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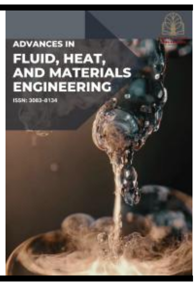

Evaluating the Buoyant Capabilities of Raft House Models

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ABSTRACT

Raft houses offer a practical solution for flood-prone and land-scarce regions, but their stability and load-bearing capacity remain challenges. This study evaluates the effect of flotation devices on raft buoyancy by comparing two models: one relying solely on its material for flotation and another equipped with inflatable bubble wraps. The experiment involved incrementally loading both rafts with marbles, recording weight limits at half-submersion and full submersion. The raft without flotation devices reached half-submersion at 67 marbles (6.88 N) and fully submerged at 110 marbles (11.30 N). In contrast, the raft with flotation devices remained stable at 80 marbles (8.22 N) and reached full submersion at 120 marbles (14.48 N). The addition of flotation devices improved buoyancy by 19.4% at half-submersion and increased load capacity by 9.1% at full submersion. Furthermore, the flotation-enhanced raft exhibited reduced tilting and better stability under uneven loading conditions. These results align with Archimedes' principle, demonstrating that increasing displaced water volume enhances buoyant force. The findings confirm that integrating flotation devices significantly improves the structural performance of raft houses, making them more viable for practical applications. The use of low-cost, readily available materials such as inflatable bubble wraps presents an accessible solution for improving floating structures, particularly in flood-affected communities. This research contributes valuable insights into sustainable raft design, with implications for disaster relief housing and modular floating platforms. Future studies should investigate full-scale implementations, alternative flotation materials, and performance under real-world conditions, including wave and current interactions. Computational simulations could further refine flotation placement strategies to optimize buoyancy and stability. By demonstrating the effectiveness of flotation devices, this study supports the development of more resilient, adaptable, and cost-effective floating structures suited to diverse environmental conditions.

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1. Introduction

Floating structures, particularly raft houses, are critical in addressing housing challenges in regions prone to flooding or with limited land availability. These structures rely on buoyancy, the upward force exerted by water, to support their weight and maintain stability. Traditional raft houses often depend on lightweight construction materials, such as wood or polymers, to achieve buoyancy. However, these designs face significant limitations when subjected to heavy or uneven loads, as well as environmental challenges like waves and currents, leading to potential instability and structural failure [1].

Advancements in engineering have introduced external flotation devices to improve the buoyancy and load-carrying capacity of floating structures. Flotation devices, such as inflatable materials or foam blocks, displace additional water, thereby increasing the upward buoyant force acting on the structure. For example, [2] demonstrated that integrating hollow components into composite materials enhanced buoyancy, while [3] reported improvements in stability and load capacity with modular flotation systems in small-scale floating platforms. Despite these promising findings, limited studies have systematically evaluated the comparative performance of raft houses with and without flotation devices, especially under controlled conditions.

Subsequently, the principles of buoyancy are well understood, there is a lack of experimental evidence specifically addressing how external flotation devices impact the load-carrying capacity and structural stability of small-scale raft houses. Additionally, readily available and low-cost materials, such as bubble wraps, have not been extensively tested for practical applications in raft design [3,4]. Significance of research: This study addresses this gap by providing empirical evidence on the role of flotation devices in enhancing raft performance. The findings are expected to inform the design of sustainable, resilient floating structures that can better withstand variable loads and challenging water conditions. Such insights are particularly valuable for flood-prone or water-scarce regions, where affordable and adaptable housing solutions are urgently needed [5-11].

2. Methodology

2.1 Geometry of Raft House and Bucket

This experiment is comparative experimental research to assess and compare the buoyancy of raft with float and without float. The geometry of the bucket is height of 0.16 m and a diameter of 0.165 m in Figure 1. The volume of water is constant throughout the whole experiment. For the raft house has dimensions of 0.08 m in height, 0.09 m in length, and 0.09 m in width in Figure 2.

