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Stability Analysis of Pontoons Under Breakwater and Mooring System

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Abstract

Floating pontoons are the new advanced method and technology in the construction industry. Land issues are very common issues in various countries. Constructing on and in the waters is the only option to overcome the land issue. Also, the construction of the bridges and other water-based structures can be constructed by using pontoons. Pontoons have been used in construction since ancient times. This includes temporary bridges and small shelters. It's also used by the military in emergency situations. In this study, the details of the pontoons prepared from concrete that are used in the water-based construction are discussed. Pontoons are basically exposed to three main forces: water current forces, wave forces, and wind forces. This study focused on the stability of the pontoons under application of the forces and helps understand the nature of the pontoon construction with floating breakwater. Floating breakwaters are used to reduce the wave intensity and the intensity of the wave force. In this study, the behavior of the pontoon in relative depth of waters. And observe the results of the waves and water currents on each level of the pontoon depth. The waves are stronger and produce a higher effect on the surface than the bottom layers of the same waters. The same wave has lowered magnitude and wave height at the bottom levels of the waters compared with the surface of the waters. The mooring system is provided from the bottom topography of the seabed or land. By using strong cables, these cables are connected strongly between the pontoon and fixed support.

Keywords: Pontoon, floating structure, floating breakwater, mooring system, constructing on waters

INTRODUCTION

Pontoons have been used since ancient times. Most of the time, the pontoons are used in emergency cases. Such as the army and emergency agencies. Basically, pontoons are the phenomenon that provides buoyancy to the other materials. In ancient times, the pontoons were made from such material, which is capable of good floating capability. In today's era, we can produce the pontoons, which are prepared from concrete. These pontoons can be used as temporary or permanent structures based in the water.

When the water-based construction is necessary and the land issue is major in the various countries, then the pontoon construction is the only option to overcome this type of critical case. Pontoons are made from RCC and have a complete hollow. The trapped air inside provides the necessary buoyant force. This force is enough to keep the pontoon afloat in the water and carry some additional weight on the pontoon. Then the superstructure can be easily constructed on or placed on the pontoon. This type of project can be done when the depth of the water is very deep and the bottom topography of the surface water is very deep. In that case, we cannot

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construct the foundation in such depth. And the stability of such construction is also lowered. The cost of such a project is also very high. Instead of taking the foundation support from the bottom of the topography, we can use the pontoons for the same construction [1–3].

Pontoons are kept afloat on the water surface; in such a case, the pontoons became very unstable. The pontoons also get affected by the wind and wave action of the water. The current forces of the water are also responsible for the instability of the pontoons. For stability of the pontoons and structure above it, we must make the pontoon structure, and the floating breakwater (FB) must be provided along the pontoon structure. Floating breakwaters are provided to absorb the wave energy. Without FB, the wave will directly collapse on the pontoons and make it unstable. FB is made of concrete and kept afloat in the water tied with the strong cables so that it can reduce the intensity of the wave magnitude. The wave energy and effect of the same wave are dependent directly on the wave height. The maximum wave height, the magnitude of the wave, is high. FB simply reduces the wave intensity and helps make the pontoon stable [4–6].

The pontoon structure needs the mooring system for additional safety against instability. The mooring system is simply taking the additional support from the bottom topography or the fixed support from the land. This can be done by using strong cables. The cables are strongly connected by the pontoons and the fixed support. The cables make sure that pontoons stay in the required place. For safety factor, we can add more than required mooring system. From different fixed supports. Multiple supports make the pontoon structure stable. The mooring system also ties along with the other pontoons, so all the structures, resting on the pontoons will be in the required place [7, 8].

POONTOON

Pontoon is defined as the floating platform used for supporting the bridges. It provides additional buoyancy to others. The pontoon has a hollow structure with air trapped inside for buoyancy. Pontoons have floating material inside for keeping the water getting inside [9, 10].

Typically, pontoons are used for the construction of bridges. The bridges required strong support for stability, where there is no space for strong support, we must have to use the pontoons which will keep floating and support the bridge. Pontoons are also used for very large floating structures. For very large structures, a number of pontoons are used for the project in a specific manner with interlocking arrangements. Pontoons have proven the effectiveness of the floating structures.

