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An experimental study on strength and durability properties of self-compacting and self-curing concrete using light weight aggregates

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ABSTRACT

Concrete is a material that is often used in the construction industry due to its strong compressive strength and durability. Currently, a lot of research is being done to find new ways to increase performance. One of these ideas is what led to the creation of self-compacting. Concrete is accepted as the most cutting-edge development in the concrete building industry. Currently, a lot of research is being done to find new ways to increase performance. Self-Compacting Concrete is becoming more and more popular for usage in overloaded reinforced concrete constructions with difficult casting circumstances. High rise buildings with multi storey construction need light weight concrete so there is a need to investigate on lightweight concrete. The mechanical and physical properties of self-compacting, self-curing, and light-weight concrete are created in this study by replacing natural aggregate with fly ash and expanded clay at percentages of 0%, 10%, 20%, 30%, 40%, and 50%. Calotropis gigantia, a self-curing agent, is incorporated in 4% of the volume of cement and super plasticizer in order to maintain the workability of concrete of M30 grade concrete. The mix proportion of light weight self-compacting concrete is 1:2.04:1.17 with water cement ratio of 0.4.

Keywords: Light Weight Expanded Clay aggregate; fly ash aggregate; self-compacting; self-curing concrete.

1. INTRODUCTION

In order to satisfy the special requirements of the building sector, a variety of innovative concrete kinds have been developed internationally [1]. To meet the demands of the construction industry, a variety of new and novel materials are being used, including chemical admixtures, mineral admixtures, and eco-friendly binders. In addition to using these elements, it's crucial to make sure the concrete is properly compacted and cured in order to increase its strength and longevity [2]. Hand rodding with mechanical vibration is utilized as traditional compaction techniques. These techniques need more labour and time during construction and might not work in buildings with a lot of reinforcement. It is crucial to give concrete the ability to self-compact in order to produce concrete with a superior surface polish, increased strength, and increased durability [3].

The light weight expanded the clay aggregate (LWECA) as well as fly ash aggregate (FAA) are used to create artificial light weight aggregate [4]. In the current work, an effort has been made to examine the suitability of expanded the clay aggregate as well as fly ash aggregate for use as a self-curing agent through replacing coarse aggregate to varying degrees (0%, 10%, 20%, 30%, 40%, and 50%), as well as to assess the impact of these materials on the strength and durability for self-compacting concrete in self-curing, light weight as well as high strength [5, 6]. According to [7, 8], curing is the process of reducing the rate and amount of moisture loss in concrete during cement hydration. Researchers have recommended a number of techniques to reduce moisture loss from concrete, including adding Super Absorbent Polymers (SAP), employing saturated lightweight particles, and covering the mortar with an impermeable component. And according to [10, p. 1] the ACI-308 code, "internal curing means the process through which the hydration in cement happens due to the presence of extra internal liquid which is not part of the original mixing water." Through internal water reservoirs, "internal curing" enables the flow of water for curing to inside to outside. Saturated wood fibres, super plasticizers polymers, or lightweight fine aggregates can all be used to achieve this.

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2. MATERIALS AND METHODS

A variety of materials were used in this experiment: water, fly ash ash, expanded clay, fine gravel (river sand), coarse gravel (blue metal), calotropic gigantia milk and super plasticizer. Coarse aggregate that was both naturally produced and artificially manufactured aggregates are used, fly ash coarse aggregate, fly ash aggregate made of expanded clay [10].

2.1. Fine aggregate

River sand, which was accessible nearby and it is cleaned, was utilized as fine aggregate (FA). The used sand must match the requirements of IS Grade Zone-II from the 383 (1970) [11] and pass through for a 4.75 mm sieve. Sand that was used in the cementitious materials made for the current study met the aforementioned requirements and was free of silt and clay. The physical characteristics of fine aggregate are shown in Table 1.

2.2. Coarse aggregate

In this experiment, natural coarse aggregate is largely substituted with fly ash aggregate (IS 3812) [12] as well as light weight expanded clay aggregates. According to Siddique [13], the basic component, plastic clay, is first prepared before being heated as expanded in a revolving kiln. The light weight expanded aggregates are acquired in 12.5 mm size and used for this purpose. The product is ignited at a temperature ranging from 900 °C along with 1250 °C to produce the final LWECA product. It is composed of burned, tiny, light, swelling clay fragments. The fly ash aggregates are prepared to 12.5 mm size by cement to fly ash ratio of 20:80 with binder ratio of 0.25 and shown in Figure 1. The physical characteristics of these materials are provided in Table 2, and their chemical characteristics are listed in Table 3.

2.3. Cement

In concrete, a substance called cement acts as a binder. OPC, or ordinary Portland cement, was selected as the cement for this experiment. Ordinary Portland Cement (OPC), grade 53, manufactured in accordance with IS 12269 [14], was used to create the various concrete combinations. Table 4 displays the physical qualities and setting time of cement, whereas Table 5 displays the chemical makeup of OPC.

Table 1: Physical properties of river sand.

