Engineering and Technology Journal e-ISSN: 2456-3358
Volume 10 Issue 01 January-2025, Page No.- 3729-3734
DOI: 10.47191/etj/v10i01.29, I.F. – 8.227

Experimental Investigation on Cement-Styrofoam Lightweight Floating Panel

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ABSTRACT: The goal of this research is to create a lightweight floating Cement-Styrofoam (CS) panel. Styrofoam of 3 different sizes were used. Three different mix ratios of cement: Styrofoam (1:1, 1:2, and 1:4) having large, medium, and small FM (5.7, 5.3, and 5.1 respectively) are taken to make standard-size concrete cylinder molds. The density of the Styrofoam cylinder molds varies from 417.88–1009.35 kg/m^3. The compressive strength of CS cylinder molds was seen to vary from 0.603–4.05 MPa. Moreover, considering the compressive strengths and density, the CS slab (610mm x 610mm x 76mm) is made to measure the maximum weight (kg) it takes before sinking. The study provides some elementary experimental results that can be used for more studies in this field.

KEYWORDS: Lightweight; Styrofoam (EPS); fineness modulus; compressive strength; mix ratios; density; buoyancy

1. INTRODUCTION

Bangladesh is a flood-prone country and frequent flooding has a significant impact on the environment and economy. In this country, floods have become more frequent, intense, prolonged, and devastating during the past few decades. By introducing floating concrete structures, the loss of lives and properties can be minimized [1-3].

A solid body constructed of lightweight elements including cement, water, aggregates, and admixtures makes up the Floating Concrete Structure. Floating concrete has a density that ranges from 600 to 1000 kg/m^3 [4-6]. To make this type of concrete float, mainly expanded polystyrene (EPS) or Styrofoam is used with cement, and water as composite admixtures. One cup of Styrofoam takes 500 years to disintegrate [7, 8]. The amount of waste made from Styrofoam is enormous. For instance, the average daily weight of rubbish produced in the USA is 547,945 tons, of which 0.25% is made up of Styrofoam items [9]. Approximately 4 million tons of trash Styrofoam are produced annually in the USA. 25% to 30% of all landfill area is made up of debris made of polystyrene [10, 11].

2. LITERATURE REVIEW

Various researchers have explored floating structures and marine energy as solutions to environmental issues such as population growth, energy shortages, and climate change [12, 13]. This research emphasizes sustainable design, innovative concepts, and the potential of floating architecture to address environmental concerns and integrate with offshore renewable energy sources [14]. The practical knowledge and engineering challenges of designing and constructing floating concrete structures are detailed in ACI PRC-357.2-10 [15]. Floating structures, which can remain afloat continuously, intermittently, or temporarily, include industrial plant ships, floating bridges, dry docks, and offshore terminals. These structures can be either towed and used as fixed installations or moved to different locations. Lightweight concrete is often employed in floating structures to enhance payload capacity and reduce power requirements, particularly in ships, barges, docks, and breakwaters [16-18].

Recently, lightweight or low-density concrete, also known as floating concrete, has garnered significant interest due to its potential applications in various engineering and construction projects [19]. Another study examines the use of expanded polystyrene (EPS) beads as a lightweight aggregate in mortars and concretes containing silica fume as an additional cementitious ingredient [20]. Depending on the required density and strength, lightweight aggregate can either completely or partially replace traditional aggregates in lightweight concrete [21, 22].

Research on eco-friendly lightweight Styrofoam bricks with higher compressive strength using strengthening admixtures has focused on cost and environmental concerns [23, 24]. One study explored the effects of adding 5%, 10%, and 20% fine sand to composites with 20%, 40%, and 60% Styrofoam on properties such as density, porosity, and compressive strength. Finite element analysis using Abaqus software showed varying densities (1250-1600 kg/m³) and strengths (9-18 MPa) [25]. Another study aimed to determine the compressive strength and density of lightweight concrete mixtures containing cement, sand, Styrofoam, and bagasse ash. Using waste materials reduces manufacturing costs and earthquake loads, enhancing safety and suitability for residential buildings in seismic zones [26].

Solikin and Ikhsan [27] confirmed that up to 50% of Styrofoam usage meets concrete brick standards. Using EPS as a coarse aggregate and fly ash (FA)/silica fume (SF) as partial cement replacements in EPS concrete (EPSC) provides a sustainable solution for reducing environmental impact. The optimal mix proportion of EPS lightweight concrete is 20% FA and 5% SF, resulting in a compressive strength of 12.8 N/mm² [28]. Another study prepared lightweight mortar cubes with Styrofoam balls and aluminum oxide, replacing Portland cement at 0%, 0.5%, and 1%. Testing over 7, 14, and 28 days revealed a 40%-50% density reduction and a slight decrease in compressive strength to 15 MPa, with slower deterioration than normal mortar [29]. Additionally, research on using plastic and Styrofoam waste in brick-making found an average compressive strength of 44.62 kg/cm², providing an eco-friendly alternative to traditional waste disposal and mitigating environmental pollution [30].

