REVIEW ON MONOPILE FOUNDATION FOR FIXED OFFSHORE STRUCTURE

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Abstract - This paper provides a broad overview of some of the key factors in the design monopile foundation for fixed offshore structure. During the last years, offshore wind turbine structures were reported to settle on the monopile structure and the resulting force flow in the structures was different to that intended at the design stage. A joint industry project was therefore carried out by Det Nordce Veritas (DNV) [1] to investigate the structural capacity of these connections from autumn 2009 to January 2011. It was found that the axial capacity of the grouted connections is a more sensitive function to the diameter and surface tolerances than that accounted for in existing design standards.

Keywords: Monopile foundation, Fixed Platform, Spar structure, offshore turbine, Heave displacement, Hydrodynamics, Offshore Wind Turbine

1 INTRODUCTION

Monopile foundation used for offshore wind farms is basically a cylindrical tube usually made of steel, which is directly installed into the seabed using hammering or vibration. This technique has been used in die offshore for erecting Platform for wind turbine and has proven to be very effective. So far the monopile support structure is the most popular support structure used for the construction of wind farms. It is estimated that 75% of all installed offshore wind turbines use the monopile support [2]. There are a lot of factois that contribute to the popularity of monopile. Firstly it is a very simple design, which can also be manufactured in two straightforward steps, rolling and welding. The calculation and analysis of this structure are also easy and always the first step while designing any type of support structure. The growing requirement for clean and sustainable energy production in die near future has resulted in die search for alternatives to fossil fuels as an energy source. As a result of that, wind energy is one of the most promising options for generating electricity.

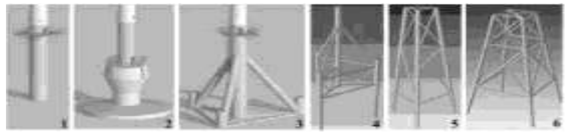

Fig.1 Types of Monopile Foundation

2 TYPES OF MONOPILE FOUNDATION

2.1 Structure 1 - Monopile Foundation

This is a simple structure consisting of a steel pipe piled into die seabed by driving and/or drilling methods. A larger diameter sleeve is attached to the pile by concrete casting, where its top rim is a flange that accommodates fixation of the turbine tower by bolting.

2.2 Structure 2 - Gravity Based Foundation

This structure is currently used on most offshore wind projects at shallow water depths up to 5 m. It consists of a large base constructed from steel and concrete, resting on the seabed. It relies on weight of the structure to resist overturning; hence the turbine is dependent on gravity to remain erect. The structure is resistant to scour and deformation due to its massive weight. The wind turbine tower is attached similarly to monopole foundations.

2.3 Structure 3 - Tripod Foundation

This design is typically used forplatforms in the oil and gas industry. It is made from steel tubes welded together, typically 1 to 2.5 *m* in diameter. It is anchored 20 to 40 *m* into the seabed by means of driven or drilled piles from 1 to 2.5 *m* in diameter. The transition piece is typically attached onto the centre column by means of concrete casting as well.

Jacket structures are made from steel tubes, typically 0.5 - 1.5 *m* in diameter, welded together to form a structure similar to lattice towers. They are anchored to the seabed by driven or drilled piles, ranging from 1-2.5 *m* in diameter. Several 3 to 4 legged jacket structures have been proposed as illustrated in Fig.1

3 DESIGN CONSIDERATIONS FOR FOUNDATIONS

One of the main aims of the foundations is to transfer all the loads from the wind turbine structure to die ground within the allowable deformations. Guided by limit state design philosophy, the design considerations are to satisfy:

1. Ultimate Limit State (ULS): This would require the computation of capacity of tire foundation. For monopiles type of foundation, this would require computation of ultimate moment, lateral and axial load carrying capacity.
2. Serviceability Limit State (SLS): This would require the prediction of tilt at the hub level over the life time of the wind turbine.
3. Fatigue Limit State: This would require predicting the fatigue life.

