OFFSHORE STRUCTURE DESIGN AND CONSTRUCTION

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Keywords: Jacket structures, topsides, design, construction, metocean, geotechnical, loads, load combinations, piling, offshore foundations, corrosion protection

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Summary

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.

1. 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, buoyed by a generally continually rising price of oil and, more recently, gas. On occasions, however, serious falls in the oil price have punctured these developments sometimes significantly, leading to major consolidation within the industry.

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.

2. Types of Offshore Structures

2.1. Overview

There are two main categories of offshore structures, fixed and floating. Each has a number of sub-categories – see Table 1 which also lists their uses, advantages and disadvantages. Subsea completions are also structures that are placed on the seafloor basically to support equipment. They are, however, not usually considered to be an offshore structure in the generally accepted use of the term.

Structure sub-categories	**Uses**	**Advantages**	**Disadvantages**
Fixed steel structures			
Jacket - see Figure 1	Drilling, production	Very common, well proven, dry trees	No storage, WD[1)] < 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
Floating steel structures			
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, ,

- see Figure 9	dry trees	several varieties	no storage, sensitive to changes in payload
Spar - see Figure 10	Drilling, production, storage (limited)	Dry trees	WD current maxm 1700 m up to 3000 m, roll, pitch & heave significant

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

Each of these units is considered in turn in the following subsections.

2.2. 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 leg piles which are inserted through the legs (Figure 1) and connected to the legs either at the top, by welding or mechanical means, or along the length of the legs, by grouting.

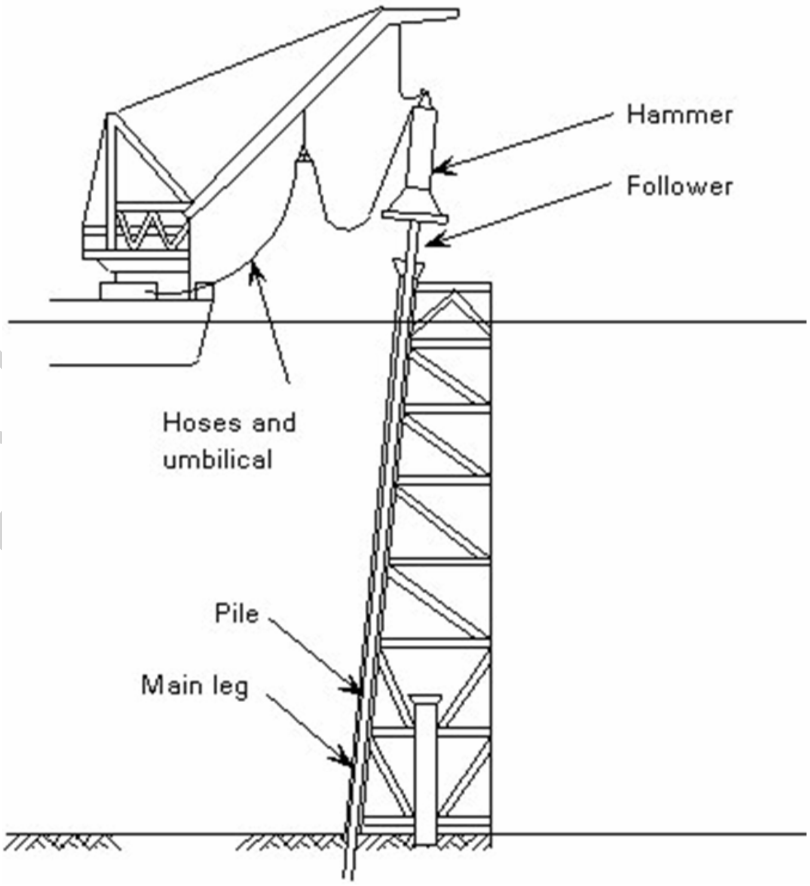

Figure 1. Jacket showing driving of pile through jacket leg

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

Where the piles are only connected to the legs at the jacket top, the forces are transferred to the piles at the connection and the jacket "hangs" from the piles. Where the piles are connected by full length grouting, the jacket behavior is similar to that of a tower (Section 2.3), with the legs and piles acting together as composite components.

2.3. 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 for the topsides, conductors, risers and other appurtenances.

