Vol. 3 No. 3 (2025)

Spectrum of Engineering Sciences

Online ISSN
3007-3138
Print ISSN
3007-312X

A Comprehensive Analysis of Mechanical Strength and Durability in Cellular Light Concrete Blocks Modified with Multiple Additives

Adnan Khan[1]
CECOS University of IT and Emerging Sciences, Peshawar, Pakistan.
adnanktk90@gmail.com
Abdul Basit Mansoor[2]
Pakistan Public Works Department, Ministry of Housing and Works, Punjab, Pakistan. a.b082@yahoo.com
Rabia Liaqat[3]
USPCAS-W Mehran University of Engineering and Technology, Jamshoro, Pakistan. engrrabiabajoi12@gmail.com
Rozi Khan[4]
National University of Science and Technology (NUST), Islamabad, Pakistan. engr.rozikhan@gmail.com
Uzair Ali*[5]
Local Government and Rural Development Department, Khyber Pakhtunkhwa, Pakistan. engruzair91@gmail.com
Muhammad Anwar Ullah[6]
Balochistan University of Engineering and Technology, Khuzdar, Pakistan.
anwarullah98@gmail.com

Abstract

The multipurpose material, cellular lightweight concrete (CLWC), comprises cement, fly ash, and a foaming agent. The popularity of cellular lightweight concrete can be attributed to its low weight, which lowers the structure's self-weight. With its cementitious qualities and mechanically entrained foam in the cement-based slurry, cellular lightweight concrete (CLWC) is a novel material that has significantly increased in popularity in the construction industry over the past ten years. CLC blocks have poor strength issues while being lightweight concrete with strong water absorption and thermal insulation qualities. CLC blocks are altered with additives like fly ash, silica fume, and marble dust to combat this issue. Due to its low strength, a study reveals that

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X
silica fume and marble dust have been utilized in several experiments to increase stability. The samples will undergo compressive strength, thermal conductivity, and water absorption tests. Regarding compressive strength, 3% silica fume and 7% marble dust work well. These findings are based on seven and 28-day curing times, while 14-day curing may be investigated in the future.
Keywords: Concrete blocks, Silica fume, foaming agent, Marble dust, Fly ash

Introduction

The multipurpose material, cellular lightweight concrete (CLWC), comprises cement, fly ash, and a foaming agent. The popularity of cellular lightweight concrete can be attributed to its low weight, which lowers the structure's self-weight. With its cementitious qualities and mechanically entrained foam in the cement-based slurry, cellular lightweight concrete (CLWC) is a novel material that has significantly increased in popularity in the construction industry over the past ten years. It is a structural component that does not support weight and is not as strong as regular concrete. Better sound and heat insulation, durability, lightweight, consistent size and shape, and low permeability are all provided by CLC. The popularity of cellular lightweight concrete can be attributed to its low weight, which lowers the structure's self-weight. It is altered with different chemicals to increase the strength of the "CLWC" blocks because of its poor strength.

Fast building construction methods using high-quality, reasonably priced materials are essential in today's growing globe. Either inexpensive resources or cementitious material can be used in place of waste materials like fly ash, silica fume, and rice husk ash, among others. Fly ash and silica fume are becoming more popular since they improve the properties of mixed cement concrete, making it more sensible and less hazardous to the environment. One component foam agent is diluted with thirty-five parts water to create the foam content. The amount of foam utilized affects the dry density of the concrete. Hence, foam content between 1% and 1.5% is employed to observe the various results. These days, fly ash and silica fume are receiving greater attention because of their potential to enhance the qualities of mixed cement

Spectrum of Engineering Sciences
Online ISSN
3007-3138
Print ISSN
3007-312X
SPECTRUM OF ENGINEERING SCIENCES

concrete, make it more cost-effective, and lessen its adverse environmental consequences. CLC blocks are not very strong. Research shows that several investigations have employed silica fumes and marble dust to increase strength. The samples undergo compressive strength, thermal conductivity, and water absorption tests. Regarding compressive strength, 3% silica fume and 7% marble dust work well.

According to this study, CLC is a multipurpose substance composed of cement, fly ash, and foaming agents. Thermal conductivity, less water absorption, and low weight are characteristics of CLC [1]. Aliabdo et al. discussed replacing cement with leftover marble dust in concrete production. Additionally, marble dust replaced cement in the concrete's qualities. It is necessary to investigate the chemical, mechanical, and physical characteristics of cement and concrete that have been altered with marble dust [2]. The effects of replacing a large amount of cement with both classified and unclassified fly ash on the properties of foamed concrete were examined by Kearsley and Wainwright P. later in 2001. Their research revealed that 67% of the cement could be substituted without significantly lowering compressive strength [3]. The impact of fly ash, silica fume inclusion, and foam content on specific mechanical and physical characteristics of foam concrete was further investigated by Gokce H, Hatungimana D, and Ramyar K. Adding silica fume produced better compressive strength, especially in mixes with a high foam content [4]. Due to its low weight, which lowers the structure's self-weight, cellular light concrete is often used. According to Vardhan et al.'s research, 35% cement and 65% fly ash are used to cast the concrete blocks with a 1.5% foam content overall [5]. Over the past ten years, CLC blocks have significantly increased in popularity in the masonry industry. The construction of the mathematical model, analysis, assessment, and design of structures composed of the CLC blocks thus requires a thorough study of its essential engineering characteristics [6]. The primary goal of John Paul, Abiraami R, et al. in 2020 was to create lightweight, high-strength foam concrete. Another name for foam concrete is lightweight concrete. The dead weight of the entire building may be decreased thanks to foam concrete. The compressive strength of lightweight concrete ranges from

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

6 MPa to 14 MPa. The project's primary goal is to use readily accessible resources to strengthen the foam concrete. [7]. Reducing the weight of the building's walls is one way to lessen the overall weight of a structure. Sutander et al.'s 2018 study looked at how the quantity or makeup of cement used affected concrete's mechanical and physical characteristics. Even if building methods and materials have changed over thousands of years, construction is still time-consuming, costly, and complex.

The cellular light brick wall in rat-trap bond is an innovative method for creating masonry units that significantly lower construction costs, time, and labour [8]. Kurweti et al. (2017) compared the various forms of lightweight concrete based on their physical characteristics. Concrete that is lightweight and has densities ranging from 400 to 1800 kg/m3 is used extensively worldwide. Their most outstanding performance is used to conclude tabulating their load-bearing capability to compression, thermal insulation, and water absorption while maintaining density as a constant parameter [9]. According to G. Deepa, employing fly ash-based cellular lightweight concrete significantly lowers density compared to regular concrete, yet the right design mix does not affect strength. For this reason, various ratios are employed to get the intended impact [10].