PHYSICAL PROPERTIES	RIVER SAND
Appearance	Grainy
Specific Gravity	2.75
Bulk Density	2.74 g/cc
Water Absorption	1.50%
Moisture Content	1.28%
Zone	II
Colour	White
Fineness Modulus	1.52
Maximum Grain Size	1.13

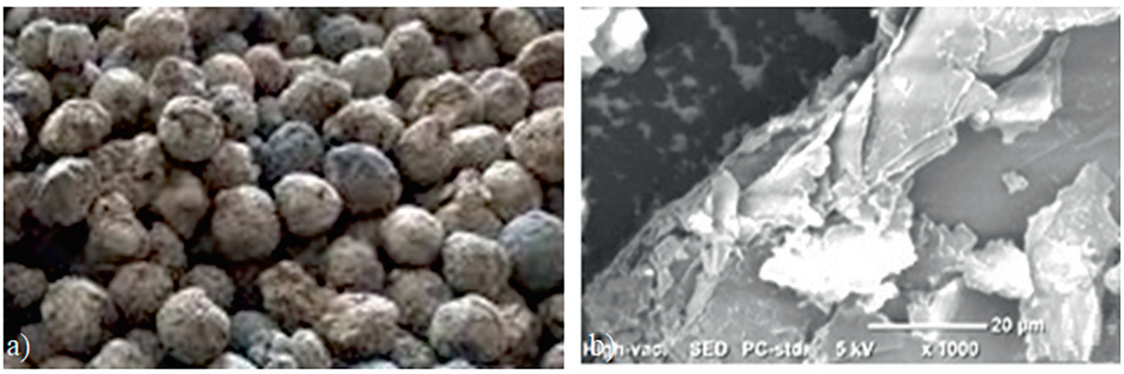

Figure 1: a) Fly ash aggregate b) microstructure of fly ash aggregate.

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Table 2: Physical properties of coarse aggregates.

PROPERTIES	NCA	FAA	LECA
Size and Shape	12.5 mm & Angular	12.5 mm & Spherical	12.5 mm & Spherical
Specific Gravity	2.65	1.34	1.45
Water Absorption (%)	1.74	20.5	32.6
Crushing Value (%)	17.54	18.5	12.8
Impact Strength (%)	14.69	16.7	14.8
Bulk Density (kg/m^3)	1620	915	525
Moisture Content (%)	0.8	9.76	17.5
Fineness Modulus (%)	6.8	5.2	5.28

Table 3: Chemical properties of coarse aggregates.

PROPERTIES	NCA	FAA	LECA
CaO	13.33	3.86	1.97
SiO_2	55.7	54.25	61.8
Al_2O_3	0.77	25.46	17.68
MgO	9.58	2.86	1.53
Na_2O	0.14	–	1.25
SO_3	–	0.76	–
P_2O_5	–	0.37	0.25
K_2O	0.09	–	1.14
MnO	–	–	0.09
Fe_2O_3	0.37	6.37	13.65
TiO_2	0.01	–	0.76

Table 4: Physical composition of cement.

PHYSICAL COMPOSITION	CEMENT
Grade	OPC 53
Colour	Grey
Specific gravity	3.14
Surface area(cm^2/gm)	2250
Physical state	Solid
Size microns mean	<90
Volume Expansion	3 mm

Table 5: Chemical properties of cement.

CHEMICAL COMPOSITION	CEMENT (%)
SiO_2	20.15
Al_2O_3	4.51
Fe_2O_3	2.57
CaO	61.34
MgO	1.05
Loss on ignition	2.45

2.4. Calotropics gigantia milk

This study makes use of calotropics gigantia milk, a waste land weed that grows naturally in Tamil Nadu and is employed as a self-curing ingredient in concrete. Polyethylene glycol latex, which improves internal curing as well as increases water retention capacity, is a component of Calotropics gigantia milk.

2.5. Super plasticizer

The super plasticizer, also known as the high-range water-reducing admixture, is the most crucial chemical admixture used in HPC (HRWRA). Super plasticizers come in four different varieties. Conplast SP430, an extremely plasticizer (SP) that makes up 2% of cement in weight, is used to render cement more workable. Water reducers called "super plasticizers" have a 30% water content reduction capability. In this experiment, a super plasticizer by the name of CONPLAST SP 430 was employed to produce practical concrete with a small w/b ratio. Regarding HRWRA compliance, CONPLAST SP 430 complies to ASTM C494, IS: 9103-1998, and HRWRA [15–17].

2.6. Water

The experiment used only potable water. The water was clear and free of impurities including grease, oil, silt, and organic debris that might interfere with the curing and concreting processes [14].

3. MIX DESIGN CALCULATION

According to EFNARC recommendations, which are followed for the design of self-compacting as self-curing concrete mixes (SCSCC), the mix composition must meet all performance parameters for the concrete in both the new and newly hardened phases. Fly ash ash, expanded clay, fine gravel (river sand), coarse gravel (blue metal), calotropic gigantia milk, and super plasticizer are all included in the M30 grade mix that is intended for SCC [18]. M30 grade is selected so that the coarse aggregate content will be minimized so the bulk density is reduced, Tables 6 and 7 contain a summary of the mix proportions that were obtained. Both the fresh and hardened states of the concrete are tested. Calotropis gigantia, a self-curing component, is put to concrete, preventing water curing.

Table 6: Mix proportions.

DESCRIPTION	CEMENT	FA	NCA	WATER
Quantity	476	975	558	190
Mix Proportion	1	2.04	1.17	0.4

Table 7: Mix designation.

