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Experimental Investigation of Ternary Blended Concrete with Sugarcane Bagasse Ash as partial replacement of Natural sand

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Abstract

Concrete are the most frequently used man-made material, with a 25 billion tonne manufacturing volume and 5% greenhouse gas emissions. Concrete composites release a lot of CO2 into the environment. Thus, replacing concrete composite raw material is a priority. To reduce this industry's carbon footprint, large-scale reuse of industrial byproducts, including Bottom Ash (BA), Silica Fume (SF), and Ground Granulated Blast-Furnace Slag (GGBS) in cementitious composites, is growing. This method addresses the waste management for industry byproducts in two ways. The mechanical strength and durability of cementitious composite products with many ingredients must be recognised. This study's major goal is to evaluate high-strength cementitious composites' mechanical strength and durability. SF (5%, 7.5%, and 10%), and GGBS (10%, 15%, and 20%) binder were used to make high-strength cementitious composites. Waste management has developed into a problem for the environment. The illegal and unethical practices involved in mining natural river sand (NRS) have gotten worse. Therefore, by substituting Sugarcane Bagasse Ash (SBA)for fine aggregate, the lack of NRS for a building is prevented. Sugarcane Bagasse Ash(SBA) was employed to replace natural river sand at different levels of replacement as the fine aggregate phase in 10%, 20%, and 30%. The fresh cementitious composites properties were evaluated, strength properties such as compressive strength and split tensile strength were also evaluated. We shall compared it with normal concrete based on the results.

Keywords: *Cement Fine aggregate Coarse aggregate, Bottom ash, Silica fume, GGBS and SBA*

1. Introduction

The Buildings and roads use concrete. Concrete is primarily Ordinary Portland Cement (OPC), natural aggregate with various OPC particle sizes, and water. Mineral admixture is used to decrease the cost of the mixture upon improvement of workability of fresh concrete. Fresh concrete mixtures containing mineral admixtures are less bleeding. Thus, the combined use of Bottom ash and silica fume is an interesting alternative. Bottom ash is widely used in blended cements and is a by- product of coal-fire dielectric power plants; Bottom ash is Low-calcium Bottom ash (class-f) produced by bituminous coal; less than 8% CaO produced by bituminous and High-calcium Bottom ash (class-c) 8–20% CaO produced by burning lignite, generally it reacts faster than low- calcium Bottom ash which is a reason for early strength of concrete. Since more than three decades ago, people have been incorporating silica fume into concrete in order to make it stronger. In smelting silicon, a pozzolanic substance called silica fume is produced as a byproduct. It is used to manufacture ferrosilicon alloys and silicon metal, which contain a high percentage of glassy phase silicon dioxide (SiO2) and extremely minute spherical particles.

These combinations are better strength than OPC Despite this, very little information is now known about the characteristics of the combination of silica fume and bottom ash, such as its new properties, as well as the

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reaction mechanism of silica fume in the system of bottom ash.

2. Materials

2.1 Bottom ash

Bottom ash is the coarse, granular, incombustible by-product of coal combustion that is collected from the bottom of furnaces.

Fig.1 Bottom ash

2.2 Silica fume

Silica fume is made up almost entirely of amorphous (non-crystalline) silicon dioxide (SiO_2). Individual nanoparticles are incredibly minute, around 1/100th of the size of a typical cement particle. The silica fume that was measured had a specific gravity of 2.63.

Table 1: Physical properties of silica fume

S.No	Physical properties	Results
1.	Physical State	Micronized Powder
2.	Pack Density	0.76 gm/ Cc
3.	Odor	Odorless
4.	pH of 5% Solution	6.90
5.	Appearance	White Color
6.	Specific Gravity	2.63
7.	Color	White
8.	Moisture	0.058%

2.3 GGBS

GGBS is a by-product of the blast furnaces that are utilized in the production of iron. The iron ore is processed until it becomes pure iron, and the byproduct of this process is a slag that floats on top of the iron. The specific gravity of GGBS is 2.9, bulk density is 1000– 1100 kg/m3, and Fineness is more than 350 m^2/kg.