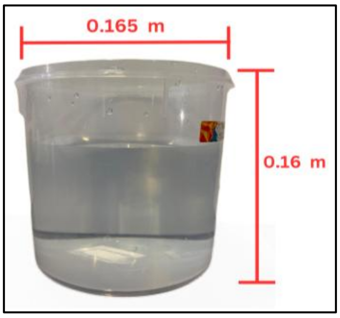
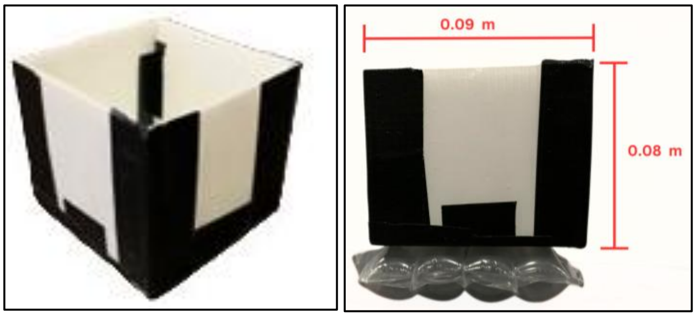


Fig. 1. Dimension of bucket



(a) (b)

Fig. 2. (a) Raft house without float (b) Raft house with float

2.2 Experimental Setup
2.2.1 Materials

The materials required for this setup include a transparent bucket, which provides clear visibility of its contents, making it suitable for monitoring raft house levels or observing experimental changes during use. A polypropylene (PP) plastic board, known for its durability and lightweight properties, serves as a supportive structure, divider, or base for mounting other components. Tape is essential for securing various walls to construct the raft house, ensuring stability and cohesion. Marbles are included, possibly to act as weights or experimental variables, given their uniform shape and density. Finally, a float is incorporated, designed to remain buoyant on liquid surfaces, possibly functioning as a level indicator or control mechanism. These materials, when combined, provide a versatile and adaptable foundation for various experimental or practical applications.

2.2.2 Making the raft house

To build the raft house, begin by cutting the PP plastic board into appropriate sections to form the walls of the structure. Ensure the pieces are accurately measured and cut for a stable assembly. Once the walls are prepared, use strong tape to join them securely, shaping the structure to resemble the design shown in Figure 3. Be thorough when taping the connections to enhance the strength and durability of the raft house. For the floatation base, you have the freedom to select any suitable material depending on your creativity and the resources available. In this experiment, we used inflatable bubble wrap, which proved to be lightweight, buoyant, and practical for keeping the raft house afloat.

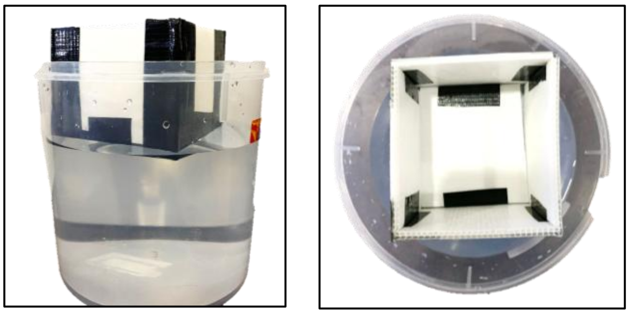
(a) (b)

Fig. 3. (a) Cutting the PP plastic board (b) Inflatable bubble wrap

2.3 Procedure

To begin the experiment, fill a bucket with water and carefully place the raft house in the bucket without attaching a float, as in Figure 4. Gradually add marbles into the raft house, observing how it behaves in the water. When the raft house becomes half-immersed, count the number of marbles it holds at that point. Record your observations carefully for comparison. Next, repeat the procedure by placing the raft house back in the bucket, again without a float. Add marbles until the raft house is fully immersed, then count the number of marbles required to reach that state.

After completing this step, attach the float to the raft house, as shown in Figure 5. Ensure the float is securely connected to support the structure during further testing. Finally, repeat the procedure from step 2 to step 4 with the float attached. Count the marbles required for the raft house to become half-immersed and fully immersed while supported by the float. Record these observations to compare the buoyancy performance with and without the float.



