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# Offshore Structure Design

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**ABSTRACT:** In civil engineering design of an offshore structure, it is unique because of the expertise technology involve and review of its structural design. The basic of offshore engineering on hydrodynamics and its movement, (the kinematics of the water particles) stems from various sources including gradually fluctuating streams from the impact of the tides and from nearby warm impacts and oscillatory movement from wave action that is typically wind-produced and two principle classes of offshore structures, fixed and floating. Each has various subcategories, which likewise records their uses benefits and bad marks. Subsea completions are additional structures that are set on the ocean bottom essentially to support equipment. The design methodology use in this study will follow the auxiliary setup, game plan, part sizes and its determination prerequisites can be touched base after few outline cycles. So as to accomplish an ideal outline suitable for the establishment technique proposed and fulfill the last working necessities, a configuration methodology suitable for the undertaking might be produced through various design stages in an offshore project like: Front End Engineering Design (FEED) or concept selection, basic design and detailed design and then calculation using water waves kinematics.

## I. INTRODUCTION

Offshore structures have developed rapidly over the last three to four decades. Much of this has been driven by the need to exploit deeper waters as a result of depletion of shallow water easy-to-reach fields.

This need for deepwater developments and, as well, a desire to continue to exploit depleting shallow water reserves has spawned new forms of offshore structures for production, such as production semi-submersibles, tension leg platforms in a variety of shapes and sizes, monohulls (ship-shaped units), spars, monotowers, and production jack-ups. Jackets have continued to be exploited in a variety of ways using different construction methods, all aimed at speeding up design, fabrication and installation.

Structures deployed offshore for oils and gas field development are reviewed and their functional needs defined. Fundamental design requirements for fixed steel structures, in particular, those for jackets and topsides, are spelt out together with the expectations of metocean and geotechnical surveys. Temporary and in-service design requirements, involving appropriate loads and combinations, are defined as well as the demands for structural analysis and materials and welding. Topsides and jacket design needs are presented in some detail and pile and other foundation assessments described. Basic corrosion protection requirements are reviewed.

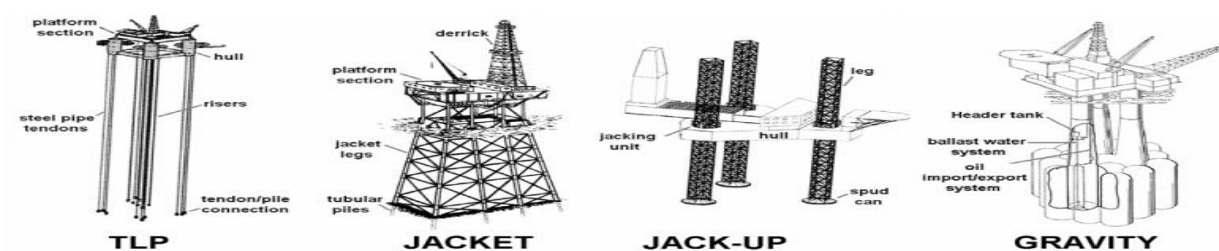


Figure 1: Sample offshore structure designs

Figure 1: Simple offshore structure design.

### Global design Standards for offshore structures in his introduction:

In standards, whether global standards or corporate standards, there are risks in changing the recipe in one clause without regard to the full suite of system requirements. Unfortunately, there has rarely been the opportunity to benchmark proposed changes in design standards against existing offshore structures before adoption of a new or updated standard. This can lead to unintended consequences. Introduction of ISO Standard: ISO 19900, which describes the basis for design within the ISO series of standards for offshore structures, see **Figure 2** ISO 19900 suite of offshore structures Standards (n.b. similar standards exist in API SC2).

