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The Effectiveness of Using Sugarcane Bagasse Ash as a Partial Replacement of Cement in Concrete

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***Abstract:*-- This study analyses the strength properties of concrete by the partial replacement of cement with sugarcane bagasse ash. The replacement of cement with sugarcane bagasse ash will help to reduce the environmental problems associated with cement production such as CO2 emission. The Ordinary Portland cement is replaced with 0%, 5%, 10%, 15% and 20% by weight and the compressive, flexural, split tensile strength and modulus of elasticity are analysed. The results of this study indicate that the strength properties of concrete ascends with the increase in sugarcane bagasse ash content up to an optimum value and then it decreases. The optimum replacement value is found to be 10% replacement. The experiments were carried out in M25 grade of concrete.**

Keywords: Sugarcane Bagasse Ash, Cement Replacement, Concrete

I. INTRODUCTION

Ordinary Portland cement is a commonly used building material. As the cement quantity demand increases, it also increases the requirement of raw materials from the natural resources. One of the greatest challenges in the civil infrastructure is to meet the requirements of human society with the protection of environment. Portland cement production emits about 5-8% of global Carbon dioxide [1]. In the manufacturing process of cement, the burning of cement clinkers require a large amount of fuel. Nowadays the studies mainly focus on reducing the emission level of Carbon dioxide which is released into the atmosphere due to the high production of cement. For producing one ton of ordinary Portland cement, energy and raw materials of about 4.0 kJ and 1.5 tons are required respectively[2]. If the raw materials are replaced by some kind of cheaper materials, the cement production cost as well as the emission of carbon dioxide can be reduced. Blast furnace slag, silica fume and fly ash which are the industrial waste can be considered as cement replacement materials [3]. Many researches have been done to utilize the agricultural and industrial waste materials as raw materials [4]. The replacement of raw materials by cheaper materials will reduce the cost of concrete [5]. The agricultural wastes namely rice husk ash, wheat straw ash, and sugarcane bagasse ash can be used as pozzolanic materials. Hazel nutshell can be used as a cement replacement material [3].

Sugarcane bagasse is obtained as a by-product from sugar industries and by the controlled burning of bagasse will produce sugarcane bagasse ash (SBA) [6]. It is approximately 1500 million tons of worldwide total production of sugarcane. Brazil and India are the two major sugarcane producers in the world. The SBA which is considered as a waste material, will create high problems of disposal [6].

Generally, it is disposed in landfills and results in environmental problems. Many studies analysed the use of sugar cane bagasse ash, which is produced in the boilers of the sugar industry as a pozzolanic material [5]. The effect of replacement of cement with bagasse ash on the physical and mechanical properties of hardened concrete was studied by Ganesan et al [3].The advantage of partial replacement of cement with sugarcane bagasse ash is well established [6]. One of the factors which affect the reactivity of sugarcane bagasse ash are the conditions which is used in burning of bagasse [7]. The factors such as temperature and rate of heating can change the nature of bagasse ash reactivity [8]. The high early strength of concrete can be achieved by the replacement of cement with SBA and can also help in reducing the permeability of concrete [9]. Application of bagasse ash in concrete was proposed by Martirena et al. It is established that the addition of SBA will increase the strength of concrete because of its fine particle size, higher surface area, higher silica content (SiO_2 = 65%), higher degree of reactivity and higher pozzolanic reaction between calcium hydroxide and reactive silica in sugarcane bagasse ash [6].

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In this research, cement is partially replaced with SBA at 0%, 5%, 10%, 15% and 20%, and its strength characteristics are studied. This paper includes the compressive test, flexural test, split tensile test and modulus of elasticity test which were done on the above proportions.

II. MATERIAL DETAILS

2.1 Cement

53 grade Ordinary Portland cement (OPC) is used in this study. Standard tests for cement are conducted and the results obtained are given in table 1 below.

Table 1: Characteristics of cement

SI no:	Property of cement	Value obtained	Range as per IS code
1	Standard consistency	33%	26-33%
2	Initial setting time	35 min	>30mins
3	Final setting time	240 min	<600mins
4	Fineness	4%	<10%
5	7 day compressive strength	39 N/mm^2	>37N/mm^2
6	28 day compressive strength	54.5N/mm^2	>53N/mm^2

2.2 Fine aggregate

River sand which passes through 4.75mm IS sieve is taken as fine aggregate. Tests for specific gravity, bulk density, porosity, void ratio, grain size distribution and bulking properties of sand were analysed as per IS specification. In this study the sand used conforms to the Indian standards.

