Mechanical Properties and Micro Structural Analysis of Light Weight Aggregate Concrete

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The construction industry is constantly seeking innovative materials and techniques to address the growing need for sustainable and energy-efficient building solutions. Light weight aggregates (LWAs) have emerged as a promising alternative to traditional heavy aggregates due to their reduced weight and improved insulation properties. This abstract provides an overview of the key characteristics, production methods, and applications of light weight aggregates, highlighting their significant contributions to sustainable construction practices. Light weight aggregates are manufactured using various materials, including expanded clay, shale, slate, and fly ash, through processes such as sintering, palletization, and foaming. These aggregates possess a cellular structure that results in reduced density and enhanced thermal insulation properties. Moreover, they exhibit excellent fire resistance, sound absorption, and durability, making them highly suitable for diverse construction applications. The lightweight nature of these aggregates offers several advantages. First, they significantly reduce the structural load, leading to more efficient designs, lower transportation costs, and simplified installation procedures. Second, the improved thermal insulation properties contribute to energy conservation by minimizing heat transfer through the building envelope. This leads to reduced reliance on mechanical heating and cooling systems, resulting in lower energy consumption and associated greenhouse gas emissions.

Keywords: Lightweight aggregate, Mechanical properties, Microstructural analysis.

1. Introduction

Lightweight aggregates (LWAs) have garnered significant attention within the construction realm owing to their distinctive characteristics and potential to foster sustainable building methodologies. As the demand escalates for construction materials that are energy-efficient and eco-friendly, LWAs have emerged as a promising substitute for traditional heavy aggregates. This preamble offers an insight into the importance of LWAs in construction, delineates the objectives of the research paper, and underscores the pivotal sections it will encompass. The construction sector stands as a pivotal contributor to global energy consumption and environmental impact, necessitating an exploration of innovative materials to address these challenges. LWAs present a practical solution by virtue of their reduced weight, enhanced insulation properties, and heightened sustainability compared to conventional aggregates. By integrating LWAs into construction materials like lightweight concrete and masonry blocks, it becomes feasible to fabricate energy-efficient structures with diminished carbon footprints. While most LWAs are derived from materials such as clay, shale, or slate, alternatives like blast furnace slag, natural pumice, vermiculite, and perlite can also be utilized. The production process involves expanding the raw material (excluding pumice) to roughly double its original volume, yielding an expanded material with similar properties to natural aggregate but with lesser density, thus resulting in lighter concrete products. The manufacturing of lightweight aggregate commences with the extraction or quarrying of the raw material, followed by crushing via cone crushers, jaw crushers, hammermills, or pugmills, and subsequent size screening. Oversized material is cycled back to the crushers, while the material passing through the screens is conveyed to hoppers. From there, it proceeds to a rotary kiln, fueled by coal, coke, natural gas, or fuel oil, reaching temperatures around 1200°C (2200°F). As the material undergoes heating, it liquefies, causing carbonaceous compounds to form gas bubbles, expanding the material and concurrently releasing volatile organic compounds (VOCs)

2. Materials

2.1.1 Cement (OPC 53)

Cement is a type of binder, which is a chemical compound utilized in construction processes to facilitate the setting, hardening, and adhesion of various materials, so creating a cohesive bond between them. Cement is typically employed as a binding agent to unite sand and gravel, also referred to as aggregate. The combination of cement with fine aggregate results in the formation of mortar, which is commonly used in masonry applications. Alternatively, when cement is mixed with both sand and gravel, it forms concrete. Concrete is an extensively utilized substance that ranks second only to water as the most consumed resource on the globe. A cement is a type of binder, which is a chemical compound employed in the field of building

2.1.2 Fine aggregate

"Fine aggregate" is commonly employed in the field of civil engineering and construction to refer to particles of sand, gravel, or crushed stone that possess a size less than 4.75 mm. Fine aggregates play a crucial role in the manufacturing of concrete and mortar, as they contribute to the overall volume stability, wear resistance, and various other desirable characteristics.

2.1.3 Cinders

Cinders is the material comes under the category light weight aggregate and it is a byproduct of steel, iron manufacturing companies. The surface of cinder aggregate is usually rough and highly porous due to mineral structure. Cinder aggregates are used for making building blocks for partition walls, for making screeding over flat roofs and for plastering purposes because of its less weight. linear Coeff. Of thermal expansion is about 3.8* 10-6 c. Cinder contains large percentage of air, so it is naturally a better material with respect to sound absorption, sound proofing and thermal insulation. Due to its low density it helps in reduction of dead load, increases the progressing of building, and lowers handling costs. The most important characteristic of light weight concrete is the relatively low thermal conductivity. Due to its low specific gravity, the concrete made with it is lighter than natural concrete.