Floating construction is also the cost-effective method for water-based structures. When compared with the traditional method of bridges and water-based structure construction. For stability of the pontoon and the pontoons structures, the floating breakwaters are required. Floating break waters just absorb the wave energy and reduce the impact on the pontoon structure. The wave height is also reduced when the wave passes through the floating breakwaters. The breakwater is also kept floating in the water. Its function is the same as the coastal breakwaters. The mooring system is also used for the stability of the pontoon. This system provides stability by means of the cables attached with the fixed support from bottom topography or from the land beside the project (Figure 1) [11, 12].

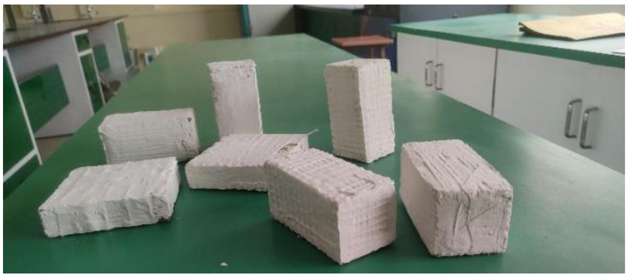

Figure 1. Pontoon.

PRECURSORY STUDIES

Literatures

A newly developed bending moment measurement method was proposed in this paper. With this method, each module was divided into two parts, connected by four equivalent connection beams to guarantee continuity. The bending moment can then be obtained from the forces measured from the connection beams.

The numerical results obtained from the classical hydroelastic theory still show a good agreement with the experimental data, indicating that the nonlinear effects on the displacement might be minor because of the lower magnitude of the displacement [1].

The influence of the moving load velocity on the dynamic response of the bridge is negligibly small with regard to the maximum amplitude, while for usual speeds (10–20 m/s), the bridge oscillation amplitude is significantly high. For relatively high speeds of the moving load, the bridge oscillation amplitude is comparably small. This is somehow expected for high speeds of the moving load since the bridge is difficult to follow the speed of the load due to inertia and buoyancy forces of each pontoon [2].

The constant action of the hydrodynamic forces due to traveling waves causes oscillations with significant amplitude in the cases of light-weighted pontoons, while for heavy-weighted pontoons this effect is significantly lower. The traveling waves' characteristics are also significantly affecting the oscillation amplitudes especially when their values are within the range of bridge eigen periods and pontoon lengths [3].

To shield the bed material from scouring, the channel must be lined at the site of the floating bridge. The minimum upstream protection length has to be 2 yt, regardless of the diameters of the bed. The morphological changes are imperceptible at the first 1 m upstream the bridge, as most of the changes, are located underneath and downstream the bridge. The maximum scour depth is located just upstream the bridge under any flow condition. The influence of any tested parameter is highlighted on the scour depth; however, it can be ignored on the scour length. Regardless of the bridge length and draft, the morphological changes increase as the discharge increment and tailwater depth decline [4].

An extensive parametric study has been performed based on 40 3-hrealizations for 12 different wave environments, accounting for changing main wave direction and spreading exponent. A low sensitivity towards the spreading exponent is observed in the average extrapolated extreme. Von Misses stress of the bridge girder, and based on structural symmetry, changes in the main wave direction are insignificant for directions within 15° from the beam sea. The transverse and vertical response spectra show a similar behavior, except for main wave directions more than 15° from Beam Sea, where a significant change is observed. This effect is thought to be linked to spatial, although the high structural complexity with several important natural periods within 0.1 s of each other makes it difficult to verify [5–7].

Specific Objectives of the Study

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

1. To check the effect of water waves and current forces for a specific duration.
2. To check the workability of pontoons provided in single and multiple in division.
3. Comparison between pontoons at surface level and pontoons in the depth.
4. To check the results under wave action of a 60-second time period with continuous wave height.
5. To check the shape and size difference of the pontoon and its effects.