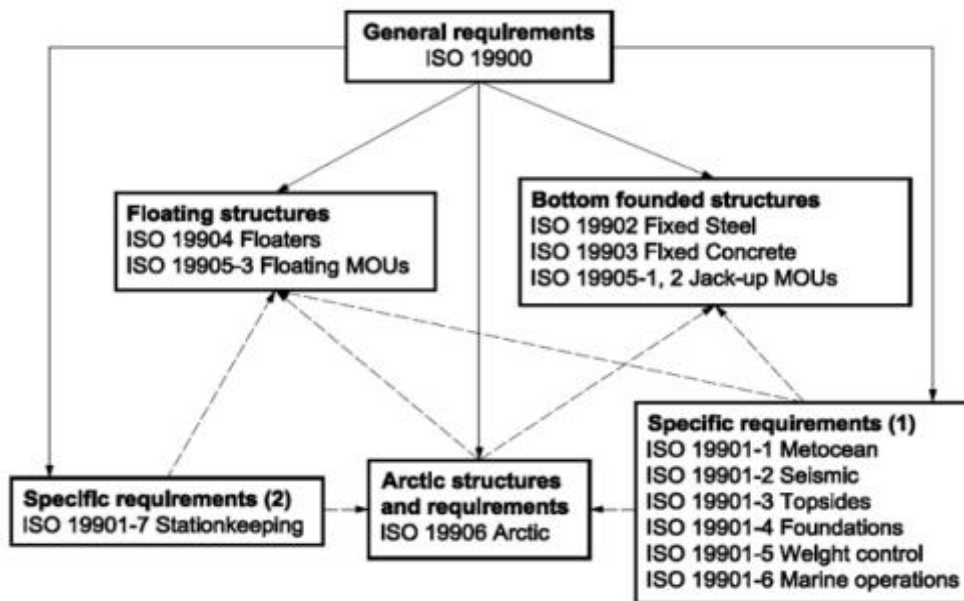


Figure 2: ISO 19900 suite of offshore structures Standards (n.b. similar standards exist in API SC2).

## II. OFFSHORE ENGINEERING BASICS:

A fundamental comprehension of various key branches of knowledge is crucial to an engineer liable to be included in the design of offshore structures, (Sarpkaya and Isaacson, 1981; Chakrabarti, 1987; Graff, 1981; DNS-OS-101, 2004).

These branches of knowledge, however not totally unrelated, would include:

- Hydrodynamics
- Structural progress
- Advanced structural analysis strategies
- Statistics of extremes amongst others.

In the accompanying segments, we give a diagram of a portion of the key components of this subject area, by method for a prologue to the general field of offshore engineering and the design of offshore structures.

### A. Hydrodynamics:

Hydrodynamics is concerned with the investigation of water in movement. In the connection of a offshore environment, the water of concern is the salty ocean. Its movement, (the kinematics of the water particles) stems from various sources including gradually fluctuating streams from the impact of the tides and from nearby warm impacts and oscillatory movement from wave action that is typically wind-produced.

The attributes of current and waves, themselves would be all that much site subordinate, with great estimations of primary enthusiasm to the LFRD approach utilized for offshore structure, related with the measurements of the climatic state of the site of interest, (Nigam and Narayanan, 1994). The topology of the sea base additionally has an impact on the water molecule kinematics as the water profundity changes from more profound to shallower conditions, (Senior member and Dalrymple, 1991). This impact is alluded to as the "shoaling impact", which accepts noteworthy significance to the field of coastal engineering.

For supposed deep water conditions (where the depth of water surpasses a large portion of the wavelength of the longest waves of interest), the impact of the sea base topology on the water molecule kinematics is viewed as negligible, evacuating a generally potential entanglement to the depiction of the hydrodynamics of offshore structures in such deep water environments.

Various standard wave speculations have been developed to portray the water molecule kinematics related with ocean waves of changing degrees of intricacy and levels of acceptance by the offshore engineering group, (Chakrabarti,



2005). These would incorporate direct or Airy wave hypothesis, Stokes second and other higher order hypotheses, and Stream Function and Cnoidal wave theories, amongst others, (Senior member and Dalrymple, 1991).

### III. TYPE OF OFFSHORE STRUCTURES

#### A. Overview:

There are two principle classes of offshore structures, fixed and floating. Each has various subcategories (Table 1) which likewise records their uses benefits and bad marks. Subsea completions are additional structures that are set on the ocean bottom essentially to support equipment. They are, be that as it may, not normally thought to be an offshore structure in for the most part acknowledged utilization of the term (Pavia et al., 1977).

