Structural Strength Analysis of a High-Density Polyethylene Floating Jetty under Ship Collision

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(Received: 2 June 2026 / Revised: 11 June 2026 / Accepted: 12 June 2026 / Available Online: 20 June 2026)

Abstract**—** Floating jetties are increasingly used in marine infrastructure because of their adaptability to water-level fluctuations and ease of installation. Recently, High-Density Polyethylene (HDPE) has attracted attention as an alternative construction material due to its corrosion resistance, lightweight characteristics, and impact-absorption capability. However, information regarding the structural behaviour of HDPE floating jetties under ship collision loads remains limited. Therefore, this study aims to investigate the structural response and deformation characteristics of an HDPE floating jetty subjected to vessel berthing impacts. The analysis was conducted using the Finite Element Method (FEM). A floating jetty with dimensions of 10 m × 2.5 m × 1.5 m was modelled and subjected to collision loads generated by a 5-ton vessel approaching at a 20° berthing angle. Berthing energies were calculated according to PIANC recommendations and converted into equivalent static impact loads under favourable, moderate, and unfavourable berthing conditions. The calculated berthing energies were 88.4 J, 198.9 J, and 353.6 J, corresponding to impact loads of 15.2 kN, 22.7 kN, and 30.2 kN, respectively. The maximum deformations obtained from the FEM analysis were 12.11 mm, 18.21 mm, and 24.22 mm. The results showed a nearly linear relationship between impact load and structural deformation, indicating stable elastic behaviour throughout the investigated loading range. Even under the most severe berthing condition, the maximum deformation represented only 0.24% of the jetty length. The study demonstrates that HDPE floating jetties possess adequate impact resistance and deformation capacity for small-vessel berthing operations. These findings provide additional insight into the application of HDPE as a structural material for floating marine infrastructure subjected to collision loading.

*Keywords***—** floating jetty, ship collision, berthing energy, finite element analysis, impact loading, structural deformation.

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I. INTRODUCTION

Floating jetties, also referred to as floating docks or floating pontoons, are widely used as marine infrastructure for passenger transportation, tourism activities, fishing operations, and small-vessel berthing, and can be relocated when operational requirements change [1], [2]. Unlike conventional fixed piers, floating jetties are designed to accommodate fluctuations in water levels caused by tides, waves, and seasonal variations while maintaining operational functionality. This adaptability makes floating structures particularly suitable for coastal and inland waterway applications where significant water-level variations occur. In addition to their operational flexibility, floating jetties offer several advantages, including relatively simple fabrication processes, ease of installation, lower construction costs, and high mobility, allowing relocation when operational requirements change. Consequently, floating jetty systems have become an increasingly attractive alternative to conventional waterfront infrastructure in many coastal regions.

As the utilisation of floating marine structures continues to expand, ensuring adequate structural integrity throughout their service life becomes a critical design consideration. Floating jetties are continuously subjected to various environmental and operational loads, including wave-induced forces, mooring loads, user live loads, and vessel berthing impacts. Among these loading conditions, ship collision or berthing impact is considered one of the most critical scenarios during the design stage [3], [4], [5], because it can generate significant localised and global structural responses within a short duration. During berthing, the kinetic energy of an approaching vessel is transferred to the jetty structure, producing impact loads that may result in excessive deformation, local damage, structural instability, or even failure if not properly accounted for during design. Therefore, assessing structural performance under collision loading is essential to ensure the safety, reliability, and long-term serviceability of floating jetty systems.

To evaluate the structural response of marine structures under complex loading conditions, structural strength analysis is commonly performed during the design and verification stages. Structural analysis enables engineers to determine whether a structure can safely withstand operational loads without exceeding allowable stress, strain, or deformation limits [6], [7]. Among the available numerical approaches, the Finite Element Method (FEM) has become one of the most widely adopted techniques due to its capability to accurately represent complex geometries, material behaviour, and loading conditions. FEM has been extensively applied in marine and offshore engineering to investigate stress distribution, deformation characteristics, structural failure mechanisms, and impact responses under various loading scenarios [8]. The FEM

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procedure generally consists of three stages: preprocessing, which involves creating the geometry, defining materials, selecting elements, and meshing; solution, where loads and boundary conditions are applied and the governing equations are solved; and postprocessing, which focuses on interpreting structural responses such as stress, strain, and displacement distributions.