MIX DESIGNATION	DESCRIPTION
M1	Conventional Concrete
M2	10% of FAA + 90% NCA + 4% CG + 2% SP
M3	20% of FAA + 80% NCA +4% CG + 2% SP
M4	30% of FAA + 70% NCA + 4% CG + 2% SP
M5	40% of FAA + 60% NCA + 4% CG + 2% SP
M6	50% of FAA + 50% NCA + 4% CG + 2% SP
M7	10% of LWECA + 90% NCA + 4% CG + 2% SP
M8	20% of LWECA + 80% NCA + 4% CG + 2% SP
M9	30% of LWECA + 70% NCA + 4% CG + 2% SP
M10	40% of LWECA + 60% NCA + 4% CG + 2% SP
M11	50% of LWECA + 50% NCA + 2% CG + 2% SP
M12	10% of FAA + 10% of LWECA + 80% NCA + 4% CG + 2% SP
M13	20% of FAA + 20% of LWECA + 60% NCA + 4% CG + 2% SP
M14	30% of FAA + 30% of LWECA + 40% NCA + 4% CG + 2% SP
M15	40% of FAA + 40% of LWECA + 20% NCA + 4% CG + 2% SP
M16	50% of FAA + 50% of LWECA + 0% NCA + 4% CG + 2% SP

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4. EXPERIMENTAL INVESTIGATION

Fresh and cured concrete has been examined for every mix from M1 to M16 according to the mix proportion. The slump flow test, v funnel test, J-Ring test, L-Box test, and U-Box test are used to analyze the fresh qualities of SCC, which should have filling ability, passage ability, and segregation resistance. There are general test methodologies available to assess the SCC's features [11, 12, 19, 20]. International and national organizations have not standardized these procedures. Below are the specifics of some tests that are more frequently used to measure the fresh SCC parameters is tabulated in Table 8 and represented in Figures 2–6.

Self-compacted concrete's fresh concrete qualities are stated in Table 8 and fall within the permitted range for the EFNARC code, as shown in Table 9. The specimens were manufactured in compliance with IS Standards, as shown in Figures 7 and 8. In this experiment, the compressive strength of items measuring 150 × 150 × 150 mm was investigated. In compliance with IS: 516-1959, this test was conducted using a Compressive Testing Machine (CTM) that had 1000 KN capability. The load is distributed in accordance with the IS codal framework's principles [21–24].

The samples are made in accordance with the guidelines, and the formula fck = P/A is used to calculate the compressive strength. Table 10 and also Figure 9 contain the results of three trials' average values, where P

Table 8: Mix designation.

MIX DESIGNATION	SLUMP FLOW (mm)	V FUNNEL (sec)	J-RING TEST (mm)	L-BOX TEST	U-BOX TEST (mm)
M1	720	9.5	6.02	0.85	25
M2	726	9.2	6.09	0.87	26
M3	732	8.9	6.12	0.86	26
M4	728	8.7	6.14	0.87	28
M5	734	8.6	6.19	0.88	29
M6	725	8.5	6.21	0.89	32
M7	722	9.4	6.12	0.86	24
M8	728	9.8	6.15	0.89	26
M9	729	9.5	6.17	0.89	28
M10	734	9.2	6.19	0.91	29
M11	736	9.3	6.21	0.92	33
M12	724	9.4	6.05	0.84	26
M13	725	9.2	6.12	0.86	28
M14	727	8.9	6.15	0.87	29
M15	729	8.6	6.17	0.89	31
M16	732	8.5	6.22	0.90	33

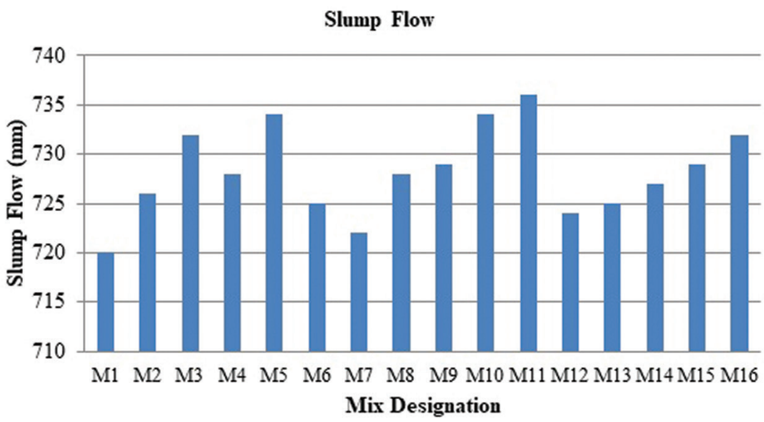

Figure 2: Slump flow test.

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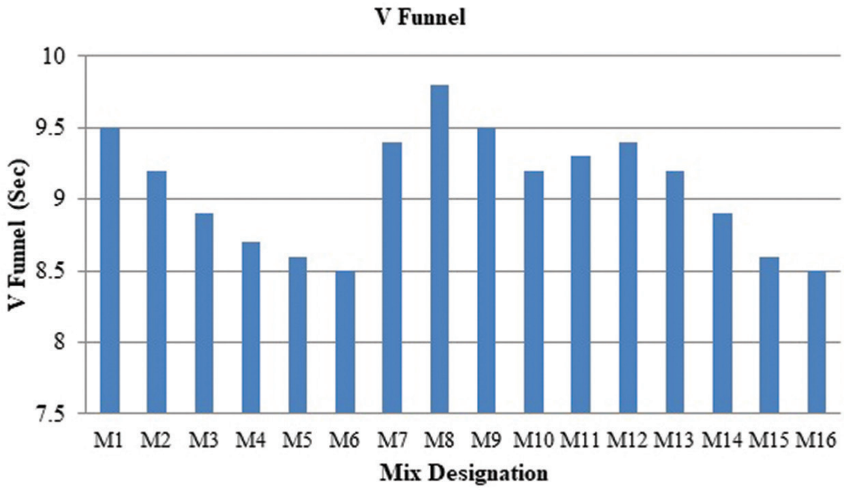

Figure 3: V funnel test.

