Experimental Investigation on Partial Replacement of Cement by Coffee Husk Ash

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***Abstract*—This study investigates the feasibility of using coffee husk ash (CHA) as a partial replacement for Ordinary Portland Cement (OPC) in M25 grade concrete. Coffee husk ash, an agricultural waste with pozzolanic properties, was used at replacement levels of 0%, 5%, 10%, 15%, 20%, and 25% by weight of cement. Concrete specimens were prepared, cured for 7, 14, and 28 days, and tested for workability and compressive strength. The results showed that workability and compressive strength decreased with increasing CHA content. However, concrete containing 5–10% CHA exhibited satisfactory performance while reducing cement consumption and promoting sustainable waste utilization. The study concludes that coffee husk ash can be effectively used as an eco-friendly supplementary cementitious material in concrete.**

***Index Terms*—Coffee husk ash, M25 Concrete, Compressive strength, Sustainable construction.**

I. INTRODUCTION

The cost of building materials, especially pozzolanic cement, environmental pollution, and global warming are the major challenges of the world today. Rice husk, coffee husks, and sugarcane bagasse ashes have pozzolanic properties. Coffee husk ash acts as a pozzolanic material when added to cement because of its silica and aluminate content, which react with free lime released during hydration of the cement and form additional calcium silicate hydrate product. This additional calcium silicate hydrate improves the mechanical strength of the cement.

Recently, coffee husk ash has been tested in some countries for its pozzolanic properties, which have been found to develop some of the properties of the paste, mortar, and concrete, like compressive strength and water tightness, in sufficient substitution percentages and fineness. Research was aimed at reducing the cost of building materials, e.g., cement, and environmental pollution by replacing cement with coffee husk ash in concrete.

The waste has generally no commercial value and is locally available at minimal transportation cost. The use of these wasters has complemented other traditional materials in construction and hence provides practical and economic advantages. Also, proper utilization of these wastes conserves natural resources and protects the environment. Coffee processing generates a large amount of solid waste (peel or pulp, depending on process). One ton of beans and one ton of waste are generated from the 2 tons of coffee. We can use this waste in the construction process. Coffee husk is traditionally used as a fertilizer, animal feed, and fuel used in the coffee drying process.

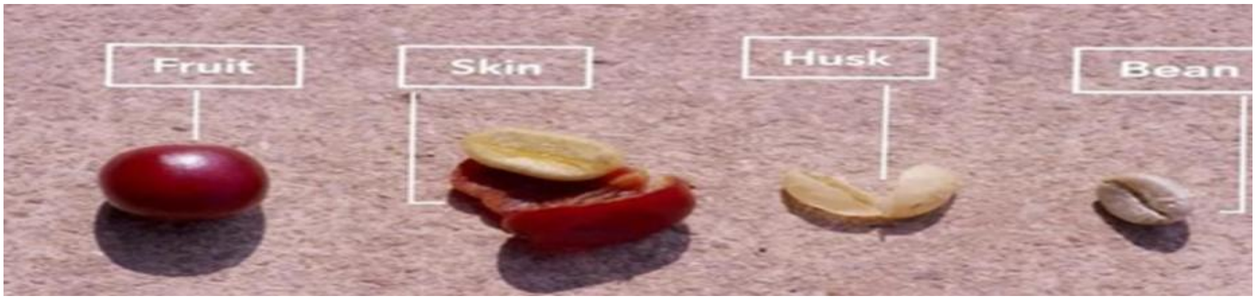


Fig 1. Processing of coffee husk

II. MATERIALS AND METHODS

1. Cement: pozzolana portland cement (ppc) produced as per 42.5 grade, containing 95% clinker and 5% gypsum, produced by Derba Capital Cement, was used throughout the experiment. The reason for selecting only one cement type is due to financial and time limitation to perform experiments.

2. Aggregate: Aggregates are materials basically used as filler with binding material in the production of concrete. Aggregates form the body of the concrete, reduce the shrinkage, and affect the economy. Therefore, it is significantly important to obtain right type and quality of aggregates on site.

3. Coarse aggregate: The coarse aggregates shall consist of crushed rock and shall be clean, hard, durable, and free from dust or friable matter, organic or other deleterious substances. Aggregates offer good compressive and shear strength; along with this they provide good interlocking facility with sufficient permeability. Coarse aggregate of 26.5 mm to 2.36 mm

4. Fine aggregate: Aggregate passing through a 4.75 mm sieve is defined as fine. They may be natural sand deposited by rivers, crushed stone sand obtained by crushing stones and crushed gravel sand. The smallest size of fine aggregate (sand) is 0.06mm depending upon the particle size. Fine aggregates are described as fine, medium and coarse sands.

5. Water: For proper chemical action, the amount of water required is about 25% of the weight of cement used; however, more water is used for proper workability of concrete. The water used for both mixing and curing should be free from injurious amounts of oils, acids, alkalis, salts, organic materials, or other substances that may be harmful to concrete. According to is 456- 2000, the ph. value of the water shall not be less than 6.

6. Coffee husk to be used for the experiment: In India, enormous amounts of coffee husk and pulp are generated from coffee processing industries annually. Nevertheless, these materials have been poorly utilized and managed or are left to decompose or burned in open fields or dumped in the environment, including water bodies, yet these activities cause and aggravate pollution of the air, the environment, and water.