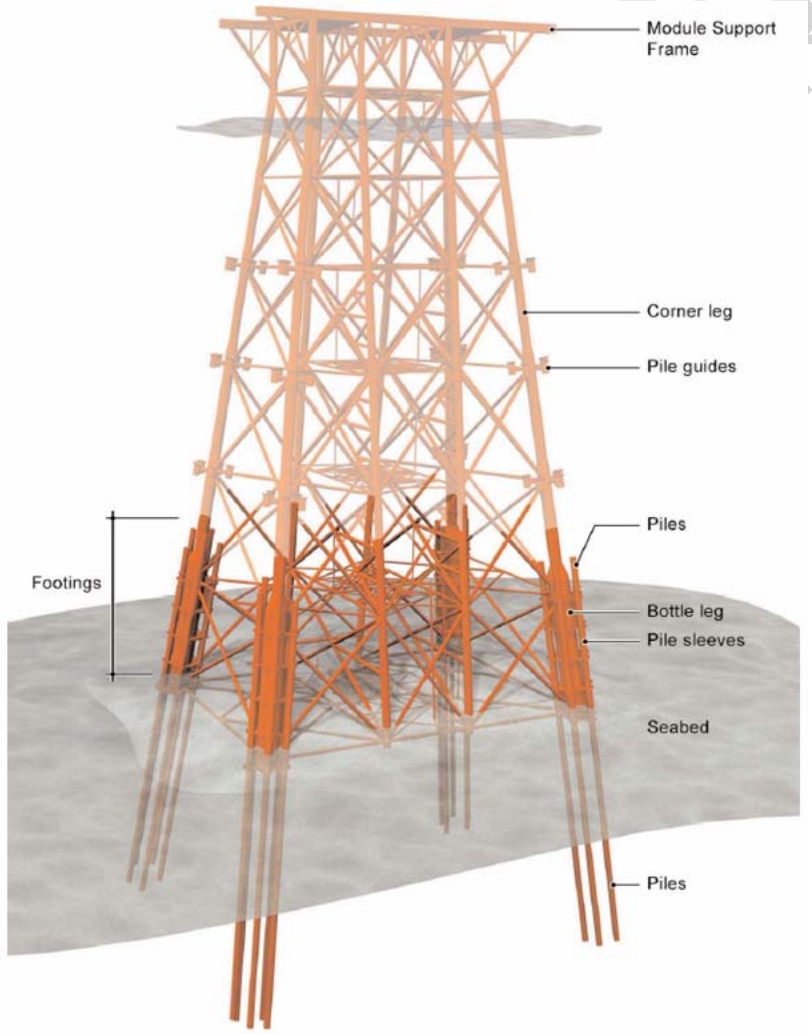

Figure 2. Tower structure showing cluster piles

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 2). 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 foundations. Cluster and skirt piles, or other foundation system, anchor the structure and transfer both vertical and horizontal actions to the seabed.

The global behavior of a tower is that of a vertical cantilever with all actions being transferred to the foundation system at the base of the tower.

