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To study the combined effect of mineral admixtures on the properties of fresh concrete as partial replacement to cement to achieve sustainable concrete

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Abstract: Concrete is one of the most used universal material. Use of concrete is increasing day by day due to increasing infrastructure demand. Increased use of concrete results in an increased use of cement, one of the most important ingredient of concrete in terms of strength and binding. Energy utilization while manufacturing of cement is very high. Besides it is also responsible for release of carbon dioxide into the atmosphere , a major reason for global warming and air pollution . Researchers globally have therefore put forth their investigations about mineral admixtures, to be used as partial replacement to cement . In the present study the two mineral admixtures to be investigated are Rice husk ash(RHA) and Sugarcane bagasse ash (SCBA) and their combined effect on the fresh properties of cement for various replacement percentages. Their use is promoted in most of the countries due to the minimization of the hazardous effects of concretization on the environment. Hence in this study the fresh properties of concrete like standard consistency, workability, compaction factor and bleeding are investigated after partially replacing cement with these admixtures. Reduction in usage of cement will be a step towards reduction in the emission of greenhouse gases and achieving a sustainable environment for the future generations.

Keywords : water cement ratio, slump , compaction factor , Workability , setting time , bleeding , Interstitial pores

1. INTRODUCTION:

India is the second largest agriculture economy with crop cultivation and harvesting going on round the year . Hence the amount of agricultural waste developed is also huge . The normal practice adopted by the farmers is either burning the crop waste in the field or transporting them to landfills [1].Large scale burning of crops increases carbon dioxide, carbon monoxide and Nitrogen dioxide in the atmosphere affecting the air quality index(AQI) and leading to air pollution . Specially states in the north are following this practice for quite some time now , and due to this Delhi is bearing the brunt as the smoke from all the neighboring states accumulates there and is causing hazardous effects to the environment [2][3]. This is causing a lot of health issues due to the alarming deterioration of the air quality in Delhi to nearly twice the permissible Indian standard and ten times higher than the WHO standard. The Indian government as well as the Delhi government has taken several measures , to curb the open field burning. This practice has reduced minimally but not completely stopped . One solution to this problem is effective use of the crop residues, by utilizing them in a better way. These crop residues are rich in amorphous silica when burnt under controlled conditions[4][5]–[7][8]. So one of their effective use based on their siliceous properties could be partially replacing them with cement. The two agricultural residues considered in this study are sugarcane bagasse ash and rice husk ash. Sugarcane and rice are two major crops of India . India is the 2nd largest producer of Rice globally (https://www.world-grain.com). Sugarcane is also cultivated largely in states like Maharashtra, Uttar Pradesh, Haryana, Punjab, Bihar to name a few. Bagasse, an abundantly produced agricultural waste, is a residue obtained after the extraction of juice from the sugarcane. Similarly rice husk is obtained after the milling process of rice. Around 20% of the weight of rice, husk is generated during the milling process and around 25to 28 % of bagasse is generated after processing of sugarcane in sugar factories [9][10]. This amounts to a large quantity of waste which needs to be either proper disposed or used . There is no standard disposal method for this waste , hence utilizing it as a replacement to cement will not only be an effective utilization of the waste but will also help in reducing the consumption of cement[11]. The present study investigates the combined effects of sugar cane bagasse ash and Rice husk ash when used in concrete as a partial replacement to cement in a ternary mix and their effect on the fresh properties of concrete.

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2. MATERIALS AND METHODS :

2.1 Portland Cement: Conforming to British Standard specification BS: 12:1996 and IS: 456 2000 fourth revision is used in this study. Artificial sand as per IS: 2386 (Part III) – 1963, is used. The Physical properties of both cement rice husk ash and sugarcane bagasse ash were investigated as per VAT TMC/110, VAT TMC /113 and chemical properties as per FCO 1985 21" Ed standards.

