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Partial replacement of fly ash with quarry dust in fly ash based cellular lightweight concrete blocks

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ABSTRACT—

The project aims to explore the development of cellular lightweight concrete blocks by partial replacement of fly ash with quarry dust. This innovative initiative integrates sustainable practices with construction material design to address environmental concerns and enhance structural functionality

Quarry dust is a by-product of mineral aggregate processing at crushing mills, and fly ash, derived from coal combustion, are often underutilized and pose disposal challenges. However, these materials possess latent potential for construction applications due to their unique properties. By incorporating them into masonry production, the project seeks to create a light weight concrete blocks that offers improved insulation, reduced weight, and enhanced thermal properties.

The research methodology involves comprehensive material characterization, including analyzing the physio-mechanical attributes of concrete blocks. Various mixtures and formulations were adopted and optimized based on the suitability for the construction purposes. The anticipated outcomes of this endeavor encompass the development of eco-friendly, cost-effective construction materials that exhibit favorable structural qualities. These cellular light weight concrete blocks have the potential to contribute significantly to sustainable building practices, reducing reliance on conventional resources while minimizing waste.

Keywords—CLC blocks, cellular lightweight concrete, blocks.

introduction

This is the start of the body text of your paper. You can use headings like the one above to divide your paper into sub-topics. Use level 1 headings first, then level 2 headings if you need further divisions inside those, and so on. Don't use a level of heading unless there will be at least two headings of that level. You don't have to use any headings at all if it doesn't make sense to divide your paper in that way. Appropriate numbering is automatically applied to headings. You don't have to number them yourself, just make sure the right heading style is applied to each one. Level 1 and 2 headings (as well as the paper title) should be written with title case capitalization, while level 3 and 4 headings are written in sentence case.

Constituents of coventional lighweight concrete blocks

Fly ash: The fly ash used here is class F Fly ash is designated in IS 3812 – 2003 and originates from anthracite and bituminous coals. It consists mainly of alumina andsilica has a higher LOI than Class C fly ash. Also, Class F fly ash has lower calciumcontent than the Class C fly ash. The specific gravity of fly ash is 2.25. It has beenused as the full replacement of OPC. It shows following advantages,

- Increased compressive strength
- Increased resistance to alkali silica reaction
- Increased resistance to sulphate attack
- Less heat generation during hydration

Foam: The foam is generated from Foam generator and it produces foam by using an appropriate agent. The air is maintained at 40 to 80 percent of total volume. The size of differs is from 0.1 to 1.5 mm in diameter. The main raw material is used togenerate Gentile and organic substance.
Cement: Cellular lightweight concrete is a homogenous combination of Portland cement, cement-silica, cement-pozzolana, lime-pozzolana, lime-silica pastes all have samecell structure and it is obtained from gas-forming chemicals of foaming agents at measured levels.
materials

Specifications of materials:

Cellular Lightweight concrete (CLC) stands as a remarkable human innovation widely applied across various construction domains. Its multitude of applications, including frames and floors, curtain walls, shell roofs, folded plates, bridges, offshore oil platforms, and precast structures, holds immense significance. CLC exhibits a strength that is 25 to 35% lighter compared to standard concrete. Cellular Lightweight Concrete (CLC) blocks have a history spanning several decades, originating in Europe during the 1920s as an initial form of insulating material. Overtime, their evolution continued through the mid-20th century, drawing recognition for their lightweight characteristics and excellent insulation capabilities. However, it was in the later periods, specifically the 1970s and 1980s, that CLC blocks garnered increased attention and popularity, propelled by advancements in foam technology and construction methodologies. Over time, these blocks became popular worldwide due to continuous progress in manufacturing methods, raw materials, and the acknowledgment of their benefits: lower density, excellent thermal insulation, and effortless construction without compromising strength. The persistent evolution and improvements in producing CLC blocks have established their reputation as a sustainable and effective construction material in modern building practices.