III. METHODOLOGY

The replacement levels of cement by coffee husk ash considered were 0, 5, 10, 15, 20, and 25%. The fresh concrete was then placed in cubical moulds of size 150x150x150 mm, lightly oiled before casting of test specimens. The specimens were demoulded after 24 hours and immersed in water in a curing tank maintained at room temperature for 3, 7, 14, and 28-dayperiod before testing for the respective strength characteristics.

3.1 Grades of concrete

According to IS: 456 - 2000 and IS: 10262, Concrete is graded according to its compressive strength, its grade which is designated as, M-25 Mix design. Mix design of concrete may be defined as the art of obtaining a concrete of the required properties, at the lowest cost, by a suitable choice and proportions of available materials.

3.1.1 Material Preparation

Materials used to cast concrete included coarse aggregate, fine aggregate (sand), cement, and water.

Both the coarse aggregate and sand were graded for use in concrete. Water was obtained directly from the campus drinking water supply and coffee husk ash was obtained from Sakleshpura town, coffee processing drilling machine.

3.1.2 Experimental work

The Coffee husk ash is collected from the coffee processing crushed plant husk where burdened by fire and used as a cement replacement material. The cement is replaced with the different percentages (0, 5, 10, 15, 20 and 25) of Coffee husk ash by the cement weight. Compressive strength testing of concrete cubes (.15x.15x.15cm) for 0% coffee husk ash replacement (conventional cube)

3.1.3 Mix proportions

In order to analyze the effects of coffee husk ash partially replaced with cement, normal concrete strength (M-25) was prepared. For this concrete mix, coffee husk ash was added for partially replacement of cement from 0%, 5%, 10%, 15%, 20%, and 25% of the mixes were used in preparing mixes S1, S2, S3, S4, S5, and S6, respectively.

Preparation of specimens and mixing procedure: The preparation of the constituent materials will be made by using weight measurements.

3.1.4 Concrete Mixing& Casting

The cement is replaced with different percentages (0, 5, 10, 15, 20, and 25) of Coffee husk ash by the cement weight. Casting of a specimen mould of size 150 x 150 x 150 mm was used to cast specimens for the compression test.

3.1.5 Curing Procedure

After an initial curing period of 24 hours, the concrete cube moulds were removed from their moulds. All cylinders were placed into a tank of lime-saturated water and remained submerged in the standard moisture curing environment until reading at 3, 7, 14, and 28 days of age.

Test on Concrete

3.1.6 Slump test.

To determine the consistency of concrete

3.1.7 Hardened concrete test.

Test procedure: The concrete mix is cast in 4 cube moulds of size 150 mm x150mm×150mm, and the concrete samples are immersed in water after 24 hours of casting. Cube compression tests are conducted after 3, 7, 14, and 28 days of curing.

3.2 Basic tests on ingredients of concrete

3.2.1 Introduction

The following were the ingredients used for Concrete:

- Cement
- Fine Aggregate
- Coarse Aggregate
- Coffee husk ash

3.2.2 Cement:

Fig 2. Ordinary Portland Cement

The following were the tests conducted on Cement and as follows:

- Fineness Test
- Specific Gravity of Cement
- Standard Consistency Test
- Setting Time of Cement
- Compressive strength of cement mortar

Table 1: Chemical Properties of OPC

Sl. No	Chemical parameters	Values in %
1	CaO	59.98
2	SiO2	21.18
3	Al2O3	5.36
4	Fe2O3	3.48
5	MgO	2.05
6	SO3	2.8
7	Na2O	0.36
8	K2O	0.69
9	LoI	2.67
10	Insoluble residue	2.32
11	Free lime	1.06

3.2.3 Fineness Test (as per IS: 4031 (Part I) - 1996)

Table 2: Fineness of cement

Sl. No	Description	Trail 1	Trail 2
1	Initial weight of cement W1gms	500	500
2	Weight of cement retained in 90µ sieve W2gms	19	18
3	Fineness of cement = (W_2) /W_1 X100	3.8%	3.6%

The Fineness of Cement is 3.7%.

3.2.4 Specific gravity of cement (as per IS: 4031 (part-I) - 1996)

Fig 3. Density bottle

Specific gravity of a material may be defined as the ratio of the weight of a known volume of the material to the weight of an equal volume of water.

Table 3: Specific gravity of cement

Sl. No	Description	Trials	
		Trial 1	Trial 2
1	Empty weight of the density bottle W_1gms	32	32
2	Weight of density + 1/3rd cement W_2gms	50	49
3	Weight of bottle + cement + kerosene W_3gms	84	83
4	Weight of bottle + kerosene W_4gms	70	70
5	Weight of bottle+ water W_5gms	88	88
6	Specific gravity $= \frac{(W_2 - W_1) X (W_4 - W_1)}{[(W_4 - W_1) - (W_3 - W_2)] X (W_5 - W_1)}$	3.05	2.88

The average specific gravity of cement is 2.965

3.2.5 Consistency of standard cement paste (as per IS: 4031 (part IV) - 1988)

Fig 4. Vicat's Apparatus for Standard Consistency

Table 4: Normal Consistency Test

Cement	% of water added	% of water added	Initial reading	Final reading	Penetration from bottom
400 grams	26%	104	40	19	21
	28%	112	40	28	12
	30%	120	40	32	8
	32%	128	40	34	6

Standard consistency of a cement paste is defined as that consistency which will permit a Vicat's plunger having a 10 mm diameter and 50mm length to penetrate to a depth of 33- 35 mm from the top of the mould.
The Normal Consistency for the given sample of Cement is 32%

3.2.6 Initial setting time (as per IS: 4031 (Part V) – 1988)
Initial setting time is regarded as the time elapsed between the moment the water is added to the cement to the time that the paste starts losing its plasticity.

