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A Study on Effect of Bagasse Ash in the Properties of Recycled Aggregate Concrete

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Abstract: ***The study presents a replacement of natural coarse aggregate (NCA) by recycled coarse aggregate (RCA) and cement by bagasse ash. The aggregate obtained from the construction and demolition waste for making a new concrete will have to give better stability same as concrete prepared by using virgin aggregate. Usage of recycled coarse aggregate in concrete is helpful for ecological protection, in other hand RCA will be material used in future. Bagasse ash is an agricultural or industrial waste by sugarcane milling process. Bagasse ash got cementitious property so it can be replaced with cement. In this project main aim is to evaluate the physical properties of both RCA and bagasse ash for M20 grade of concrete. NCA is replaced with 20%, 30% and 40% of RCA and replacement of cement with 5%, 10%, 15% and 20% bagasse ash with 30% RCA. The mix proportion and water cement ration of 1:2.4:3.9 and 0.45 used with 1% super plasticizer (SP). The rheological property of concrete like slump cone and hardened properties like compression strength and split tensile strength for 7 and 28days and flexural strength test for 28days of curing was conducted. Durability and micro structural analysis like scanning electron microscope (SEM) also presented in the work. The results shows from hardened properties strength increased up to the replacement of bagasse ash 10% with 30% recycled aggregate***

Keywords: Recycled Coarse Aggregate, Natural Coarse Aggregate, Bagasse Ash, Compressive Strength, Spilt Tensile Strength, Flexural Strength Test, Durability Test, Scanning Electron Microscope

1. Introduction

In civil engineering, concrete is very essential material is used in all types of construction works. It is fundamental material essential for environmental protection, domestic developments; high and low raise buildings, bridges and dam's etc. concrete consists of cement, aggregates, water and admixtures. The aggregates are traditionally obtainable at low price. Yet, in present years the foresight of our followed wholesale elicitation and the use of aggregates from non-artificial sources are to be questioned worldwide. This will leads to the scares of primary aggregate quality and enhance in the awareness of environmental protection. Demand of the aggregates increased due to the urbanization also by increasing in the waste generated during the construction leads to the supplementary source of aggregate. Quantity of recycle depends upon the local and regional condition. Recycling business requires an investment of about four dollar to eight dollar per metric ton as per annual cost of aggregate production.

By the year of 2050, the need of concrete expected to spring up to nearly 18 billion tons. More researches have to be developed and improvised for overcoming waste management and enhancing its recycling, re-use and waste to energy operation. Bagasse ash is by product of sugarcane milling process in sugarcane factories which contains high amount of silica, alumina, iron and calcium oxides these are very essential chemical requirements used in concrete. Baggase ash acts as an essential pozzalonic material can be used as alternative cementatious material in preparation of concrete. It is helpful for improving the workability, durability and strength of the concrete. Using the bagasse ash reduction in the cement content can be achieved it leads to the cost effectiveness in the production of the concrete.

2. Background

Performance of concrete was conducted by **Tushar et al. (2011)** in this work of research the writings mainly states the basic properties of RCA and compared with the NCA. Prime concrete properties like compressive strength, flexural strength are recorded. The grade of concrete was taken as M30 and got the maximum compressive strength and flexural strength of 43.92Mpa and 4.80Mpa for 28 days of curing with the 20% replacement of NCA with RCA. They replaced NCA with RCA with 10%, 20%, and 30%.RCA usage up to 30% doesn't affect the functional requirement of the structure.

Ateek and Chaturvedi (2016) determined the cause of RCA on concrete. In this research the RCA is obtained from the demolished water tank and found that the physical properties of the RCA is similar that of NCA as per codal provision. In this literature used a concrete grade of M20 with the water cement ratio of 0.52. Here researcher replaced the NCA with RCA in varying percentage of 0%, 30%, and 100%. Cubes and beams are casted to know the concrete strength of hardened one. Researcher got a highest strength for the 30% replacement of RCA about 36Mpa compressive strength and 6.6Mpa of flexural strength for 28days of curing period. They concluded their research saying that the RCA can be utilized in place of NCA for both non-structural and structural works.

Sowmya et al. (2016) determined the cause of bagasse ash on the recycled coarse aggregate. The RCA taken as 25%, 50%, 75% and 100% replaced with natural coarse aggregate, bagasse ash as 10% and 20% with cement replacement. Both RCA and bagasse was replaced for NCA and cement as 10% and 20% bagasse ash with 50% RCA. Concrete was produced with a water cement ratio of 0.53 for M20 grade of the concrete. cubes were casted to get compressive strength of 28 days. Cylinders also have been casted to get split tensile strength of 28 days. The compressive and split tensile strength was obtained at 28 days was 34.81N/mm2 and 2.88N/mm2 for the combination of 50%RCA and 10% bagasse ash. Replacement of the combination with 10% BA and 50% RCA yielded a better compressive strength compared to other.

