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Industrial Waste–Paper Sludge Ash as Partial Replacement to Cement in Making Concrete Paver Blocks

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ABSTRACT

Scarcity of available natural resources, high cost of virgin materials, and land depletion caused by the disposal of waste materials, has led to the need for sustainable alternatives in road construction. One such industrial waste emanating from the paper industry is the paper sludge. This paper sludge ash (PSA) can be used as an alternative construction material. The present study envisages the use of PSA in making interlocking concrete block pavements (ICBP). It uses PSA as a replacement to cement in the concrete used for the ICBP, by varying percentages viz., 0%, 5%, 10%, and 15% of cement. All the tests were conducted as per IS: 15658-2006. It was observed that the compressive, split tensile, and flexural strength increased by 15.7%, 6%, and 35.7%, respectively. The water absorption is less for 10% replacement. Overall a 10% replacement is recommended.

INTRODUCTION

Paver blocks have been used across the globe as an alternative option for the pavements. The basic materials like cement and aggregates are used for preparing blocks. Sustainability aims at to reduce the exploitation of conventional resources and attempts should be made to reuse the recycled waste. The usage of natural resources has created shortage and led to increase in cost of construction. In order to reduce the impact on environment and to save energy, it is necessary to use ecofriendly and renewable materials for construction. Therefore, this project is one such effort in minimizing the use of natural resources.

PAPER SLUDGE

The waste paper from the paper mills is processed in treatment plant to produce sludge. It is the solid residue which is recovered from wastewater stream of pulping and papermaking process. Sludge is produced in two steps by treating the effluent. Primary clarification and secondary treatment by micro-organisms. The obtaining solids are removed through clarification. This sludge can be broken down to produce ash. The paper sludge ash thus produced is disposed as landfill, creating environmental pollution and degradation of land. In India, about 10.11 million tons [(1)] of paper is produced every year. Some authors state that for every 1 ton of paper nearly 30kg of primary sludge is produced. This sludge can be dried and sieved to get powder or can be burnt to produce ash.

OBJECTIVES OF PRESENT STUDY

In this study, an attempt has been made to use the paper sludge ash in paver blocks as an environmental friendly alternative. The main objectives of project are:

- To determine the suitability of using paper sludge ash as a replacement to cement in paver blocks.
- To approach at an optimum replacement of paper sludge ash from strength, durability and economy point of view.
- To develop an eco-friendly paver block with good aesthetic view.

METHODOLOGY

The experimental program was planned to utilize the paper sludge ash as a substitute to the cement in the manufacturing of paver blocks. The cement is replaced by 0%, 5%, 10% and 15% with environmental waste - paper sludge ash. The mix design and tests are carried out as per the standard IS codes specified.

The outcome obtained from the experimental work is analysed and the ideal percentage which fulfils the strength parameters and performance is recommended to be used in paver blocks. The cost comparison of both conventional and varied percentage of paper sludge ash is calculated.

MATERIALS

The materials used for production of paver blocks are -

- Cement
- Coarse Aggregates
- Fine Aggregates (M-Sand)
- Paper Sludge Ash

BASIC TESTS OF MATERIALS

CEMENT: As per IS code 12269: 1987 [16], OPC Birla Super (53 Grade) cement was used for the entire study. The essential tests performed on the cement have been performed adn found to meet the specifications. The 7-day and 28-day compressive strength of mortar cubes were reported as 27.03 N/mm^2 and 53.96 N/mm^2 respectively which are permissible as IS 4031:1988[18]

COARSE AGGREGATE: For the study, aggregates were taken from Harohalli, Kanakapura taluk, Karnataka. The aggregates of maximum size 12 mm and minimum of 4.75 mm size is used. The basics tests performed on coarse aggregates were as per specifications of IS 383:1970[17] and found to meet the codal requirements.

FINE AGGREGATE TESTS

The test for fine aggregate were conducted as per code IS 4031:1988[18] and found to meet the codal requirements. The particle distribution of fine aggregates and conforms to Zone II of the codal provisions as per IS 383:1970.