4 HYDRODYNAMICS

The characteristics of currents and waves, themselves would be very much site dependent, with extreme values of principal interest to the LFRD approach used for offshore structure design, associated with the statistics of the climatic condition of the site of interest. A number of regular wave theories have been developed to describe the water particle kinematics associated with ocean waves of varying degrees of complexity and levels of acceptance by the offshore engineering community, [4]. These would include linear or Airy wave theory, Stokes second and other higher order theories, Stream- Function and Cnoidal wave theories, amongst others, [5]. The rather confused irregular sea state associated with storm conditions in an ocean environment is often modelled as a superposition of a number of Airy wavelets of varying amplitude, wavelength, phase and direction, consistent with the conditions at the site of interest, [3]. Consequently, it becomes instructive to develop an understanding of the key features of Airy wave theory not only in its context as the simplest of all regular wave theories but also in terms of its role in modeling the character of irregular ocean sea states.

5 AIRY WAVE THEORY

The surface elevation of an Airy wave of amplitude *a,* at any instance of time *t* and horizontal position *x* in the direction of travel of the wave, is denoted by q *(x,t)* and is given by:

$$q\ (x,t) = a \cos(kx: -cot)$$

where wave number *k = 2ji* / *L* in which *L* represents the wavelength and circular frequency oo = *In IT in.* which *T* represents the period of the wave. The celerity, or speed, of the wave *C* is given by *L/T* or *oq/k,* and the crest to trough wave height, *H,* is given by *2a.* Le Mahaute [6] provided a chart detailing applicability of various wave theories using wave steepness versus depth parameter in his description. With the increasing popularity of wind- turbines in the United States, an increasing number of these structures are being placed in the Western United States due to higher wind energy; however, this region is also prone to high seismicity. Amongst several ofthe studies cited those by Taniwaki and Ohkubo [7] and Kocer and Arora [8] are amongst toe very few to consider seismic loading.

Wijngaarden [9] outlined a feasibility study of various

supporting structures for OWT considering different design considerations and found that monopile foundation is an efficient solution up to 20 m water depth. A review on cost effective design of OWT on the basis of theoretical basics of dynamics were addressed by Tempel and Molenaar [10]. Camp et al. [11] outlined various design aspects of OWT considering different foundation modeling techniques and hydrodynamic loading and suggested that combination of soil-monopile and tower in dynamic model is essential in order to achieve an optimized design.

Research studies on design issues of an OWT in order to reduce the risk of failure incorporating dynamic soil- monopile-tower interaction are limited in number. LeBlanc [12] outlined various design considerations for OWT support structure in sand considering long term response of monopile under cyclic loads. An optimum design of wind turbine stower and foundation system was carried out by Nicholson [13] without taking into account of dynamic soil-structure interaction. It was observed that foundation stiffness greatly affects the optimal design of an OWT. Morgan and Ntambakwa [14] pointed out toe strength; stiffness and stability of foundation are the essential design criteria for wind turbine foundation design. They indicated that cost of toe foundation can be minimized if appropriate soil-structure interaction including fatigue and ultimate limit state is accounted for wind turbine analysis.

6. OBJECTIVE:

The objective of this concept design study is to investigate the technical and economic feasibility of offshore wind turbine platforms for offshore wind turbine installation. More specifically, the goals are to:

1. To design and analysis Of Monopile foundation for Offshore platform.

2. Identify the optimal Monopile platform configuration for the specified wind turbine and design

3. Identify technical challenges to the successful development of the selected concept.

7. DESIGN METHODOLOGY

A .Geometry

B. Model

C. setup

D. Results

PRELIMINARY DESIGN & MODELLING

Design Codes and Standards

There are several design standards and guidelines for the design of offshore wind turbines. Two commonly used design standards:

1. Guidelines for the design of wind turbines (DNV, 2001);
2. Design of offshore wind turbine structures (DNV, 2007).
3. American Petroleum Institute Recommended Practice for Fixed Offshore Structures (API RP2A, 2000)