Fig 5. Vicat's Apparatus for Initial Setting Time

Table 5: Initial Setting Time Test

Cement	% of water added	Water added(ml)	Time(min)	Initial reading	Final reading	Penetration from the top
400gms	0.85 times the normal consistency	108	5	40	0	40
		108	10	40	1	39
		108	15	40	2	38

	value	108	20	40	4	36
		108	25	40	5.5	34.5
		108	30	40	7	33

The Initial setting time of cement is 30 minutes.

3.2.7 Final setting time: (as per IS: 4031 PART- V - 1988)

The final setting time is the time elapsed between the moment of water is added to the cement and the time when the paste as completely lost its plasticity and has attained sufficient firmness to resist a certain pressure.

Fig 6. Vicat's Apparatus for Final Setting Time

The Final setting time of cement is 600 minutes (IS Limits ≥600mins).

3.2.8 compressive strength of cement (as per IS: 1489 (Part 1): 1991)

The compressive strength of hardened cement is the most important of all the properties. Therefore, it is not surprising that the cement is always tested for its strength at the laboratory before it is used in important works. Strength test is not made on neat cement paste because of the difficulties of excessive shrinkage and subsequent cracking of neat cement. Strength of cement is indirectly found on cement sand mortar in specific proportion. The standard sand is used for finding the strength of cement. It shall conform to IS 650-1991

Fig7. Compression Test on Cement Mortar

Calculation of materials for cube: -

Grade of cement = Ordinary Portland cement

Indian Standard consistency of cement sample p = 32%

Area of cube sample = 70.60 × 70.60 = 4984.36 mm^2

Cement = 200 gms

Indian Standard sand = 600 gms

Water = $\frac{P}{4} + 3\%$ (mass of cement and sand)

$= \left(\frac{32}{4} + 3\right)\%$ (200 + 600)

= 88 ml

For 3 Cubes: -

Cement = 200 × 3 = 600 gms

Indian Standard sand = 600 × 3 = 1800 gms

Water = 88 × 3 = 264 ml

Table 6: Compressive Strength of Cement mortar at 28 days

Sl. No	Area (mm²)	Failure load (kN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
1	4984.36	174.8	35.06	35.93
2	4984.36	184.2	36.96	
3	4984.36	178.4	35.79	

Compressive strength = $\frac{P}{A} = \frac{178.4 \ X \ 10^3}{4984.36}$ = 35.79 N/mm^2

The compressive strength of cement mortar at 28 days = 35.93N/mm².

Table 7: Physical Properties of Cement

Sl. No	Tests On Ordinary Portland Cement	Results Obtained
1	Type Of Cement	OPC
2	Specific Gravity	2.965

3	Fineness	3.7%
4	Normal Consistency of Cement	32%
5	Initial Setting Time of Cement	30 min
6	Final Setting Time of cement	600 min
7	Compressive strength of cement mortar	35.92 N/mm^2

3.3 Fine Aggregates

3.3.1 Sieve analysis on fine aggregate (as per IS: 2386 (Part I) - (1963)

Sieve analysis is the operation of dividing a sample of aggregate into various fraction each consisting of particles of the same size. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation.

Fineness Modulus: Fineness modulus is an empirical factor obtained by adding the cumulative percentage of aggregate retained on each of the standard sieve and dividing this sum by an arbitrary number 100.

Fig 8. IS Sieve for Fine Aggregate

Table 8: Sieve analysis of fine aggregate

Sl. No	I.S sieve size	Empty Weight of Sieve in (gms) W_1	Weight of Sieve + Aggregates in (gms) W_2	Weight of Aggregates Retained ($W=W_2-W1$)	% of weight retained gms	Cumulative % of weight Retained 'X'	Cumulative % passing N = 100 - X
1	4.75 mm	370	390	20	2.70	2.70	97.3
2	2.36 mm	410	450	40	5.41	8.11	89.13
3	1.18 mm	330	430	100	13.51	21.62	78.38
4	600µ	320	540	220	29.73	51.35	48.65
5	300µ	300	580	280	37.84	89.19	10.81
6	150µ	310	360	60	8.11	97.30	2.70
7	PAN	260	280	20	2.70	100.00	0.00

$$\text{Fineness modulus} = \frac{Cumulative\ \%\ of\ Weight\ retained}{1000}\ X\ 100$$

The Fineness modulus of fine aggregate is 3.26 (As per IS-383:1970. Table No. 4 Zone-1)

3.3.2 Specific gravity of fine aggregate (as per IS:2386 (Part III) - 1963)

Specific gravity of a material may be defined as the ratio of weight of known volume of the material to the weight of equal volume of water.

