STM JOURNALS

Journal of
Offshore Structure and Technology

https://journals.stmjournals.com/joost

ISSN: 2349-8986
Volume 11, Issue 2, 2024
May–August
DOI (Journal): 10.37591/JoOST

Research JoOST

Efficiency Analysis of the Floating Breakwater with Mooring System

Pravin M. Sarwade[1],*, Vaibhav B. Chavan[2]

Abstract

Floating structures are the new advance method for the water-based structures. Floating structures can eliminate land issue. The floating structures are being used since ancient time for emergency and temporary purposes. For permanent structures, the floating structure should overcome and be completely resistant to water forces, that is, wave forces, water current forces, and wind forces and water static forces. wAve forces and water forces are major forces that exerts maximum magnitude of force and produce higher stresses in the floating structures. The floating structures should be capable of resisting these forces. The wave forces and the water current forces make the floating structure unstable and sway. By using floating breakwater and breakwaters with mooring system, the floating structures can be made more stable and maintain equilibrium. Floating breakwaters are like the coastal breakwaters. Their purpose is same, that is, absorb the wave energy. They are kept afloat in the water. Mooring system provides a strong support with the help of the cables from the bottom topography and from the land. Breakwaters can consume the wave energy to some extent for supporting the floating structure's stability and equilibrium. In this study, the efficiency of the floating breakwaters is calculated in the laboratory on the scale models of the pontoons and breakwaters.

Keywords: Floating breakwaters, pontoons, mooring system

INTRODUCTION

Most engineers face economic challenges and construction method challenges for constructing bridges and others water-based structures. For making the safe, stable, and economical construction in or on the waters, the pontoons nature and its functionality helps significantly. Use of pontoons not only reduces the cost of the project but also helps in the construction of the project. Pontoons are made and then deployed in the site. Precast pontoons easily move in the required place, and they easily interlock with other pontoons creating a long and stable pontoon frame, which can keep afloat on the water. Rigidly interlocked pontoons can deal with the tide and waves. In major cases, two adjacent pontoons behave as two individual bodies. The challenge is to make the pontoons behave as a single body. It will help in the stability of the structure based on the pontoons.

Pontoons provides excellent buoyancy and stability. Buoyancy force is measured and then the pontoon is constructed as per the requirement. Floating capacity of pontoons depends upon the material used in the preparation of the pontoons. For every structure which will construct in or on the waters, pontoons with the floating breakwaters are more stable. Floating breakwaters function limits to reduce the wave height and wave intensity. More the wave height the more energy will exerted on the pontoon. By using the floating breakwaters, we can easily reduce the wave intensity. Mooring system add more stability and keep the pontoon in the desire place against wave and current of the water flowing. All the water drags and the wave energy is distributed and absorbed by the floating breakwater.

***Author for Correspondence**
Pravin M. Sarwade
E-mail: pravinsarwade0@gmail.com

[1]Student, Department of Civil, Shreeyash College of Engineering & Technology, Maharashtra, India
[2]Associate Professor, Department of Civil, Shreeyash College of Engineering & Technology, Maharashtra, India

Received Date: July 17, 2024
Accepted Date: July 25, 2024
Published Date: July 30, 2024

Citation: Pravin M. Sarwade, Vaibhav B. Chavan. Efficiency Analysis of the Floating Breakwater with Mooring System. Journal of Offshore Structure and Technology. 2024; 11(2): 50–56p.

Mooring system especially keep the pontoon position horizontally stable while the floating breakwater keep the position of the pontoon vertically stable, vertical instability is permissible at some extent but horizontal instability is not permissible.

Breakwaters

When the waves hit floating breakwaters, the wave energy absorption is done by the floating breakwater. This results in less impact on the floating structure. The wave before hitting the breakwater is known as initial wave and denoted as H_i. The wave after hitting the breakwater is known as transmitted wave and denoted as H_t.

It is observed that the wave height of H_t is less than H_i. We know that the wave energy depends upon the wave height. By providing the floating breakwater, wave energy is reduced by the breakwater. Waves lose their energy through breakwater movement in vertical direction, keeping the floating structure stable.

The waves after passing the floating breakwaters have low height. For maximum stability, the pontoon floating structure and the breakwaters positioning is done in such a way that the waves pass the floating structure without generating pushing effect. This can be achieved by making a safe pass for the transmitted waves. The floating breakwater not only reduces the wave energy but also breaks the wave into small waves. These smaller waves can then safely pass through the floating structure.

