

Hydrodynamic Performance of a Floating Platform with a Heave Plate Adjacent to a Partially Reflective Vertical Wall

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Received: 20 May 2025 / Accepted: 05 September 2025
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Abstract

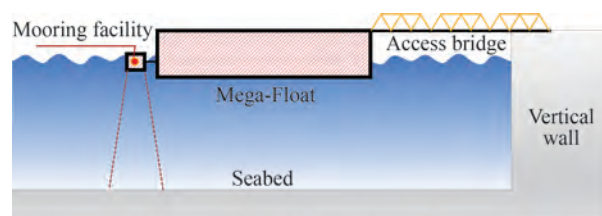
In this paper, a numerical study is performed to investigate the hydrodynamic responses of a floating platform equipped with a heave plate adjacent to a partially reflective vertical wall. Based on the linear potential flow theory, a three-dimensional (3D) boundary element method (BEM) model, incorporating an image Green's function, is developed to solve the wave radiation/diffraction problem in the presence of a partially reflective wall. The results confirm the efficacy of the heave plate, and the hydrodynamic response is governed by the reflection coefficient of the coast and the dimensionless distance between the coast and the platform (C/W_p , where C and W_p are the offshore distance and the width of the floating platform). Compared with open water conditions, the increasing of reflection coefficient suppresses surge motion but amplifies heave motion in the lower frequency region ($\omega < 0.5$ rad/s). Moreover, the surge motion in the lower frequency range increases and the peak heave motion decreases as C/W_p increases within the range of 0.5–3 rad/s.

Keywords Potential theory; Coastal reflection; Hydrodynamic performance; Boundary element method; Heave plate

1 Introduction

The recent expansion of marine development and ocean space utilization has spurred the creation of various novel floating structures (Bagbanci et al., 2012; Nguyen et al., 2020; Micallef and Rezaeiha, 2021; Zhao et al., 2023, 2024; Amouzadrad et al., 2024; Yuan et al., 2025). These novel floating systems are often deployed in nearshore areas, particularly near wharves and breakwaters. Examples of these

systems include the floating airport (e.g., Mega-Float) and floating piers (e.g., Kimberley Marine Support Base), as shown in Figure 1 (Watanabe et al., 2004; KMSB, 2025), as well as floating structures near islands and reefs (Wang et al., 2025a). The hydrodynamic interactions between floating structures and adjacent coastal boundaries are essential for evaluating the response of such floating systems.



(a) Mega-Float (Watanabe et al., 2004)



(b) Kimberley Marine Support Base (KMSB, 2025)

Figure 1 Schematic of the novel floating system

Nearshore wave reflection is a typical hydrodynamic phenomenon due to coastal boundaries. It occurs when incident waves or structure-induced disturbances propagate

Article Highlights

- An image Green's function for the partial wave reflection condition is proposed.
- A BEM model is developed to analyze the effects of partial coastal reflections.
- The influence of the heave plate on hydrodynamic characteristics is investigated.

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toward the shoreline, thereby modifying the local fluid dynamics. Theoretically, the wave-structure interaction in front of vertical walls is often idealized as a full reflection scenario. For instance, Teng et al. (2004) employed an image source technique to investigate wave radiation from a vertical cylinder in front of a wall under full reflection conditions. Ning et al. (2005) extended this approach by introducing a dual-image method to analyze wave diffraction from a cylinder near orthogonal walls. Bhattacharjee and Guedes Soares (2010, 2011) further evaluated wave interaction with a floating structure near a wall with a stepped bottom. Similarly, Zheng and Zhang (2015) developed analytical models to evaluate the wave diffraction from a cylinder near a wall. Loukogeorgaki and Chatjigeorgiou (2019) and Cong et al. (2020) analyzed the hydrodynamic responses of cylinder arrays positioned in front of a vertical wall.

Owing to its flexibility, the boundary element method (BEM) is widely adopted for modeling three-dimensional (3D) problems of wave interaction with arbitrary structures. For example, Xin (2005) employed a 3D potential flow model to analyze the responses of ships in confined waters. Sun et al. (2009) extended the BEM framework to simulate wave-induced forces on vertical cylinders adjacent to vertical walls. Wang et al. (2025b) investigated the hydrodynamic performance of a power take-off damped floating breakwater near a coastal area.

Shoreline generally shows the property of partial reflection. Berkhoff et al. (1976) were the first to propose the concept of a partial reflecting boundary condition, defined by the equation: $\partial\phi/\partial n + \alpha K\phi = 0$, where ϕ denotes the total potential (including the incident and reflected components), and α is a theoretical reflection coefficient. Elchahal et al. (2008) implemented the partial reflection boundary condition in numerical simulations of floating breakwaters in coastal areas. Zhao et al. (2021) investigated the influence of coastal reflection on responses of wave energy devices. More recently, Teng et al. (2025) extended the image method to incorporate partial reflection, thereby enabling 3D analyses of wave radiation and diffraction from a circular cylinder in front of a partially reflective wall.

The mitigation of the motion responses of floating structures is essential for their safety and reliable operation. Numerous studies have focused on improving hydrodynamic performance by incorporating physical attachments, including additional components on floating bridges (Duan et al., 2017; Zhang et al., 2018; Wang et al., 2024), anti-rolling devices for FPSO vessels (Ji et al., 2019; Li et al., 2025), and heave plates to mitigate the motion of platforms and floating wind turbines (Tao and Cai, 2004; Srinivasan et al., 2006; Lopez-Pavon and Souto-Iglesias, 2015; Lavrov and Guedes Soares, 2016; Gui et al., 2025).

Herein, this study focuses on the motion responses of a floating platform in nearshore regions, with particular atten-

tion to mitigating the hydrodynamic responses. A frequency-domain BEM code considering partial coastal reflection is developed. The remainder of the paper is organized as follows: Section 2 introduces the theory and numerical model, Section 3 validates the model, Section 4 presents the parametric study of system performance, and Section 5 concludes the study.

2 Mathematical model

2.1 Governing equation and boundary conditions

A 3D floating body in finite water depth (h) near an infinitely long vertical wall is modeled using the image method. According to this principle, the wave-structure interaction can be equivalently represented using two symmetrically placed floating bodies. As illustrated in Figure 2, the pink and transparent floating boxes represent the real body and its mirror image, respectively. A right-handed Cartesian coordinate system, o -xyz, is also established, where the o -xy and o -yz planes represent the still water surface and vertical wall, respectively. Notably, the positive z -axis extends vertically (upward).

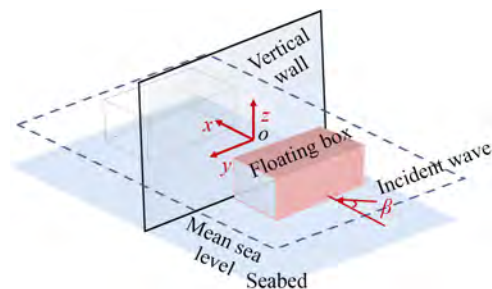


Figure 2 Sketch of the image method (β is the incident wave angle relative to the x -axis)

Based on the linear wave radiation/diffraction theory, the total velocity potential (ϕ) induced by a floating body in waves can be decomposed into incident (ϕ_0), diffraction (ϕ_7), and radiation (ϕ_m) potentials. ϕ is expressed as follows:

$$\phi = \phi_0 + \phi_7 - i\omega\eta_m\phi_m \quad (1)$$

where $i = \sqrt{-1}$; ω is the wave frequency; η_m ($m = 1, 2, \dots, 6$) are the response amplitudes of the body in surge, sway, heave, roll, pitch, and yaw degree of freedom (DOF), respectively; ϕ_m ($m = 1, 2, \dots, 6$) denote the radiation potentials induced by the unit-amplitude forced harmonic motion of the body in the m th DOF.