METHODOLOGY

In this study, the scale models of the pontoons are prepared and observed for its stability under the wave action and the water current forces. Two pontoons are prepared of 10X5X5 and 10X10X5 of sizes with the same weight. Named Model I and Model II, respectively.

Pontoons are placed at the water surface level, considered Case I, and pontoons placed in the depth are considered Case II. And then the wave action and water current force applied to the pontoons for the observation. The result of these observations has been specified as under [8–10].

RESULTS AND DISCUSSIONS

Pontoon Stability Test

- To check the Stability of pontoon at surface as well as in the depth, stability test was used.
- The results of the same have been specified as under Tables 1–6 and Figures 2–7.

Table 1. Case I: Pontoon (without breakwaters and mooring system).
Model I: Pontoon, length = 10 cm, width = 5 cm, height = 5 cm.

S.N.	Description	Pontoons at surface level	Pontoons at depth level
1.	Pontoon depth height (cm) from water surface	0	15
2.	Pontoon draught height (cm)	2	5
3.	Pontoon weight (gm)	150	150
4.	Pontoon length (cm)	10	10
5.	Pontoon height (cm)	5	5
6.	Pontoon width (cm)	5	5
7.	MX. –ve X Displacement (cm)	–5	–3.5
8.	MX. +ve X Displacement (cm)	5	3.5
9.	MX. –ve Y Displacement (cm)	–2	–1
10.	MX. +ve Y Displacement (cm)	2	1
11.	MX. –ve Z Displacement (cm)	–4	–2
12.	MX. +ve Z Displacement (cm)	4	2
13.	Wave action period (sec)	60	60
14.	Wave height (cm)	5	5

Table 2. Case I: Pontoon (without breakwaters and mooring system).
Model II: Pontoon, length = 10 cm, width = 10 cm, height = 2.5 cm.

S.N.	Description	Pontoons at surface level	Pontoons at depth level
1.	Pontoon depth height (cm) from water surface	0	15
2.	Pontoon draught height (cm)	1	2.5
3.	Pontoon weight (gm)	150	150
4.	Pontoon length (cm)	10	10
5.	Pontoon height (cm)	2.5	2.5
6.	Pontoon width (cm)	10	10
7.	MX. –ve X Displacement (cm)	–4	–3
8.	MX. +ve X Displacement (cm)	4	3
9.	MX. –ve Y Displacement (cm)	–2	–1
10.	MX. +ve Y Displacement (cm)	2	1
11.	MX. –ve Z Displacement (cm)	–5	–4
12.	MX. +ve Z Displacement (cm)	5	4
13.	Wave action period (sec)	60	60
14.	Wave height (cm)	5	5

Table 3. Case II: Pontoon with breakwaters. Model I: Pontoon length = 10 cm, width = 5 cm, height = 5 cm.

S.N.	Description	Pontoons at surface level	Pontoons at depth level
1.	Pontoon depth height (cm) from water surface	0	15
2.	Pontoon draught height (cm)	2	5
3.	Pontoon weight (gm)	150	150
4.	Pontoon length (cm)	10	10
5.	Pontoon height (cm)	5	5
6.	Pontoon width (cm)	5	5
7.	MX. –ve X Displacement (cm)	–3	–2
8.	MX. +ve X Displacement (cm)	3	2
9.	MX. –ve Y Displacement (cm)	–1	–0.5
10.	MX. +ve Y Displacement (cm)	1	0.5
11.	MX. –ve Z Displacement (cm)	–2.5	–1
12.	MX. +ve Z Displacement (cm)	2.5	1
13.	Wave action period (sec)	60	60
14.	Wave height (cm)	5	5

Table 4. Case II: Pontoon with breakwaters. Model II: Pontoon length = 10 cm, width = 10 cm, height = 2.5 cm.

