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Effect of Banana Fibre on Strength Properties of Bagasse ash & Rice Husk ash blended high performance concrete composite

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Abstract

This paper presents the details of an experimental investigation conducted on various specimens to understand the behavior of high-performance fiber reinforced concrete composites with banana fibers of 0.2%, 0.4% and 0.6% to the total volume of concrete blended with agricultural wastes such as bagasse ash (BA) and rice husk ash (RHA). All the mix contains varying proportions of 7.5%, 10% and 12.5% of RHA and constant 10% of BA replaced with Portland cement. The results of the experimental investigation show that the addition of 10% BA and 10% RHA enhances the mechanical properties of the conventional concrete. By the incorporation of banana fiber, the properties of BA &RHA blended high performance concrete was substantially increased. From the various combinations of banana fiber, the best performance was attained by the mixture that contains the proportions of 0.2% of banana fiber.

Keywords: Bagasse ash, Rice husk ash, Strength tests and Durability test.

1. Introduction

Construction industry is one of the fastest growing sectors in India. Rapid construction activity and growing demand of houses has led to the short fall of traditional building materials. Bricks, Cement, sand, and wood are now becoming scares materials. Demand of good quality of building materials to replace the traditional materials and the need for cost effective and durable materials for the low-cost housing has necessitated the researchers to develop variety of new and innovative building materials. Construction materials of special requirements for the houses in different geographical region to overcome the risk of natural hazard and for protection from severe climatic conditions has also emphasized the need for development of lightweight, insulating, cost effective, durable and environment friendly building materials. During the 20th century there has been an increase in the consumption of mineral admixtures by the cement and concrete industries. This rate is expected to increase. The increasing demand for cement and concrete is met by partial cement replacement. Substantial energy and cost savings can result when industrial by products are used as partial replacement for the energy-intensive Portland cement[2]. The presence of mineral admixtures in concrete is known to impart significant improvements in workability and durability. The use of by-products is an environmental-friendly method of disposal of large quantities of materials that would otherwise pollute land, water and air. The current cement production rate of the world, which is approximately 1.2 billion tons/ year, is expected to grow exponentially to about 3.5 billion tons/ year by 2015. Most of the increase in cement demand will be met by the use of supplementary cementing materials, as each ton of Portland cement clinker production is associated with a similar amount of CO_2emission [6].

2. Research Significance

Few investigations had been carried out on the strength and durability assessment of BA with RHA as a supplementary cementitious material. But there were very few study's available with the incorporation of banana fibre in the composite concrete, which induced the authors to study about the performance of the banana fibre reinforced composite concrete. Preliminarily the strength properties were investigated with various compositions (7.5%, 10% & 12.5%) of RHA and a constant 10% of BA as partial replacement of cement. This composite concrete had shown the enhancement in strength properties with 10% BA and 10% RHA. Also, this blended composite concrete had varying percentage (0.2%, 0.4% & 0.6%) of banana fibre. This mechanical and workability properties were tested for this banana fibre reinforced composite concrete had shown that there was an improvement in its properties with 0.2% of banana fibre compared to other compositions and conventional concrete. The above percentages of agro industrial wastes and volume fractions of banana fibres used in the investigation were taken from the maximum suggested literature.

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3. Materials and Methods

***A.Cement*:** It is a binding material and an important constituent used on concrete. Portland Pozzolana Cement (PPC) was used which conforms to Indian standards [15]and the properties are shown in Table 1.

***B.Fine aggregate*:** The fine aggregate used was locally available M-Sand which conforms to Indian standards [16] and the properties are shown in Table 2

***C.Coarse aggregate*:** For this experimental work 20mm size angular coarse aggregates was used. Aggregates are tested as per Indian standards [16]and its properties are shown in Table3

***D.Water*:** Portable water conforms to Indian standards [17] specifications, available in college campus.

***E. Super plasticizer*:** Polycarboxylate ether named glenium sky 8233 was used. The specific gravity of the super plasticizer is 1.08.