The potential ϕ_m , near the reflective wall, comprises the normal potential, $\phi_{N,m}$, and reflected potential, $\phi_{R,m}$, induced by the vertical wall in the x -direction. These wave potentials satisfy the boundary conditions of the reflected vertical wall, as follows:

$$\phi_m = \phi_{N,m} + \phi_{R,m}, \phi_{R,m} = R\phi_{N,m} (m = 1, 2, \dots, 7) \quad (2)$$

Here, R is the reflection coefficient ($R = K_R e^{i\sigma}$), where K_R represents the ratio of $\phi_{R,m}$ to ϕ_0 , and σ denotes the phase lag, indicating that $\phi_{R,m}$ lags ϕ_0 by $-\sigma$ radians.

Additionally, ϕ_0 is expressed as:

$$\phi_0 = -\frac{igA}{\omega} \frac{\cosh k(z+h)}{\cosh kh} \cdot \left(e^{ik(x \cos \beta + y \sin \beta)} + R e^{ik(-x \cos \beta + y \sin \beta)} \right) \quad (3)$$

where A , ω , and β denote the wave amplitude, the wave frequency, and the incident wave angle, respectively; g is gravitational acceleration; the wave number (k) satisfies the linear dispersion relation: $\omega^2 = gk \tanh(kh)$.

Further, ϕ satisfy the governing equation of the Laplace equation, $\nabla^2 \phi = 0$, in the entire field region. Here, S_F , S_B , and S_D denote the free surface, wetted surface of the body, and seabed, respectively. Additionally, the following boundary conditions must be satisfied:

$$\begin{cases} \frac{\partial \phi}{\partial z} - K\phi = 0 & \text{at } S_F \\ \frac{\partial \phi}{\partial z} = 0 & \text{at } S_D \\ V_m = n_m & m = 1, 2, \dots, 6 \text{ at } S_B \\ V_m = \frac{\partial \phi}{\partial \mathbf{n}} & m = 7 \text{ at } S_B \end{cases} \quad (4)$$

where $K = \omega^2/g$ denotes wave number in deep water; $(n_1, n_2, n_3) = \mathbf{n}$ and $(n_4, n_5, n_6) = \mathbf{x} \times \mathbf{n}$, $\mathbf{n}$ is the unit normal vector on the surface and points toward the interior of the fluid domain, $\mathbf{x}$ is the position of a point on the body. Additionally, the far-field Sommerfeld condition shall be satisfied.

2.2 Green's function and the integral equations

Green's function satisfying the S_F condition can be expressed as follows (Newman, 1985):

$$G(\xi, \mathbf{x}) = \frac{1}{r_1} + \frac{1}{r_2} + \int_0^\infty \frac{2(k+K) \cosh(k(z+h)) \cosh(k(\zeta+h))}{k \sinh(kh) - K \cosh(kh)} e^{-kh} J_0(kr) dk \quad (5)$$

where $\xi = (\xi, \eta, \zeta)$ and $\mathbf{x} = (x, y, z)$ represent the coordinates of the source and field points, respectively; r_1 is the distance between the source and the field points; r_2 is the distance between the field point and the image of the source point with respect to S_D ; $J_0(x)$ is the zero-order Bessel function; and r is the horizontal distance between the source and field points.

For semi-infinite open water with a partially reflective vertical wall, Green's function must satisfy the boundary condition at S_F , the Sommerfeld condition, and the vertical wall boundary condition. Further, the partially reflected image Green's function G_M can be expressed as a combination of the values of the open water and its reflected mirror:

$$G_M(\xi, \mathbf{x}) = G(\xi, \mathbf{x}) + RG(\xi', \mathbf{x}) \quad (6)$$

where $\xi' = (-\xi, \eta, \zeta)$ is the coordinate of the source point image with respect to the vertical wall.

In this paper, ϕ_m on S_B is determined using a mixed source-dipole boundary integral equation (BIE) as follows:

$$2\pi\phi_m(\mathbf{x}) + \phi_m(\xi) \iint_{S_B} \frac{\partial G_M(\xi, \mathbf{x})}{\partial n(\xi)} ds = \iint_{S_B} G_M(\xi, \mathbf{x}) V_m(\xi) ds \quad (7)$$

S_B is further discretized into N_p mesh elements, where curved surfaces are approximated using planar quadrilateral elements. The BIE can also be discretized into a system of equations by applying a discretization scheme ($m = 1, 2, \dots, 7; i, j = 1, 2, \dots, N_p$):

$$2\pi\phi_m(\mathbf{x}_i) + \sum_{j=1}^{N_p} \phi_m(\xi_j) \frac{\partial G(\xi_j, \mathbf{x}_i)}{\partial n(\xi_j)} \Delta S_j = \sum_{j=1}^{N_p} G(\xi_j, \mathbf{x}_i) V_m(\xi_j) \Delta S_j \quad (8)$$

The procedure for solving the integral equation is similar to that used for the open water case, as described in Zhou et al. (2024). Thus, ϕ_m can be determined by solving the linear algebraic system through Gaussian elimination.

The first-order wave exciting force in m th DOF ($F_E^{(m)}$) and the radiation force in the m th DOF induced by the forced motion of the body in the n th DOF ($F_R^{(m,n)}$) are expressed as follows ($m, n = 1, 2, \dots, 6$):

$$F_E^{(m)} = -i\omega\rho \iint_{S_B} (\phi_0 + \phi_7) V_m ds \quad (9)$$

$$F_R^{(m,n)} = -i\omega\rho \iint_{S_B} \phi_m V_n ds \quad (10)$$

The added mass ($A_{m,n}$) and radiation damping ($B_{m,n}$) along the m th DOF caused by the body motion in n th DOF can be expressed as follows:

$$\begin{cases} A_{m,n} = \text{Im}(F_R^{(m,n)})/\omega \\ B_{m,n} = -\text{Re}(F_R^{(m,n)}) \end{cases} \quad (11)$$

Following Haskind's relation (Haskind, 1957), the wave exciting force can also be calculated as follows:

$$F_{E,H}^{(m)} = -i\omega\rho \iint_{S_b} \left(\phi_0 \frac{\partial \phi_m}{\partial V_m} - \phi_m \frac{\partial \phi_0}{\partial \mathbf{n}} \right) d\mathbf{s} \quad (12)$$

The dimensionless wave exciting forces and hydrodynamic coefficients are defined as follows:

$$\bar{F}_m = \frac{F_E^{(m)}}{\rho g A S}, \quad m = 1, 3 \quad (13)$$

$$\bar{A}_{m,n} = \frac{A_{m,n}}{\rho V}, \quad m = n = 1, 3 \quad (14)$$

$$\bar{B}_{m,n} = \frac{B_{m,n}}{\rho V \sqrt{ga}}, \quad m = n = 1, 3 \quad (15)$$

Here, S and V represent the waterline surface area and displacement of the body, respectively. These parameters take specific geometric forms depending on the model: For Section 3, $S = \pi a^2$ and $V = \pi a^2 h$; for Section 4, $S = L_b D_b$ (when $m = 1$) and $L_b W_b$ (when $m = 3$), and $V = L_b D_b W_b$. The symbols are clarified in Figure 3.

