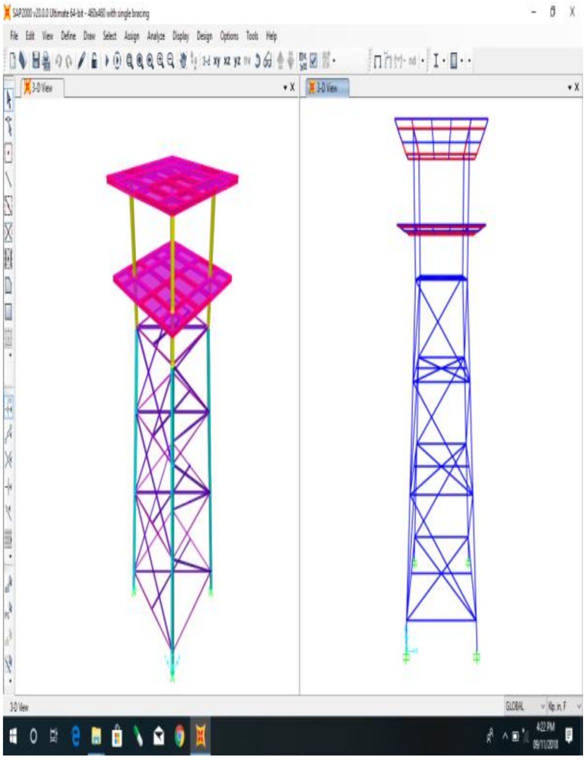
3. RESULTS AND CONCLUSION

Offshore platform with 40 degree inclined leg model

1. Offshore platform with double bracing 40 degree inclined leg
2. Offshore platform with knee bracing 40 degree inclined leg
3. Offshore platform with single bracing 40 degree inclined leg



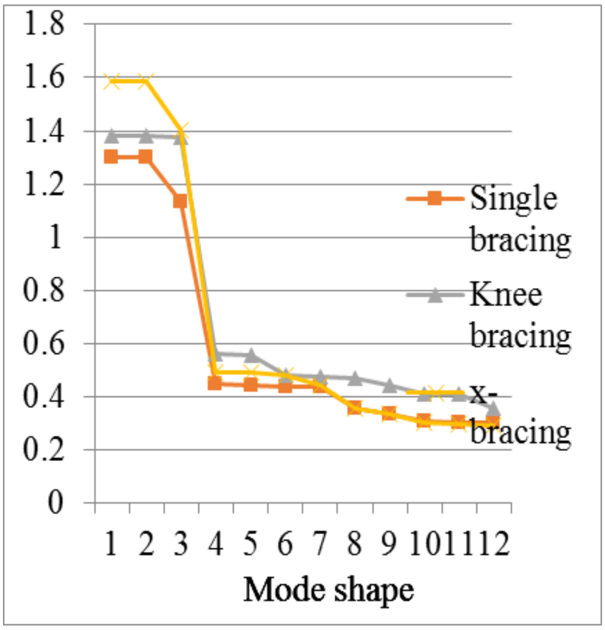




The results of the study are presented and discussed with reference to the objective and scope of the study. The results are mainly categorized in two main parts various angle and different type of bracing. The angle requirement includes modal mass participation and displacement. The majority of the world's platforms have been designed according to the different editions of recommended practice by "The American Petroleum Institute", which until 1993 has been in working stress design format. American Petroleum Institute LRFD, 1993 provisions provide characterization of environmental load and design requirement for fixed offshore platform for use in design. The consideration of environmental loads are consist, wind, and wave.

Modal time periods results 40 degree inclined leg model

Modal Time Periods			
Mode	X-bracing (Sec)	Knee bracing (Sec)	Single bracing (Sec)
1	1.2977	1.38214	1.58742
2	1.29758	1.38192	1.58717
3	1.1322	1.37606	1.40057
4	0.44868	0.55926	0.49233
5	0.44076	0.55608	0.49218
6	0.43522	0.47895	0.48154
7	0.43506	0.4715	0.44084
8	0.35748	0.47128	0.35755
9	0.33155	0.44081	0.33171
10	0.30472	0.4075	0.30362
11	0.30357	0.4073	0.29766
12	0.30042	0.35754	0.2919



1.1 Graph: mode shape vs. time period

Offshore platform 40 degree leg angle model

Vibration mode of offshore structure

The offshore platform structure with 40 degree angle providing double bracing. This type of structure is directly in contact with sea bed so the lateral stability of this structure is very high. This type of structure is generally made up of steel. The top dimension of platform is (460"x460") and base dimension is (720"x720") of structure is same in 40 degree angle with double bracing.

