Investigation on Binary Blended Construction Products

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Abstract—Binary blended construction products are increasingly being investigated for their potential to enhance the performance, sustainability, and economic viability of modern construction materials. These products typically combine two distinct types of materials, such as Portland cement and supplementary cementitious materials (SCMs) like fly ash, slag, or silica fume. This study explores the synergistic effects of binary blends on the mechanical properties, durability, and environmental impact of construction materials. By analyzing various binary combinations, the research aims to identify optimal mixtures that maximize strength and longevity while minimizing carbon footprint and resource consumption. The findings are expected to contribute to the development of more sustainable and efficient construction practices, aligning with global efforts to reduce the environmental impact of the construction industry.

***Index Terms* -Sugar Cane Bagasse Ash-characterization, Physical Properties, Chemical properties -Rice Husk Ash-FlyAsh.**

1.INTRODUCTION

The construction industry continually seeks innovative solutions to enhance the performance, durability, and sustainability of building materials. One promising area of research is the development and application of binary blended construction products. These products combine two distinct types of materials to leverage their complementary properties, potentially leading to superior performance characteristics compared to traditional single-material systems.

Binary blends typically involve the combination of cement with supplementary cementitious materials (SCMs) such as fly ash, slag, silica fume, or natural pozzolans. The rationale behind this approach lies in the synergistic effects that can be achieved, including improved mechanical properties, enhanced durability, and greater resistance to environmental degradation. Additionally, the use of SCMs can contribute to sustainability goals by reducing the carbon footprint associated with cement production and by utilizing industrial by-products that would otherwise be disposed of as waste.

This investigation focuses on the synthesis, characterization, and performance evaluation of binary blended construction products. Key areas of interest include the optimization of blend proportions, the assessment of physical and chemical interactions between constituents, and the evaluation of long-term performance under various environmental conditions. By systematically exploring these aspects, this study aims to provide valuable insights into the practical applications and benefits of binary blends in modern construction practices.

1.2 SUGAR CANE BAGASSE ASH (SCBA)

Sugarcane is a major crop in many countries. It is one of the plants with the highest bioconversion efficiency. Sugarcane crop is able to efficiently fix solar energy, yielding some 55 tonnes of dry matter per hectare of land annually. After harvest, the crop produces sugar juice and bagasse, the fibrous dry matter. This dry matter is biomass with potential as fuel for energy production. Bagasse can also be used as an alternative source of pulp for paper production. Global sugar crop acreage is approximately 31.3 million hectares, among which sugar cane accounts for approximately 70%. Figure 1.1 shows the generation process of Sugarcane Bagasse Ash (SCBA). Sugar cane bagasse ash when used as a partial replacement it decreases the amount of CO2 and enhance the strength properties.

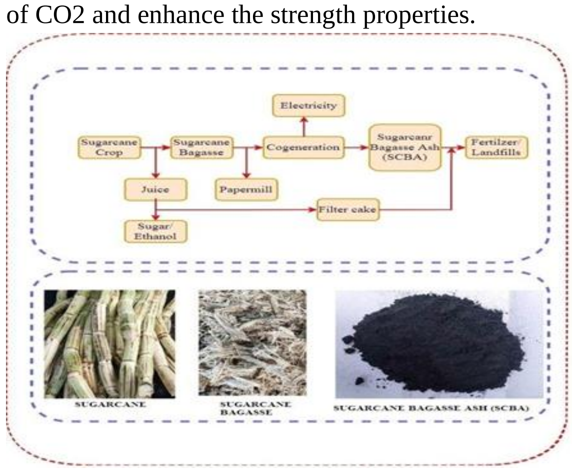


Figure 1.1 – Generation process of SCBA

1.2.1 SCBA Characterization

The physical properties and compositions of SCBA vary with many factors, such as sugar cane varieties, growth, combustion temperature, combustion duration, purity of bagasse, bagasse ash collection location, cooling type, boiler equipment, bagasse ash collection methods and ash fineness. For example, bagasse ash collected from the bottom of the boiler may be coarser and contain irregular particles, and the bagasse ash collected through a filtration system contains less carbon.

1.2.2 Morphology and Physical Properties

Macroscopic Morphology and Physical Properties

The color of power plant-generated SCBA is dark black to light black. Dark black indicates higher carbon content mainly due to incomplete combustion. Owing to crystallization and decomposition at high temperatures, SCBA appears gray above 800 °C re calcination temperature and appears white above 900 °C. As the calcination temperature and duration increases, the ash gradually changes from char to white ash. SCBA from power plants is produced under uncontrolled calcinated temperatures and durations and therefore the SCBA is a mix of different micro morphology and color particles.