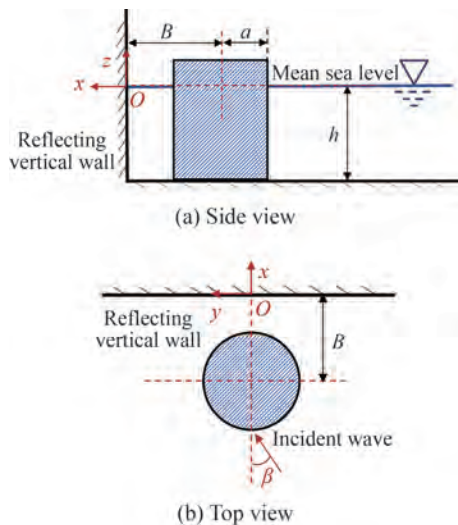


Figure 3 Configuration of the bottom-mounted cylinder near a vertical wall

The floating body motion equation can be written as follows:

$$\{-\omega^2(\mathbf{M} + \mathbf{A}) - i\omega\mathbf{B} + \mathbf{C}\}\boldsymbol{\eta} = \mathbf{F}_E \quad (16)$$

where $\mathbf{M}$ is the mass matrix; $\mathbf{A} = [A_{m,n}]$ and $\mathbf{B} = [B_{m,n}]$ are the added mass and damping matrices; $\mathbf{C}$ is hydrostatic restoring force matrix; $\boldsymbol{\eta} = \{\eta_m\}^T$ and $\mathbf{F}_E = \{F_E^{(m)}\}^T$ ($m, n = 1, 2, \dots, 6$).

2.3 Removal of irregular frequencies

Irregular frequencies are a common issue in formulating the BIE. These frequencies correspond to the natural eigen-

frequencies of the interior fluid domain (the volume enclosed by the body). When the incident wave frequency matches one of these internal eigenfrequencies, the Equation (8) fails to provide a unique solution.

An over-determined boundary integral approach is adopted to mitigate the effects of such irregular frequencies. This method assumes that ϕ on the internal water surface enclosed by the water line is zero. To do this, several panels (S_{WP}) are placed along the interior waterline surface of the floating body. By applying Green's theorem as well as incorporating these additional panels into the Equation (8), an extra BIE is derived, resulting in an over-determined system of equations.

Furthermore, mirror-image panels can be arranged on a symmetrically extended region of the waterline surface to account for wave reflection from the vertical wall. Based on the image Green's function, an irregular frequency removal method that accounts for coastal reflection conditions can be constructed as follows:

$$\phi_m(\boldsymbol{\xi}) \iint_{S_b} \frac{\partial G_M(\boldsymbol{\xi}, \mathbf{x})}{\partial n(\boldsymbol{\xi})} d\mathbf{s} = \iint_{S_b} G_M(\boldsymbol{\xi}, \mathbf{x}) V_m(\boldsymbol{\xi}) d\mathbf{s}, \quad \mathbf{x} \in S_{WP} \quad (17)$$

By discretizing S_{WP} into N_{WP} elements, a set of over-determined linear algebraic equations is obtained as:

$$\mathbf{A}_{(N_p + N_{WP}) \times N_p} \boldsymbol{\phi}_{N_p \times N_p} = \mathbf{B}_{(N_p + N_{WP}) \times N_p} \quad (18)$$

The over-determined integral equations can be numerically solved using the least squares method (Anderson et al., 1999).

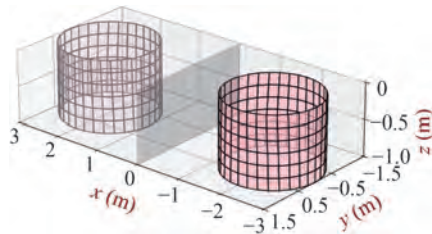
3 Model verification

This section employs a bottom-mounted cylinder for model verification (Figure 3). The cylinder has a radius $a = 1$ m, and its center is located at a distance $B = 2a$ from the vertical wall. The draft of the cylinder is $h = a$.

Convergence tests were conducted across four mesh cases (Meshes I, II, III, and IV), consisting of 80, 168, 288, and 550 panels, respectively. In these tests, the cylinder's wetted surface was discretized into uniformly distributed quadrilateral elements. The wave exciting force was calculated at $\beta = 0^\circ$, and the dimensionless wave exciting forces in the surge mode are presented in Table 1. The results obtained for Meshes III and IV agree up to the fifth significant digit. Although all meshes yielded reasonably accurate results, Mesh III provided a satisfactory balance between accuracy and computational efficiency and was adopted for subsequent simulations. Figure 4 depicts Mesh III. The pink mesh represents the actual mesh of the cylinder, the gray mesh denotes its mirror image, and the gray plane is the symmetry plane.

Table 1 Convergence evaluation on the dimensionless surge force ($\beta = 0^\circ$)

ka	Mesh I	Mesh II	Mesh III	Mesh IV
0.5	1.925334	1.925516	1.925466	1.925401
1.0	1.378504	1.378646	1.378029	1.378029
1.5	0.275181	0.275375	0.275206	0.275211
2.0	0.760027	0.760102	0.760113	0.760112
2.5	0.659354	0.659320	0.659313	0.659311
3.0	0.060377	0.060396	0.060523	0.060523

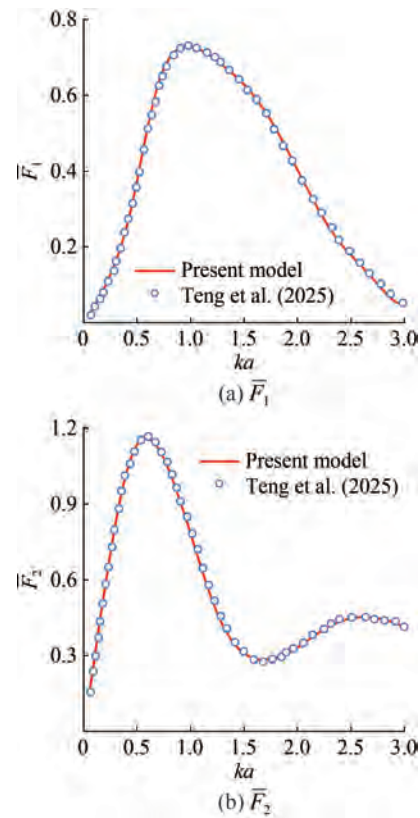
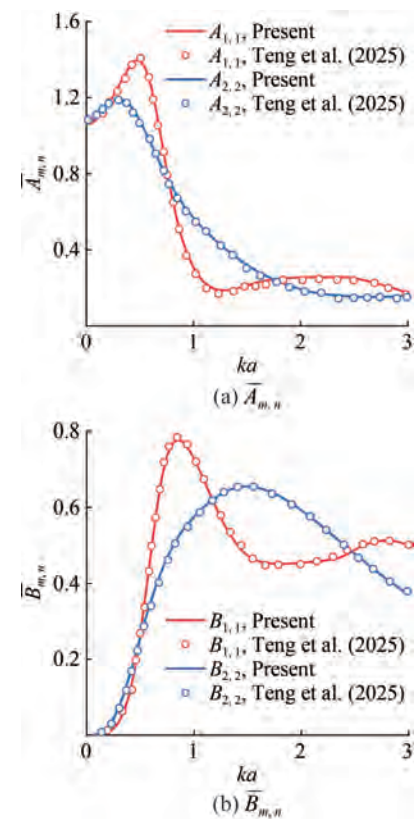
**Figure 4** Computational mesh of the cylinder

The dimensionless wave exciting forces in the surge ($\bar{F}_1$) and sway ($\bar{F}_2$) directions are compared with those in Teng et al. (2025). Figure 5 shows the dimensionless surge and sway exciting forces obtained at $\beta = 60^\circ$, with $R = 0.6$. Additionally, Figure 6 compares the $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$ in the surge and sway modes for $R = 0.6$. The present results demonstrate good agreement with those of Teng et al. (2025). This verifies the present model for calculating the wave exciting force and hydrodynamic coefficients considering the partially reflective wall.

