REVIEW ON ANALYSIS OF OFFSHORE STRUCTURE

Ashwini Chalke [1] Supriya Nalawade [2] Navnath Khadake[3]

[1]PG Student, Civil Engineering Department, JSPM's ICOER Wagholi, Pune 412207, Maharashtra, India
[2]Assistant Professor, Civil Engineering Department, JSPM's ICOER Wagholi, Pune 412207, Maharashtra, India
[3]Professor and Head, Civil Engineering Department, JSPM's ICOER Wagholi, Pune 412207, Maharashtra, India

---

Abstract. *Analysis and design of offshore structures are challenging as these structures are subjected to extreme environment conditions. Steel offshore jacket platform is a type of offshore structure, which is fixed to the sea bed and is provided with a deck at its top that acts as platform used for all the activities involved in the production and supply process.. Thus, in the present paper an attempt has been done to review the types, design parameters and modeling and analysis process of offshore structure.*

Key Words: **Offshore Structure, API WSD 2000, SAP2000 V20, Wave Loading, Wind Loading.**

I. INTRODUCTION

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.. Offshore structures may be fixed to the seabed or may be floating. Floating structures may be moored to the seabed, dynamically positioned by thrusters or may be allowed to drift freely. The engineering of structures that are mainly used for the transportation of goods and people, or for construction, such as marine and commercial ships, multiservice vessels (MSVs) and heavy lift crane vessels (HLCVs) used to support field development operations as well as barges and tugs are not discussed in detail in this book. While the majority of offshore structures support the exploration and production of oil and gas, other major structures, e.g. for harnessing power from the sea, offshore bases, offshore airports are also coming into existence. The design of these structures uses the same principles as covered in this book. However they are not explicitly included herein. We focus primarily on the structures used for the production, storage and offloading of hydrocarbons and to a lesser extent on those used for exploration.

1.1 Historical Development

The offshore exploration of oil and gas dates back to the nineteenth century. The first offshore oil wells were drilled from extended piers into the waters of Pacific Ocean, offshore Summerland's, and California in the 1890s. However, the birth of the offshore is commonly considered as in 1947 when Kerr-McGee completed the first successful offshore well in the Gulf of Mexico in 15 ft of water off Louisiana Burleson, 1991. The drilling derrick and draw works were supported on a 38 ft by 71 ft wooden decked platform built on 16 to 24 inch. Pilings driven to a depth of 104 ft. Since the installation of this first platform in the Gulf of Mexico over 50 years ago, the offshore industry has seen many innovative structures, fixed and floating, placed in progressively deeper Waters and in more challenging and hostile environments. By 1975, the water depth extended to 475 ft within the next three years the water depth dramatically leapt two fold with the installation of COGNAC platform that was made up of three separate structures, one set on top of another, in 1025 ft. COGNAC held the world record for water depth for a fixed structure from 1978 until 1991. Five fixed structures were built in water depths greater than 1000 ft in the 1990s. The deepest one of these is the Shell Bullwinkle platform in 1353 ft installed in 1991.

1.2 Types of Offshore Structures

A. Fixed platforms

Fixed jacket platform is best suited for low water depth (around 1500 feet). This type of structure is directly in contact with sea bed so the lateral stability of this structure is very high (Sadeghi & Sadeghi, 2007). This type of structure is generally made up of steel or concrete. This structure consists of three or four legs on which top side platform is constructed. This structure becomes uneconomical when it is used in deep water.

B. Template (jacket) platforms

This kind of structure is made up of steel. It consists of jacket, deck and piles. This structure is also used for shallow water depth body; the difference is there in installation process. Here first jacket is placed; this jacket will work as template (guiding structure) for the pile. After installation of leg (jacket), piles are installed.

C. Compliant towers (tower platforms)

Compliant tower is narrow tower which is attached to foundation. It is also same as jacket platform but it can be used in deep water as it is more flexible compare to fixed platform. Compliant tower is generally strong enough to stand against hurricane.

D. Seastar platforms

Seastar platform consists of a floating rig, a lower hull and tension cables. A lower hull is filled with water, which increases the stability of the platform against wind and water movement. Apart from the semi submersible rig, it also consists of a tensioned system. Tension system includes tension leg which is consists of high strength steel cables. These cables resist tension stress. This structure is liable to affected by high wave pressure and wind pressure, but the water filled body will resist this effect and make structure more stable.