2.4. Jack-Up

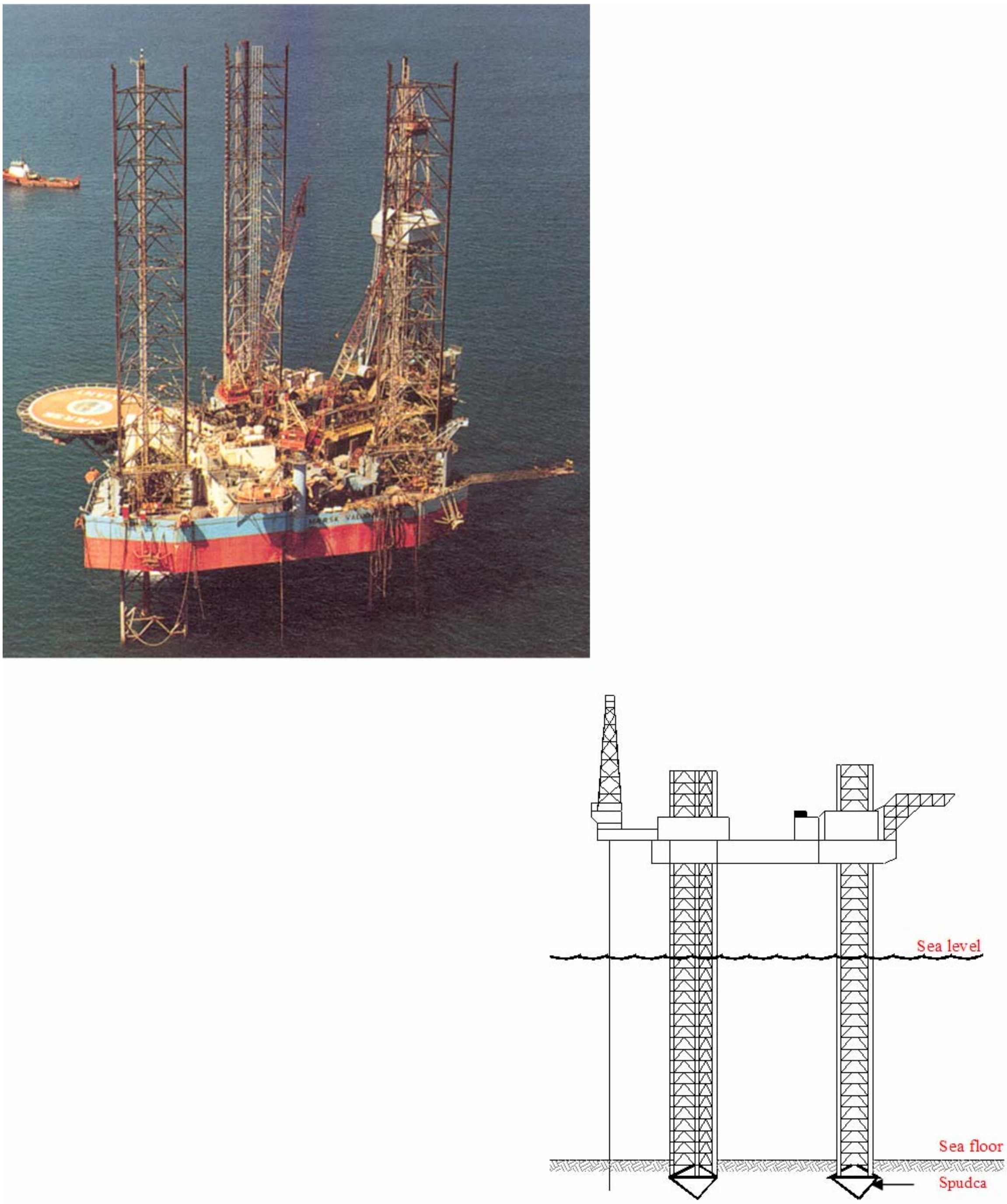

Figure 3. Jack-ups in the elevated positions

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 3). 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.

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.

2.5. Compliant Tower

A compliant tower is a flexible structure with flex elements (principally flexible legs or axial tubes) to control mass and stiffness characteristics so as to mitigate the effects of periodic wind, wave and current forces. Natural periods are usually greater than 25 sec so they are generally well outside wave periods.

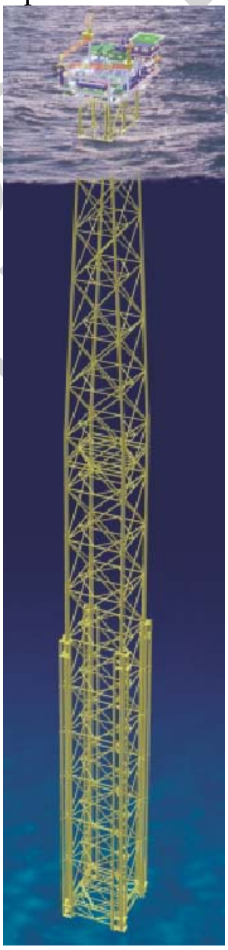

Figure 4. Compliant tower

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 4).

2.6. Gravity Structure

Gravity structures (or gravity-based structures as they are often termed) 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 5) although a very limited number have been built of steel.

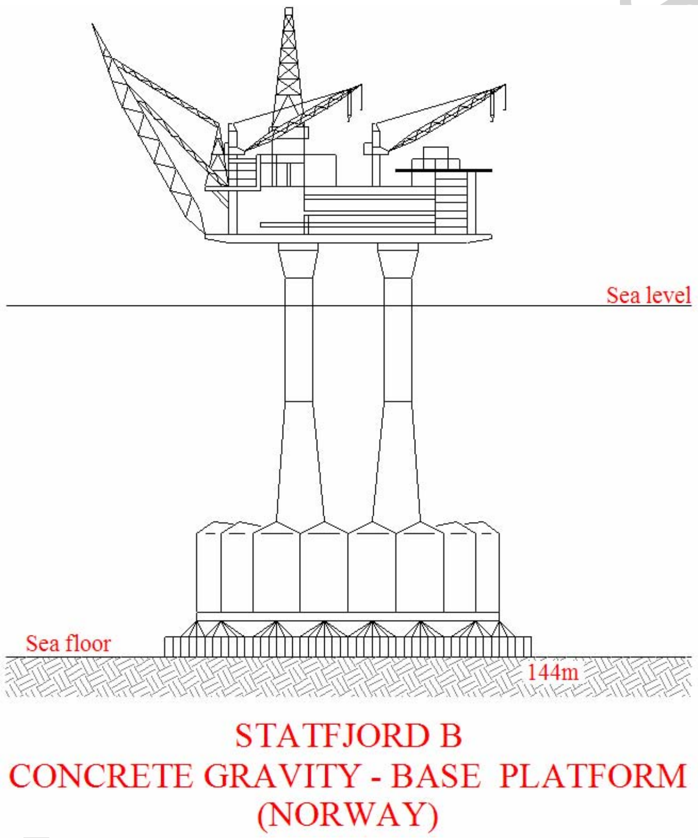

Figure 5. Gravity structure

2.7. Monotower

A monotower is a fixed structure in which the whole structure, or at least the upper part of the structure, consists of a single vertical column (tubular or framed) that carries the topsides (Figure 6).

Figure 6. Monotower - here with only one deck with helipad on top

Where the monotower consists of a single vertical column over its full height that continues into the seabed as the foundation pile, this is described as a ‘free-standing caisson’ or simply ‘caisson’. A ‘braced caisson’ is a monotower where the lower part of the column is laterally supported by one or more inclined braces between the column and one or more foundation piles.

Monotowers are designed to be unmanned or not normally manned.

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Biographical Sketch

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WG 5/P3 Floating Structures - Convener Inspection & Condition Monitoring
WG 7/P3 Jack-Ups - Member Structural Strength
WG 7/P10 Jack-Ups – Member Calibration & Acceptance Criteria
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