Experimental Study on Partial Replacement of Cement with Coffee Husk Ash for Manufacturing Concrete Pavers

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Abstract: **The concrete paver bricks are a porous form of brick formed by mixing small stone hardcore, dyes, cement and sand. Concrete pavers will aligned to one another on a suitable sub base, providing a specific joint space among them to be filled with jointing sand. The main purpose of this study is to assemble a concrete paver by using solid waste like coffee husk ash (CHA). While the use of agricultural by-product like coffee husk ash (CHA) as a partial replacement with conventional cement is expected to serve the purpose of serving in the constructional works. This study reviews in the examination of concrete produced by partial replacement of cement with CHA. CHA was obtained and used to put back cement partially in specified ratios for every 5% up to 25%. And test was carried out on the concrete pavers as per the Indian standards for precast concrete blocks for paving IS 15658:2006 for 7, 28 and 56 days. The conducted results are further compared with the results of the conventional paver blocks.**

Keywords - Concrete pavers, coffee husk ash (CHA)

I. INTRODUCTION

The concrete paving block is a system of independent shaped blocks arranged to form a continuous long-lasting surface. The concrete pavers are more seen in commercial industrial and the residential areas for pedestrian walk, footpaths and parking areas and it also fortunately used for, slope protection, embankment walls and the erosion control. For the manufacturing of concrete pavers, we need the constructional materials like coarse aggregate, fine aggregate, cement and the water. Cement plays a magnificent role in concrete for which it binds a bond between aggregates and gives the strength, as we know manufacturing of cement produces a lot of pollution to the environment by producing carbon di-oxide (CO_2) and it also the most expensive as compared to other constructional materials to overcome this problem we can use an alternative sources like industrial or agricultural wastes like rice husk, coffee husk etc. the coffee husk is one the solid waste produce from coffee industries we can use it an partial replacement for cement as it shows some chemical properties which are having a similar to cement so by making it into ash as it can use for partial replacement for cement. In this study we are going to understand the behavior of ash as a replacement of cement and manufacture the concrete pavers and test was carried out on the pavers.

These test results are then compared with conventional paver block.

Fig. 1- CONCRETE PAVERS

II. EXPERIMENTAL INVESTIGATION

In this experiment the materials which are used to prepare the concrete pavers were tested in the laboratory so that we can find the properties of that materials which are help to calculate the mix design was done on basis of IS 10262:2019.

A. PROPERTIES OF CEMENT

Cement in general, which is a viscous substance of all kinds, but in a narrow sense that binding materials provide strength and workability to the concrete. In this experiment we use OPC43 grade cement which is a good for the concrete pavers and some of the basic tests are carried on to know the properties of it.

TABLE 1- Properties of Cement

Properties of cement	Values
Specific gravity test	3.13
Fineness test	7.2%
Initial and final setting time	29 Min. and 300 Min.

Fig. 2 – CEMENT

B. PROPERTIES OF FINE AGGREGATE

It is naturally occurring material which is a composition of mineral particles. In this experimental study we use the river sand and some of the basic tests conducted are,

TABLE 2- Properties of fine aggregate

Properties of fine aggregate	Values
Specific gravity test	2.6
Water absorption	1.2%
Sieve analysis	Confining to zone II

Fig. 3- FINE AGGREGATE

C. PROPERTIES OF COARSE AGGREGATE

It is used for ensuring the durability of the structure the aggregates used for manufacturing of block should be honeycombed and inaudible. In this experiment the nominal size of the aggregate used is 12mm down and some of the basic tests conducted are,

TABLE 3- Properties of coarse aggregate

Properties of coarse aggregate	Values
Specific gravity	2.7
Water absorption	1.6%
Sieve analysis	Confining to zone II

Fig. 4- COARSE AGGREGATE

D. PROPERTIES OF COFFEE HUSK ASH (CHA)

Coffee husk is the solid waste produced from coffee industries, it was collected from the coffee industries in chikmagalur [D] in India. This collected husk were burnt, before burning the husk it should be exposed to sun to eliminate the moisture content present in it. And later, it was burnt at the temperature of 500℃ - 600℃.

TABLE 4 – Chemical composition of coffee husk ash

Constituent	Coffee husk ash by weight (%)
Alumina (Al_2O_3)	11.85
Silica (SiO_2)	14.15
K_2O	47.13
Iron oxide (Fe_2O_3)	4
P_2O_5	3.25
Na_2O	0.50
Lime (CaO)	13.25

Constitute	Cement by weight (%)	Coffee husk ash by weight (%)
Alumina (Al_2O_3)	5.5	11.85
Lime (CaO)	64.68	13.25
Silica (SiO_2)	21.3	14.15
Iron oxide (Fe_2O_3)	3.33	4
N_2O	0.05	0.50
Magnesia (MgO)	2	
Sulphur tri-oxide	2.14	

TABLE 5 – Properties of CHA

Properties of CHA	Values
Specific gravity	3

Fig. 5- COFFEE HUSK ASH

III. METHADOLOGY

A. MIX DESIGN

It is worked as per IS 10262-2019, in this study we selected M40 grade as it very suitable for mid-traffic condition. By calculating the mix design, we got mix proportions as 1:1.5:1.7 and the water-cement ratio is 0.36.

