An Experimental Study on Pozzolanic Activity of Sugarcane Bagasse Ash as Partial Replacement for Cement in Recycled Aggregate Concrete

Sowmya N[1] Yashwanth.M.K[2] Devanand.R[3]
[1]Student [2,3]Assistant Professor
[1,2,3]Department of Civil Engineering
[1,3]GEC, HASSAN, Karnataka [2]MIT MYSORE, Karnatakat

Abstract— The study presents a replacement of cement by bagasse ash in industrial scale aiming to reduce the carbon dioxide emission into the atmosphere and natural coarse aggregate by recycled coarse aggregates (RCA) due to abundantly available Construction & Demolition waste aiming to preserve natural resources. Bagasse ash(BA) is a byproduct of sugar/ethanol industries abundantly available in the region of Mandya and Mysure and has cementitous properties indicating that it can be used together with cement. In this study bagasse ash were physically and chemically characterized and partially replaced in the ratio of 0%,10%,and 20% by weight of cement to produce bagasse ash based concrete and natural coarse aggregate is replaced by recycled coarse aggregate in the ratio of 25%, 50%, 75% and 100% to produce recycled aggregate concrete(RAC). The optimum level of bagasse ash and recycled coarse aggregate were found and then cast to produce bagasse ash based recycled aggregate concrete. The mix design of all the concrete is done as per IS specifications. The rheological properties of concrete like slump test and hardened properties like compressive strength, split tensile strength were studied. The results shows that strength of the concrete can be increased at the optimum percentage of recycled coarse aggregate and bagasse ash.
Key words: Bagasse Ash, Recycled Coarse Aggregate Slump, Compressive Strength, Split Tensile Strength, Normal Concrete, XDR SEM Analysis

I. INTRODUCTION

Concrete is the premier construction material across the world and the most widely used in all types of civil engineering works, including infrastructure, low and high-rise buildings, defense installations, environment protection and local/domestic developments. Researchers all over the world today are focusing on ways of utilizing either industrial or agricultural waste & C & D waste as a source of raw material for construction industry.

Fly ash is considered as cementitious materials compared to other industrial and agricultural by products because of its chemical composition, particle size and its availability but other potential byproduct of agricultural waste such as sugarcane bagasse ash needs to be investigated. Aggregates such as sand, crushed stone or gravel form the major part. Traditionally aggregates have been readily available at economic price. However, in recent years the extraction and use of aggregates from natural resources and carbon di oxide emissions from cement and shortage of limestone for the production of cement has becoming major constraint. This is mainly because of the depletion of quality primary aggregates.

Motivation for use of Bagasse ash is as it is a cementitious material available locally in and around Hassan, Mysore and Mandya districts as compared to other supplementary cementitious material and for use of recycled coarse aggregates is, as natural coarse aggregates is in huge demand in the construction sector with a significant gap in its demand and supply, which can be reduced to a certain extent by recycling construction and demolition waste. There is a need for proper handling, storage and treatment of C&D waste in India with systematic approach to segregate, reuse and recycle the same. Hence, an attempt has been made to use bagasse ash as alternative cementitious material for cement and recycled coarse aggregates as substitute for natural coarse aggregates in order to produce recycled aggregate concrete. This helps in preservation of natural resources, effective utilization of the growing waste. Hence an experimental study is carried out to ascertain the suitability of bagasse ash and recycled coarse aggregates for production of recycled aggregate concrete.

