THE UTILIZATION OF AGRICULTURAL WASTE MATERIAL IN PATRIAL REPLACEMENT OF CEMENT FOR CONCRETE OF IMPROVED STRENGTH CHARACTERISTICS

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Abstract-

Construction Industry is presently facing three fold problems namely: Occurrence of cracks in new building, Poor split tensile strength of concrete and increasing cost of cement. The utilization of "Natural Fiber" occurring in abundance with renewable nature, as Agricultural Waste Material in Chhattisgarh [CG] seems to be most appropriate solution for the prevailing problems of Construction Industry. The CG state is rich in production of Paddy & Sugarcane crop during Kharif season. It generates two agricultural waste materials namely Rice Husk and Bagasse through Rice Milling units as well as society based Sugar Factories, respectively.

The ashes of both agricultural waste material as Rice Husk Ash [RHA] and Sugar Cane Bagasse Ash [SCBA] have ample scope as partial replacement of cement with improved strength quality and reduced cost of concrete. The pre-elementary study of RHA & SCBA in terms of basic characterization and geotechnical evaluation has revealed that M10 to M30 grade conventional concrete have much improvement in their workability, compressive strength, split tensile strength, compaction factor & water cement ratio as 1 to 15 % [by weight] partial replacement of cement. It has further advantage of being eco-friendly material towards conservation of environment.

INTRODUCTION

The majority of rural population for their livelihood depends upon agricultural sector in Chhattisgarh state. Rice is the main food crop of state and well known as "Rice Bowl" in India. The state has 426 Rice Milling units under Paddy Industry, distributed in districts namely: Raipur, Baloda- Bazaar, Mungali, Bilaspur, Rajim and Jajgiri Champa. The Rice Milling Units produce variety of rice and its products, besides generation of Rice Husk as agricultural waste material. The term Rice Husk refers to the waste material from processing of paddy through milling units [5]. Rice Husk contains about 75 % organic fickle matter-as renewable natural fiber crushed by machine processing and the remaining 25 % [by weight] as broken rice with impurities. The burning/combustion of rice husk provide ash, which is known as Rice Husk Ash [RHA].

The Sugar cane is the major commercial crop of Chhattisgarh state. Sugar cane is the member of grass family and tree free renewable for Kharif season. Sugar cane is "Carbon Neutral" [i.e. Emissions are equal to Energy generated]. One Ton of sugar cane generates about 26 % Bagasse and 0.62 % residual ash. Bagasse is waste material after treatment of sugar cane in Sugar Factory, having light yellow in color. There are four Sugar Factories in Chhattisgarh and locally known as Maryadit Shakkar Karkhana with their locations at Ambikapur, Balod, Kabirdham and Kawardha. Sugar Factories produce gaggery, bheli, Khad, Raab, Brown Sugar, White Sugar, Liquid Sugar, Sugar cubes and Ethanol [6]. Bagasse is extremely rich in "Cellulose Fiber" and its decomposition may cause Methane gas emission in certain circumstances [12]. The burning /combustion of Bagasse provide ash, which is known as Sugar Cane Baggase Ash [SCBA].

METHODOLOGY & OBJECTIVES-

The evolved methodology is based upon conventional approach as relevant literature review and geotechnical evaluation of strength parameters of RHA, SCBA compatible to conventional concrete. The objectives of study are as follows:-

- Basic characteristic of RHA
- Basic characteristic of SCBA
- Strength characteristic of RHA, as per geotechnical evaluation
- Strength characteristic of SCBA, as per geotechnical evaluation

LITERATURE REVIEW-

The concrete had been used in Construction Industry since 120 AD, when the exterior of Roman Pantheon [a kind of temple] at Rome was made of large dome having diameter of 42 m, without internal support and with use of unreinforced concrete [15]

The first Indian cement factory had established in 1913 at Porbander [Gujarat], with manufacturing Portland cement of 1000 Tons in 1914[15]. Concrete is the mixture of set proportion of cement, coarse aggregate and fine aggregate and water as per cement water ratio in accordance with different grade as M5 to M80. The utilization of 1 to 15 % of RHA, SCBA [by weight] as partial replacement of cement has been studied for M5 to M30 grade concrete towards in improvement of their strength characteristics namely: compressive strength, split tensile strength, slump [workability] and compaction factor respectively [12].