Fig 9. Pycnometer

Table 9: specific gravity of fine aggregate

Sl. No.	Description	Trial 1	Trial 2
1	Empty weight of Pycnometer W_1 gms	599.5	599.5
2	Weight of Pycnometer + 1/3rd fine aggregate W_2 gms	1192	1133

3	Weight of Pycnometer + fine + water W_3 gms	1839.5	1802.5
4	Weight of Pycnometer + water W_3 gms	1480	1480
5	Specific gravity G = $\frac{(W_2 - W_1)}{(W_4 - W_1)-(W_3 - W_2)}$	2.54	2.52
6	Average specific gravity of fine aggregates is	2.53	

The Specific gravity of fine aggregate is 2.53

3.3.3 Moisture content in sand (as per IS: 2386 (Part-1)-1963)

Fig 10. Moisture content in sand

The aggregate contains surface moisture they contribute some water to the dilution of cement paste and this will increase water cement ratio and strength will go down. On the other hand, if aggregates are dry, they will be absorbing water from the cement paste and hence reducing the water cement ratio. Consequently, workability of the mix is affected.

Table 10: Moisture content of fine aggregate

Sl. No.	Description	Trail 1	Trail 2	Trail 3
1	Weight of empty container in gms (W_1)	18.01	18.88	18.53
2	Weight of container + wet sand in gms (W_2)	27.07	24.74	25.92
3	Weight of container + dry sand in gms (W_3)	27.06	24.73	25.91
4	Water content = - $\frac{W_2 - W_3}{W_3}$ X 100 %	0.11 %	0.148%	0.135%
5	Average water content	0.131%		

Formula: - $\frac{W_2 - W_3}{W_3}$ X 100 = $\frac{27.07-27.06}{27.06}$ X 100 = 0.11%

Trail-1= 0.11%   Trail-2= 0.148%   Trail-3= 0.135%

The Average Moisture content of sand is 0.131%.
Specific gravity of Sand G = 2.53

Bulk density of fine aggregates

- Weight of measuring cylinder (W_1) = 8670 gms
- Diameter of measuring cylinder (D) = 25.5 cm
- Height of cylinder (h) = 21.5 cm
- Volume of cylinder, V = $\frac{\pi d^2}{4}$ x h = $\frac{\pi X 25.5^2}{4}$ X 21.5 = 10980.16 cm^3

- Loose state:
- Weight of cylinder+ loose sand (W_2) = 22320 gms
- Weight of sand = W = W_2 - W_1 = 13650 gms
- Bulk density = $\frac{W}{V}$ = $\frac{13650}{10980.16}$ = 1.24 g/cc
- % Voids = $\frac{G-\gamma}{G}$ X 100 = $\frac{2.5 - 1.24}{2.5}$ x 100 = 50.4%

Compact State:

- Weight of cylinder + loose sand (W_2) = 23910 gms
- Weight of sand = W = W_2 - W_1 = 15240 gms
- Bulk density = $\frac{W}{V}$ = $\frac{15240}{10980.16}$ = 1.38 g/cc
- % Voids = $\frac{G-\gamma}{G}$ X 100 = $\frac{2.5 - 1.38}{2.5}$ x 100 = 44.8%

3.4 Coarse aggregates:

3.4.1 Sieve analysis of course aggregate: (as per IS: 2386 (Part I) 1963)

Sieve analysis is the operation of dividing a sample of aggregate into various fraction each consisting of particles of the same size. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation.

Fig 11. IS Sieve for Coarse Aggregate

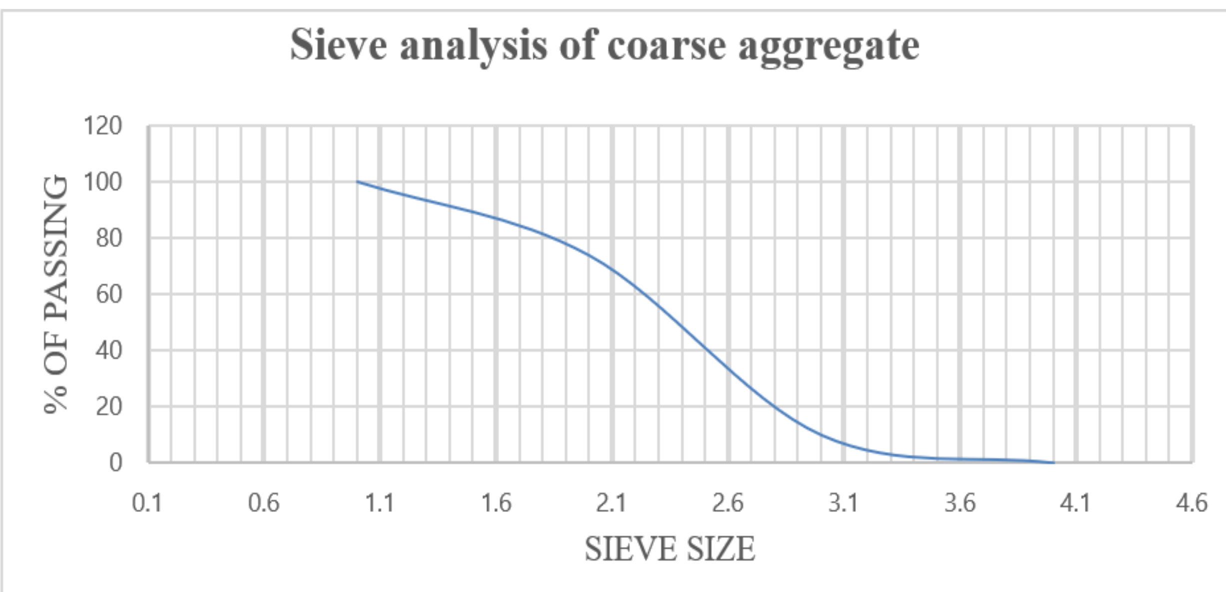
Table 11: Sieve analysis of coarse aggregate