4 Results and discussions

Motivated by the Mega-Float design, the hydrodynamic performance of a floating platform positioned in front of a vertical wall is investigated here. As shown in Figure 7, the vertical wall corresponds to the $x = 0$ plane. The floating platform is positioned at a distance C from this wall. In this system, the floating platform and the heave plate are connected by rigid rods. The hydrodynamic effect of the connecting rods is neglected in this study owing to their negligible cross-sectional area compared to the main floating components. L_b , W_b , and D_b represent the length, width, and draft of the floating platform. Similarly, L_p , W_p and H_p denote the corresponding dimensions of the heave plate. These parameters are presented in Table 2 and are kept constant. D_p denotes the distance from the bottom of the heave plate to the free surface.

Figure 8 shows the mesh of the floating platform and the heave plate after convergence verification ($D_p = 2a$). It comprised 2 269 wetted surface mesh elements (illustrated in pink). And 50 additional mesh elements (illustrated in

**Figure 5** Results of $\bar{F}_m$ for the cylinder ($\beta = 60^\circ$, $R = 0.6$)**Figure 6** Results of $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$ for the cylinder ($R = 0.6$)

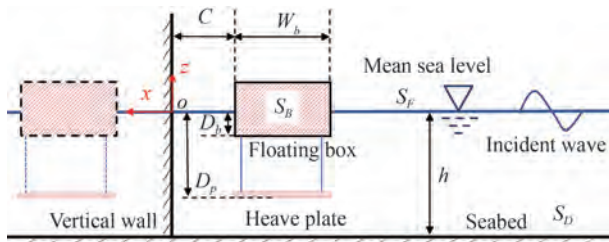


Figure 7 Sketch of the floating platform with a heave plate system in front of a vertical wall

Table 2 Parameters of the floating platform and heave plate

L_b	W_b	D_b	h
$10a$	$5a$	a	$10a$
L_p	W_p	H_p	a
$10a$	$5a$	$0.1a$	2 m

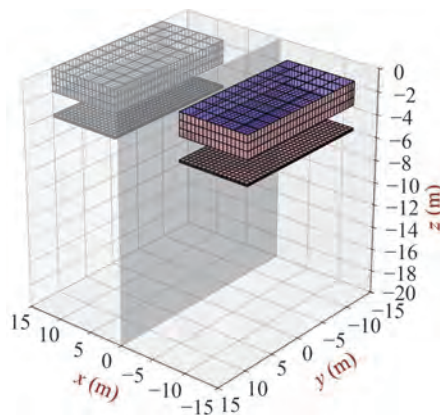


Figure 8 Computational mesh for the floating platform and the heave plate

blue) were added to remove irregular frequencies. The gray meshes are image surface elements.

4.1 Effects of the position of the heave plate

The influence of the heave plate position, expressed by the dimensionless spacing ratio, $D_p/D_b = 1.5, 2, 3, 4$, and 5 , on the wave loads and motion responses of the floating platform was first examined under open water condition ($R = 0$) for $C = 2.5a$ and $\beta = 0^\circ$. In this subsection, the results of $\bar{F}_m$, $\bar{A}_{m,n}$, $\bar{B}_{m,n}$, and the response amplitude operators (RAOs) are presented and discussed.

Figure 9 illustrates the variations in the dimensionless surge and heave exciting forces ($\bar{F}_1$ and $\bar{F}_3$) as functions of ω for different D_p/D_b cases in open water case. Further, $\bar{F}_1$ (Figure 9(a)) exhibits a single-peak trend, reaching a maximum at $\omega = 1.35$ rad/s. The heave plate position influences the magnitude of this peak. Specifically, at $D_p/D_b = 1.5$, $\bar{F}_1$ reaches a maximum of 1.92, corresponding to an 11% increase relative to the baseline case without a heave plate. As D_p/D_b increases to 5, the force amplitude gradu-

ally converges toward that of the reference case. Conversely, $\bar{F}_3$ (Figure 9(b)) follows a different trend: the presence of the heave plate decreases the overall magnitude, whereas D_p/D_b slightly impacts its amplitude.

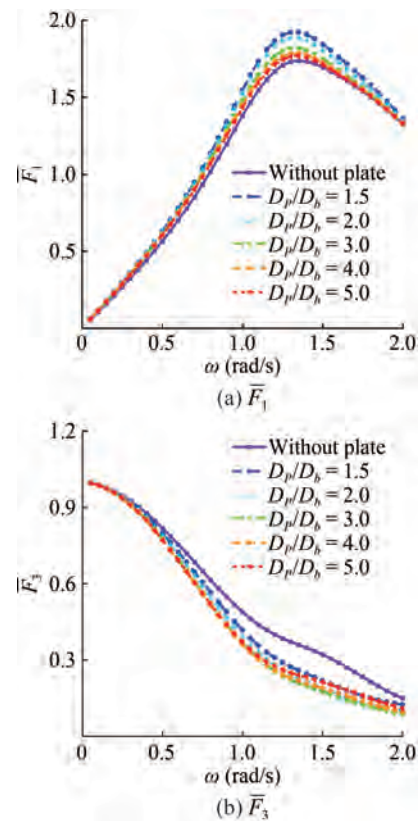


Figure 9 Results of $\bar{F}_m$ ($m = 1, 3$) in open water case

Figure 10 shows the results of $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$ as functions of ω for different D_p/D_b . In the surge direction, $\bar{A}_{1,1}$ and $\bar{B}_{1,1}$ reach their respective peaks at $\omega = 1.05$ and 1.60 rad/s, respectively. The maximum values are observed at $D_p/D_b = 1.5$ for both coefficients, with $\bar{A}_{1,1}$ and $\bar{B}_{1,1}$ reaching 0.77 and 0.21, respectively. As D_p/D_b further increases, $\bar{A}_{1,1}$ and $\bar{B}_{1,1}$ exhibit a decreasing trend, approaching those of the configuration without the heave plate. In the heave direction, $\bar{A}_{3,3}$ increases significantly with D_p/D_b whereas $\bar{B}_{3,3}$ decreases.

Figure 11 illustrates the RAO behavior as a function of ω for different D_p/D_b . The figure reveals that the surge RAO decreases rapidly with increasing frequency, exhibiting insensitivity to varying D_p/D_b . The baseline configuration (without the heave plate) shows a peak RAO of 0.72 at $\omega = 0.6$ rad/s. The heave RAO peak remains fixed at $\omega = 0.6$ rad/s when $D_p/D_b \leq 2$; however, for $D_p/D_b > 2$, the peak shifts toward the lower frequency, reaching $\omega = 0.55$ rad/s. Additionally, the heave RAO increases with increasing D_p/D_b . These results confirm that the RAO of the platform can be modulated by optimizing the position of the heave plate within specific frequency ranges.