Alongside advances in numerical analysis, the selection of structural materials has also become an important aspect of the development of floating marine infrastructure. Traditionally, floating structures have been constructed using steel, concrete, timber, or composite materials. However, High-Density Polyethylene (HDPE) has recently emerged as a promising alternative due to its excellent resistance to corrosion, chemical exposure, ultraviolet degradation, and marine environmental conditions. In addition, HDPE is lightweight, recyclable, durable, and requires relatively low maintenance compared with conventional construction materials [9], [10], [11]. These advantages have led to its increasing application in marine structures, including small vessels, floating pontoons, floating docks, and aquaculture facilities [10], [11].

A substantial body of research has investigated the application of HDPE in marine structures. HDPE has attracted considerable attention because of its resistance to corrosion, ultraviolet degradation, and chemical attack, which are common deterioration mechanisms in marine environments [0], [11]. Furthermore, HDPE exhibits high ductility and favourable impact resistance compared with traditional construction materials such as steel and timber. Experimental studies conducted by Abdullah et al. [12] and Wibawa et al. [13] demonstrated that HDPE possesses sufficient tensile and flexural strength for structural applications in marine engineering. These advantages make HDPE an attractive material for floating docks, pontoons, aquaculture facilities, and small vessels [9],[10], [11].

Research related to collision loading and berthing energy has traditionally focused on conventional marine structures [3], [4]. According to PIANC recommendations, vessel approach velocity is the dominant parameter influencing berthing energy because collision energy increases proportionally to the square of velocity [3], [4]. Several studies have investigated berthing loads acting on marine terminals, dolphins, and fixed jetty structures. However, most of these studies considered steel or reinforced concrete structures, while investigations involving HDPE-based floating infrastructure remain scarce [15], [4], [5].

The Finite Element Method (FEM) has become one of the most widely used numerical approaches for evaluating the structural behaviour of marine structures under complex loading conditions. Previous researchers have successfully applied FEM to analyse floating bridges, pontoons, marine barriers, and HDPE structural components [2], [16], [17], [18]. FEM enables detailed evaluation of deformation patterns, stress distribution, and energy dissipation mechanisms, making it particularly suitable for collision-response investigations. Nevertheless, studies specifically addressing the collision behaviour of HDPE floating jetties under PIANC-based berthing scenarios remain very limited.

Despite the growing adoption of HDPE in marine engineering applications, research focusing specifically on the collision behaviour of HDPE floating jetties remains limited. Existing studies have primarily concentrated on material characterisation, mechanical properties, welding performance, and general structural assessments of HDPE-based marine structures. Although these investigations have confirmed the suitability of HDPE for marine applications, limited information is available regarding the structural response of HDPE floating jetties under vessel berthing impacts, which represent one of the most critical operational loading conditions in floating marine infrastructure. Furthermore, previous investigations of berthing structures have predominantly focused on steel and reinforced concrete systems, leaving uncertainties regarding the deformation characteristics, load-transfer mechanisms, and impact resistance of HDPE floating jetty structures under realistic berthing scenarios. This knowledge gap highlights the need for a comprehensive structural assessment to support the safe and reliable design of HDPE floating infrastructure [13],[17],[18].

The novelty of this study lies in the integration of PIANC-based berthing energy calculations with finite element modelling to evaluate the collision behaviour of a full-scale HDPE floating jetty. Unlike previous studies that focused primarily on HDPE material performance or pontoon structures, the present work establishes a quantitative relationship between berthing energy, equivalent impact load, and structural deformation of an HDPE floating jetty. The findings provide new insights into the impact resistance of HDPE marine structures and contribute to the development of design references for floating jetty applications subjected to vessel collision loading.