(a) (b)

Fig. 4. Raft house without float in the bucket (a) Side view (b) Top view

Fig. 5. Attaching the float to the raft house

2.4 Analysis of the Raft House Buoyancy

This equation defines the buoyant force (Fb) experienced by an object submerged in a fluid. The force depends on the fluid's density (ρ), gravitational acceleration (g), and the volume of the object submerged (V). A higher fluid density results in a greater buoyant force, as does a larger displaced fluid volume. Gravitational acceleration remains constant at approximately 9.81 m/s^2 near Earth's surface.

$$Fb = \rho g V \tag{1}$$

This equation defines the weight of an object (W) based on its density, gravitational acceleration, and volume. It has the same structure as the Eq. (1) but applies to the object rather than the fluid. When comparing an object's force to the buoyant force acting upon it, can determine whether the raft house will sink or float. The equation is essential in evaluating material properties for buoyant designs.

$$W = \rho g V \tag{2}$$

This formula is used to calculate the volume of raft house, where (l) represents the length, (w) the width, (h) and the height. This will be substituted in Eq. (2) to get the weight of the raft house. It assumes that all angles between the dimensions are right angles.

$$V = l \cdot w \cdot h \quad (3)$$

This formula calculates the volume of a sphere. It requires only the radius (r) of the sphere and incorporates the mathematical constant π (approximately 3.14159). Spherical volume calculations are used for the marbles to substitute in Eq. (2) to find the weight.

$$V = \frac{4}{3}\pi r^3 \quad (4)$$

This formula determines the volume of a cylinder, where (r) is the radius of the circular base, and (h) is the cylinder's height. The constant π ensures accurate calculations for the circular cross-section. This equation is particularly useful for analysis of storage bucket in this experiment.

$$V = \pi r^2 h \quad (5)$$

3. Results

3.1 Test Results

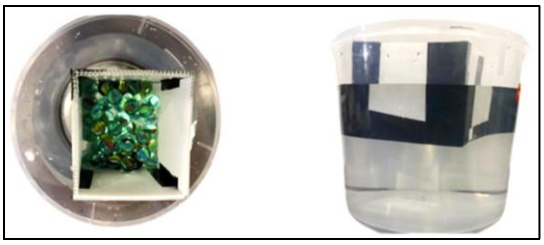
After conducting the test, this section discusses the results obtained from different between the raft with float and without float for accommodate the weight to maintain floating on water surface. There is different effect with floats and without float.

3.2 Raft Without Float

Table 1 presents data on the number and total weight of marbles placed on a raft without float under two conditions half submerged in Figure 6 and fully submerged in Figure 7. The weight of the marble was obtained using Eq. (2) and volume of sphere Eq. (4)

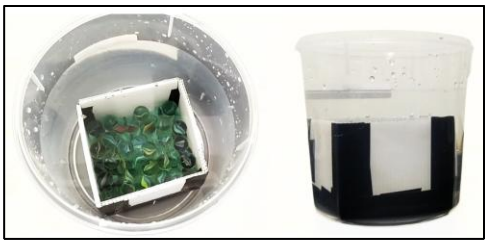
Table 1
The number and weight of marbles

Condition of raft house	Number of marbles	Weight of marbles, W (N)
Half Submerged	67	6.8809
Fully Submerged	110	11.297



(a) (b)

Fig. 6. Raft house when half submerged (a) Top view (b) Side view



(a) (b)

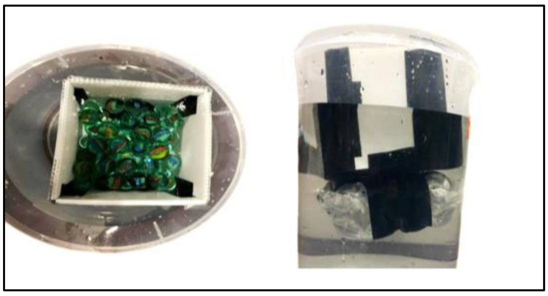
Fig. 7. Raft house when fully submerged (a) Top view (b) Side view

3.3 Raft with Float

Table 2 shows results for the test of the raft with supporting system with floats, under two conditions half submerged in Figure 8 and fully submerged in Figure 9. The weight of the marble was obtained using Eq. (2) and volume of sphere Eq. (4). This shows that are manipulated variables that used in this test.