F. Sugar cane bagasse ash (BA): It is a by-product of sugar and alcohol production, is a potential pozzolanic material. However, its effective application in mortar and concrete requires first the controlled use of grinding and classification processes to allow it to achieve the fineness and homogeneity that are required to meet industry standards. In general, bagasse ash is disposed of in landfills and is now becoming an environmental burden. It is estimated that more than 200,000 tons of bagasse ash are produced every year in India, and this increases annually. For the experiment BA which passes through 75 µ IS sieve was used and its specific gravity was 1.89.

Table 1 Properties of cement

S.No.	Experiment conducted	Results
1.	Fineness (IS 403 PART 1)	2%
2.	Consistency (IS 403 Part 4)	32%
3.	Initial setting time (IS 403 Part 5)	120 min
4.	Final setting time (IS 403 Part 5)	360 min
5.	Soundness (IS 4301 Part 3)	1mm

Table 2 Properties of Fine aggregate

S.No.	Experiment conducted	Results
1.	Specific gravity (IS 2386 part 3)	2.57
2.	Bulk density (IS 2386 part 3)	1657.142 g/m^3
3.	Water absorption (IS 2386 part 1)	3%
4.	Fineness Modulus (IS 2386 part 1)	3.186
5.	Grading zone	II

Table 3 Properties of Coarse aggregate

S.No.	Experiment conducted	Results
1.	Specific gravity (IS 2386 part 1)	2.779
2.	Water absorption (IS 2386 part 3)	0.52%
3.	Bulk density (IS 2386 part 3)	Loose state – 1673.41 kg/m^3 Rodded state - 1729.59 kg/m^3
4.	Elongation index (IS 2386 part 1)	27.96%
5.	Flakiness index (IS 2386 part 1)	8.2%

G. Rice husk ash (RHA): It is a major by-product of the rice milling industry, is one of the most commonly available lignocelluloses materials that can be converted to different types of fuels and chemical feedstock's through a variety of thermo chemical conversion processes. Rice husk is an agricultural residue abundantly available in rice producing countries. About 20 million tons of Rice husk ash (RHA) is produced annually. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. Lots of ways are being thought of for disposing them by making commercial use of this RHA. For the experiment RHA which passes through 75 µ IS sieve was used and its specific gravity was 2.25.

***H. Banana fibres*:** Banana fibres are generally lignocelluloses material, consisting of helically wound cellulose micro-fibrils in amorphous matrix of lignin and hemicelluloses. The cellulose content serves as a deciding factor for mechanical properties along with micro fibril-angle. A high cellulose content and low micro-fibril angle impart desirable mechanical properties for banana fibres. Lignin's are associated with the hemicelluloses and play an important role in the natural decay resistance of the lignocellulos's material. The tensile property of banana fibre was tested as per ASTM D3822.

The properties of banana fibre

- Diameter - 40µm
- Length – 20mm
- Aspect ratio - 500
- Tensile strength – 1160 MPa
- Elongation at break – 1.9%

4. Mix Proportions

The mix design for M50 grade of concrete was done as per Indian standards [1] and shown in Table no.6 above. The material compositions are shown in the Table no.5. For control mix (P1) cement content was arrived as 512 kg/m^3 from this 10% BA was constantly replaced with variables. The variables considered in this paper includes RHA with different percentages of 7.5%,10% and 20% to cement and Banana fiber with 0.2%,0.4%, and 0.6% to volume of concrete.

Table 5 Material composition

Proportion No.	BAGASSE ASH CONTENT (%)	RHA CONTENT (%)	BANANA FIBRE CONTENT (%)
P1.	10	-	-
P2.		7.5	-
P3.		10	-
P4.		12.5	-
P5.		7.5	0.2
P6.		7.5	0.4
P7.		7.5	0.6
P8.		10	0.2
P9.		10	0.4
P10.		10	0.6
P11.		12.5	0.2
P12.		12.5	0.4
P13.		12.5	0.6

