Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 10 (1976)

Artikel: A new kind of hybrid construction

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DOI: https://doi.org/10.5169/seals-10535

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A new Kind of Hybrid Construction

Une construction hybride nouvelle

Eine neue hybride Konstruktion

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1. Introduction

In the earlier stages of the development of deep water oil production platforms for the North Sea the choice was oversimplified to one of using a pile supported steel jacket or a concrete gravity structure. Recent designs have combined both materials and are often referred to as "hybrids". (Fig. 1). In this paper the arguments for a new type of hybrid are explored and the resulting design (Tricon) briefly described. (Fig. 2).

2. The Problems and Some Solutions

An offshore platform structure in deep and exposed waters is a special case of a tall building with almost its entire payload concentrated in the "penthouse", subject to exceptionally large horizontal loadings of a cyclic nature and with uniquely difficult site access and foundation conditions. However, having accepted these rather special design and construction parameters, the design of such a structure should still be tackled and ultimately make as much sense as that of any other structure. In other words, the design concept should be governed by the "payload" and the permanent working conditions, be reasonably easy to construct and in the process possibly permitting some temporary overstressing.

The present generation of self-floating "jacket" structures does make sense in that respect, albeit with some obvious shortcomings.

The tubular joints, the node points, have become so large that the secondary stresses have reached a magnitude of prime importance, requiring a great amount of internal stiffening. They are however still not large enough to permit more than one or two welders to work inside the joint. Furthermore, the number of node points in a major structure is still so large that the prefabrication of these node points is a very critical element in the construction programme.

A tubular space frame with a minimum number of members and hence node points leads to a much more satisfactory structural concept. The tubular members become so big that they achieve a natural buoyancy even if made of reinforced or prestressed concrete, and the node point become so spacious, that a considerable work force can get inside them They also become so accessible, that the internal stiffening members can be designed and positioned so correctly that secondary stresses can be reduced to what they ought to be; i.e. of secondary importance.

Another serious shortcoming of the larger pile supported jacket structures is the great proportion of weather and crane barge dependant offshore work. This proportion will ultimately, with increasing water depths and wave heights and narrowing weather windows, reach a "point of no return", and in the North Sea it lead to the introduction of the "gravity" structures.

The present generation of concrete, steel or hybrid gravity structures has solved the offshore installation problem by avoiding it - but at a very heavy premium. For their construction they require very special facilities - such as extremely deep and sheltered water - and their design leave no room for the designer to produce an optimum solution to the prime purpose of the structure; i.e. to support the payload safely and economically above the waves. It is a fact, that the optimum solution for the permanent conditions is incompatible with the temporary conditions, and that the structure is governed by the requirements for floating stability and structural strength during the towing and sinking operation. Having met these temporary conditions as well as those imposed by the restrictions of the available construction site, the designer is then left with the rather unsatisfying task of just checking, whether the structure is adequate for the permanent conditions. Hardly the way to produce the most economic structure, and at times, when the upper soil strata of the seabed are too weak, not even a way to produce just an acceptable structure.

It is in the approach to the foundation problem that both types of existing offshore structures show their worst limitations.

The pile supported structures suffer not only because the piles are difficult and costly to drive, but also because they are not the best and most economic foundation method. Loads of the same order of magnitude are often supported under water; bridge piers in connection with river or harbour crossings. In such cases one would generally dig down to a suitable foundation level and one would never contemplate driving piles to carrying capacities of several thousand tons a piece.

Similarly the gravity structures suffer not only because they become disproportionately large and impose high stresses on the upper and weaker soil strata, but also because they impose an impossible tas on the designers. It is impossible to tailor make a foundation to suit an unprepared and practically unknown seabed or to determine the right length and strength of a penetrating skirt without exact information on the soil into which the skirt has to penetrate. Still, this is the very first design decision, which has to be made.

From the above considerations it would appear, that deep footings (assuming it is feasible to install them) are cheaper than long steel piles and also a more rational foundation method than resting directly on top of the seabed.

They are independant of the seabed topography and they eliminate the risk of sliding and the risk associated with scour of the seabed. They can furthermore be designed properly, taking full account of the prevailing soil properties, if the construction of the footings can be reversed to become the last item and not the first on the construction programme.