3. Need for the Study

Concrete industry facing many challenges for the improvement of eco-friendly cement manufacturing technology, usage of supplementary cementatious materials, recycling of concrete and other material. Hence the managing technique of waste which is generated by the industry has to be improvised. By the usage of concrete recycling aggregate and supplementary cementatious material helps in the protection of environmental which decreases waste disposal and saves the natural resources.

4. Objective for the Study

In civil engineering concrete is a base material used for all construction work parameters. By keeping this aspects some of supplementary materials are used for concrete following objective can be investigated based on literature review.

1) As per IS specifications basic properties of materials are to be determined.
2) Carry out the different test on bagasse ash and RCA to verify the suitability and comparing the result with natural coarse aggregate and cement.

Carry out different tests on concrete made up of RCA, NCA and bagasse ash such as slump cone, compressive strength, split tensile, flexural strength, SEM and durability tests.

5. Scope of present Work

The present aspect focus on the effects of bagasse ash on recycled coarse aggregate on both fresh and hardened properties of M20 grade of concrete, RCA is replaced with the NCA in proportion of 20%, 30% and 40% and cement with bagasse ash of 5%, 10%, 15% and 20% with 30% RCA in the each mix. Maximum size of both RCA and NCA used are 20mm down sized. For each mix of hardened concrete compressive strength, split tensile and flexural strength tests are performed.

6. Materials Used

6.1 Cement

OPC of 53 grades is used in this study. Physical properties of binding cement is given in Table 1

Table 1: Physical properties of 53 grade cement

SL No.	*Properties*		*Result*	*IS code*
1	Specific gravity		3.1	----
2	Normal consistency		29%	----
3	Initial setting time of cement		140	>30(min)
4	Final setting time of cement		295	<600(max)
5	Fineness of cement (%)		5	<10%
6	Compressive Strength(N/mm^2)	3 Days	31.92	>23
		7 Days	42.36	>33
		28 Days	58.23	>43

6.2 Fine Aggregates

M sand is a substitute for the river sand produced by crushing the hard granite stones.

Table 2: Properties of M Sand

SL No.	*Tests*	*Value*	*IS code*
1	Specific gravity	2.64	IS 2386
2	Water absorption	1.8	(part-111)-1963

The size of the manufactured sand is less than 4.75mm. Physical properties and sieve analysis of M sand are specified in the Table 2 and 3 respectively.

Table 3: Sieve analysis of M sand

IS sieve size	*Percentage passing (%)*	*Grading requirement for zone II*	*Remarks*
4.75mm	100	90-100	Conforming zone II requirement as per IS383-1970
2.36mm	89	75-100	
1.18mm	60	55-90	
600µm	46	35-59	
300µm	27	8-30	
150µm	7.6	0-10	

6.3 Coarse Aggregate

Natural aggregate of 20mm downsize aggregate is used which is collected from the quarry. RCA was obtained by crushing the lab specimen of around two years old by using the hammer. Properties of RCA and NCA are examined. Table 4 and Table 5 shows the characteristics of coarse aggregates and sieve investigation of the coarse aggregates respectively.

Table 4: Properties of coarse aggregate

SL No.	*Tests*	*Results*		*IS Code*
		NCA	*RCA*	
1	Specific gravity	2.7	2.40	IS 2386 (part-III)-1963
2	Water absorption, %	0.5	2	
3	Aggregate crushing value, %	22.20	27.50	IS 2386 (part-IV)-1963
4	Aggregate impact value, %	29	32	

Table 5: Sieve analysis of coarse aggregate

IS sieve size (mm)	*Percentage passing (%)*		*Grading for graded aggregate of nominal 20mm size*	*Remarks*
	NCA	*RCA*		
40	100	100	100	Conforming the graded aggregate as per IS:383-1970
20	98	96	95-100	
10	47.4	46.4	25-55	
4.75	5.4	6.6	0-10	

6.4 Bagasse Ash

Bagasse ash is a by-product of sugarcane milling industries. Fruitfulness of bagasse ash contains silica, alumina, iron and calcium oxide. These are essential chemical requirements in the concrete. Characteristics and chemical composition of baggase ash are given in Table 6 and 7. Fig.1 shows the picture of bagasse ash powder and Fig 2 shows the SEM analysis of SCBA powder.

Figure 1: Bagasse ash

Figure 2: Microstructure of bagasse ash

Table 6: Properties of bagasse ash

SL No.	Tests	Results
1	Specific gravity	2.17
2	Standard consistency (%)	34
3	Initial setting time	160
4	Final setting time	320

By using the SEM, morphology of the bagasse ash was studied. From this noticed that the bagasse ash sample composed of different shaped grains they are spherical, prismatic and fibrous in shape. Both the spherical and prismatic shape particles contains Si and O compounds. It also contains some amount of mg, pb and k. carbon presents in fibrous particles.