E. Floating production systems

Floating production systems are semi submersible drilling rigs. It consists of drilling equipments and petroleum production equipments placed on the system symenteniously. This system is anchored at bottom of the sea bed properly. This type of system is more effective in small oil storage places. That's how this system is work; this system can be used up to 1500 to 6000 ft. These systems are generally less stable against high wave loading condition.

F. Tension leg platforms

Tension leg platform works on same principle as discussed in seastar platform. The stability of such structure is less as compared to seastar platform as there is no water chamber to resist lateral movement of structure. Tension leg platform can be used up to 7000 feet.

G. Spar platforms

Spar platform is largest platform used to extract oil. This platform consists of huge cylinder supporting system with typical fixed rig platform. This big cylinder is not extended to sea bed level. It is tied with big steel cables which are attached to sea bed. Above this cylinder the extraction machines are installed and they will do its operation. Spar platform can be used up to 2000 to 10000 feet.

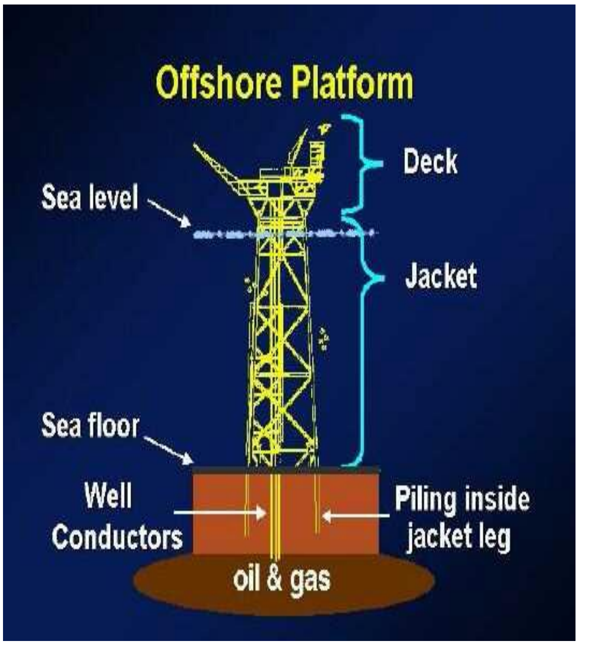

Fig 1.1: Fixed offshore platform

1.3 Design Criteria

Design criteria as used herein include all operational requirements and environmental data which could affect the detailed design of the platform

Operational considerations

1] Function

The function for which a platform is to be designed is usually categorized as drilling, producing, storage, materials handling, living quarters, or a combination of these. The platform configuration should be determined by a study of layouts of equipment to be located on the decks. Careful consideration should be given to the clearances and spacing of equipment before the final dimensions is decided upon.

2] Location

The location of the platform should be specific before the design is completed. Environmental conditions vary with geographic location; within a given geographic area, the foundation conditions will vary as will such parameters as design wave heights, periods, and tides

3] Orientation

The orientation of the platform refers to its position in the plan referenced to a fixed direction such as true north. Orientation is usually governed by the direction of prevailing seas, winds, currents, and operational requirements

4] Water depth

Information on water depth and tides is needed to select appropriate oceanographic design parameters. The water depth should be determined as accurately as possible so that elevations can be established for boat landings, fenders, decks, and corrosion protection.

5] Deck elevation

Large forces and overturning moments result when waves strike a platform's lower deck and equipment.

Unless the platform has been designed to resist these forces, the elevation of the deck should be sufficient to provide adequate clearance above the crest of the design wave. In addition, consideration should be given to providing an "air gap" to allow passage of waves larger than the design wave. Guidelines concerning the air gap are provided.

1.4 Environmental considerations

General meteorological and oceanographic considerations (API WSD 2000 Cl. No. 1.3.1)

Experienced specialists should be consulted when defining the pertinent meteorological and oceanographic conditions affecting a platform site. The following sections present a general summary of the information that could be required. Selection of information needed at a site should be made after consultation with both the platform designer and a meteorological oceanographic specialist. Measured and/or model generated data should be statistically analyzed to develop the descriptions of normal and extreme environmental conditions as follows:

Normal environmental conditions (conditions that are expected to occur frequently during the life of the structure) are important both during the construction and the service life of a platform.