Therefore, this study aims to investigate the structural strength of a High-Density Polyethylene floating jetty subjected to ship collision loads using the Finite Element Method. A floating jetty with principal dimensions of 10 m in length, 2.5 m in width, and 1.5 m in height is analysed under berthing impact scenarios generated by an 8 m vessel with an approximate displacement of 5 tons. The collision loads are determined based on berthing energy calculations under favourable, moderate, and unfavourable berthing conditions at a berthing angle of 20°. The analysis focuses on evaluating the deformation response and overall structural behaviour of the floating jetty under impact loading. The findings are expected to contribute to understanding HDPE structural performance in marine infrastructure applications and to provide useful references for the design and safety assessment of floating jetty systems subjected to ship berthing impacts.

II. METHOD

A. Floating Jetty Geometry and Structural Arrangement

The object investigated in this study is a High-Density Polyethylene (HDPE) floating jetty designed for small vessel berthing operations. The floating jetty has principal dimensions of 10 m in length, 2.5 m in width, and 1.5 m in height. These dimensions represent a typical floating dock configuration commonly used for passenger transfers, tourism activities, recreational boating, and small-fishing-boat operations in sheltered coastal waters. Similar floating jetty dimensions are commonly adopted for small-vessel berthing and marina [1], [19], [20].

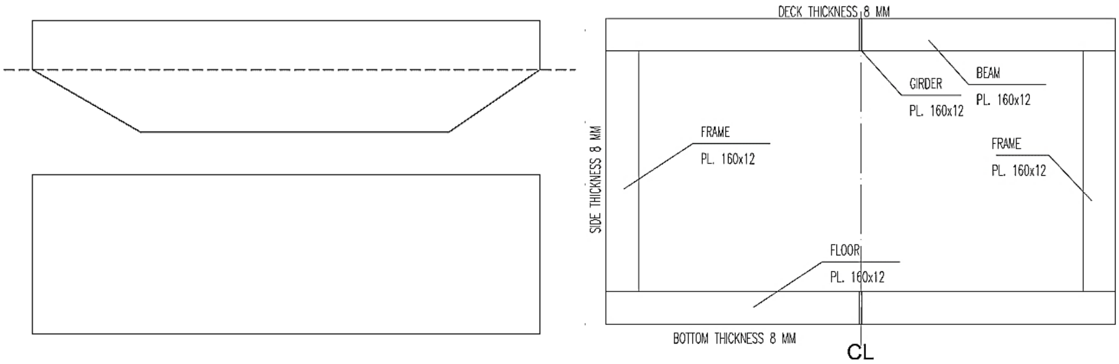

Figure 1. The shape of the floating jetty and the midship constructions

The structural arrangement of the floating jetty consists of deck plating, side plating, girders, beams, frames, and longitudinal stiffeners. The structural configuration is illustrated in Figure 1, while the detailed construction dimensions are presented in Table 1. The adopted structural arrangement was designed to provide adequate strength while maintaining the lightweight characteristics required for floating marine structures.

TABLE 1.
JETTY CONTRUCTIONS

Items	Value (mm)
Deck Plate	8 mm
Deck Beam	Plate 160x12
Deck Girder	Plate 160x12
Side Plate	8 mm
Frame	Plate 160x12
Side Longitudinal	Plate 160x12
Deck Plate	8 mm
Floor	Plate 160 x12
Center Girder	Plate 160x12
Frame Spacing	500 mm

B. Design Vessel and Collision Scenario

Determining a representative design vessel is an important step in evaluating the collision loads acting on the floating jetty. The selected vessel should reflect realistic operational conditions while remaining compatible with the dimensions and intended function of the floating jetty. Considering the jetty length of 10 m and width of 2.5 m, a small craft was selected as the design vessel. In practical marina and floating dock operations, the vessel length should generally be smaller than the jetty length to ensure safe berthing, proper mooring arrangements, and acceptable load distribution. These recommendations are consistent with general marina and floating jetty design practices [1], [20]. Likewise, the vessel beam should remain smaller than the jetty width to avoid excessive eccentric loading during docking operations. The vessel characteristics adopted in this study are summarised as follows:

- Length Overall (LOA): 8 m
- Beam: 2 m
- Draft: 0.5 m
- Displacement: 5 tons

These dimensions represent a typical passenger boat, tourism vessel, or utility craft frequently encountered in floating dock operations. A ship collision was simulated through a berthing scenario in which the vessel approached the floating jetty at an angle of 20°. This condition represents a relatively conservative docking situation that may occur due to environmental disturbances such as wind, waves, or current effects. The collision scheme adopted in this study is shown in Figure 2.