India has production of 120 Million Tons [MT] paddy and 24 MT rice husk annually on average. Chhattisgarh state has share of about 77% in national production of paddy. The paddy purchased by registered farmers during the last five years in CG state is summarized as Table 1 [8]. The rice husk is sold at rate of Rs. 1500/- per MT in CG state [5]. RHA is obtained through burning/combustion of rice husk. RHA is carbon neutral green material having pozzolanic substances and biodegradable waste through Rice Milling units.

S N	Financial Yea[Kharif season]	Amount of Paddy purchased in MT	% of Registered Farmers in CG state
1	2015-2016	59.29	83.95
2	2016-2017	69.59	87.66
3	2017-2018	56.82	76.97
4	2018-2019	80.30	92.34
5	2019-2020 [Feb 2020]	82.81	93.71

Table 1 Paddy production in CG state during period of 2015 to 2020

The physical appearance of raw rice husk and processed RHA as carbonized, grinded and composited has been illustrated as Fig.1 [11]

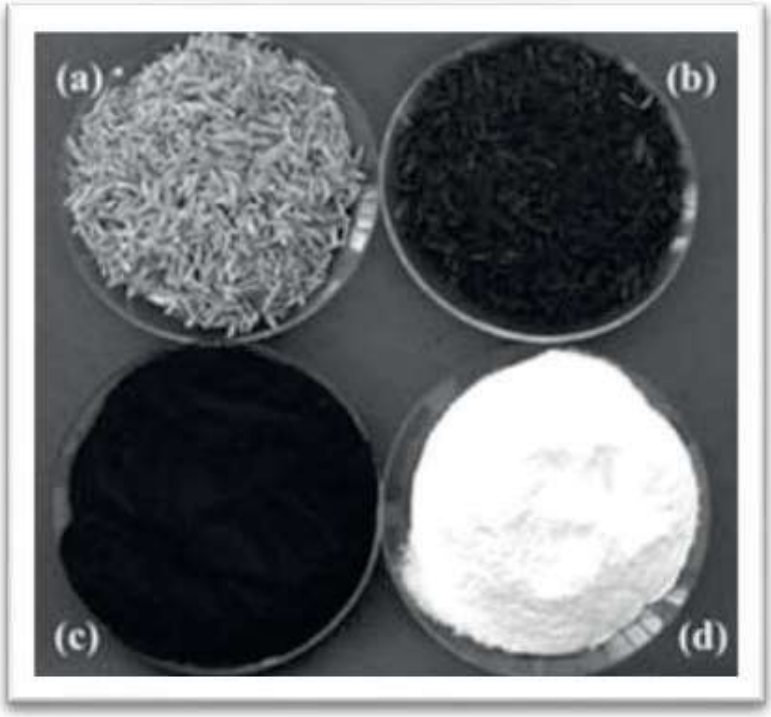

Fig. 1 Physical Appearance of Raw Rice Husk and Processed RHA

The sugar cane is processed at Sugar factory for extraction of sugar cane juice and related sugar products with generation of Bagasse as waste material. One ton of sugar cane generates about 280 Kg of Bagasse having 45-50 % moisture content. The physical appearance of Bagasse has been illustrated as Fig.2. When bagasse is burnt at temperature of 1200 [degree centigrade] for five hours in open air, the black color material is obtained as raw ash. The ash is sieved through 300 micron size sieve and grinded for long period in order to get SCBA. The difference in between raw Bagasse and SCBA has been illustrated as Fig.3.