Extreme conditions (conditions that occur quite rarely during the life of the structure) are important in formulating platform design loadings.

All data used should be carefully documented. The estimated reliability and the source of all data should be noted, and the methods employed in developing available data into the desired environmental values should be defined.

1.5 Loads consideration

Introduction of design loading conditions Design environmental load conditions (API WSD 2000 Cl. No 3.6.10)

Design environmental load conditions are those forces imposed on the platforms by the selected design event; whereas, operating environmental load conditions are those forces imposed on the structure by a lesser event which is not severe enough to restrict normal operations, as specified by the operator.

The platform should be designed for the appropriate loading conditions which will produce the most severe effects on the structure. The loading conditions should include environmental conditions combined with appropriate dead and live loads in the following manner.

1. Operating environmental conditions combined with dead loads and maximum live loads appropriate to normal operations of the platform.
2. Operating environmental conditions combined with dead loads and minimum live loads appropriate to the normal operations of the platform.
3. Design environmental conditions with dead loads and maximum live loads appropriate for combining with extreme conditions.
4. Design environmental conditions with dead loads and minimum live loads appropriate for combining with extreme conditions.
5. Environmental loads, with the exception of earthquake load, should be combined in a manner consistent with the probability of their simultaneous occurrence during the loading condition being considered. Earthquake load, where applicable, should be imposed on the platform as a separate environmental loading condition.
6. The operating environmental conditions should be representative of moderately severe conditions at the platform. They should not necessarily be limiting conditions which, if exceeded, require the cessation of platform operations. Typically, a 1-year to 5-year winter storm is used as an operating condition in the Gulf of Mexico.
7. Maximum live loads for drilling and production platforms should consider drilling, production and work over mode loadings, and any appropriate combinations of drilling or work over operations with production.
8. Variations in supply weights and the locations of movable equipment such as a drilling derrick should be considered to maximize design stress in the platform members.

1.6 LOADS

A. Dead loads

Weight of the platform structure in air, including where appropriate the weight of piles, grout and ballast.

Weight of equipment and appurtenant structures permanently mounted on the platform. Hydrostatic forces acting on the structure below the water-line including external pressure and buoyancy.

B. Live loads

Live loads are the loads imposed on the platform during its use and which may change either during a mode of operation or from one mode of operation to another. Live loads should include the following:

1. The weight of drilling and production equipment which can be added or removed from the platform.
2. The weight of living quarters, heliport and other life support equipment, life saving equipment, diving equipment and utilities equipment which can be added or removed from the platform.
3. The weight of consumable supplies and liquids in storage tanks. The forces exerted on the structure

from operations such as drilling, material handling, vessel mooring and helicopter loadings.

4. The forces exerted on the structure from deck crane usage. These forces are derived from consideration of the suspended load and its movement as well as dead load.

C. 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.

D. Wind load

Wind force is exerted upon that portion of structure that is above the water, as well as on any equipment, deck houses, derricks that are located on the platform. The wind speed may classify as;

1. Guest as average less that average one minute or longer in duration. Wind data should be adjusted to a standard elevation, such as 33 feet (10m) above mean water level, with a specified averaging time, such as one hour. Wind data may be adjusted to any specified averaging time or elevation using standard profile and guest factors.

2. Spectrum of wind speed fluctuations about the average should be specified in some instance. For example complaint structure like guyed towers and tension leg platforms in deep water may have natural sway period in the range of one minute, in which there in significant energy in the wind speed fluctuations

3.The frequency of occurrence of specified sustained wind speeds from various directions for each month or season.

4.The persistence of sustained wind speeds above specified thresholds for each month or season.

E. Gravitational Loads

Loads resulting from fabrication, load out, transportation and installation should be considered in design and are further defined

Removal and reinstallation loads

For platforms which are to be relocated to new sites, loads resulting from removal, on loading, transportation, upgrading and reinstallation should be considered in addition to the above construction loads

Dynamic loads

Dynamic loads are the loads imposed on the platform due to response to an excitation of a cyclic nature or due to reacting to impact. Excitation of a platform may be caused by Waves, wind, earthquake or machinery. Impact may be caused by a barge or boat berthing against the platform or by drilling operations

F. Wave Load (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.

Drag and mass coefficients

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

Smooth $C_d = 0.65$, $Cm = 1.6$
Rough $C_d = 1.05$, $Cm = 1.2$

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 $U_{mo} T_{app}/D < 30$, 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.