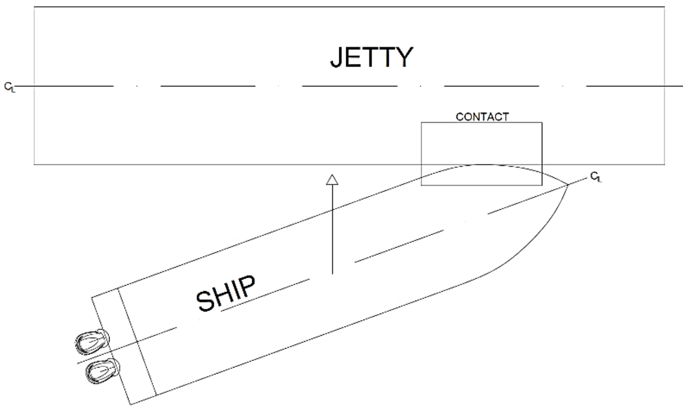

Figure 2. Collision scheme

C. Berthing Energy Calculation

The collision load acting on the floating jetty was determined based on the berthing energy formulation recommended by PIANC [3], [4], [14]. The berthing energy was calculated based on internationally recognised port and harbour design recommendations, where vessel kinetic energy is transformed into impact energy during docking operations. Berthing energy represents the kinetic energy transferred from the vessel to the structure during docking operations and is expressed as:

$$E = \frac{1}{2} m\, v_n^2 . C_m C_e C_s C_c \qquad (1)$$

where:
(E) = berthing energy (J)
(m) = vessel mass (kg)
(vn) = effective normal berthing velocity (m/s)
(Cm) = added mass coefficient
(Ce) = eccentricity coefficient
(Cs) = structural coefficient
(Cc) = configuration coefficient

The vessel and operational parameters adopted in the analysis are:

- Vessel mass = 5000 kg
- Added mass coefficient = 1.1
- Eccentricity coefficient = 1.0
- Structural coefficient = 1.0
- Configuration coefficient = 1.0
- Berthing angle = 20°

Three berthing conditions to represent different operational scenarios commonly considered in berthing analyses, favourable, moderate, and unfavourable conditions.

TABLE 2.
BERTHING APPROACH VELOCITY

Condition	Approach Velocity (m/s)
Favorable	0.20
Moderate	0.30
Unfavorable	0.40

Since only the velocity component normal to the jetty contributes to collision loading, the effective normal velocity was calculated using:

$$v_n = v\cos\theta \qquad (2)$$

The resulting effective normal velocities and corresponding berthing energies are presented in Table 3. The calculated berthing energies were subsequently converted into equivalent static impact loads and applied to the finite element model to evaluate the structural response of the floating jetty.

TABLE 3.
EFFECTIVE NORMAL VELOCITY AND BERTHING ENERGY

Condition	Approach Velocity (v) (m/s)	Effective Normal Velocity, (vn)	Berthing Energy (J)
Favorable	0.20	0.188	88.4
Moderate	0.30	0.282	198.9
Unfavorable	0.40	0.376	353.6

D. Finite element methods

The structural analysis was performed using the Finite Element Method (FEM) implemented in ANSYS Mechanical APDL. The finite element model was developed to evaluate the deformation response of the HDPE floating jetty under ship collision loads. SHELL181 elements were employed to model deck plates, side plates, and other shell components [20], [21]. This element type is suitable for thin-to-moderately thick structures and can accurately capture bending and membrane behaviour. Meanwhile, BEAM189 elements were used to model the beam, girder, frame, and longitudinal stiffening members, as they can model slender structural components under complex loading conditions [8], [20], [21].

The modelling procedure consisted of geometry creation, material assignment, mesh generation, load application, and solution processing [8]. Following the analysis, post-processing was performed to evaluate deformation contours and structural response characteristics under each collision scenario.