Table 2: Characteristics of fine aggregate

Sl. No.	Material test	Result
1.	Uniformity coefficient	4.45
2.	Effective size	0.22 mm
3.	Fineness modulus	4.9
4.	Coefficient of curvature	0.898
5.	Bulk density	1.689g/cc
6.	Void ratio	0.46
7.	Porosity	31.488%
8.	Specific gravity	2.667
9.	Moisture content of maximum bulking	10%
10.	Moisture content of zero bulking	17%
11.	% of maximum bulking	23.3%

2.3. Coarse aggregate

The crushed aggregates from original bed rocks of 20mm nominal maximum size are used for this study. Tests for Specific Gravity, Bulk Density, Porosity, Void Ratio and grain size distribution are conducted and found to be satisfying the Indian standards and results were within the permissible limit.

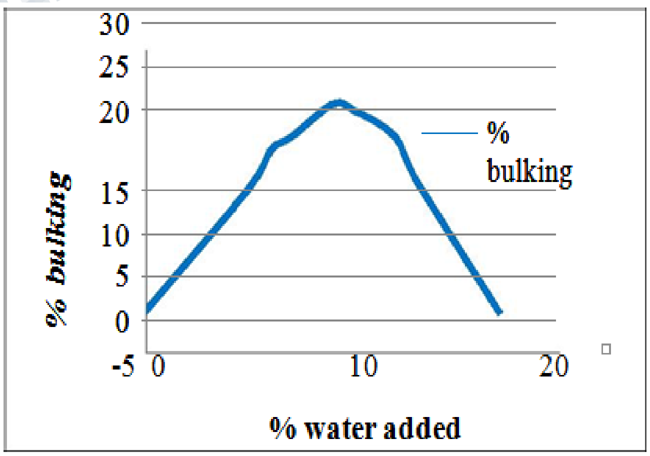

Fig.1. Bulking of sand

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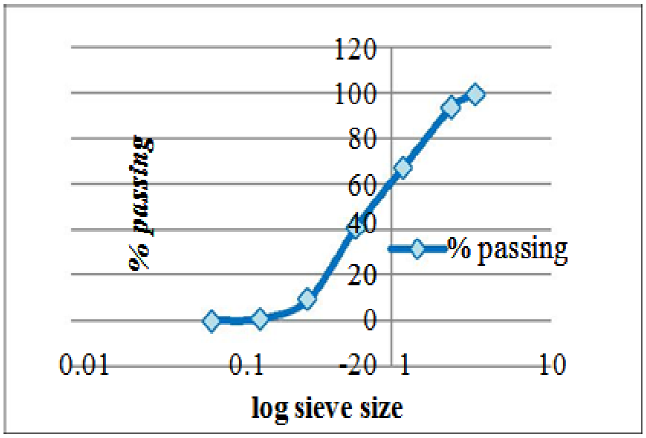

Fig.2. Grain Size Distribution of FA

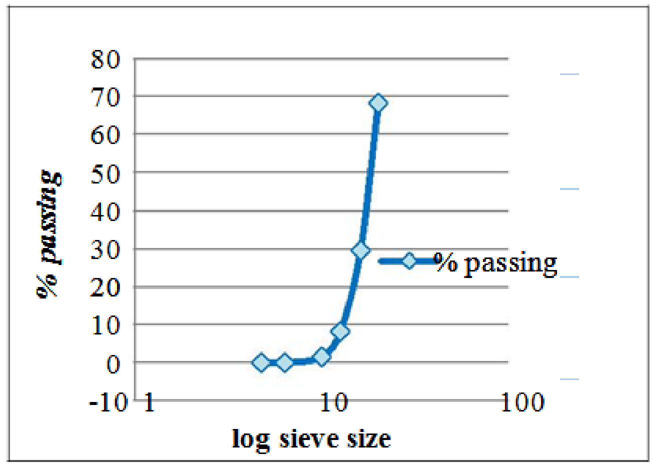

Fig.3. Grain Size Distribution of CA

Table 3: Characteristics of coarse aggregate

SI no:	Property of Coarse aggregate	Value obtained	IS Specifications
1.	Effective size	13	IS 2386(Part 1)-1963
2.	Uniformity coefficient	1.46	
3.	Fineness modulus	4.92	
4.	Bulk density	1.55 g/cc	IS 2386(Part 3)-1963
5.	Void ratio	0.849	
6.	Porosity	45.9%	
7.	Specific gravity	2.86	