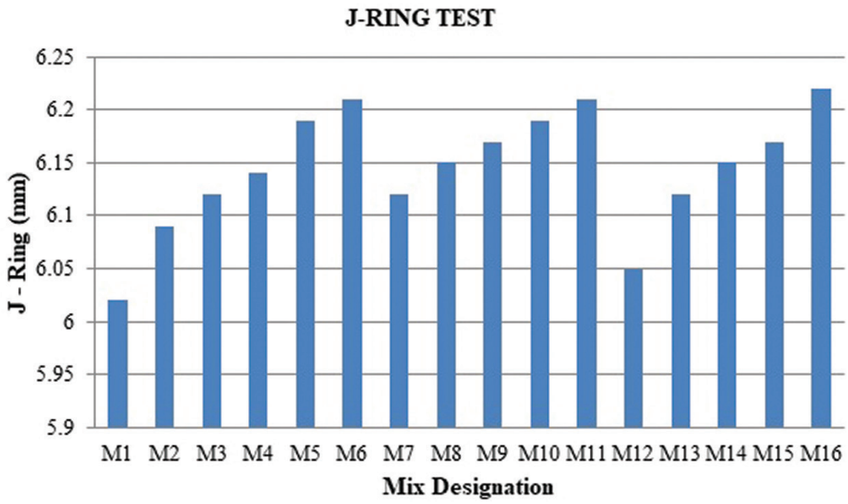

Figure 4: J-Ring test.

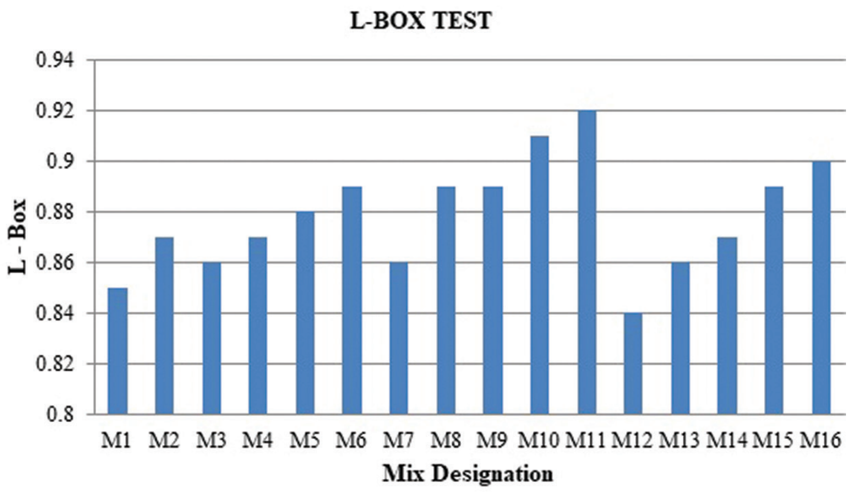

Figure 5: L-Box test.

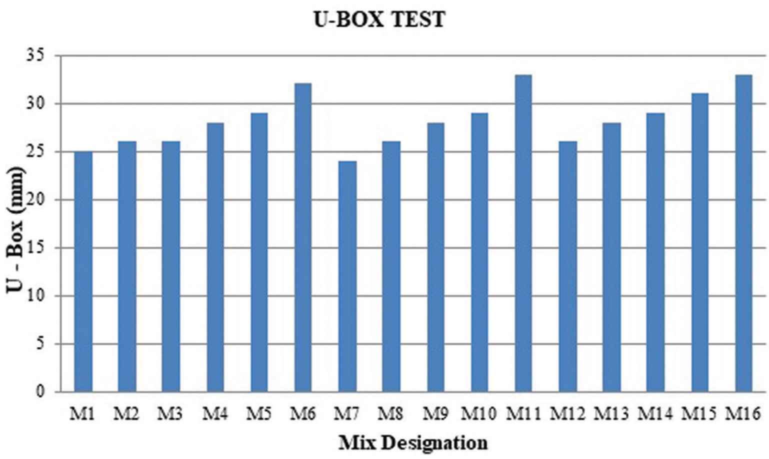

Figure 6: U-Box test.

Table 9: Fresh concrete codal provisions.