Sl. No	I.S sieve size	Empty Weight of Sieve in (gms) W_1	Weight of Sieve + Aggregates in (gms) W_2	Weight of Aggregates Retained ($W=W_2-W_1$)	% of weight retained gms	Cumulative % of weight retained 'X'	Cumulative % passing N = 100 -X
1	40 mm	1790	1790	0	0	0	100
2	20 mm	1690	3000	1310	26.2	26.2	73.8
3	10 mm	1640	5295	3655	73.1	99.3	0.7
4	4.75mm	1810	1842	32	0.64	99.9	0.1
5	PAN	1880	1885	5	0.1	100	0

$$\text{Fineness modulus} = \frac{Cumulative\ \%\ of\ Weight\ retaid + 500}{100} \text{ X } 100$$

The Fineness modulus of Course aggregate is 8.25%

Conforming to IS-383:1970, Table No.2 combined 100%



Graph 1: sieve analysis of Coarse aggregates

3.4.2 Specific gravity test on coarse aggregates (as per IS: 2386 (Part III) -1963): Specific gravity of a material may be defined as the ratio of weight of known volume of the material to the weight of equal volume of water.

Fig 12. Pycnometer

Table 12: Specific gravity of coarse aggregate

Sl. No.	Description	Trial 1	Trial 2
1	Empty weight of Pycnometer W_1 gms	599.5	599.5
2	Weight of Pycnometer + 1/3rd Coarse aggregate W_2 gms	1131.5	1182.5
3	Weight of Pycnometer + Coarse + water W_3 gms	1813.0	1840.1
4	Weight of Pycnometer + water W_4 gms	1480	1480
5	Specific gravity	2.67	2.71
6	Average specific gravity	2.69	

$$\text{Formula} = \frac{(W_2 - W_1)}{(W_4 - W_1)-(W_3 - W_2)} = \frac{(1131.5-599.5)}{(1480-599.5)-(1813.0-1131.5)} = 2.67$$

Trial 1 =2.67 Trial 2 = 2.71

The Average specific gravity coarse aggregate is 2.67

3.4.3 Moisture content in coarse aggregate (IS 2386 (Part- I) - 1963)

Fig 13. Moisture content of coarse aggregate

The aggregate contains surface moisture they contribute some water to the dilution of cement paste and this will increase water cement ratio and strength will go down. On the other hand, if aggregate is dry, they will be absorbing water from the cement paste and hence reducing the water cement ratio. Consequently, workability of the mix is affected.

Table 13: Moisture Content Coarse Aggregate

Sl. No.	Description	Trail
1	Weight of empty container in gms (W_1)	990
2	Weight of container + wet Aggregates in gms (W_2)	1338
3	Weight of container + dry Aggregates in gms (W_3)	1336
4	Water content %	0.57%

Formula: - $\frac{W_2 - W_3}{W_3}$ X 100 = $\frac{348-346}{346}$ X 100 = 0.578%

The moisture content present in coarse aggregate is 0.578%.

3.4.4 Bulk density of coarse aggregates

Specific gravity of Sand G = 2.53

Weight of measuring cylinder (W_1) = 8670 gms

Diameter of measuring cylinder (D) = 25.5 cm

Height of cylinder (h) = 21.5 cm

Volume of cylinder, V = $\frac{\pi d^2}{4}$ x h = $\frac{\pi \, X \, 25.5^2}{4}$ X 21.5 = 10980.16 cm^3

Loose state:
Weight of cylinder + loose coarse aggregates (W_2) = 23342gms
Weight of sand = W = W_2 - W_1 = 14672 gms
Bulk density = $\frac{W}{V} = \frac{14672}{10980.16}$ = 1.336 g/cc
% Voids = $\frac{G-\gamma}{G}$ X 100 = $\frac{2.7-1.336}{2.7}$ x 100 = 50.51%

Compact State:
Weight of cylinder + loose sand (W_2) = 24880 gms
Weight of sand = W = W_2 - W_1 = 16210 gms
Bulk density = $\frac{W}{V} = \frac{16210}{10980.16}$ =1.476 g/cc
% Voids = $\frac{G-\gamma}{G}$ X 100 = $\frac{2.7-1.476}{2.7}$ x 100 = 45.33%

3.5 Coffee husk ash as a replacement of cement: -

Fig 14. Coffee husk ash

Coffee husk ash acts as a pozzolanic material when added to cement because of its silica and aluminate content, which reacts with free lime released during hydration of the cement and forms additional calcium silicate hydrate product. This additional calcium silicate hydrate improves the mechanical strength of the cement.
Recently, coffee husk ash had been tested in some countries for its pozzolanic possessions, which has been found to develop some of the properties of the paste, mortar and concrete like compressive strength and water tightness in confident substitution percentages and fineness Research was aimed at reducing the cost of building materials e.g. Cement, and environmental pollution by replacing cement with coffee husk ash in concrete.
3.5.1 Specific gravity test on coffee ash: -
Specific gravity of a material may be defined as the ratio of weight of known volume of the material to the weight of equal volume of water.