Since other studies have previously been conducted using various additives, this research aims to create an optimal Cellular Lightweight Concrete (CLC) block with better qualities than traditional CLC [11–14]. In addition to having a higher compressive strength for increased stability and longevity, the suggested block will be lightweight, making it easier to handle and requiring less structural load. It will provide superior thermal insulation to increase energy efficiency and support a more environmentally friendly building method. By using sustainable materials and reducing their adverse effects on the environment, the block will also be intended to be environmentally friendly. Finally, aesthetic appeal will be considered to ensure the blocks keep the practical advantages of buildings while improving their visual quality.

Materials and Method

A research strategy efficiently deals with problems. It may be interpreted as examining the methods used to conduct legitimate research. We

Spectrum of Engineering Sciences
Online ISSN
3007-3138
Print ISSN
3007-312X
SPECTRUM OF ENGINEERING SCIENCES

discuss the numerous advancements made by an expert who has carefully considered the research challenge and its causes. There are several approaches to problem-solving and the problems apply them. We suggest the following changes to typical CLC blocks to enhance their qualities and boost their compressive strength.

Cement

To make cement, a combination of clay and limestone is ground and heated to 1,450°C. The end product is a granular material known as "clinker," a mixture of iron oxide, calcium, silicate, and alumina. The most widely used type of cement worldwide is an essential ingredient in mortar, concrete, and most non-speciality grouts. This study was conducted in Peshawar, Pakistan, using local cement.

Marble Dust

One of the waste products created during the marble-making process is marble dust. The cutting operation produces a significant amount of powder. Consequently, a quarter of the current marble concentration is lost as dust. Leaving these waste items out in the open might lead to environmental issues, including soil alkalinity, which can impact plants and people. Marble powder can occasionally be added to concrete to strengthen the material. Marble dust is a byproduct of the refining of marble that may be used as fine aggregates or as filler in cement when building concrete. Marble dust has been utilized as a construction ingredient since prehistoric times. Marble powder can be added to concrete to boost strength [15–17]. The civil engineering community can assure economic infrastructure projects and address the issue of environmental degradation by utilizing this trash to produce more affordable and durable concrete. This stuff was gathered in the industry on Warsak Road in Peshawar, Pakistan.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Figure 1: Marble Dust Sample

Fly Ash

As a byproduct of coal-fired power plants, fly ash is a fine grey powder made up primarily of spherical, glassy particles. Because of its pozzolanic qualities, fly ash can react with lime to create cementitious compounds [18–19]. It is frequently referred to as an additional cementitious substance. When added to concrete mixtures, fly ash increases the concrete's strength and segregation, making it easier to pump.

Figure 2: Fly Ash Sample

Silica Fume

A highly pozzolanic byproduct of the ferrosilicon industry, silica fume improves concrete's durability and mechanical qualities. It is applied in a dry state as a mineral admixture [20]. Silica fume is composed of very minute particles that create a greyish-black powder, with 95% of the particles being smaller than one µm.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Figure 3: Silica Fume Sample

Foaming Agent

CLC blocks are prepared using a conventional foaming agent based on proteins [21]. Animal proteins, including keratin, casein, cow and bovine hoof scales, and other leftovers from animal corpses, are hydrolyzed to create protein-based foaming agents. A material that helps create foam content is called a foaming agent, such as a surfactant.

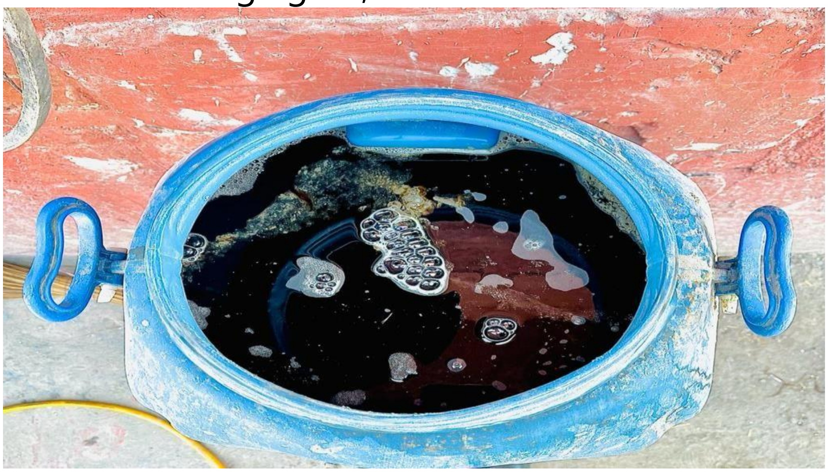

Figure 4: Foaming Agent Sample

This part will cover the study methodology, sample composition of the conventional block, conventional CLC, and modified CLC blocks, material procurement, needed material calculations, sample casting, and the manufacturing process. A literature review is the first step in the procedure, followed by material procurement, a foam generator pump, and casting. Curing and testing follow casting. The results and Conclusion are the last steps, while report writing is the previous step.

Spectrum of Engineering Sciences
Online ISSN
3007-3138
Print ISSN
3007-312X
SPECTRUM OF ENGINEERING SCIENCES

Mix Design and Sample Composition

Mix design is defined as the method of choosing appropriate materials for concrete and then determining their proportions. The goal of concrete making is to make its strength and durability as cheap as possible.

Samples Casted

We worked on various samples for the different blocks, which are given below.

Conventional CLC = 12; Modified CLC = 48

Conventional CLC Blocks

Table 1: Composition of Conventional CLC

S. No.	Fly Ash	Cement	Water Content	Foam Agent
A-1	65%	35%	40%	1%
A-2	65%	35%	40%	1.5%

There will be 16 total samples of conventional CLC blocks cast, eight blocks of each composition.

Modified CLC Blocks

We took the same percentage of the CLC composition and introduced some additives that may improve the compressive strength of the block. We replaced 10% cement out of 35%, 65% fly ash, and 40% water in the composition with different foam content percentages of 1%and 1.5%.