II. METHODOLOGY

- Cement: The ordinary Portland cement is tested according to IS specification (IS: 12269-2013) to determine its various properties. The overall quantity of cement required for the investigation was procured in a single lot and stored in the appropriate manner & the specific gravity is 3.1.
- Fine Aggregate: The fine aggregate used in this study is local river sand which confirms to Zone I of IS: 383 specificationsand its specific gravity is 2.62.
- Coarse Aggregate: The normal coarse aggregate used in this study is crushed angular aggregates which confirm Table 2 of IS: 383 specifications.
- Bagasse ash: The bagasse ash was procured from panadavapura sugar factory mandya district. The sample of sugarcane bagasse ash was found to have completely burnt silica-rich fine particles and carbon-rich fibrous unburnt particles named coarse fibrous particles. Therefore, it becomes necessary to recondition the sample for use as pozzolanic material by grinding to a fineness of less than 90 microns and the resulting ash was chemically analyzed and physically characterized as shown in table 1 and table 2. The test on Bagasse ash blended with ordinary portland cement is done as per specification.

Chemical Composition	SiO_2%	Al_2O_3 %	Fe_2O_3%	CaO %	LOI %
Bagasse Ash	76.52	0.18	5.70	1.55	6.82

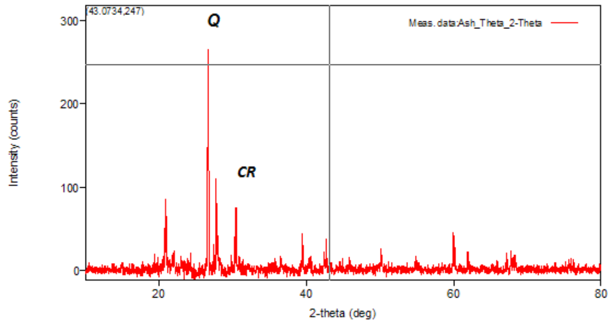
Table 1: Chemical properties of bagasse ash

Tests	Results	Requirements as per IS: 1489-1991
Specific Gravity By Le chateliers	2.08	
SiO_2+ Al_2O_3+Fe_2O_3	82.4	> 70%
Loss on Ignition	6.82	< 7%

(LOI)		
Normal Consistency (%)	45	
Initial setting time (min)	245	> 30
Final setting time (min)	290	< 60
Soundness (mm)	2	< 10
Fineness by sieve analysis (%)	7	< 10

Table 2: Physical Properties of Bagasse ash.

A. *X-Ray Diffraction Analysis of Bagasse Ash*



The mineralogical investigation of bagasse ash was carried out by XRD. The material essentially contains an amorphous silica composition with a wide scattering peak focused at about 22^0 2ɵ.Little quantities of crystal-phases as quartz & crystabolite also present in the material.

B. *Recycled Coarse Aggregate:*

Laboratory waste casted cubes are initially crushed into required sizes by using hammer. Then the adhered mortar is separated in los angeles abrasion machine by giving 150 revolutions. Obtained aggregates are then separated from mortar powder. Then aggregates which are passed through sieve size of IS 20mm& retained on sieve size of IS 4.75 mm is considered as recycled aggregate and these aggregates are saturated for 24 hours i.e.,, SSD Condition & surface dried of these aggregates as shown below Fig(1)(2)(3)(4)(5)(6)(7) were used & physical properties are shown in table 3.

Fig. 1: Crushed cubes by hammer

Fig. 2: Separation of mortar by using Los Angeles Abration Machine.

Fig. 3: Sieving of RCA

Fig. 4: Separated mortar after sieving

Fig. 5: Soaking of recycled aggregates

Fig. 6: Surface drying of RCA

Fig. 7: Dried RCA

Tests	**results**	**Requirements as per IS 383-1970**
Specific gravity	2.51	2.5-3
Water absorption	4.53	
Fineness modulous	6.28	5-8
Impact value	20.51	< 30

Table3: Physical Properties of RCA

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

Mixing process is an important stage in preparation of concrete specimen. The mix design of all the concrete is done as per IS specifications. The design of M20 is carried out in present study. Normal Mixing is done for normal concrete (NC) and two stage mixing approach(TSMA) is implemented for RAC.