Mooring System

Mooring system is provided from the bottom topography of the seabed, by using strong cables. These cables are connected strongly between pontoon and fixed support. The horizontal movement of the pontoon floating structure is prohibited by this mooring system. Maximum and minimum horizontal movement depends upon the number of mooting systems provided. The mooring system is provided in a three-dimensional (3D) way for better performance. The dimensions include bottom topography of the waters and the land fixed supports. The arrangement of the cable and pontoon connection is known as “dolphin”.

Effectiveness of the mooring system can be measured in the horizontal displacement of the floating pontoon structure. The floating pontoon structure is introduced to waves for specific time period. The wave height and wave time is increased for further readings of the experiment. Same experimental procedure done on the floating pontoon structure without mooring system. The observed data is compared and the effectiveness of mooring system is calculated.

Water buoyant force is exerted on the floating pontoon by the water in upward direction (+ve Y axis) and the structure resting on the pontoon exert load by means of the weight in downward direction (-ve Y axis). Wave force and water current forces exert force on pontoons sideways (horizontal direction +ve and -ve on X axis). Minor forces include wind action force. Wind forces exert on the pontoon in horizontal direction (X axis).

PRECURSORY STUDIES

Literature

Wave load has a small effect on the bridge motion in the transverse direction and a comparable contribution in the vertical direction. The second-order wave load only has a limited contribution to the transverse bridge displacement. The first-order wave load has a dominant influence on all bending and torsional moments of the bridge girder while the second-order wave load has almost no contribution to the girder response. The wind load induces large bending and torsional moments in the cable-stayed spans. In addition, it also contributes to the torsional moment of the girders in the middle bridge [1].

A series of numerical simulations with combined wind, wave, and current load are then conducted. Waves are short-crested and second-order difference frequency wave loads are considered. Wind loads are modelled using approach III that considers the aerodynamic lift, drag, and moment on the bridge girder and uses the N400 Kaimal spectrum. It is found that among wind, wave, and current loads, the mean values and standard deviations of sway motion, axial force, and strong axis bending moment are mainly induced by wind loads. The standard deviations of heave motion, weak axis bending moment, and torsional moment are mainly induced by wave loads. Turbulent wind can induce significant larger low-frequency eigen-mode resonant responses than the second-order difference frequency wave loads. Current loads mainly contribute damping, and hence, reduce the variations of sway motion, axial force, and strong axis bending moment [2].

Measuring both response (accelerations and displacements) and environmental actions (wind and waves), system identification has been successfully performed on the acceleration recordings and are interpreted in light of the recorded environmental factors. The Cov-SSI (covariance-driven stochastic subspace identification), Data-SSI (data-driven stochastic subspace identification), and FDD (frequency domain decomposition) methods have been applied for manual identification surveys, and the resulting identified modes have been compared with the modal quantities obtained from the solution of the eigenvalue problem from a comprehensive numerical model set-up [3].

Natural frequencies and mode shapes are very well identified, whereas there are relatively large uncertainties in the identification of the damping ratios. However, the overall damping levels are consistent with the estimates from the eigenvalue solution of the numerical prediction model. Large damping levels, closely spaced modes, and a geometric design resulting in coupled motion, make the identification procedure challenging. Due to scattered stabilization plots, the interpretation and manual selection are tasks that add additional uncertainties to the results [4].

In case studies on a three-connected-modular platform, the relationship between the stiffness combinations of the Floating Breakwater Hybrid Configuration (FBHC) and responses of the Very Large Floating Structure (VLFS). is investigated based on the orthogonal experiment method. We find that the connector loads and the relative displacements both depend on the stiffness in corresponding directions. There is a dilemma in designing the stiffness in three directions to simultaneously satisfy with the minimum for connector load and the minimum relative displacement of the modules [5].

Methodology for calibrating numerical models is a field that is still under development. The application of model updating to suspension bridges and cable-stay bridges is well represented in the literature. However, no attempts have been made to update a floating bridge model. This paper presents a case study of the sensitivity method in finite element (FE) model updating with application to the Bergsoysund Bridge, a floating pontoon bridge. In floating structures, the fluid interaction governs the dynamic behavior. Commonly, this can be modeled by including frequency-dependent added hydrodynamic mass and damping matrices obtained from software based on linearized potential theory. The established model of the bridge combines an FE model of the structure with the added hydrodynamic matrices. A technique for establishing an analytical sensitivity matrix was shown, taking the frequency-dependent system matrices of the model into account [6].

