Sensitivity of Wave Period on Hydrodynamics Loading of Jacket Structure

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Abstract: ***Any structure installed in the sea will experienced external loading due to the wave structure interaction. The magnitude of this external loads will depend upon many factors such as wave height, wave period, wave speed, current velocity, wave direction, water depth and etc. This paper investigates the effects of variation in wave period on hydrodynamic loading on a typical jacket structure installed in intermediate water depth. Jacket structure is modeled and input environmental parameters are subsequently used to represent the local hydrodynamics loading condition experienced by the structure. Environmental forces acting on a fixed structure installed in the sea mainly comes from wave. Wave height and wave period are two main parameters affected the magnitude of forces transferred on to the structure. In this study selected wave periods are T = 12.5 s associated to wave height, H = 16.1 m and T = 13.1 s associated to wave height, H = 16.8 m. For a jacket structure installed in an intermediate water depth, overturning moment of the structure appeared to be more sensitive to the variation in wave period.***

Keywords: sensitivity study, wave period variation, jacket structure, hydrodynamic loading, structural response, base shear, overturning moment.

1. Introduction

Jacket structure installed on the seabed will experience external loading from environment such as wave, current and wind. The effects from environmental loading further increased with the present of marine growth as well as unidirectional interaction of wave, current with the structure. This paper investigates the sensitivity of hydrodynamics loading with a variation in wave period. Initially, two wave periods were selected for the study namely 50-year and 100-year return wave periods. The variation of 10-percent in wave period was adopted in order to generate results in structural response. The assumption was adopted that the wave and current are unidirectionally interact with the structure. The jacket structure used in this study is a 55 m tall installed in water depth of 45 m. This investigation is a continuation of previous studies reported in [1], [2] and [3]. The investigation methods are similar but water depth parameter use in this study is different.

2. Structural Model

Model of jacket structure used in this study is a typical four-legged structure as shown in Fig. 1. The structure is 55 m tall and it is assumed that the structure is rigidly connected to the sea floor at four corners of the jacket legs. The water depth where the structure is installed is 45 m. Jacket legs made from a steel tubular with a diameter of 0.75 m while all bracing has a diameter of 0.35 m. The base dimension of the structure is 25 m x 25 m and 15 m 15 m at elevation +45 m.

3. Wave Theory

Wave forces acting on the structure are derived from velocities of water particle passing the structure. These forces were estimated based on Morison's equation which assumes the force to be composed of inertia and drag forces

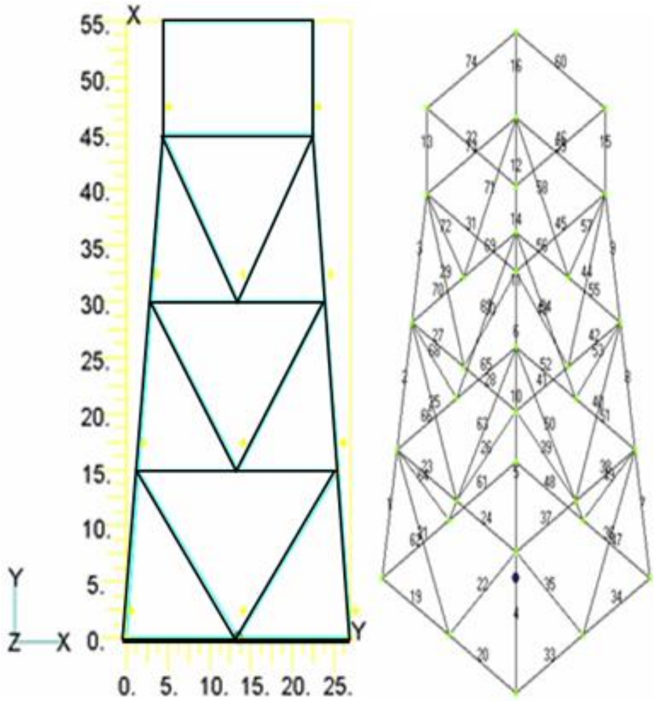

Figure 1: Jacket structure

linearly added together [4]. This relationship is applicable when the structure is drag dominance which is usually the case for jacket structure where the tubular member's diameter is small compared to the wave length. In this study small amplitude wave theory was adopted in the investigation of hydrodynamics loading on jacket structure.

