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EFFECT OF MICRO SILICA AND POLYPROPYLENE FIBER ON THE PROPERTIES OF CELLULAR LIGHT-WEIGHT CONCRETE BLOCKS: A COMPARATIVE STUDY

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ABSTRACT

Cellular Lightweight Concrete (CLC) blocks are becoming increasingly popular in developing countries for several reasons, such as cost, low structural loads, easier handling, thermal insulation, speed of construction, versatility, use of local materials, environmental factors, natural disasters, and earthquake resistance. Thus, there is a seminal need for innovation to improve the performance of CLC blocks by replacing alternative raw materials in place of some of the admixtures. This study examined the effects of micro silica and polypropylene fiber (PPF) on the density and compressive strength of CLC blocks. Laboratory tests were added for micro silica, with 0%-15% of the total weight of cement, and PPF, with 0%-1.5%, as additional materials. The CLC block specimen that did not contain micro silica produced a compressive strength of 5.87 MPa. The combination of 10% micro silica produced a compressive strength of 6.82 MPa at 28 days, and we found 1% was optimum for PPF. The optimum sample contained 10% micro silica and 1% PPF with a compressive strength of 7.35 MPa, which represented a 25.21% increase over the control mix. If we exceeded these optimum amounts, we saw a reduction in compressive strength.

Cellular Lightweight Concrete (CLC) is gaining popularity in developing countries for a various reasons, including cost efficiency, reduced structural load, ease of handling and thermal insulation.

Keywords: Silica Fume, Polypropylene Fiber, Cellular Lightweight Concrete, Foam Concrete, and Compressive Strength Test

1. Introduction

Lightweight concrete is an innovative building material widely utilized in construction for its energy efficiency, mechanical strength, and positive environmental impact on building envelopes (Grabois, Cordeiro and Toledo Filho, 2016; Sassine et al., 2021). However, despite continuous progress in material science, our current ability to create and engineer materials still lags in reproducing the properties and functions of natural materials (Burgos-Morales et al., no date). Now supplying the most used construction materials production of bricks faced challenges due to scarcity of land, the energy required for burning, and environmental degradation issues (Hossain et al., 2020). In developing nations, the construction industry is rapidly growing, using brick as a prevalent but environmentally polluting material (Gomes and Hossain, 2003). So that lightweight concrete (LWC), despite being used for over 2000 years, continues to generate significant interest and has become highly sought-after in a wide variety of construction projects due to its versatility and increasing industrial demand in recent years (Jiang and Wu, 2019).

In developing countries, the crucial goal is to build cost-effective, high-quality infrastructure promptly. However, the construction sector is responsible for consuming around 40% of global energy and emitting up to 30% of carbon dioxide emissions (Paik and Na, 2019). The cement industry is responsible for 5% of global carbon dioxide emissions, with each ton of concrete producing 0.05 to 0.13 tons of carbon dioxide. Foam concrete must meet sustainability criteria to be considered a viable material (Shi et al., 2021). In contrast, Cellular Lightweight Concrete (CLC) masonry gained popularity due to sustainability, low heat conductivity, and efficient mortar use (Rasheed and Prakash, 2015). Geopolymer concrete (GeoC) offers a durable and sustainable alternative, aligning with 12 of the UN's sustainable development goals (Shehata et al., 2022). To address climate change, adopting clean technologies is crucial (Ayling & Gunningham,2017). The innovative use of materials like cellular concrete (ACI 523) can contribute to sustainable construction (Chica and Alzate, 2019).

Lightweight concrete provides design freedom and significant cost savings by reducing dead loads, improving seismic response, offering better fire ratings, and using smaller structural elements (Adnan, Abadalla and Jamellodin, 2017). Cellular lightweight concrete (CLC) blocks have a lower bulk density than clay bricks, leading to reduced dead loads in masonry and savings in frame element design. Yet, CLC blocks have higher water absorption capacity, requiring caution in exterior or moist environments (Amran et al., 2022). Despite improved capillary suction properties, CLC units and masonry assemblies have lower compressive strength than clay bricks, rendering them unsuitable for load-bearing walls (Bhosale et al., 2020). Passive heating and cooling systems in building construction offer significant opportunities for energy conservation, promoting sustainable development by reducing heating and cooling loads in buildings (Asim et al., 2020).

Understanding the mechanical and physical properties of infill brickwork significantly influences the performance of a framed construction. Key strength properties of infill masonry, such as compressive strength, bond strength, Young's modulus, and failure modes, are crucial for designing new structures and assessing existing ones (Bhosale et al., 2020). The infill wall's functionality and durability can also be significantly affected by the masonry unit's water absorption and transfer capabilities and the quality of the packing mortar used. CLC blocks are commonly used as infill masonry in current framed building construction due to their 40% lighter weight compared to solid concrete or clay bricks. Therefore, comprehending the strength characteristics of infill masonry is vital for designing new buildings and evaluating existing structures, ensuring optimal performance and longevity. Past studies have conducted various experimental and analytical investigations on the strength and durability of clay brick masonry (Bhosale et al., 2020).

Alternative building materials, both conventional and non-conventional, are proposed for environmentally friendly construction. These materials are considered more eco-friendly, cost-effective, low energy-consuming, and have high thermal conductivity (Islam, 2020). CLC blocks are suitable for developing countries due to their cost-effectiveness (Tantisattayakul, Kanchanapiya and Methacanon, 2018), lightweight nature (Rasheed and Prakash, 2015), excellent thermal insulation properties (Asim et al., 2020), potential for utilizing waste byproducts (Junaid et al., 2022), good fire resistance (Chinnu et al., 2021), and sustainability (Bareschino et al., 2020). These blocks are made from natural materials, resulting in a lower carbon footprint compared to conventional concrete blocks (Bin Marsono and Balasbaneh, 2015). Additionally, they are easy to work with and suitable for small-scale construction projects (Tam, Soomro and Evangelista, 2018).

In this context, the objective of this research is to investigate the effects of Micro Silica and Polypropylene Fiber on the properties of Cellular Lightweight Concrete (CLC) blocks. The specific objectives include determining the optimal amount of micro silica for maximum compressive strength in CLC blocks and determining the optimal combination of polypropylene fiber and micro silica for maximum compressive strength in CLC blocks.

The significance of the study lies in the optimization of Cellular Lightweight Concrete (CLC) blocks with micro silica and polypropylene fiber additives (Abhilasha et al., 2023). The research improves CLC block compressive strength by identifying the most effective percentages of these materials, resulting in more efficient and sustainable building materials (Hamdaoui et al., 2023). The findings benefit the construction industry by assisting engineers in making informed decisions about the use of additives for cost-effective and environmentally friendly practices (Hegab et al., 2023). Furthermore, increased CLC block adoption can help to conserve energy and reduce environmental impact while also advancing construction materials and supporting sustainable infrastructure development.