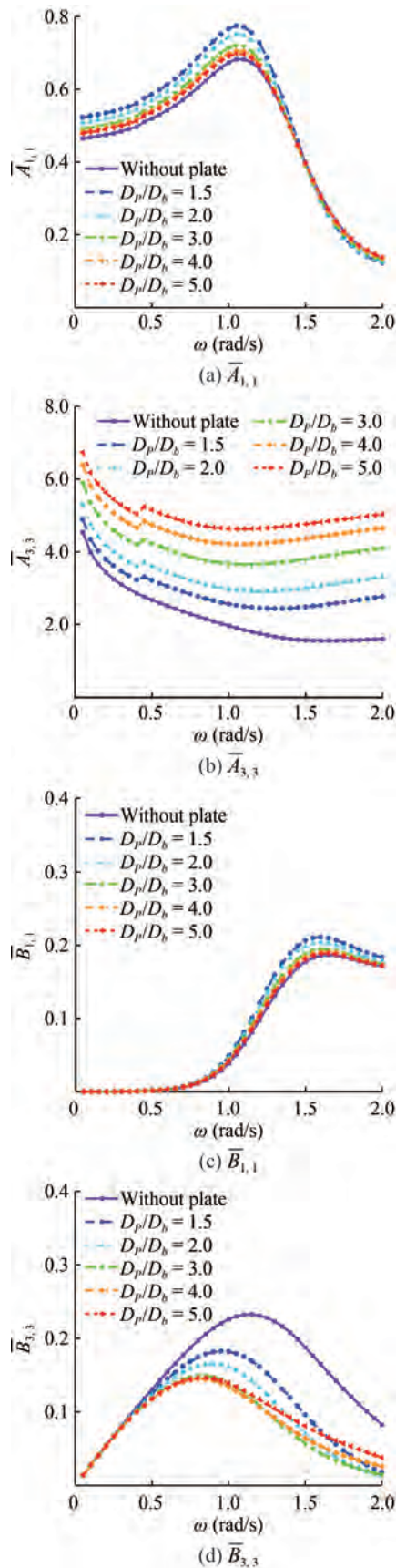


Figure 10 Results of $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$ ($m = n = 1, 3$) in open water case

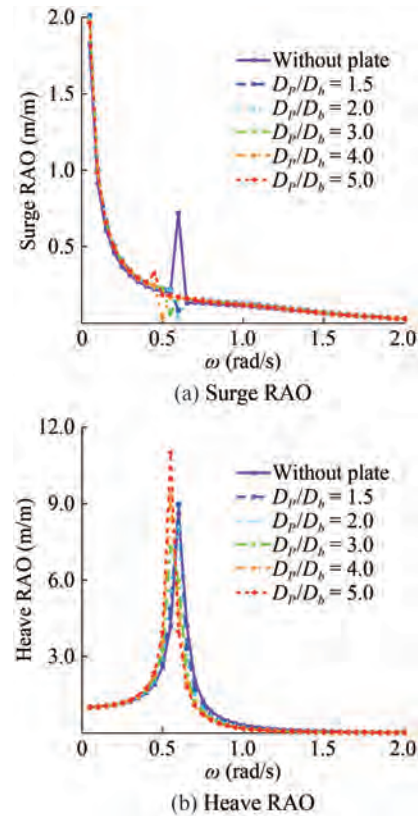


Figure 11 Results of the RAO in open water case

Figure 12 illustrates the results of $\bar{F}_m$ as functions of ω for different D_p/D_b in the presence of a fully reflective wall. Figure 12(a) shows that $\bar{F}_1$ exhibits a peak and a trough at $\omega = 1.2$ and 1.55 rad/s, respectively. Within the $0.7 < \omega < 1.2$ rad/s range, the $\bar{F}_1$ decreases with increasing D_p/D_b , displaying a consistent trend with that observed in open water case (Figure 9(a)). The influence of the plate position becomes negligible at $\omega > 1.55$ rad/s. As depicted in Figure 12(b), $\bar{F}_3$ exhibits a more complex behavior: it decreases at $\omega < 1.2$ rad/s, increases within the $1.2 \leq \omega \leq 1.4$ rad/s range, and decreases again at $\omega > 1.4$ rad/s. Notably, $\bar{F}_3$ reaches a minimum ($\bar{F}_3 = 0.07$) at $\omega = 1.2$ rad/s, corresponding to the $\bar{F}_1$ peak.

Figure 13 illustrates the influence of $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$ in the presence of a reflective wall. In the surge direction, $\bar{A}_{1,1}$ reaches a peak and a trough at $\omega = 1.1$ and 1.4 rad/s, respectively, whereas $\bar{A}_{3,3}$ displays a single trough around $\omega = 1.25$ rad/s. Notably, $\bar{A}_{3,3}$ increases with increasing D_p/D_b . The peak of $\bar{B}_{3,3}$ shifts toward the lower frequency region as D_p/D_b increases.

The presence of a fully reflective wall significantly alters the motion response characteristics of the platform (Figure 14), and a direct comparison with the open water case (Figure 11) highlights these differences. For instance, the wall effectively suppresses low-frequency ($\omega < 0.5$ rad/s) surge RAO. Conversely, the heave RAO increases by a

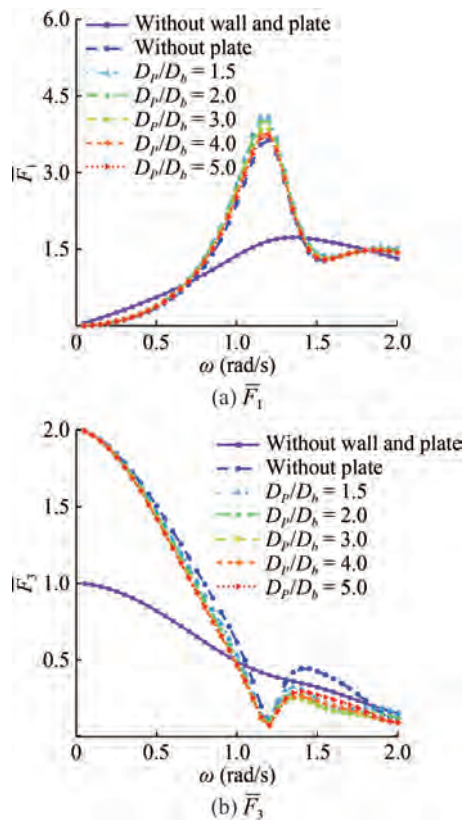


Figure 12 Results of $\bar{F}_m$ ($m = 1, 3$) in front of a vertical wall

factor of two in the low-frequency band owing to the presence of the reflective wall. However, at higher-frequency range ($\omega > 0.5$ rad/s), the response behavior resembles that observed in open water, and the presence of the wall has little influence on the RAO peak value or its corresponding frequency.

4.2 Effects of the coastal reflection coefficient

The effects of varying wall reflection coefficient (R) values (0, 0.25, 0.50, 0.75, and 1) on $\bar{F}_m$, $\bar{A}_{m,n}$, $\bar{B}_{m,n}$, and RAOs of the floating platform are investigated. Figure 15(a) illustrates $\bar{F}_1$ as a function of ω . The results indicate that $\bar{F}_1$ increases with ω , reaching a peak around $\omega = 1.2$ rad/s. Thereafter, it decreases gradually with increasing ω . Notably, the peak amplitude increases with R . For the fully reflective case ($R = 1$), $\bar{F}_1$ attains a local minimum of $\bar{F}_1 = 1.35$ at $\omega = 1.55$ rad/s.

