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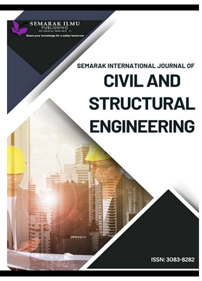


# Lightweight Plastic-Cellular Concrete Block (LPCCB) for Construction Applications over Peat Ground

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**ABSTRACT**

The rapid infrastructure development has forced construction over peat ground, causing a rising need for innovative construction solutions without replacing the existing soil. This paper aims to investigate an alternative lightweight fill material derived from by-products as a substitute for the unsustainable and expensive soil replacement method. This study incorporates recycled plastic bottles filled with rubber-sand mixtures as the primary structural component within a cellular concrete matrix, referred to as Lightweight Plastic-Cellular Concrete Block (LPCCB). The study was divided into three experimental phases to assess the mechanical and physical performance of the proposed lightweight fill block: (1) bottle structure containing various rubber-sand mixtures, (2) cellular concrete mix design, and (3) LPCCB developed based on findings from Phases 1 and 2. The results demonstrate that the densities of filled plastic bottle structures increased in a linear trend with the increase in sand content in the bottle structures. The study found that the 75R25S rubber-sand mixture exhibited the greatest compressive strength (6.40 MPa), with a density less than 1000 kg/m$^3$. The cellular concrete properties showed that the compressive strength continued to decrease with the increase in foam content, consistently demonstrating a decrease in both density and compressive strength, while also increasing porosity and water absorption. In the final phase, the fabrication of LPCCB has used foam agents of 0.5, 1.0, and 3%. The findings showed that utilising foam more than 1% led to structural failure. Overall, it can be concluded that the rubber-sand mixture plays an important role in terms of density and strength, and that the 0.5% foam agent creates a solid and sturdy grasp of the plastic bottle. This research adds to more sustainable construction designs and applications, combining both recycled plastic and rubber waste to make it a structural material with a lightweight approach, with no negative impact on the environment in soft soil conditions, including peatlands.

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## 1. Introduction

The performance and stability of infrastructure, such as roads and slopes, are heavily dependent on the underlying soil conditions. However, the existing soil is not always suitable for construction purposes, especially when dealing with soft soil, such as peat and clay soils. Soft soils, such as clay and peat, which have a high-water content, low shear strength, and high compressibility, pose significant challenges in construction given their poor bearing capacity and tendency to settle, which results in structural instability [1,2]. These soils are prevalent in regions such as Malaysia's coastal states, where peatlands cover extensive areas, notably in Sarawak [3]. Existing research indicates that traditional soil stabilization methods, such as soil replacement, are frequently expensive, time-consuming, and environmentally unsustainable. In response, modern lightweight fill technologies that may minimize differential settlement, decrease strain on soft soils, and speed up construction timelines, such as cellular concrete and expanded polystyrene (EPS) geofoam, have drawn interest [4]. However, despite their advantages, these materials have limitations that need addressing to improve their practical application. To improve the performance of lightweight fills, geotechnical engineers are increasingly turning to environmentally friendly, cost-effective, and sustainable solutions that use locally available agents and recycled materials. By investigating alternative materials and techniques to increase infrastructure durability on soft soils, our work supports these trends.

Cellular concrete and expanded polystyrene (EPS) geofoam are two popular forms of lightweight fill materials. EPS geofoam is made from rigid blocks of expanded polystyrene foam with a cellular structure that traps air, resulting in extremely low density and compressibility. Cellular concrete, often referred to as foamed concrete, is a cementitious material that has been combined with foaming agents to create millions of tiny air bubbles, which lowers the density of the concrete without affecting strength. By substituting lighter alternatives for heavy soil fills, these materials' mechanism considerably lessens the strain on soft subgrades and lessen differential movement and consolidation settling. Lightweight fill materials have advantages beyond simply reducing load. By using recycled materials and reducing excavation and transportation, they promote environmental sustainability, speed up construction timelines since they are easy to handle and install, and eliminate the need for significant ground improvement. Lightweight fills have a wide range of uses, such as utility trench support, retaining wall backfills, bridge abutments, slope stabilization, road and highway embankments, and land reclamation. In areas with problematic soft soils, these materials have proven very useful, allowing for safer and more resilient infrastructure.

Despite the promising benefits of lightweight fill materials such as EPS geofoam and cellular concrete, there remain significant gaps in their practical application. Although EPS geofoam works well to reduce settlement, it has poor fire resistance and buoyancy concerns that might jeopardize stability over time [5]. Despite its potential, cellular concrete may have densities that are comparable to those of conventional fills and have higher water absorption, which raises questions over its longevity [6]. Furthermore, the practical and economic feasibility of lightweight cellular concrete is limited by the frequent application of expensive synthetic foaming agents in its preparation [7-8]. There is a notable research gap in exploring affordable, locally available natural foaming agents and optimizing their use to produce stable cellular concrete with desirable mechanical properties. To create lightweight fill materials that are affordable, sustainable, and appropriate for soft soil applications, these gaps must be filled.

Through the incorporation of recycled plastic bottles containing different rubber-sand mixtures into cellular concrete, this study aims to investigate the development of an alternative lightweight plastic-cellular concrete block (LPCCB). By reusing waste materials, the research aims to improve the block's mechanical and physical characteristics, such as density, buoyancy, water absorption, and compressive strength, while also advancing environmental sustainability. This study's main research questions are:

i. What effects do varying ratios of rubber to sand have on the block structure's density and compressive strength in plastic bottles?
ii. Using foam agents that are obtained locally, what are the mechanical and physical characteristics of cellular concrete at different porosities?
iii. What effects does the addition of plastic bottle structures have on the lightweight plastic-cellular concrete block's overall performance?

The present study explores the potential of Lightweight Plastic-Cellular Concrete Blocks (LPCCB) developed by using recycled PET bottles filled with rubber-sand mixtures and cellular concrete prepared with locally available foaming agents. The objective of this research is to (1) investigate the density and compressive strength characteristics of a plastic bottle structured filled with various rubber-sand mixtures, (2) examine the physical (density, porosity, and water absorption) and mechanical (compressive strength) properties of a cellular concrete block at various porosities without plastic bottle structure, and (3) evaluate the physical and mechanical properties of the lightweight plastic-cellular concrete block (LPCCB) through density, porosity, water absorption, buoyancy, and compressive strength.