Conductor shielding factor

Depending upon the configuration of the structure and the number of well conductors, the wave forces on the conductors can be a significant portion of the total wave forces. If the conductors are closely spaced, the forces on them may be reduced due to hydrodynamic shielding. A wave force reduction factor, to be applied to the drag and inertia coefficients for the conductor array. This shielding factor is appropriate for either (a) steady current with negligible waves or (b) extreme waves, with Umo π. For less extreme waves with Umo Tapp/S < 5π, asTapp/S>5

In fatigue analyses, there may be less shielding. The Commentary provides some guidance on conductor shielding factors for fatigue analyses.

- **Shape coefficients**

In the absence of data indicating otherwise, the following shape coefficients (CS) are recommended for perpendicular wind approach angles with respect to each projected area.

Table 3.2 Shape Coefficient

Element	Shape factor
Beams	1.5
Sides of buildings	1.5
Cylindrical sections	0.5
Overall project area of platform	1.0

Shielding coefficients

Shielding coefficients may be used when, in the judgment of the designer, the second object lies close enough behind the first to warrant the use of the coefficient.

Wave kinematics factor

The extreme forces will be dominated by hurricanes and consequently a wave kinematics factor of 0.88 should be used

Growth

Use 1.5 inches from Mean Higher High Water (MHHW) to –150 ft. unless a smaller or larger value of thickness is appropriate from site specific studies. MHHW is one foot higher than MLLW.

Structural members can be considered hydro dynamically smooth if they are either above MHHW or deep enough (lower than about –150 ft.) where marine growth might be light enough to ignore the effect of roughness. However, caution should be used because it takes very little roughness to cause a Cd of 1.05. In the zone between MHHW and –150 ft. structural members should be considered to be hydro dynamically rough. Marine growth can extend to elevations below –150 ft. Site specific data may be used to establish smooth and rough zones more precisely.

II. DESIGN BASE

Design shall be such that no applicable strength or serviceability limit state shall be exceeded when the structure is subjected to all applicable load combinations. Design for strength shall be performed according to the provisions for load and resistance factor design to the provisions for allowable strength design.

Modelling and analysis

A. Offshore Jacket Platforms are normally designed using one of the following offshore design codes:

1. American Petroleum Institute 2000.
2. American Petroleum Institute 1993 or ISO 19902.
3. International Standards Organization 2007.
4. API RP2A-LRFD and ISO 19902 codes are limit state design based approaches for design of steel jacket platforms.
5. Working Stress Design by American Petroleum Institute uses a common factor of safety for material Static nonlinear analysis.
6. AISC code use for selection of steel section.
7. Design Wave Loading Use code for wave loading API WSD 2000

B. offshore structure is analyzed using SAP2000 V20 software to understand mode behavior of structure for safe design.

Equivalent static analysis is done. The analysis result are studied for the structural condition.

From analysis results modal mass participation, natural time period and displacement is determined.

III. CONCLUSION

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 analysis. The consideration of environmental loads are consist wind and wave. Offshore structure is analyzed using SAP2000 V20 software to understand mode behavior of structure for safe design.

REFERENCES

[1] Jain, K. (2000). "Dynamics of offshore structures under sea waves and earthquake forces", American Society of Mechanical Engineers, Offshore Technology, 1, pp. 191-198.
[2] Dr M C Deo. "Waves and Structures", Professor of civil engineering Indian institute of technology Bombay powai.
[3] American petroleum institute (API, 2007), APIRP2A-WSD: recommended practice for planning designing and construction fixed offshore structure- working stress design 21st addition.
[4] Haritos, N., (2007). "Introduction to the analysis and design of offshore structures", and overview. EJSE special issue: loading on structures the University of Melbourne, Australia.
[5] Patil, T. (2017). "Dynamic response of offshore structures. International journal of latest technology in engineering, management and applied science" (IJLTEMAS) Volume VI, Issue VIII. Pune University, (PP. 278-285), India.