Table 2: Composition of Modified CLC Block with 1.0% Foam content

Sr. #	Weight of samples (kg)	Fly Ash	Cement	Silica Fume bywt. of cement	Marbledust bywt. of cement	Water Content	Foam Content
B-1	3.882	65%	25%	7%	3%	40%	1.0%
B-2	3.880	65%	25%	5%	5%	40%	1.0%
B-3	3.938	65%	25%	3%	7%	40%	1.0%

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Table 3: Composition of Modified CLC Block with 1.5% Foam content

Sr. #	Weight of samples (kg)	Fly Ash	Cement	Silica Fume bywt. of cement	Marbledust bywt. of cement	Water Content	Foam Content
B-4	3.310	65%	25%	7%	3%	40%	1.50%
B-5	2.288	65%	25%	5%	5%	40%	1.50%
B-6	3.320	65%	25%	3%	7%	40%	1.50%

Foam Generator Setup

The foaming generator is a device that creates stable foam from liquid substances. Depending on its ability to store and turn liquid substances into foam, foaming generators come in various sizes. A foaming generator generates foam content when a 1:35 solution is created, with one standing for the foaming agent and 35 for the water. Simply put, the foam content solution is created by adding water 35 times the amount of foaming agent.

Casting and Manufacturing of Concrete Blocks

Sample Preparation Procedure

We completely combine the components using power-driven mixing before casting the sample. We get the composition weight ready and mix. To avoid ingredient loss, we first lubricate the power-driven mixer with several samples. The mixer is then still and ready to eliminate excess water and components. We arrange the components one by one.

After adding half of the water to the mixer, the components were gradually added in a revolving mixer drum. After that, add the remaining water and let the machine mix for two to three minutes. The mixer is then turned off and left running for two more minutes.

Tests performed on CLC Blocks

Three types of tests are performed on the samples.

- Compressive Strength Test
- Water Absorption Test
- Thermal Conductivity Test

Result and Discussion

The study aimed to confirm the impact of marble dust and silica fume on

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

CLC blocks by utilizing them in conjunction with fly ash, cement, and water. Verifying the effect of marble dust and silica fume on various foam compositions and admixture ratios in CLC concrete blocks was the primary goal of this investigation. Test first, then cure the sample for seven and twenty-eight days to examine the findings. As to ACI Code 318-19, concrete takes 7 days to attain 65% strength, 28 days to set, and 99% strength in the first 28 days of curing.

Compressive Strength Test

Conventional CLC

The compressive strength was performed in Sarhad University Workshop according to the standard test method provided by ASTM-C39/C39M. The CLC blocks were prepared according to the dimension of block 6×6. In total, 12 modified CLC blocks and 4 conventional blocks were tested to compare the results of the compression strength test.

Table 4: Compressive Strength Results of Conventional CLC Block

Sr.#	FlyAsh (%)	Cement (%)	Water Content (%)	Foam content	7 Days Compressive strength (psi)	28 Days compressive strength (psi)
A-1	65	35	40	1.00%	319.3	412.5
A-2	65	35	40	1.50%	214.7	354.6

Modified CLC Blocks with 1% Foam Content

Table 5: Compressive Strength Results of Modified CLC Block with 1/0% Foam Content

Sr.#	Fly Ash (%)	Cement (%)	Silica Fume (%)	Marble Dust (%)	Water (%)	Foam content (%)	7 Days Compressive strength (psi)	28 days compressive strength (psi)
B-1	65	25	7	3	40	1.00	697.7	1178.1
B-2	65	25	5	5	40	1.00	909.3	998.5
B-3	65	25	3	7	40	1.00	1208.8	1566.2

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Modified CLC Blocks with 1.5% Foam Content

Table 6: Compressive strength Results of Modified CLC Blocks with 1.5 % Foam Content

Sr.#	Fly Ash (%)	Cement (%)	Silica Fume (%)	Marble Dust (%)	Water (%)	Foam content (%)	7 Days Compressive strength (psi)	28 days compressive strength (psi)
B-4	65	25	7	3	40	1.50	454.2	603.5
B-5	65	25	5	5	40	1.50	503.1	578.7
B-6	65	25	3	7	40	1.50	700.6	847.0

Compressive Strength Comparison Graphs

The compressive strength of conventional CLC blocks and modified CLC blocks are comparedin the graph below.

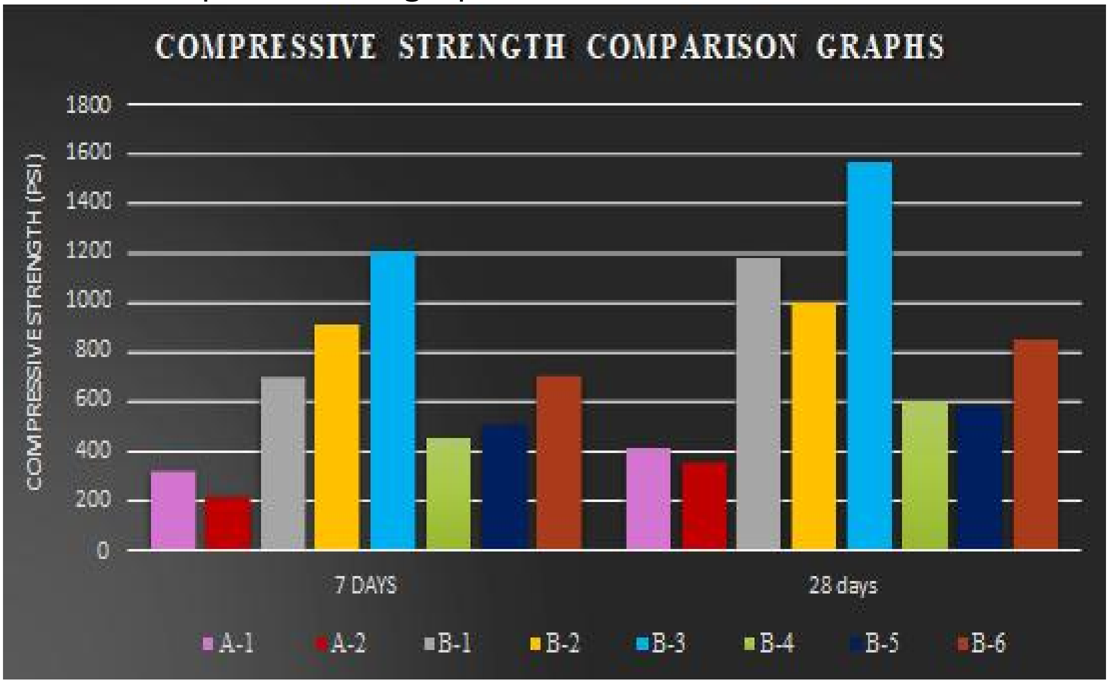

Figure 5: Compressive Strength Comparison Graph of 7 and 28 days

7 Days Compressive Strength Comparison Graph

The graph below compares the 7-day compressive strength of conventional CLC blocks and modified CLC blocks with1% foam content.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