The aforementioned studies have explored floating structures as solutions to environmental challenges, emphasizing sustainable design and innovative floating architecture. Practical and engineering aspects of floating concrete structures, such as floating bridges, dry docks, and offshore terminals, are now of global interest. Lightweight concrete is frequently used to increase payload capacity and reduce power requirements, especially in vessels and fixed floating structures. Research on lightweight concrete has commonly utilized expanded polystyrene (EPS) beads, silica fume, cement, sand, stone, and other additives to enhance properties like density and compressive strength. Additionally, studies have focused on eco-friendly Styrofoam bricks and mortar cubes with aluminum oxide to reduce costs, improve safety, and mitigate environmental impact by using waste materials. However, no study has exclusively used cement and Styrofoam beads to produce floating panels and conduct buoyancy tests, which may offer better practical applications. This gap presents an opportunity for further research, and this study's objectives are formulated accordingly.

3. OBJECTIVE

In this study, Styrofoam, cement, and water are used to make floating concrete panels. Altering stones and sands in concrete, and introducing Styrofoam can lessen the dead load of the structure. Floating concrete structures can be easy and affordable to transport, quickly constructible, cost-effective, used as portable flood shelters, have a pleasant Appearance, and are not vulnerable to earthquakes. The fact that Styrofoam is one of the main ingredients that can have a big impact on significant characteristics like weight, strength, and cost may be the reason why this type of panel is referred to as a floating concrete panel. The objectives of the research described are:

1. To develop a lightweight floating Cement-Styrofoam (CS) panel and measure its strength.
2. To evaluate the buoyancy capacity of the CS panel in water under applied dead loads.

4. METHODOLOGY

At first, the FM of the three types of Styrofoam was measured (Figure: 1). After that Cement-Styrofoam (CS) cylinders (height: 200mm, diameter: 100 mm) were made to know the 28 days compressive strength after curing (Figure: 2-4)

Fig 1: Sieve analysis

Fig 2: Casting the concrete specimen

Fig 3: Curing the specimen

Fig 4: Testing the specimens

For the above tests, the most suitable combination of Cement-Styrofoam was selected which was used for the Buoyancy (or Flotation) Test. The Buoyancy test is used to determine the net buoyancy of individual flotation objects. For that, a 2' x 2' x 3" CS slab panel was produced (Figure 5-8).

Figure 5: Casting the slab

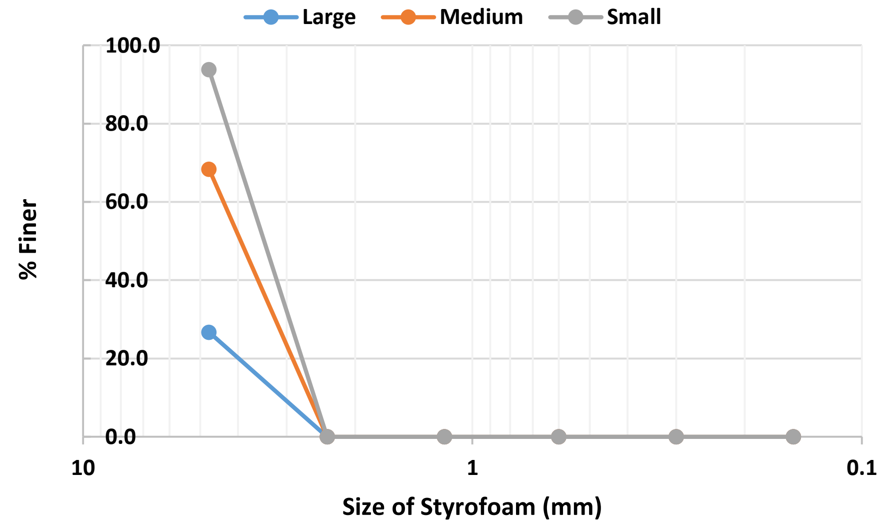
Figure 6: weighing the slab

Figure 7: Buoyancy test

Figure 8: Deadweight used for test

5. RESULTS ANALYSIS

Three sizes of Styrofoam were used in this study (FM = 5.7, 5.3, 5.1, Figure 9). Also, three mix ratios of cement-styrofoam were used (1:1, 1:2, 1:4). The test results of compressive strength and density are presented in Table 1.



FM

Styrofoam size	FM
Large	5.7
Medium	5.3
Small	5.1

Figure 9: Gradation of Styrofoam

The CS cylinder with a mix ratio of 1:1 and Medium FM has the highest compressive strength (4.05 N/mm^2). The lowest compressive strength (0.603 N/mm^2) was found in the CS cylinder with a Large FM mix ratio of 1:4. This analysis underscores the influence of mix ratio and grain size on the load-bearing capacity of Styrofoam cylinders. For engineering applications where load-bearing capability (i.e. compressive strength) is a significant aspect, understanding these variances is essential. Using this information, producers and designers may choose the right grain sizes and mix ratios to fulfill Styrofoam cylinder load standards. More efficient design and construction methods may result from modifying these characteristics in light of the patterns that have been noticed.