Table 6 Mix proportions

Mix number	1	2	3	4	5	6	7	8	9	10	11	12	13
Designation	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13
W/B	0.25	0.31	0.32	0.33	0.31	0.31	0.31	0.32	0.32	0.32	0.33	0.33	0.33
Water (kg/m^3)	154	154	153	154	154	154	154	153	153	153	154	154	154
Cement (kg/m^3)	512	422	410	397	422	422	422	410	410	410	397	397	397
Bagasse ash (kg/m^3)	-	52	52	52	52	52	52	52	52	52	52	52	52
Rice husk ash (kg/m^3)	-	39	52	64	39	39	39	52	52	52	64	64	64
Banana fiber (%)	-	-	-	-	0.2	0.4	0.6	0.2	0.4	0.6	0.2	0.4	0.6
Fine aggregate (kg/m^3)	595	582	581	579	582	582	582	581	581	581	579	579	579
Coarse aggregate (kg/m^3)	1280	1250	1249	1245	1250	1250	1250	1249	1249	1249	1245	1245	1245
Super plasticizer (kg/m^3)	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56

5. Preparation of Test Specimens

The weight of the materials is calculated from mix proportions and weighed. The ingredients for concrete such as cement, fine aggregate, coarse aggregate, water and super plasticizer were hand mixed properly still uniform consistency occurred. Before casting, the moulds were oiled properly, then the concrete was poured in mould and compacted thoroughly using needle vibrator. The specimens were removed after 24 hours, then kept cured under water for 7 days and 28 days. The specimens are tested for compressive strength test, split cylinder strength test, and flexural strength test. Thedetails of hardened concrete test specimens are shown in below Table 7.

Table 7Details of hardened concrete test specimens and tests

S.No.	Type of Test	Specimens description	No. of specimens
1	Compressive strength test	150mm x 150mm x 150mm Cube	78
2	Splitting tensile strength test	150mm diameter and 300mm height cylinder	78
3	Flexural strength test	100mm x 100mm x 400mm prism	78

6. Results and Discussion

6.1 Workability studies

Workability is an important property of the freshly mixed concrete, which determines its ease and homogeneity conducted as per Indian standards [18]. The workability indicates the plasticity and stiffness of freshly mixed concrete. It also imparts the strength and durability of the concrete.

By the addition of BA and RHA there was no increase in workability observed. Similarly, there is decrease in workability by the addition of banana fiber, which was represented in Fig.1 and Fig.2. It also indicates that the increase of fiber content decreases the slump values i.e,. reduction in workability.

The decrease in workability was also confirmed by compaction factor test. This test confirms that there is a decrease in workability. It indicates by the addition of BA, RHA and banana fiber the concrete stiffens and the becomes more plastic.

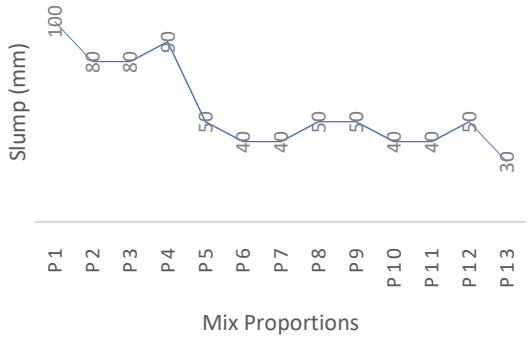

Fig.1 Slump values

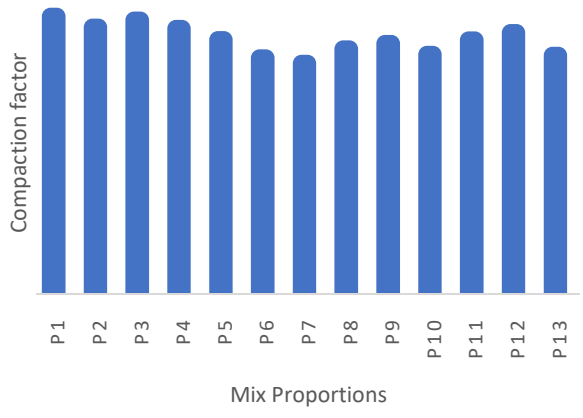

Fig.2 Compaction factor values

6.2. Compressive Strength

The compression strength test results for various concrete proportions are conducted after 7 days and 28 days of curing conducted as per Indian standards [19]. The compression test results after 7 days and 28 days at curing were shown in the below figure no.3 and 4. These results confirms that by the incorporation of BA, RHA and banana fiber slightly increases the compressive strength of concrete.Since the available of siliceous content in BA and RHA are more than the PPC, it improves the strength properties of concrete which confirms that the replacement of cement with pozzolanic materials increases the strength properties. From the 7 days compressive strength test results, there is a slight decrease in strength for about 5% to 16% compared to control mixed concrete. And from 28 days compressive strength test results, there is a significant increase in compressive strength for about 2% – 3% by the addition of pozzolanic materials and banana fiber. The test results show that the banana fiber also improve the compressive strength properties by increase in its volume.