Fig.2 GGBS

2.4 Sugarcane Bagasse Ash

The by-products generated from the cogeneration and combustion process at certain temperatures of sugar cane bagasse, which is called bagasse ash (BA) shown in fig.2. Bagasse ash have low specific gravity comparative to cement i.e. 2.31–2.68. Its density varies from 1.85–2.65 g/cm^3.

Fig.3 Sugarcane Bagasse ash

3. Methodology

The present study focuses on conducting an experimental investigation to assess the strength properties. The specimens used for testing consist of cubes and cylinders which are employed for each concrete casting prior to conducting the slump test.

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The process of testing in mix consists of four distinct stages.

- ➢Binary mix (Cement + BA)
- ➢Ternary mix (Cement + BA + SF)
- ➢Quaternary mix (Cement + BA + SF + GGBS)
- ➢Quaternary mix + SBA (Replacement for NRS)

The strength properties of each mixture are tested at intervals of 7 and 28 days. The mixing process before casting is conducted for both cube specimens, with dimensions of 150 mm × 150 mm x 150 mm and cylinder specimens, with dimensions of 100 mm × 300 mm. Prior to the placement of concrete, a lubricant is applied to the moulds. Following the completion of the casting process, the moulds are subsequently extracted. The cubes and cylinders are transferred with caution to the curing tank. The cement utilized in the project was a 53-grade ordinary Portland cement, which was readily accessible and complied with the specifications outlined in the IS 12269-1987 standard.

4. Experimental Results

In the casting technique, two different types of concrete specimens are formed in corresponding moulds. The specimens consist of cubes and cylinders. Test specimens are cured by keeping them in an environment free of vibrations. Following the conclusion of this period, the specimens are labeled and removed from the moulds. They are immediately immersed in fresh, clean water kept there until precisely before testing unless the testing has to be done within 24 h. Every seven days, the water or solution immersed in the specimens is changed to maintain the same temperature of 27 ◦C + 2 ◦C. Before the specimens have been inspected, there is a strict prohibition against allowing them to get dry.

4.1. Concrete mixture composition

4.1.1. Samples preparations and test methods

In this study Bottom ash, silica fume, and GGBS were used to replace OPC up to 52.5% by weight. The replacement level of Bottom ash was 20, 30, 40%, silica fume was 5, 7.5, 10%, and GGBS was 10%, 15%, 20% by weight of OPC same water cement ratio is used as per reference mix. Finding the optimum percentages from the above in which the cement containing Bottom ash, silica fume, and GGBS, then SBA was used as the fine aggregate in place of natural river sand at various substitution levels such as 10%, 20%, and 30%. The total mix samples are 13.

4.2. Compressive strength

After the sample's surface dried, it was put to the test. The load was put on the smooth sides and kept heavier until the specimen broke. The compressive strength for Bottom ash concrete mixes values are determined. It is observed that at early age (7 days), for mixes BA20, BA30, and BA40 the percentage is decreased by 13.3%, 9.7%, 16.3%, and 13.3%, 9.7%, 16.4% when compared to OPC Concrete. Therefore, the BA30 mix exhibited higher compressive strength at later ages. At later age (28days) for BA20, BA30, and BA40, the percentage is increased by 3.8%, 1.73%, 2.04 and 2.08%, 4.08%, and 2.5%
compared to OPC Concrete.

4.2.1. Compressive strength of Bottom ash and silica fume concrete

It is observed that at an early age (7 days) for mixes BA30SF5, BA30SF7.5, and BA30SF10, the percentage increased by 20.9%, 27.7%, 22.8%, 20.8%, 27.6%, and 22.7% when compared to OPC Concrete. Therefore, the BA30SF7.5 mix exhibited higher compressive strength in the later ages.