The variations of $\bar{F}_1$ are attributed to changes in the wave pressure distribution and phase differences across the body's wetted surface, as Teng et al. (2025) reported. The total pressure on the body stems from the superposition of incident waves, wall-reflected waves, and diffraction waves generated by the body. The magnitude and phase of each wave component vary with the incident frequency, reflection coefficient, and the platform-to-wall distance. Hence, $\bar{F}_1$ is sensitive to these factors.

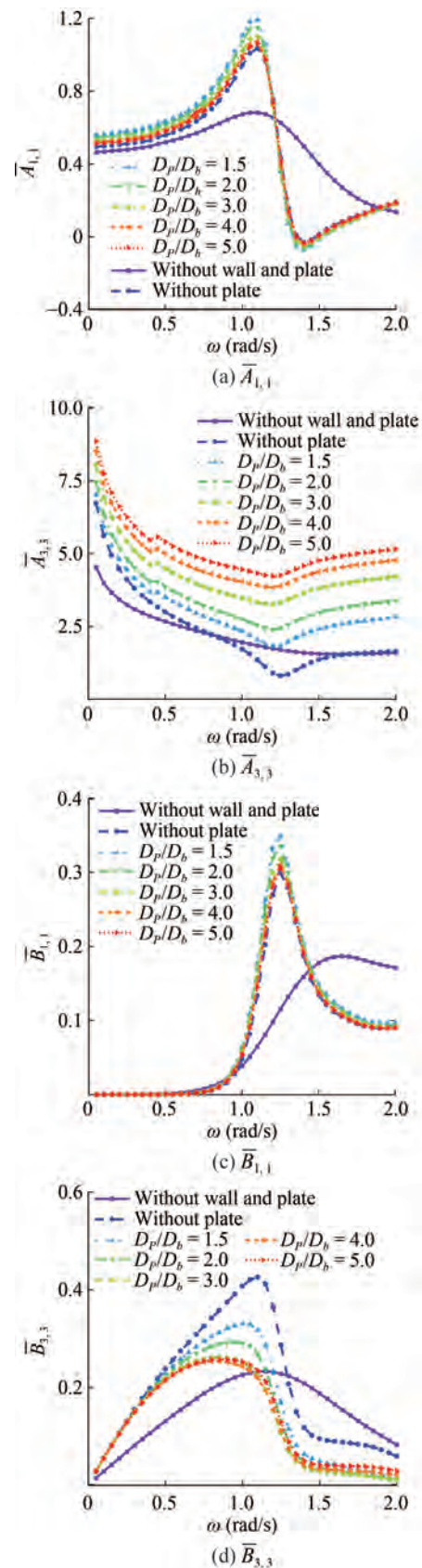


Figure 13 Results of $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$ ($m = n = 1, 3$) in front of a vertical wall

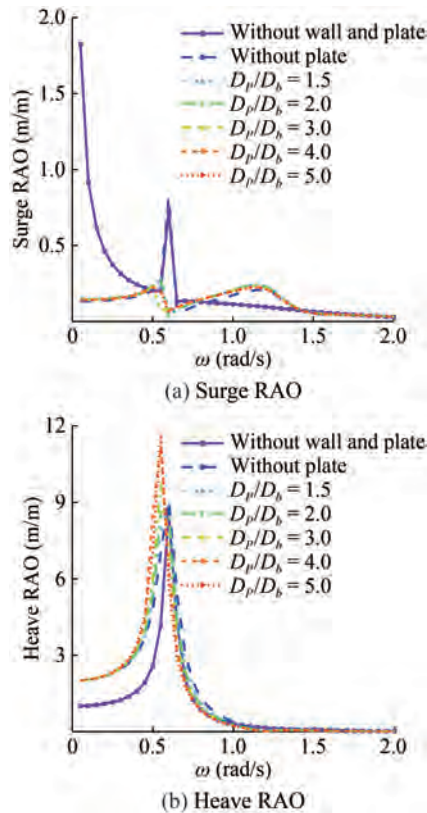


Figure 14 Results of the RAO in front of a vertical wall

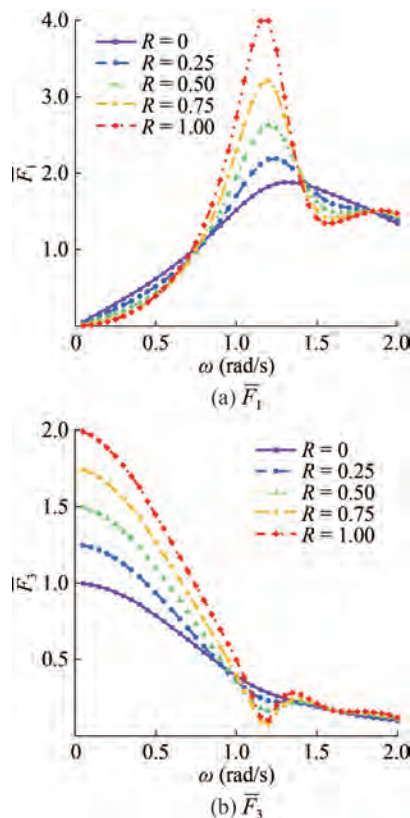


Figure 15 Results of $\bar{F}_m$ ($m = 1, 3$) in front of a partially reflective vertical wall

Figure 15(b) shows the variations of $\bar{F}_3$ in open water cases ($R = 0$), $\bar{F}_3$ begins at 1.0 ($\omega \approx 0$), decreasing monotonically as ω increases. Additionally, as R increases, the wave exciting force notably increases in the range of $0 < \omega < 1.05$ rad/s. And a valley value is observed at $\omega = 1.2$ rad/s due to the presence of wall-reflected waves. For $R = 1$, $\bar{F}_3$ reaches a maximum of 2.0 at $\omega \approx 0$, and a minimum of 0.07, around $\omega = 1.2$ rad/s.

Figure 16 illustrates the influence of R on the hydrodynamic coefficients. At $R > 0$, an oscillatory behavior with an “N” shape is observed for $\bar{A}_{1,1}$. As R increases, higher peaks and lower troughs are found in Figure 16(a). These variations originate from the interference of wall-reflected waves. Some troughs of the $\bar{A}_{1,1}$ may even become negative at higher R values. This is similar to the findings from the results of a two-dimensional box near fully reflective walls (Porter and Evans, 2011). Comparatively, the reflective wall slightly affects $\bar{A}_{3,3}$. As for $\bar{B}_{1,1}$, the peak value increases as R increases and its location approaches the lower frequency region. Also, for $\bar{B}_{3,3}$, its peak increases significantly.

Figure 17 further depicts the effects of R on the RAO. The results demonstrate that increasing R significantly suppresses surge RAO while enhancing the heave RAO in the lower frequency region (i. e., $0 < \omega < 1.05$ rad/s). This should be considered when designing such systems in nearshore regions.

4.3 Effects of the distance between the coast and the platform

Here, the effects of C/W_b (0.5, 1, 2, and 3, $R = 1$) on $\bar{F}_m$, $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$, and RAOs of the floating platform are investigated. Figure 18 shows the results of $\bar{F}_1$ and $\bar{F}_3$. The curve of the horizontal force $\bar{F}_1$ shows stronger oscillations as C/W_b increases, which is characterized by multiple peaks and troughs in the case of higher C/W_b . Sahoo et al. (2023) reported a similar oscillatory trend, which was attributed to wave entrapment within a confined region.