## 2. Methodology

### *2.1 Lightweight Plastic-Cellular Concrete Block (LPCCB) Mix Design Ratio*

The cellular concrete mixture was prepared by combining four key ingredients, namely Ordinary Portland Cement (OPC), water, fine aggregates, and a foaming agent. Portland cement is commonly used as a primary binder. Water is essential for initiating the hydration process, and its water ratio must be carefully measured to maintain the desired water-cement ratio. The foaming agent plays a vital role in creating a lightweight cellular structure by introducing air bubbles into the mixture. Table 1 outlines the mix design of the cellular concrete in a volume of 0.001 $m^3$ with various percentages of foam agent contents, which are 0, 0.5, 1, 3, 5, 7, and 9% weight of cement, respectively. The cement-to-sand ratio and water/cement (w/c) ratio were fixed at 60:40 and 0.60 throughout the mix. The mass of cement and sand used in 0.001 $m^3$ is 0.8113 kg and 0.5411 kg, respectively, for all mixes. The control mix contains no foam agent; it acts as a benchmark.

**Table 1**
Mix design of Lightweight Plastic-Cellular Concrete Block (LPCCB)

| Mix Design for 0.001$m^3$ | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sample Code | Cement | | Sand | | Foam Agent (FA) | | Water/Cement Ratio (%) |
| | % | kg | % | kg | % | kg | |
| Control | 60 | 0.8113 | 40 | 0.5411 | 0 | 0 | 0.60 |
| CC-$FA_{0.5}$ | 60 | 0.8113 | 40 | 0.5411 | 0.5 | 0.0004 | 0.60 |
| CC-$FA_1$ | 60 | 0.8113 | 40 | 0.5411 | 1 | 0.0008 | 0.60 |
| CC-$FA_3$ | 60 | 0.8113 | 40 | 0.5411 | 3 | 0.0024 | 0.60 |
| CC-$FA_5$ | 60 | 0.8113 | 40 | 0.5411 | 5 | 0.0041 | 0.60 |
| CC-$FA_7$ | 60 | 0.8113 | 40 | 0.5411 | 7 | 0.0057 | 0.60 |
| CC-$FA_9$ | 60 | 0.8113 | 40 | 0.5411 | 9 | 0.0073 | 0.60 |

Notes: CC = Cellular Concrete, FA = Foam Agent

### *2.2 Mix Procedure and Fabrication of Plastic Bottle Structure*

In this study, the plastic bottles were filled with varying ratios of rubber and sand, specifically 100:0, 75:25,50:50, 25:75, and 0:100 by volume of plastic bottle (500ml). Rubber-sand mixture was accurately weighed and thoroughly mixed manually for each mixing ratio until they achieved a homogeneous mixture was achieved. The mixtures were then carefully poured into the cleaned plastic bottles in three equal layers (see Figure 1). Each layer was gently pressed to eliminate trapped air and promote compaction within the bottle. The bottles must be filled uniformly to ensure the consistency of the final lightweight plastic-cellular concrete blocks. The filled plastic bottles play a crucial role, as they provide structural support and contribute to the overall performance of the lightweight plastic-cellular concrete blocks.

(a) (b)

**Fig. 1.** Material preparation (a) Plastic bottle (b) Weighing plastic bottles filled with 100% rubber chips

### *2.3 Mix Procedure and Fabrication of Cellular Concrete*

The fabrication process of the cellular concrete began with careful preparation of all required materials, including Ordinary Portland Cement (OPC), fine aggregates (sand), water, and a foaming agent. The mix design maintained a consistent water-to-cement (w/c) ratio of 0.60 and a cement-to-sand ratio of 60:40. The foaming agent was added based on a specified percentage by weight of the cement, which ranging from 0%, 0.5%, 1%, 3%, 5%, 7% and 9%. The cement and sand were first accurately measured and properly dry-mixed to ensure even distribution. Separately, a hand mixer was used to produce the foam, which produced a stable and uniform foam texture appropriate for mixing concrete. To provide a uniform and workable cellular concrete mixture, the pre-mixed dry components were blended with foam and water in a mixing container after the foam was ready. The fresh cellular concrete was then poured into prepared molds, followed by gentle compaction to eliminate trapped air and ensure uniformity (see Figure 3). The moulded samples were then allowed to cure for seven to twenty-eight days under carefully monitored conditions to properly hydrate and develop their strength. The detailed procedure for fabricating this product is shown in Figure 2.

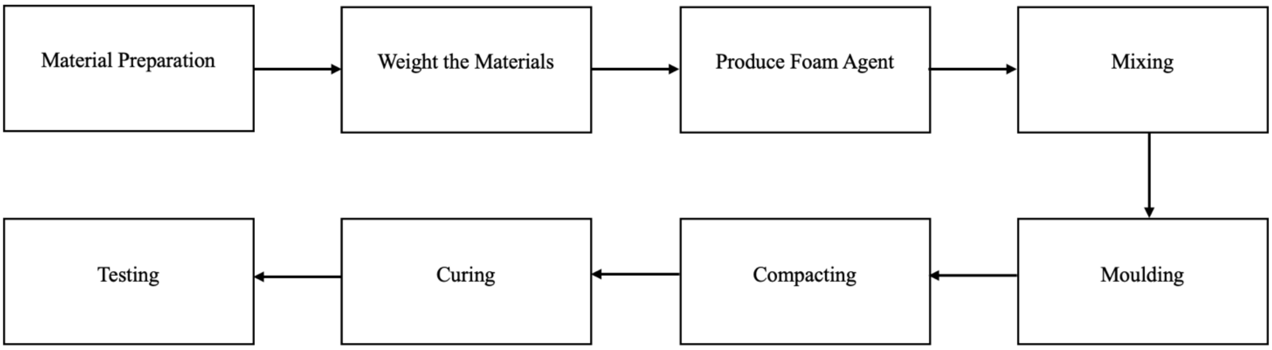
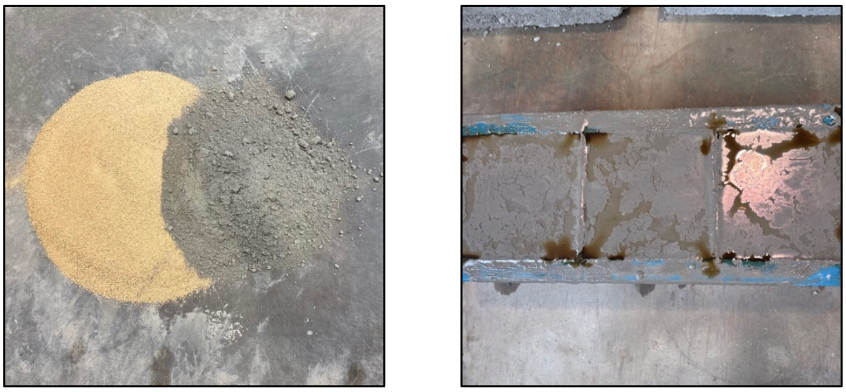