S.N.	Description	Pontoons at surface level	Pontoons at depth level
1.	Pontoon depth height (cm) from water surface	0	15
2.	Pontoon draught height (cm)	1	2.5
3.	Pontoon weight (gm)	150	150
4.	Pontoon length (cm)	10	10
5.	Pontoon height (cm)	2.5	2.5
6.	Pontoon width (cm)	10	10
7.	MX. –ve X Displacement (cm)	–3	–2.5
8.	MX. +ve X Displacement (cm)	3	2.5
9.	MX. –ve Y Displacement (cm)	–1.5	–0.5
10.	MX. +ve Y Displacement (cm)	1.5	0.5
11.	MX. –ve Z Displacement (cm)	–3	–2
12.	MX. +ve Z Displacement (cm)	3	2
13.	Wave action period (sec)	60	60
14.	Wave height (cm)	5	5

Table 5. Case III: Pontoon with breakwaters and mooring system.
Model I: Pontoon length = 10 cm, width = 5 cm, height = 5 cm.

S.N.	Description	Pontoons at surface level	Pontoons at depth level
1.	Pontoon depth height (cm) from water surface	0	15
2	Pontoon draught height (cm)	2	5
3.	Pontoon weight (gm)	150	150

4.	Pontoon length (cm)	10	10
5.	Pontoon height (cm)	5	5
6.	Pontoon width (cm)	5	5
7.	MX. –ve X Displacement (cm)	–2	–1
8.	MX. +ve X Displacement (cm)	2	1
9.	MX. –ve Y Displacement (cm)	–0.5	0
10.	MX. +ve Y Displacement (cm)	0.5	0
11.	MX. –ve Z Displacement (cm)	–1.5	–0.5
12.	MX. +ve Z Displacement (cm)	1.5	0.5
13.	Wave action period (sec)	60	60
14.	Wave height (cm)	5	5

Table 6. Case III: Pontoon with breakwaters and mooring system.
Model II: Pontoon length = 10 cm, width = 10 cm, height = 2.5 cm.

S.N.	Description	Pontoons at surface level	Pontoons at depth level
1.	Pontoon depth height (cm) from water surface	0	15
2.	Pontoon draught height (cm)	1	2.5
3.	Pontoon weight (gm)	150	150
4.	Pontoon length (cm)	10	10
5.	Pontoon height (cm)	2.5	2.5
6.	Pontoon width (cm)	10	10
7.	MX. –ve X Displacement (cm)	–2.5	–1
8.	MX. +ve X Displacement (cm)	2.5	1
9.	MX. –ve Y Displacement (cm)	–0.5	0
10.	MX. +ve Y Displacement (cm)	0.5	0
11.	MX. –ve Z Displacement (cm)	–1	0.5
12.	MX. +ve Z Displacement (cm)	1	0.5
13.	Wave action period (sec)	60	60
14.	Wave height (cm)	5	5

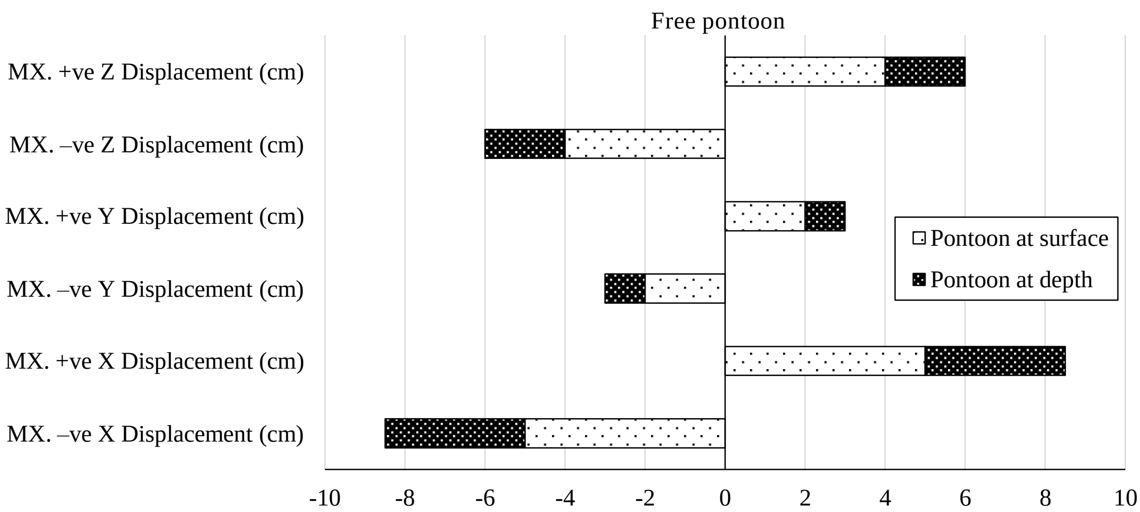

Figure 2. Result of case I model I.