Specific Objectives of the Study:

After reviewing the precursory available literature, following objectives were decided for the research work:

1. To check the effect of waters waves and current forces on the breakwaters for specific time period
2. To check the efficiency of breakwaters provided in single layer and multiple layers in series.
3. Comparison between breakwaters and breakwaters with mooring system.
4. To check the results under wave action of 60 second time period with continuous wave height.
5. To check the shape and size difference of the breakwaters and its effects.
6. To check the effect of the floating breakwater self-weight.

METHODOLOGY

In this study, the scale models of the floating breakwaters are prepared and observed for its efficiency under the wave action and the water current forces. Two floating breakwaters are prepared of 10 × 5 × 5 and 10 × 10 × 2.5 cm of L × W × H with same weight, named Model-I and Model-II respectively [7].

Floating breakwaters are placed horizontally and vertically at water surface without mooring system considered as Case-I and floating breakwaters placed at water surface with mooring system considered as Case-II. And then the wave action and water current force applied on the pontoons for the observation. Result of these observations has been specified as under [8–12].

RESULTS AND DISCUSSIONS

Floating Breakwaters Efficiency Test

To check the efficiency test, floating breakwater at surface with and without mooring system stability of the pontoon is observed and horizontal displacement is calculated in centimeters with least count of 0.5 cm. The results of the same have been specified as in Figures 1 to 4 and Tables 1 to 4.

Stability Test

- *Water tank dimensions:* length 80 cm, width 30 cm, height 30 cm.
- *Wave action period (t):* 60 s
- *Wave height (H):* 5 cm
- *Pontoon weight:* 150 g
- *Pontoon draught height:* The portion water surface level.

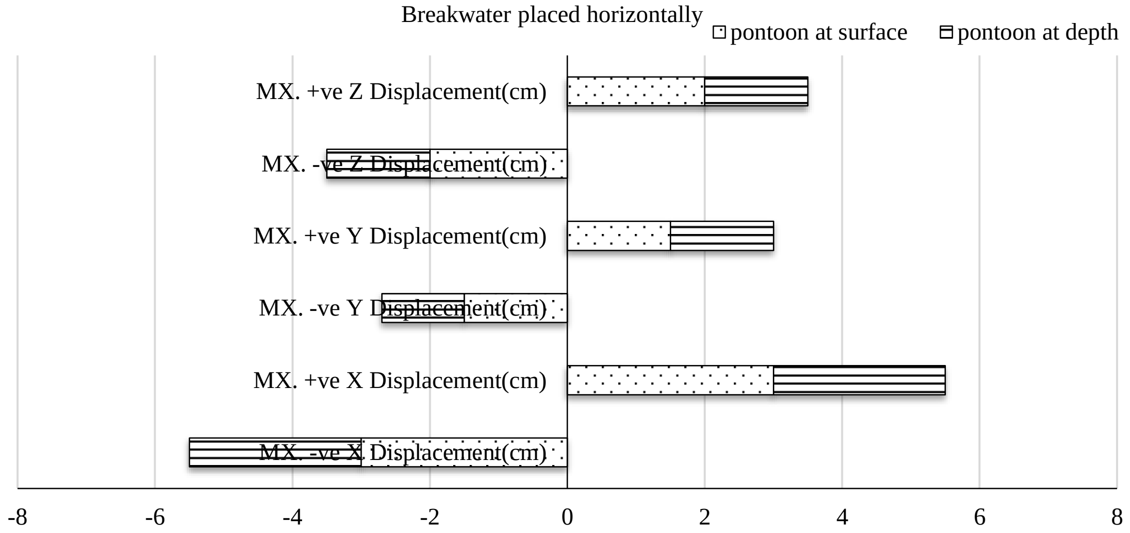

Figure 1. Results of Table 1.