- Cement
- Fly ash (Dry ash)
- Quarry dust
- Sodium silicate
- Synthetic foaming agent

Cement: A cement is a binder, a chemical substance used for construction that sets, Hardens, and adheres to other materials to bind them together. Cement is seldomused on its own, but rather to bind sand and gravel (aggregate) together. Cementmixed with fine aggregate produces mortar for masonry, or with sand and gravel,produces concrete.

Ordinary Portland Cement (OPC) is the most commonly used cement in construction as it offers a low-cost proposition with high resistance to cracks andshrinkage. Produced by grinding a mixture comprising limestone and other typesof raw materials, this cement genre comes in three types of grades: OPC 33 grade,OPC 43 grade, and OPC 53 grade. OPC is the go-to cement when rapid construction is required. Nevertheless, its use has declined as Portland PozzolanaCement (PPC) is more affordable and causes lower pollution and energy consumption. It is available at a marginally lowprice,making it more cost-effectivecompared to other types of cement OPC provides excellent resistance to cracks and shrinkage within the structure. The setting time of OPC is considerably less as opposed to PPC, thereby making it a good choice for construction purposes. The curing period of OPC is less as compared to the normal PPC.

Fig.1. Cement

Fly ash: Flyashisthe finelydivided residuethat resultsfromthecombustion ofpulverized Coal and is transported from the combustion chamber by exhaust gases. Fly ash utilization, especially in concrete, has significant environmental benefits including: (1) increasing the life of concrete roads and structures by improving concrete durability, (2) net reduction in energy use and greenhouse gas and other adverse air emissions when fly ash is used to replace or displace manufactured cement, (3) reduction in amount of coal combustion products that must be disposed in landfills,and (4) conservation of other natural resource sand materials.Fly ash is typically finer than Portland cement and lime. Fly ash consists of silt- sized particles which are generally spherical, typically ranging in size between 10and 100 micros

Fig.2. Fly ash

Quarry dust: **Quarry dust is a byproduct of the crushing process which is a concentrated material to use as aggregates for concreting purpose, especially as fine aggregates.**

In quarrying activities, the rock has been crushed into various sizes; during the process the dust generated is called quarry dust.
Quarry dust is highly compactible material commonly used to backfill trenches, pipe bedding, packing under concrete slabs, and building up low areas and createpaths and other hard base areas.

Fig.3. Quarry dust

Sodium silicate: **Sodium silicate, when added to the concrete mix reacts with calcium hydroxide in the presence of carbon dioxide to form calcium silicate hydrate, which contributes to the strength and durability of the concrete.**

Sodium silicate solutions, due to their ability to react with calcium compounds and form additional binding materials, contribute to the overall strength and stability of the CLC blocks. Sodium silicate gel exhibit various specifications tailored for numerous applications. Primarily derived from sodium silicate solutions, the gel's viscosityand solid content are key parameters, often adjusted to suit specific purposes. These gels typically possess a pH range of 10-12, providing alkalinity conducive to various chemical reactions and formulations. Their gelation time, influenced by factors like temperature and concentration, dictates their usability in different processes, ranging from quick-setting adhesives to long-curing binders. Sodium silicate gels often demonstrate excellent adhesive properties, forming strong bonds with various substrates, and their adjustable rheological characteristics make them suitable for diverse applications, including in coatings, binders for foundry molds, and even in certain medical or pharmaceutical formulations. Additionally, the ratio of silicon dioxide (SiO_2) to sodium oxide (Na_2O) in thesegels is meticulously controlled, ensuring consistency and performance across different industrial and commercial uses.

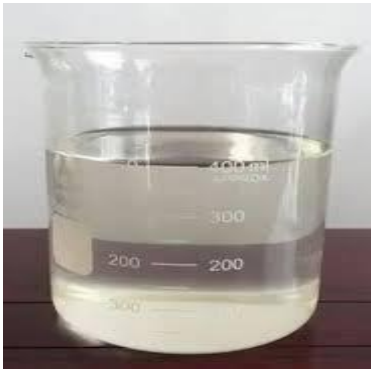


Fig.4. Sodium silicate

Synthetic foaming agent: Foamed concrete typically consists of a slurry of cement or fly ash and sand and Water, although some suppliers recommend pure cement and water with the foaming agent for very lightweight mixes. This slurry is further mixed with a synthetic aerated foam in a concrete mixing plant. The foam is created using a foaming agent, mixedwithwaterandairfromagenerator.Thefoamingagentmustbe able to produce air bubbles with a high level of stability, resistant to the physical and chemical processes of mixing, placing and hardening. Foamed concrete mixture may be poured or pumped into molds, or directly into structuralelements. The foam enables the slurry to flow freely.