2.2Rice husk Ash : Commercially available rice husk ash was procured and used in the experimental investigation. The rice husk was taken from a paddy field in Gujarat India. If the incinerating temperature of rice husk is lower than 700°C, silica in RHA remains in amorphous state. If the temperature of incineration of rice husk is higher than 800°C, silica in RHA crystallizes and hence has a lower chemical reactivity compared to amorphous state of silica[12]. Hence the ash produced has low reactivity when mixed with cement and water. So the temperature of burning rice husk ash is kept lower than 800^0C so that the ash produced is amorphous and highly reactive when mixed with cement and water[13][14].
Sugarcane bagasse ash : Sugarcane bagasse ash was taken from a sugar industry from Maval, District Pune, Maharashtra India. Prismatic particles and irregular particles are rich in silicon.
Physical parameters of both the cement rice husk ash(RHA) and sugarcane bagasse ash(SCBA) used in this work are shown in Table 1.

2.3Aggregates: The aggregates used for the preparation of mortar confirm to IS 2383(I) and (ASTM C33)The aggregates used are hard, strong, dense, durable, and clean and free from veins, adherent coatings and injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. The aggregates used are cubical. crushed dolomite aggregate, passing through a 12.5- retained on a 4.75 mm sieve with a fineness modulus of 6.26 and a specific gravity of 2.4.

2.4 Fine Aggregates

The fine aggregate conforming to IS 383 -1970 grading zone II were used. The fine aggregate used is sand with ore than 90% passing through the 4.75 mm IS sieve and less than 10% retained on the 150μ sieve.

2.5 Water

Water used for mixing and curing was clean and free from injurious amounts of oils, acids, alkali's, salts, sugar, and organic materials that may be deleterious for concrete.

Table 1 : Physical properties of cement , RHA and SCBA

Sr.No.	Physical Property	Cement	Rice husk Ash	Sugarcane bagasse ash
01	Colour	Greyish green	Greyish Black	Black
02	Particle density	1.15	0.61	0.49
03	Specific Gravity	3.15	2.06	1.69
04	Particle Size	20 μm	7 μm	4.1μm
05	Fineness passing 45 µm sieve	80	96	100
06	Specific surface area	<1 m^2/g	50-100 m^2/g	145 m^2/g
07	Shape	Angular, Irregular	Cellular . irregular	spherical, prismatic, fibrous and irregular

Table 2 : Chemical properties of cement , RHA and SCBA

Sr.No.	Chemical property	Cement	Rice husk ash	Sugarcane bagasse ash
01	Silica as SiO2	21.22	93.66	78.39
02	Aluminium Oxide	5.69	0.05	2.23
03	Iron Oxide	3.39	0.05	4.6
04	Potash	0.55	1.3	1.64
05	Sodium Oxide	0.33	0.1	0.28
06	Sulphite	2.47	0.01	1.6
07	Calcium Oxide	64.25	1.11	2.86
08	Magnesium Oxide	0.85	0.35	0.16
09	LOI	1.8	3.38	8.5

The above table shows that rice husk ash and sugarcane bagasse ash have combined percentages of (SiO_2 +Al_2O_3 +Fe_2O_3) more than 70%, indicating that they are good pozzolanic materials in accordance with the requirements in ASTM C 618[15][16] and they belong to Class F pozzolana.

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3 METHODOLOGY :

The fresh properties of concrete like standard consistency, Initial and final setting time workability , compaction factor , are studied for both the control mix which contains only cement and 0% of mineral admixtures and the other ternary mixes containing different replacement proportions of both RHA and SCBA. Here the percentage of SCBA is fixed to 15% and the replacement percentage of RHA is varied from 5% to 30% . The performance of concrete for various replacement percentages is monitored.

The standard consistency test and initial and final setting time test is carried out using vicat apparatus. The standard consistency test is one of the most important test as it determines the amount of water required to obtain a consistent and workable mix . Both the rice husk ash and sugarcane bagasse ash have particle size lesser than that of cement. Hence the surface area increases and there by the water demand also increases.

The standard consistency of the paste is determined by adding water at different percentage levels till the paste has a given resistance to penetration. Consistency is recorded when the plunger of the Vicat apparatus penetrated into the paste 5 mm to 7 mm above the bottom of the mould. Consistency was determined by taking an average of three samples.. Once the standard consistency had been established the setting time was determined. Initially it is called initial setting time and final setting time. The initial setting time is recorded as per IS: 4031 part-5. For the initial setting time test, a needle of 1 mm square is used to penetrate into the paste at every 10 min intervals till the scale on the vicat apparatus shows 5 + 0.5 mm from the bottom of the mould. For determining the final setting time, the 1 mm needle is replaced by the needle with an annular attachment. The needle is then released at an interval of 30 minutes till the needle makes an impression on the test block. Initial and final setting time values are recorded . Similar procedure is followed two more times and an average of all the three is taken as Initial and final setting time of the ternary mix.