E. Material Properties and Boundary Conditions

The floating jetty structure was assumed to be constructed entirely from High-Density Polyethylene (HDPE). HDPE was selected because of its excellent corrosion resistance, low maintenance requirements, lightweight characteristics, and superior impact resistance compared with conventional marine construction materials [22], [23], [9], [24].

The material properties adopted in the finite element model are summarised in Table 4. The material was assumed to behave as an isotropic linear-elastic material throughout the analysis [22], [17], [25]. Collision loads obtained from the berthing energy calculations were applied at the impact location shown in Figure 2. The resulting deformation response was then evaluated to determine the structural performance of the HDPE floating jetty under favourable, moderate, and unfavourable berthing conditions.

TABLE 4.
MECHANICAL PROPERTIES OF HDPE

Property	Value
Yield Strength	25 MPa
Elongation at Yield	9 %
Modulus of Elasticity	1000 MPa
Density	0.95 g/cm³
Poisson's Ratio	0.40–0.45

III. RESULTS AND DISCUSSION

A. Finite Element Deformation Response

To investigate the structural response of the HDPE floating jetty under ship-collision loading, a three-dimensional finite element model was developed and analysed using equivalent static impact loads derived from calculated berthing energies. The finite element method (FEM) provides an effective numerical approach for evaluating structural behaviour under complex loading conditions, enabling the prediction of deformation patterns, stress distribution, and load transfer mechanisms within marine structures. Similar numerical approaches have been widely applied in floating marine structures and pontoon systems [16], [21], [23]. In the present study, the HDPE floating jetty measuring 10 m × 2.5 m × 1.5 m was subjected to collision loads representing favourable, moderate, and unfavourable berthing scenarios.

Figure 3 presents the deformation contour obtained from the finite element analysis. The results indicate that the maximum deformation is concentrated in the vicinity of the impact region where the collision load is applied. The deformation gradually decreases toward adjacent structural members, producing a smooth deformation gradient across the floating jetty. Such behaviour demonstrates that the applied impact load is not confined to a localised area but is effectively redistributed throughout the structural system. This load-transfer mechanism is desirable in floating marine structures because it reduces stress concentration and minimises the likelihood of localised structural damage. Similar deformation characteristics have been reported in floating pontoon structures subjected to external loading [15], [16].

The deformation pattern also reveals that the global structural response dominates the collision behaviour of the floating jetty. No abrupt displacement discontinuities, severe local distortions, or signs of structural instability were observed in any of the investigated loading conditions. The observed response is closely associated with the inherent mechanical characteristics of High-Density Polyethylene (HDPE), which exhibits relatively high ductility and impact resistance compared with conventional marine construction materials. Unlike brittle materials that tend to concentrate stresses near the impact zone, HDPE is capable of redistributing collision energy through controlled deformation, thereby reducing the risk of catastrophic failure. Similar findings were reported by Li et al. [16], who demonstrated that HDPE pontoon systems exhibit favourable impact energy-absorption characteristics. Experimental and numerical investigations on HDPE marine structures also confirmed that the material can accommodate relatively large strains without immediate structural failure [12], [13], [34].

From a structural mechanics perspective, the deformation contours suggest that the collision energy was primarily dissipated through elastic deformation of the floating jetty structure. This behaviour indicates that the investigated loading conditions remained within the structure's operational capacity and that the selected structural configuration maintained its overall integrity during berthing impact events.

B. Impact Load versus Maximum Deformation

The relationship between impact load and maximum deformation is presented in Figure 4. The finite element results demonstrate a consistent increase in deformation with increasing collision load. Under the lowest investigated impact load of 15.2 kN, the maximum deformation was 12.11 mm. As the load increased to 18 kN, 20 kN, 22.7 kN, 25 kN, and 27 kN, the corresponding deformations increased to 14.44 mm, 16.04 mm, 18.21 mm, 20.05 mm, and 21.65 mm, respectively. The highest load investigated, 30.2 kN, produced a maximum deformation of 24.22 mm.