1. The methodology carried out for this Project is worked out in ANSYS AQWA.

2. In Ansys Aqwa, the design is carried out in Hydrodynamic Diffraction (AQWA)

3. Sequence of operations performed to design are

A .Geometry

B. Model

C. setup

D. Results

4. For performing the operations in Geometry Select by double clicking it, obtaining Design Modular

5. In the Design Modular give the input details like sketching, diameter of the monopile, height of the monopile

Top diameter	4.6 m
Bottom diameter	4.6 m
Thickness	0.06m
Height of monopile	125m
Free board	15m

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Draft	110m
Water depth	150m
Rating	5 MW
Rotor Orientation	Upwind
Hub Height	80 m
Rotor Mass	110 tonnes
Nacelle Mass	240 tonnes
Total point Mass	55000 tonnes

6. The preliminary design steps are shown as in fig. 1 to 10

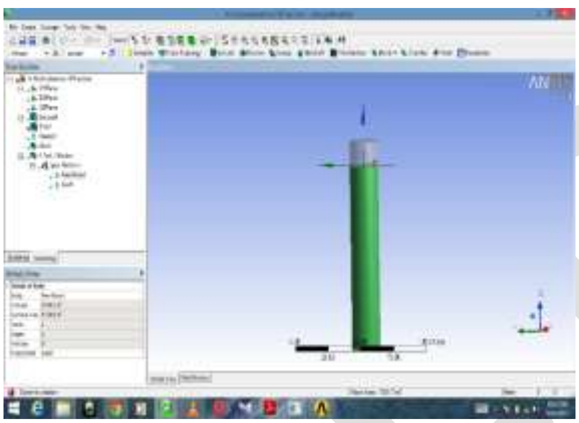

Fig.1

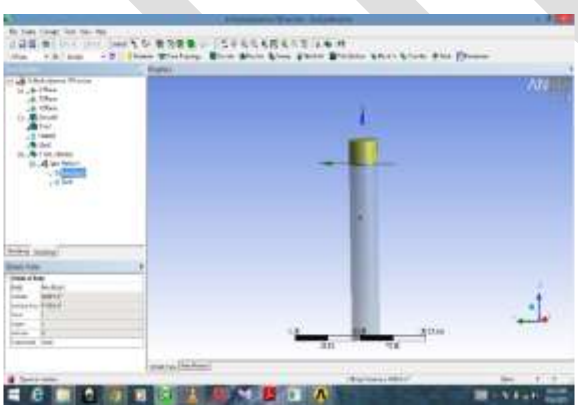

Fig.2

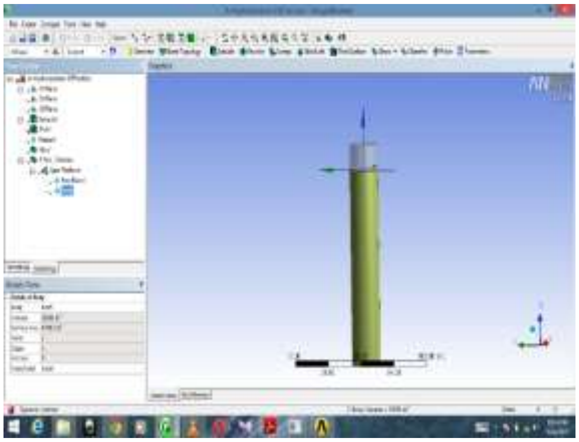

Fig.3

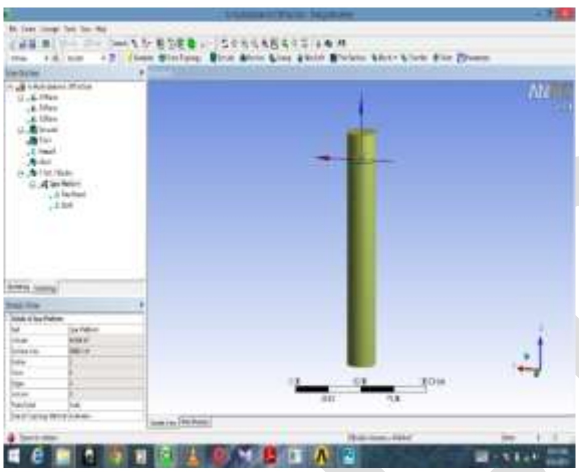

Fig.4

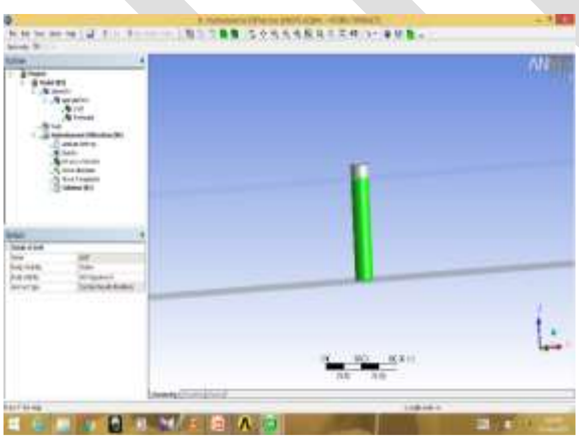

Fig.5

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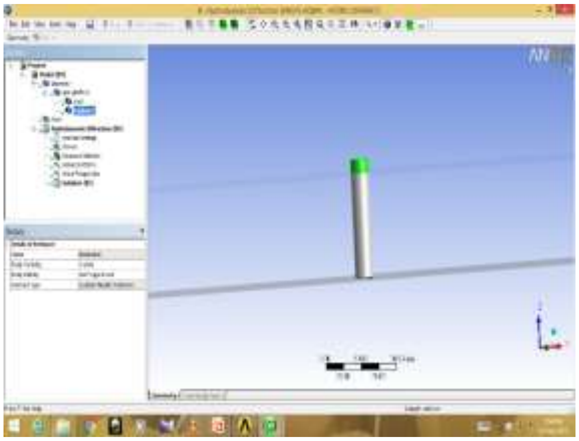


