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Structural analysis of the Gravity Tripod and a path to a new offshore wind business model

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Introduction

The need for cost reduction within the Offshore Wind industry is clear. At the moment the industry is heavily subsidised and government agencies are making clear statements about the price targets. Based on a background of extensive oil and gas construction experience and multiple years' experience of offshore wind development OWLC completed a business case sensitivity analysis of the offshore wind industry in order to identify technologically based, market realisable initiatives to reduce cost. In conducting the business model analysis, OWLC identified that construction cost and construction stage finance together were one of the largest cost centres.

OWLC identified that the cost of the offshore operations was defined by piling into the seabed. As a lengthy and risk laden process it not only consumes expensive vessel time, but delays revenue streams increasing the proportion of Levelised Cost attributable to construction stage finance. However conventional gravity bases, because of the high loads they place on the seabed, require significant amounts of seabed preparation and reinforcement (with high costs), as well as having a high cost of construction. To address this OWLC identified an innovative hybrid lattice/gravity base structure – The Gravity Tripod.

The Gravity Tripod is an innovative concrete gravity base structure with a low hydrodynamic profile. It is optimised for manufacturing, installation, operation and decommissioning. With a stiff structural form and high mass it has excellent frequency characteristics and it can accommodate a wide range of turbine sizes in water depths well beyond the capability of Monopiles. Its low hydrodynamic profile reduces the level of seabed preparation required as well as scour effects, while the gravity base nature ensures installation noise is kept to a minimum.

This presentation will provide in insight to the first independent structural analysis of the Ultimate Load State for the design as well as provide an overview of the manufacturing and installation considerations.

Basis of the Engineering Analysis

In order to provide independent verification of OWLC's conceptual calculations, Ramboll was commissioned to analyse the loads within the structure and identify the required dimensions for the components. Ramboll used an in-house software package 'ROSAP' (Ramboll Offshore Structural Analysis Programme), a package which in recent years has been extended to solve problems regarding offshore wind turbine support structures.

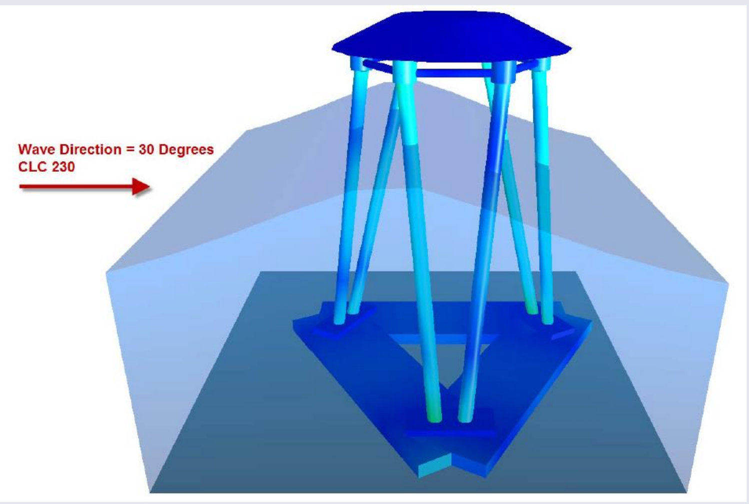
ROSAP determines the deformations and sectional forces in the entire structure. Environmental loads due to gravity, buoyancy, wave and current are generated automatically. Furthermore load time series and accelerations (to estimate inertia forces) can be imported into the programme and applied to the structure. The package includes a module known as WAVGEN (Wave generation programme). WAVGEN generates velocities, accelerations and excess pressures in a rectangular grid for waves and current. Several wave theories and spectra are available.

The structure was modelled in ROSAP using tubular, conical beam, and box elements for the tripod, gravity base and transition piece. It was then exposed to the Ultimate Load State of a 14m wave and 8MW turbine loads. The wave was modelled at three angles of incidence to ensure that the critical loads were identified. From these data the design criteria were identified and the structure was designed according to DNV's requirements, i.e. in accordance with J101 and the Eurocode package. The concrete column design has been performed to Eurocode 2.