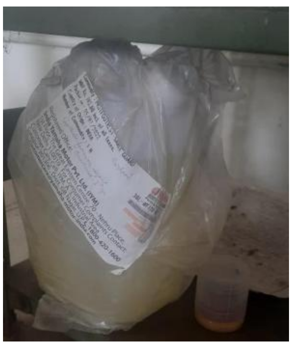


Fig.5. Foaming agent

mix proportion

The above discussed materials are used for various mix proportions and they are tabulated below.

TABLE I. MIX PROPORTION

Mix Ratio	Cement (kg)	Fly ash(Kg)	Quarry dust (kg)	Foam (kg)	Sodium Silicate Solution(ml)	W/C ratio
Mix 1	347.16	1041.67	0	20.83	1736.67	0.5
Mix 2	347.16	990	52.08	20.83	1736.67	0.5
Mix 3	347.16	937.5	104.16	20.83	1736.67	0.5

Methodology

Preparation of specimen: The materials used in this study usually consist of the fly ash, Quarry dust,Cement, Sodium silicate solution and synthetic foaming agent. Based on the ASTM Standard, the grading of fine clayey particles is done.The materials collected were of Class- F fly ash, Quarry dust from the CLCmanufacturing factory. All the materials were dried toremove the moisture content, which affect the water ratio and binding.
Mixing of materials: There is at present, no guidance or standard method for proportioning foamed concrete,because the hardened density of foamed concrete depends on thesaturation level in its pores. The mix design or ratio for producing CLC block is obtained using trial and error mix procedure. In this project, five mix proportion have been adopted as follows. The Cement to sand ratio is maintained 2:3 for allproportions and w/c is taken as 0.5. The fly ash is partially replaced with sand dustin various dosages as 0%, 5%, 10%.
Size of the mould: The mould which were selected for casting brick samples of size,600mmx200mmx100mm.
Curing: The molds were kept in the ambient temperature for 21 days to retain itsshape and ensuring no breakage will happen while demoulding.

Results And Discussion

This present project aims at the development of cellular masonry products. In this regard three different mixes were initially proposed. Based on the density and compressive strength, the conclusions were drawn.

Compressive strength:

TABLE II. COMPRESSIVE STRNGTH RESULTS

Mix	Specimen	Load (kN)	Compressive strength (N / mm2)	average compressive strength (N / mm2)
0%	1	150	2.5	
	2	132	2.2	2.2
	3	120	2	
5%	1	228	3.8	
	2	222	3.7	3.65
	3	207	3.45	
10%	1	238.8	3.98	
	2	233.4	3.89	3.9
	3	234	3.9	

The compressive strength development of Conventional and 5% and 10% replacement of quarry dust is presented in Table II, declaring that the compressive strength of conventional block is 2.2 MPa and of replacement of quarry dust have slightly increased the compressive strength. The average compressive strength of 5% and 10% replacement of quarry is found to be 3.65 MPa and 3.9 MPa which is slightly higher that of the conventional block.

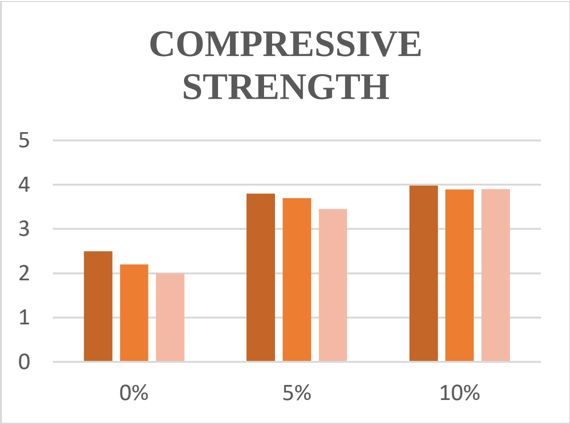


Fig.6. Compressive strength test results

From the above graph, we inferred that the compressive strength gradually increases for the varying percentage of replacement of quarry dust with the Conventional block.