The force exerted by wave on the structure is composed of two components, namely inertia and drag. For linear wave theory, water particle velocities, u and v were illustrated in Fig.2 for the estimation of wave forces on submerged cylindrical structural members.

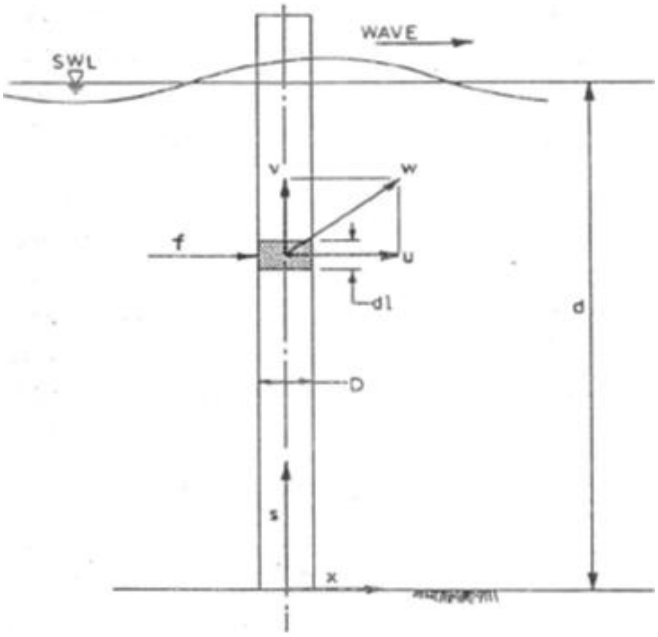

Figure 2: Wave forces on small diameter cylinder [5].

Water particle velocity and acceleration can be written as;

$$u = \frac{\pi H}{T}\frac{\cosh ks}{\sinh kd}\cos\theta$$

$$\dot{u} = \frac{2\pi^2 H}{T^2}\frac{\cosh ks}{\sinh kd}\sin\theta$$

where T is the wave period, H is wave height, *s* is location as referred to from the seabed. Similar expressions can be written for vertical water kinematics, v and $\dot{v}$.

Total forces on submerged structural members is given by the following equation [5];

$$F = \int_0^d f ds = \int_0^d \left[\rho\frac{\pi}{4}C_M D^2\dot{u} + \frac{1}{2}\rho C_D D|u|u\right] ds$$

where *d* is water depth, D is structural diameter, C_M, C_D is inertia and drag coefficient respectively.

4. Loading Assumption

In this study two wave heights were selected that are 16.1 m and 16.8 m representing waves of 50-year and 100-year return period respectively. The associated wave periods for these wave heights were presented in Table 1. The Table also presented other relevant parameters such as water depth and current velocities. It is so selected that there are variations in wave period for each wave height to investigate the sensitivity of wave period on the hydrodynamics response of the jacket structure. The structural response has been investigated in water depth of 45 m. The variation of wave period in this study is about 20 percent ($\pm 10\%$ from selected wave period). In this study it was assumed that the structure is free from any attachment of marine growth and inertia coefficient, Cm, and drag coefficient, Cd, for a clean structure were adopted as 2.0 and 0.6 respectively.