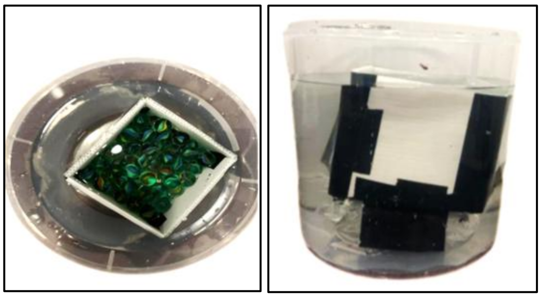
Table 2
The number and weight of marbles

Condition of raft house	Number of marbles	Weight of marbles, W (N)
Half submerged	80	8.216
Fully submerged	120	14.484



(a) (b)

Fig. 8 Raft house when half submerged (a) Top view (b) Side view



(a) (b)

Fig. 9. Raft house when fully submerged (a) Side view (b) Top view

The graph in Figure 10 clearly highlights the impact of floats on the buoyancy and weight-bearing capacity of the raft. When the raft was tested without floats, it was observed that it could initially float but began to sink after 67 marbles were added, reaching full submersion at 110 marbles. This indicates that without any additional support, the raft had a limited capacity to bear weight before losing buoyancy. In contrast, when floats were added to the raft, the results showed a significant improvement in its ability to stay afloat. Before adding weight, the raft remained stable on the water surface, and after weight was added, it took 80 marbles for it to reach a half-submerged state. The results showed that with the support of floats, the raft could withstand up to 120 marbles before fully submerging. This demonstrates that the addition of floats provided better stability and increased the raft's weight-bearing capability, preventing it from sinking as quickly as the raft without floats. The experiment confirms that implementing a floatation support system enhances the raft's overall performance, making it more effective in maintaining buoyancy and carrying additional load.

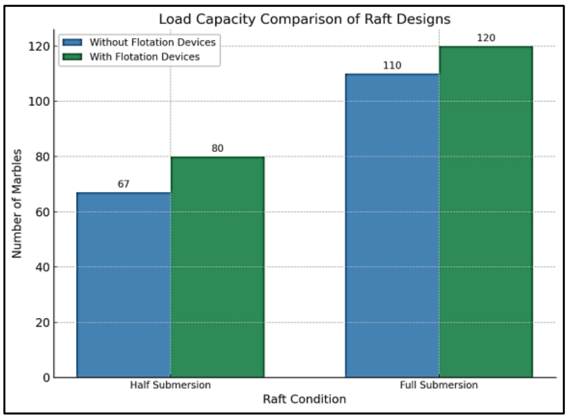


Fig. 10. The graph of load capacity for half and fully submerged

Two raft designs are compared for weight-carrying ability in "Weight Capacity Comparison of Raft Design" as shown in Figure 11 where both designs have either a floating device or no such device during half-submerged and completely submerged states. The float-equipped raft proves to be superior in terms of buoyant resistance when compared to the unfloated raft. The raft with the float tolerates approximately 10 N of weight during half-submersion but the plain raft without float only sustains 8 N. Under full immersion the raft equipped with float supports 16 N whereas the unmodified design maintains approximate weight bearing capacity of 12 N. Adding a float to the raft design provides unmatched benefits to buoyancy since it enhances weight capacity and underwater stability under all immersion levels especially under full submersion conditions.