Compressive strength (N/mm^2)

Mix	Specimen	Dry wt. (kg)	Wet wt. (kg)	water absorption %	avg water absorption
0%	1	9.35	11.154	14	
	2	9.25	10.89	15.5	14.6
	3	9.08	10.75	14.3	
5%	1	9.502	10.226	7.6	
	2	9.3	10.5	12.9	11.62
	3	9.445	10.8	14.3	
10%	1	9.802	10.436	6.5	
	2	9.5	10.78	13.5	9.77
	3	9.62	10.52	9.4	

Fig.7. Compressive strength test

Water absorption:

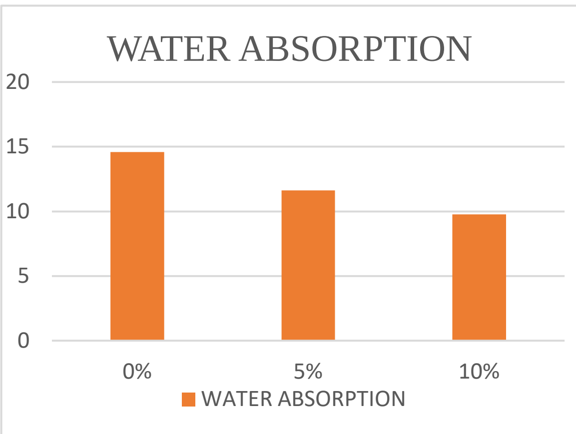


TABLE III. WATER ABSORPTION TEST

Fig.8. Water absorption test results

From the above graph, it is inferred that the water absorption rate decreases gradually for the various replacement percentage of quarry dust. With 0% replacement the water absorption was found to be 14.6%, 11.62% for 5% replacement of quarry dust and 9.77% for 10% replacement of quarry dust which is found to be the minimum percentage of water absorption.

Fig.9. Water absorption test

Initial rate of absorption:

TABLE IV. INITIAL RATE OF ABSORPTION RESULTS

Mix	Specimen	Dry wt. (kg)	Wet wt. (kg)	Initial rate of absorption (kg/min)	avg initial rate of absorption
0%	1	9.356	11.154	29.97	
	2	9.25	10.89	21.39	27.56
	3	9.08	10.75	31.31	
5%	1	9.502	10.226	27.15	
	2	9.3	10.5	24.00	22.47
	3	9.445	10.8	16.26	
10%	1	9.802	10.436	11.19	
	2	9.5	10.78	16.70	13.39
	3	9.62	10.52	12.27	