Structure sub-categories	Uses	Advantages	Disadvantages
<b>Fixed steel structures</b>			
Jacket - see Figure 1	Drilling, production	Very common, well proven, dry trees	No storage, WD <sup>1)</sup> < 100 m
Tower - see Figure 2	Drilling, production	Very common, well proven, dry trees	No storage, WD 400 m
Jack-up - see Figure 3	Drilling, production (few)	Common, well proven for production, dry trees	No storage, water depth < 100 m, foundation stability issues
Compliant tower - see Figure 4	Drilling, production	Dry trees, large no of wells, large payload	No storage, current maxm 535 m up to 1000 m, large heavy structure in deep water
Gravity structure - see Figure 5	Drilling, production	Storage, dry trees	WD 300 m
Monotower - see Figure 6	Drilling, production	Unmanned, well proven, dry trees	No storage, limited number of wells, WD < 100 m
<b>Floating steel structures</b>			
Monohull - see Figure 7	Production	Early production, storage, well proven, large variation in payload, large deck space, deep water	WD current maxm 1850 m up to 3000 m, wet trees, sensitive to motions
Semi-submersible - see Figure 8	Drilling, production	Early production, low heave motion, well proven, dry trees	WD current maxm 2440 m up to 3000 m, no storage, wet trees
Tension leg platform	Drilling, production,	Dry trees, roll, pitch & heave negligible,	WD current maxm 1450 m up to 1500 m, ,

**Table 1:** Categories of fixed and floating offshore structures – their uses, advantages and disadvantages

#### B. Jacket:

A jacket is a welded tubular space frame with three or more near vertical tubular chord legs with a bracing system between the legs. The jacket provides support for the foundation piles, conductors, risers and other appurtenances. A jacket foundation includes legs pile which are inserted through the legs **Figure 3** and connected to the legs either at the top welded or by mechanical process or along the length of the legs by grouting.

Additional piles called skirt piles can be inserted through and connected to sleeves at the base of the structure. Legs and skirts piles jointly anchor the structure and transfer both vertically and horizontal actions to the seabed.

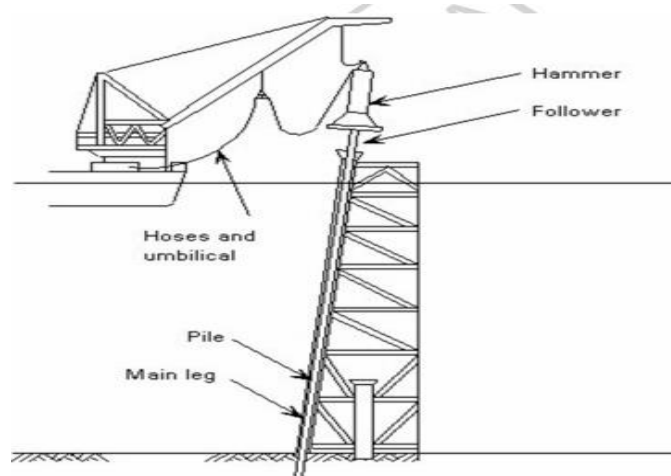


Figure 3: Jacket showing driving of pile through jacket

**C. Tower:**

The tower is also a welded tubular space frame with three or more near vertical tubular chord legs with a bracing system between the legs. The tower provides support topsides, conductors, risers and other appurtenances.

A tower foundation usually includes cluster piles, which are inserted through and connected to sleeves around the corner legs at the base of the structure Figure 4. Additional piles called skirt piles can be inserted through and connected to sleeves at the base and along the perimeter of the structure. As an alternative to piles, a tower can be supported by another foundation system that supports it at its base such as bucket foundation. Cluster and skirt piles or other foundation system.