One gap in research is the lack of technical expertise in developing countries to explore alternative building materials beyond admixtures, cellular lightweight concrete (CLC), and foam concrete. To achieve the necessary strength when using CLC blocks in load-bearing or non-load-bearing walls, it is essential to regulate the amount of micro silica and polypropylene fiber (PPF) (Hollaway, 2010). While CLC and foam concrete are sustainable and have unique properties, there may be other materials that offer comparable or even better benefits. Furthermore, additional research is needed to determine the long-term durability and performance of CLC masonry in various environments (Kanchanapiya, Methacanon and Tantisattayakul, 2018).

Cellular Lightweight Concrete (CLC) Block is a precast masonry unit manufactured from foam concrete. Foam concrete is poured into a mold and is cured and shaped to a standard block size, typically 600 × 200 × 100–250 mm. CLC block is so light, with a density of 600 to 800 kg/m^3, that it can be used for partition walls, external walls of low-rise and mid-rise buildings, and for other non-load-bearing masonry applications. As a finished product from foam concrete, CLC blocks have a lightweight characteristic and ease of handling along with the thermal insulation properties and construction speed(Bhosale et al., 2020).

Foam concrete is an adaptable, non-structural, and lightweight cement-based material created by ad-mixing stable, pre-formed foam (created from a foaming agent) into cement-sand-water slurry. The material is typically produced in a fresh liquid form, which means it can be pumped or poured into molds of almost any shape. Foam concrete is used in a density range of around 300 kg/m³ to 1,800 kg/m³ for a variety of practical applications such as thermal insulation layers on roofs, void filling, stabilization of ground, and lightweight sub-bases. Foam concrete is a material, rather than a product form, allowing for flexibility in the design and its function (Raj, Sathyan and Mini, 2019).

2. Material and Methodology

2.1 Conventional to Modern Construction Material

Conventional construction materials encompass both human-made materials such as concrete and steel, and natural materials like wood, stone, and clay bricks, which have been utilized in the construction industry for a significant period.

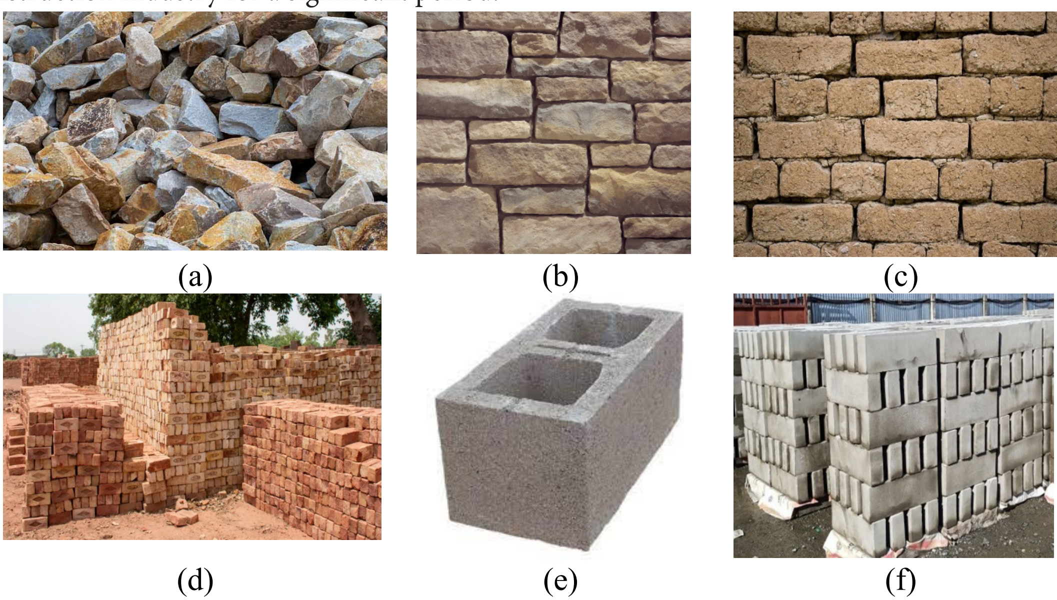


Figure:1 Conventional to Modern Construction Materials (a) Extracted Natural Construction Stone, (b) Faces dressed in stone, (c) Raw clay bricks, (d) Burn clay brick, (e) Hollow Concrete Blocks, and (f) Cellular Lightweight Concrete Blocks

Natural Construction Extracted Stone: In rural mountainous areas, stone is still a popular building material. However, rising market demand has created economic imbalances in stone extraction, which are being exacerbated by unfavorable economic conditions. Unregulated extraction practices worsen environmental damage, necessitating the use of stone substitutes (Bridge, 2000). Faces Dressed Stone: This stone type has shaped faces, resulting in uniform construction appearances. However, extracting it frequently involves environmental exploitation, necessitating the development of innovative alternatives (Mathias Kondolf, 1994). The energy-intensive firing and land use of brick production have a significant environmental impact. Thus, eco-friendly wall construction materials such as wood help to mitigate embodied environmental effects (Bin and Parker, 2012). Although hollow concrete blocks and cellular lightweight blocks have similarities, they are used in different ways. Hollow concrete blocks (cement, water, and aggregates) are suitable for load bearing, partition, and retaining walls. Cellular lightweight blocks made of lightweight aggregates perform exceptionally well in terms of thermal insulation and fire protection for non-load-bearing walls. Their lower carbon footprint and improved insulation balance out the relative strength of hollow concrete blocks. Choosing between them is dependent on the needs of the project (Sassine et al., 2021).

2.2 The provisions for Cellular Lightweight Blocks in the code

Table:1 Density and Compressive Strength as per Code

In essence, lightweight cellular concrete is composed of air voids that are incorporated into the

Code	Density	Compressive strength (28 days)
IS Code 16598-1972	Up to 300 kg/ m^3	4.5 kg/cm^2
American Concrete Institute (ACI)	300 to 2000 kg/m^3	<17 MPa
NHBC Standard	<1500 kg/ m^3	>7.3 N/mm^2
ASTM C 796-97	800 kg/ m^3	72.5 MPa

cement paste or mortar matrix, accounting for at least 20% of its overall volume. These voids are generated by blending a pre-formed stable foam, with a desirable density ranging from 30 kg/ m3 to 65 kg/ m3 (Kumar, 2021).

3. Methodology

This study utilized critical raw materials in the production of Cellular Lightweight Concrete (CLC) blocks, including Ordinary Portland Cement, fine sand, expanded perlite aggregate, water, micro silica, and polypropylene fibers. These materials were selected due to their previous applicability in concrete production and their capacity to enhance the physical and mechanical properties of CLC blocks.

To assess the effects of silica fumes and polypropylene fibers, several different mix ratios were simulated based on initial tests reporting maximum workability and strength. The dry materials (cement, sand, and expanded perlite) were mixed for 2 minutes before the required water was added and then blended for 3 more minutes to provide adequate time for hydration and for the dry materials to coat the substrate. Micro silica was added and mixed for 2 minutes, then polypropylene fibers were added slowly over a period of 1 minute to facilitate uniform dispersion. The mixture was further mixed for 3 minutes to ensure full integration.