Chemical Compositions

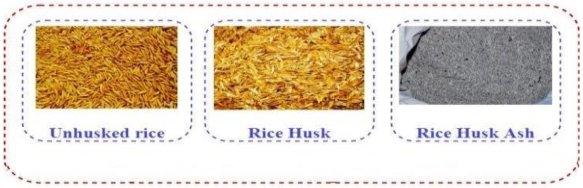
Table 1.1. Chemical Compositions of SCBA

S.No.	Component	Symbol	Percentage (%)
1	Silica	SiO_2	63
2	Alumina	Al_2O_3	31.5
3	Ferric Oxide	Fe_2O_3	1.79
4	Manganese Oxide	MnO	0.004
5	Calcium Oxide	CaO	0.48
6	Magnesium Oxide	MgO	0.39
7	Loss Of Ignition	LOI	0.71

Table 1.1 shows the chemical composition of SCBA in earlier studies. The chemical composition is significantly different among different SCBA samples. However the samples share the main components of silica, aluminum and other metal elements. According to the ASTM C618-08a specifications natural pozzolana with a ratio of the $SiO_2 + Al_2O_3 + Fe_2O_3$ sum to the total mass above 50% may be categorized as class C pozzolana and as class F pozzolana when that ratio is above 70%. Based on this criterion, most SCBA samples could be judged as class F pozzolana.

1.3 RICE HUSK ASH (RHA)

India is the second largest rice grower in the world produce on average 90 million metric tons (MT) of rice paddy per year. During milling, this rice paddy yields almost 20 million MT (approximately 22%) of husk. Rice husk has a significant calorific value of 13 to 16 MJ/kg. This is comparable with lignite (brown coal) and is approximately one-half the energy density of high quality coal. This makes rice husk a good source of fuel for industries close to where rice is milled. While leveraging rice husk as fuel is a great way to reuse what would otherwise be waste, this process still results in up to 5 million tonnes (25% of husk) of rice husk ash each year in India. Rice husk contains about 50% cellulose, 25-30% lignin, and 15-20% silica. When rice husk is burned, cellulose and lignin are removed to leave behind rice husk ash composed primarily of silica. Figure 1.2 shows the generation process of RHA. Currently the most common commercial use of RHA is as an insulation material known as tundish powder in steelmaking. Unused RHA are disposed of in landfills. However, the scale of the RHA dumping problem by considering that even if the steel industry uses RHA for all of its tundish powder needs, only 40,000 MT of RHA will be consumed each year. This means the amount of RHA ending up in landfills is in the millions of metric tons each year. This rice husk is mostly used as a fuel in the boilers for processing of paddy. Rice husk is also used as a fuel for power generation. Rice husk ash (RHA) is about 25% by weight of rice husk when burnt in boilers. It is estimated that about 70 million tons of RHA is produced annually worldwide. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. During milling of paddy about 78% of weight is received as rice, broken rice and bran. Rest 22% of the weight of paddy is received as husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75% organic volatile matter and the balance 25% of the weight of this husk is converted into ash during the firing process, is known as rice husk ash (RHA). This RHA in turn contains around 85% – 90% amorphous silica.



1.4 MARBLE WASTE (MW)

One of the major industrial wastes is the marble sludge produced by marble processing industries. In India, marble processing industry generates around 7 million tons of wastes mainly in the form of powder during sawing and polishing processes. These are dumped in the open which pollute and damage the environment. Out of the total waste generated in India, contribution from Rajasthan state itself is 95% of the total accounting to 6 million tons annually. Generally the marble wastes are being dumped in any nearby pit or vacant space near the marble processing industries, although notified areas have been marked for dumping the same. This leads to increased environmental risks as dust pollution spreads alongside for a large area. In addition, the deposition of such generated huge amount of fine wastes certainly creates dangerous ecological conditions for changing landscapes and habitats. The accumulated waste also contaminates the surface and underground water reserves. Disposal and reusing of the waste materials of the marble industry is one of the environmental problems all over the world. Figure 1.3 shows the generation process of Marble Waste. As a solution to these negative effects, the marble waste can be used in the construction industry as partial percent substitutes for aggregate.