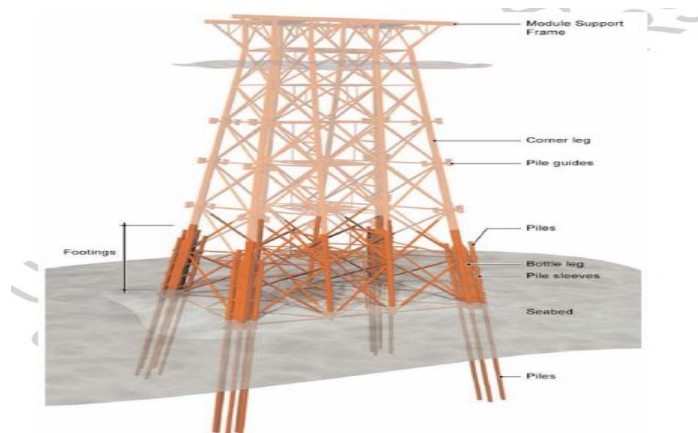
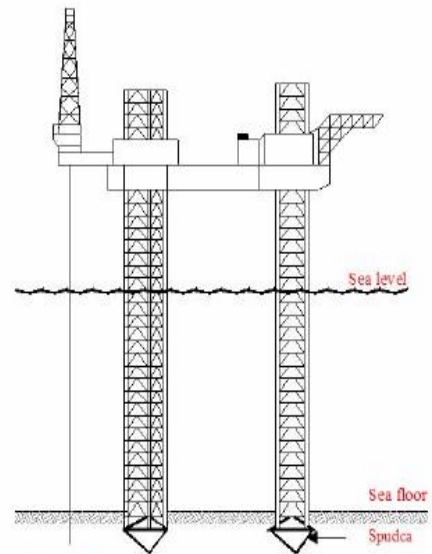


Figure 4: Tower structure showing cluster pile

**D. Jack-Up:**

A jack-up comprises a floating hull and three or more legs, which can move up and down relative to the hull. It reaches its operational mode by lowering the legs to the sea floor and then raising the hull to the required elevation. The legs can be moved independently and are supported at their bottom ends by spudcans (Figure 5). Prior to raising the hull, the spudcans are pressed into seabed, a process termed “preloading”. Preloading pre-compresses the soil so as to reduce the chance of punch-through which if it occurs can partly or fully destabilize the platform (Freudenthal and Gaither, 1969).

The majority of jack-ups are built for short-term operation at different locations around the world. As metocean and foundation conditions vary between locations, such jack-ups have to be assessed for each particular location. A few jack-ups are purpose-built for production at a single location, although there can be the intent for eventual their reuse at other locations.

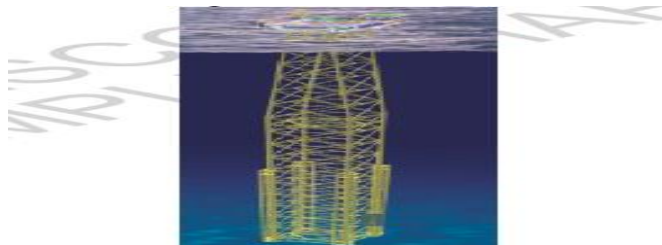


Jack-ups in the elevated positions

**Figure 5:** Jack-ups in the elevations positions

**E. Compliant Tower:**

A compliant tower is a flexible structure with flex elements (principally flexible legs axial tubes) to control mass and stiffness characteristics so as to mitigate the effect of periodic wind, wave and current forces. Natural periods are usually greater than 25 sec so they are generally well outside wave periods. Compliant towers are relatively slender compared with jacket/tower structures but have higher installation costs and use a considerable amount of steel. They can support a large number of wells (>40) with dry trees and can sustain a large payload **Figure 6**.



**Figure 6:** Compliant tower

**F. Gravity Structure:**

Gravity structures (or gravity-based structures) are fixed structures that are held in-place against environmental actions solely by their weight plus that of any contained ballast, together with foundation resistance resulting from their weight and lateral resistance from any skirts. The majority of gravity structures are constructed of concrete **Figure 7**, although a very limited number have been built of steel.