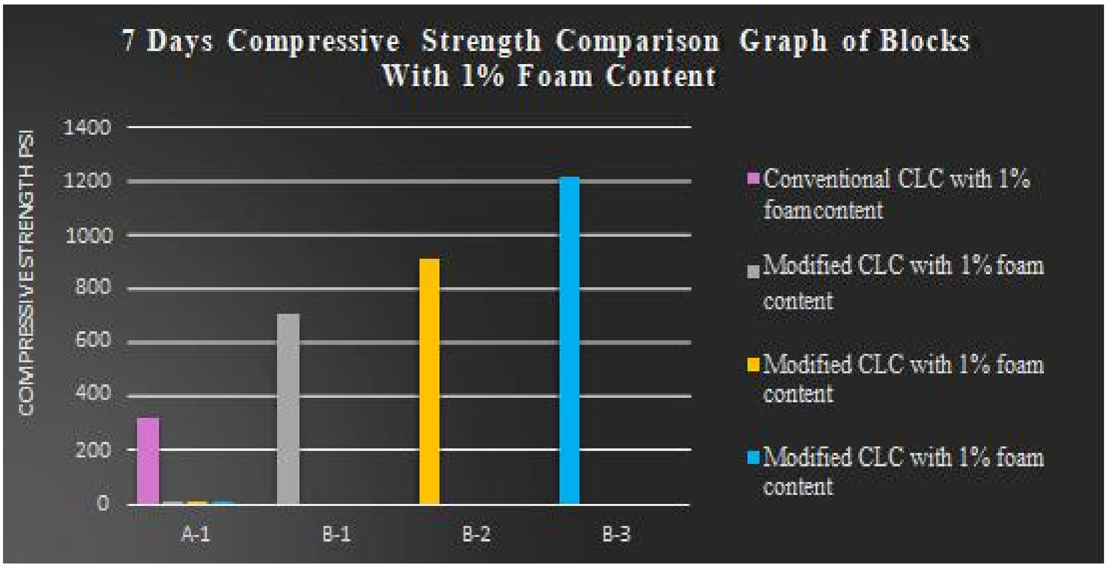

Figure 6: 7 Days Compressive Strength of 1% Foam Content Blocks Graph

The graph below compares the 7-day compressive strength of conventional CLC blocks and modified CLC blocks with 1.5% foam content.

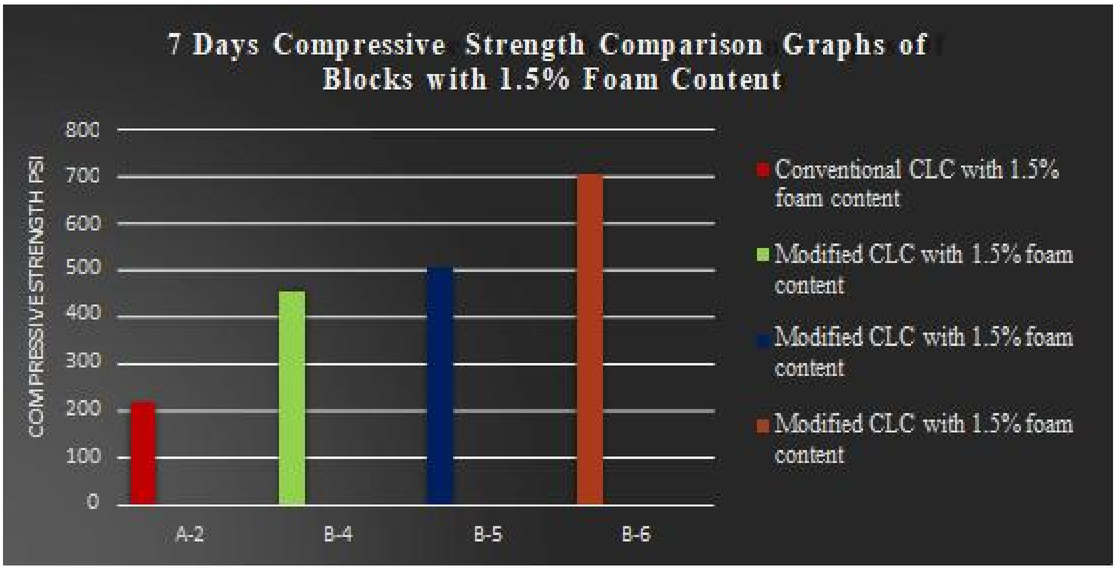

Figure 7: 7 Days Compressive Strength of 1.5% foam content Blocks Graph

The graph below compares the 7-day compressive strength of conventional CLC blocks and modified CLC blocks with 1% and 1.5% foam content.

Spectrum of Engineering Sciences
Online ISSN
3007-3138
Print ISSN
3007-312X

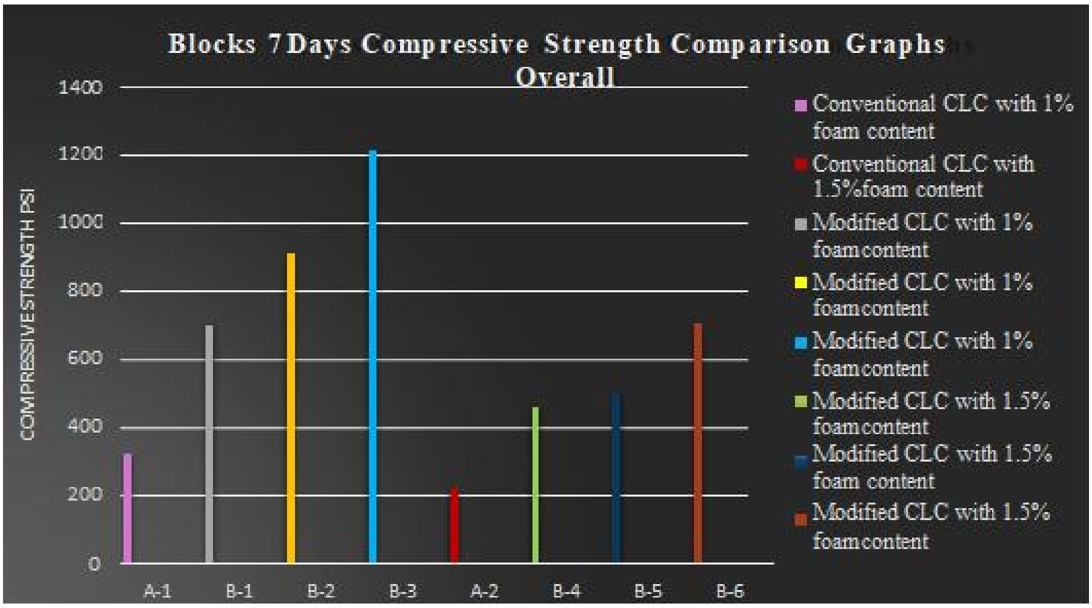

Figure 8: 7 Days Compressive Strength Comparison Graph

28 Days Compressive Strength Comparison Graph

The graph below compares the 28-day compressive strength of conventional CLC blocks and modified CLC blocks with 1% foam content.