Figure 1.3 – Generation process of Marble Waste as Fine Aggregate

1.5 FLY ASH

Fly Ash generated from combustion of Coal in Thermal Power Plants is a major environmental concern. As of now about 25 million tons of fly ash is generated from Thermal Power Plants.

Fly ash is classified into three types:

Fly ash from Electrostatic Precipitator (ESP) of thermal power plants.

Pond ash stored in ash pond/mounds.

Bottom ash – collected at bottom ash hopper of the boiler, which has high concentration of carbon.

Fly ash is utilized in many sectors such as construction materials, road making, cement, asbestos, dykes etc. Therefore, it is considered as a resource. At present around 1 million tons of fly ash is utilized in Brick making in Tamil Nadu, contributing to 4% use of total ash generated in the state. Fly Ash is a fine grey amorphous powder, rich in Silica and Alumina. The properties of Fly Ash may vary both physically and chemically depending on the nature of the coal and the combustion process.

Pulverized fuel ash-lime bricks are made from materials consisting of fly ash in major quantity, lime and an accelerator acting as a catalyst. Pulverized fuel ash lime bricks are manufactured by blending above raw materials and then molded to form bricks. Crushed bottom fuel ash or sand is also used in the composition as a coarse material to control water absorption in the final product.

2. METHODOLOGY

Methodology is adopted as shown in Figure 2.1. Five Construction products (Fly Ash Bricks, Cubes, Cylinders, Paver Blocks and RCC Beams) are casted and tested as mentioned below.

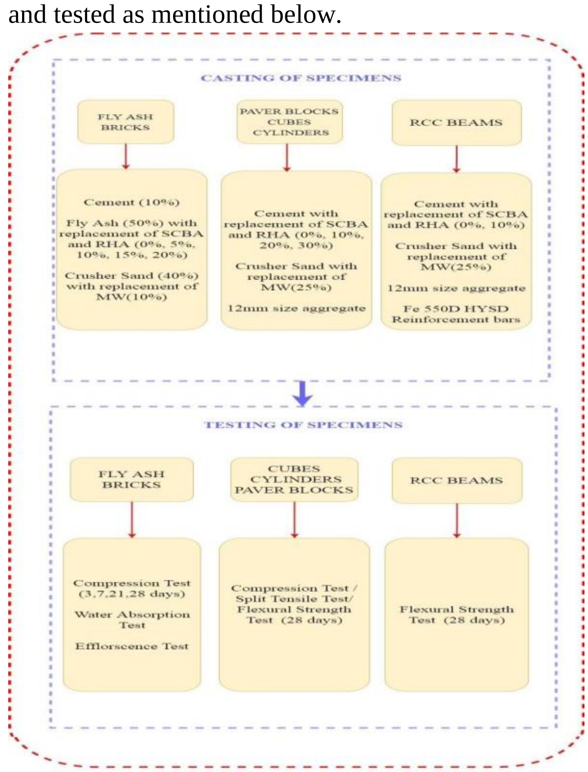


Figure 2.1 Methodology

3. MATERIALS

3.1 General
In this research seven types of materials are used for casting construction products which are listed below.

3.2 Cement
Cement in general adhesive substances of all kinds but in a narrower sense the binding materials used in building and civil engineering construction. Cements of this kind are finely ground powders that when mixed with water set to a hard mass. Setting and hardening result from hydration, which is a chemical combination of the cement compounds with water that yields submicroscopic crystals or a gel-like material with a high surface area. Because of their hydrating properties constructional cements which will even set and harden under water are often called hydraulic cements. The most important of these is Portland cement (OPC and PPC). In this study Coromandel cement of OPC 53 Grade was used.

3.3 Fine Aggregate

Fine aggregates are essentially any natural sand particles won from the land through the mining process. Fine aggregates consist of natural sand or any crushed stone particles that are 4.75mm or smaller. In this study Crusher Sand procured nearby was used after sieving as per Indian standards.

3.4 Coarse Aggregate

Coarse aggregates are construction component made of rock quarried from ground deposits. In this study 12mm aggregate were used for casting which are procured nearby.

3.5 Sugar Cane Bagasse Ash (SCBA)

Sugarcane Bagasse Ash collected from the nearby Sugar Industry. A large amount of sugarcane processed on sugar mill and sugarcane bagasse is burn in boiler around at temp 400 C to 600 C. The samples were collected from the landfill of the sugar mill. The Sieving is done in the laboratory to remove other dust particles and the fine sugarcane ash obtained.