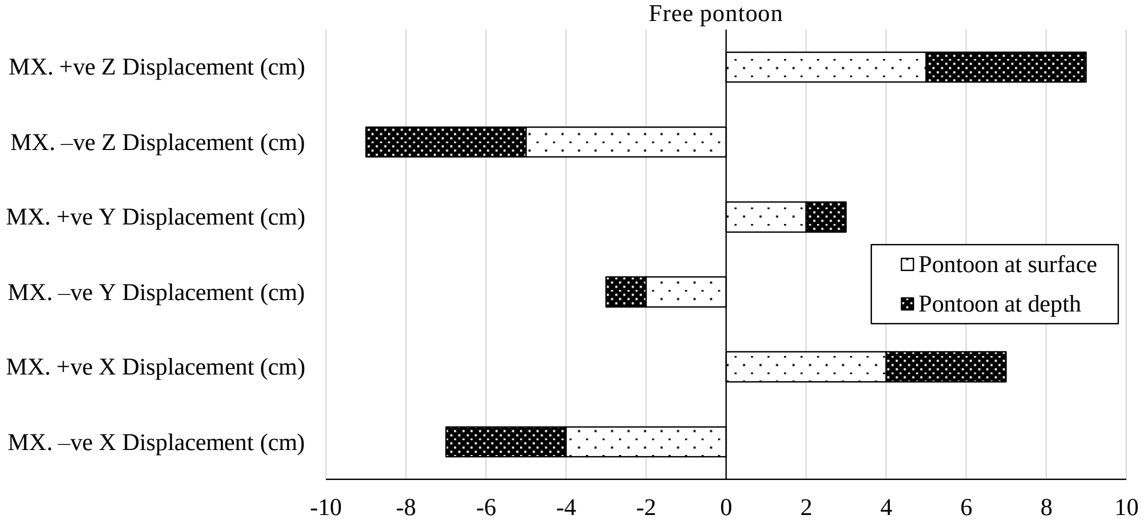

Figure 3. Result of case I model II.

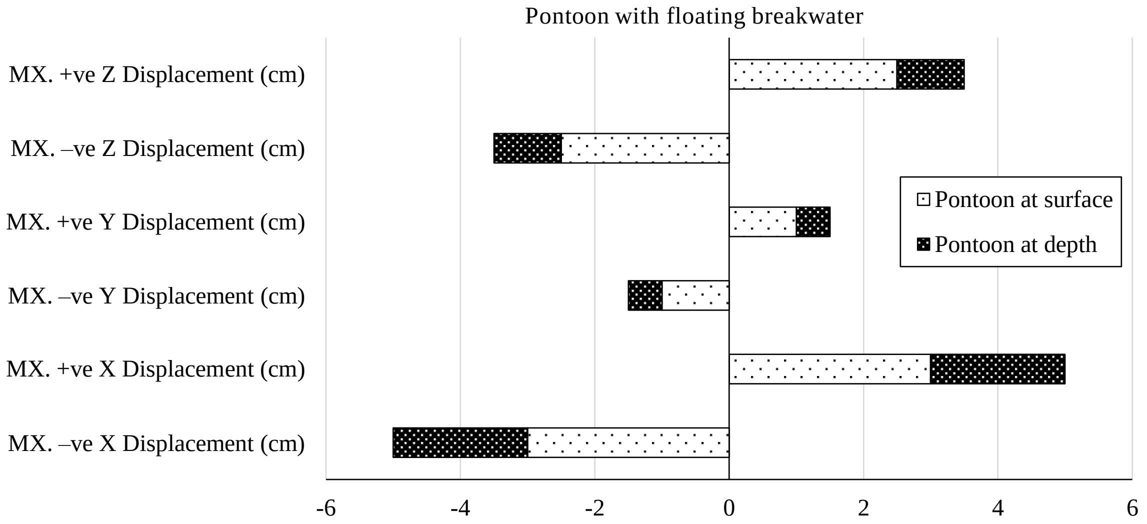

Figure 4. Result of case II model I.