CODAL PROVISION	SLUMP FLOW (mm)	V FUNNEL (sec)	J-RING TEST (mm)	L-BOX TEST	U-BOX TEST (mm)
EFNARC Codal Limits	650–800	6–12	0–10	0.8–1	0–30

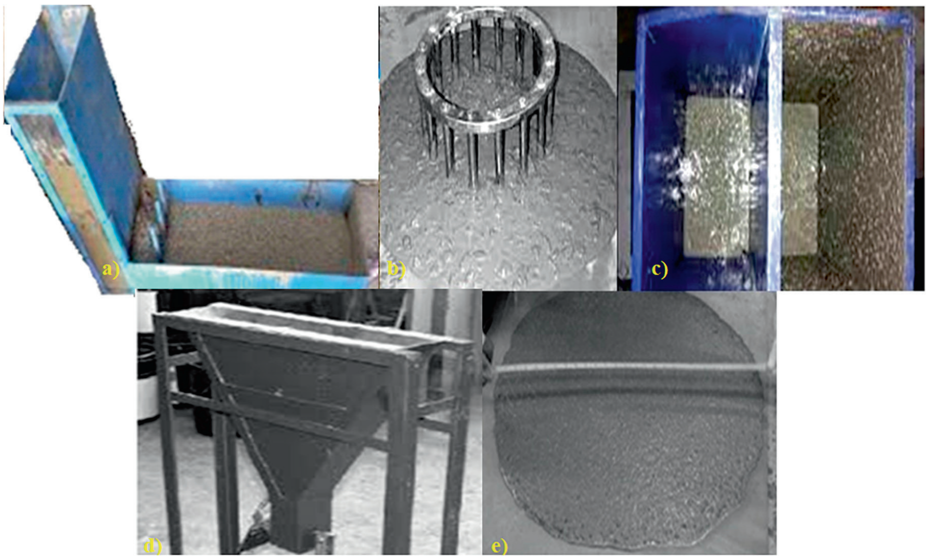

Figure 7: Fresh concrete testing.

Figure 8: Casting of specimens.

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Table 10: Compression strength results.

MIX NO	COMPRESSIVE STRENGTH (MPa)		
	7 DAYS	14 DAYS	28 DAYS
M1	21.21	29.38	32.64
M2	23.16	32.08	35.64
M3	**23.11**	**32.20**	**35.96**
M4	19.76	27.37	30.41
M5	17.64	24.43	27.14
M6	14.65	20.29	22.54
M7	**23.55**	**32.62**	**36.24**
M8	22.23	31.54	35.26
M9	21.60	29.92	33.24
M10	18.56	25.70	28.56
M11	14.52	20.11	22.34
M12	**23.58**	**32.65**	**36.75**
M13	19.76	27.37	31.41
M14	18.56	25.70	28.56
M15	16.51	22.87	25.41
M16	15.02	20.81	23.12

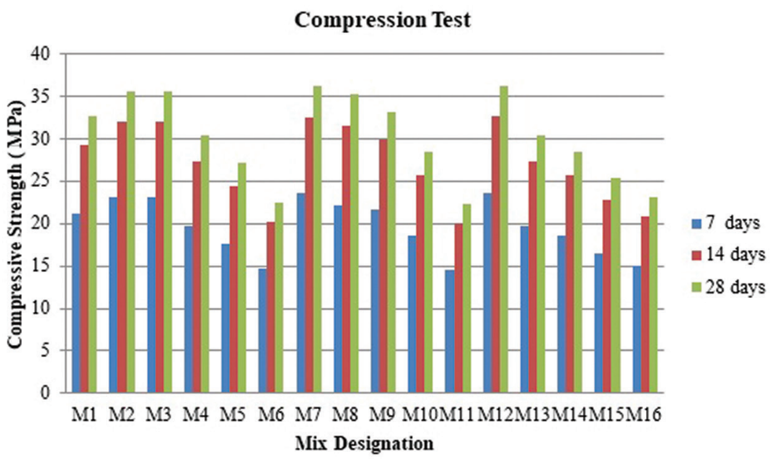

Figure 9: Compressive strength variations.

represents the failure load in N, fck is the strength at compression in N/mm^2, and A is the cross-sectional area for a cube specimen in mm. It is discovered that the M12 mix proportion of 10% FAA + 10% LWECA + 80% NCA + 4% CG + 2% SP mix has the maximum compressive strength. With values of 36.75 MPa, 36.24 MPa, and 35.96 MPa, the next highest value in the M7 mix proportion is 10% of LWECA + 90% NCA + 4% CG + 2% SP, followed by 20% of FAA + 80% NCA + 4% CG + 2% SP for M3 [25, 26].

A split tensile strength test was conducted in accordance with IS 5816:1999 [22]. At ages 7, 14, and 28 days (CTM), the split tensile strength of concrete specimens with dimensions of 150 mm in diameter and 300 mm in height was measured [13].

According to the instructions, the samples are prepared, and a table with the average results for the initial three trials is provided. The formula 2P/(dl), whereby fck was the tensile strength as N/mm^2, P is the load that fails in N, d is the measurement of the diameter of the cylindrical specimen in mm, while l is the specimen's length in mm, is used to calculate compressive strength. Variations in split tensile strength are shown in Figure 10, and test results are plotted in Table 11.

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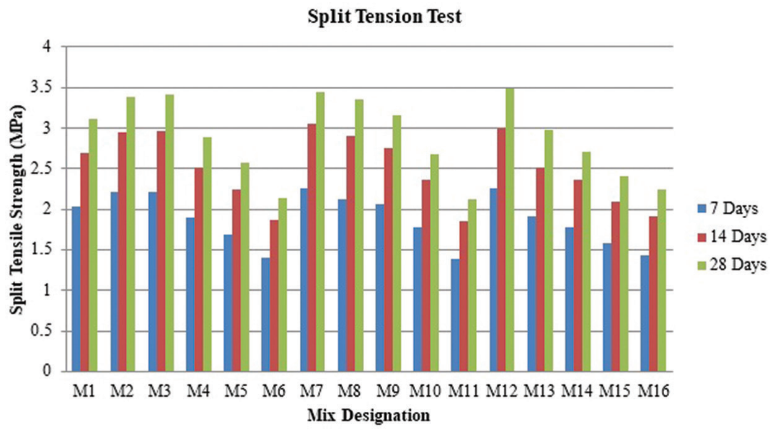

Figure 10: split tensile strength variations.