Sugarcane Bagasse Ash (SBA)

The SBA passing through 90 micron sieve was collected from Dharani Sugar Factory, Rajapalayam, Tamil Nadu. The SBA was obtained during the cleaning operation of boiler of the factory. SBA contains high amorphous silica and aluminium ion content. The SBA with high silica content and the components of cement will react during the hydration process and will The effectiveness of using sugarcane baggage ash as a partial replacement of cement in concrete contribute to chloride resistance, corrosion resistance etc. [9]. The shape of cement particles are irregular and angular whereas the bagasse ash particles have rough surfaces with high porosity and large surface areas. Once the sugarcane bagasse ash is ground, it will become small in shape, still it will have rough and porous surfaces [5]

Fig.4. Sugarcane Baggage Ash

III. EXPERIMENTAL SETUP

In this research work, the total number of concrete samples casted are 60, among which 30 numbers were cubes with 150mm side, 15 numbers were 150mm diameter and 300mm long cylinders, and 15 numbers of 500mm x 100mm x

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100mm size beams. The mix design of concrete was done as per IS 10262-2009 for M25 grade and the water cement ratio is 0.5.

IV. RESULTS

4.1. Compressive strength

The 7 day strength and 28 day compressive strength of concrete cubes replaced with the SBA are shown in Fig 5 and Fig.6. The compressive strength increases with the increase in percentage replacement of cement by SBA up to 10%, beyond which the value decreases.

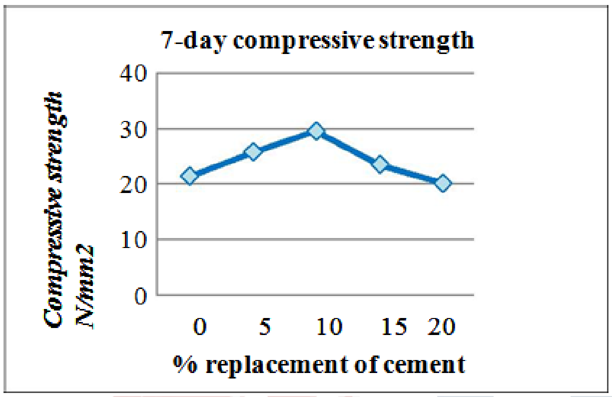

Fig.5. 7-Day compressive strength

With the 10% replacement of cement with SBA, the hydration reaction will be more than that of 15% and 20%. The increase in compressive strength at 10% replacement with SBA is because of the pozzolanic reaction between the bagasse ash and the Ca(OH)2 from the cement hydration.

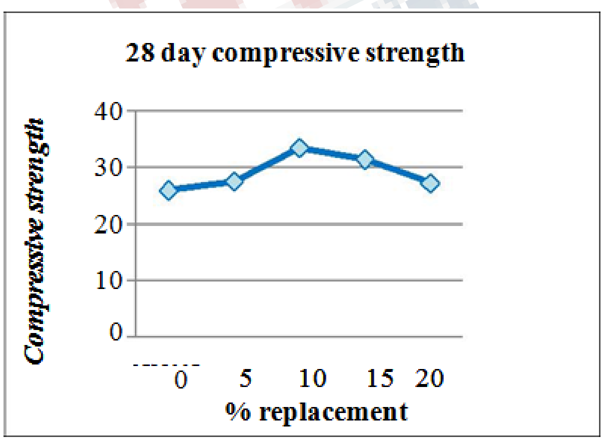

Fig.6. 28-Day compressive strength

Table 4: Comparison of SBA and OPC

Oxides	SBA	OPC
SiO_2	67.81%	20.98%
Al_2O_3	19.41%	5.42%
Fe_2O_3	3.85%	3.92%
CaO	4.03%	62.85%
MgO	1.11%	1.76%
Na_2O	0.35%	0.28%
K_2O	1.69%	0.53%
SO_3	0.66%	2.36%
Loss in ignition	1.09%	1.9%

Table 5: Proportions of M25 grade concrete (1m3 volume of concrete)

Sl no	Material	Quantity
1	Cement	414kg/m^3
2	Fine aggregate	708kg/m^3
3	Coarse aggregate	1090kg/m^3
4	Water	207kg/m^3

10% replacement of SBA, which may be due to the silica content and the degree of reactivity of the SBA.