6.3. Splitting Tensile Strength

The split tensile strength for 7 days and 28 days conducted as per Indian standards [19] are shown in the Fig. 5 and 6. It shows that by the addition of BA, RHA and banana fiber gives satisfactory results at 7 days and 28 days of curing. Generally, the fiber reinforced concrete has high strength properties compared to conventional concrete, this has been confirmed by comparing split tensile strength results between control mixed concrete and hybrid-fiber reinforced concrete. It infers that there is about 4% increment of strength at 7 days and 10% increment of strength at 28 days of curing.

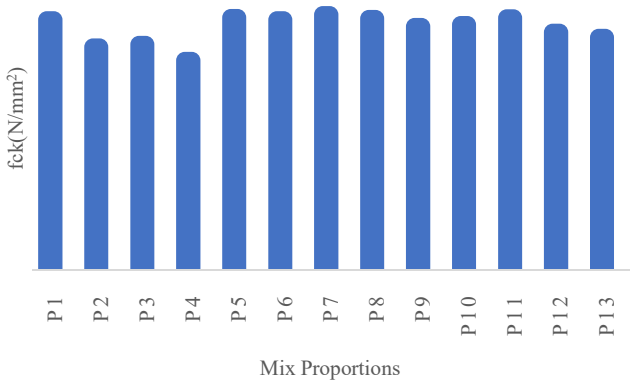

Fig. 3 Compressive strength test results at 7 days

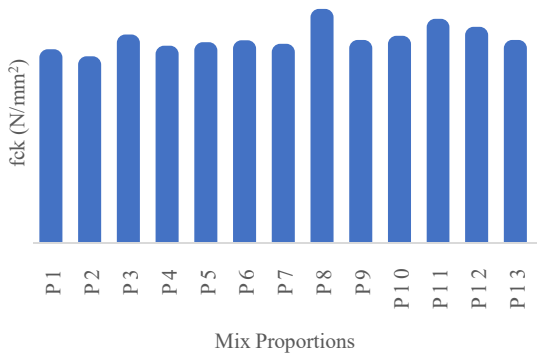

Fig. 4 Compressive strength test results at 28 days

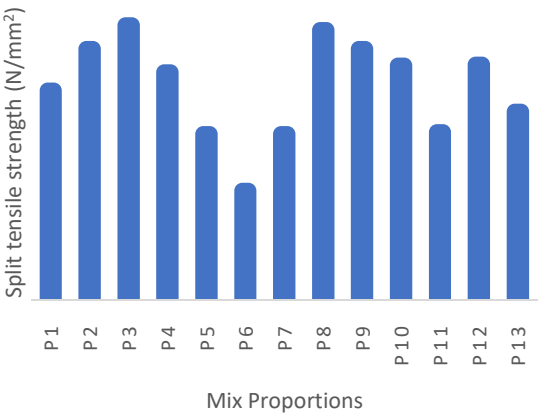

Fig. 5 Split tensile strength test results at 7 days

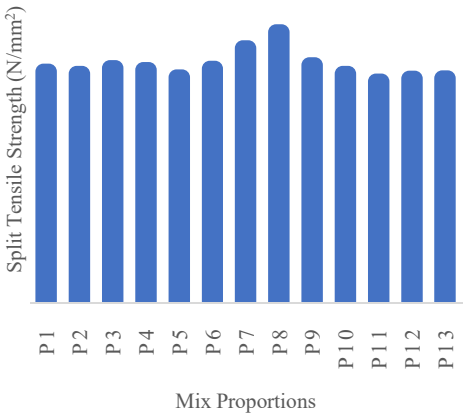

Fig. 6 Split tensile strength test results at 28 days

6.4. Flexural Strength

The flexural strength results for conventional concrete and hybrid-fiber reinforced concrete conducted as per Indian standards [19] was shown in the below Fig. 7 and 8. The flexural strength is one of the main properties of concrete which defines the maximum bending stress that can be applied before it yields. Even though there is no significant