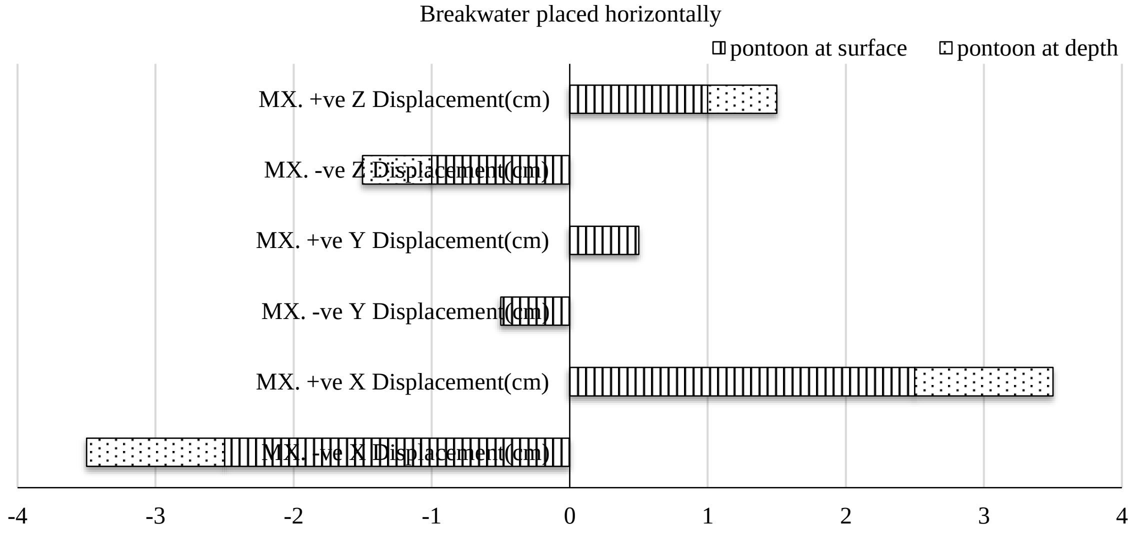

Figure 2. Results of Table 2.

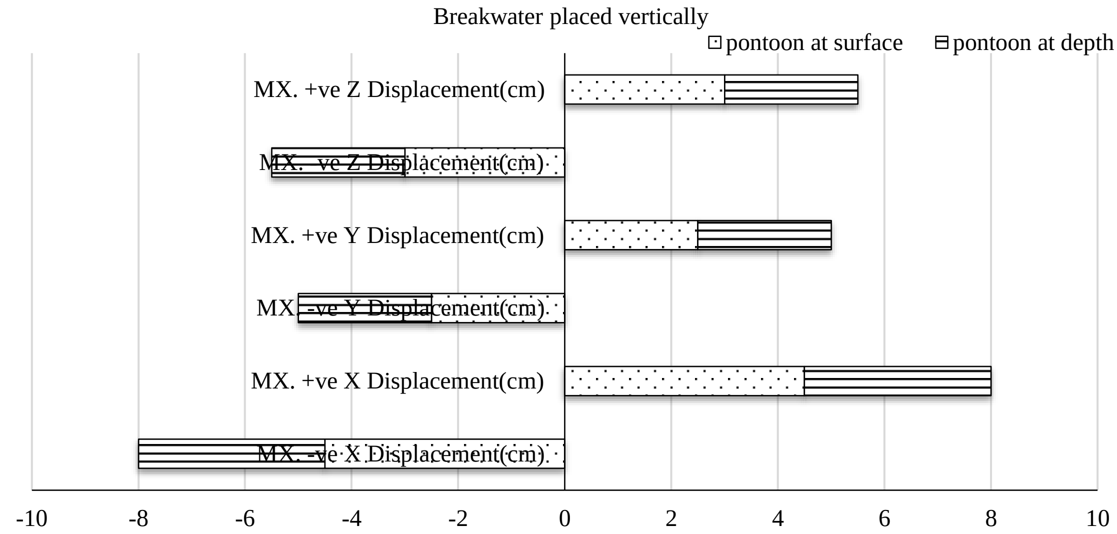

Figure 3. Results of Table 3.