4.2.2. Compressive strength for the Bottom ash, silica fume and GGBS

It is observed that at an early age (7 days) for mixes BA30SF7.5GGBS10, BA30SF7.5GGBS15, and BA30SF7.5 GGBS20, the percentage is increased by 51.4%, 58.5%, 47.46% and 48.9%, 56.4%, 47.2% when compared to OPC Concrete. At later age (28days) for BA30SF7.5GGBS10, BA30SF7.5GGBS15, and BA30SF7.5GGBS20, the percentage increased by 46.6%, 51.4%, 42.8%, and 44%, 52.2%, 38.9% when compared to OPC Concrete. Therefore, the BA30SF7.5GGBS15 mix exhibited higher compressive strength at later ages. A collapse slump will generally mean that the mix is too wet. Bottom ash, silica fume, and GGBS react with the calcium hydroxide produced during the hydration of cement to form additional cementitious compounds. This reaction continues over time, resulting in denser and stronger concrete.

4.2.3. Compressive strength of Bottom ash, silica fume, GGBS and SBA concrete

It is observed that at early age (7days) for mixes BA30SF7.5GGBS15SBA10, BA30SF7.5GGBS15SBA20, and BA30SF7.5GGBS15SBA30, the percentage is increased by 64.5%, 81.3%, 73.3% and 53.9%, 62.5%, 56.6% when compared to OPC concrete. At later age (28 days) for the mixes like BA30SF7.5GGBS15SBA10, BA30SF7.5GGBS15SBA20, and BA30SF7.5GGBS15 SBA30, the percentage is increased by 54.4%, 62.6%, 53.3% and 58.3%, 54.6%, 51.7% when compared to OPC Concrete. Therefore, the BA30SF7.5GGBS15SBA20 mix exhibited higher compressive strength in later age.

4.2.4. Comparison of binary, ternary, and quaternary mixes for compressive strength

Strength for compressive strength of optimum bottom ash, silica Fume, GGBS and SBA are determined and shown in Table 2. Due to studies regarding the extraction of raw materials, CO_2 emissions, and other topics, the use of SCMs in concrete has become more prevalent in recent years, rising in parallel with the development of the concrete industry. As a result of these effects, there has been a need for a reduction in the utilization of cement- making raw materials via the utilization of supplementary cementitious materials such as Bottom ash, micro silica, and other similar minerals.

Table 2 Compressive strength of optimum bottom ash, silica Fume, GGBS and SBA

	Compressive strength (MPa)	
MIX	**7DAYS**	**28DAYS**
OPC	27.96	42.37
BA20	24.24	36.73
BA30	25.24	38.24
BA40	23.38	35.43
BA30SF5	33.83	51.25
BA30SF7.5	35.72	54.12
BA30SF10	34.35	52.05
BA30SF7.5GGBS10	42.29	63.08
BA30SF7.5GGBS15	44.45	66.33
BA30SF7.5GGBS20	41.22	62.45
BA30SF7.5GGBS15SBA10	46.01	65.23
BA30SF7.5GGBS15SBA20	50.71	68.87
BA30SF7.5GGBS15ASBA30	48.8	66.35

The waste products generated by companies contribute to achieving sustainable development in the existing environment. The data shown in Fig.4 represents that the compressive strength of Bottom ash, silica fume, GGBS and SBA is optimal. Combining the maximum amount of cement with mineral admixtures may increase the concrete's qualities and ability to self-compact.

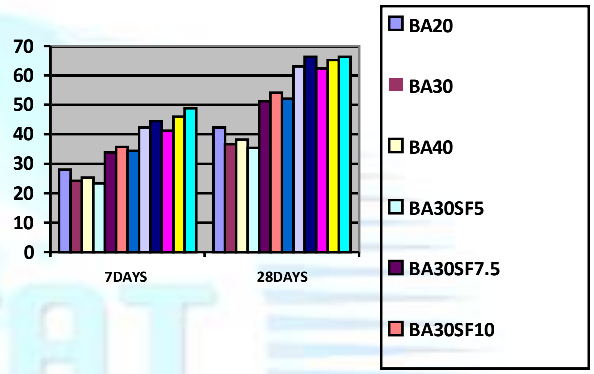

Fig.4 Strength for compressive strength of optimum bottom ash, silica Fume, GGBS and SBA.