3. The Design

The above design considerations have resulted in the Tricon concept. Tricon consists of three basic elements: (i) on the top a short legged jack-up platform designed to the clients requirements, (ii) a main three legged space frame optimised to carry the payload and resist wave action, made up of large tubular members with few node points, and (iii) caisson footings sunk to a firm foundation.

The tubular space frame is constructed horizontally as a normal jacket structure. All the tubular members have considerable natural buoyancy and the structure as a whole floats in a very shallow water. The footings are circular hollow cylinders suitably stiffened to be able to spread the column load over the required foundation area. They can be made of steel, but even made of concrete will they possess enough buoyancy to float in shallow water.

Since the structure is being constructed horizontally, (Fig. 3) the footings can be added as the last item on the programme, and even with the diameter fixed the height can be increased until the last minute.

The structure is obviously extremely stable floating horizontally, but because of the positive buoyancy of all the tubular members it remains stable during all phases of the upending process which is achieved by controlled flooding.

Having touched down with the three footings resting on top of the seabed the tops of the columns are well above the waters surface. The caissons are now sunk into the seabed by means of excavation inside the footings. The excavation process is a self-contained and

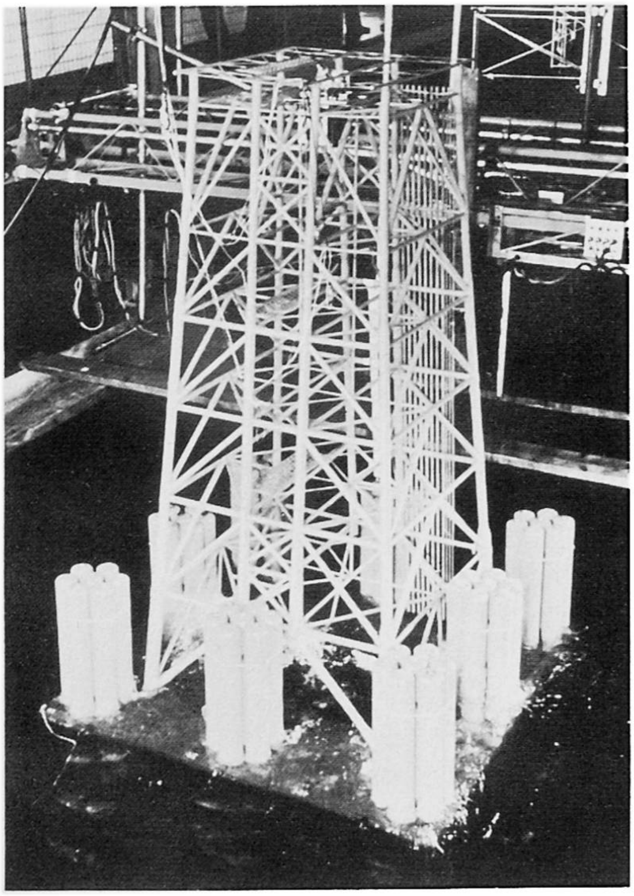


Fig. 1. RDL (NORTH SEA) HYBRID

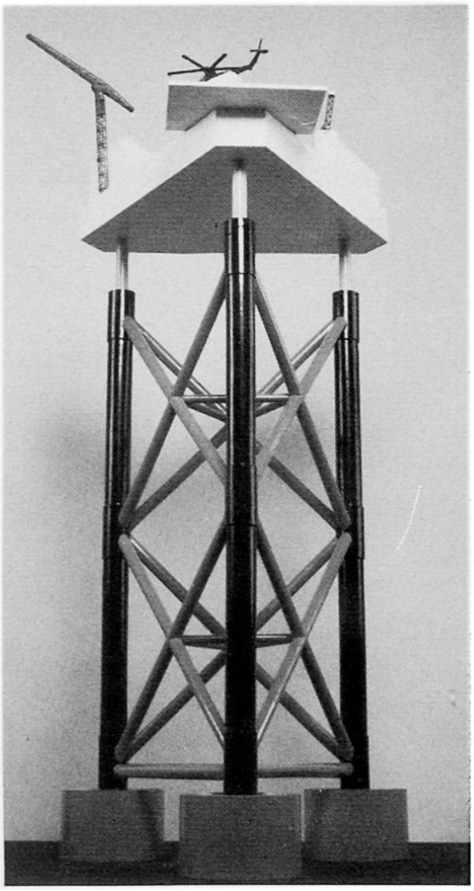
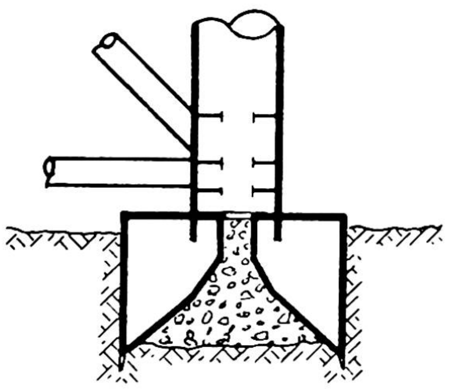