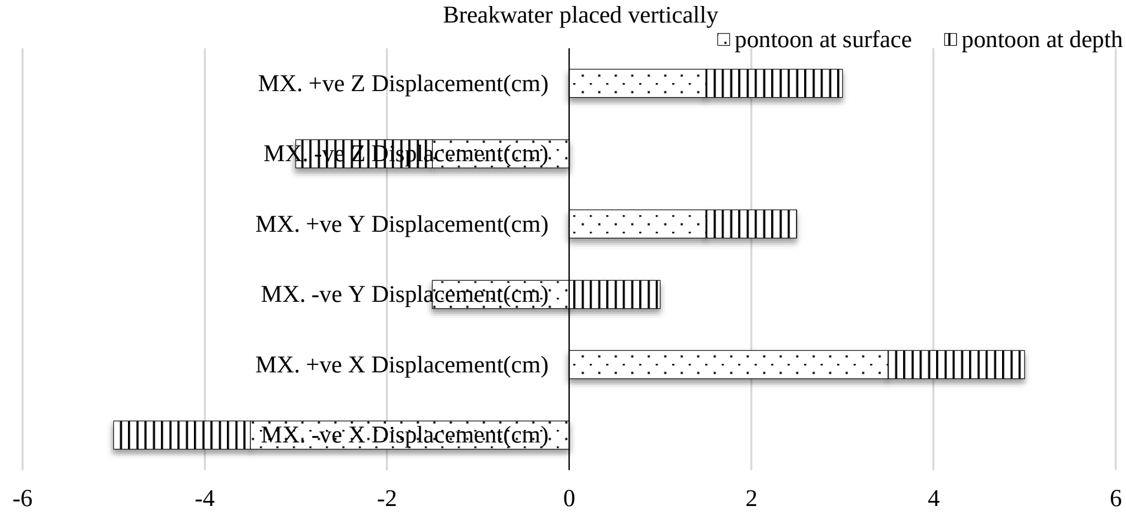

Figure 4. Results of Table 4.

Table 1. Breakwater placed horizontally (Model I).

S.N.	Description	Deflection of Pontoon	
	Model I	***Breakwater Without Mooring System (Case I)***	***Breakwater With Mooring System (Case II)***
1	Pontoon draught height (cm)	2	2
2	Breakwater weight (g)	150	150
3	Breakwater length (cm)	10	10
4	Breakwater height (cm)	5	5
5	Breakwater width (cm)	5	5
6	MX. -ve X displacement (cm)	-3	-2.5
7	MX. +ve X displacement (cm)	3	2.5
8	MX. -ve Y displacement (cm)	-1.5	-1.2
9	MX. +ve Y displacement (cm)	1.5	1.5
10	MX. -ve Z displacement (cm)	-2	-1.5
11	MX. +ve Z displacement (cm)	2	1.5
12	Wave action period (s)	60	60
13	Wave height (cm)	5	5

Table 2. Breakwater placed horizontally (Model II).

S.N.	**Description**	**Deflection of Pontoon**	
	Model II	***Breakwater Without Mooring System (Case I)***	***Breakwater With Mooring System (Case II)***
1	Pontoon draught height (cm)	1	1
2	Breakwater weight (m)	150	150
3	Breakwater length (cm)	10	10
4	Breakwater height (cm)	2.5	2.5
5	Breakwater width (cm)	10	10
6	MX. -ve X displacement (cm)	-2.5	-1
7	MX. +ve X displacement (cm)	2.5	1
8	MX. -ve Y displacement (cm)	-0.5	0
9	MX. +ve Y displacement (cm)	0.5	0
10	MX. -ve Z displacement (cm)	-1	-0.5
11	MX. +ve Z displacement (cm)	1	0.5
12	Wave action period (s)	60	60
13	Wave height (cm)	5	5

Table 3. Breakwater placed vertically (Model I).

S.N.	**Description**	**Deflection of Pontoon**	
	Model I	***Breakwater Without Mooring System (Case I)***	***Breakwater With Mooring System (Case II)***
1	Pontoon draught height (cm)	2	2
2	Breakwater weight (g)	150	150
3	Breakwater length (cm)	10	10
4	Breakwater height (cm)	5	5
5	Breakwater width (cm)	5	5
6	MX. -ve X displacement (cm)	-4.5	-3.5
7	MX. +ve X displacement (cm)	4.5	3.5
8	MX. -ve Y displacement (cm)	-2.5	-2.5
9	MX. +ve Y displacement (cm)	2.5	2.5
10	MX. -ve Z displacement (cm)	-3	-2.5
11	MX. +ve Z displacement (cm)	3	2.5
12	Wave action period (s)	60	60
13	Wave height (cm)	5	5

Table 4. Breakwater placed vertically (Model II).