Table 1: Wave period study

Parameter	Value/Remark					
Wave Theory	Small amplitude wave theory					
Wave Height (m)	16.1			16.8		
Wave Period (s)	11.5	12.8	14.1	11.8	13.1	14.4
Water depth (m)	45			45		
Current Velocity (Surface/seabed) (m/s)	1.55/0.3			1.55/0.3		

Total force on structural members beneath the SWL can be obtained from equation [5],

$$F = \rho\frac{\pi}{4}C_M D^2\left(\frac{2\pi^2 H}{T^2\sinh kd}\right)\int_0^d \cosh ks\, ds \sin\theta$$

$$+\frac{1}{2}\rho C_D D\left(\frac{\pi H}{T\sinh kd}\right)^2\int_0^d \cosh^2 ks\, ds\, |\cos\theta|\cos\theta$$

5. Results and Discussion

Outcome of the study presented in term of structural responses to external loading experienced by the structure during the interaction with wave and current. Table 2 shows results of global loading related to wave periods for two selected wave heights. Sensitivity of wave period variation on the hydrodynamic loading of jacket structure were presented in Fig. 3 and Fig. 4

Table 2: Results of wave period study

Wave Height (m)	Wave Period (s)	Base Shear (MN)	OTM (MNm)
16.1	11.5	4.715	94.549
	12.8	4.681	90.920
	14.1	4.674	88.207
16.8	11.8	5.058	101.562
	13.1	5.042	97.719
	14.4	5.009	94.845

Fig. 3 shows the effect of wave period variation of base shear (BS) loading on the structure. While in Fig. 4 it shows the effect of wave period variation on overturning moment (OTM) experienced by the structure. Sensitivity of the structural loading to change in the wave period is not very significant. Graphs indicates that base shear and overturning moment decrease with the increase in wave period. This is due to the reciprocal relationship between water particle velocity and the wave period of the wave that interacted with the structure.

From the results it was clear that the effect of variation in wave period is small for base shear loading on the structure which is only about 1 to 2 percent change in BS magnitude with the change of about 10 percent in wave period. This is clearly shown in Fig. 2 where the graph for both wave heights were quite similar trend. However, for similar percentage changes in wave period will results in about 4 percent changes in OTM. This trend was shown in Fig. 3. Sensitivity of variation in wave period and its effect on base shear and overturning moment presented in this study is applicable for intermediate water depth structure.

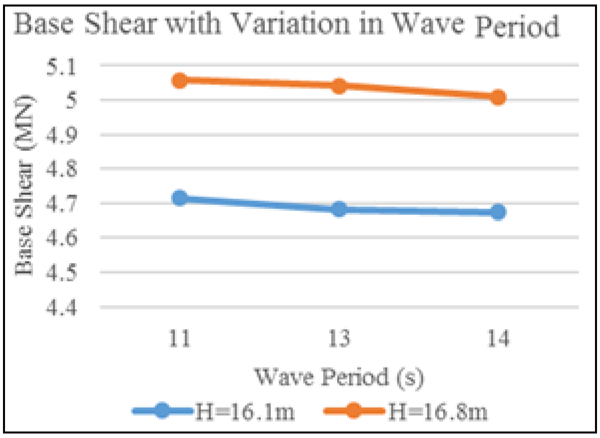

Figure 3: Sensitivity of BS to variation in wave period

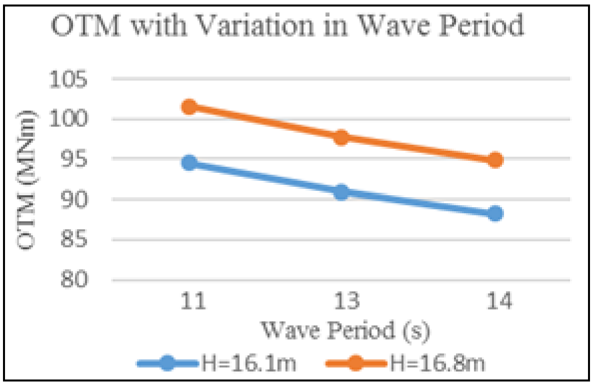

Figure 4: Sensitivity of OTM to variation in wave period

6. Conclusions

The finding of this study may be concluded as the following;

1) Overturning moment is more sensitive to the variation in wave period. Variation of $\pm$10% in wave period give rise to about 4% changes in OTM.
2) Small variation of $\pm$10% in wave period has an effect of about 1% - 2% changes in base shear.
3) The results of this study is applicable for jacket structure installed in an intermediate water depth. Results may differ for the structure install within other water depth ranges such as shallow water or deep water.

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