The resulting load–deformation relationship exhibits a nearly linear trend throughout the investigated loading range. Such behaviour is characteristic of structures operating predominantly within the elastic region, where deformation is directly proportional to the applied load according to Hooke's law. Similar linear responses have been observed in HDPE structural components subjected to moderate loading conditions [12], [24], [34]. The absence of significant deviation from linearity suggests that no substantial material yielding, stiffness degradation, or progressive structural damage occurred during loading. Consequently, the floating jetty maintained a stable structural response under all investigated collision scenarios.

The nearly proportional increase in deformation can be attributed to HDPE's relatively low elastic modulus and high strain capacity. While metallic structures typically rely on high stiffness to resist impact loads, HDPE structures dissipate impact energy through a combination of elastic deformation and material ductility [10], [22], [23], [16]. This characteristic enables the material to accommodate larger displacements without compromising structural continuity. Previous investigations on HDPE-based marine structures have similarly reported stable deformation behaviour and enhanced impact resistance resulting from the material's ability to absorb and redistribute external loads.

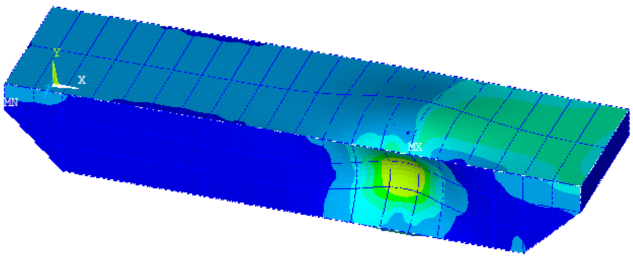

Figure 3. Finite element deformation contour of the HDPE floating jetty subjected to ship collision loading.

A further observation from Figure 4 is that the deformation growth rate remains relatively constant over the entire loading range. This indicates that the floating jetty's structural configuration provides a predictable response to increasing impact loads, which is advantageous for design. Predictable structural behaviour facilitates more reliable estimation of allowable collision loads and serviceability limits during the design process.

From an operational standpoint, the maximum deformation of 24.22 mm recorded under the highest collision load represents only approximately 0.24% of the total jetty length. Considering the overall structural dimensions, this deformation level is relatively small and does not indicate excessive global flexibility. Furthermore, the deformation ratios corresponding to favourable, moderate, and unfavourable loading conditions were approximately L/826, L/549, and L/413, respectively. These values suggest that the floating jetty retained adequate geometric stability and operational functionality throughout the investigated loading range. These deformation levels are considerably smaller than commonly accepted serviceability limits for marine structures and floating systems [8], [9], [15].

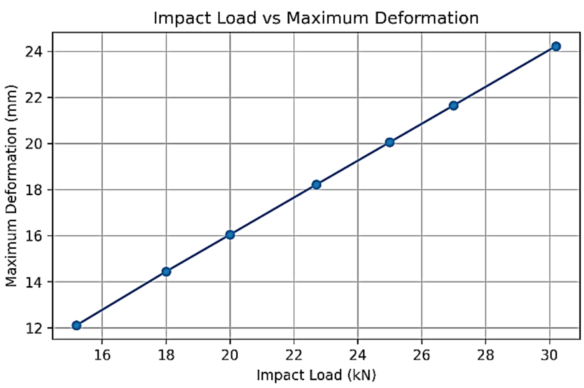

Figure 4. Relationship between impact load and maximum deformation of the HDPE floating jetty.

C. Berthing Energy versus Maximum Deformation

PIANC guidelines identify vessel approach velocity as the dominant parameter governing berthing energy, as the energy varies proportionally to the square of the velocity [3], [14]. The influence of berthing energy on structural deformation is presented in Figure 5. Berthing energy was calculated based on the vessel's approach velocity under favourable, moderate, and unfavourable operating conditions. The resulting berthing energies were 88.4 J, 198.9 J, and 353.6 J, respectively, corresponding to maximum deformations of 12.11 mm, 18.21 mm, and 24.22 mm.