3.6 Rice Husk Ash (RHA)

RHA is a good super-pozzolana. RHA can be used in a big way to make special concrete mixes. There is a growing demand for fine amorphous silica in the production of special cement and concrete mixes, high performance concrete. Rice Husk Ash collected from the nearby Rice Industry

3.7 Marble Waste (MW)

Marble Waste is collected from nearby marble Industry and they were crushed into fine particles in stone crusher. Sieve analysis is done as per Indian standards and the Marble Waste passing through 4.75mm sieve are used as Marble Waste Fine Aggregate.

3.8 Fly Ash

Fly Ash of class F is collected from nearby Mettur Thermal Power Plant.

4. MIX DESIGN

4.1 FLY ASH BRICKS

In this study Fly Ash Bricks mix proportion as per recommended standards are followed. Three types of proportions are available according to the materials used. In this study Proportion – 1 was adopted.

Proportion – 1

- Fly ash (50-60%)
- River Sand or Crusher Sand (30-40%)
- Cement (8-12%)

Proportion – 2

- Fly ash (55-60%)
- River Sand or Crusher Sand (20-25%)
- Sludge Lime (15-22%)
- Gypsum (5%)

Proportion – 3

- Fly ash (57-65%)
- River Sand or Crusher Sand (18-27%)
- Hydrated Lime (9-12%)
- Gypsum (5%)

5. RESULTS AND DISCUSSION

5.1 COMPRESSIVE STRENGTH

From Table 7.1, the fly ash bricks (FB2) with marble waste as fine aggregate shows 8.45% increased compressive strength when compared to control specimen (FB1). Addition of sugarcane bagasse ash blended specimens (FB3-FB6) reduces the strength but gives minimum desired strength.

5.1.1 Compressive Strength Results of fly ash bricks

Table 5.1 Mean compressive strength of fly ash bricks

S. No.	MIX ID	Mean Compressive strength (in N/mm2)			
		3 Days	7 Days	14 Days	28 Days
1	FB 1	3.14	3.59	7.38	7.69
2	FB 2	3.64	3.94	7.56	8.34
3	FB 3	3.86	4.02	6.46	6.79
4	FB 4	3.52	3.98	6.27	6.53
5	FB 5	3.35	3.42	4.54	4.69
6	FB 6	3.18	3.24	4.32	4.55
7	FB 7	3.59	3.96	6.08	6.33
8	FB 8	3.38	3.82	6.15	6.44
9	FB 9	2.95	3.11	4.32	4.55
10	FB 10	2.1	3.22	4.3	4.41

Addition of rice husk ash blended specimens (FB7) at 10% gives more strength than other mixes (FB8-FB10). The Graph (Figure 5.1) indicates the compressive strength of ten mix proportions at 3, 7, 21, 28 days curing.

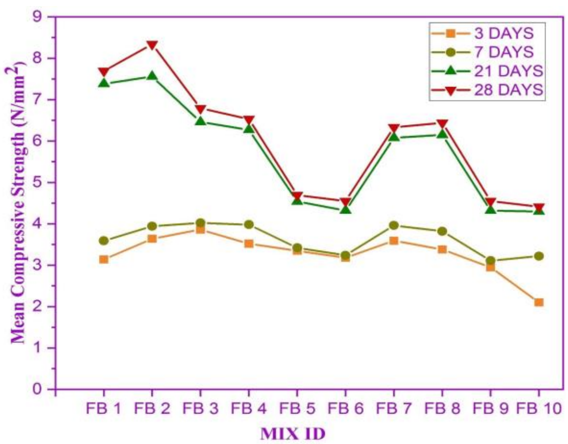


Figure5.1 Compressive Strength of Fly Ash Bricks

5.1.2 Compressive Strength Results of Cubes

Table 5.2 shows the mean compressive strength of cubes at 28 days curing and from the graph (Figure 5.2) it identifies that C2 mix achieves higher compressive strength of 6.8% than C1 mix. C3 mix strength is 11% decreased than C2 mix, 5% than C1 mix and C6 mix strength is 12.6% decreased than C2 mix, 6.7% than C1 mix. C8 mix get lower compressive strength of 33.19N/mm2.