Table 14: Specific gravity of CHA

Sl. No.	Description	Trial 1	Trial 2
1	Empty weight of Pycnometer W_1 gms	599.5	599.5
2	Weight of Pycnometer + 1/3rd Bagasse ash W_2 gms	830	827
3	Weight of Pycnometer + Bagasse + water W_3 gms	1610	1603
4	Weight of Pycnometer + water W_4 gms	1520	1521
5	Specific gravity	1.64	1.56
6	Average specific gravity	1.6	

Formula =
$$\frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)} = \frac{(830-599.5)}{(1520-599.5)-(1610-830)} = 1.64$$
Trial 1 = 1.64 Trial 2 = 1.56
The Average specific gravity of CHA is 1.6

3.5.2 Bulk density of CHA: -
Specific gravity of Sand G = 1.6
Weight of measuring cylinder (W_1) = 8670 gms
Diameter of measuring cylinder (D) = 25.5 cm
Height of cylinder (h) = 21.5 cm
Volume of cylinder, V = $\frac{\pi d^2}{4}$ x h = $\frac{\pi \, X \, 25.5^2}{4}$ X 21.5 = 10980.16 cm^3

Loose state:
Weight of cylinder + loose sand (W_2) = 16252 gms
Weight of sand = W = W_2 - W_1 = 7582 gms
Bulk density = $\frac{W}{V} = \frac{7582}{10980.16}$ = 0.690 g/cc
% Voids = $\frac{G-\gamma}{G}$ X 100 = $\frac{1.6-0.690}{1.6}$ x 100 = 56.875%

Compact State:
Weight of cylinder + loose sand (W_2) = 17052 gms
Weight of sand = W = W_2 - W_1 = 8382 gms

Bulk density = $\frac{W}{V} = \frac{8382}{10980.16}$ = 0.763 g/cc
% Voids = $\frac{G-\gamma}{G}$ X 100 = $\frac{1.6-0.763}{1.6}$ x 100 = 52.31%

3.5.3 Sieve analysis on CHA: -
Sieve analysis is the operation of dividing a sample of aggregate into various fraction each consisting of particles of the same size. The sieve analysis is conducted to determine the particle size distribution in a sample, which we call gradation.

Fineness Modulus:

Fineness modulus is an empirical factor obtained by adding the cumulative percentage of material retained on each of the standard sieve and dividing this sum by an arbitrary number 100.

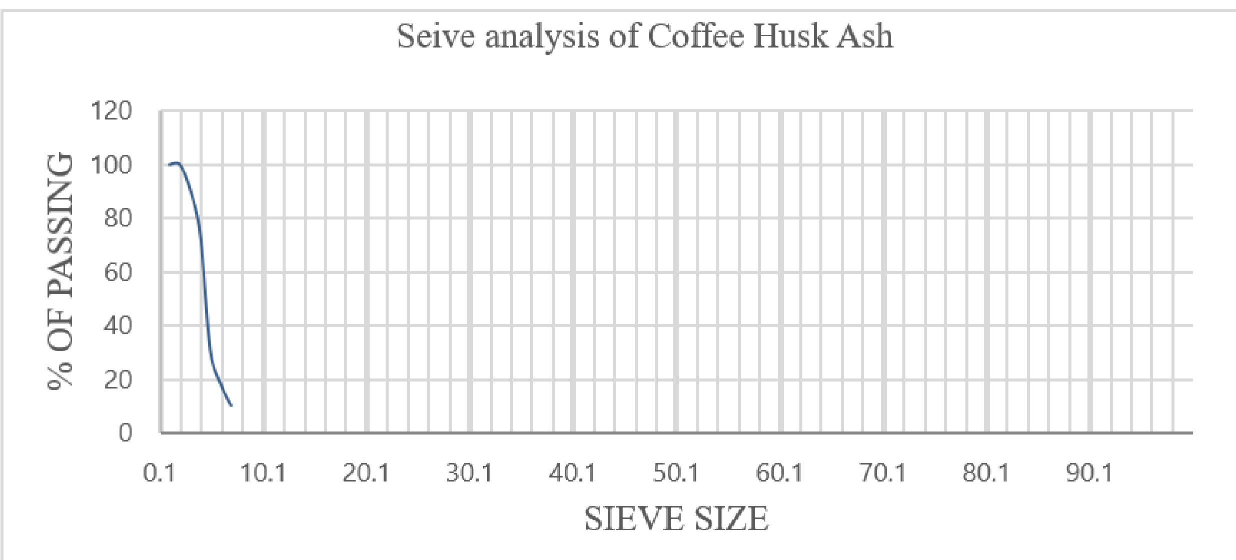
Fig 15. IS Sieve for CHA

Table 15: Sieve analysis of Coffee husk ash

Sl. No	I.S sieve size	Empty Weight of Sieve in (gms) W_1	Weight of Sieve + CHA in (gms) W_2	Weight of CHA Retained ($W=W_2-W1$)	% of weight retained gms	Cumulative % of weight retained 'X'	Cumulative % passing N = 100 -X
1	4.75 mm	430	430	0	0	0	100
2	2.36 mm	370	370	0	0	0	100
3	1.18 mm	340	430	90	9	9	91
4	600µ	310	480	170	17	26	74
5	300µ	300	560	260	26	52	48
6	150µ	320	580	260	26	78	22
7	PAN	540	670	130	13	91	9

$$\text{Fineness modulus} = \frac{Cumulative\ \%\ of\ Weight\ retained}{1000}\ X\ 100$$

The Fineness modulus of Bagasse ash is 2.56%.