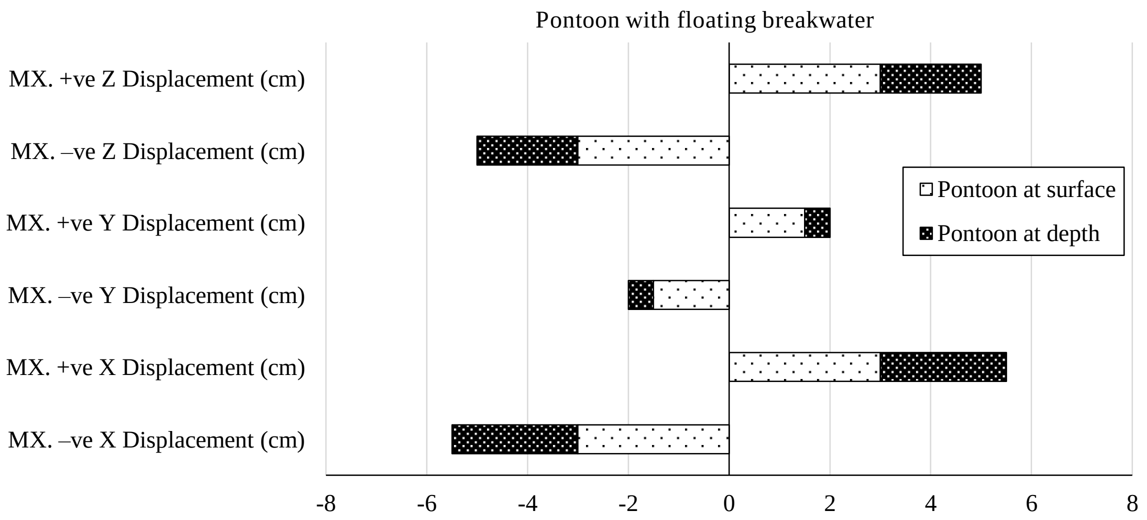

Figure 5. Result of case II model II.

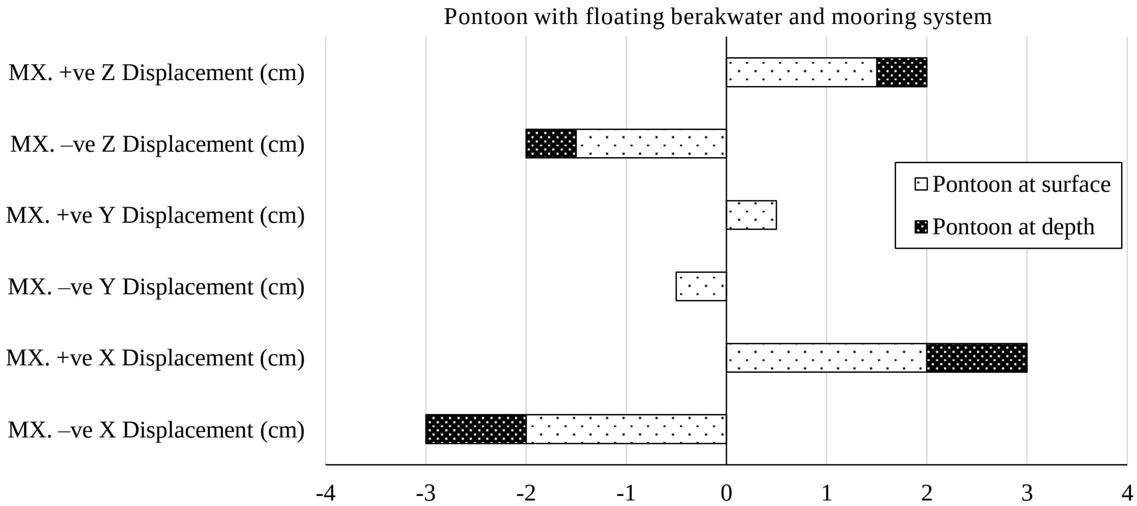

Figure 6. Result of Case III Model I.