Fig 2. TRICON

Fig 3. TRICON IS FABRICATED & FLOATED HORIZONTALLY

practically weather independant operation. The necessary tools are built into the structure and there is plenty of room in the top of the columns to accommodate the working crew.

The excavation takes place under water with purpose made digging or tunnelling tools dragging the excavated material from the perimeter of the footings to the centre, where it can be removed by pumping or air lifting.



Caisson Foundation

As soon as the cutting edge of the footings has penetrated into the seabed and sealed off the interior of the footings from the outside water pressure, the structure gains instant "fixity" and it is possible to reduce the internal pressure and thus utilising the external hydrostatic pressure to assist the penetration into the seabed. In that respect the sinking of the Tricon feet is easier and more controllable than a caisson sinking in compressed air or even an open excavation for a bridge pier. Compared to the piledriving, where each hammer blow must exert a force of several thousand tons to achieve penetration, the excavation process is obviously much simpler, requiring a force of only a few tons to break down the soil into removable lumps and thus achieve penetration into the seabed.

The excavation process is continued until the tops of the columns are at a predetermined depth below the waters surface, access to the working space in the columns being gained through removable access shafts. With the footings at the right depth the space underneath the footings is backfilled with granular material and the Tricon foundation is completed.

The temporary access shafts are then removed and the underwater foundation is ready to receive the "jack-up" superstructure.

To land the "jack-up" legs on the Tricon columns requires a spell of calm weather, but only a very short spell, and no calmer than what is required to carry out one lift with a crane barge; i.e. equivalent to bringing one pile section into the pile guides or placing the hammer on top of one pile.

If required the whole process can be put in reverse for the removal and movement to a similar site. Excess hydraulic pressure can be utilised to force the raising of the caissons in a controlled manner.

If, as intended, the Tricon concept combines the structural economy of a "jacket" with the offshore installation economy of a gravity structure, it should logically lead to cheaper offshore structures.

SUMMARY

The new type of hybrid construction "TRICON" divides naturally into three distinct main sections:

the top - a conventional three-legged "jack-up" platform

the tower - a triangular tubular space frame with minimum number of members

the foundation - three deep caisson footings sunk into the seabed to a suitable foundation level.

It combines the best structural features of a "jacket" and the offshore installation advantages of "jack-ups" and "gravity" structures.

RESUME

La nouvelle construction hybride "TRICON" se divise en trois parties distinctes:

le sommet - une plate-forme conventionnelle à trois pieds sur vérin

la tour - un treillis tubulaire triangulaire avec un minimum de membrures

la fondation - trois profonds caissons de pied ancrés à un niveau de fondation convenable au fond de la mer.

Ceci combine les meilleures caractéristiques de chaque élément et les avantages d'une plate-forme auto-élévatrice et à embase.

ZUSAMMENFASSUNG

Die neue hybride Konstruktion "TRICON" lässt sich in drei Hauptabschnitte unterteilen:

oben befindet sich die übliche Plattform, die an drei Beinen auf und ab bewegt werden kann

der Turm ist eine fachwerkartige Rohrrahmenkonstruktion mit einem Minimum an Stäben

die Gründung erfolgt über drei Tiefcaissons, welche in den Seegrund bis zur tragfähigen Bodenschicht abgesenkt werden.

Damit werden gleichzeitig die Vorteile einer Hubinsel und einer Schwergewichts-Plattform realisiert.