4.3. Split tensile strength for OPC concrete

As anticipated, the flexural strength of the concrete sample increased as the number of curing days increased. The split tensile strength of cylinders is measured after 7 and 28 days. The study demonstrates that the size variations of GGBS as coarse aggregate replacement affect the characteristics of lightweight concrete. As the present study determined that the largest size of GGBS produced more strength, the larger sizes of GGBS will probably continue to enhance the attributes of lightweight concrete .

4.3.1. Split tensile strength for Bottom ash mix

At early age (7 and 28 days), the percentage of mixes BA20, BA30, and BA40 decreased by 6.5%, 4.7%, 8.1%, and 6.6%, 4.8%, 8.2% compared to OPC Concrete. At later age (90 and 180 days) for BA20, BA30, and BA40, the percentage increased by 1.8%, 0.85%, 1.0% and 1.03%, 1.9%, and 1.2% compared to OPC Concrete Therefore, the BA30 mix exhibited higher split tensile strength in later age. Concrete is the most adaptable building material because it can be constructed to resist

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the toughest situations and take on the most inventive shapes. With innovative chemical admixtures and extra cementation materials, engineers continuously push the boundaries to improve performance. Typically, strength gains persist beyond 28 days when moisture and temperature conditions are optimal

4.3.2. Split tensile strength for Bottom ash and silica fume mix

It is observed that at early age (7 days) for mixes BA30SF5, BA30SF7.5, and BA30SF10 Table is increased by 9.4%, 12.3%, 10.2%, and 9.6%,12.6%, 10.5% when compared to OPC Concrete. At later age (28days) for BA30SF5, BA30SF7.5, and BA30SF10, the percentage increased by 7.0%, 11.4%, 8.3% and 6.6%, 9.9%, 6.9% when compared to OPC Concrete. Therefore, the BA30SF7.5 mix exhibited higher split tensile strength at later age. Concrete's tensile strength is one of its most essential qualities. The concrete's tensile strength is required to determine the load at which concrete members may crack. This cracking is an example of tension failure.

4.3.3. Split tensile strength for Bottom ash, silica fume and GGBS mix

It is observed that at early age (7days) for mixes BA30SF7.5GGBS10, BA30SF7.5 GGBS15, and BA30SF7.5GGBS20, the percentage is increased by 21.8%, 24.7%, 20.3% and 21.3%, 24.3%, 20.7% when compared to OPC Concrete. At later age (28days) for BA30SF7.5GGBS10, BA30SF7.5GGBS15, and BA30SF7.5GGBS20, the percentage increased by 21.0%, 22.9%, 19.5%, and 20.0%, 23.3%, 17.9%. When compared to OPC concrete. Mix Design is selecting appropriate concrete materials and determining their relative proportions to produce concrete with specified minimum attributes, such as strength, durability, and consistency, as economically as possible. The maximum nominal size of aggregates used in concrete may be as large as possible within the IS 456:2000 restrictions. The cement content must be restricted to prevent shrinkage, cracking, and creep. Silica fume and GGBS are very fine particles that can fill in the voids between cement particles, resulting in a more compact and cohesive matrix. This microfiller effect contributes to improved packing and increased strength.

4.3.4. Split tensile strength of Bottom ash, silica fume, GGBS and SBA concrete

It is observed that at early age (7 days) for mixes BA30SF7.5GGBS15SBA10, BA30SF7.5GGBS15SBA20 and BA30SF7.5GGBS15SBA30 the percentage is increased by 26.8%, 32.8%, 30% and 23.3%, 26.6%, 31% when compared to OPC Concrete.