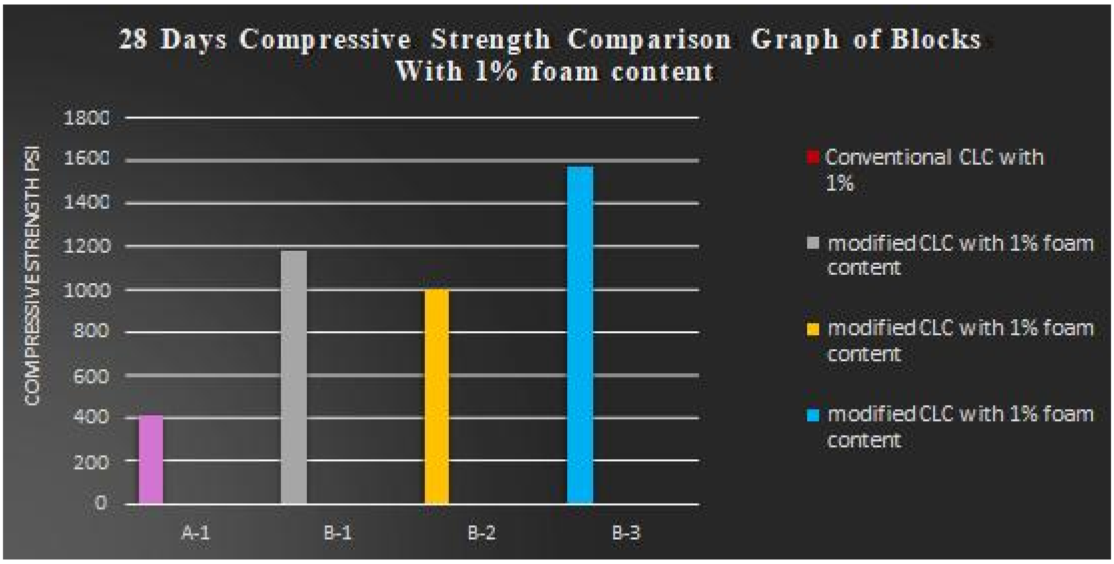

Figure 9: 28 Days Compressive Strength of 1% Foam Content Blocks Graph

The graph below compares the 28-day compressive strength of conventional CLC blocks and modified CLC blocks with 1% foam content.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

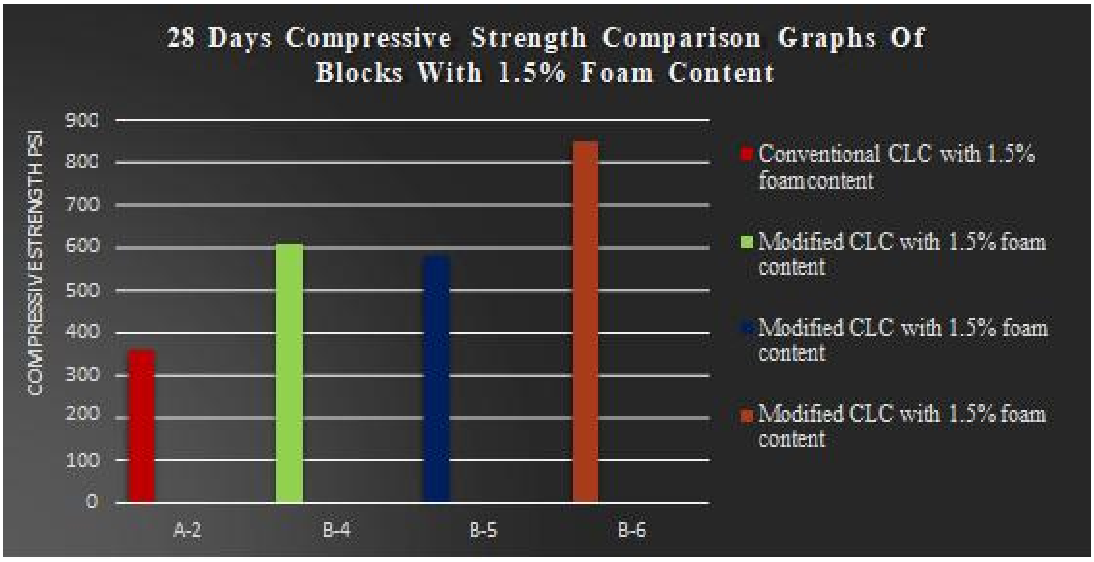

Figure 10: 28 Days Compressive Strength of 1.5% Foam Content Blocks Graph

The graph below compares the 28-day compressive strength of conventional CLC blocks and modified CLC blocks with 1% and 1.5% foam content.