Figure (a)

Figure (b)

Figure (c)

Figure (d)

Figure 1: (a) cement, (b) M- sand (c) Cinder and (d) Coarse aggregates

3. Methodology

The work is to evaluate the feasibility of concrete using cinder as coarse aggrgates replacement materials. The mix design was completed in accordance with IS 10262-2019, using the optimal cement content. This study adopted (OPC 53) and M30 grade of concrete. In the first trail (0%, 60%, 80% and 100%. SPs are also used to enhanced by increasing. To improve the efficiency of concrete in workability and strength standards, the attributes are examined in both fresh and hardened states and modulus of elasticity . Concrete is converted into cubes, and prisms . The test is carried out after 7 and 28 days of curing for hardened concrete and microstuctural analysis is to be done uing SEM images.

4. Experimental Investigation

4.1 Components

4.1.1 Ordinary Portland cement:

In this Study, Ordinary Portland Cement grade 53 is used to comply with IS 12269:2013 and for physical testing according to IS 4031:1996[12].

Table 1. Properties of Cement

Sl. No	Test Conducted	Result Obtained
1	Specific gravity	3.2
3	Initial setting time	25 min
4	Final setting time	230 min
5	Fineness	2.7 %
6	Soundness	2 mm
7	Normal consistency	27%

4.1.2 Manufactured Sand [M Sand]

M Sand is used in this study and conforming to IS 383:2016 is used [13].

Table 2. Properties of M-Sand

Sl. No	Tests on M- sand	Test Results
1	Specific gravity	2.57
2	Water absorption in percentage	1.1 %
3	Fineness modulus	2.68

4.1.3 Coarse Aggregate (CA)

CA of 12.5 mm to 20 mm size aggregate are used in this study and conforming to IS 383:2016 is used [13].

Table 3. Properties of CA

SL No	Tests Conducted on CA	Tests Results
1	Size	12.5 mm to 20 mm
2	Shape of CA	Angular
3	Specific gravity	2.75
4.	Water absorption	0.5%
5	Fineness modulus	4.6

4.1.4 Cinders

CA of 12.5 mm to 20 mm size aggregate are used in this study

Table 4. Properties of Cinders

SL No	Tests Conducted on CA	Tests Results
1	Size	12.5 mm to 20 mm
2	Shape of CA	Angular
3	Specific gravity	2.05
4.	Water absorption	1.3%
5	Fineness modulus	2.82

4.1.5 Superplasticizer

In this study Poly carboxylate ether superplasticizer is used it is manufactured by the Buildplast super confirms to IS 9103:1999 is used.

Table 5. Properties of Superplasticizer

SL No.	SP properties	Results Obtained
1	Colour	Brownish
2	Ph	6.3
3	Specific gravity	1.08
4.	Chloride content	<0.2%
5.	Chemical	Polycarboxylate ether
6.	Air entrained	<1.5%
7.	Shelf life	12 months

4.2 Mix Proportioning

Constructing a Concrete mix M30 grade is a way of modifying the amount of various components, such as cinder, cement, coarse and fine aggregates, to achieve the desired results. To increase workability and strength, chemical admixtures were also utilised in concrete. IS 10262-2019 [22] served as the foundation for the mix design. additionally to IS 456-2000[18] This is study poly-carboxylate ether are used as a chemical admixures by 0.25% wieght of cement. , which increases concrete performance. Fine aggregates from Zone II are used. M-sand is substituted with natural river sand, and a 12.5mm to 20 mm size of coarse aggregate and some percentage of replacement of cinder are used as a coarse aggrgates .adopted concrete Mix propotions as 1:2:2.71:0.45

Table 6. Various Concrete Mix Proportions

	Concrete Design Mix							
Mix identity	Grade	Cement (OPC)	Free water	FA	CA	Cinder	SPs (% by weight of cement)	W/C ratio
CA100%+CINDER0%	M30	391	154.6	791	1068	0	0.25	0.45
CA40%+CINDER60%	M30	391	154.6	791	427.2	640.8	0.25	0.45
CA20%+CINDER80%	M30	391	154.6	791	213.6	854.4	0.25	0.45
CA0%+CINDER100%	M30	391	154.6	791	0	1068	0.25	0.45

5. Results and Discussion

5.1 Workability Test

5.1.1 Slump Test

The Table 9 displays the Slump flow values of the control and ternary mixtures. Slump flow test is conducted as per IS code 1199: 1959. The standard mix will show the better slump values than the other mix. By adding admixture will increase the workability

Table7. Slump Flow test results

Mixes	Slump Flow (mm)
CA100%+CINDER0%	70
CA40%+CINDER60%	62
CA20%+CINDER80%	58
CA0%+CINDER100%	56

5.2. Mechanical properties

5.2.1 Compressive Strength

Compressive strength of M30 grade of concrete is carried out with a mixture of percentage replacement of cinder and cube moulds are of standard size 150x150x150 mm is used the compressive strength of a standard mix and a replaced mix was determined. In this test both 7 and 28 days of the standard mix yields a greater compression strength of 24.16 MPa and 36.14 MPa respectively than other mixes and alone cinder gives lesser strength.