**Fig. 2.** Procedure for the fabrication of cellular concrete (CC)



(a) (b)

**Fig. 3.** Sample preparation (a) Mixing of dry materials (b) Casting of fresh cellular concrete into the mould

### *2.4 Mix Procedure and Fabrication of Lightweight Plastic-Cellular Concrete Block*

The fabrication process involved filling the 500 ml volume of the plastic bottle with the rubber-sand mixture. The preparation process of the plastic bottle structure is discussed in Section 2.2. Once the bottles were filled, they were placed in a mould. The cement and sand were then measured following the specified mix proportions. These materials were placed in a clean mixing tray and dry-mixed until a uniform consistency was achieved. Meanwhile, foam was produced using a paint mixer by blending water and the foam agent at the predetermined ratio until a stable foam with uniform density was formed. The dry cement-sand mixture was gradually combined with water and the prepared foam, and all components were mixed thoroughly until a homogeneous mixture with evenly distributed foam was obtained. Freshly mixed cellular concrete was poured around the mould, ensuring that the rubber-sand-filled bottles were completely encased. The blocks were cured at controlled temperature and humidity for 7 days to allow the cement to set and achieve the desired strength. The mould accommodated a total of 3x3 plastic bottles, which consist of 9 bottles in one lightweight plastic-cellular concrete block. The proposed dimensions of each fabricated block were 200 mm x 200 mm x 210 mm. The detailed procedure for fabricating this product is shown in Figure 4. The prototype of the Lightweight Plastic-Cellular Concrete Block (LPCCB) and the fabricated product are shown in Figure 5.

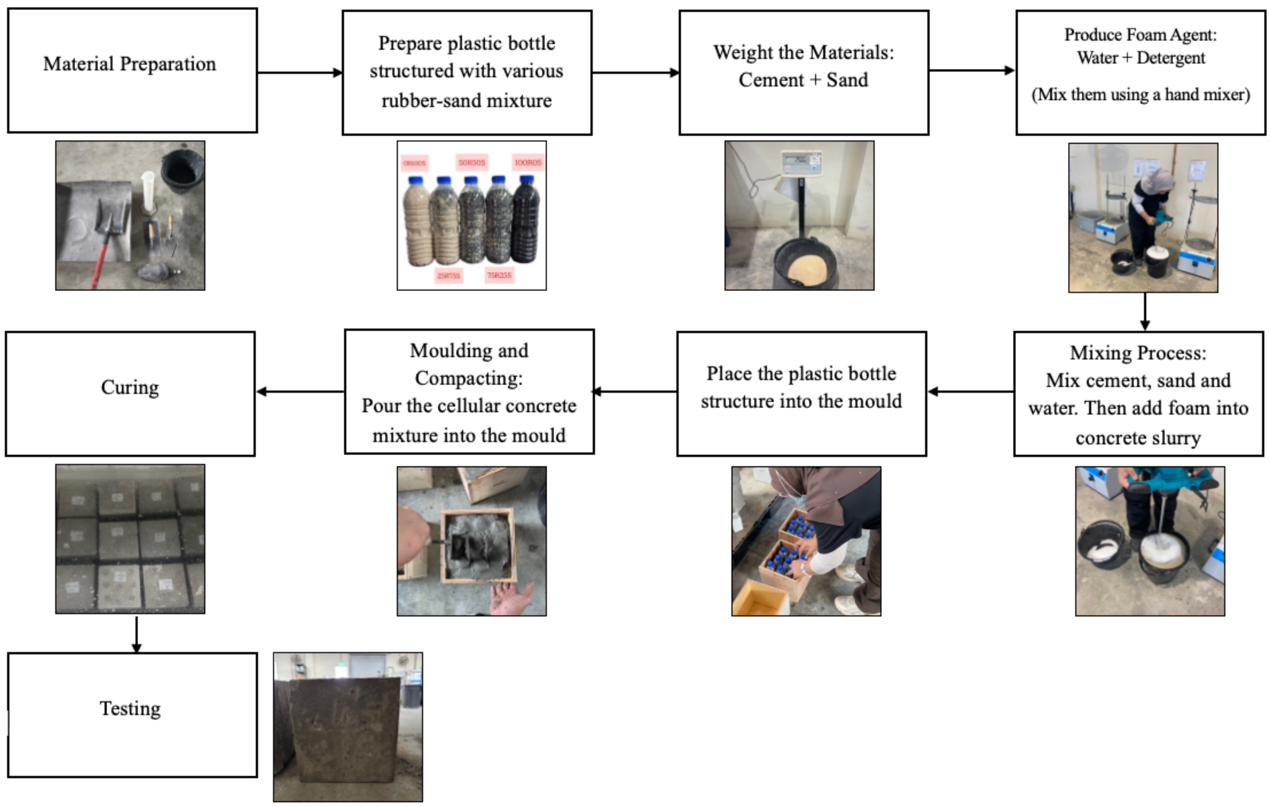
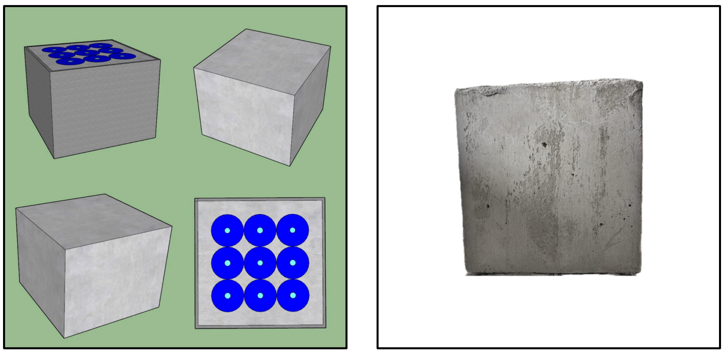