Similar energy dissipation mechanisms have been observed in HDPE pontoons and floating barrier systems subjected to impact loading [16]. The results clearly indicate that increasing berthing energy results in greater structural deformation. This behaviour is consistent with the fundamental work–energy principle, which states that the kinetic energy of the approaching vessel must be transformed into strain energy within the structure. Consequently, larger collision energies require greater structural deformation to dissipate the incoming energy. Since berthing energy is proportional to the square of vessel velocity, relatively small increases in approach velocity can result in substantial increases in collision energy. This observation highlights the importance of maintaining controlled berthing operations, particularly in small floating jetty facilities.

An important finding is that the increase in deformation remained gradual despite the substantial increase in collision energy from favourable to unfavourable conditions. While the berthing energy increased approximately 4 times, the resulting deformation increased only about 2 times. This response suggests that the HDPE floating jetty has an effective energy-absorption mechanism that prevents excessive deformation growth as impact severity increases. Such behaviour is consistent with the ductile nature of HDPE, which allows impact energy to be distributed throughout the structural system rather than being concentrated at the impact location.

The results also demonstrate that the equivalent static loads derived from the PIANC berthing energy formulation provide a reasonable representation of the collision scenario for preliminary structural assessment [3], [14]. Under the most severe condition, corresponding to a berthing energy of 353.6 J and an equivalent impact load of 30.2 kN, the floating jetty maintained structural stability without exhibiting signs of excessive deformation or failure. These findings indicate that the investigated HDPE floating jetty possesses adequate deformation capacity and impact resistance for the operational scenarios considered in this study.

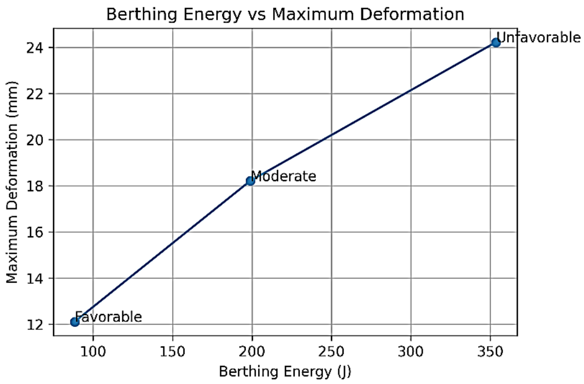

Figure 5. Relationship between berthing energy and maximum deformation of the HDPE floating jetty.

Table 5 summarises the principal results obtained from the collision analysis of the HDPE floating jetty under favourable, moderate, and unfavourable berthing conditions. The results indicate a consistent increase in equivalent impact load and maximum deformation with increasing berthing energy. As the berthing energy increased from 88.4 J to 353.6 J, the corresponding equivalent impact load increased from 15.2 kN to 30.2 kN, while the maximum deformation increased from 12.11 mm to 24.22 mm. This trend confirms the direct relationship between collision energy and structural response, where higher impact energies require greater deformation to dissipate the incoming kinetic energy.

Despite the fourfold increase in berthing energy between the favourable and unfavourable conditions, the resulting deformation remained relatively small compared with the overall jetty length of 10 m. The deformation ratio varied from approximately L/826 under favourable conditions to L/413 under unfavourable conditions, indicating that the global structural response remained within acceptable operational limits. These findings suggest that the HDPE floating jetty possesses adequate deformation capacity and impact resistance to accommodate typical small-vessel berthing operations without exhibiting excessive structural flexibility or instability.

TABLE 5.
SUMMARY ENERGY AND DEFORMATION RATIO

Condition	Energy (J)	Force (kN)	Maximum Deformation (mm)	Deformation Ratio
Favorable	88.4	15.2	12.11	L/826
Moderate	198.9	22.7	18.21	L/549
Unfavorable	353.6	30.2	24.22	L/413

The findings of this study provide important implications for the design and application of HDPE floating marine infrastructure. The observed deformation behaviour demonstrates that HDPE floating jetties can effectively absorb and redistribute collision loads generated during vessel berthing operations. This capability is particularly beneficial for small marinas, tourism facilities, recreational ports, and coastal transportation terminals, where repeated low-to-moderate collision loads are commonly encountered [18], [27], [35].