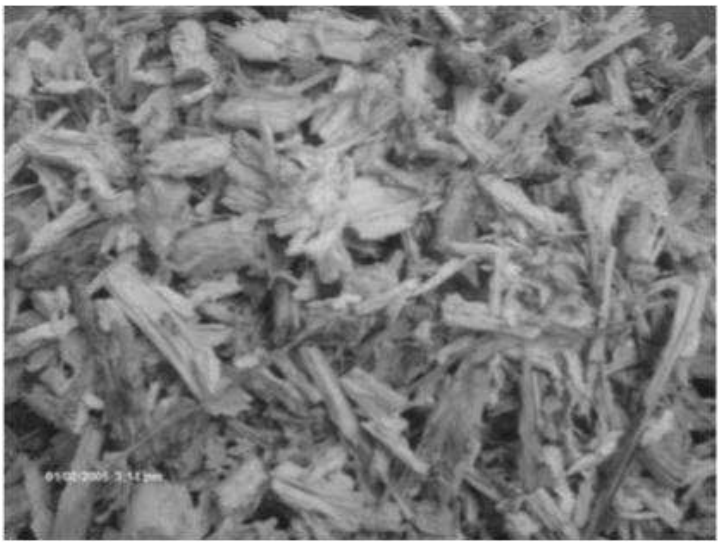

Fig. 2 Physical Appearance of Bagasse

Fig.3 The difference in Bagasse & SCBA as per Physical Appearance

The Bastar region of CG state has Maize [Macca-corn] production of 6 lakh Quantal during Kharif season of 2019-2020 with worth of Rs 65/- crore. The Maize crop is semi-food with generation of leaf [covered portion] and remains of stem as waste material, after processing corn. The generated waste material has enough proportion of "Natural Fiber" and Corn Steep Liquor [CSL]. The CSL has been the source material for carbonate producing Bacteria in abundance and base for Bacterial Concrete, having self healing mechanism for taking care of crack occurrence in newly constructed concrete building. It has been already studied successfully for improvement of compressive strength of M 30 grade concrete [9].

RESULT & DISCUSSION-

The conventional concrete of M5 to M30 grade has been studied through geotechnical evaluation for strength characteristic towards partial replacement of cement through utilization of 1 % to 15% RHA, SCBA [by weight]. It has provided improved strength parameters like- compressive strength, split tensile strength, workability, Water cement ratio and compaction factor of modified concrete at reduced cost, as per

BIS Code provision [12, 13]. The geotechnical evaluation has been carried out through systematic approach for achieving the desired objectives.

- ✓ Basic characteristic of RHA-

[1] RHA is green concrete material with eco-friendly in nature. The partial replacement of cement through RHA reduces the cost of construction by 3.5 % [3].

[2] RHA has water absorption character. It plays critical role in high performance of concrete [12].

[3] RHA has pozzalanic character. It improves the surface area of transition zone in between microscopic structure of concrete paste [14].

[4] RHA has 85 to 95 % amorphous silica by weight. It encourages the role of 'Natural Fiber'. The chemical character of RHA from Rice Milling unit of Rampur [U P] has been summarized as Table 2 [14].

[5] RHA has high porosity. It promotes hydraulic reaction more effective for longer period. The experimental study has established that, around 200 M Pa, after 91 days, curing in ambient environment has increasing trend of curing [11].

[6] RHA acts as composite material, having capability for turning agricultural waste into industrial wealth and with environmental conservation [11].

S N	Name of chemical component	Amount in %
1	Silicon Dioxide	62.5 -97.6
2	Carbon	02.0 –06.4
3	Phosphorous Oxide	0.1-2.4
4	Potassium Oxide	0.1-2.1

Table 2 Chemical component of RHA

- ✓ Basic characteristic of SCBA-

[I] SCBA has natural fiber, which is not soluble in either water or sugar cane juice. It consists of cellulose, pentissai, lign, wax and remains of sugar impurities.

[II] SCBA is composed of crushed material after machine processing. It has physical properties, as summarized in Table 3.

[III] SCBA has chemical composition, as summarized in Table 4. The source of SCBA belongs to Sukhi Sugar factory, located at Satyamangalam [Tamilnadu]. The Bagasse was burned in open air for 72 hours at temperature of 600-700 [degree centigrade].

[IV] SCBA has pozzolinic character. It has critical role in arresting cracks, improvement in stability of static and dynamic properties of concrete [12].