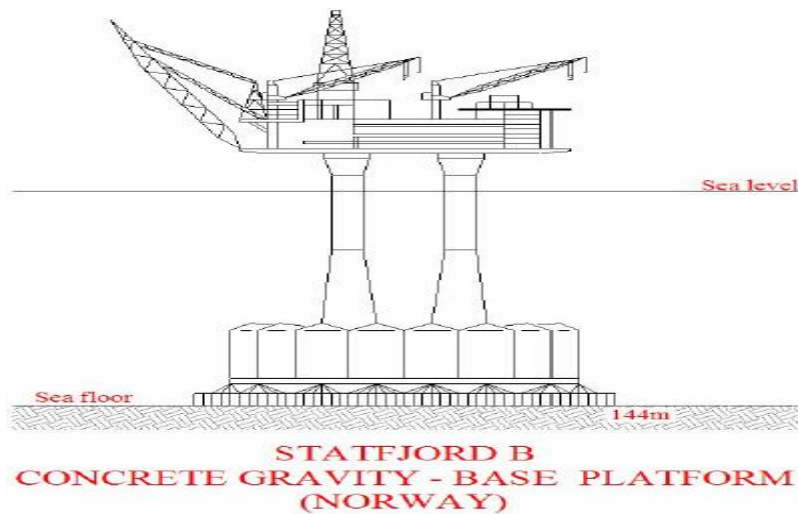


Figure 7: Gravity structure

**G.SPAPAR:**

Spar is an altered structure in which the entire structure or if nothing else the upper piece of the structure comprises of a solitary vertical section (tubular or surrounded) that conveys the topsides. It comprises of a solitary vertical section over its full stature that proceeds into the seabed as the establishment heap, this is depicted as an 'unattached caisson'. A 'propped caisson' is a spar where the lower a portion of the segment is along the side bolstered by one or more slanted supports between the section and one or more establishment heaps. spar are intended to be unmanned or not typically kept an eye on.

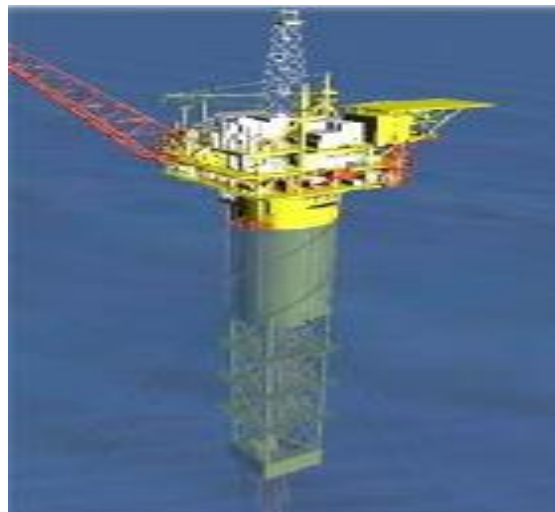


Figure 8: SPAR with only one deck with helipad on top

**H. Tension Leg Platform :**

**Design production;** semisubmersible extends to the bottom of sea with vertical anchor lines (cables or pipes) to maintain the tension is through buoyancy of the platform.

Depth: shallow to deep... 120 - 1500 m.

**Advantages:** (1) mobile & reusable, (2) stability - little vertical movement, (3) low cost increase with depth increase, (4) deep water capability, (5) reduce maintenance cost.

**Disadvantages:** (1) high initial cost, (2) high subsea cost, (3) fatigue of tension legs, (4) complicated maintenance under surface of the sea, (5) little or no storage.