Standard-size wooden molds were disinfected and pre-coated with a release agent before casting. The ready CLC mix was poured in layers into the molds and gently tamped or manually leveled to avoid disrupting the foam structure because mechanical vibration can lead to air entrainment collapse, which is important in low density. Surfaces were leveled using a trowel.

Recently cast samples were covered with plastic sheets and cured for 24 hours in a controlled condition, meaning an indoor environment at a temperature of 23 ± 2°C and ≥95% relative humidity—to minimize loss of moisture and prevent premature drying. Samples were demolded and kept in a curing room under normal conditions until the desired testing age.

ASTM C39: Compressive strength was also evaluated using cube samples per ASTM C39 (Kim, Jeon and Lee, 2012) at curing ages of 7, 15, and 28 days (minimum of three specimens per mix). Density and void content were calculated from the mass and dimensions of the specimens, as well as by comparing the measured density to the theoretical densities. Water absorption tests per ASTM C642 were carried out by submerging the specimens in water and weighing them to record mass gain over a duration of time.

Preparation of Sample

Table: 2 All components measured in a Kg

Cement	Micro Silica	Fly ash	Water	Foam
4.0	0	7.43	2	0.14
3.8	0.2	7.43	2	0.14
3.6	0.4	7.43	2	0.14
3.4	0.6	7.43	2	0.14

The water content of all mixes is maintained at 50% of the combined weight of cement and micro-silica. One part foaming agent is mixed with 35 parts of water to make the foam. Since the amount of foam impacts the dry density of concrete foam content is kept constant at 1.25 percent.

Mix procedure and Sample sizes

The process of producing Cellular Lightweight Concrete (CLWC) is different than traditional concrete, as there is a specific mix design for producing the material. The process consists of two steps. The first step is to prepare the cement-based slurry, which consists of cement, fly ash, and silica fume. For the second step, stable foam is produced from the hydrolyzed protein-based foaming agent and water, which is then mixed with the slurry to create a cellular matrix having a low density (Jones, Zheng and Ozlutas, 2016).

For the current research, 42 samples were prepared in total. Step one determined the optimum micro silica contents with 24 samples, and step two determined the optimum polypropylene fiber (PPF) contents with 18 samples designated for maximum compressive strength. All samples were cast into a 230 mm × 110 mm × 50 mm mold.

Mix design

Cellular Lightweight Concrete (CLC) blocks are manufactured using advanced techniques. Cement, aggregate, water, foaming agent, micro-silica, and additives are mixed in either a drum or pan mixer before the stable foam produced by a foaming machine is slowly put into the mix and poured into steel, plastic, or some other mold. A vibrating table aids with the packing of the pour and helps remove the air. The blocks are cured in a controlled environment, and while curing, the temperature and humidity are regulated to reach the desired strength. The blocks can be cut to size, if necessary, and used for general construction purposes.

Table 3: Mix design/ proportion of CLWC using silica fume.

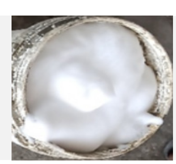
Mix Name	MS 0%	MS 5%	MS 10%	MS 15%	Image
Cement	35%	33.25%	31.50%	29.75%	
Micro Silica	0.00%	1.75%	3.50%	5.25%	
Fly ash	65%	65%	65%	65%	
Water	50%	50%	50%	50%	
Foam	1.25%	1.25%	1.25%	1.25%	

Table 3 shows the result of CLC using micro silica, which shows the result of dry density and compressive strength.

CLC Molds

Battery Moulds These molds are adjustable and can be used to create blocks of various sizes. With a single mold, we can adjust the size of blocks according to our requirements, obtaining 10, 15, or 20 blocks per mold. Vertical Moulds Similar to battery molds, vertical molds are also adjustable in size and can be used to create blocks of different sizes. The capacity of the vertical mold is 1m3.


(a) (b) (c) (d) (e) (f)

Figure: 2 Raw Materials to CLC Block Production Unit (a)- weighing the ingredients, (b)-mixing the ingredientss, (c)-mixing water to mortar,(d)-Checking the mortar,(e)-Preparing Molds, (f)-Manufacturing CLC blocks for curing

Cellular Lightweight Concrete (CLC) is made under specific steps (Fig. 2). The raw materials are cement, fly ash, sand, water, and foaming agent. These materials are sized, dry-mixed, and eventually bonded with water to the point where the mixture resembles mortar. Prior to pouring into prepared molds, properties of the mixture are assessed as per the test sequence. After pouring, the mold vibrated to remove air bubbles and compact evenly. The blocks are then cured by air, i.e., no moisture, or with steam curing to the point of strength.

This study examined dry density and compressive strength for conditional lightweight concrete blocks with density targeting between 1000 and 1200 kg/m³. One of the variables tested was the proportion of micro silica (15% replacement for cement, where micro silica content varied from 0 to 15% by weight). The objective of the study was to assess the properties of CLC with varying amounts of micro-silica to determine optimum micro-silica content. The other variable tested was polypropylene fiber (PPF). In the CLC we tested, PPF proportions varied from 0.5% to 1.5% in increments of 0.5% to determine the best use level.

Curing

For curing methods for CLC blocks, natural curing and steam curing have been the most-used methods. This study has only used natural curing by water sprinkling and not steam curing. It may be possible to produce blocks four times faster with steam curing and 15-150 m³ production of blocks (Łaźniewska-Piekarczyk and Szwabowski, 2012).

The test setupprovided the equipment used and methods to test 42 CLC block samples (230 mm × 110 mm × 50 mm) and the load used, measuring, and collection of information. All measurements and specifications were taken to ensure a full and proper experimental program (Suryanita et al., 2022).

The foam generators

These are equipped with electronic controls and various indicators that regulate their operation. They are commonly utilized for producing foam for lightweight concrete using foaming agents available in the market. Made with a corrosion-resistant steel body, along with timer and lance units, these generators ensure trouble-free operation

The Foam Concrete Machine, also known as the CLC Machine, can be used to create foam concrete blocks or pour foam concrete directly for compound walls, flooring, etc. The capacity range of the machine varies from $15m^3$ to $150m^3$.

(a) (b)

Figure: 3 Machines Used: (a)The foam generators (b) Compression Testing Machine

Foaming Agent

The foaming agent is an anti-foaming agent available in two types, synthetic-based and protein-based. Synthetic-Based is a purely natural-based foaming agent and Protein-Based is derived from animals.

Compression Testing Machine

The DM/TG is a hand-operated hydraulic-electric machine with a 200-ton capacity, equipped with three pressure gauges, including a Flexure Test Attachment. The machine's speed can be adjusted with a hand wheel, and in case of a power outage, it has a hand-pumping feature. It also has electrical overload protection and includes a manual pumping unit for manual operation.