Table 04: Values of different properties of specimens

CS Mix Ratio	Properties	Large FM	Medium FM	Small FM
1:1	Compressive stress (N/mm^2)	3.568	4.05	3.593
	Density (kg/m^3)	941.05	1009.35	886.37
1:2	Compressive stress (N/mm^2)	1.98	1.75	2.39
	Density (kg/m^3)	678.86	685	721.54
1:4	Compressive stress (N/mm^2)	0.603	0.85	0.74
	Density (kg/m^3)	428.86	417.88	406.5

The CS cylinder with a mix ratio of 1:4 with Small FM has the lowest density (406.5 kg/m^3). The highest density, 1009.35 kg/m^3, was found in the Medium FM with a mix ratio of 1:1. This analysis demonstrates the influence of mix ratio and grain type on the density of Styrofoam cylinders. Determining mix ratios and grain types that provide the appropriate density for Styrofoam cylinders can be made easier by having a better understanding of these variables. CS cylinders with consistent and acceptable density standards can be produced by modifying these parameters based on the trends that have been noticed.

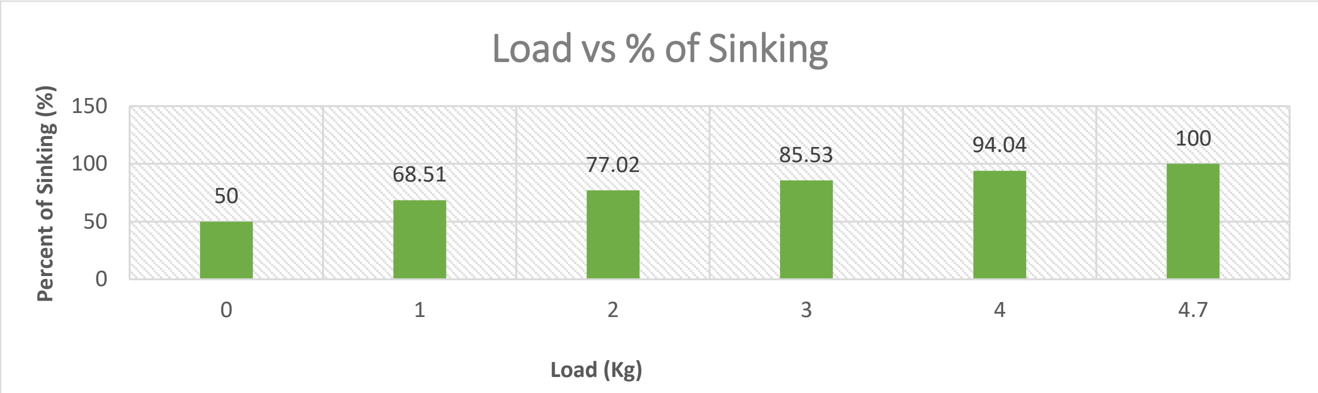


Figure 8: Load vs Percent Sinking

To continue the additional observations, a CS slab panel (a 2' x 2' x 3") with a mix ratio of 1:2 of large FM has been made from Table 4 by comparing the density and compressive stress with other ratios. The CS slab panel’s (Fig. 7) buoyancy was about 50% lower when submerged in water for observation. When 1 kg of Load was applied consistently, sinking finally occurred at a rate of around 68.51% and grew steadily to 94.04% for 4 kg of load. After applying a total of 4.7 kg, it began to sink completely (Figure 8). Note that the self-load of the 2' x 2' x 3" panel was 20.4 Kg. As per the current market price of Holcim-Strong (water-repulsive) cement and Styrofoam, the material cost of this CS panel (2' x 2' x 3") was 578 BDT.

6. CONCLUSION

This review on Styrofoam concrete shows that Styrofoam concrete can be used in civil engineering works as lightweight concrete. Styrofoam can be a good substitute for the aggregates in lightweight concrete but it needs the correct percentage of Styrofoam used [31].

1) This research underscores the importance of compressive strength, density, weight, and load in determining the quality of construction slabs. It focuses on the development of lightweight floating Styrofoam panels with improved compressive strength, essential for various construction applications. The study experimented with different fineness modulus Styrofoam beads and varying cement-to-Styrofoam ratios, resulting in a range of specimens with compressive strengths from 0.603 to 4.05 MPa and densities between 417.88 and 1009.35 kg/m³. Additionally, buoyancy tests on Styrofoam-concrete slabs provided insights into their practical applications.
2) This research reveals that incorporating Styrofoam into concrete can produce lightweight, buoyant materials suitable for construction projects aiming to reduce structural weight while maintaining strength and buoyancy. Such innovations enhance cost and energy efficiency and support sustainability by lowering material consumption and environmental impact. The findings advocate for the broader use of lightweight concrete with Styrofoam in various construction scenarios, presenting a promising direction for future advancements in construction materials and techniques.
3) However, the study also highlights limitations, such as the lower compressive strength of floating concrete, and relatively high cost, which may restrict its use in critical structural applications. Additionally, its limited fire resistance and handling challenges due to lower density pose further concerns. Future applications include floating bodies like platforms, homes, bridges, and temporary infrastructure for emergency response, offering viable solutions for construction in challenging conditions.

7. ACKNOWLEDGMENTS: Not applicable.

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