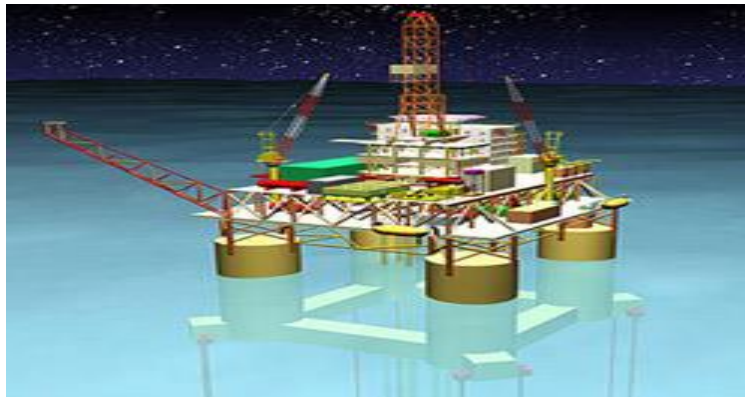


Figure 9 tension leg platform

#### IV. DESIGN METHODOLOGY

The outline of offshore structure is not a single step configuration process. The auxiliary setup, game plan, part sizes and its determination prerequisites can be touched base after few outline cycles. So as to accomplish an ideal outline suitable for the establishment technique proposed and fulfill the last working necessities, a configuration methodology suitable for the undertaking might be produced (Clauss et al., 1993). In a offshore venture, the configuration of auxiliary components can't be started unless the fundamental understandings of the needs are distinguished. The essential needs are: What is the sort of stage? Oil or Gas, Process or Wellhead or Quarters and so on what is floor territory of topsides required? Expected most extreme weight of offices? What is fundamental water profundity and ecological parameters, for example, wave and ebb and flow? Where is it found? Earth quake inclined? What is sort of establishment? Lift introduced or Launch introduced? Any CAPEX requirements?

##### A. STRUCTURAL DESIGN :

###### Loads:

Offshore structures in design rely on following types of loads:

- ✓ Permanent (dead) loads.
- ✓ Operating (live) loads.
- ✓ **Environmental loads including:**
  - Wind load.
  - Wave load.
  - Earthquake load.
- ✓ Accidental loads.

The design of offshore structures depend mainly on wave load.

###### Permanent(dead) Loads:

including the weight of the structure in air such as weight of ballast. Weights of equipment, and existing structures permanently on the platform.

Hydrostatic forces on the members below the waterline. These forces include buoyancy and hydrostatic pressures.

###### A.1. Operating (Live) Loads:

Operating loads include the weight of all movable equipment or material, as well as forces generated during operation of equipment. The weight of drilling, facilities such as living quarters, furniture, life support systems, heliport, workers etc.

Forces generated during operations, e.g. drilling, vessel mooring, helicopter landing, crane operations.

###### Wind Loads:

Wind load act on the part of platform which is above the water level as well as on any equipment, housing, derrick, etc.

**The equation of wind loads are :**

$$F_w = (1/2) \rho V^2 C_s A \quad (2)$$



where:

$\rho$  is the wind density ( $\rho \gg 1.225 \text{ Kg/m}^3$ )

$V$ (m/s) wind velocity.

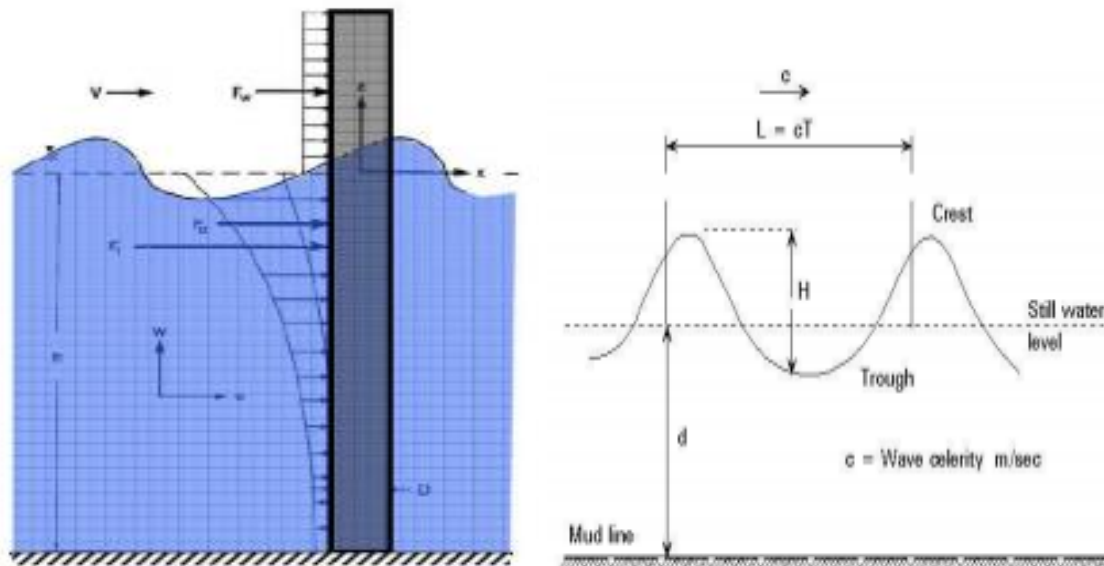
$C_s$  is the shape coefficient ( $C_s = 1,5$  for beams and sides of buildings ,  $C_s = 0,5$  for cylindrical sections and  $C_s = 1,0$  for total projected area of platform).