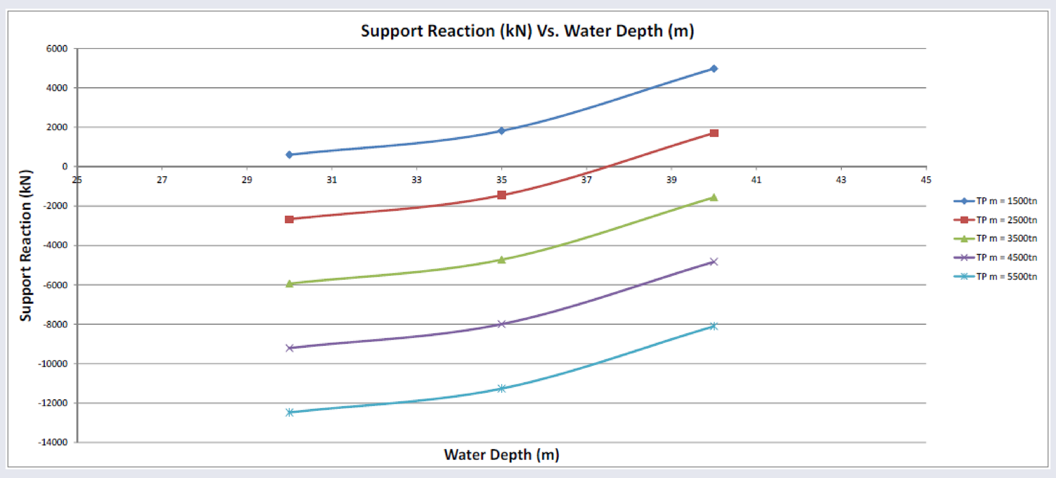
The structure was analysed for a range of transition piece masses and a range of water depths. For all cases a maximum wave height of 14m was used and turbine forces for a theorised 8MW turbine.

Modelling and Column Design

As a gravity base structure, the main concept of the Gravity Tripod is that the base is always in compression against the seabed, even during an extreme event. Therefore, the resultant forces at the boundary conditions give an insight into the scale and magnitude of the forces seen at the base of the structure.

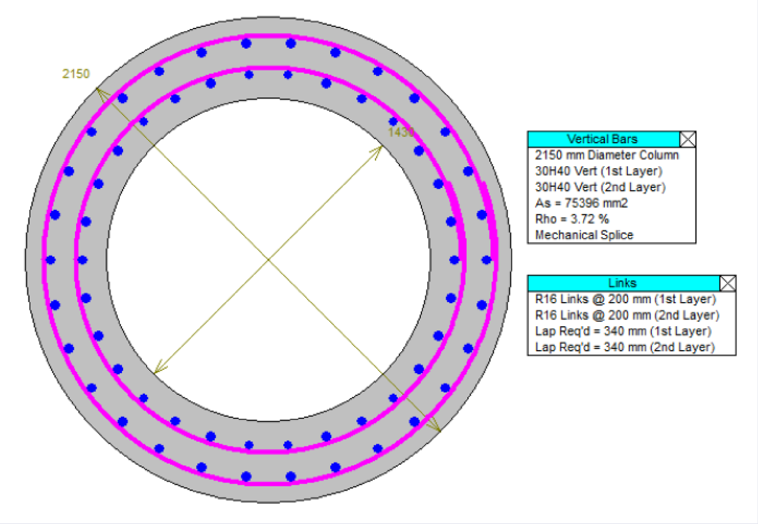


A wave direction of 030 Degrees was established to be the worst-case scenario. The forces were calculated for a range of water depths and a range of transition piece masses.



An initial design of the hollow concrete legs was carried out. A large number of possible maximum forces were available due to the number of variables considered in the analysis (3 water depths and 5 TP masses). The preliminary column design was therefore performed with the following restrictions:

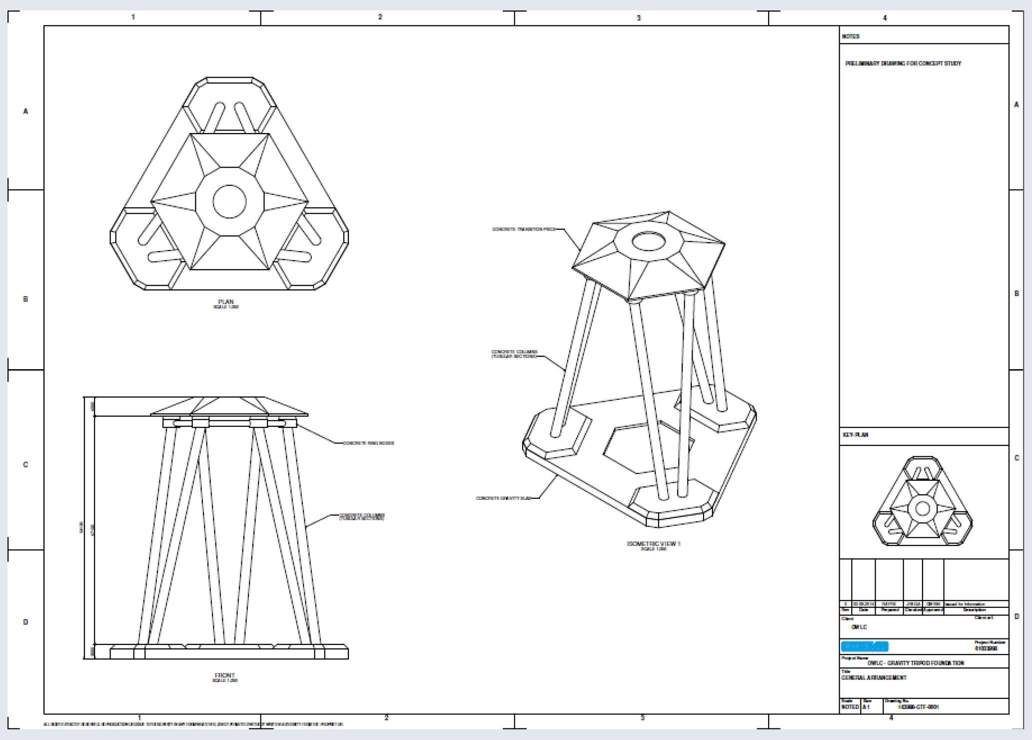
Two wave directions were found to be critical, the 000 degree and the 030 degree waves, all other combined load cases were excluded



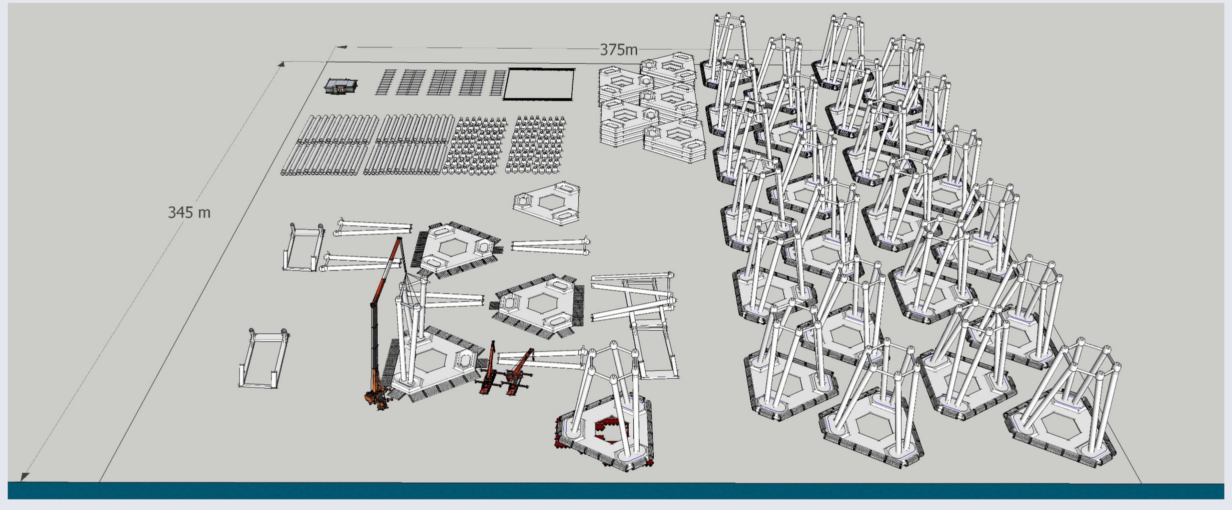
The worst-case shear utilisation was found to be at the bottom of one element due to a wave angle of 30 deg, while the worst-case moment utilisation was found to be at the bottom of the same element due to a wave angle of 0 deg. Forces in all the other legs and due to all other cases were not considered.