The compressive strength of a concrete cube is tested using a Compression Testing Machine Electric Operated, which involves casting fresh concrete in a standard test mold. The obtained compressive strength value is then used to determine if the concrete batch meets the required strength standards

4. Result

The goal of the current research was to determine the optimal micro silica (MS) content for optimum compressive strength of CLC blocks and the optimum ratio between polypropylene fiber (PPF) and micro silica for the same.

Table 4: Mix proportion of cellular light weight concrete (CLWC) using silica fume.

Mix Name	Components in percentage				
	Cement Content	Silica Content	Fly ash Content	Water Content	Foam Content
MS 0%	35%	0.00%	65%	50%	1.25%
MS 5%	33.25%	1.75%	65%	50%	1.25%
MS 10%	31.50%	3.50%	65%	50%	1.25%
MS 15%	29.75%	5.25%	65%	50%	1.25%

The table 4 mentioned above shows the changes in dry density and compressive strength results for Cellular Lightweight Concrete as the quantity of micro silica is varied.

Optimum Micro Silica Content Compressive strength increased with the increase of micro silica up to 10% and thereafter dropped. The maximum compressive strength attained was 6.82 MPa at 28 days for 10% MS, with the corresponding dry density being 1275.36 kg/m³ (Tables 4–5, Figs. 4 & 5). This supports 10% MS as the best ratio in conditions tested to fulfill the first requirement.

Table 5: Compressive strength and density with micro silica content

Mix Name	Components in gram(gm)					Compressive Strength (Mpa)		Density (kg/m³)
	Cement	Silica	Fly ash	water	Foam	7days	28days	
MS 0%	4000	0	7430	2000	142.88	2.51	5.87	1183.14
MS 5%	3800	200	7430	2000	142.88	2.81	6.51	1214.76
MS 10%	3600	400	7430	2000	142.88	2.89	6.82	1275.36
MS 15%	3400	600	7430	2000	142.88	2.84	6.56	1229.25

The table 5 mentioned above shows the changes in dry density and compressive strength results for Cellular Lightweight Concrete as the quantity of micro silica is varied.

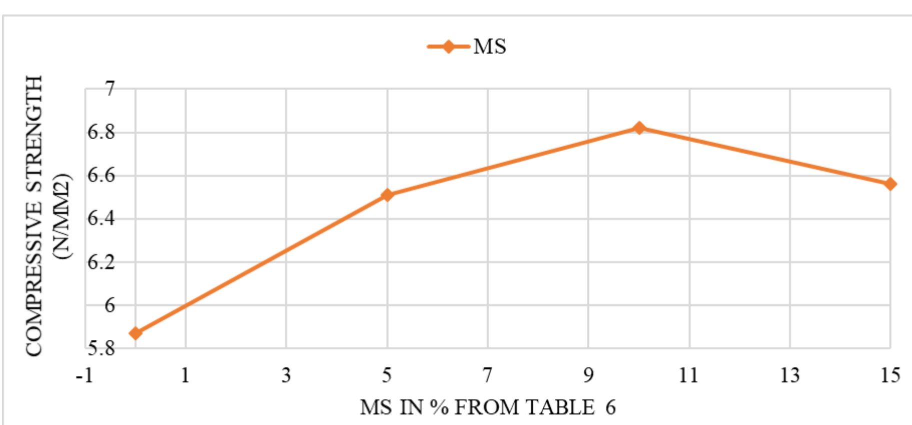


Figure: 4 Variation Micro Silica Quantities Vs Compressive Strength

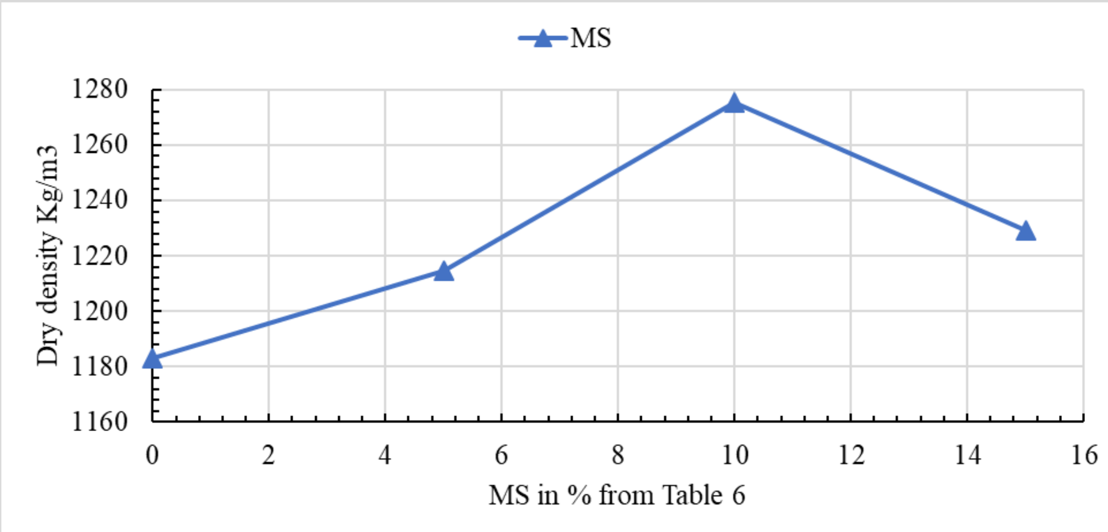


Figure: 5 Micro Silica Content Vs Density

Optimal Micro Silica–PPF Ratio

With 10% fixed micro silica, the incorporation of PPF improved compressive strength to 1% content and then reduced it. The maximum compressive strength of 7.35 MPa at 28 days was realized at 10% MS and 1% PPF with a dry density of 1289.86 kg/m³ (Tables 6–7, Figs. 7, 8, 9 & 10). The combination fulfills the second goal by providing the best strength-density balance.

In the table 6, all ingredients are in percentage

Table 6: Compressive strength and density with micro silica content

Mix Name	Components in gram(gm)					Compressive Strength (Mpa)		Density (kg/m³)
	Cement	Silica	Fly ash	water	Foam	7 days	28 days	
MS 0%	4000	0	7430	2000	142.88	2.51	5.87	1183.14
MS 5%	3800	200	7430	2000	142.88	2.81	6.51	1214.76
MS 10%	3600	400	7430	2000	142.88	2.89	6.82	1275.36
MS 15%	3400	600	7430	2000	142.88	2.84	6.56	1229.25

The variations in dry density and compressive strength results for Cellular Lightweight Concrete are presented in Table 6 mentioned above, as the quantity of micro silica remains constant and the quantity of polypropylene fiber is varied.