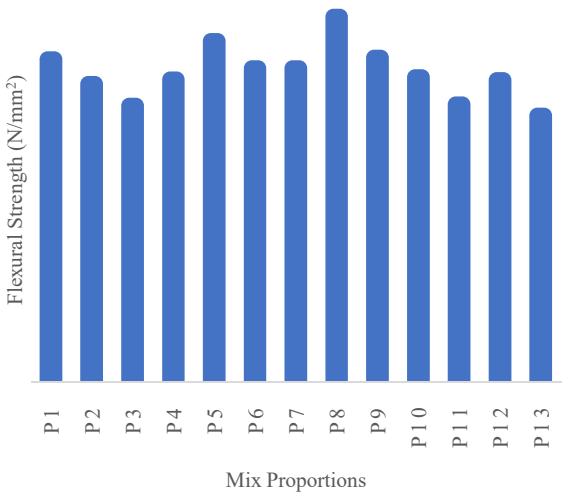

Fig. 7 Flexural strength test results at 7 days

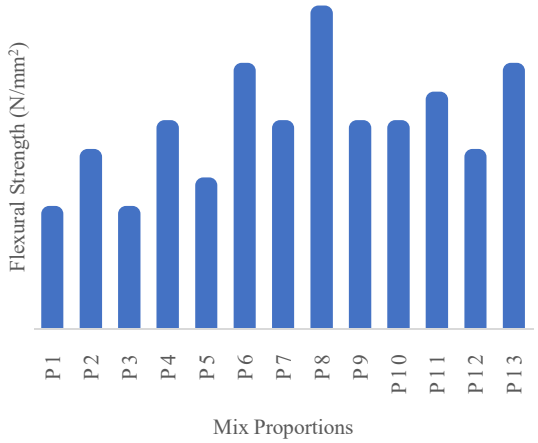

Fig. 8 Flexural strength test results at 28 days

increase in flexural strength after the addition of BA and RHA, the banana fiber which has high tensile strength restricts the deformation of specimen during loading and imparts more flexural strength. From the test results it confirms that there is an increase in flexural strength of about 6% and 9% at 7 days and 28 days respectively.

6.5. Drying Shrinkage

Generally, the shrinkage in concrete imparts reduction on durability of concrete. Since there are more amount of silica content in both cement substitute materials (BA and RHA) and their high fineness, the possibility for drying shrinkage is more due to the formation of more amount of higher C3S content. Due to the addition of banana fiber, the shrinkage strain has been controlled. The shrinkage strain was monitored for 3 days, 7 days, 14 days, 21 days and 28 days by using length compactor as per Indian standards [20]and the test results was shown in the below Fig. 9-13. These test results confirm that the addition of banana fiber control the shrinkage strain at significant rate.