PAPER SLUDGE ASH (PSA): The paper sludge ash is produced by burning the paper sludge obtained from the treatment plant. The paper sludge ash used was sieved using 90 micron sieve set. The basic tests like fineness, specific gravity, chemical composition were carried out. The paper sludge ash was procured from Dev Kiran Paper Mills Private Limited, Kumbalagodu, Bengaluru. Some tests performed on paper sludge ash are as tabulated below. It has a sprcific gravity of 1.67 and fineness of 5.2%

Figure 1: Paper Sludge Ash

Table 1: Chemical composition of paper sludge ash

Sl.No.	Parameter	Symbol	Result (%)
1.	Silica	SiO_2	60.00
2.	Aluminium Oxide	Al_2O_3	10.86
3.	Iron Oxide	Fe_2O_3	4.60
4.	Calcium Oxide	CaO	2.70
5.	Magnesium Oxide	MgO	1.21
6.	Sodium Oxide	Na_2O	0.90
7.	Potassium Oxide	K_2O	0.10
8.	Sulphur Oxide	SO_3	1.60
9.	Loss of Ignition	-	13.3

MIX DESIGN

In this project, M35 grade concrete was designed by considering different percentage for replacements of cement by paper sludge ash. The design is calculated as per the IS Code 10262-2009[14] and IS: 456-2000[19]. The details are tabulated below in the tabular column –

Table 2: Mix design for M35 Grade

Sl. No	Particulars	Specifications as per code
1.	Grade of Concrete	M35
2.	Cement Type	OPC 53 Grade
3.	Maximum size of aggregates	12 mm
4.	Minimum cement content	250 kg/cm^3 (Table 5 of IS:456)
5.	Maximum cement content	450 kg/cm^3
6.	Maximum water content	0.50 (Table 5 of IS:456)
7.	Workability / Slump value	0 mm slump

Table 3: Test results of materials

Property/ Material	Cement	Paper Sludge Ash	Coarse Aggregates	Fine Aggregates	Super plasticizer
Specific Gravity	2.93	1.67	2.66	2.78	1.00
Water Absorption	-	-	0.25%	2.34%	-

Table 4: Mix Proportion

Sl. No	Particulars	Specifications as per code
1.	Target strength	39.5 N/mm^2
2.	W/C Ratio	0.38
3.	Water Content	150 litres
4.	Cement content	395 kg/m^3
5.	Volume of C.A	0.484
6.	Volume of F.A	0.516

Table 5: Quantity calculation of materials

Sl. No	Materials	% Replacement			
		0%	5%	10%	15%
1.	Cement (kg)	395	375.25	355.5	335.75
2.	Paper Sludge Ash (kg)	-	19.75	39.5	59.25
3.	Fine Aggregate (kg)	1008	1008	1008	1008
4.	Coarse Aggregate (kg)	905	905	905	905
5.	Mix Proportion	**1 : 2.29 : 2.55** **C : CA : FA**			

CASTING OF ICBP

After finalising the mix design, ingredients were weighed and prepared for casting. The coarse aggregates and fine aggregates were surface dried before casting. The batched materials were dry mixed in mixer and then required quantity of water was added along with superplasticizer, mixed and poured into moulds. The machine had the inbuilt vibrator which ensured that the air voids are removed and the mix is evenly distributed in moulds. The moulds would move to next section, where they were pressed by means of Heavy hydraulic system. The moulds are compacted with high pressure and are ejected out at next section and stored on wooden pallets for curing. The moulds were then labeled and left to harden for 24 hours and placed for curing in a curing tank. Casting was carried out in Parijatha Machinery, Peenya Industrial Area 3 station press with APM-316 ED facility.