**Fig. 5.** Procedure for the fabrication of LPCCB



(a) (b)

**Fig. 5.** (a) Prototype of LPCCB; (b) Fabricated Lightweight Plastic-Cellular Concrete Block (LPCCB)

## 3. Results

### *3.1 Phase 1: Density and Compressive Strength of Plastic Bottle Structure*

The density of a mixture of sand and rubber increases with the amount of sand added as shown in Figure 6. The 100R0S sample had the lowest density at 755 kg/m³, while the 0R100S sample had the highest density at 1661.2 kg/m³. The density increases gradually with sand content, with 75R25S having the highest density at 981.4 kg/m³. The observed pattern in a composite material is due to the natural physical differences between sand and rubber. Rubber is generally less dense and more elastic than sand, which has a greater specific gravity [9].

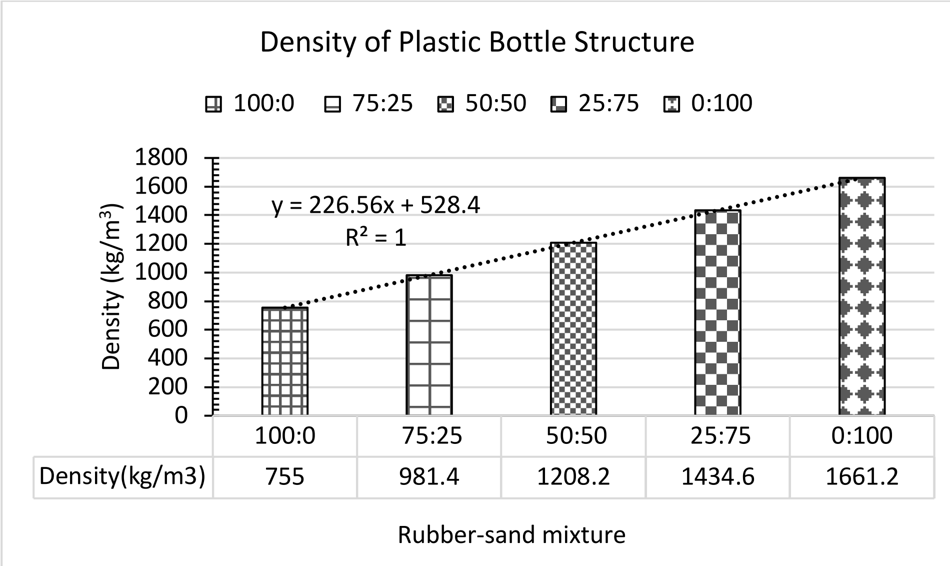



**Fig. 6.** Density of plastic bottle structure

The result shown in Figure 7 indicates that the ratio of mixtures affected compressive strength, with 75R25S having the highest strength at 6.40 MPa. However, the strength decreased by 22.5% for 50R50S, 60.5% for 25R75S, and 11.7% for 0R100S. The regression equation showed a weak negative linear relationship between sand content and compressive strength. The observations during testing showed that samples with a higher sand content tend to be more fragile and are more likely to fracture upon loading. On the other hand, samples containing more rubber were more elastic and resistant to breaking. Additionally, up to a specific percentage of rubber content, rubber aggregates may help maintain a lower density by partially filling the spaces within the sand matrix [10]. This implies that adding rubber to the mixture improves the absorption of energy and helps to increase its compressive strength, as demonstrated by the 75R25S.

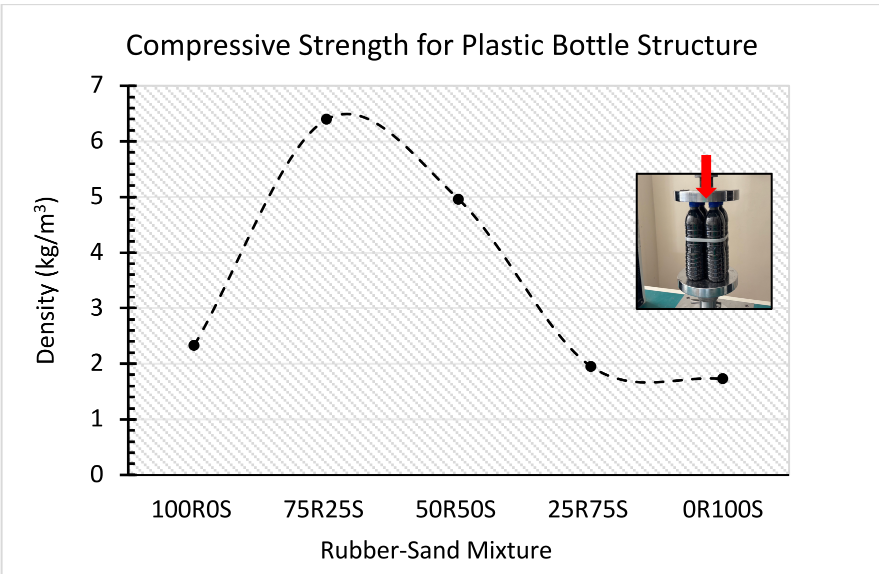



**Fig. 7.** Compressive strength of plastic bottle structure

### *3.2 Phase 2: Density, Porosity, Water Absorption, and Compressive Strength of Cellular Concrete*

The experimental finding demonstrates a clear pattern of density decrease in cellular concrete with increasing foam agent amount. The control sample exhibits the highest density at 1891.71 kg/m³. Increasing the foam agent led to a 13.7% decrease, while increasing the foam agent resulted in a 36.9% decrease. This trend persisted with varying foam agent amounts. The foam agent introduces air voids, reducing density in lightweight concrete. This effect is supported by Shill *et al.,* [11] study, which found that foam concentration and content significantly impact concrete density. Higher foam content results in lower density but may affect water absorption and compressive strength.