Table 11: Split tension test results.

MIX NO	TENSILE STRENGTH (MPa)		
	7 DAYS	14 DAYS	28 DAYS
M1	2.04	2.70	3.12
M2	2.22	2.95	3.39
M3	**2.22**	**2.96**	**3.42**
M4	1.90	2.52	2.89
M5	1.69	2.25	2.58
M6	1.41	1.87	2.14
M7	**2.26**	**3.05**	**3.44**
M8	2.13	2.90	3.35
M9	2.07	2.75	3.16
M10	1.78	2.36	2.68
M11	1.39	1.85	2.12
M12	**2.26**	**3.00**	**3.49**
M13	1.92	2.52	2.98
M14	1.78	2.36	2.71
M15	1.58	2.10	2.41
M16	1.44	1.91	2.25

It is found that the highest tensile strength falls in M12 mix proportion it is 210% of FAA + 10% of LWECA + 80% NCA + 4% CG + 2% SP mix. The next highest value fall in M7 mix proportion it is 10% of LWECA + 90% NCA + 4% CG + 2% SP and next is M3 20% of FAA + 80% NCA + 4% CG + 2% SP, the values are 3.49 MPa, 3.44 MPa and 3.422 MPa.

At ages 3, 7, 14, and 28 days, a 100 mm × 100 mm × 500 mm prism was tested to single point loading conditions on a Universal Testing Machine (UTM) to determine its flexural strength in accordance with IS: 516-1959 [21]. The experimental setup for the flexural strength test is shown in Figure 6. Calculating the flexural strength requires the equation PL/bd2 [27, 28]. L is the specimen's length in millimeters, where b is the specimen's width in millimeters and d is its specimen's depth at its point of failure. P is the specimen's maximum load in N, where L = L/2. The outcomes from the flexural test are listed in Table 12, and the variations are plotted in Figure 9. The highest flexural strength is demonstrated by the M12 mix proportions.

A 100 mm × 100 mm × 500 mm prism was tested on a Universal Testing Machine (UTM) under single point loading circumstances at ages 3, 7, 14, and 28 days to ascertain its flexural strength in accordance with IS: 516-1959 [21]. Figure 7 depicts the experimental configuration for the flexural strength test. The equation PL/bd2 must be used to get the flexural strength. L stands for the specimen's length in mm, b for its breadth

Table 12: Flexural strength results.

MIX NO	FLEXURAL STRENGTH (MPa)		
	7 DAYS	14 DAYS	28 DAYS
M1	1.96	2.65	3.06
M2	2.13	2.89	3.32
M3	**2.13**	**2.90**	**3.35**
M4	1.82	2.47	2.83
M5	1.62	2.21	2.53
M6	1.35	1.83	2.10
M7	**2.17**	**2.99**	**3.37**
M8	2.04	2.84	3.28
M9	1.99	2.70	3.10
M10	1.71	2.31	2.63
M11	1.33	1.81	2.08
M12	**2.17**	**2.94**	**3.42**
M13	1.84	2.47	2.92
M14	1.71	2.31	2.66
M15	1.52	2.06	2.36
M16	1.38	1.87	2.21

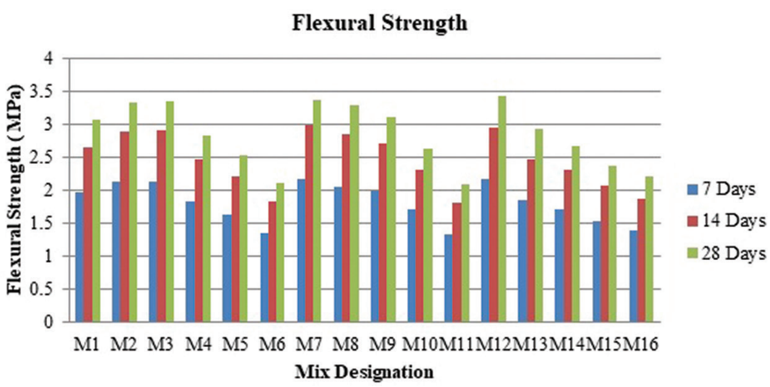

Figure 11: Flexural strength variations.

in millimeters, and d for its depth at the failure point P, where L = L/2, is the specimen's maximum load in N. Table 12 lists the results of the flexural test, and Figure 11 plots the variances. The mix ratios for M12 show the greatest flexural strength [29–33]. It is found that the highest flexural strength falls in M12 mix proportion it is 210% of FAA + 10% of LWECA + 80%NCA + 4% CG + 2%SP mix. The next highest value fall in M7 mix proportion it is 10% of LWECA + 90%NCA + 4% CG + 2%SP and next is M3 20% of FAA + 80%NCA + 4% CG + 2%SP, the values are 3.42 MPa, 3.37 MPa and 3.35 MPa.