Figure 2: Hydraulic with 3-station press APM 360-ED

TESTS ON PAVER BLOCKS

The paver blocks, are first visually examined in daylight. The paver blocks should be free from cracks and other small defects. The tests carried out as per procedure given in the IS Code 15658-2006[(20)] as mentioned below:

1. Test on Abrasion Resistance
2. Test on Compressive Strength
3. Dimensions of block
4. Test on Flexural Strength
5. Test on Splitting Tensile Strength

Figure 3: Abrasion Resistance Test Machine

Figure 4: Dimension of block using Vernier Calipers

Figure 5: Compressive Test

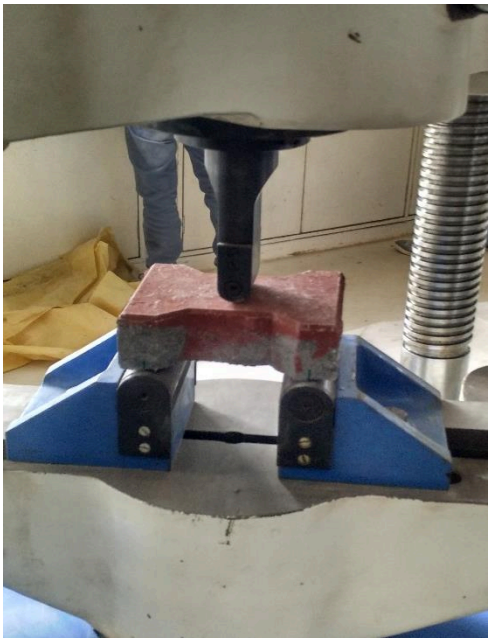

Figure 6: Flexural Test

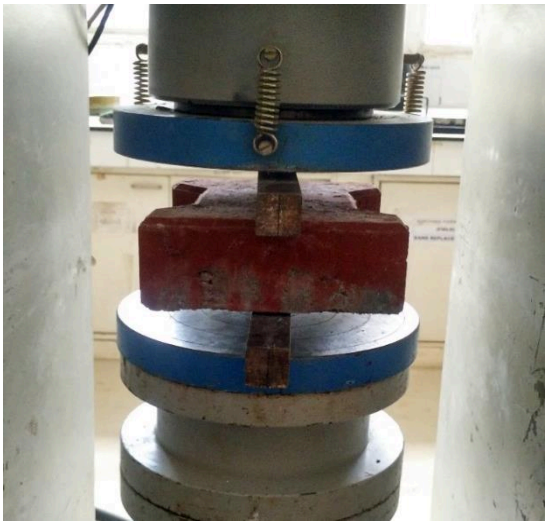

Figure 7: Split Tensile Test

Figure 8: Dried paver blocks

DATA ANALYSIS & RESULTS

Paver blocks after casting were tested for its strength parameters. The paver blocks were cured in RASTA Laboratory by immersing them in curing tank. After a period of 7, 14 and 28 days, the various strength tests were carried out as per IS: 15658-2006[20] standard code specification. The acquired results have been appropriately recorded and classified below.

ASPECT RATIO:

The aspect ratio of paver block is given by formula = $\frac{\text{(Average length)}}{\text{(Average thickness)}}$

= 200 / 60

= 3.33

As per Table 2 of IS: 15658-2006 [20] code, the maximum suggested value for aspect ratio of the specimen is 4 and the obtained value from samples is 3.33, which is inside permissible limit.

COMPRESSIVE STRENGTH TEST RESULTS

The specimens casted are tested as per the guidelines given in the IS 15658:2006. Maximum load taken by the specimen, before failure is considered. Test results obtained after 7, 14 and 28 days are tabulated below:

Table- 6: Compressive Strength Results

% Replacement	7-day strength (N/mm^2)	14 day strength (N/mm^2)	28 day strength (N/mm^2)
0%	23.96	32.04	36.51
5%	24.39	33.80	38.14
10%	26.01	35.30	41.7
15%	24.46	34.17	39.83