**Wave load :**

The wave loading of an offshore structure is more significant of all environmental loadings usually which the structure must be designed.

The forces on the structure are produced by the motion of the water due to the waves which are generated by the action of the wind on the surface of the sea.

**Wave theories** used for calculation of wave forces on offshore structures are based on wave height( $h$ ) is small in comparison to its wavelength( $L$ ), and water depth( $d$ ) and mass coefficients ( $C_d, C_m$ ) and particle velocity.



**Figure 10:** Calculation of wave theory According to Morison's equation

- According to Morison's equation :

$$F_f = (\Delta \cdot a_f + C_a \cdot \Delta \cdot a_r) + \frac{1}{2} \cdot \rho \cdot C_d \cdot A \cdot V_r |V_r|$$

where:

- $F_f$  is the fluid force.
- $\Delta$  is the mass of fluid displaced by the body.
- $a_f$  is the fluid acceleration relative to earth.
- $C_a$  is the added mass coefficient for the body.
- $a_r$  is the fluid acceleration relative to the body.
- $\rho$  is the density of water.
- $V_r$  is the fluid velocity relative to the body.
- $C_d$  is the drag coefficient for the body.
- $A$  is the drag area.

**Earthquake load:**

Offshore structures are designed for two levels of earthquake intensity :

**Strength level :** Earthquake, defined as having a “reasonable likelihood of not being exceeded during the platform's life” (mean recurrence interval ~ 200 - 500 years), the structure is designed to respond elastically.

**Ductility level :** Earthquake, defined as close to the “maximum credible earthquake” at the site, the structure is designed for inelastic response and to have adequate reserve strength to avoid collapse.



### Ice and Snow Loads:

Ice is a primary problem for marine structures in the arctic and sub-arctic zones. Ice formation and expansion can cause big pressures that give rise to horizontal as well as vertical forces. In addition, large blocks of ice moved by winds and waves with speeds up to 0,5 to 1,0 m/s, may hit the structure and produce impact loads.

### Temperature Load:

change in Temperature produce thermal stresses. To cater such stresses, change in values of sea and air temperatures which are likely to effect during the life of the structure shall be estimated. In addition to the environmental sources , sudden move of cryogenic material may result in temperature increase, which must be taken into account as accidental loads. The temperature resulting from oil and Gas production should are taken.

### Accidental Load :

According to the DNVrules , accidental loads are loads, which might act as a result of accident or exceptional circumstances.

For example , fire or explosion, dropped objects, Special studies must be taken to reduce the risk from accidental loads.

## V. CONCLUSIONS

Mainly every type in platforms is chosen due to water depth considerations, and due to the deck equipment necessary to decrease its service. The first type which is called jackup platforms uses in relatively shallow water depths up to 150 m (about 500 feet). the second type is fixed template (jacket) platforms vary in height and size, this type can be used in water depths up or about 300 meters, even though it commonly depths in water less than 150 meters. Moreover, the semi-submersible platforms/rigs are used in water depths about 6,000 feet (1800 meters). furthermore, the Tension Leg Platforms are used in water depths rather than 300 meters. Finally, in the last type it can be considered the SPAR platforms are used in very deep water exploration. Since the selection of petroleum platform type and drilling rig depend on the depth of seawater in which the oil/gas fields are situated as a result .

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