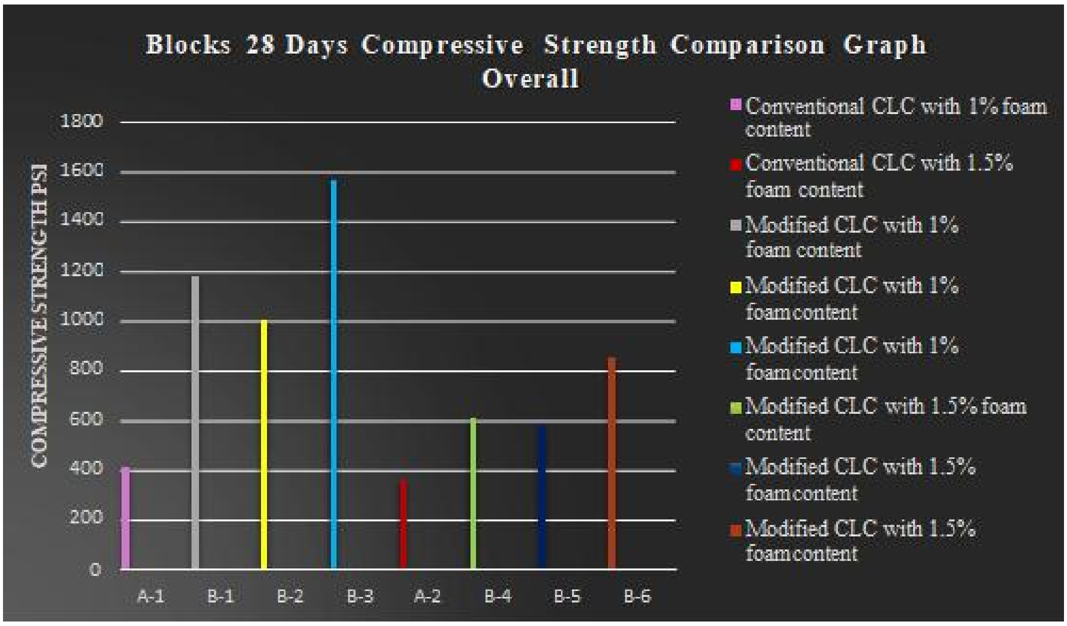

Figure 11: 28 Days Compressive Strength Comparison Graph

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

The above tables list the compressive strength results of conventional and modified CLC blocks, and it is evident that B3 is the recommended sample. The composition of the B3 block is fly ash 65%, cement 25%, silica fume 3%, marble dust 7%, water content 40%, and foam content 1%. Based on the compressive strength test results, we found that, of all the samples, we recommend sample B3 because it has the highest compressive strength of all modified CLC blocks and conventional blocks.

Water Absorption Test

The water absorption of conventional CLC blocks and modified CLC blocks are given below.

Conventional CLC

Table 7: Water Absorption Results of Conventional CLC Blocks

Block Type	Dry Weight (Kg)	Wet Weight (Kg)	Water Absorption (%)
A-1	3.956	4.137	4.57
A-2	4.386	4.552	3.78

Modified CLC

Table 8: Water Absorption Results of Modified CLC Blocks

Block Type	Dry Weight (Kg)	Wet Weight (Kg)	Water Absorption (%)
B-1	3.882	4.170	7.4
B-2	3.880	4.470	15.2
B-3	3.938	4.210	4.62
B-4	3.310	3.610	9.06
B-5	2.288	2.450	7.0
B-6	3.320	3.680	10.8

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

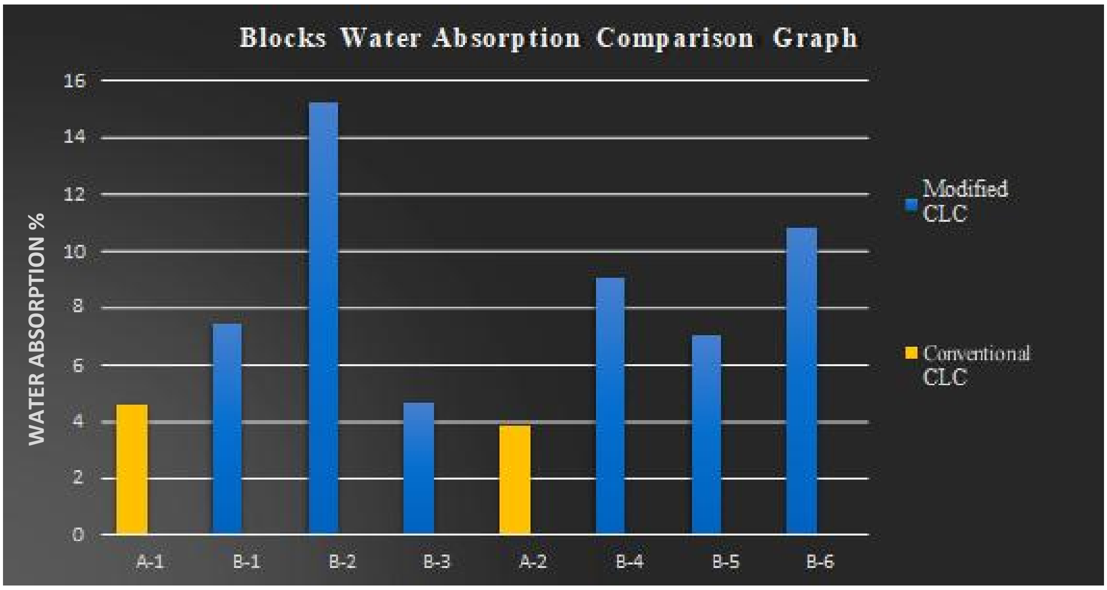

Figure 12: Water Absorption Comparison Graph

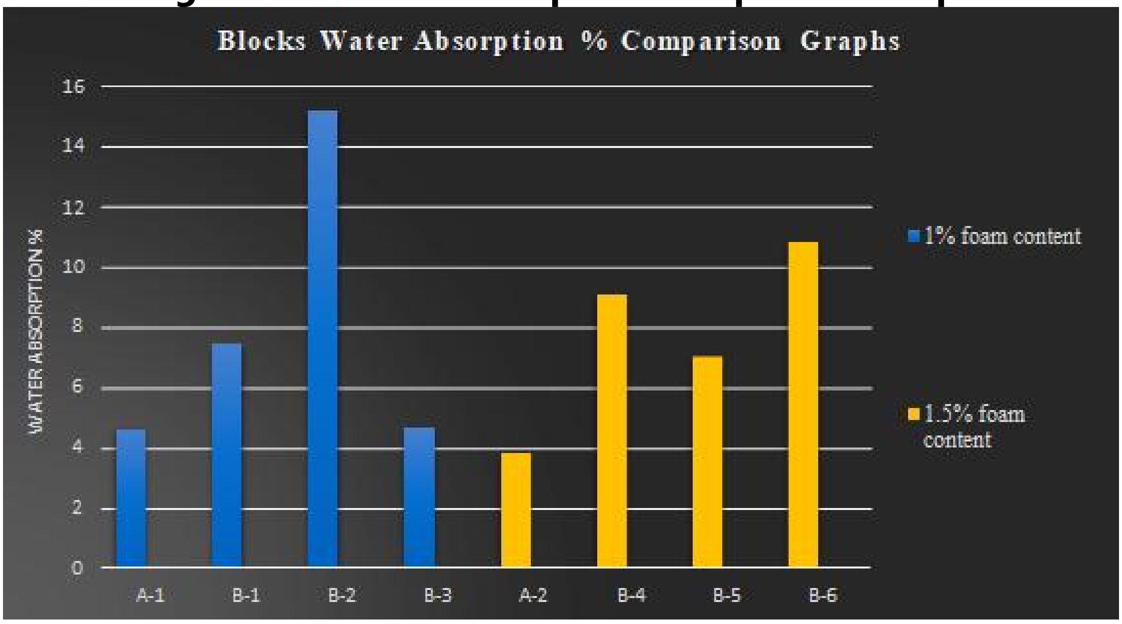

Figure 13: Water Absorption (%) of 1% and 1.5% foam content CLC blocks

Thermal Conductivity Test

The thermal conductivity of conventional CLC blocks and modified CLC blocks are given below.