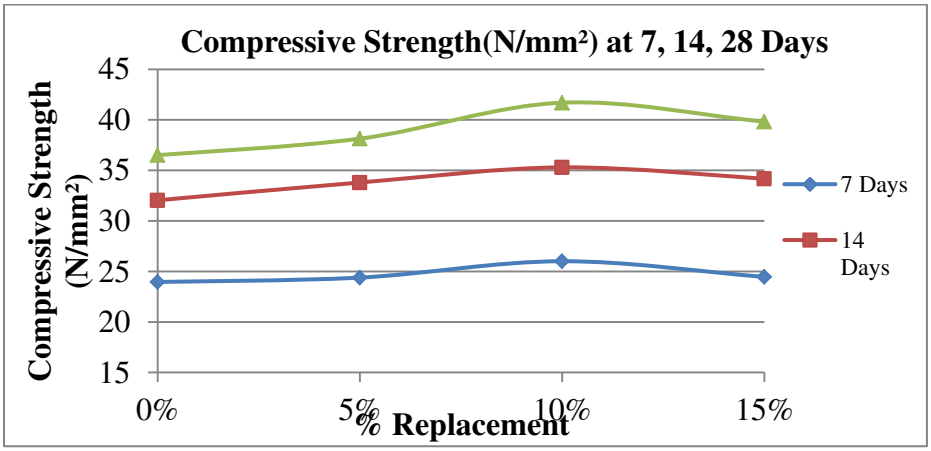

Fig 9: Graph showing Compressive Strength Results of 7, 14 & 28 days

The graph trend shows that the compressive strength of paver block increases with increase in percentage of Sludge ash upto 10% and then decreases for 15% sludge ash. The maximum value is obtained for a 10% replacement of paper sludge ash with cement.

FLEXURAL STRENGTH TEST RESULTS

The flexural strength test is carried out to check the capability of paver block to withstand the bending load before failure. Results obtained after testing of 7, 14 and 28 days cured samples are as follows

Table- 7: Flexural Strength Results

% Replacement	7-day strength (N/mm^2)	14 day strength (N/mm^2)	28 day strength (N/mm^2)
0%	2.78	3.17	3.48
5%	2.80	3.22	3.62
10%	3.075	3.45	4.18
15%	2.96	3.36	3.84

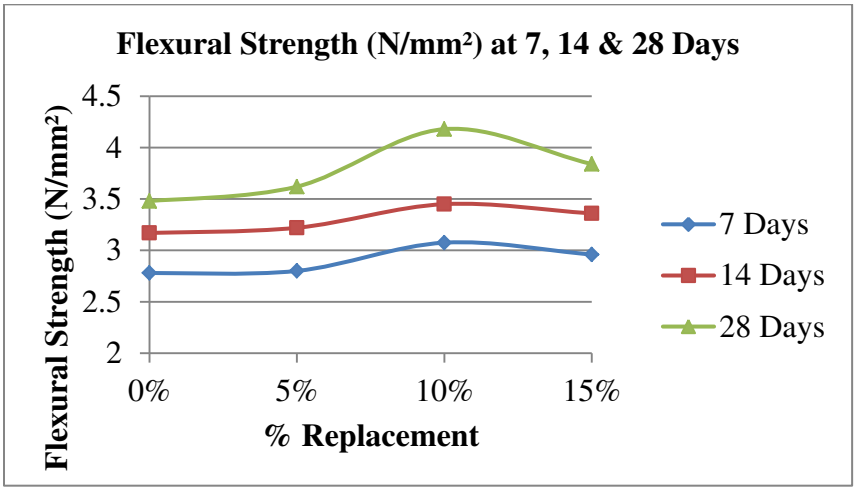

Figure 10: Flexural test results of 7, 14 & 28 days

TENSILE SPLITTING STRENGTH TEST RESULTS

Table- 8: Tensile Splitting Strength Results

% Replacement	7-day strength (N/mm^2)	14 day strength (N/mm^2)	28 day strength (N/mm^2)
0%	2.77	2.76	2.81
5%	2.84	2.87	3.08
10%	3.05	3.48	3.36
15%	2.93	3.03	2.93