5. CONCLUSIONS

The workability characteristics of SCSCC mixtures meet the specifications set by EFNARC, SCSCC, LWECA, and FAA, however, have no negative effects on the ability of concrete to move through a structure.

- The self-curing substance employed in this study Calotropis gigantia also shown that there isn't a change in strength during room temperature curing. As a result, milk from Calotropis gigantia can act as a self-curing agent. With water, air curing at room temperature can be accomplished without the need for a curing process.
- The ideal replacement ratio for natural coarse aggregate that gives SCSCC the greatest compressive strength is 20% FAA and 10% LWCA. To attain the highest compressive strength and a 12.5% improvement in

strength when using blended material, a blend of 10% FAA and 10% LWECA was the ideal percentage for substituting the coarse aggregate for this experiment.

- The blend of 10% FAA and 10% LWECA is overall optimum proportion for substituting the coarse aggregate in this experiment in order to achieve the maximum compressive strength as well as strength improvement of 8.7%. The blended material has the highest tensile strength.

To attain the highest compressive strength and a 9.4% increase in strength, the blend of 10% FAA with 10% LWECA is the best percentage to use in place of the coarse aggregate throughout this experiment. The material selected for the investigation is light weight, self-compacting, self-curing and comparatively high strength.

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Erratum: An experimental study on strength and durability properties of self-compacting and self-curing concrete using light weight aggregates

In the article "An experimental study on strength and durability properties of self-compacting and self-curing concrete using light weight aggregates", with DOI code number https://doi.org/10.1590/1517-7076-RMAT-2023-0156, published in the Matéria (Rio de Janeiro), 28(3):e20230156,

Where it read:

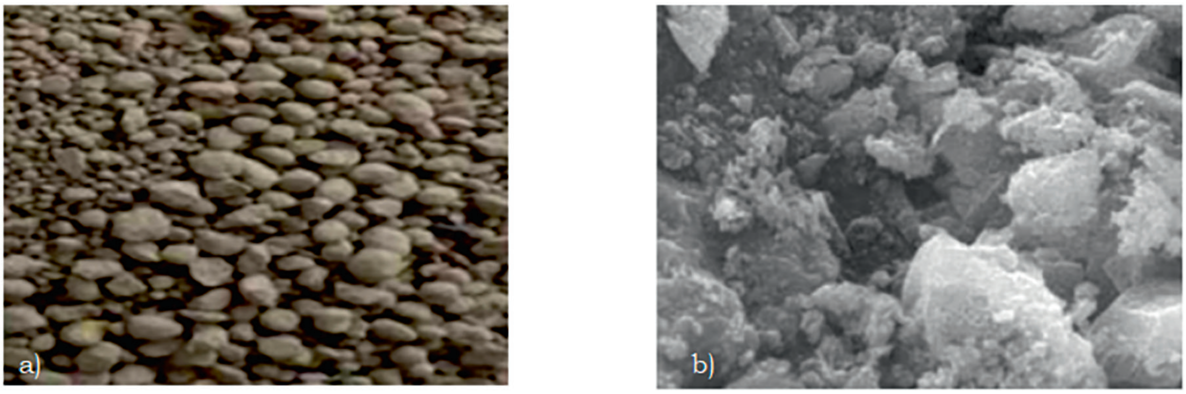

Figure 1: a) Fly ash aggregate b) microstructure of fly ash aggregate.

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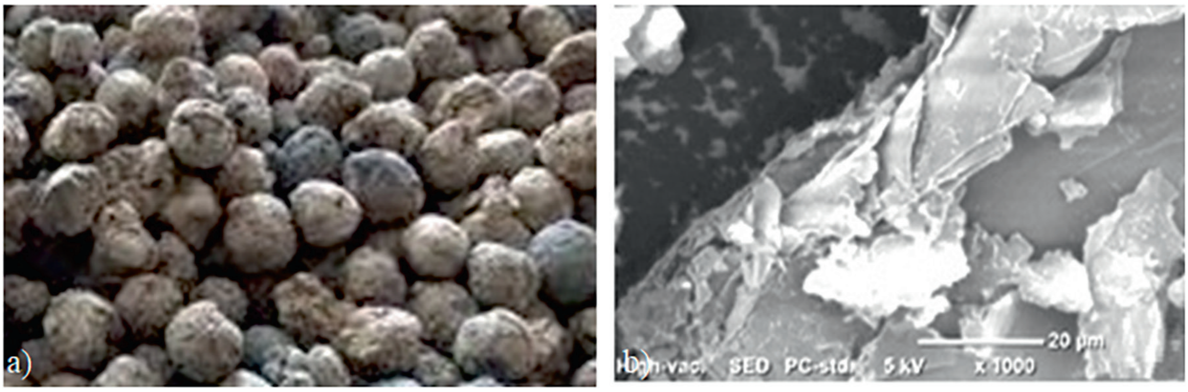

Figure 1: a) Fly ash aggregate b) microstructure of fly ash aggregate.