Vibration mode of offshore structure double bracing with 40 degree inclined leg

Modal participating mass ratios					
Output Case	Step No.	Period	Sway-X	Sway-Y	Torsion
	Unit less	Sec	Unit less	Unit less	Unit less
Modal	1	1.2977	4.4E-07	0.8865	2.3E-07
Modal	2	1.29758	0.88631	4.4E-07	1.7E-06
Modal	3	1.1322	1.6E-06	2E-07	0.85965
Modal	4	0.44868	2.4E-07	1.2E-07	0.07427
Modal	5	0.44076	6.4E-07	9.2E-13	8.7E-12
Modal	6	0.43522	6.2E-09	0.06017	2.1E-07
Modal	7	0.43506	0.05974	6.2E-09	6E-07
Modal	8	0.35748	9E-08	3.5E-16	1.6E-12
Modal	9	0.33155	1.5E-07	9.3E-13	6.3E-14
Modal	10	0.30472	0.00103	5.4E-11	2.8E-10
Modal	11	0.30357	1.3E-06	2E-10	3.4E-13
Modal	12	0.30042	2.7E-12	0.00393	2.5E-09

Vibration mode of offshore structure knee bracing with 40 degree inclined leg

Modal participating mass ratios					
Output Case	Step No.	Period	Sway-X	Sway-Y	Torsion
	Unit less	Sec	Unit less	Unit less	Unit less
Modal	1	1.38214	0	0.917	0
Modal	2	1.38192	0.9135	0	0.0031
Modal	3	1.37606	0.0031	0	0.9036
Modal	4	0.55926	6.8E-20	0.0043	0
Modal	5	0.55608	2.2E-19	3E-14	0
Modal	6	0.47895	3.3E-07	0	0.0323
Modal	7	0.4715	0	0.0379	0
Modal	8	0.47128	0.04	0	5E-07
Modal	9	0.44081	5.1E-19	1.8E-15	1.2E-19
Modal	10	0.4075	1.7E-20	2.7E-05	0
Modal	11	0.4073	0	9.7E-12	0
Modal	12	0.35754	1.3E-07	1.1E-19	1.2E-13

Vibration mode of offshore structure single bracing with 40 degree inclined leg

Modal participating mass ratios					
Output Case	Step No.	Period	Sway-x	Sway-y	Torsion
	Unit less	Sec	Unit less	Unit less	Unit less
Modal	1	1.58742	0.0318	0.91	6.49E-08
Modal	2	1.58717	0.91	0.0317	3.7E-07
Modal	3	1.40057	1.1E-06	1.3E-08	0.9134
Modal	4	0.49233	0.0099	0.01	5.19E-07
Modal	5	0.49218	0.0101	0.0098	2.37E-06
Modal	6	0.48154	9.7E-07	3.3E-08	0.0295
Modal	7	0.44084	3.5E-09	1E-09	1.3E-05
Modal	8	0.35755	2.6E-07	1.2E-06	8.55E-09
Modal	9	0.33171	5.9E-08	3.3E-07	2.1E-06
Modal	10	0.30362	5.3E-08	1.1E-08	1.23E-05
Modal	11	0.29766	0.0011	2E-06	1.04E-05
Modal	12	0.2919	2.4E-07	0.00055	0.000346

4. CONCLUSIONS

1. offshore platform with double bracing and knee bracing with 40 degree model, shows natural time period of 1.29 sec and 1.38 sec respectively, which is nearly close spaced

value , while single bracing shows natural time period of 1.58 sec for same model ,hence double and knee bracing perform quite well as compare to single bracing for natural time period.

2. Offshore platform with single and knee bracing with 40 degree model shows, model mass participation of 94.18 and 91.70 percentage respectively which have above 90 percentage, value indicates good performance while double bracing gives 88.65 percentage which is also near to 90 percentage criteria, allow the save orientation but results of knee bracing and single bracing are closely spaced which performs better than double bracing.

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