Porosity measurement revealed that the addition of foam substantially increases the porosity of cellular concrete. The control sample had the lowest porosity, while higher foam content increased porosities. The results suggest that higher foam content can cause more air voids or weaken the concrete's structure. Water absorption tests further supported these findings. The foam agent creates more interconnected pores in the concrete matrix, reducing density and strength while allowing more water to be absorbed. The higher the foam agent percentage, the more water is absorbed, as shown in Table 2. Ramamurthy *et al.,* [12]. found that the number of pores in a capillary suction process affects sorptivity, with higher water absorption when interconnected pores are present. The control sample's lower absorption value is due to the compact matrix.

**Table 2**
Result of density, porosity, water absorption, and compressive strength for cellular concrete

| Sample Code | Density(kg/m$^3$) | Porosity (%) | Water Absorption (%) | Compressive Strength (MPa) | |
|---|---|---|---|---|---|
| | | | | 7 days | 28 days |
| Control | 1891.71 | 1.75 | 2.70 | 12.930 | 15.000 |
| CC-FA$_{0.5}$ | 1751.80 | 2.89 | 4.03 | 7.260 | 8.440 |
| CC-FA$_1$ | 1632.45 | 5.21 | 5.27 | 5.820 | 8.080 |
| CC-FA$_3$ | 1193.90 | 7.03 | 7.63 | 0.998 | 1.260 |
| CC-FA$_5$ | 1100.00 | 13.04 | 15.00 | 0.814 | 0.931 |
| CC-FA$_7$ | 938.07 | 13.93 | 16.24 | 0. 729 | 0.559 |
| CC-FA$_9$ | 790.97 | 14.56 | 17.13 | 0.506 | 0.252 |

Notes: CC = Cellular Concrete, FA = Foam Agent

In terms of mechanical performance, compressive strength decreased as foam content increased. The control sample showed the greatest strength at both ages, but increased foam content led to a 43.8% decline. Other samples also showed further decreases. CC-FA7 and CC-FA9 showed a decrease in strength over time, with a 23.3% reduction and a 50.2% drop, despite expected strength growth from 7 to 28 days. The curing technique may have weakened the internal matrix structure due to excessive water absorption and increased foam content. Shill *et al.,* [11] found that higher foam percentages compromise strength, compressive strength, and mechanical performance, especially if not properly accommodated by curing techniques.

### *3.3 Phase 3: Density, Water Absorption, Buoyancy, and Compressive Strength of Lightweight Plastic-Cellular Concrete Block (LPCCB)*

This phase is to evaluate the physical and mechanical properties of the lightweight plastic-cellular concrete block (LPCCB) through density, porosity, water absorption, buoyancy, and compressive strength.

### *3.3.1 Density*

Figure 8 shows that the density of the samples grew significantly as the amount of sand and rubber in the samples decreased. The 100% sand mixture (FA1-0R100S) had the maximum density at 1643 kg/m³, while the 100% rubber sample (FA1-100R0S) had the lowest density at 1131 kg/m³. This indicates that the density of the 100% sand mixture increased by 45.3% compared to the 100% rubber mixture. Given that sand has a larger specific gravity than rubber, this tendency is to be expected. The total mass per unit volume rises with the amount of sand added to the mixture, increasing the density.

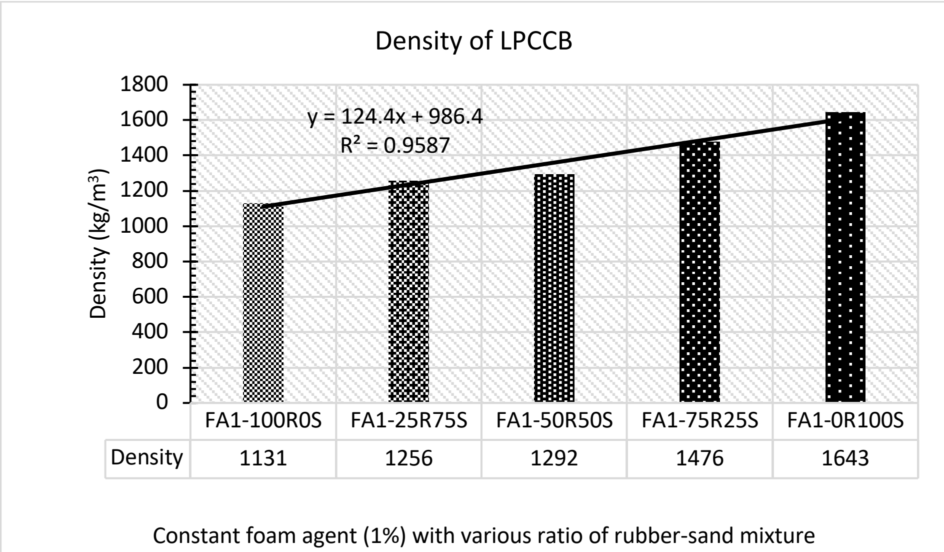



**Fig. 8.** Density of lightweight plastic-cellular concrete block with constant percentage of foam agent (1%) and various ratios of rubber-sand mixture

Figure 9 indicates that as the amount of foam increases, the density decreases. The density dropped 2.1% from FA0.5-50R50S to FA1-50R50S and more significantly (22.2%) from FA1-50R50S to FA3-50R50S. This is because the foam agent creates more air voids, which partially replace the solid matrix with low-density air. In conclusion, the density of LPCCB is greatly influenced by the foam agent concentration as well as the rubber-to-sand ratio. Higher foam content reduces density by adding more internal voids, but higher sand content increases density because of the heavier particle weight. These results are essential for optimizing the design of the LPCCB mix to strike a balance between lightweight properties and structural performance.