Table 7: Compressive strength and density with constant micro silica and variation of PPF content

Mix Name	Components in gram(gm)				Compressive Strength (Mpa)		Density (kg/m³)
	Cement	Silica	PPF	Fly ash	7 days	28 days	
MSPF 0%	3600	400	0	7430	2.89	6.82	1275.36
MSPF 0.5%	3600	400	20	7430	2.90	6.93	1278.00
MSPF 1.0%	3600	400	40	7430	3.17	7.35	1289.86
MSPF 1.5%	3600	400	60	7430	3.05	7.20	1258.89

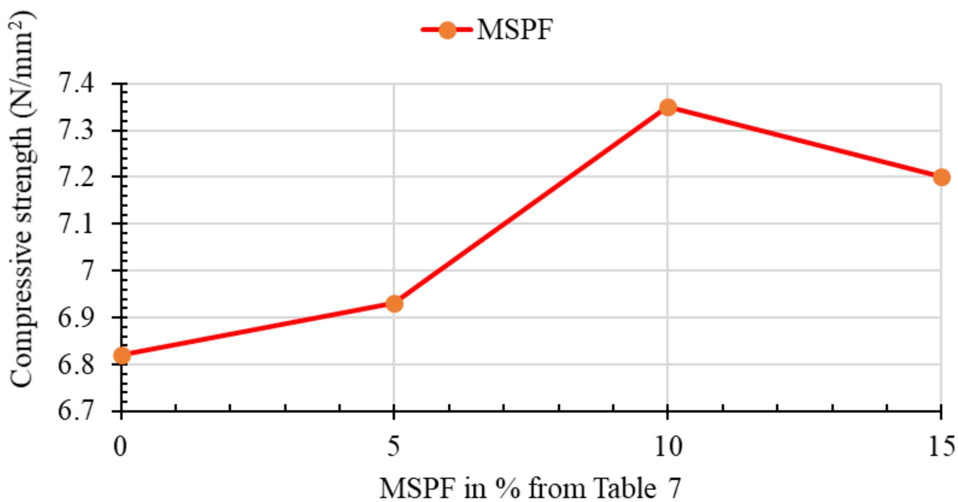


Figure: 6 Variation Polyproline Fiber Quantities Vs Compressive Strength

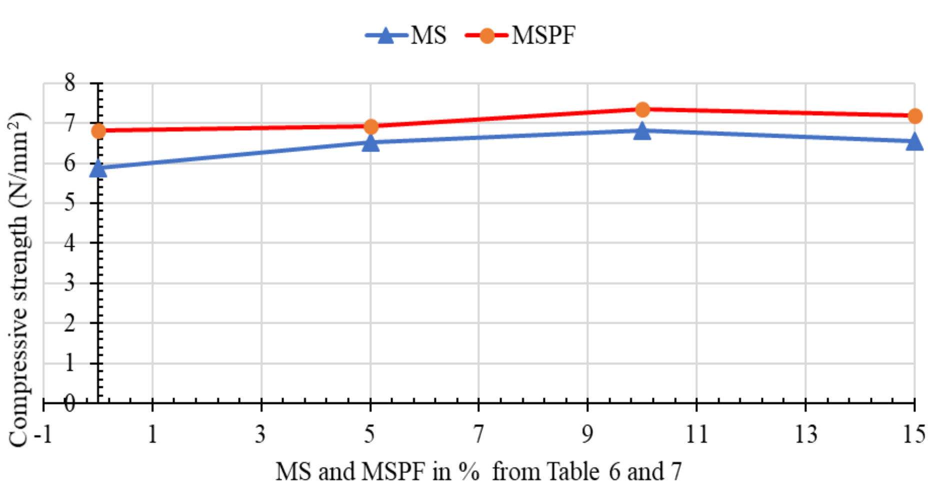


Figure: 7 Micro Silica and Polypropylene Fiber Content Vs Compressive Strength

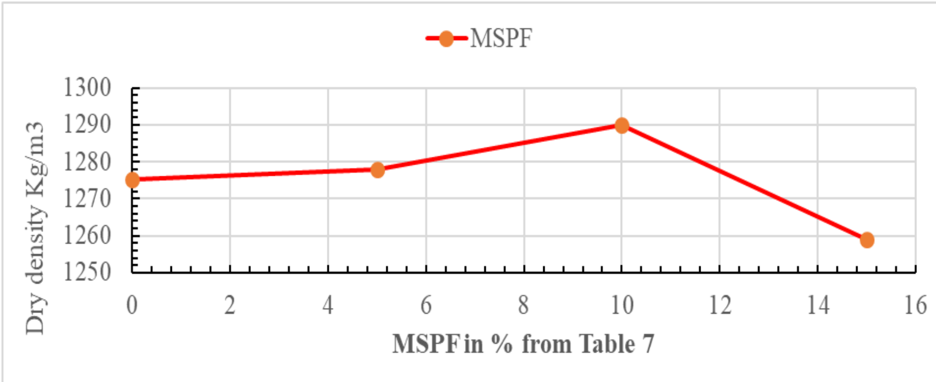


Figure: 8 Polypropylene Fiber Content Vs Density

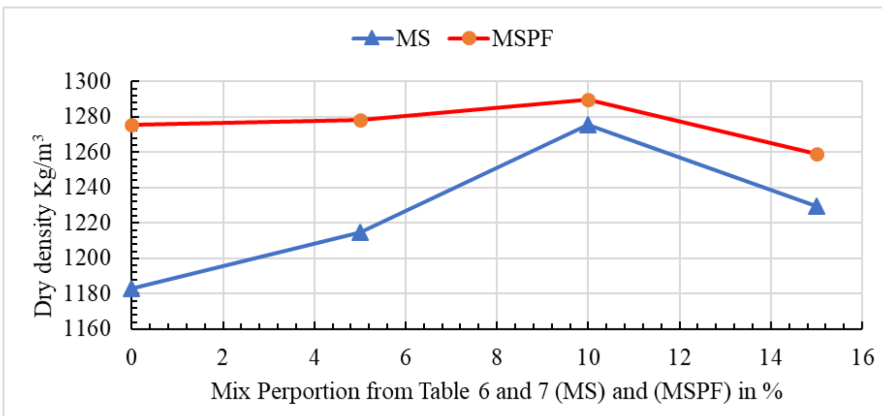


Figure: 9 Micro Silica and Polypropylene Fiber Content Vs Dry Density

4.2. Optimal Micro Silica–PPF Ratio

With 10% fixed micro silica, the incorporation of PPF improved compressive strength to 1% content and then reduced it. The maximum compressive strength of 7.35 MPa at 28 days was realized at 10% MS and 1% PPF with a dry density of 1289.86 kg/m³ (Tables 6–7, Figs. 6, 7, 8 & 9). The combination fulfills the second goal by providing the best strength-density balance.

4.3. Summary of Findings

Maximum compressive strength and maximum MS content: 10% of cement by weight. Maximum compressive strength and maximum density with optimal MS–PPF mix: 10% MS + 1% PPF. The findings apply only to the tested material, mix proportions, and curing conditions. They relate directly to the study objectives and indicate that micro silica and PPF contents can enhance the mechanical properties of CLC blocks.