TSMA: Initially concrete ingredients are proportioned as per mix design IS 10262-2009. Firstly cement and water is split into two parts. fine aggregate, half portion of cement ,and collective aggregates are mixed for about 60 sec then half of the water is added to the above ingredients then they are mixed for a min and remaining cement were added & mixed for about 30 sec, then remaining water is added & finally whole ingredients are mixed for 120 sec to get homogenity in the mixture.

A. Workability

The workability of the prepared samples was determined by standard practice. The below table shows the slump value of various samples.

Specimen	W/C	Slump value(mm)
NC	0.53	110
BA 10	0.53	120
BA 20	0.53	100
RCA 25	0.53	90
RCA 50	0.53	80
RCA 75	0.53	70
RCA 100	0.53	65
BA10+RCA50	0.53	100
BA20+RCA50	0.53	90

Table 4: slump values of tests specimens

From the above table it can be note that as bagasse ash increased by weight of cement slump value also increased as compared to ordinary Portland cement which is more than desired slump and it also indicates that as recycled aggregates increased by weight of natural coarse aggregate slump value decreased as compared to normal concrete which is due to adhered mortar absorbs the mixing water used.

B. Compressive Strength

Compressive strength of the prepared samples was determined by standard practice. The below table shows average compressive strength.

Replacement of BA & RCA(%)	7 Days in (MPa)	14 Days in (MPa)	28 Days in (MPa)
0	25	29.23	33.86
BA10	16.34	22.34	28.36
BA20	13	15.23	19.20
RCA25	21	26.74	33.33
RCA50	24	28.33	36
RCA75	22.56	25.48	28
RCA100	17.77	24.28	32
RCA50+BA10	20.23	34.81	34.81
RCA50+BA20	23.28	29.63	29.63

Table 5: compressive strength of concrete with varying percentage of BA and RCA

From the above table it can be note that as bagasse ash increases there will be decrease in Compressive strength at 7 days compared to normal concrete but after 28 days there will be increase in compressive strength value at 10%.because since it is a low heat of hydration blended cement the pozzolanic activity will begin at 28 days. Hence upto 10% bagasse ash can be replaced .and it also indicates that increase in recycled aggregate content there will be decrease in compressive strength at 7 days compared to normal concrete and at 14 days compressive strength value has increased slightly and reaches to same value as that of controlled concrete at 50% recycled aggregate replacement but at all other percentage of replacement level compressive strength decreased because the adhesive mortars were still present on the periphery of recycled aggregate even after processing of recycled aggregate. At 28 days there will be increase in compressive strength value at 50% as compared to NC further than there will be reduction in compressive strength value. It shows that filler effect is chief only up to 50% recycled aggregate substitution. This may caused by high absorption capacity of old adhered mortar to the RCA and rough texture of RCA provides improved bonding and interlocking characteristics between the mortar & RCA. This may also due to the proper gradation of RCA when it is replaced with normal coarse aggregate. This is may also due to two stage mixing approach where weak area of interfacial zone has been strengthened due to very low w/c ratio which fills the weak zone in RAC causes additional strength to RAC.

C. Split Tensile Strength

The Split Tensile Strength test was conducted on cylinder samples were cured for 28 days and below table shows average tensile strength

Percentage replacement of SCBA & RCA (%)	28 days tensile strength(MPa)
0	2.97
BA10	2.78
BA20	2.26
RCA25	2.11
RCA50	2.82
RCA75	1.83
RCA100	1.69
RCA50& BA10	2.88
RCA5050&BA20	2.54

Table 6: Tensile strength of concrete with varying percentage of BA and RCA.