Fig.6

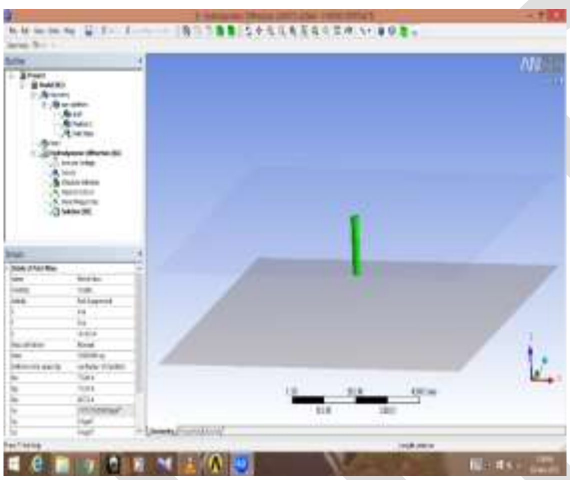


Fig.7

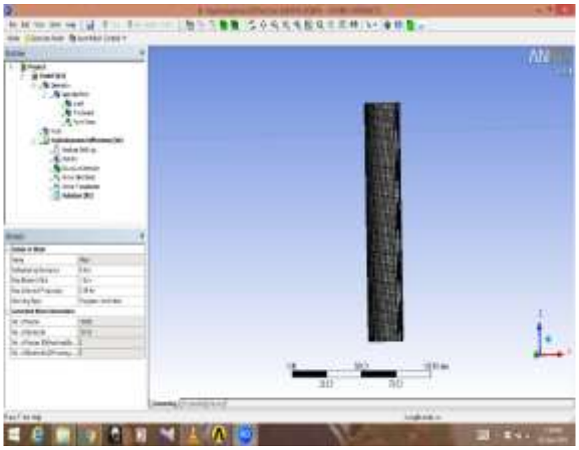


Fig.8

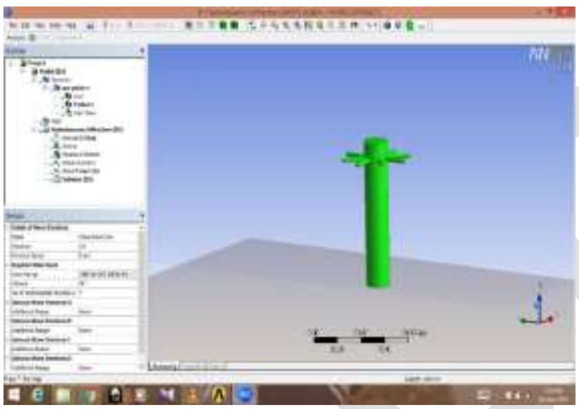


Fig.9

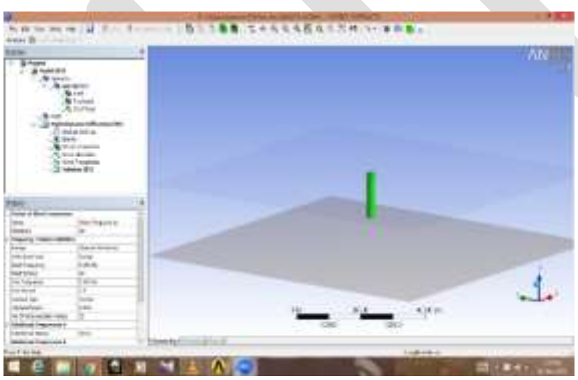
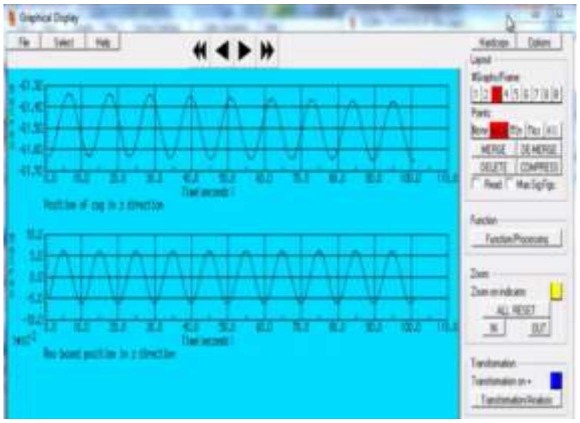


Fig.10

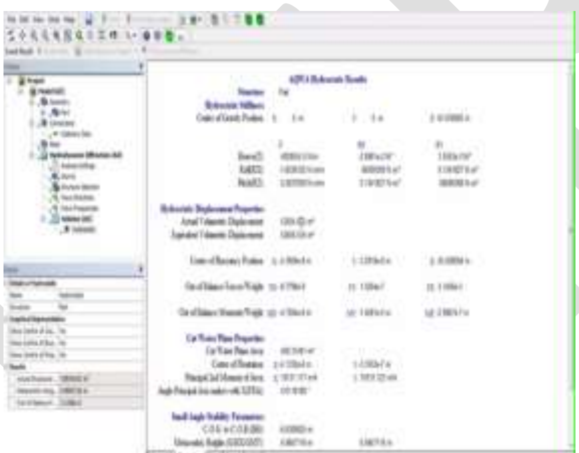
8. RESULTS & CONCLUSION

Graphical display: showing very little displacement.



AQWA Hydrostatics Results

1. The designed monopile is able to control the Heave displacement to a great extension.
2. Wind speed largely affects toe material consumption of an OWT system. The steel requirement is less when the structure is designed at less wind speed due to reduction in aerodynamic load. Fatigue life of structure also improves due to decreased wind speed value. An increase in embedded length of monopile marginally affects the total steel consumption of an OWT structure, since response and fatigue life of the structure vary marginally due to increase in embedment depth beyond its critical depth



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