This study aims to provide comprehensive insights into the complex relationship between material composition and the resulting physical and mechanical properties of CLC by meticulously analyzing the effects of varying micro silica proportions and polypropylene fiber concentrations while maintaining controlled water and foam content.

Table 8: Mix proportion of cellular light weight concrete (CLWC) using silica fume.

Mix Name	Components in percentage				
	Cement Content	Silica Content	Fly ash Content	Water Content	Foam Content
MS 0%	35%	0.00%	65%	50%	1.25%
MS 5%	33.25%	1.75%	65%	50%	1.25%
MS 10%	31.50%	3.50%	65%	50%	1.25%
MS 15%	29.75%	5.25%	65%	50%	1.25%

In the above table, all ingredients are in percentage

Table 9: Compressive strength and density with micro silica content

Mix Name	Components in gram(gm)					Compressive Strength (Mpa)		Density (kg/m^3)
	Cement	Silica	Fly ash	water	Foam	7 days	28 days	
MS 0%	4000	0	7430	2000	142.88	2.51	5.87	1183.14
MS 5%	3800	200	7430	2000	142.88	2.81	6.51	1214.76
MS 10%	3600	400	7430	2000	142.88	2.89	6.82	1275.36
MS 15%	3400	600	7430	2000	142.88	2.84	6.56	1229.25

The table 9 mentioned above shows the changes in dry density and compressive strength results for Cellular Lightweight Concrete as the quantity of micro silica is varied.

Table 10: Compressive strength and density with constant micro silica and variation of PPF content

Mix Name	Components in gram(gm)				Compressive Strength (Mpa)		Density (kg/m^3)
	Cement	Silica	PPF	Fly ash	7 days	28 days	
MSPF 0%	3600	400	0	7430	2.89	6.82	1275.36
MSPF 0.5%	3600	400	20	7430	2.90	6.93	1278.00
MSPF 1.0%	3600	400	40	7430	3.17	7.35	1289.86
MSPF 1.5%	3600	400	60	7430	3.05	7.20	1258.89

The variations in dry density and compressive strength results for Cellular Lightweight Concrete are presented in Table 10 mentioned above, as the quantity of micro silica remains constant and the quantity of polypropylene fiber is varied.

4.1. Compressive Strength

4.1.1. Compressive Strength as Variation of Micro Silica

The analysis presented in the statement is based on Figure 10 given below, which shows the compressive strength of a material at varying levels of micro silica content in percentage. The statement suggests that increasing micro silica content initially results in an increase in compressive strength up to a certain level, beyond which the compressive strength starts to decrease. Therefore, the statement concludes that the optimal level of micro silica content for maximum compressive strength is 10%, as the compressive strength of the material is highest at this level. However, it is critical to emphasize that this conclusion is limited to the tested material and conditions. Different materials and conditions may have different optimal levels of micro silica content for maximum compressive strength.

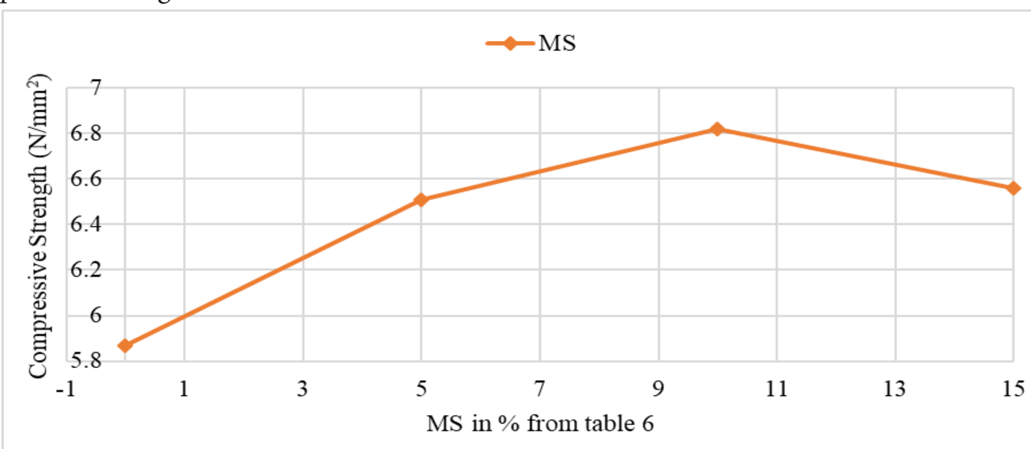


Figure 10 Variation Micro Silica Quantities Vs Compressive Strength

Other variables, such as curing time, temperature, and mixing procedure, must also be considered because they can affect compressive strength and alter the optimal micro silica content required for maximum results.

Overall, while the statement provides a reasonable conclusion based on the analysis of Figure 10, it is important to acknowledge that the conclusion may not apply to all materials or conditions and that other factors can impact the optimal micro silica content required for maximum compressive strength.

4.1.2. Compressive Strength as a variation of Polypropylene fiber

The analysis is based on Figure 11, which depicts material compressive strength at various micro silica and PPF levels. It is proposed that increasing micro silica and PPF increases strength until a certain point, after which it decreases. The maximum compressive strength of 10% micro silica and 1% PPF is supported by their peak compressive strength. However, it is important to note that this conclusion is specific to the material and conditions being tested in the experiment. Other materials or conditions may have different optimal levels of micro silica and PPF content for maximum compressive strength.

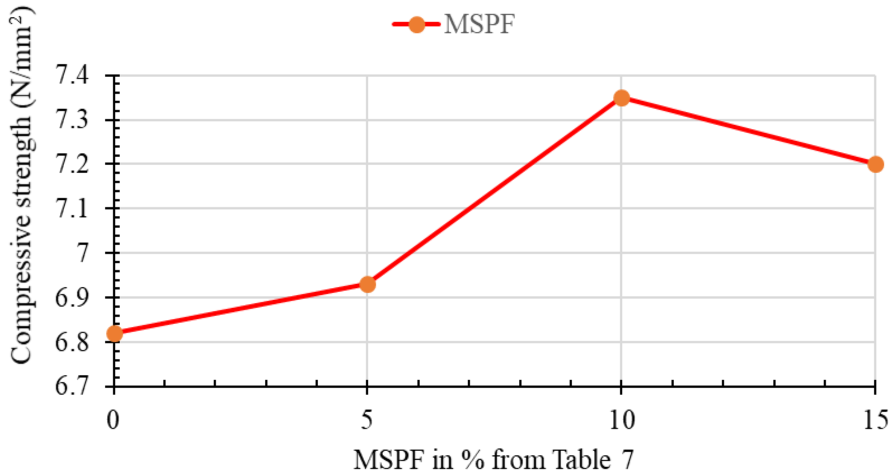


Figure: 11 Variation Polyproline Fiber Quantities Vs Compressive Strength

Additional factors, such as the passage of time during curing, the temperature of that curing, and even the intricate dance of mixing procedures, all play an important role in compressive strength. These unnoticed variables have the potential to influence not only the material's strength, but also the sweet spots of micro silica and PPF content that yield the highest compressive power. While the assertion revealed by the figure's analysis is reasonable, it should be viewed with caution because its dominion may not be universal. The delicate interplay of materials and conditions elsewhere could tip the scales, adjusting the magical proportions of micro silica and PPF content required to unlock the highest echelons of compressive strength.