Table 3 : Results of the ternary mix for different proportions of the Cement , SCBA and RHA

Sr.No.	Sample		Standard consistency	Initial setting Time in minutes	Final setting time in minutes
01	Control mix(CC)	0+0+100	0.35	150	280
02	SCBA+ RHA+C	15+5+80	0.45	180	650
03		15+10+75	0.48	200	670
04		15+15+70	0.55	210	700
05		15+20+65	0.60	230	740
06		15+25+60	0.67	260	750
07		15+30+55	0.75	300	780

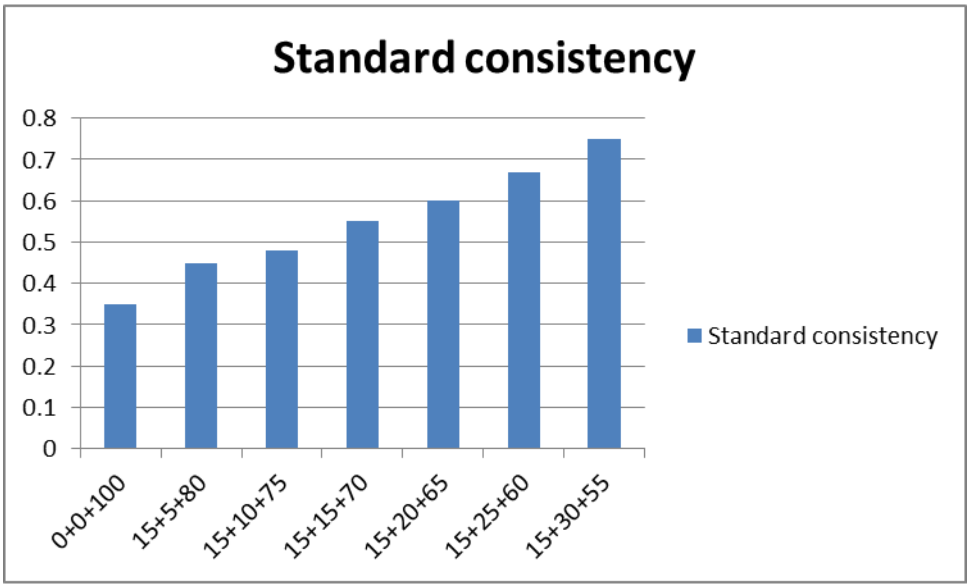

Fig :1 showing the standard consistency of the ternary mix in various percentages

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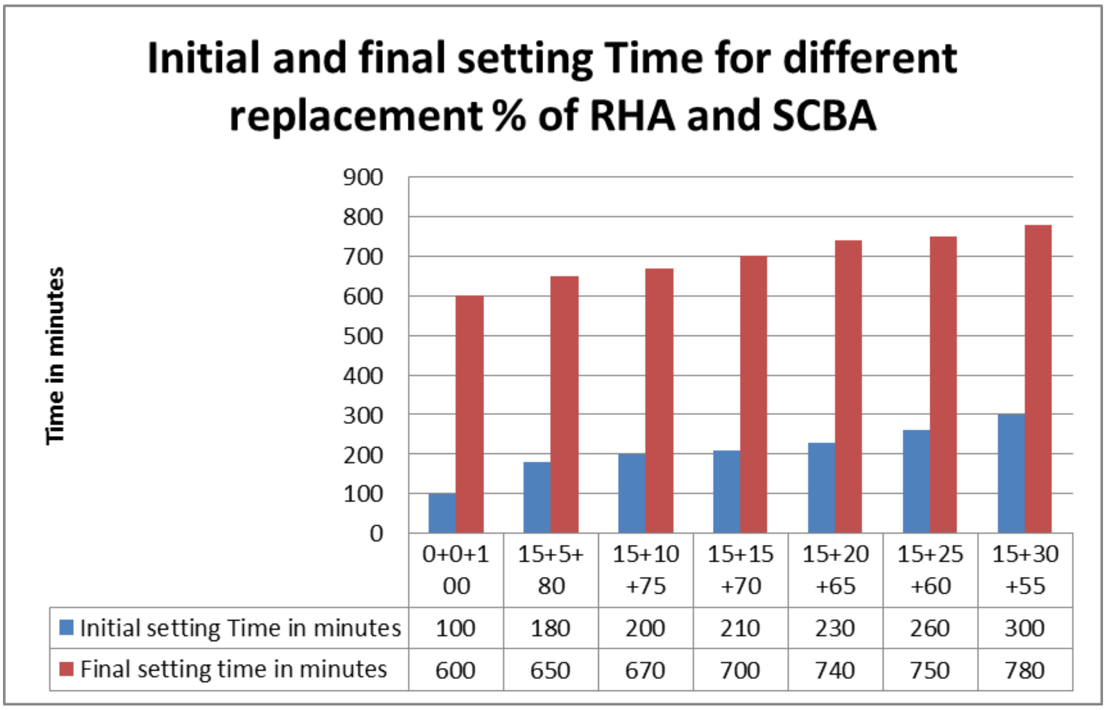

