University of Tabriz

Journal of Civil and Environmental Engineering
Volume 51 (2021), Issue 3 (Autumn), 1-10

EXTENDED ABSTRACT

Effects of Floating Wave Barriers with Square Cross Sections on the Wave-induced Forces Exerted to an Offshore Jacket Structure

Arash Dalili Osgouei [a], Ramin Vafaei Poursorkhabi [b*], Ahmad Maleki [a], Hamid Ahmadi [c]

[a] *Department of Civil Engineering, Maragheh Branch, Islamic Azad University, Maragheh, Iran*
[b] *Department of Civil Engineering, Tabriz Branch, Islamic Azad University, Tabriz, Iran*
[c] *Faculty of Civil Engineering, University of Tabriz, Tabriz 5166616471, Iran*

Received: 01 April 2019; **Accepted:** 14 January 2020

Keywords:
Jacket structure, Random waves, Floating wave barrier, NIMALA flume, Base shear, Overturning moment.

1. Introduction

The jacket-type platform is the most common offshore structure employed for the oil and gas production from the reservoirs below the seabed. It consists of three main parts: superstructure or topside, substructure or jacket, and the foundation or piles. Construction of floating breakwaters and wave barriers is one of the commonly used methods for the protection of harbors and coastal structures. However, their application for the protection of offshore structures has not been extensively studied. The present paper investigates the effects of a floating wave barrier installed in front of an offshore jacket structure on the wave height, wave-induced forces, and consequently jacket's base shear and overturning moment.

Abul-Azm and Gesraha (2000) studied the hydrodynamics of floating pontoons under oblique waves. Gesraha (2006) analyzed the shaped floating breakwater in oblique waves. Rahman et al. (2006) presented a numerical modeling for the estimation of dynamic responses and mooring forces of submerged floating breakwaters. Christensen et al. (2018) conducted a set of experimental and numerical studies on floating breakwaters. Dong et al. (2008) carried out a number of experiments on the wave transmission coefficients of floating breakwaters.

In the present research, a jacket model with the height of 4.55m was fabricated and tested in wave flume of NIMALA marine laboratory. The wave flume was 402m long. The jacket was tested at the water depth of 4m subjected to JONSWAP waves with the height of 20cm, 23cm, and 28cm. The mechanism of wave energy dissipation due to hitting a wave barrier is mainly a combination of the wave diffraction and the wave reflection. A square cross section was selected for the wave barrier. Results showed that a floating wave barrier can effectively reduce the base shear and overturning moment in an offshore jacket structure.

2. Details of experimental study

2.1. Wave-maker flume

Experiments of the present research were conducted in NIMALA marine laboratory. Its wave flume, that is the biggest one in Iran, is 402m long, 6m wide, and 4.5m high (Fig .1).

2.2. Models of jacket structure and floating wave barrier

The jacket structure studied in the present research was a scaled model of C13 jacket installed in the South Pars gas field of the Persian Gulf. The height of the actual jacket is 80m operating at the water depth of 72m.

* Corresponding Author
E-mail addresses: arash_dalili@yahoo.com (Arash Dalili Osguei), vafaei@iaut.ac.ir (Ramin Vafaei Poursorkhabi), maleki_civil@yahoo.com (Ahmad Maleki), h-ahmadi@tabrizu.ac.ir (Hamid Ahmadi).

With a scale factor of 1 to 18, the model of the jacket was 4.4m high installed in the flume at the water depth of 4m. The distance between the jacket and the wave maker was 70m; while its distance from the flume end was 332m. Fig. 2 shows the isometric view of the jacket structure. As an idea to reduce the wave energy, a floating wave barrier with square cross section was installed in front of the jacket structure. The material used for the fabrication of wave barriers was polystyrene. Since its specific weight is quite low, almost 98% of the wave barrier's cross section was above the water surface level when it was allowed to be floated freely. A set of weights was attached to each wave barrier in order to ballast it to a position in which 50% of its cross section lies beneath the water surface level; i.e. to set its draft equal to half of its total height. The wave barriers were 5m long having a 30cmX30cm cross section. There was a 50cm gap between each barrier end and the adjacent flume wall. The wave barrier was located at the distances of 3m and 5m from the wave probes and the jacket structure, respectively. Fig. 3 illustrates the longitudinal section of the wave flume along with the jacket structure and the equipment.

Fig. 1. Wave flume and manned chariot of NIMALA marine laboratory

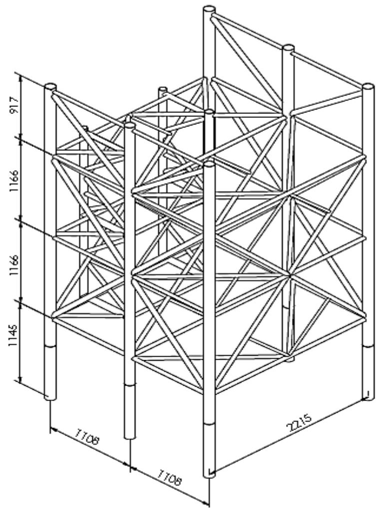

Fig. 2. Isometric view of the jacket model (unit: mm)

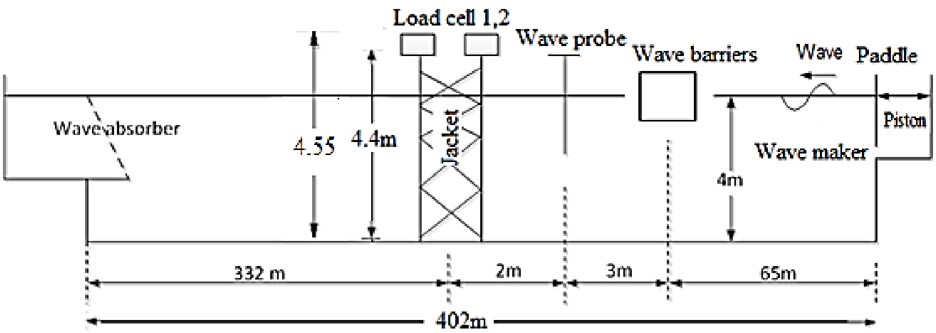

Fig. 3. Longitudinal section of the wave flume along with the jacket, wave barrier, and the equipment