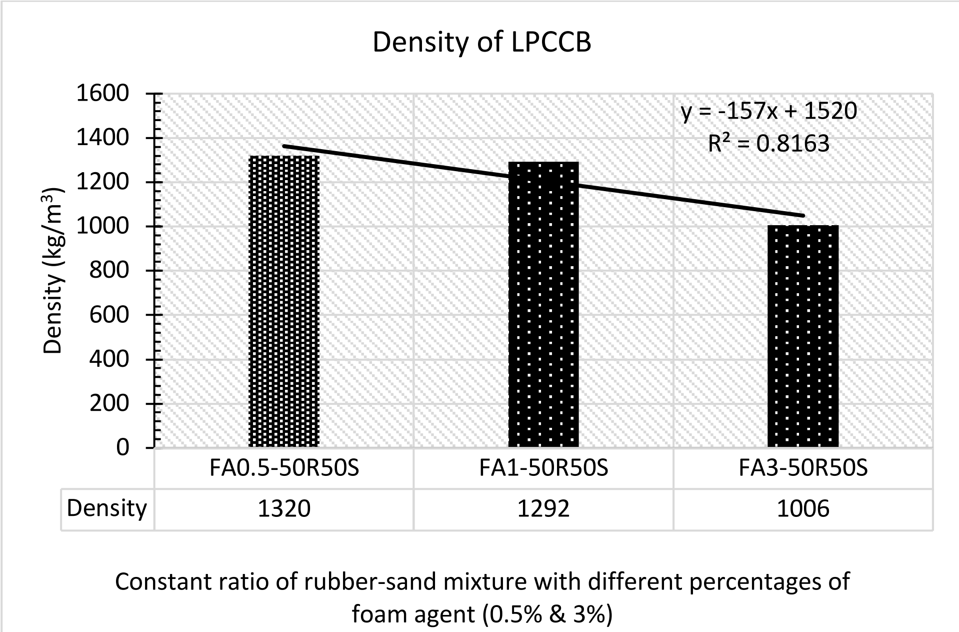



**Fig. 9.** Density of lightweight plastic-cellular concrete block with a constant ratio of rubber-sand mixture and different percentages of foam agent (0.5% and 3%)

### *3.3.2 Water absorption*

Figure 10 indicates that uneven patterns in water absorption were observed in the investigation using different rubber-sand mistures and a constant foam agent percentage of 1%. It was shown that the FA1-100R0S had the highest value (4.79%), while the FA1-50R50S had the lowest (2.83%), indicating a notable 40.9% drop. Human mistakes during mixing, compaction, or foam preparation may be the cause of these discrepancies. A denser solid matrix caused by over-compaction during casting would have decreased porosity and impacted the outcomes of water absorption. Additionally, inconsistent bottle packing and uneven foam distribution during mixing may have further contributed to the variations. These results emphasize the necessity of better sample preparation control to guarantee more reliable results in further research.

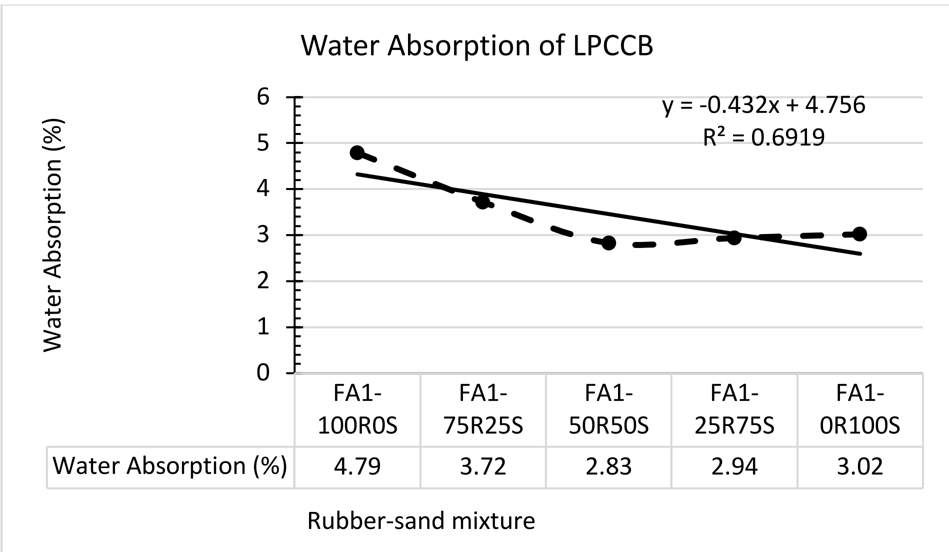



**Fig. 10.** Effect of different ratios of rubber-sand mixture on water absorption of LPCCB

Figure 11 concludes by demonstrating that water absorption is greatly impacted by raising the percentage of foam agent in foam concrete incorporated with a 50:50 ratio of rubber-to-sand mixture filled in the bottle structure. Water absorption increases with foam content because of the formation of air spaces and open pore structures. Water absorption was lowest in the sample with the lowest foam content (FA0.5-50R50S) at 1.98%, and the highest in the sample with the highest foam content (FA3-50R50S) at 6.51%. These results indicate that porosity and moisture retention are directly influenced by foam content. Variability in the results might have been caused by variations in the rubber-to-sand ratio and possible over-compaction during casting an LPCCB. To increase the uniformity and reliability of sample preparation and casting techniques, future research should concentrate on improving the mixing and compaction procedures.