From the above table, it indicates that as increase in RCA there is a decrease in tensile strength value when compared to normal concrete but at 10% BA with 50%RCA tensile strength reaches slightly near to normal concrete beyond that there is decrease in tensile strength because of adhered mortar absorb mixing water

1) Flexural Strength

The flexural Strength test was conducted on beam samples were cured for 28 days and below table shows average flexural strength

Percentage replacement of BA & RCA (%)	28 days flexural strength (MPa)
RCA_{50}&$SCBA_{10}$	0.685
RCA_{50} &$SCBA_{20}$	0.4

Table 7: Flexural strength of concrete with varying percentage of BA and RCA

From the above table it indicates that increase in bagasse ash content up to 10% with 50% recycled aggregate there is a greater tensile strength value of concrete beyond that there is a reduction in flexural strength.

D. Scanning Electron Microscope Analysis

In this case the samples are analysed using SEM. The SEM analysis of 50% RCA & combination of 50% RCA with 10% BA is shown as below fig

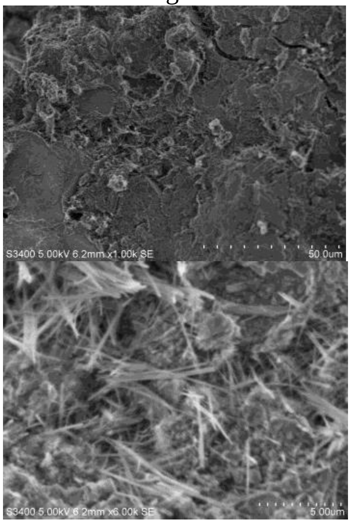


Fig 5: SEM Analysis of 50% RCA +10%BA

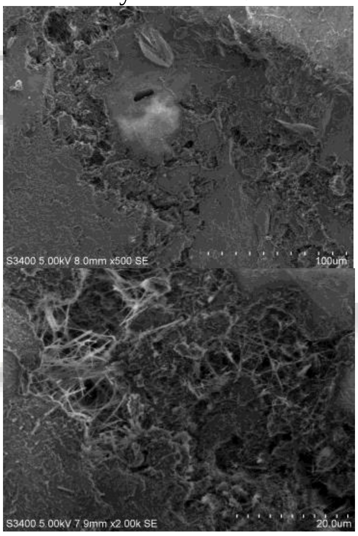


Fig 6: SEM Analysis of 50% RCA

Under the examination of SEM, both the new ITZ and old ITZ of RAC are identified. The plate 20 & plate 21 shows a stronger and denser new ITZ in RAC after adopting TSMA. Therefore TSMA can improve the ITZ of recycled aggregate and thus the CS of RAC

IV. CONCLUSIONS

1) The oxide composition test indicated that, the bagasse ash from Pandavapura sugar factory can be classified as class N pozzolana as prescribed by ASTM C 618.
2) The chemical composition of hopper bottom bagasse ash SiO_2+ Al_2O_3+Fe_2O_3 is 82.4% has concluded that it is siliceous ash.
3) The increase in percentage of replacement of cement by bagasse ash resulted in higher normal consistency for bagasse ash and longer setting time for bagasse ash.
4) Experimental investigations concluded that compressive strength, tenile strength goes on reduces as substitution of recycled aggregate raised.
5) It is found that 50% of recycled aggregates can be replaced to normal concrete.
6) Utilization of SCBA and RCA will reduces disposal problem and provide pleasant environment.
7) Replacement of bagasse ash upto 10% to cement and replacement of recycled aggregate upto 50% to normal aggregate will yield better compressive strength as compared to normal concrete.
8) And also it is found that combination of replacement of recycled aggregate of 50% to normal aggregate and baggase ash of 10% to cement will yield better compressive strength comparatively tensile strength compare to the combination of bagasse ash of 10% with recycled aggregate of 50%.
9) It is found that compressive strength of RAC is increased due to two stage mixing approach.
10) And also it is found that TSMA can develop the ITZ of RCA and thus the compressive strength of RAC.
11) Strength of the concrete can be increased at the optimum percentage of recycled coarse aggregate and bagasse ash.
12) At the last, it can also be conclude that without reburning of bagasse ash only by grinding the material can be incorporated in the concrete so that economy is achieved.

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