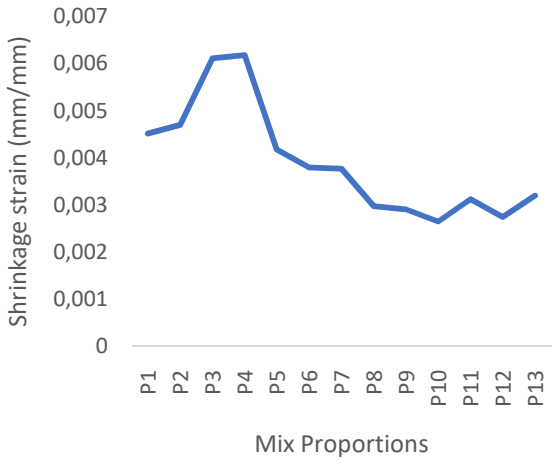

Fig. 9 Shrinkage strain at 3 days

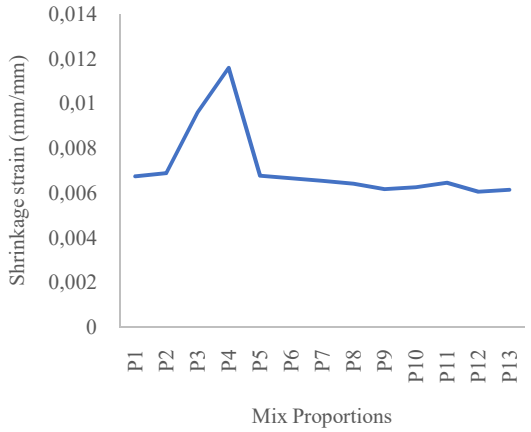

Fig. 10 Shrinkage strain at 7 days

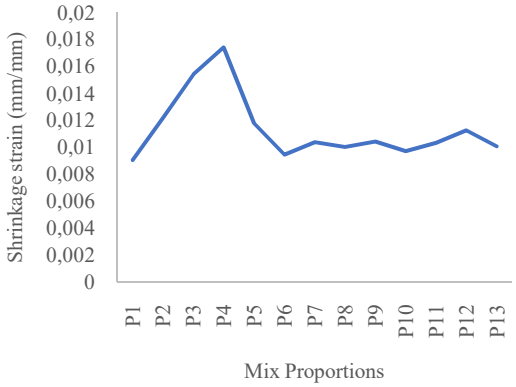

Fig. 11Shrinkage strain at 14 days

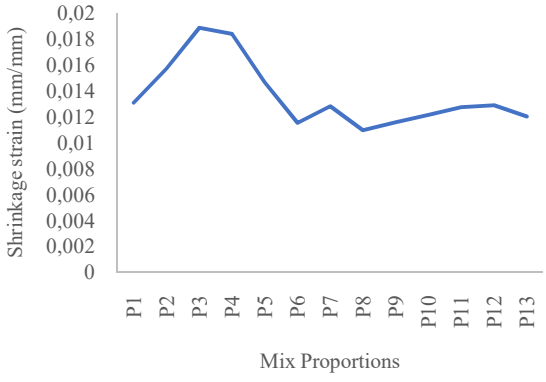

Fig. 12 Shrinkage strain at 21 days

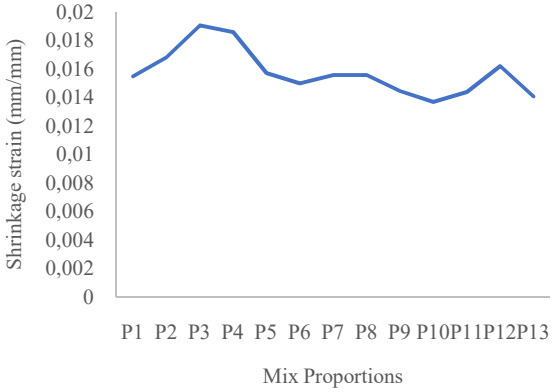

Fig. 13 Shrinkage strain at 28 days

7. Conclusions

The strength properties of high strength concrete which blended with BA and RHA was increased by the addition of banana fibers. Based on the test results and discussion from the above presented paper, the conclusions are;

- The workability of concrete was not achieved to the required value by the increase of natural fiber content. And the compaction factor value infers that the increase in fiber content makes the concrete stiffer and more plastic.
- By the replacement of BA-10% and RHA-10% has improved strength properties compared to other mixes. This is due to increased density of cementitious material which improves bond between aggregates and cementitious paste, finally there is an increase in strength properties.
- Introduction of fibers to concrete improves its strength properties due to the effective bond between the fibers and matrix of concrete. It is observed that banana fiber of 0.2% has significantly improves the tensile properties of concrete.
- The addition of fibers in the hybrid concrete controls the shrinkage strain and makes the concrete more durable compared to other mixes.
- The hybrid-fiber reinforced concrete with BA-10%, RHA-10% and banana fiber-0.2% has enhanced strength properties compared to other mixes and improves the durability by reducing the shrinkage strain.

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