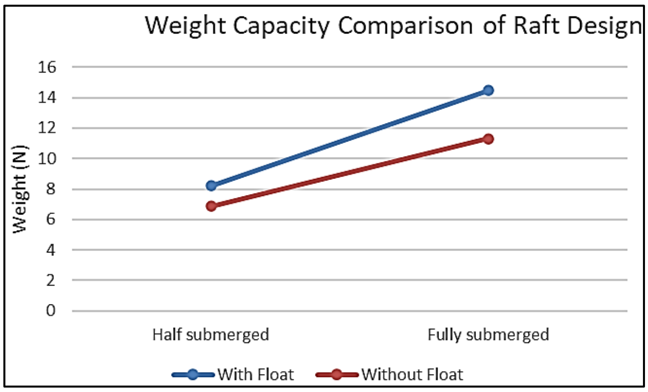


Fig. 11. The graph of weight capacity for half and fully submerged

4. Discussion

The results of this study provide critical insights into the buoyancy and load-bearing characteristics of raft houses with and without flotation devices. By systematically comparing the performance of both configurations, this research highlights the significant advantages of incorporating flotation devices into raft designs.

4.1 Performance Without Floats

The raft without flotation devices demonstrated limited buoyancy and structural stability. Half-submersion was achieved after accommodating 67 marbles, and complete submersion occurred at 110 marbles. This outcome aligns with fundamental buoyancy principles, where the buoyant force is limited to the volume of water displaced by the submerged portion of the raft [12]. Without additional flotation support, the inherent material properties of the raft dictated its load capacity.

Previous studies have similarly noted the limitations of traditional designs under dynamic or heavy loading conditions. For instance, [13] emphasized that structures relying solely on material buoyancy often fail to maintain stability when subjected to uneven weight distribution or environmental forces. The observed tilting and rapid sinking of the raft in this study reinforce these findings, highlighting the challenges of relying on basic designs for practical applications.

4.2 Performance with Floats

The integration of flotation devices into the raft significantly enhanced its buoyancy and load-bearing capacity. Half-submersion was delayed until the raft held 80 marbles, and full submersion required 120 marbles. This improvement can be attributed to the increased buoyant force provided by the floats, which displaced additional water and counteracted the added weight [14].

The use of inflatable bubble wraps as flotation devices proved effective in improving the raft's stability and capacity. Similar results were reported by Smith and Brown [15], who demonstrated that modular flotation systems could improve the adaptability and resilience of floating platforms. This study builds upon their findings by showcasing how lightweight, readily available materials can be used to achieve similar benefits in small-scale applications. The observed reduction in tilting and improved stability further highlights the practical advantages of such enhancements.

4.3 Practical Implications

The results of this research have several practical implications for the design and use of floating structures. Incorporating flotation devices can significantly extend the load-bearing capabilities of raft houses, making them suitable for a wider range of applications [16-18]. The use of lightweight and cost-effective materials, such as inflatable bubble wraps, offers an accessible and scalable solution for communities in flood-prone regions. Moreover, modular flotation systems, as discussed by Zhang *et al.,* [19], could be adapted for raft houses, allowing for customization based on specific load requirements or environmental conditions. This approach not only improves performance but also enhances the adaptability and longevity of floating structures in diverse settings [20].

4. Conclusions

This study successfully evaluated the buoyancy and load-bearing capacity of raft house models with and without flotation devices. The experimental results confirmed that adding flotation devices significantly improves the raft's performance by increasing its ability to support weight while maintaining stability. The final calculations demonstrated that the raft without flotation devices reached half-submersion at 67 marbles and full submersion at 110 marbles, while the raft with flotation devices reached half-submersion at 80 marbles and full submersion at 120 marbles. These results indicate that flotation devices increase the volume of displaced water, thereby enhancing the buoyant force acting on the raft, as predicted by Archimedes' principle. Additionally, the raft with flotation devices exhibited better stability, reducing tilting, and maintaining balance under uneven loading conditions.

The experimental results demonstrate that flotation devices play a crucial role in improving the buoyancy, stability, and load-bearing capacity of raft houses. By incorporating these enhancements, floating structures can become more reliable, adaptable, and resilient, offering practical and sustainable solutions for communities affected by flooding and limited land availability.

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