For the vertical force $\bar{F}_3$, a trough value is always observed across these cases, but its location shifts to the lower frequency region as C/W_b increase. As C/W_b increases, the decay rate and oscillatory peaks increase. Thus, a higher C/W_b corresponds to a higher peak heave exciting force (Zheng and Zhang, 2015; Kim et al., 2025).

Figure 19 shows the results of $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$ for various C/W_b . The results indicate that the change of C/W_b affects the hydrodynamic coefficient significantly. For the horizontal components of $\bar{A}_{1,1}$ and $\bar{B}_{1,1}$ the effect of C/W_b is mainly reflected in the higher frequency region (i.e., $\omega > 1$ rad/s). While variations in C/W_b do not affect the trend of $\bar{A}_{3,3}$, they adjust its values to a certain degree. Within the scope of the present calculations, increasing C/W_b causes the $\bar{B}_{3,3}$ curve to exhibit a multi-peaked behavior.

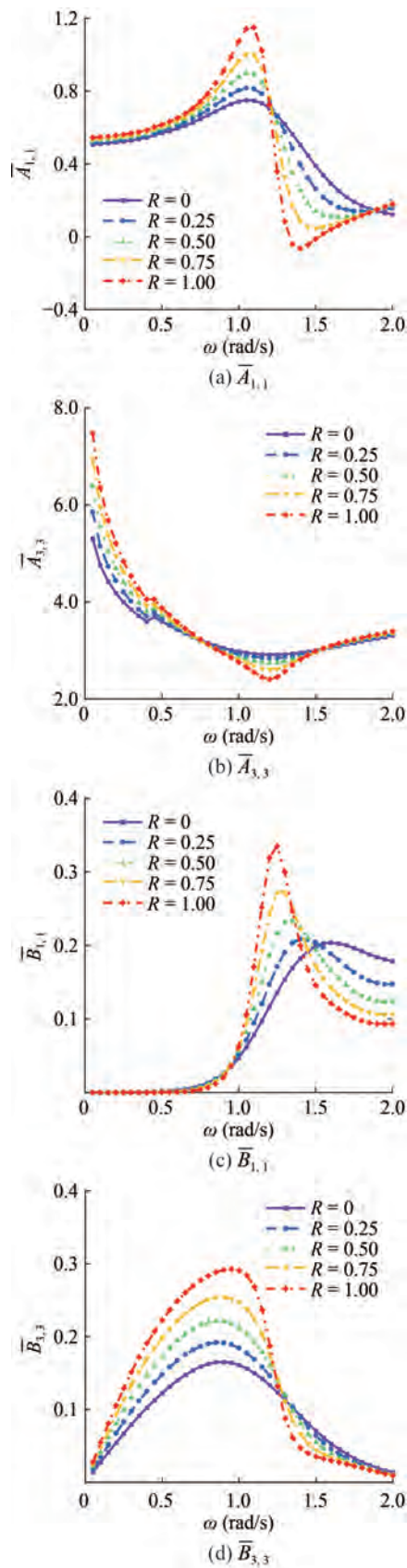


Figure 16 Results of $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$ ($m = n = 1, 3$) in front of a partially reflective vertical wall

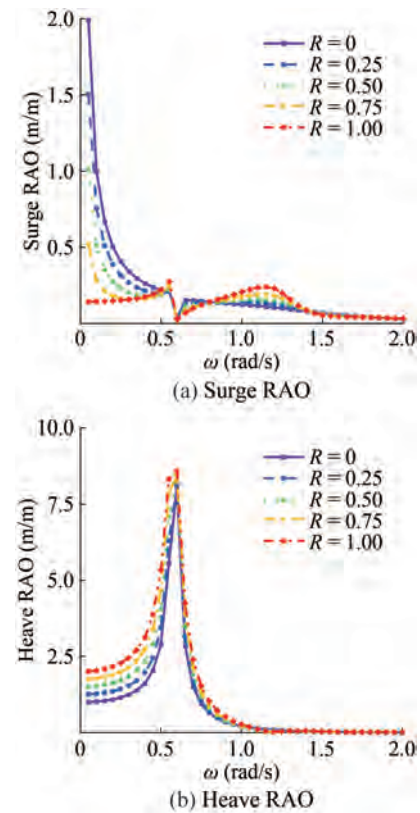


Figure 17 Results of the RAO in front of a partially reflective vertical wall

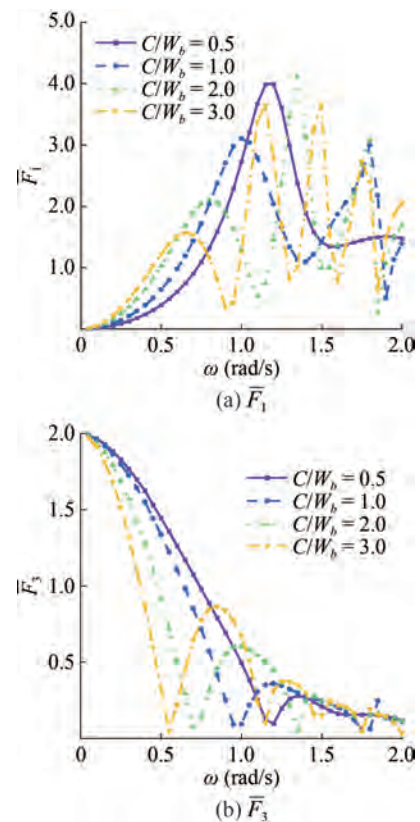


Figure 18 Results of $\bar{F}_m$ ($m = 1, 3$) with different C/W_b in front of a vertical wall

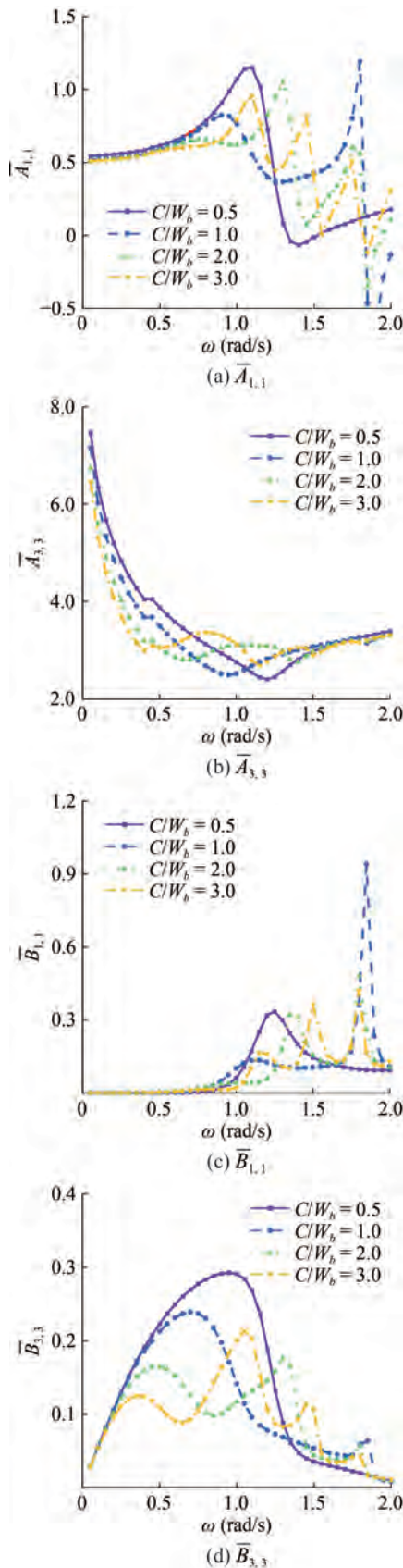


Figure 19 Results of $\bar{A}_{m,n}$ and $\bar{B}_{m,n}$ ($m = n = 1, 3$) with different C/W_b in front of a vertical wall

Figure 20 shows the results of RAO in surge and heave DOF for different C/W_b . The surge RAO at the lower frequency region ($\omega < 0.5$ rad/s) increases with increasing C/W_b . At higher frequencies ($\omega > 0.5$ rad/s), the surge RAO exhibits oscillatory behavior. The peak of the heave RAO curve decreases substantially as C/W_b reaches 3.