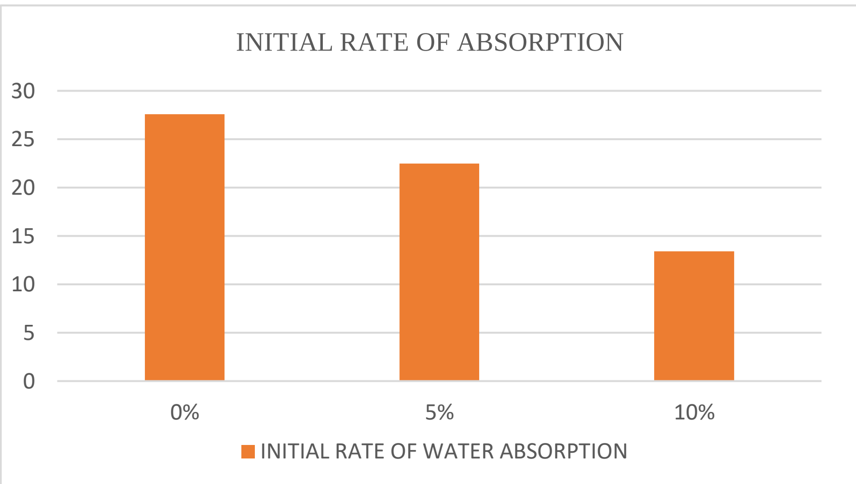


Fig.10. Initial rate of absorption test results

From the above graph, it is inferred that the water absorption rate decreases gradually for the various replacement percentage of quarry dust. With 0% replacement the water absorption was found to be 14.6%, 11.62% for 5% replacement of quarry dust and 9.77% for 10% replacement of quarry dust whichis found to be the minimum percentage of water absorption.

Initial rate of absorption

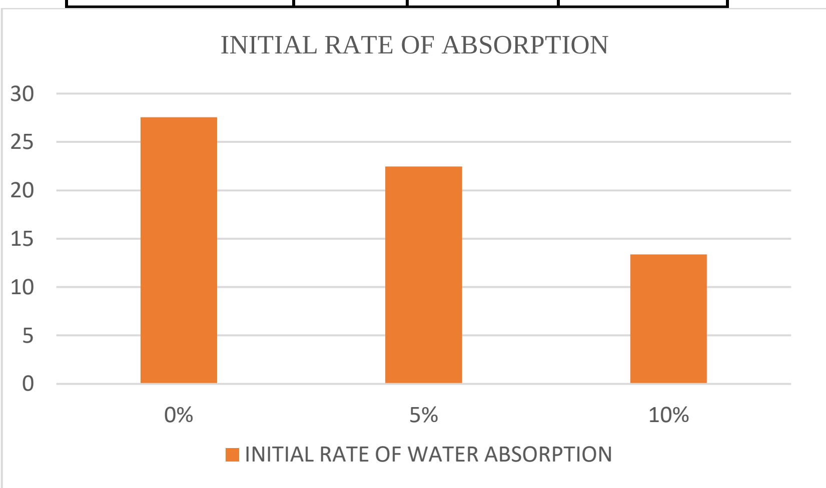
Axial compressive strength (MPa)

Fig.11. Initial rate of absorption

Axial compressive strength:

TABLE V.AXIAL COMPRESSIVE STRENGTH RESULTS

SPECIMEN	LOAD (KN)		AXIAL COMP STRENGTH (MPa)
	FIRST CRACK LOAD	ULTIMATE LOAD	
CONVENTIONAL CLC MASONRY WALL	43.35	767.18	3.17
OPTIMAL CLC MASONRY WALL	470.88	1325.25	5.47



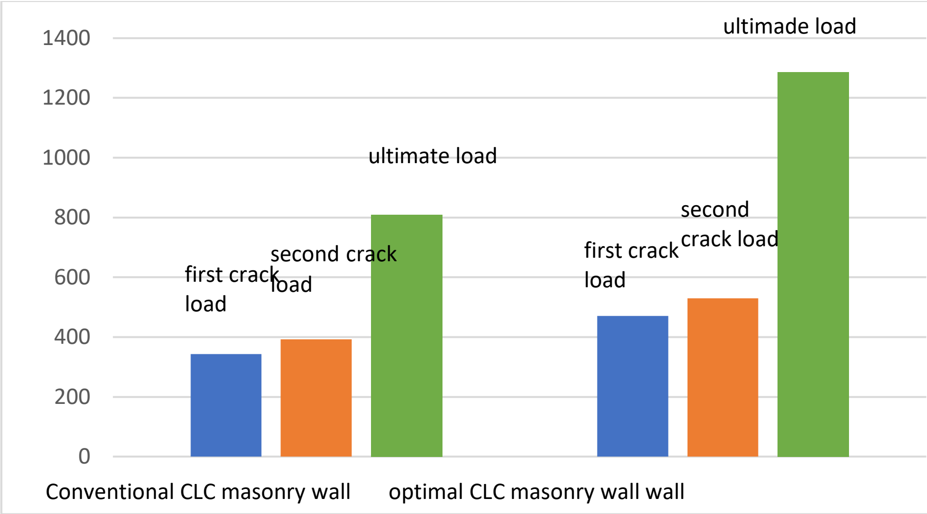


Fig.12. Comparison of axial compressive strength of conventional and Optimal CLC masonry wall