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

Conventional CLC

Table 9: Thermal conductivity Results of Conventional CLC Blocks

Block Type	Temperature (°C)	Bottom (°C)	Top (°C)	Difference Btw Top & Bottom (°C)
A-1	65	60	30	30
A-2	63	58	29	29

Modified CLC

Table 10: Thermal conductivity Results of Modified CLC Blocks

Block Type	Temperature (°C)	Bottom (°C)	Top (°C)	Difference Btw Top & Bottom (°C)
B-1	72	69	31	38
B-2	96	87	31	56
B-3	97	93	32	61
B-4	80	78	32	46
B-5	75	69	30	38
B-6	87	82	32	51

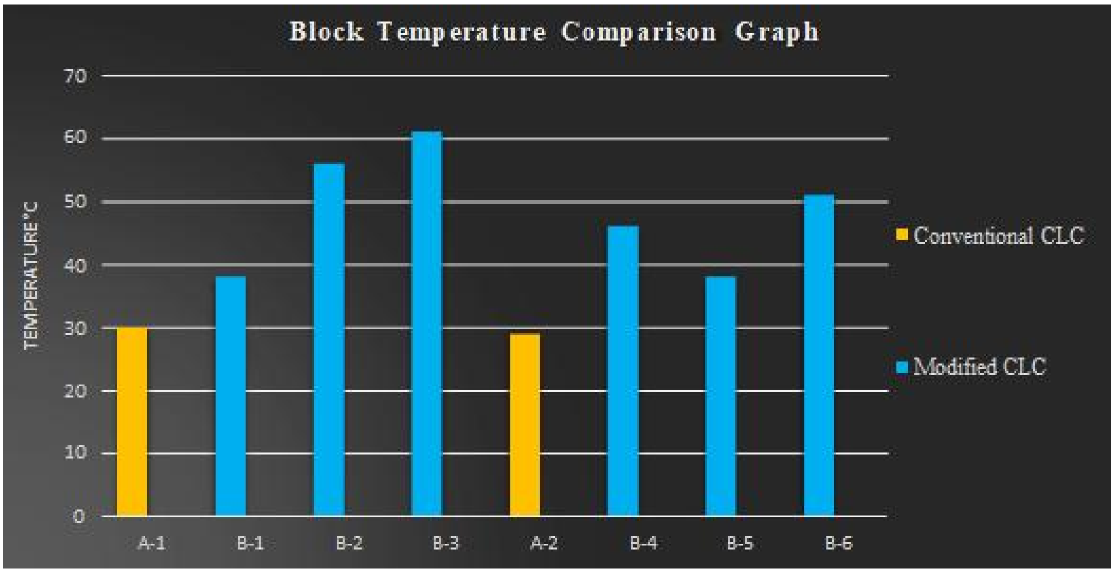

Figure 14: Thermal Conductivity Comparison Graph

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

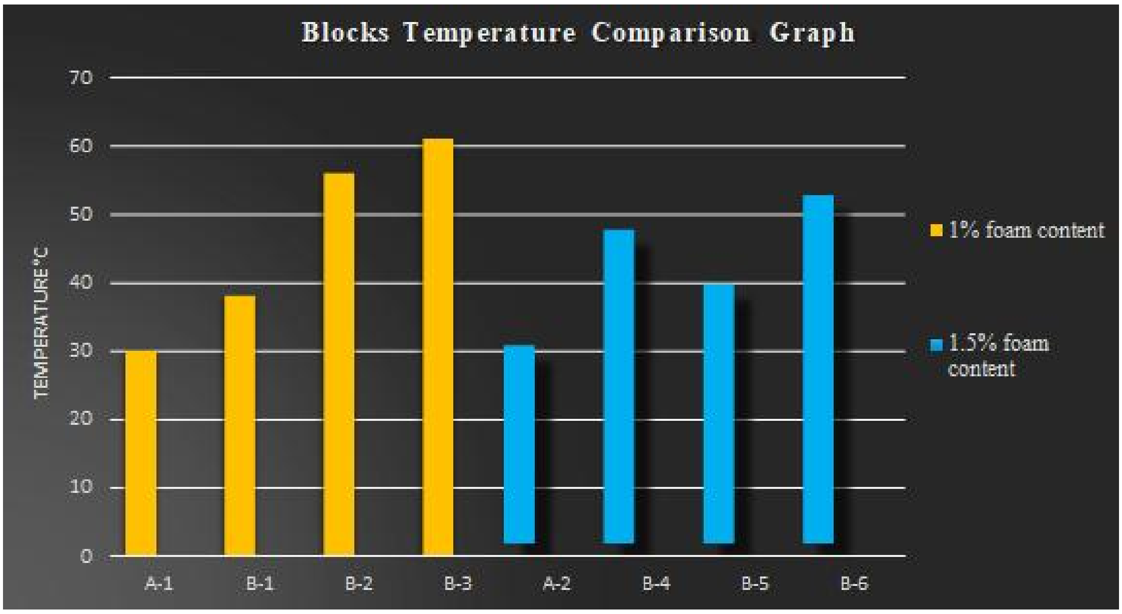

Figure 15: Thermal Conductivity of 1% and 1.5% foam content CLC blocks

Discussion

To study the effect of different proportions and additives, multiple samples were cast. The results for compressive strength, water absorption, and thermal conductivity are mentioned above.

Conventional CLC Block

These samples have varying foam content and a 1:2 cement-to-fly ash ratio cast with plain water. Blocks weighing 3.956 kg with 1.5% foam content had compressive strengths of 319.3 and 412.5 psi, respectively, water absorption of 4.57%, and a thermal conductivity value of 30°C between the two ends. Blocks weighing 4.386 kg with a 1.0% foam content have compressive strengths of 214.7 and 354.6 psi, respectively, water absorption of 3.78%, and a thermal conductivity value of 29*C between the ends.