In addition to its corrosion resistance, lightweight characteristics, and low maintenance requirements, HDPE also exhibits favourable impact resistance, enhancing structural resilience during berthing events. The results suggest that the investigated floating jetty configuration possesses sufficient structural capacity to accommodate typical operational collision loads while maintaining acceptable deformation levels. Therefore, HDPE may be considered a viable alternative to conventional marine construction materials for floating jetty applications, particularly in environments where durability, sustainability, and impact resistance are primary design considerations [10], [11], [16], [35].

Overall, the summarised results demonstrate that the investigated HDPE floating jetty maintained a stable structural response throughout all collision scenarios considered in this study. The nearly linear increase in deformation with increasing impact load and berthing energy indicates that the structure predominantly operated within its elastic deformation range. Consequently, the floating jetty could absorb collision energy through controlled deformation while preserving its overall structural integrity, highlighting the suitability of HDPE for floating marine infrastructure subjected to routine berthing impacts.

The present study provides additional understanding of the collision behaviour of HDPE floating jetty structures. Previous investigations primarily focused on HDPE material properties, welding performance, and pontoon applications [12], [13], [16], whereas quantitative evaluation of structural deformation under realistic vessel berthing impacts has rarely been reported. The numerical results obtained in this study demonstrate that the deformation response increases almost linearly with increasing impact load, indicating that the structure remained within its elastic operating range throughout the investigated collision scenarios.

An important finding is that a fourfold increase in berthing energy, from 88.4 J to 353.6 J, resulted in only a twofold increase in maximum deformation. This behaviour suggests that the HDPE floating jetty possesses an effective energy dissipation mechanism through distributed elastic deformation. Unlike conventional metallic structures that primarily rely on stiffness to resist collision loads, HDPE structures are capable of absorbing and redistributing impact energy through controlled deformation while maintaining structural continuity. Similar observations regarding the impact-absorption capability of HDPE structures were reported by Li et al. [26]; however, the present study extends these findings to a full-scale floating jetty configuration.

The deformation ratios obtained in this study, ranging from L/826 to L/413, indicate that the investigated structure maintained adequate geometric stability under all collision scenarios. These values are considerably smaller than commonly accepted serviceability limits for floating marine structures and suggest that the jetty can continue to operate safely after berthing events without significant loss of functionality. From an engineering perspective, this behaviour is particularly beneficial for floating infrastructure subjected to frequent docking operations because repeated impacts are less likely to generate severe local damage.

The principal contribution of this study is the establishment of a quantitative relationship between berthing energy, equivalent impact load, and structural deformation of an HDPE floating jetty. This relationship provides useful preliminary design information for engineers involved in the development of HDPE-based marine infrastructure. Furthermore, the results support the broader application of HDPE as a sustainable and impact-resistant material for floating docks, marinas, tourism facilities, and coastal transportation terminals.

IV. Conclusion

This study aimed to investigate the structural response of a High-Density Polyethylene (HDPE) floating jetty subjected to ship collision loads using the Finite Element Method (FEM). Collision loads were determined from PIANC-based berthing energy calculations representing favourable, moderate, and unfavourable berthing conditions.

The numerical results showed that increasing berthing energy generated larger impact loads and correspondingly higher structural deformation. Maximum deformations of 12.11 mm, 18.21 mm, and 24.22 mm were obtained under favourable, moderate, and unfavourable conditions, respectively. The deformation response exhibited a nearly linear relationship with impact load, indicating stable elastic behaviour throughout the investigated loading range.

A significant finding of this study is that the HDPE floating jetty effectively absorbed and redistributed collision energy while maintaining structural integrity. Even under the most severe collision scenario, the maximum deformation represented only 0.24% of the overall jetty length, confirming adequate stiffness, deformation capacity, and operational stability. The study further establishes a quantitative relationship between berthing energy, equivalent impact load, and structural deformation, which constitutes the principal contribution of this work.

These findings demonstrate the suitability of HDPE as a collision-resistant material for floating marine infrastructure and provide valuable references for future floating jetty design. Further investigations should incorporate nonlinear material behaviour, dynamic impact simulations, hydroelastic effects, and experimental validation to enhance prediction accuracy and support the development of design guidelines for HDPE floating structures.

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