For each mould of area 250 X 120 X 75 we got,

TABLE 6 – Mix proportions

Materials	By weight (kg/m^3)
Cement	1.42
Fine aggregate	2.13
Coarse aggregate	2.41
Water	600 ml

TABLE 7 – The replacement of cement by CHA

Sl.no.	Percentage of CHA added in replacement of cement	CHA in kg	Cement in kg
1	0%	0	1.42
2	5%	0.071	1.35
3	10%	0.142	1.278
4	15%	0.213	1.207
5	20%	0.284	1.136
6	25%	0.355	1.065

B. TEST ON FRESH CONCRETE

After knowing the mix proportions, aggregates are mixed and water is added eventually. Later, we got a fresh concrete to check the workability and durability of the concrete. Based on the concrete, we have done slump cone test. In this test we will fill the fresh concrete into the 75 mm height cone shaped mould in three layers. After completing a layer, we will tamp it 25 times by tamping rod, after completing 3 layers must remove the additional surface and then remove the cone mould and after taking the measurements it will categorize as true slump, shear slump, and collapse slump. By this, we studied the workability of the concrete.

TABLE 8 – Slump test

Sl.no.	Percentage of CHA replaced with cement	Water-cement ratio	Slump in mm	Nature of slump
1	0%	0.36	2	True slump
2	5%	0.36	6	True slump
3	10%	0.36	12	True slump
4	15%	0.36	18	True slump
5	20%	0.36	25	Shear slump
6	25%	0.36	28	Shear slump

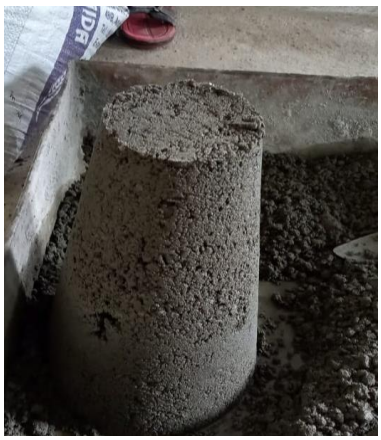

Fig. 6 – SLUMP CONE TEST

C. MOULDING

Moulding is the process where the prepared concrete is placed to get unique specified shape. In study, we selected the unipaver shape which having a dimension of 250 X 120 X 75 mm. Before casting the concrete into the mould, oil it and after casting keep it on vibrator for a 5 – 10 minutes to avoid air void space in the concrete and keep it in mould for 24 hours of time to get a specified shape.

Fig. 7- MOULDING OF CONCRETE

D. DEMOULDING

After 24 hours of moulding the concrete was demoulded and then it was placed in the water for curing.

Fig. 8 - DEMOULDING

E. CURING

Curing plays an important role to give a strength for the concrete paver blocks. After demoulding the concrete paver, it was kept in a water for curing for 7, 28 and 56 days to gain the strength.

Fig. 9 – CURING

F. TEST ON CONCRETE PAVERS

The test on pavers is done as per IS 15658 -2006

1. Determination of water absorption:

   The absorption samples was determined at 7 days of the curing. Initially, blocks were kept in a tap water for 24 hours and after separating from the water, the surface water is wiped off. The block sample and the weight were measured as W_1. Then, the sample were oven dried at 105°C for an hour then weigh it and take it as a W_2. The water absorption is calculated as,

$$W_A = \frac{W1-W2}{W2} \text{ X } 100$$

Where,

W_A = water absorption in percentage (%),
W_1 = wet weight of the concrete paving block in kg,
W_2 = dry weight of the concrete paving block in kg.

Fig. 10 – WATER ABSORPTION TEST

2. Determination of compressive strength:

The compressive strength of the concrete paver block was tested at 7, 28 and 56 days of curing by using universal testing machine. The load was applied 15 N/mm^2/min at the top of the block until the strength of the block is collapsed, then the compressive strength was calculated as,

$$C = P/A$$

Where,

C = compressive strength in N/mm^2 ,
P = failure load of the sample in N,
A = surface area of the sample in mm^2.

Fig. 11 – COMPRESSIVE STRENGTH

3. Determination of Tensile Splitting Strength:

The Tensile splitting strength of the paver bricks was tested at 7,28 and 56 days using universal testing machine.The sample was placed in the longest splitting section ,later a 10mm rod was placed on both surfaces .The load is steadily and smoothly applied at a rate which corresponds to increase in stress of 0.05 MPa. The failure load was noted and the Tensile spilt was calculated by using below formula,

$$S = t \text{ X } I$$

Where,

S = Failure Area in mm^2,
t = Average of three measurements of thickness at the failure plane, one in the middle and another two at either ends in mm,
l = Average of two measurments of the failure length, one at the top another at the bottom of the specimen in mm .