4.3.5. Comparison of binary, ternary and quaternary mixes for split tensile strength

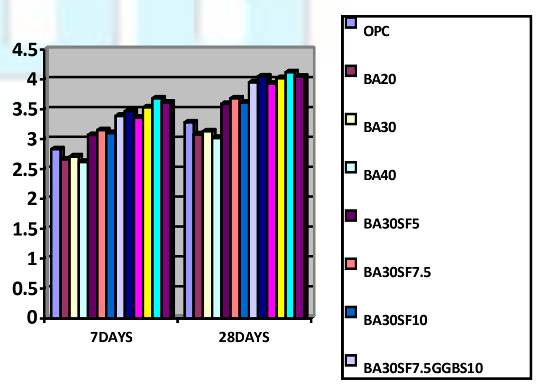
The characteristics of blended concrete exhibit values comparable to those of ordinary concrete and strength has been demonstrated for concrete, including micro silica, because of its high silica content. The Comparison of binary, ternary and quaternary mixes for split tensile strength is shown in table 3.

Table 3 Split tensile strength of optimum bottom ash, silica Fume, GGBS and SBA

	Split tensile strength (MPa)	
MIX	**7DAYS**	**28DAYS**
OPC	2.83	3.28
BA20	2.66	3.08
BA30	2.71	3.13
BA40	2.62	3.02
BA30SF5	3.07	3.59
BA30SF7.5	3.15	3.68
BA30SF10	3.10	3.61
BA30SF7.5GGBS10	3.39	3.95
BA30SF7.5GGBS15	3.47	4.05
BA30SF7.5GGBS20	3.36	3.93
BA30SF7.5GGBS15SBA10	3.53	4.02
BA30SF7.5GGBS15SBA20	3.68	4.12
BA30SF7.5GGBS15ASBA30	3.61	4.05

Conventional concrete may have its qualities improved with additives, which can also minimize the amount of chemical admixture required during the mixing process. The split tensile strength variations are shown in fig.5

Fig.5 Strength for Split tensile strength of optimum bottom ash, silica Fume, GGBS and SBA.



The results of the experimental investigation lead to the following inferences: maximal replacement of waste from industrial processes may be employed in concrete.

Conclusions

1. The integration of waste materials into construction practices offers the potential to mitigate the need for primary resources, diminish the production of waste, and foster the development of a construction sector that is more sustainable and environmentally conscious.
2. Bottom ash, silica fume, and GGBS, were implemented in the production of concrete. The materials above were employed as partial alternatives to cement and as substitutes for sugarcane bagasse ash, a frequently utilized river sand substitute in concrete production. Substituting conventional materials with waste materials can effectively mitigate resource consumption and encourage adopting sustainable practices within the construction sector.
3. The concrete mixture composed of BA30SF7.5GGBS15SBA20 demonstrated enhanced mechanical characteristics compared to Ordinary Portland Cement (OPC) concrete. The combination exhibited elevated compressive strength and split tensile strength, suggesting enhanced overall efficacy. By integrating waste materials into concrete composition, the resultant composite displayed improved strength properties, rendering it a more viable and long-lasting choice for various construction purposes.
4. The BA30SF7.5GGBS15SBA20 mix exhibited a percentage increase in compressive strength of 81.3% and 62.54% at early age, precisely at 7 days, respectively. The compressive strength of the concrete at later ages, precisely 28 days, exhibited a percentage increase of 61.6% and 56.6%, respectively, when compared to ordinary Portland cement (OPC) concrete. Similarly, the split tensile strength exhibited a percentage augmentation of 30% and 25.8% during the initial stages and 26.2% and 24.3% during the subsequent stages. The findings presented in this study illustrate the enhanced mechanical properties exhibited by the BA30SF7.5GGBS15SBA20 composite mixture, thereby suggesting its viability for implementation in various structural contexts.

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