DOI: https://doi.org/10.1590/1517-7076-RMAT-2023-0156er

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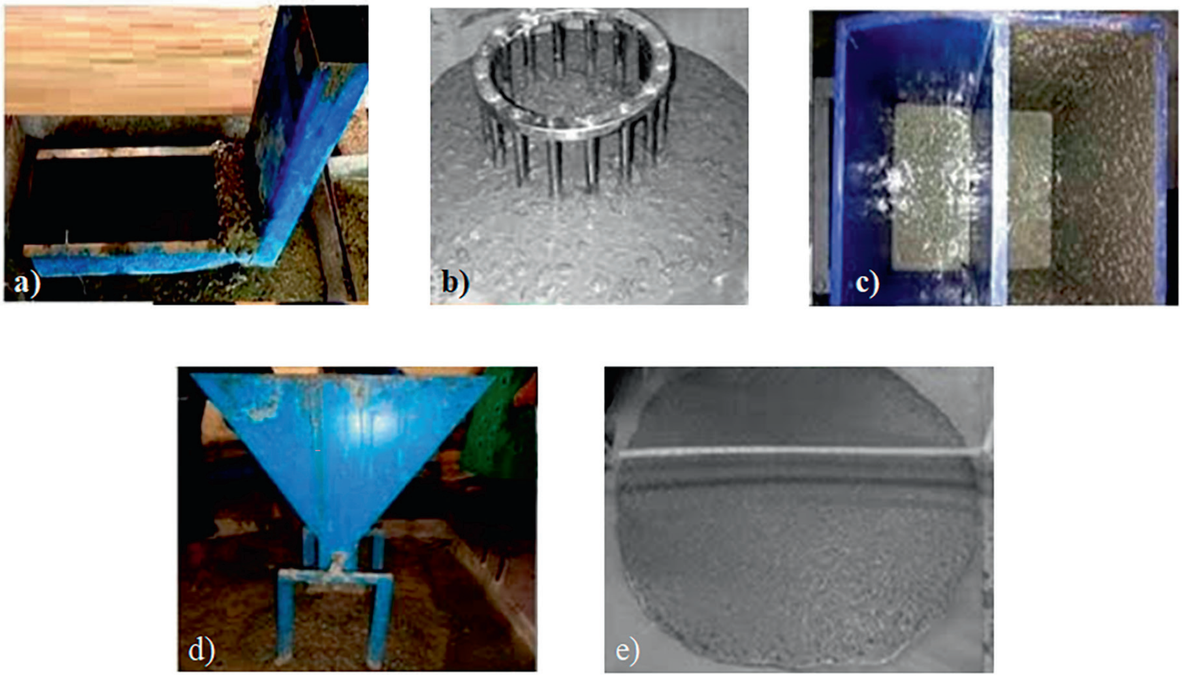

Figure 7: Fresh concrete testing.

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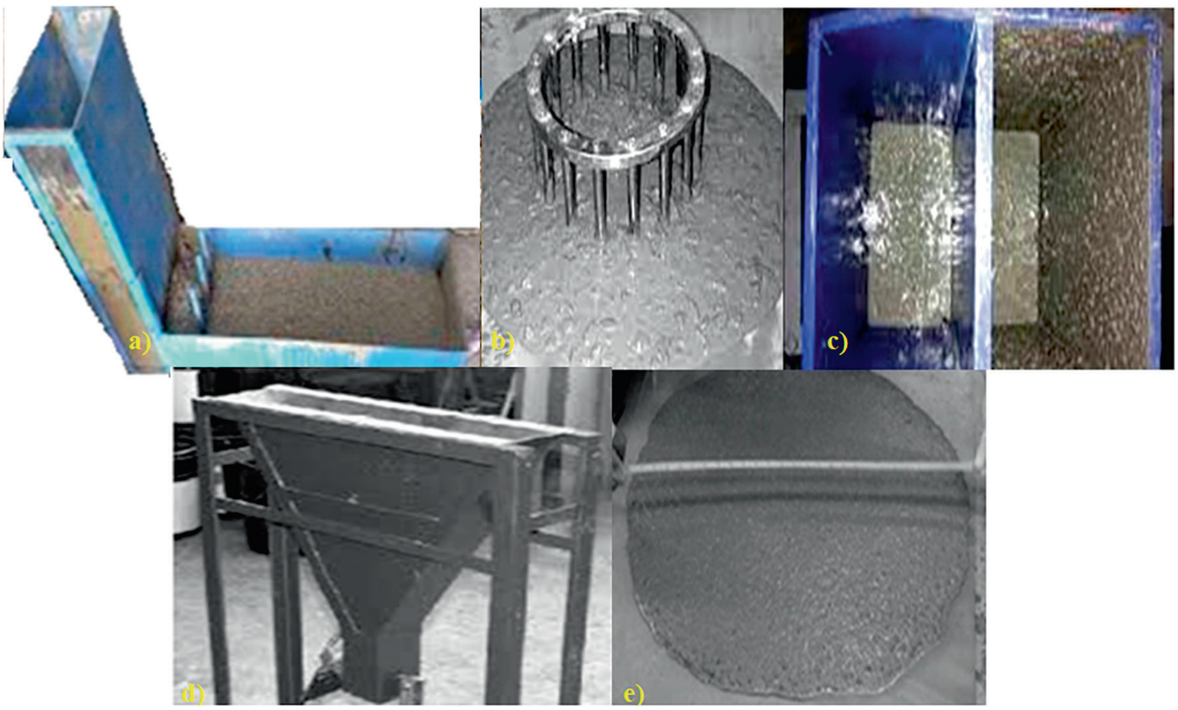

Figure 7: Fresh concrete testing.