The tensile splitting strength of the test specimen is calculated from equation:

$$T = 0.637 \text{ X } k \text{ X } (P/S)$$

Where,

T = tensile splitting strength , in Mpa,
P = Failure load N.

The failure load per unit length of the specimen is calculated for the equation :

$$F = (P/l)$$

Where,

F= Failure load in N/mm.

Fig. 12 –TENSILE SPLIT TEST

IV. RESULT AND DISCUSSION

A. WATER ABSORPTION TEST ON CONCRETE PAVER

TABLE 9 – Water absorption test results

Sl.no.	Percentage of CHA replaced with cement	Average water absorption In %
1	0	0.80
2	5	1.3
3	10	1.56
4	15	1.75
5	20	2
6	25	3

Conducting the water absorption test after 7 days of curing, the output results shows that as increase in the replacement of cement by coffee husk ash the water absorption will be more.

B. COMPRESSIVE STRENGTH TEST ON CONCRETE PAVERS

TABLE 10 – Compressive strength test results

Sl. no.	Percentage of CHA replaced with cement	Mean compressive strength for 7 days (N/mm^2)	Mean compressive strength for 28 days (N/mm^2)	Mean compressive strength for 56 days (N/mm^2)
1	0	30.742	47.28	48.21
2	5	27.38	45.24	50.14
3	10	25.42	44.28	48.21
4	15	20.84	32	40
5	20	10	15.38	36.8
6	25	6.125	11.45	28.54

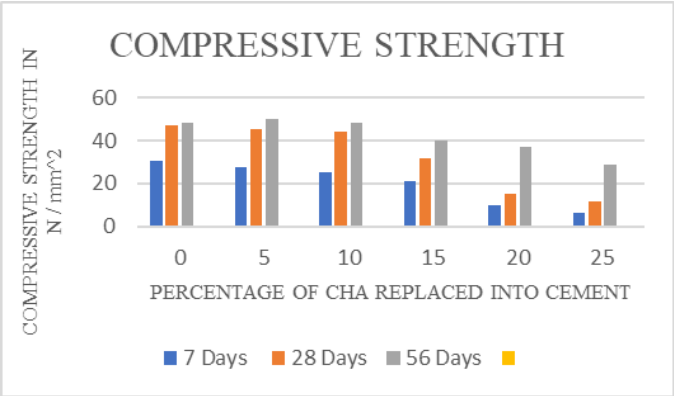

Fig. 13- COMPRESSIVE STRENGTH RESULT

The results of pavers show that after 56 days of curing the 5% replacement of cement with CHA attains 4% more strength compared with the conventional one.

C. TENSILE SPLIT STRENGTH TEST ON CONCRET PAVERS

TABLE 11- Tensile split strength test results

Sl. no.	Percentage of CHA replaced with cement	Average split tensile strength for 7 days (N/mm)	Average split tensile strength for 28 days (N/mm)	Average split tensile strength for 56 days (N/mm)
1	0	3.881	4.813	4.860
2	5	3.662	4.708	4.956
3	10	3.529	4.656	4.860
4	15	3.195	3.959	4.427
5	20	2.213	2.945	4.315
6	25	1.732	2.368	3.741

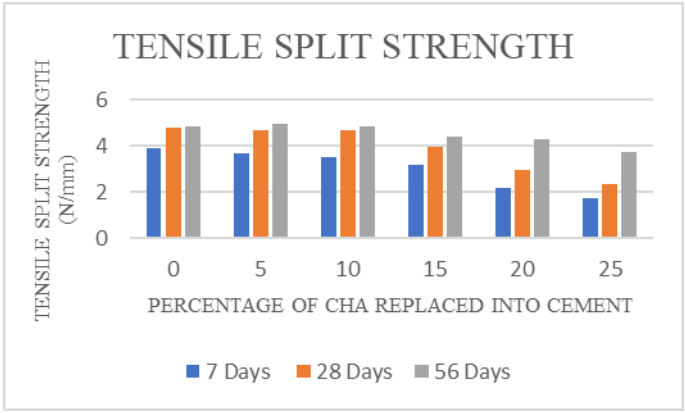

Fig no. 13 – Tensile split strength test result

The tensile split test results shows that the spilt strength shows that after 56 days of curing the split strength shows 2% more in 5% CHA replacement compared to conventional sample.

V. CONCLUSION

- The replacement of coffee husk ash as 5%, 10%, 15%, 20% and 25% with the cement can helps Compressive and Tensile split behaviors.
- Increase in the percentage replacement of CHA increases the water observation of concrete pavers.
- As the percentage of CHA increases the workability of the concrete decreases.
- At 5% of CHA replaced into cement gives the finest value of the compressive strength and the Tensile split strength as it compared with conventional concrete paver.
- Effective utilization of CHA reduces the impact on environmental pollution.

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