Table 5.2 Mean Compressive Strength of Cubes

S. No.	MIX ID	Mean Compressive strength (in N/mm2)
1	C 1	45.78
2	C 2	48.89
3	C 3	43.49
4	C 4	40.71
5	C 5	36.02
6	C 6	42.73
7	C 7	40.02
8	C 8	33.19

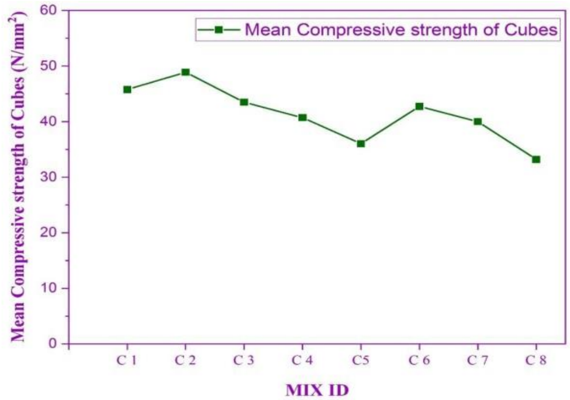


Figure5.2 Mean Compressive Strength of Cubes

5.2 SPILT TENSILE STRENGTH

From Table 5.3, it shows that cylinder specimens cast with 25% percentage of Marble Waste as fine aggregate shows slightly higher split tensile strength, when compared to control specimen. Addition of sugarcane bagasse ash for cement percentage decreases the split tensile strength. Similarly, Addition of Rice Husk Ash also shows decreased strength.

Table 5.3 Mean Split Tensile Strength of Cylinders

S. No.	MIX ID	Mean Split Tensile Strength (in N/mm2)
1	C 1	4.44
2	C 2	4.81
3	C 3	3.61
4	C 4	2.68
5	C 5	1.94
6	C 6	3.15
7	C 7	2.13
8	C 8	1.39

The SCBA/RHA blended specimens (C3-C8) shows reduced strength by increasing the proportion percentage. Figure 5.3 shows the mean split tensile strength at 28days curing, C2 mix achieves higher strength about 8.3% than C1 mix. Bagasse ash blended C3 mix get 25% lesser strength of C1 mix, 18.7% of C2 mix. Rice husk ash blended C6 mix get 29% lesser strength of C1 mix, 34.5% of C2 mix.

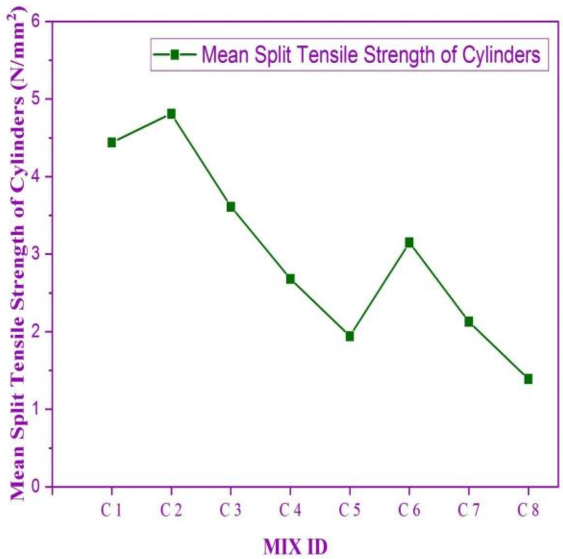


Figure 5.3 Mean Split Tensile Strength of Cylinders

5.3 FLEXURAL STRENGTH

5.3.1 Paver Blocks

From Table 7.4, the paver block specimens cast with 25% percentage of marble waste (C2) as fine aggregate shows 19.5% higher flexural strength when compared to control specimen (C1). Addition of sugarcane bagasse ash for 10 and 20 percentages gives desired flexural strength of M40 mix. Similarly Addition of 10 percentage rice husk ash (C6) gives 7.5% increased strength than control specimen (C1).

Table 5.4 Mean Flexural Strength of paver blocks

S. No.	MIX ID	Mean Flexural Strength (in N/mm2)
1	C 1	45.07
2	C 2	53.88
3	C 3	44.56
4	C 4	42.40
5	C 5	33.59
6	C 6	48.46
7	C 7	38.55
8	C 8	29.74

Flexural strength of paver blocks for eight different mixes (C1-C8) in which C2 mix attains 19.5% maximum increased strength of C1 mix as shown in Figure 7.4. Bagasse ash blended mix C3 mix strength decreased about 1.1% of C1 mix, 17.3% of C2 mix. Rice husk ash blended mix C6 mix strength decreased about 7.5% of C1 mix, 10.05% of C2 mix.