The Gravity Tripod, Manufacturing and Installation

The Gravity Tripod is a modular substructure concept. It utilises 2 main components. The first is a concrete load distributing slab and integrated three-footed, six legged concrete lattice structure, or the Hyperboloid Jacket. The second is a concrete transition piece with integrated ballast tanks for the addition of mass through the insertion of water or aggregates, the Gravity Transition Piece.

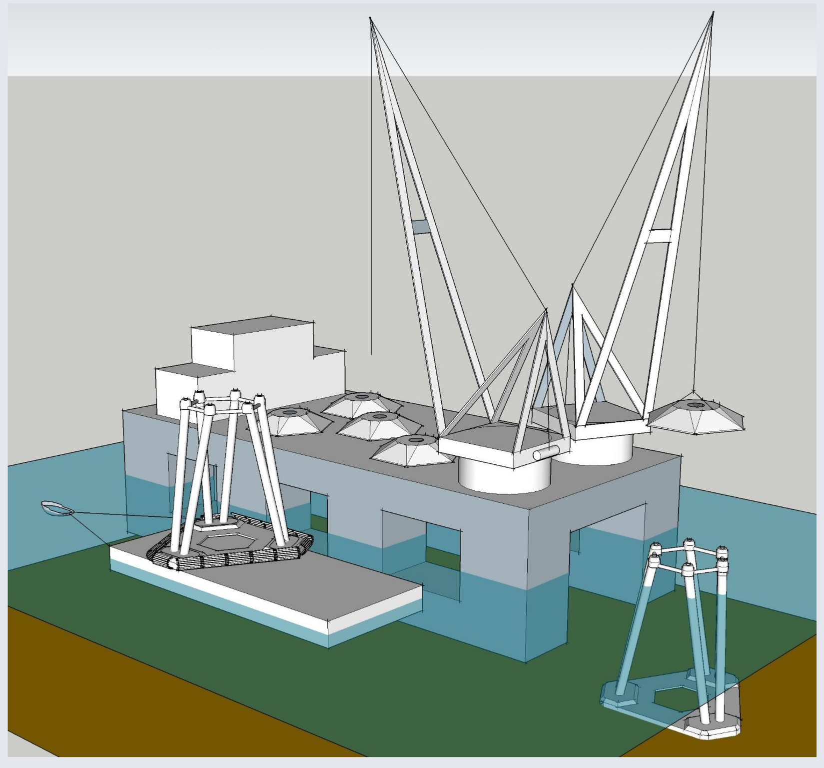


As a gravity structure the Gravity Tripod removes sub-seabed risk and the geometry, as well as mass distribution, of the design simplifies design of the nodal connections between components. Through modular design the Gravity Tripod minimises component manufacturing and assembly times as well as the space requirements for construction, making it suitable for manufacture at a wider range of locations than for other offshore wind sub-structures.



The Gravity Tripod is designed for rapid assembly. As a modular structure manufacturing of the components ahead of assembly limits the space and time required to supply a large number of structures.

The structure is designed to be installed as a barge fed solution. With the use of submersible barges the range of vessel types capable of installing the structure includes SSCVs (shown), as well as monohull heavy lift vessels and shear-leg crane barges.



Within minimal seabed preparation and a high installation rate, the higher day rate of the installation vessels is mitigated on a per unit basis; while the construction and weather risk for the design is significantly lower than for competing structures.

Cost Reduction

Due to a significantly shorter, lower risk, offshore construction programme, as well as a lower capital cost for the structure, the Gravity Tripod is modelled as an 8-13% reduction in the Levelised Cost of Electricity.

This cost modelling accounts for the higher day rate of the vessels used to install the structure as well as the weather restrictions for the transportation of both the Hyperboloid Jacket as well as the Gravity Transition Piece.

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