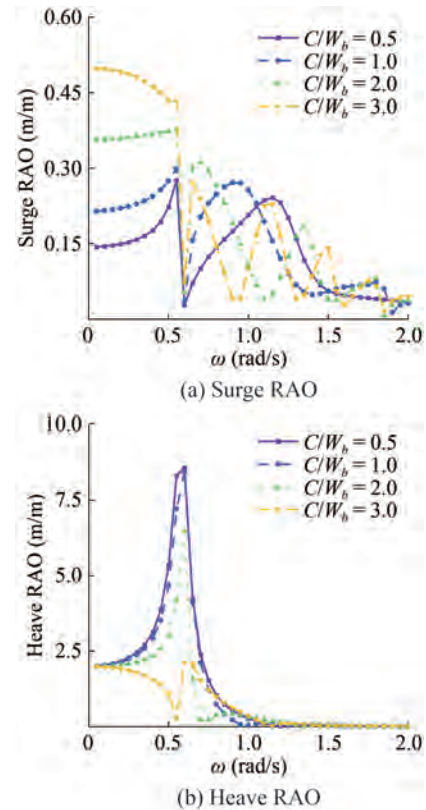


Figure 20 Results of the RAO with different C/W_b in front of a vertical wall

4.4 Effects of the incident wave angle

Finally, the effects of incident wave angle β (0° , 30° , 45° , and 60°) on $\bar{F}_m$, $\bar{A}_{m,n}$, $\bar{B}_{m,n}$, and RAOs of the floating platform are investigated. Figure 21 shows the results of $\bar{F}_1$ and $\bar{F}_3$. The results indicate that the peak of the $\bar{F}_1$ decreases with increasing β , and the peak location is slightly affected by changes in β . The influence of β on $\bar{F}_3$ is mainly reflected in the frequency region of $\omega > 0.75$ rad/s.

Figure 22 shows the results of the RAO in surge and heave mode for various β . The changes in β significantly affect the RAO in surge DOF. It can be found that, as β increases, the surge RAO decreases over the whole frequency region. This trend is similar to the wave exciting force in the heave mode shown in Figure 21(a). However, the trend of heave RAO versus ω is slightly affected by changes in β . But, as β increases, the peak of heave RAO increases slightly.

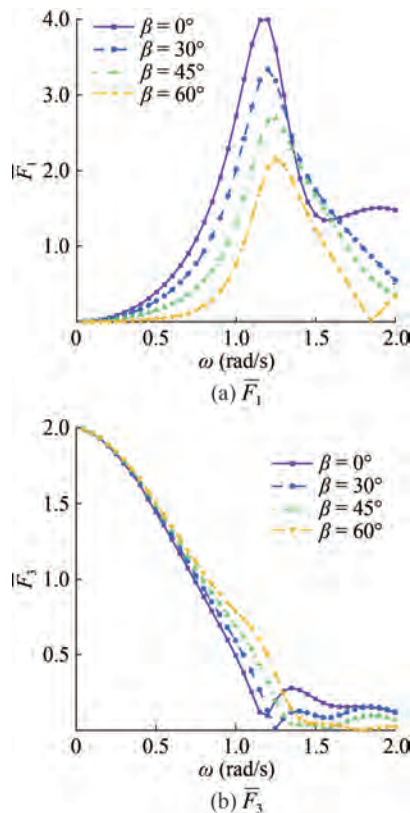


Figure 21 Results of $\bar{F}_m$ ($m = 1, 3$) with different β in front of a vertical wall

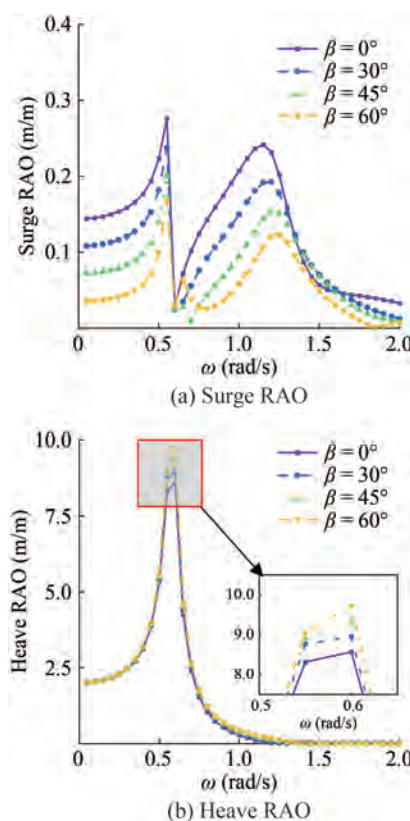


Figure 22 Results of the RAO with different β in front of a vertical wall

5 Conclusions

Based on the image method, a 3D BEM solver is developed for analyzing wave interactions with a floating body under a partial coastal reflection condition. The hydrodynamic characteristics of the floating body in front of the coast are then numerically investigated. The study emphasizes the effects of the heave plate on the motion response of the floating platform. Furthermore, parametric studies are performed to explore the performance of the floating platform equipped with a heave plate. The main conclusions are as follows:

1) A 3D BEM model was developed within context of wave diffraction/radiation theory to solve the problem of wave interaction with a floating body in the presence of partial coastal reflection.

2) The heave plate significantly modified the hydrodynamic responses of the floating platform in nearshore areas. It suppressed the surge motion peak, and a smaller spacing between the platform bottom and the heave plate leads to smaller heave motion and shifts the peak frequency.

3) Within the present study, compared to the open water condition ($R = 0$), an increase in the reflection coefficient from coast wall suppresses surge motion while amplifying the heave response, particularly in the low-frequency range ($\omega < 0.5$ rad/s).

4) The increasing distance between the platform and the coast reduces the peaks of the heave motion but increases surge motion in the lower frequency region.

Funding Supported by the Science and Technology Special Fund of Hainan Province (ZDYF2023GXJS017) and Hainan Province Foreign Experts Project (G20250218009E). This work contributes to the Strategic Research Plan of the Centre for Marine Technology and Ocean Engineering (CENTEC), which is financed by the Portuguese Foundation for Science and Technology (Fundação para a Ciência e Tecnologia-FCT) under contract UIDB/UIDP/00134/2020.

Competing interests C. Guedes Soares is one of the Editors for the Journal of Marine Science and Application and was not involved in the editorial review or the decision to publish this article. Xuanlie Zhao is an editorial board member for the Journal of Marine Science and Application and was not involved in the editorial review or the decision to publish this article. All authors declare that there are no other competing interests.

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