S N	Name of physical property with unit	Amount
1	Diameter [mm]	0.20 to 0.44
2	Specific Gravity	1.12 to 1.35
3	Modulus of elasticity [10x6 M Pa]	15 to19
4	Ultimate Tensile strength [10x3 M Pa	184 to 290
5	Water Absorption [%]	70 to 75

Table 3 Physical properties of SCBA

S N	Name of chemical	Amount [by mass]	S N	Name of chemical	Amount [by mass]
1	Silica Oxide	78.34	6	Phosphorous Oxide	1.07
2	Alumina Oxide	08.55	7	Sodium Oxide	0.12
3	Ferric Oxide	03.81	8	Manganese Oxide	0.13
4	Potassium Oxide	03.11	9	Loss by ignition	0.92
5	Calcium Oxide	02.15			

Table 4 Chemical Composition of SCBA

✓ Strength characteristic of RHA, as per geotechnical evaluation –

RHA based modified concrete has excellent application in construction of Bridge, Marine Structure and Nuclear Power Plant.

[a] The 5 % RHA replacement to cement [by weight] for conventional concrete has provided improvement in water cement ratio, slump [mm] and compaction factor, as summarized in Table 5 [14].

S N	Water-Cement Ratio	Slump [mm]	Compactor Factor
1	0.40	00	0.84
2	0.45	00	0.74
3	0.50	00	0.72
4	0.55	10	0.71
5	0.60	20	0.68

Table 5. Variation in Water Cement Ratio, Slump & Compaction Factor with 5 % RHA replacement to cement [by weight]

[b] The 9 % RHA replacement to cement [by weight] for conventional concrete has sustained Split Tensile Strength of 172 M Pa and illustrated as Fig.4 [11].

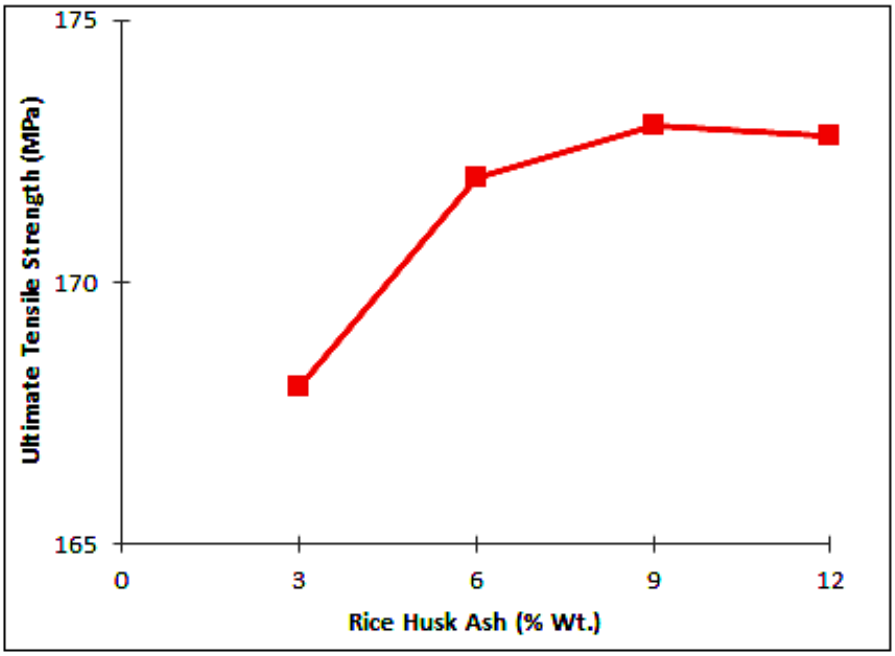

Fig. 4 Variation in Split Tensile Strength with 9 % RHA replacement to cement

[c] The 12 % RHA replacement to cement [by weight] for conventional concrete has sustained Compressive Strength of 500 M Pa and illustrated as Fig.5 [11].