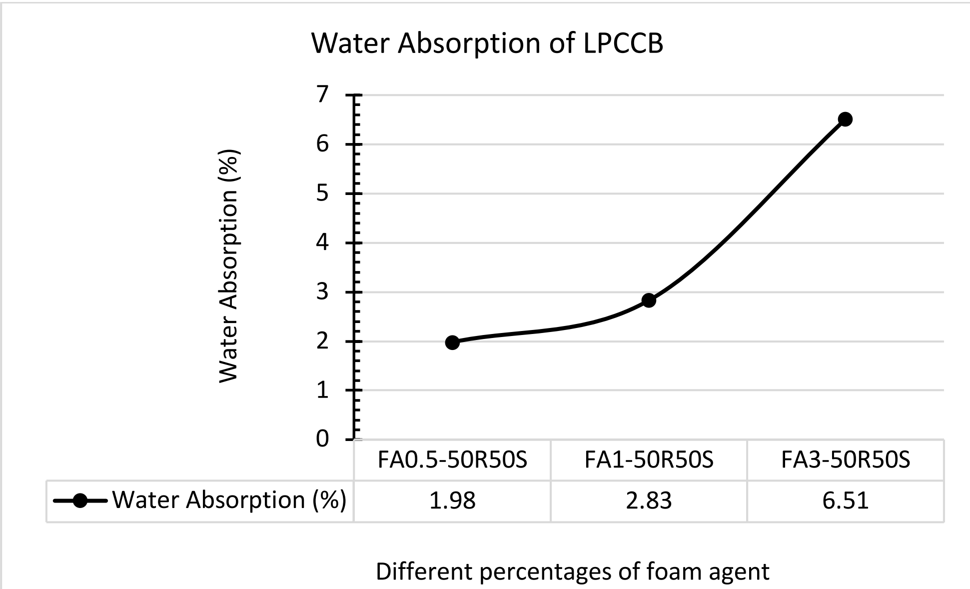



**Fig. 11.** Effect of different percentages of foam agent on water absorption of LPCCB

### *3.3.3 Buoyancy*

Figure 12 shows an inverse connection between density and buoyant performance, with the buoyancy force tending to decrease as density increases. As the ratio of sand raised and rubber decreased, the density increased from 1131 kg/m³ to 1643 kg/m³ (a 45.3% increase). As a result, the average buoyancy force decreased by 15.6%, from 83.86 N to 70.80 N. This pattern is to be expected as mixtures with a higher density displace less water volume per unit mass, which lowers the buoyant force. Since it had the largest buoyancy force and the lowest density, the 100% rubber sample (FA1-100R0S) was more likely to move or float within the concrete block. The 100% sand sample (FA1-0R100S), on the other hand, had the lowest buoyancy force and the maximum density, indicating greater stability in damp or flooded conditions.

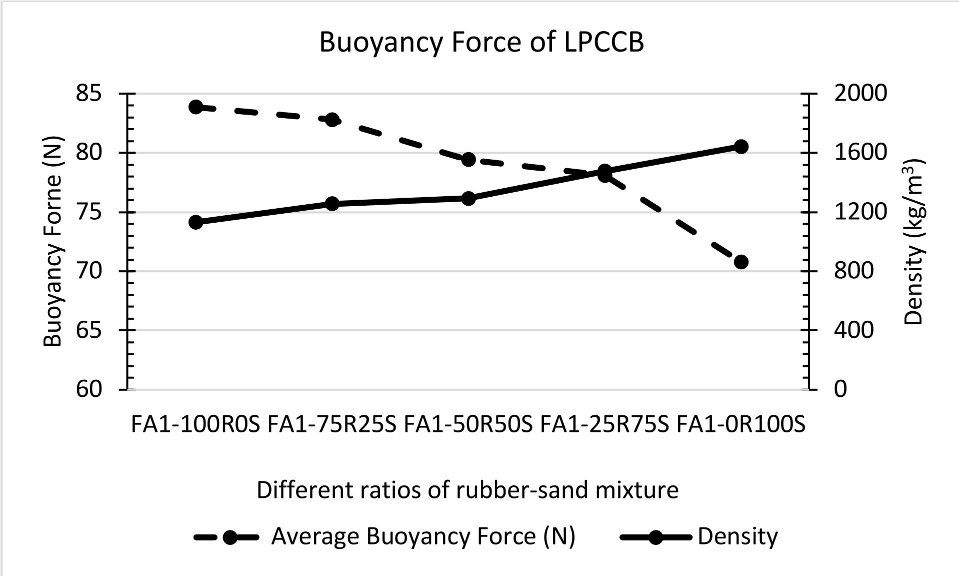



**Fig. 12.** Effect of different ratios of rubber-sand mixture on buoyant force of LPCCB

Figure 13 shows a significant variation between buoyant force and sample density across various foam agent levels in the buoyancy results from the tests. Remarkably, the FA1-50R50S sample also had a strong buoyant force at a greater density (1292 kg/m³), whereas the FA3-50R50S sample had the highest buoyant force while having the lowest density (1006 kg/m³). Conversely, the buoyant force was lowest for FA0.5-50R50S, which had the maximum density (1320 kg/m³). These changes imply that foam concrete with a lower density tends to be more buoyant because of its higher air content and bigger bubble production. Jones *et al.,* [13] states that foam concrete with a lower density usually has a higher air content and bigger air bubbles, which increases the buoyant force acting inside the material. On the other hand, foam concrete with a higher density has more contained, smaller bubbles, which results in a lower buoyant force.