4.1.2. Compressive Strength as a variation of Micro Silica and Polypropylene fiber

The stage is painted with hues of micro silica, a green line, and Polyproline fiber (PPF), a fiery red line, beneath the gaze of Figure 12. The statements unfold their stories, woven from the threads of these visual narratives, like a sage deciphering omen. The initial proclamation stands firm, confirming that the pinnacle of compressive strength is attained at the 10% micro silica content crossroads. However, the second pronouncement goes a step further, being dual in nature, proposing that this zenith corresponds to a confluence of 10% micro silica and 1% PPF content. Both decrees echo the caveat that their dominion is only a fief within the realm of the tested material and conditions in the air.

The focus shines not only on the elements of micro silica and PPF, but also on the unsaid players, time's embrace in curing, temperature's symphony, and the secret dance of mixing. While drawing nods of agreement, the grand tapestry they reveal rests on a bedrock of specificity, its universality like a distant star. Both statements entwine reason and inference in this unfolding saga, but like petals carried by the wind, they remind us that their truths may find solace only within certain borders, beyond which lie realms unknown.

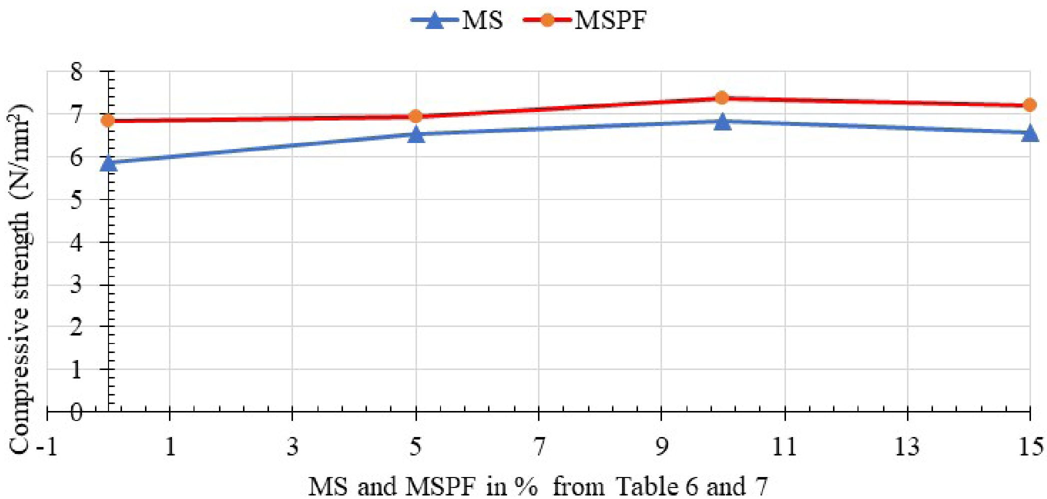


Figure: 12 Micro Silica and Polypropylene Fiber Content Vs Compressive Strength

4.2. Density

4.2.1. Density as a variation of Micro Silica

Looking at Figure 13, the idea is that adding more micro silica to the material improves its dryness, but only up to 10%. After that, it begins to dry out again. As a result, 10% micro silica is the best amount for the driest material. But keep in mind that this only applies to the items used in the test. Other things may require varying amounts of micro silica to be super dry. There are other factors that can influence how dry it becomes, such as how much water is added and how tightly it is pressed together.

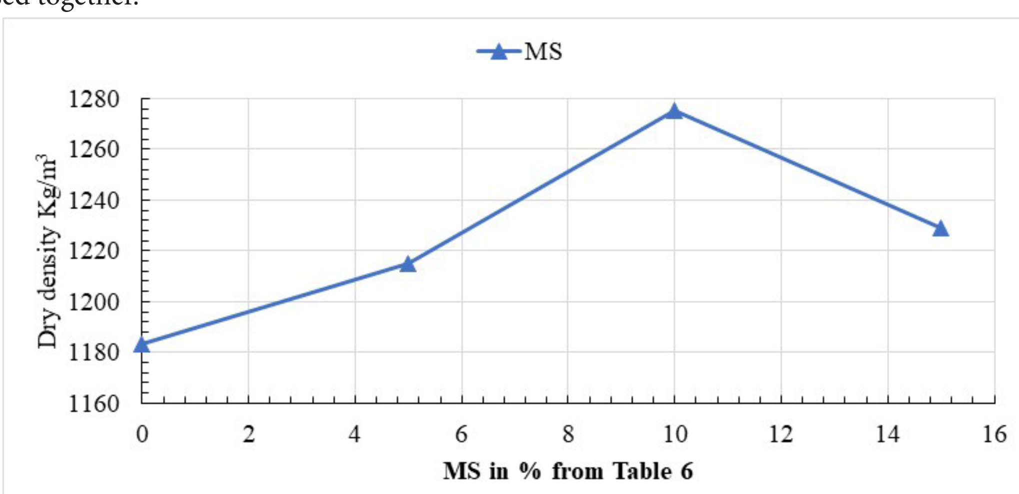


Figure: 13 Micro Silica Content Vs Density

4.2.2. Density as a variation of Polypropylene fiber (PPF)

The information we're talking about comes from Figure 14 below. This picture shows how dry a material gets when we change how much micro silica and PPF are in it. The point made here is that when we add more micro silica and PPF, the material gets drier, but only up to a certain point. After that, it starts getting less dry. So, the best amounts of micro silica and PPF to make the material super dry are 10% and 1% respectively, because that's when it's the driest.