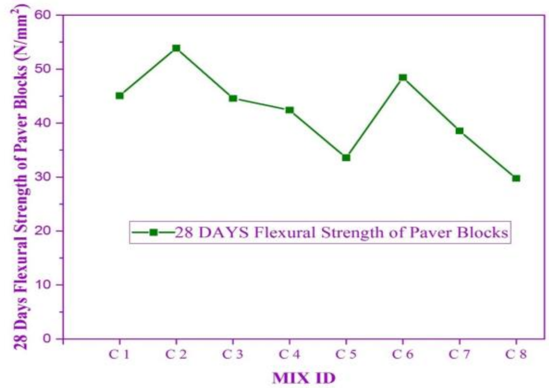


Figure 5.4 Mean Flexural Strength of Paver Blocks

5.3.2 RCC Beams

From Table 7.5, the beam specimens cast with 25% of marble waste as fine aggregate withstand Ultimate load of 86.2 kN, sugarcane bagasse ash for 10% gives ultimate load of 79.1kN and rice husk ash gives the least ultimate load of 44.6 kN.

Table 5.5 Load Vs Deflection of Beams

SI. No	B1 (25% MW)		B2 (10% SCBA)		B3(10% RHA)	
	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)	Load (kN)	Deflection (mm)
1	2.80	0.20	3.00	0.20	2.60	0.20
2	5.40	0.50	5.70	0.50	6.40	0.40
3	8.10	0.70	8.50	0.70	9.00	0.70
4	12.40	1.00	12.90	1.00	12.70	0. 9
5	15.90	1.20	16.60	1.20	16.40	1.20
6	20.00	1.50	19.40	1.50	19.60	1.40
7	23.10	1.70	22.90	1.60	23.10	1.70
8	29.00	2.00	27.60	2.00	26.50	1.90
9	33.30	2.20	30.90	2.20	30.40	2.20
10	37.30	2.40	34.30	2.40	33.50	2.40
11	41.40	2.70	39.40	2.70	36.70	2.60
12	47.60	2.90	44.60	2.90	41.00	2.90
13	52.40	3.20	49.00	3.10	45.40	3.10
14	57.70	3.24	53.80	3.40	47.90	3.40
15	61.80	3.60	58.50	3.60	50.70	3.60
16	68.50	3.90	64.90	3.90	54.20	3.90
17	73.60	4.10	69.20	4.40	57.10	4.10
18	76.30	4.40	74.60	4.30	57.10	4.40
19	80.90	4.60	79.10	4.60	42.90	4.60
20	84.00	4.80	75.80	4.70	44.60	4.80
21	86.20	5.10	72.60	5.00	43.80	5.10
22	72.20	5.40	69.10	5.10	43.30	5.30
23	72.20	5.60	65.60	5.10	41.70	5.60
24	71.70	5.80	63.50	5.20	39.80	5.60
25	69.60	6.10	62.10	5.40	36.00	5.70

Load Vs Deflection curve of three different mixes (B1, B2, and B3) as shown in Figure 7.5 are plotted where B1 attains maximum ultimate load of 86.2kN with 5.1mm deflection, B3 attains lower ultimate load of 44.6kN with 4.8mm deflection, B2 attains higher ultimate load than B3, lower ultimate load than B1.

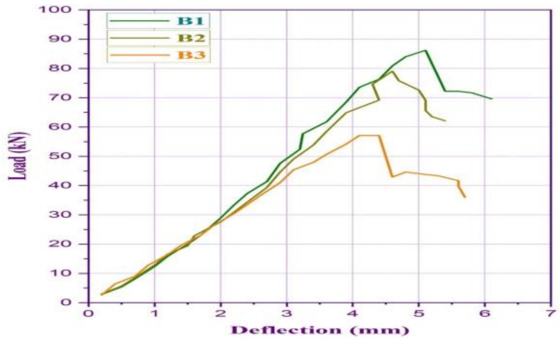


Figure 5.5 Flexural Strength of Beams

5.4 WATER ABSORPTION TEST

Table 7.6 shows the water absorption of fly ash bricks specimens. It clearly explains that with increase in replacement of sugarcane bagasse ash and rice husk ash increases the water absorption percentage.