Table 8. Compressive Strength Results of 7 and 28 days

Mix designation	Compressive Strength in 7 days MPa	Compressive Strength in 28 days MPa
CA100+CINDER0	24.16	36.14
CA40+CINDER60	17.87	24.46
CA20+CINDER80	15.87	23.21
CA0+CINDER100	13.14	21.01

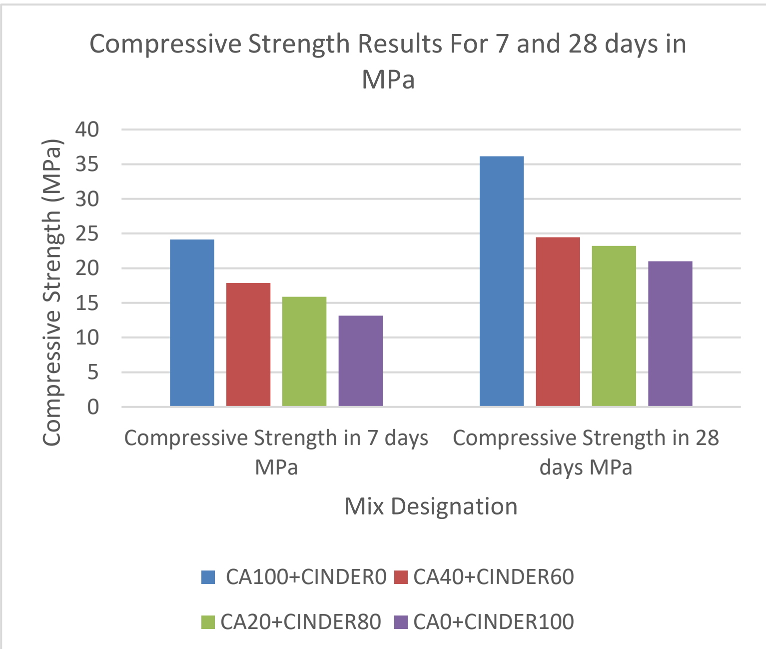


Figure 2. Compressive Strength light weight concrete of 7 and 28 days

5.2.2 Flexural Strength

The flexural strength M30 grade of concrete is carried out with a mixture of percentage replacement of cinder. The prism size 150x150x500 mm are employed. Three trials were completed to achieve flexural strength for 7 and 28 days. Table.11 shows the greater flexural strength of beams after 7 and 28 days. The flexural strength of the Control Mix is 6.12 MPa. The greatest flexural strength achieved in the is CA40+CINDER60 is 5.81 MPa when compared to other mixes.

Table 9 Flexural Strength of 7 and 28 days

Mixes	Flexural Strength in MPa in 7 days	Flexural Strength in MPa in 28 days
CA100+CINDER0	3.24	6.12
CA40+CINDER60	2.24	5.81
CA20+CINDER80	1.20	2.24
CA0+CINDER100	0.98	1.13