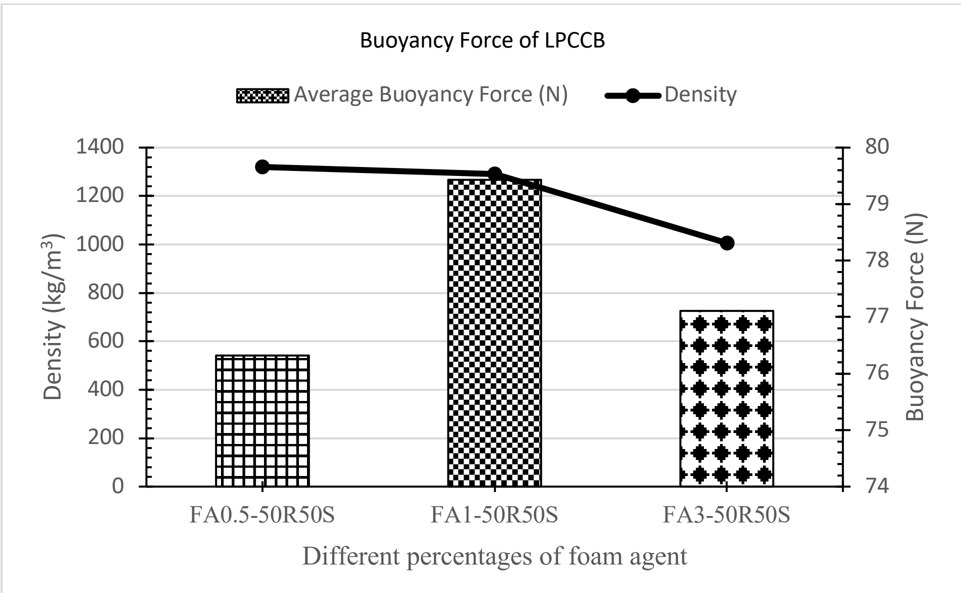



**Fig. 13.** Effect of different percentages of foam agent on the buoyant force of LPCCB

### *3.3.3 Compressive strength*

Figure 14 indicates that samples with varying rubber-to-sand mixture were evaluated for compressive strength using a set 1% foam agent proportion. The following were the 7-day strength results: 1.174 MPa was reported by FA1-100R0S, 1.115 MPa by FA1-75R25S, 0.883 MPa by FA1-50R50S, 1.020 MPa by FA1-25R75S, and 1.076 MPa by FA1-0R100S. From FA1-100R0S to FA1-50R50S, there was a noticeable decrease in strength of around 24.7%. As more sand replaced rubber within the bottles, this may be the result of decreased elasticity and poor compaction. But after FA1-50R50S, the strength began to rise once more. The increase implies that a larger sand content enhanced the bottle's internal packing and strengthened its connection with the foam concrete.

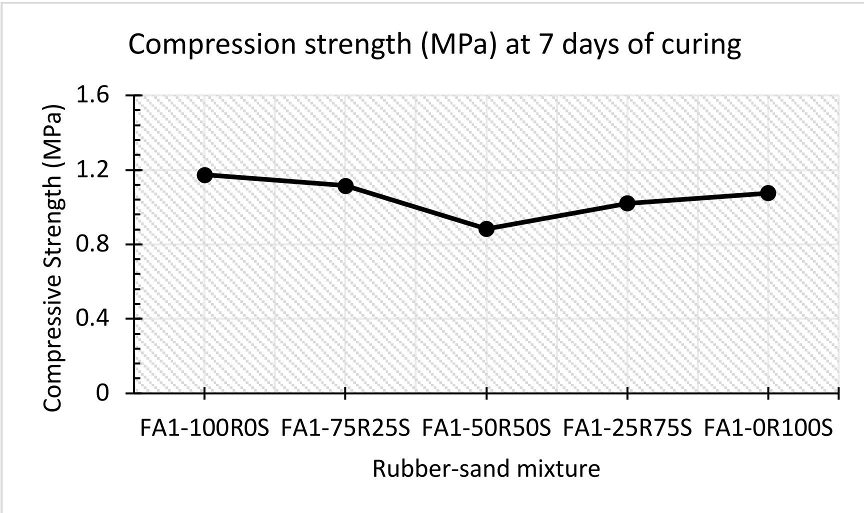



**Fig. 14.** Effect of different ratios of rubber-sand mixture on compressive strength of LPCCB

The compressive strength evaluation of the Lightweight Plastic-Cellular Concrete Block (LPCCB) revealed significant differences based on foam content. Table 3 indicates that a compressive strength of 0.332 MPa was attained by the LPCCB-$FA_{0.5}$-50R50S sample, whereas the LPCCB-$FA_3$-50R50S sample experienced structural failure under load. This notable decrease in strength as the foam content increases highlights the negative effects of too much foam, which increases air voids in the concrete matrix and lowers density, cohesiveness, and eventually compressive capacity. Similarly, foamed concrete with smaller pores and a narrower pore size distribution had greater compressive strength at the same density, according to Bian *et al.,* [14]. This suggests that a larger foam component reduces the material's load-bearing capacity, increases air voids, and decreases density. Interestingly, the sample with the highest compressive strength (0.883 MPa) was the LPCCB-FA1-50R50S, which included 1% foam agent. Theoretically, because a higher foam content produces more air spaces, which generally lowers material density and strength, the compressive strength of the 1% foam content sample should be lower than that of the 0.5% sample. However, the reported increase may have been caused by human mistakes during the compaction process, which might have resulted in uneven foam distribution, or by equipment limitations during sample preparation and testing, which could have impacted on the precision and dependability of the findings. The findings also indicate that the amount of foam agent and the rubber-sand combination within the bottle have an impact on compressive strength. Mixtures with higher sand content, up to 100%, tend to improve strength. However, too much foam seriously impacts the LPCCB's structural performance. Technical issues or equipment malfunctions during testing or preparation may also be the cause of variations in the test results.

**Table 3**
Result of density, porosity, water absorption, and compressive strength for cellular concrete

| Sample Code | Compression Strength (MPa) at 7 days |
|---|---|
| LPCCB-$FA_{0.5}$-50R50S | 0.332 |
| LPCCB-$FA_1$-50R50S | 0.883 |
| LPCCB-$FA_3$-50R50S | FAILED |

## 4. Conclusions

The study examined the compressive strength and density properties of plastic bottle structures filled with different rubber-sand mixtures. Results showed that density increased with higher sand content, and compressive strength reached its peak at 75% rubber and 25% sand mixture (75R25S). The optimal cellular concrete mix design with 0.5% foam agent (CC-FA0.5) showed balanced performance, moderately reduced density, and acceptable porosity and water absorption values. The LPCCB study showed that the rubber-sand mixture and foam agent content significantly impacted buoyancy, density, strength, and water absorption. The originality of this study lies in the multi-material synergy that combines waste-derived rubber, sand, and foam agents within plastic bottle casings to create a lightweight, high-performance fill material. LPCCB utilises rubber-sand-filled bottles as primary structural and load-bearing components. Meanwhile, cellular concrete acts as filler to reduce the overall density of the block without compromising its compressive strength. Overall, all the objectives of the study have been achieved. Effective research was done on the density and compressive strength of plastic bottle structures that were filled with rubber-sand mixtures. Cellular concrete's mechanical and physical characteristics at different porosities were effectively investigated. Additionally, LPCCB was controlled by buoyancy and structural stability to make it ideal for use on soft soil conditions, which prevent excessive settlement and enhance long-term performance. Ultimately, the comprehensive evaluation of the LPCCB revealed important information regarding its capability and potential as a lightweight fill material for road construction. As a modular system, LPCCB was to improve the construction efficiency, which reduced reliance on heavy machinery during construction. These features make LPCCB a highly sustainable solution in line with the construction industry's sustainability initiatives.

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