5.4.1 Fly Ash Bricks

Table 5.6 Water Absorption Test of fly ash bricks

S. No.	MIX ID	WATER ASORPTION (%)
1	FB 1	4.32
2	FB 2	4.18
3	FB 3	4.5
4	FB 4	4.95
5	FB 5	5.3
6	FB 6	5.65
7	FB 7	4.8
8	FB 8	5.01
9	FB 9	5.9
10	FB 10	6.21

From the graph it clearly indicate that FB 2 attains least water absorption than other mixes as shown in Figure 7.6. By increasing the SCBA/RHA proportions the water absorption percentage increases, FB10 get higher water absorption of 6.2%.

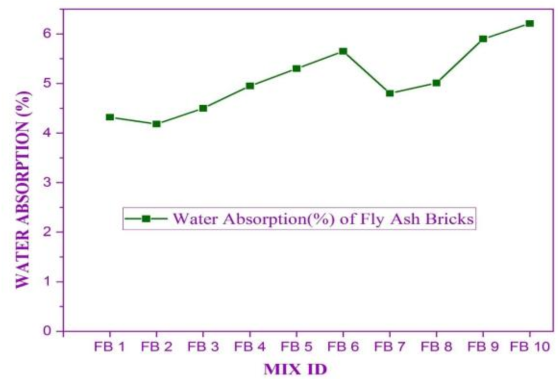


Figure 5.6 shows the water absorption of fly ash bricks.

5.4.2 Paver Blocks

Table 5.7 shows the water absorption of paver blocks specimens. It clearly explains that with increase in replacement of sugarcane bagasse ash and rice husk ash increases the water absorption percentage. From the graph Figure 5.7 it clearly indicate that C2 mix is least than other mixes, by increasing the SCBA/RHA proportions the water absorption increases.

Table 5.7 Water Absorption Test of paver blocks

S. No.	MIX ID	WATER ASORPTION (%)
1	C 1	3.89
2	C 2	3.76
3	C 3	4.05
4	C 4	4.46
5	C 5	4.77
6	C 6	5.09
7	C 7	4.32
8	C 8	4.51

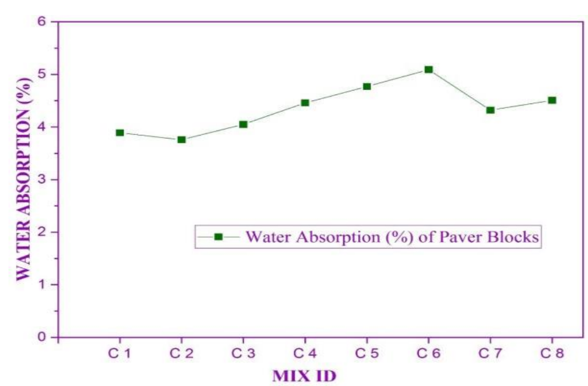


Figure 5.7 Water Absorption Test of paver blocks

5.5 EFFLORESCENCE TEST

Table 5.8 shows the efflorescence reported as ‘Slight’ and ‘Moderate’ for all specimens tested.

Table 5.8 Efflorescence Test of fly ash bricks

S. No.	MIX ID	EFFLORESCENCE
1	FB 1	Slight
2	FB 2	Slight
3	FB 3	Slight
4	FB 4	Moderate
5	FB 5	Moderate
6	FB 6	Moderate
7	FB 7	Slight
8	FB 8	Moderate
9	FB 9	Moderate
10	FB 10	Moderate

6.CONCLUSION

From this experimental study, the results are concluded as

The addition of marble waste (10% for fly ash bricks, 25% for concrete specimens) on the substitution of fine aggregate increases the compressive strength, split tensile strength, and flexural strength.

At 5% replacement of fly ash with sugarcane bagasse ash, the compressive strength of fly ash bricks is higher when compared to other SCBA proportions. Likewise at same percentage of rice husk ash gives higher strength.

At 10% replacement of cement with sugarcane bagasse ash, the concrete strength is higher when compared to other SCBA proportions. Likewise at same percentage of rice husk ash gives higher strength.

At 25% replacement of marble waste as fine aggregate the flexural strength of reinforced concrete beams gives the highest ultimate load of 86.2kN with

5.1mm deflection than other proportions.

Beyond 10% replacement of SCBA/RHA, the strength decreases than the control specimen but the obtained strength are efficient enough to use in Non-bearing structures like partition walls, parapet walls, and temporary sheds.

Addition of SCBA/RHA in both fly ash bricks and Concrete specimens leads to higher water demand.

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