S.N.	**Description**	**Deflection of Pontoon**	
	Model II	***Breakwater Without Mooring System (Case I)***	***Breakwater With Mooring System (Case II)***
1	Pontoon draught height (cm)	1	1
2	Breakwater weight (m)	150	150
3	Breakwater length (cm)	10	10
4	Breakwater height (cm)	2.5	2.5
5	Breakwater width (cm)	10	10
6	MX. -ve X displacement (cm)	-3.5	-1.5
7	MX. +ve X displacement (cm)	3.5	1.5
8	MX. -ve Y displacement (cm)	-1.5	1
9	MX. +ve Y displacement (cm)	1.5	1
10	MX. -ve Z displacement (cm)	-1.5	-1.5
11	MX. +ve Z displacement (cm)	1.5	1.5
12	Wave action period (s)	60	60
13	Wave height (cm)	5	5

CONCLUSIONS

After evaluating all the comparative results, the following conclusions can be drawn:

1. Floating breakwaters placed horizontal consume the wave energy efficiently compared to vertically placed breakwaters.
2. Floating breakwater with interlocking increases the stress level in the joints. Flexible joints between breakwaters reduce stress levels.
3. Floating breakwaters provided in the single lane are less efficient than breakwaters provided in multiple lanes.
4. Horizontal drag of the wave has same effect on both vertically and horizontally placed breakwaters.
5. Horizontal drag force of water current has more effect on vertically placed breakwater than on horizontally placed breakwater.
6. Mooring system inclusion can improve the relative position stability of the breakwaters.
7. Horizontal mooring system from land fixed support is more effective than vertical mooring system from bottom topography of water body.
8. Floating breakwaters can also be used for energy production due to the mechanical movement of the pontoon.
9. Self-weight of floating breakwater is dominant on the wave energy: The more the self-weight of the breakwater, the more wave energy consumption done by the breakwater.
10. Break waters can be provided from all directions for the maximum stability of the floating structure.
11. Mooring system can also be provided from the floating structure to the breakwater by means of the moving arm. No ground and bottom topography support is needed for the mooring system.
12. In case of breakwater, movement of the breakwater consumes the wave energy, the mooring system is less important compared to the floating structure.

REFERENCES

1. Sun J, Jiang P, Sun Y, Song C, Wang D. An experimental investigation on the nonlinear hydroelastic response of a pontoon-type floating bridge under regular wave action. Ships Offshore Struct. 2018; 13 (3): 233–243.
2. Raftoyiannis IG, Avraam TP, Michaltsos GT. Analytical models of floating bridges under moving loads. Eng Struct. 2014; 68: 144–154.
3. Ghanim AD, Ibrahim MM, Hassan MA. Effect of floating bridges on bottom topography. Ain Shams Eng J. 2021; 12 (1): 475–486.
4. Viuffa T, Leiraa BJ, Xiang X, Øisethc O. Effects of wave directionality on extreme response for a long end-anchored floating bridge. Appl Ocean Res. 2019; 90: 101843.
5. Cheng Z, Gao Z, Moan T. Extreme responses and associated uncertainties for a long end-anchored floating bridge. Eng Struct. 2020; 219: 110858.
6. Petersen ØW, Øiseth O, Lourens E. Full-scale identification of the wave forces exerted on a floating bridge using inverse methods and directional wave spectrum estimation. Mech Syst Signal Process. 2019; 120: 708–726.
7. Kvåle KA, Sigbjörnsson R, Øiseth O. Modelling the stochastic dynamic behaviour of a pontoon bridge: a case study. Computers Struct. 2016; 165: 123–135.
8. Sha Y, Amdahl J, Aalberg A, Yu Z. Numerical investigations of the dynamic response of a floating bridge under environmental loadings. 2018; 13 (Sup1): 113–126.
9. Cheng Z, Gao Z, Moan T. Numerical modeling and dynamic analysis of a floating bridge subjected to wind, wave, and current loads. J Offshore Mech Arctic Eng. 2019; 141 (1): 011601.
10. Kvåle KA, Øiseth O, Rønnquist A. Operational modal analysis of an end-supported pontoon bridge. Eng Struct. 2017; 148: 410–423.
11. Shia QJ, Xua DL, Zhanga HC, Zhaoa H, Wub YS. Optimized stiffness combination of a flexible-base hinged connector for very large floating structures. Marine Struct. 2018; 60: 151–164.
12. Petersen ØW, Øiseth O. Sensitivity-based finite element model updating of a pontoon bridge. Eng Struct. 2017; 150: 573–584.