Modified CLC Blocks

Add 10% cement replacement additives and cast these blocks with varying fly ash ratios to cement. Additionally, these sample blocks' foam contents differ by 1.5% and 1.0%. There are three marble dust and silica fume options for each foam concentration. Our best results were obtained with a composition of 7% marble dust and 3% silica fume, weighing 3.938 kg, 1% foam content, water absorption of 4.62%,

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

compressive strengths of 1208.8 and 1566.2 psi, and a thermal conductivity value of 61*C for the difference between the two ends. The composition that produced the best results for a 1.5% foam content was 7% marble dust and 3% silica fume, weighing 3.320 kg, with compressive strengths of 700.6 and 847 psi, respectively, water absorption of 10.8%, and a thermal conductivity value of 51*C from one end to the other.

Summary

All of these data demonstrate that our modified CLC block samples, which contain additives, have a compressive strength similar to that of regular concrete blocks and superior to that of conventional CLC blocks.

Conclusion

The results above lead us to the Conclusion that using silica fume and marble dust significantly affects the compressive strength of CLC blocks, which also have minimal water absorption and strong thermal insulation. According to the findings, CLC blocks made with marble dust and silica fume in place of cement have 3.8 times the strength of CLC blocks made without these materials.

The best results for compressive strength over seven days are 1208.8 psi with 1% foam content and 700.6 psi with 1.5% foam content. The best 28-day compressive strength results are 1566.2 psi with 1% foam content and 847 psi with 1.5% foam content. The optimal water absorption levels for these different foam compositions are 4.62% and 7.0%, respectively. For the aforementioned foam content, the blocks with the most significant temperature differential between the two sides are 61°C and 51°C, respectively. We may also say that using 3% silica fume and 7% marble dust instead of cement produced the most outstanding results. The study's findings unequivocally demonstrate that silica fume and marble dust significantly affect the strength of CLC blocks.

References

1. YS, M., Mujeeb, A., & US, H. (2020). Cellular Light Weight Concrete Blocks. Institute ofScholars (InSc).
2. Aliabdo, A. A., Abd Elmoaty, M., & Auda, E. M. (2014). Re-use of waste marble dust in the production of cement and concrete. Construction and building materials, 50, 28-41.
3. Kearsley, E. P., & Wainwright, P. J. (2001). The effect of high fly ash

Spectrum of Engineering Sciences
SPECTRUM OF ENGINEERING SCIENCES
Online ISSN
3007-3138
Print ISSN
3007-312X

content on the compressive strength of foamed concrete. Cement and concrete research, 31(1), 105-112.

4. Gökçe, H. S., Hatungimana, D., & Ramyar, K. (2019). Effect of fly ash and silica fume on hardened properties of foam concrete. Construction and building materials, 194, 1-11.

5. Sakale, R. V. S. C. R. Study of Cellular Light Weight Concrete.

6. Bhosale, A., Zade, N. P., Sarkar, P., & Davis, R. (2020). Mechanical and physical properties of cellular lightweight concrete block masonry. Construction and Building Materials, 248, 118621.

7. Johnpaul, V., Abiraami, R., Sindhu, R., Balasundaram, N., & Mathi, S. S. (2020, December). High Strength Lightweight Foam Concrete. In IOP Conference Series: Materials Science and Engineering (Vol. 1006, No. 1, p. 012013). IOP Publishing.

8. Sutandar, E., Supriyadi, A., & Andalan, C. P. (2018). Effect of cement variation on properties of clc concrete masonry brick. In MATEC Web of Conferences (Vol. 159, p. 01008). EDP Sciences.

9. (Kurweti A, chandrakar R, Rabbani (2017). Comparative analysis on aac, clc and fly ash concrete blocks.

10. Deepa, G. (2015). Research Scholar,". Cellular Light Weight Concrete Blocks With Different Mix Proportions" International Journal of Research and Innovation on Science, Engineering and Technology (IJRISET), 178-183.

11. Ullah, E. S., Shahid, M. R., Tariq, S., & Khan, A. A. (2021). Influence of Waste Marble Powder and Waste Granite Powder on the Mechanical and Durability Performance of Concrete. Neutron, 21(1), 46-51.

12. Ullah, S., Bilal, H., Qadeer, A., Usman, A., Khan, A., & Akhtar, N. (2024). Synergic effects of recycled concrete aggregate and styrene butadiene rubber (SBR) latex on mechanical properties of concrete. International Journal of Membrane Science and Technology, 11(1), 506-522.

13. Khan, M. S., Tufail, M., & Mateeullah, M. (2018). Effects of waste glass powder on the geotechnical properties of loose subsoils. Civil Engineering Journal, 4(9), 2044-2051.

14. Khan, M. S., Khattak, A., Yaqoob, M. U. Z. A. M. I. L., & Alam, K. A. S. H. I. F. (2021). ``Strength and thermal conduction assessment of

Spectrum of Engineering Sciences
Online ISSN
3007-3138
Print ISSN
3007-312X
SPECTRUM OF ENGINEERING SCIENCES

lightweight aromatic hydrocarbon waste polystyrol glass concrete,''. Journal of Engineering Science and Technology, 16(2), 1082-1097.

15. Sharma, N., Singh Thakur, M., Goel, P. L., & Sihag, P. (2020). A review: Sustainable compressive strength properties of concrete mix with replacement by marble powder. Journal of Achievements in Materials and Manufacturing Engineering, 98(1).

16. Ashish, D. K. (2019). Concrete made with waste marble powder and supplementary cementitious material for sustainable development. Journal of cleaner production, 211, 716-729.

17. Zhang, S., Cao, K., Wang, C., Wang, X., Wang, J., & Sun, B. (2020). Effect of silica fume and waste marble powder on the mechanical and durability properties of cellular concrete. Construction and Building Materials, 241, 117980.

18. Golewski, G. L. (2022). The role of pozzolanic activity of siliceous fly ash in the formation of the structure of sustainable cementitious composites. Sustainable Chemistry, 3(4), 520-534.

19. Fauzi, A., Nuruddin, M. F., Malkawi, A. B., & Abdullah, M. M. A. B. (2016). Study of fly ash characterization as a cementitious material. Procedia Engineering, 148, 487-493.

20. Liu, J., & Wang, D. (2017). Influence of steel slag-silica fume composite mineral admixture on the properties of concrete. Powder technology, 320, 230-238.

21. Gołaszewski, J., Klemczak, B., Smolana, A., Gołaszewska, M., Cygan, G., Mankel, C., ... & Koenders, E. A. (2022). Effect of foaming agent, binder and density on the compressive strength and thermal conductivity of ultra-light foam concrete. Buildings, 12(8), 1176.