Fig :2 showing the initial and final setting time of the ternary mix in various percentages

Table 4: Workability requirement as per IS 456:2000

Workability	**Compaction Factor**	**Slump (mm)**
Very Low	0.78	0 - 25
Low	0.85	25 - 50
Medium	0.92	50 - 100
High	0.95	100 - 175

4 RESULTS AND DISCUSSION:

Rice husk ash and sugar cane bagasse ash are both reactive micro filler materials due to their low particle size and high concentration of silica. These micro filler mineral admixtures increase the workability and setting time of concrete but decrease the heat of hydration and reactivity. In general, small particle size and higher specific surface area of mineral admixtures are favourable to produce highly dense and impermeable concrete [17][18].The low particle size results in reducing the pores of concrete (the interstices left by cement are filled by RHA and those left by RHA are filled by SCBA) . This pore filling property makes the concrete denser and hence increases the durability of concrete as the permeability of concrete is reduced[19]. The chemistry of rice husk ash and sugarcane bagasse ash cements involves the chemical reaction of the amorphous silica in these ashes with lime to form calcium silicate hydrates, which is primarily responsible for development of compressive strength of the resulting concrete[20][21]. In the case of mixture of OPC-RHA -SCBA, the silica reacts with extra lime in the OPC which in some cases can be as high as 30 % (Boateng and Skeete 1990). The silicate formed are of the kind, CSH (I) and CSH (II) (Jose James and Subba Rao 1986 – 1). As per the results achieved by Chiara F. Ferraris et.al.(2001) , the water content decreases if finer mineral admixtures are partially replaced by cement. Similarly the investigations carried out by Niragi Dave et.al.(2016) as the percentage [22]

During the year Boateng and Skeete investigated the physical and chemical properties of Rice husk ash to anticipate its effect of concrete ash produced is amorphous and highly reactive when mixed with lime and water. Sadaqat Ullah Khan et.al studied the effect of mineral admixtures like fly ash Silica flume , metakaolin and Rice husk ash on the fresh properties of concrete and concluded that mineral admixtures may be categorized into two groups namely chemically active mineral admixtures and micro filler mineral admixtures.

Chemically active mineral admixtures decrease workability and setting time of concrete but increase the heat of hydration and reactivity whereas, micro filler mineral admixtures increase workability and setting time of concrete but decrease the

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heat of hydration and reactivity[17]. In general, small particle size and higher specific surface area of mineral admixture are favourable to produce highly dense and impermeable concrete; however, they cause low workability and demand more water.

5. CONCLUSION :

The present study focuses on the use of agricultural waste products like rice husk ash and sugarcane bagasse ash used as partial replacement materials to cement and to study the performance of the ternary blend on the mechanical and durability properties of concrete. The study proves substantial reduction in carbon footprint, due to reduction in cement content.. Though the low early strength delays the removal of formwork. The cost of raw materials is reduced as both the agricultural wastes are free of cost and this is a way of disposing them effectively without any negative environmental impact .it also improves the durability of the concrete .

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