Graph 2: Sieve analysis of Coffee Husk Ash of comparison characteristics of mortars and concrete with river sand has also been explored.

3.6 Mix design for M25 grade of concrete:
Stipulations for proportioning
1. Grade designation: M25
2. Type of cement: Ordinary Portland Cement
3. Maximum nominal size of Aggregates: 20mm
4. Minimum cement content: 300 kg/m^3
5. Maximum water-cement ratio: 0.50
6. Workability: 75-100 mm (slump)
7. Exposure condition: Mild exposure condition
8. Method of concrete placing: Hand mixing (Concretemixture)
9. Degree of supervision: Good
10. Type of aggregate: Well graded aggregates
11. Maximum cement content: 384 kg/m3

Test data for materials
A) Cement Used: OPC
B) Specific Gravity of Cement: 2.965
C) Fly Ash: NOT USED
D) Chemical Admixture: NOT USED
E) Specific Gravity Of:
1) Coarse Aggregate: 2.67
2) Fine Aggregate: 2.53

F) Water Absorption:
1) Coarse Aggregate: 0.57%
2) Fine Aggregate (Surface Moisture): 0.11%
J) Sieve Analysis:
1) Coarse Aggregate: Zone 1 (well graded aggregate)
2) Fine Aggregate: zone 1

Target strength for mix proportioning:
f^1ck = fck+1.65 X S
f^1ck = M25+ 1.65 X S
= 25+1.65 X 4.0
f^1ck = 31.6 N/mm^2

Water Content
Max water content = 186litres.
Max size of aggregate = 20 mm
Water content for 50 mm slump = 186 + ($\frac{3}{100}$ X 186)
= 191.5
= 192 liters

Water Cement Ratio
Max water cement ratio = 0.55
Therefore, adopt water cement ratio = 0.50

Calculation of cement content
Water cement ratio = 0.50

Cement content = $\frac{192}{0.50}$
= 384 kg/m^3

Min cement content = 300 kg/m^3
Since 384>300 kg/m^3
Therefore, adopt cement content = 300 kg/m^3
This is for mild exposure condition.

Proportion of volume of coarse aggregate and fine aggregate content
Volume of coarse aggregate for water cement ratio of 0.5 is 0.63
Volume of fine aggregate = 1- 0.63 = 0.37
Mix Calculation
A) Volume of concrete = 1 m^3
B) Volume of cement = $\frac{mass\ of\ cement}{specific\ gravity\ of\ cement}\ x\ \frac{1}{1000}$

Volume of cement = $\frac{426.66}{3.144}\ x\ \frac{1}{1000}$
= 0.12213 m^3

C) Volume of water
= $\frac{Mass\ of\ water}{specific\ gravity\ of\ water}\ X\ \frac{1}{1000}\ m^3$
= $\frac{192}{1}\ X\ \frac{1}{1000}$
Volume of water = 0.192 m^3
D) Volume of all in aggregate = [A-(B+C)]
= [1-(0.12213+0.192)]
=0.6858 m^3
Mass of coarse aggregate = D X (volume of coarse aggregateX
(Specific gravity of coarse aggregate)10^3
= 0.6858 X 0.63 X 2.67 X 1000

= 1153.70 kg
Mass of fine aggregate = D X (volume of fine aggregate) X
(Specific gravity of fine aggregate)X 10^3
= 0.6858 X 0.37 X 2.53 X 1000
= 641.97 kg
Actual mix proportion
Cement: fine aggregate: coarse aggregate: water
384: 641.97: 1153.70: 192
Mix Ratio: - 1:1:2
For 1 cube