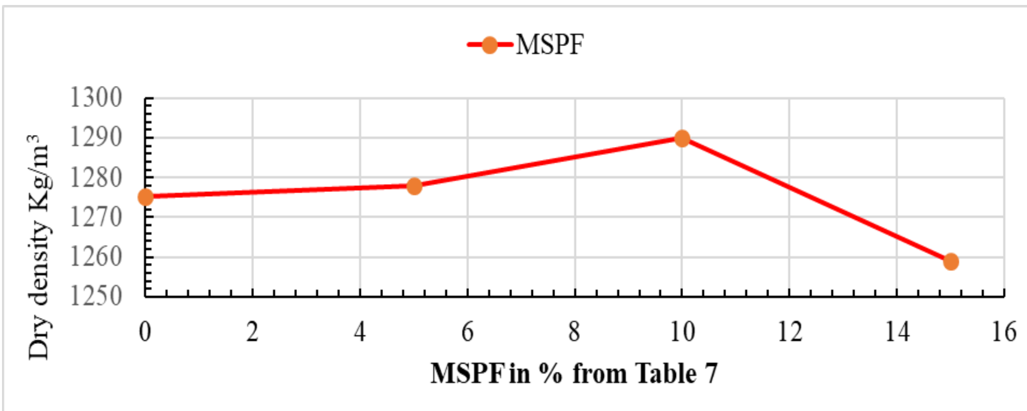


Figure: 14 Polypropylene Fiber Content Vs Density

But here's the catch: this idea works only for the exact stuff they tested under certain conditions. Different things might need different amounts of micro silica and PPF to get super dry. Plus, there are other things that can change how dry it gets, like how much water goes in and how it's squished together. So, while what the statement says makes sense based on Figure 14, remember that it might not be true for everything. Other things can also change how much micro silica and PPF are needed to make something very dry, especially in different situations or materials.

4.2.3. Density as a variation of Micro silica and Polypropylene fiber (PPF)

Consider Figure 10 to be an enormous picture in which two lines tell stories. Consider these lines to be paths to the best dry density, similar to a treasure hunt for the most stuff in a material. One line is about micro silica, a density booster, and the other is about Polypropylene Fiber (PPF), which has its own method of increasing dry density and also collaborates with micro silica. As these lines intersect on the image, they reveal secrets, but these secrets are limited to the material and conditions they are discussing.

Outside of this specific location, there are various materials and situations in which micro silica and PPF may have different effects. As we investigate further, we discover that there are hidden factors influencing this, such as the amount of liquid used and how things are mixed. Even when the same conditions are used, these hidden factors can cause outcomes to change. So, while these two stories are instructive, keep in mind that they may not be applicable everywhere. They're like explorers on a winding road, showing us what they've discovered, but the path ahead may be different.

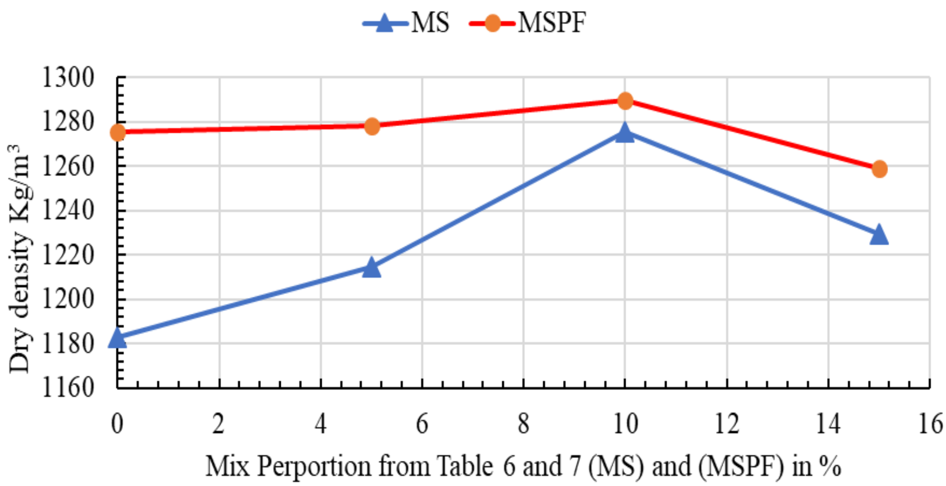


Figure: 15 Micro Silica and Polypropylene Fiber Content Vs Dry Density

Discussion

Compressive strength of CLC blocks increased with the addition of MS up to 10% by weight of cement and then decreased. The maximum strength of 6.82 MPa at 28 days and the respective dry density of 1275.36 kg/m³ were achieved. The results indicate 10% MS is the best rate under experimental conditions. To date, we can claim to have met our first research objective. Our results support the findings of (Najaf, Abbasi and Zahrai, 2022), who found that 10% MS can increase the compressive strength of LWC by approximately 42%, while additional MS will increase the water–cement ratio, lowering strength. (Suryanita et al., 2022), reported in another study that the use of silica fume in place of binder increased CLC block strength when compared to the control mixes in their study.

When the MS content remained at 10%, adding polypropylene fiber (PPF) increased compressive strength to 1% PPF content, at which point the compressive strength declined. The optimum performance was 7.35 MPa at 28 days at a dry density of 1289.86 kg/m³. The mix had the optimum strength and density balance and met the second research objective. The enhancement seen can be attributed to the fiber reinforcement, which bridges the microcracks and enhances load transfer, in concurrence with the results on other fiber-reinforced lightweight concretes(Akbulut et al., 2025).

Overall findings indicate that MS and PPF can greatly improve the mechanical performance of CLC blocks if incorporated at optimal levels. The research confirms that 10% MS maximizes compressive strength, and its combination with 1% PPF realizes the best strength–density performance within the specified mix design and curing regime. Nevertheless, as identified by (Bhosale et al., 2020), CLC blocks have higher water absorption than clay bricks, and, therefore, suitable protection measures are recommended for structures exposed to moisture.

From above results and discussion all results are correlated and consistent, therefore it is relevant with the research.

5. Conclusion

The study found that the best micro silica (MS) content for CLC blocks is 10% by weight of cement, which gave a maximum compressive strength of 6.82 MPa at 28 days, a dry density of 1275.36 kg/m^3, and a modulus of elasticity of 2470.69 MPa. Adding 1% polypropylene fiber (PPF) increased the compressive strength to 7.35 MPa, with a density of 1289.86 kg/m^3 and a modulus of elasticity of 3495.25 MPa. Higher amounts of MS or PPF reduced strength. Therefore, 10% MS and 1% PPF provide the best strength–density balance under the tested conditions.

Further research is needed to investigate the durability, water absorption, and thermal performance of the optimal mixes subject to varying climates and time. There needs to be more diversity in supplementary cementitious materials, and fibers to improve the structural and sustainability performance of the CLC blocks furthermore.

- **Embrace optimal mix ratios**—In practical applications, 10% micro silica and 1% polypropylene fiber by weight of cement will provide the best combination of compressive strength and dry density for CLC blocks.
- **Implement quality control for production**—To produce CLC blocks with consistent performance in high quantities, the mix proportions, amount of water added, and period of curing must remain consistent throughout manufacture.
- **Perform additional performance testing**—In order to further diversify the use of optimally proportioned CLC blocks in various climatic conditions and combinations, studies of the long-term durability, water absorption, and thermal insulation of CLC blocks in optimally proportioned mixtures must be evaluated.

Recommendations:

- Follow the best proportions in practice, use 10% micro silica and 1% polypropylene fiber (by weight of cement) in CLC block making to achieve the best combination of compressive strength, density, and mechanical performance.
- Maintain consistency in manufacturing quality, use strict control over mix ratios, water content, and cure time when producing blocks so that consistent strength and density are achieved when producing large quantities of CLC blocks.

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