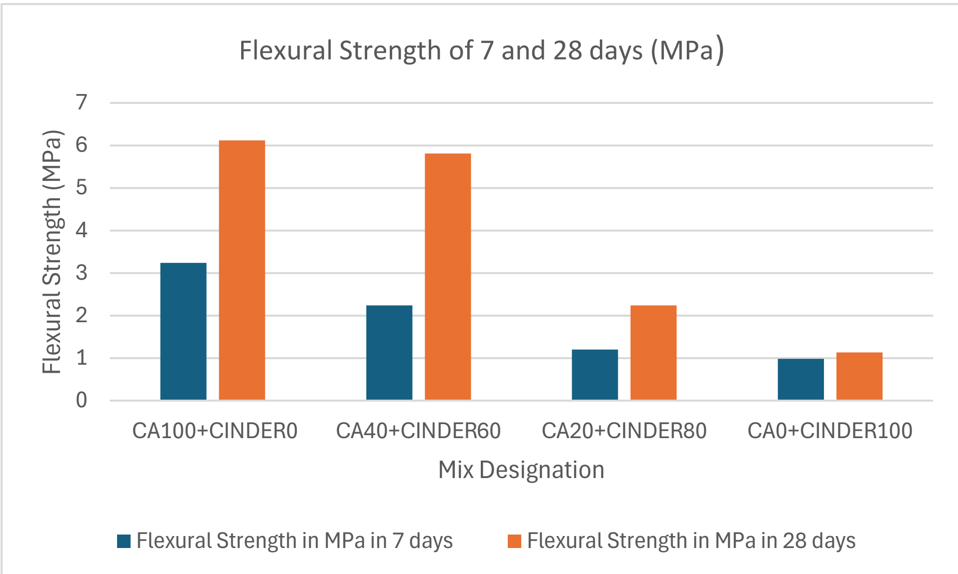
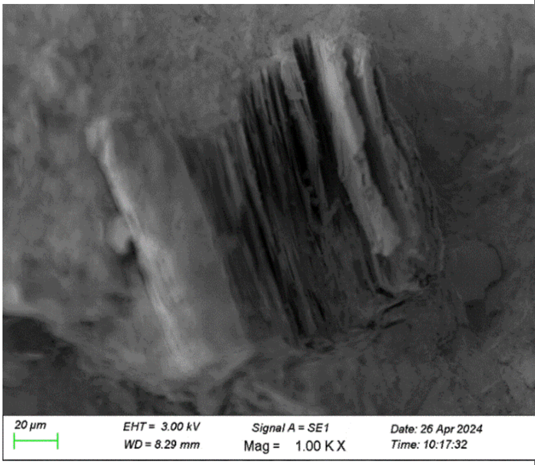
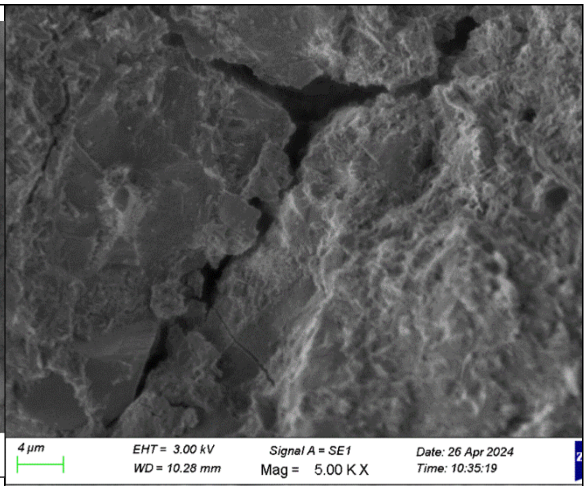


Figure 3. Flexural Strength of 7 and 28 days

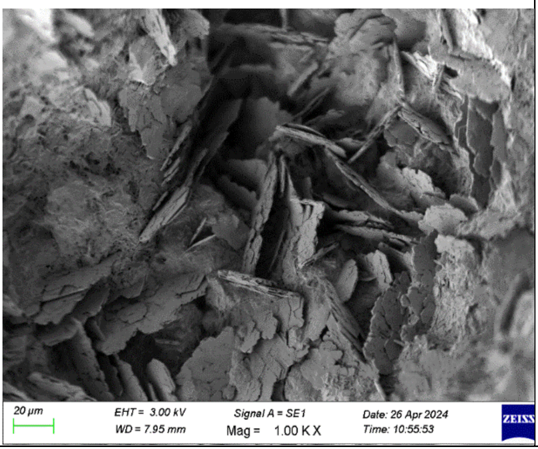
5.3 SEM images



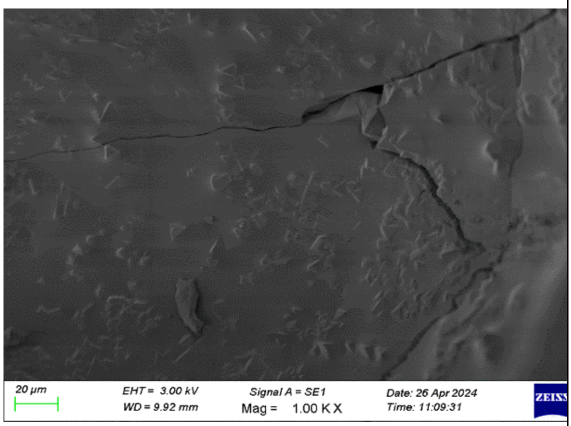
(a) Normal concrete (100% CA and 0% Cinder)



(b) 40% CA and 60% Cinder



(c) 20% CA and 80% Cinder



0 % CA and 100% Cinder

Figure 4: SEM images (a) Normal concrete (100% CA and 0% Cinder) , (b) 40& CA and 60% Cinder (c) 20% CA and 80% Cinder and (d)) 0% CA and 100% Cinder

From figure 4, it was observed that 0 % CA and 100% Cinder will have more mortar nature than other mixes. 20% CA and 80% Cinder , this looks like shell like structure i.e entrigates formation.

6. Conclusion

- Standard mix is giving better compression and flexural strength
- 60% replacement of cinders gives maximum strength among all.

- Declination of strength is observed at 80% and 100% replacement.
- Usage of cinders is cost effective, and it is a reused material
- Light weight concrete can be used where weight reduction is needed

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