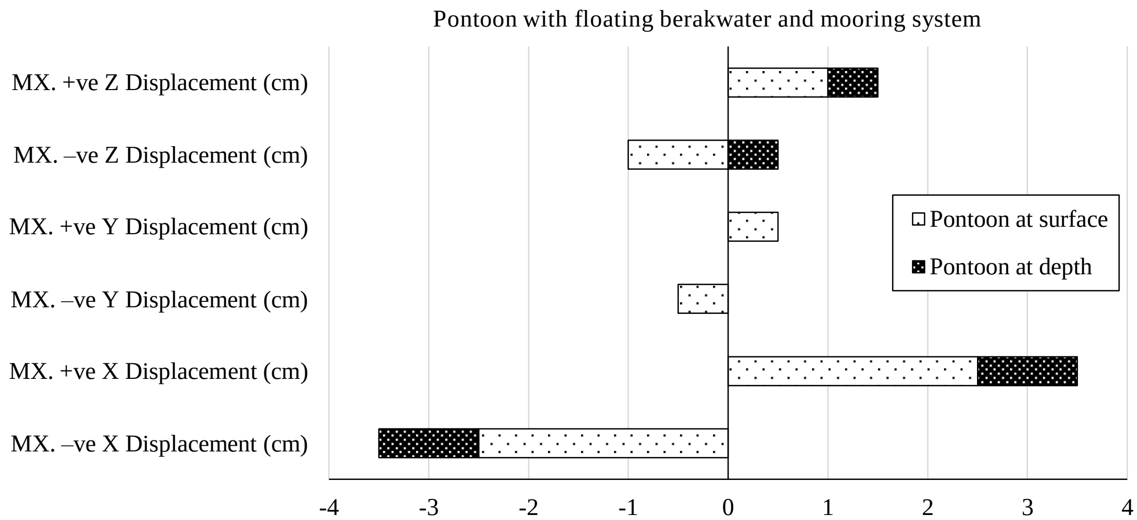

Figure 7. Result of case III model II.

Stability Test

- *Water tank dimensions:* Length = 80 cm; width = 30 cm; height = 30 cm.
- *Wave action period (t):* 60 sec
- *Wave height (H):* 5 cm
- *Pontoon weight:* 150 gm
- *Pontoon draught height:* The portion of the pontoon below water surface level.

CONCLUSIONS

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

1. The inclusion of floating breakwaters and mooring system improves the pontoons’ stability.
2. Fluid filling in the pontoon improves stability and overcomes the overturning effect due to the C.G.
3. The mooring system keeps the pontoon in the position effectively with the strong cable. Cable tensile strength is an important factor in the case of a mooring system.
4. Dolphins of the mooring should be flexible enough to absorb the shock effect during the sway of the pontoon due to waves.
5. Pontoon drag depends on the surface area facing the wave and current; pontoon surface area and the drag are directly proportional.

6. The pontoons buoyant forces depend on the self-weight distribution over the water surface area.
7. Pontoons provided in multiple divisions have the least stability but strong stress-resistant capability. Pontoons provided in single division have more stability but least stress-resistant capability.
8. Diversion of the flow of the current through the pontoon ensures the stability of the pontoons.
9. Division of the waves through the floating breakwater enhances the stability of the floating structure.
10. Mooring systems connected from the bottom of the water topography ensure the vertical stability of the pontoon along the Y axis, while mooring systems connected from the land ensure the horizontal stability of the pontoon along the X axis.
11. Providing multiple mooring supports ensures the highest stability of the pontoon with the floating breakwaters.

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