4.2. Flexural strength

Fig.5 represents the 28 day flexural strength of concrete replaced with the SBA. The flexural strength of concrete is found to be higher at 10% replacement of cement.

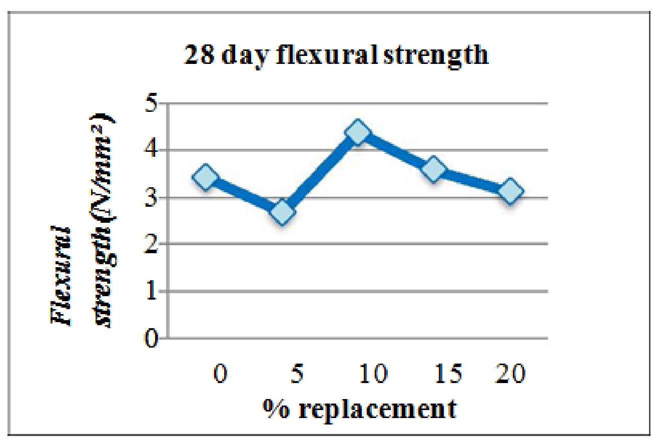

Fig.7. Flexural strength

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4.3. Split tensile strength

The variation of split tensile strength with the percentage replacement of SBA is represented in Fig.6. The split tensile strength is maximum at 10% replacement of cement with SBA. The decrease in split tensile strength beyond 10% replacement might be due to the dilution effect of concrete.

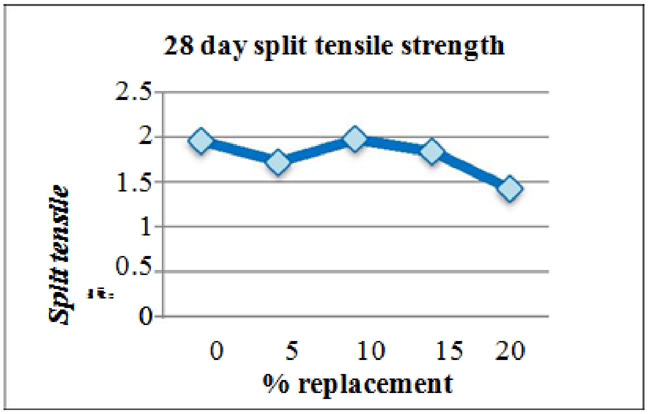

Fig.8. Split tensile strength

4.4 Modulus of Elasticity

The fig. 9 shows the variation of modulus of elasticity of concrete with the percentage replacement of the SBA. The modulus of elasticity increases up to

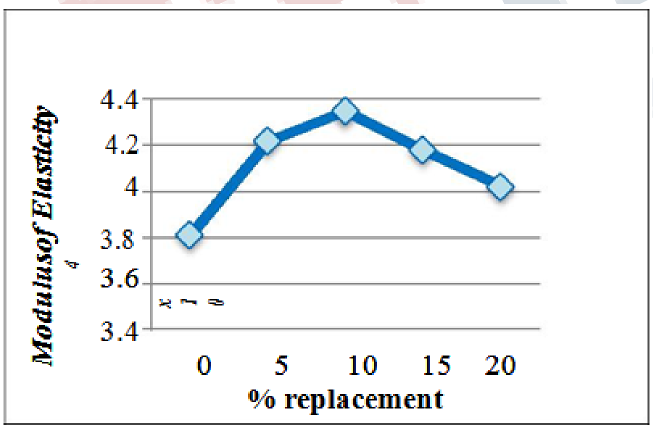

Fig.9. Modulus of elasticity

CONCLUSIONS

The study on the replacement of cement with various proportions of SBA was done and the following conclusions are drawn.

The compressive strength, flexural strength and split tensile strength increase up to 10% replacement of cement with SBA and after that it decreases. Hence the optimum percentage of replacement of cement with SBA is 10%.

The compressive strength, flexural strength and split tensile strength of concrete containing 10% SBA replacing cement is found to be higher than that of normal concrete. Thereby it can be recommended for construction works.

By replacing cement with SBA, we can reduce the cost of concrete as well as the CO2 emission due to cement production.

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