Density = $\frac{Weight}{Volume}$

1 cube Volume = 0.15 X 0.15 X 0.15 m^3

V = 3.375 X 10^{-3} m^3

W = Volume X Density of concrete

= 3.375 X 10^{-3} m^3 X 2500 kg/ m^3

W = 8.4375 kg

W = 10 kg

Weight of cement = $\frac{10}{1+1+2}$ X 1 = 2.5 kg

Weight of Fine Aggregates = $\frac{10}{1+1+2}$ x 1 = 2.5 kg

Weight of coarse Aggregates = $\frac{10}{1+1+2}$ x 2 = 5 kg

For 1 Cylinder

1 cylinder Volume = $\frac{\pi d^2}{4}$ X h

= $\frac{\pi \text{ X } 0.15^2}{4}$ X 0.3

V = 5.30 X 10^{-3} m^3

Density = $\frac{weight}{volume}$

W = V X d

= 5.30 X 10^{-3} X 2500

W = 13.25 kg

W ≈ 15 kg

Weight of cement = $\frac{15}{1+1+2}$ x 1 = 3.75 kg

Weight of Fine Aggregates = $\frac{15}{1+1+2}$ x 1.5 = 5.62 kg

Weight of Coarse Aggregates = $\frac{15}{1+1+2}$ x 2 = 7.5 kg

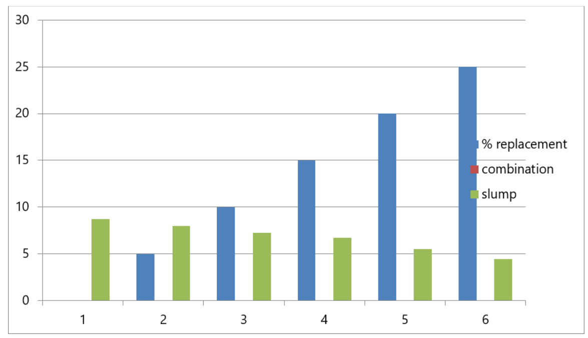
IV. RESULTS AND DISCUSSIONS

4.1 Fresh properties of concrete:

Fig 16. Slump test

Table: - 16 Slump Analysis

Sl. No	% of Replacement	Combination	Slump mm
1	0	100% Cement 0% CHA	8.75
2	5	95% Cement 5% CHA	8
3	10	90% Cement 10% CHA	7.25
4	15	85% Cement 15% CHA	6.75
5	20	80% Cement 20% CHA	5.5
6	25	75% Cement 25%	4.45



Graph 3: Slump Test

Observations:

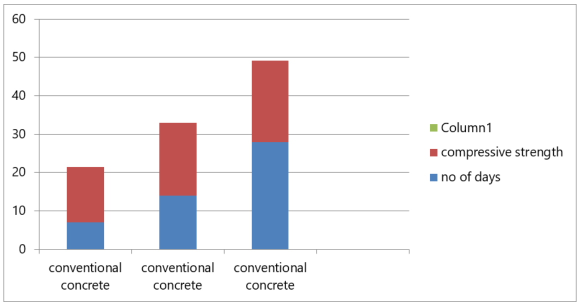
4.2 Hardened properties of concrete:

4.2.1 Compressive strength analysis

Fig 17. Casting of concrete cubes

Table 17: Compressive strength Analysis: -

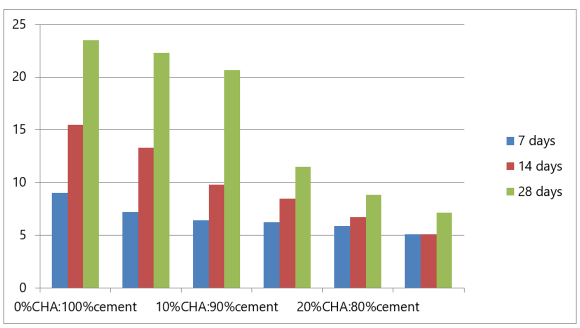
Type of concrete	Number of Days	Compressive strength in N/mm²
		Cube
Conventional concrete	7 Days	14.44
	14 Days	18.88
	28 Days	21.11



Graph 4: Compressive strength Analysis for conventional concrete

Table 18: compressive strength analysis for CHA

Combination	7 days (KN/m2)	14 days (KN/m2)	28 days (KN/m2)
0%CHA: 100% Cement	9.03	15.48	23.52
5% CHA: 95% Cement	7.2	13.29	22.3
10%CHA: 90% Cement	6.45	9.77	20.67
15%CHA: 85% Cement	6.22	8.44	11.48
20%CHA: 80% Cement	5.85	6.74	8.81
25%CHA: 75% Cement	5.11	5.106	7.17



Graph 5: compressive strength analysis for CHA

V. CONCLUSION

- The workability of Concrete was decreased as the percentage of CHA were increased with 5%, 10, 15, 20, 25%. The workability of concrete had been found to be decrease CHA with increase Cement in concrete. There is a significant reduction of workability in fresh lining concrete with the increase amount of CHA content in concrete.
- Compressive strength and workability of concrete were decreased with the increase percentage of CHA and decrease of percentage of cement. The unit weight of concrete increased uniformly with the decrease in CHA content. The compressive strength increased with curing period and decreases with increased amount of CHA.
- The physical properties of CHA try to compare the pozzlana portland cement. CHA are normal consistency = 22%, initial and final setting time =190 -394 min specific gravity =2,3 g/cc get and to partially to purpose for binding materials.
- Only 5% CHA substitution is adequate to enjoy maximum benefit of strength gain. The maximum 28 dayscompressive strength was obtained with 10%CHA. The partial replacement of cement by CHA indicates that at long term ages, the CHA concrete showed higher compressive strength in comparison with that of the concrete without CHA

REFERENCES

[1] Abebe Demissew, F. Fufa, and S. Assefa, “Partial replacement of cement by coffee husk ash for C-25 concrete production,” *Journal of Civil Engineering, Science and Technology*, vol. 10, no. 1, pp. 12–21, Apr. 2019.

[2] Abebe Demissew, “Assessment on cement production practice and potential cement replacing materials in Ethiopia,” vol. 12, no. 1, pp. 22–28, 2020.

[3] A. C. de Almeida, M. A. L. da Silva, and S. P. Ribeiro, “Evaluation of partial sand replacement by coffee husk in concrete production,” *Journal of Environmental Science and Engineering B*, vol. 8, pp. 129–133, 2019.

[4] G. M. Makebo, “Partial replacement of cement material in Ethiopia,” *International Research Journal of Engineering and Technology*, vol. 6, no. 10, pp. 1002–1005, Oct. 2019.

[5] Y. Reta and S. Mahto, “Experimental investigation on coffee husk ash as a partial replacement of cement for C-25 concrete,” vol. 6, no. 6, pp. 152–158, Jun. 2019.