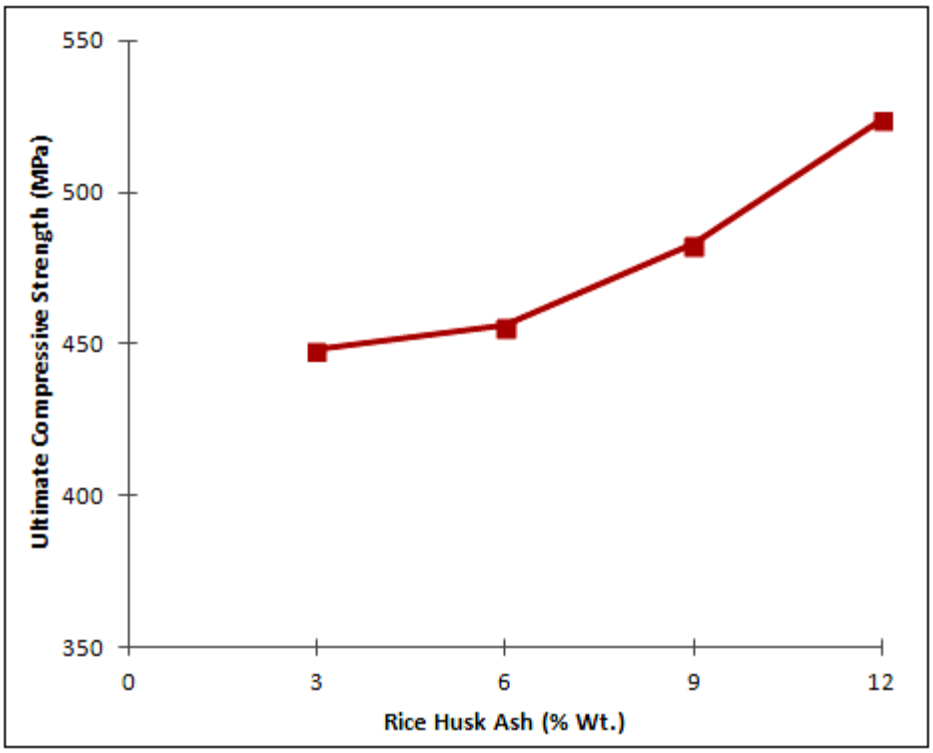

Fig. 5 Variation in Compressive Strength with 12 % RHA replacement to cement

[d] The 15 % RHA replacement to cement [by weight] for conventional concrete has provided the same strength characteristic, but drastic reduction in cost factor [14].

✓ Strength characteristic of SCBA, as per geotechnical evaluation –

SCBA based modified concrete has exciting application in replacement of coarse aggregate as well as cement in conventional concrete of M15 to M20 grade [1]. It is good bendable material for Construction Industry and eliminates out the need of Super plasticizer in Fresh concrete.

[p] The 1% SCBA replacement to Coarse Aggregate [by weight] for conventional concrete has provided significant factor in reducing the cost.

[q] The 5% SCBA replacement to Cement [by weight] for M30 grade concrete has provided 5% increment in compressive strength [12].

[r] The 10 % SCBA replacement to Cement [by weight] for conventional concrete has provided 10 % increment in Split Tensile Strength and workability [12].

[s] The 12 % SCBA replacement to Cement [by weight] for M20 grade concrete has provided Cement Water Ratio of 0.48 [12].

CONCLUSION-

The agricultural based Paddy and Sugar Industry generates vast quantity of RHA & SCBA in CG State. These wastes are under renewable category and ample scope for production of modified concrete at reduced cost with improved strength characteristics. It may act as boon for Construction Industry towards 'economic viable' for several pending projects with eco-friendly nature. The conducted study is preliminary type and needs to consider the following for integrated and coordinated Industrial development of State:-

- 3 to 8 % RHA [by weight] replacement to cement provides better Cement Water Ratio with increased compressive strength, durability and stability of modified concrete.
- 8 to 12 % RHA [by weight] replacement to cement provides better Split Tensile Strength for crack-proof building construction.
- 1 % SCBA [by weight] replacement to cement and coarse aggregate provides better workability and improved cost factor respectively.
- SCBA seems to be good Bendable material for 15 to M20 grade concrete.
- Bacterial concrete is future green material based upon waste material through Maize Industry.

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