3. Results and discussion

Recorded data was used to develop a set of equations expressing the relationships between the wave height (H) and base shear (F)/overturning moment (M) in the forms of Eqs. (1)–(6). The unknown coefficients calculated based on the regression analysis are given in Table 1. Fig. 4 depicts the amount of reductions in the base shear and overturning moment due to the presence of a floating wave barrier with a square cross section. It can be seen that, when the significant wave height is considered, the square-cross-section wave barrier has led to 24.67% and 19.78% reduction in the jacket's base shear and overturning moment, respectively.

$$F = a_1 H + b_1 \tag{1}$$

$$F/F_{\max} = a_2(H/H_{\max}) + b_2 \tag{2}$$

$$F/(\rho g H_{\mathrm{av}}^3) = a_3(H/gT_{\mathrm{av}}^2) + b_3 \quad (3)$$

$$M = a_1' H + b_1' \quad (4)$$

$$M/M_{\max} = a_2'(H/H_{\max}) + b_2' \quad (5)$$

$$M/(\rho g H_{\mathrm{av}}^4) = a_3'(H/gT_{\mathrm{av}}^2) + b_3' \quad (6)$$

Table 1. The unknown coefficients of Eqs. (1)-(6) calculated based on the regression analysis of the data extracted from the experiments conducted on the jacket with a wave barrier having a square cross section

Test ID	Eq. (1)				Eq. (2)				Eq. (3)			
	a_1	b_1	R^2	*RMSE*	a_2	b_2	R^2	*RMSE*	a_3	b_3	R^2	*RMSE*
FN23	1.73	7.03	0.98	1.63	0.88	0.12	0.98	0.02	28.22	5.14	0.98	1.19
FS23	1.92	-0.34	0.98	1.17	0.97	-0.01	0.97	0.02	37.62	-0.32	0.98	1.01
Test ID	Eq. (4)				Eq. (5)				Eq. (6)			
	a'_1	b'_1	R^2	*RMSE*	a'_2	b'_2	R^2	*RMSE*	a'_3	b'_3	R^2	*RMSE*
MN23	7.27	-3.76	0.98	6.61	1.09	-0.01	0.98	0.03	1066.00	-24.19	0.98	42.52
MS23	7.76	-12.47	0.97	6.50	1.18	-0.07	0.97	0.03	1301.01	-101.40	0.98	52.93

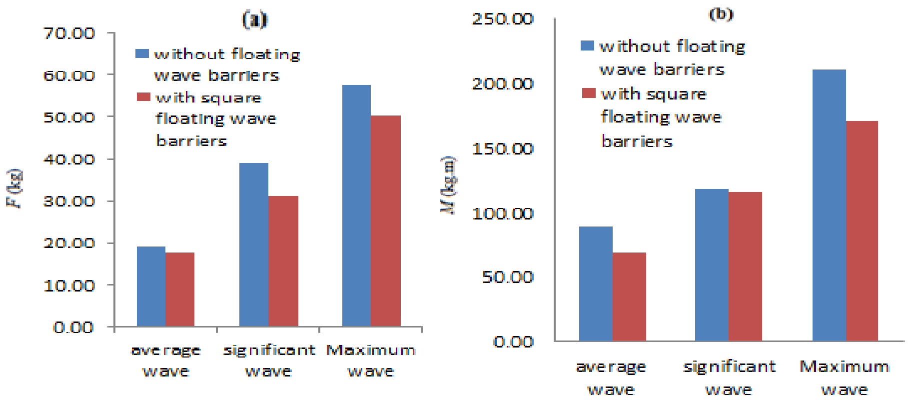

Fig. 4. The reduction of the: a) base shear, b) overturning moment due to the presence of a square-cross-section wave barrier

4. Conclusions

The effects of a floating wave barrier installed in front of an offshore jacket structure on the wave height and jacket's base shear and overturning moment were experimentally investigated. A jacket model with the height of 4.55m was fabricated and tested in wave flume of NIMALA marine laboratory. A square cross section was selected for the wave barrier. Results showed that the average decrease in the jacket's base shear due to the presence of a floating wave barrier with square cross section was 24.67%. The use of the wave barriers with square cross section also resulted in 19.78% decrease in the jacket's overturning moment. Hence, it can be concluded that a wave barrier can significantly reduce the base shear and overturning moment in an offshore jacket structure.

5. References

Abul-Azm AG, Gesraha MR, "Approximation to the hydrodynamics of floating pontoons under oblique waves", Ocean Engineering, 2000, 27, 365-84.

Christensen ED, Bingham HB, Skou Friis AP, Larsen AK, Jensen KL, "An experimental and numerical study of floating breakwaters", Coastal Engineering, 2018, 137, 43-58.

Dong GH, Zheng YN, Li YC, Teng B, Guan CT, Lin DF, "Experiments on wave transmission coefficients of floating breakwaters", Ocean Engineering, 2008, 35, 931-38.

Gesraha MR, "Analysis of shaped floating breakwater in oblique waves: I. Impervious rigid wave boards", Applied Ocean Research, 2006, 28, 327–38.

Rahman MA, Mizutani N, Kawasaki K, "Numerical modeling of dynamic responses and mooring forces of submerged floating breakwater", Coastal Engineering, 2006, 53, 799–815.