Fig.13 Crack after testing of conventional masonry wall

Fig.14 Crack after testing of optimal masonry wall

TABLE VI .COMPARISON OF EXPERIMENTAL AND ANSYS RESULTS

This indicates that a controlled experiment or assessment was carried out to compare the performance of two types of masonry walls: one made with conventional CLC and another made with CLC containing 10% quarry dust as a replacement material. The focus of the test was on the ability of these masonry walls to withstand compressive forces applied along their length. This is a crucial aspect in construction, especially for load-bearing structures like walls, where the ability to resist compression is essential for structural integrity.

E. Axial Compressive strength –ANSYS Results

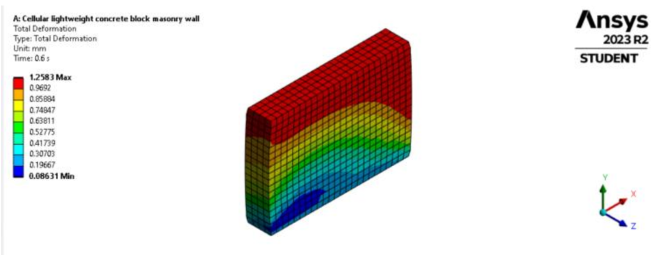


Fig.13. Total deformation of conventional CLC masonry wall

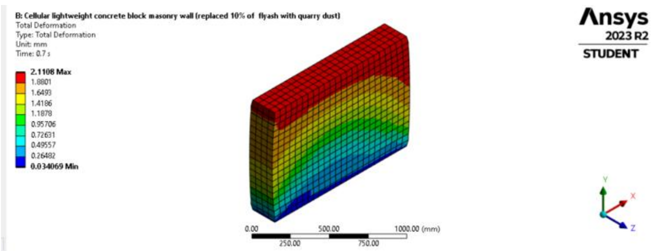


Fig.14. Total deformation of Optimal CLC masonry wall

In this context, it seems that ANSYS simulations predicted higher ultimate loads for the tested structure compared to experimental results. Data obtained through physical testing, likely involving the application of loads to a physical model or prototype of the structure.so the ultimate load values predicted by ANSYS software were greater than those observed in the experiments.

Conclusion

The following conclusions were made based on the discussion on the results and Inference.

1. Compressive strength got slightly increased by the varying percentage of replacement of quarry dust with fly ash.
2. Water absorption percentage got reduced when compared with the conventional blocks
3. Carbonation effect was high in the conventional block when compared to 5% and 10% replacement of fly ash with quarry dust.
4. It suggests that the masonry wall made with the optimal mix exhibits higher axial compressive strength compared to the conventional CLC wall making it more suited for load-bearing application.

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First and foremost, I would like to thank almighty, who has showered his grace and blessings enabling me to complete this training programme in an excellent manner.

I take this opportunity to express my sincere gratitude to the **Management of Kumaraguru College of Technology**, Joint Correspondent, **Shri Shankar Vanavarayar** and Our Principal **Dr.M.Ezhilarasi** for providing necessary facilities for preparing this report.

SPECIMEN	ULTIMATE LOAD (KN)		AXIAL COMPRESSIVE STRENGTH (MPa)	
	EXP. result	Ansys result	EXP. RESULT	ANSYS RESULT
CONVENTIONAL CLC MASONRY WALL	767.18	877.14	3.19	3.65
OPTIMAL CLC MASONRY WALL	1325.25	1494.50	5.47	6.22

I avail this opportunity to voice my deep sense of reverence to **Dr.V.Selvan**, Associate Professor, Head and my guide, **Dr.V.Gayathri**., Associate Professor and PG coordinator and **Mr. Satheesh Kumar K R P**, Assistant Professor II, Class Advisor, for their valuable guidance, suggestions and encouragement at various stages of this project.

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