Table 7: Chemical composition of bagasse ash
(Source: Ganesha consultancy mysuru)

SL No.	Chemical properties	Chemical composition (%)	Is code recommendation as per is 3812(part II)2003
1	SiO_2	80.11	35% minimum
2	Al_2O_3	0.35	SiO_2+ Al_2O_3+ Fe_2O_3=70%(min)
3	Fe_2O_3	5.29	
4	CaO	3.1	----
5	LOI	7.11	12% maximum

6.5 Water

Portable water is used in study. Water plays a vital role in concrete from mixing to curing. It acts as an important component for aggregate, it makes the concrete workable.

6.6 Super plasticizer

Plasticizer used in the study was Conplast SP 430. About 1% of SP is used by the mass of cement. SP enhance the both strength and quality of cement. The chemical property is given in Table 8.

Table 8: Chemical properties of Conplast SP 430
(Source: FORSAC chemicals (India) Ltd)

Sl No.	Tests	Results
1	Specific gravity	1.20-1.25
2	Chloride content	Nil
3	Solid content	40%
4	Recommended dosage	5ml to 20ml/kg
5	Operating temperature	10-40^{o}c
6	Colour	Dark brown liquid

7. Experimental Methodology

The concrete mix is designed for M20grade as per IS code and adopted 0.45 water cement ratio. For this Super Plasticizer (SP) is added. About 1% of SP is added by the weight of cement.

Table 9: Mix Proportion

Mix	Cement Kg/m^3	Proportion	W/C ratio	Super plasticizer %	Compressive Strength(N/ mm^2) 28 days	Slump (mm)
M20	320	1:2.2:3.9	0.45	1	47.93	100

The mix proportion of M20 grade of concrete is 1:2.2:3.9. In this study the natural aggregate is replaced with the RCA of 20%, 30% and 40%. Later as a trail with 30% of RCA the cement is replaced by bagasse ash at the range of 5%, 10%, 15% and 20% respectively. The mix designation and details of M20 grade of concrete are given in Table 9.

In the investigation of the present study to know the various properties of concrete mixes cube, cylinder and beam were casted to know the strength of each specimen. Such as compression, split tensile and flexural strength.

The mixing operation is carried as follows
1) The specimen was prepared by weigh batching of the materials. The mixing of the material was done with the help of concrete mixer for M 20 grade of the concrete.
2) The mix was done by adding recycled aggregate to the virgin one and bagasse ash with cement in various percentage levels.
3) Firstly, the cement, M sand was mixed by adding the water with the SP later RCA and NCA was added (two stage mixing approach). The mix continued and maintains the homogeneity in each mixing process.
4) The drum is rotated and the homogeneous of mix observed carefully. Then the mix is carried to the tray.
5) Prepared moulds were filled with the concrete after the proper mix and it is compacted by using mechanical vibrator.
6) De-mould was done after the 24 hours. Later concrete specimen were kept in the curing tank for certain period as per IS code designation.
7) After curing specimens were tested for different parameters and tabulated.

8. Result and Discussions

8.1 Slump Cone Test

Workable of the concrete is noticed by the slump test. Control concrete slump value is 100mm for the designed M20grade concrete. After the replacement of 20% RCA to virgin aggregate the reduction of 10% slump is noticed further increasing in the RCA percentage the slump gets reduced. This is may because of the old mortar paste which is in that RCA absorbs the added water due to this the slump value gets decreased. By adding the sugarcane baggase to the 30% RCA in percentage of 5%, 10%, 15% and 20% the slump gets increased this is due to the finer particles present in bagasse may makes flow ability to the concrete or more surface area of the SCBA. After adding SCBA requires minimum amount of water to saturate the particles of the cement.

8.1.1 Effect of RCA on Utilization of Concrete Mix

Fig 3 shows the graphical representation of slump by adding the RCA to the normal concrete mix.

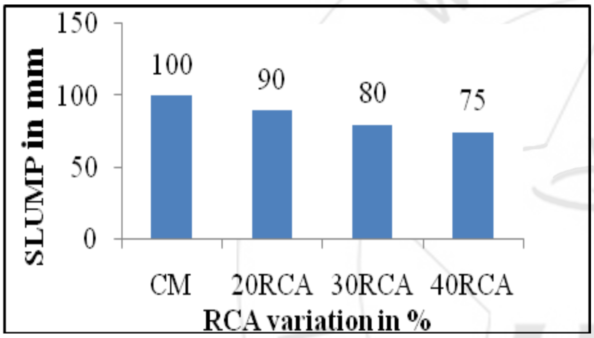

Figure 3: Effect of RCA on slump

Increasing in the percentage of RCA decreased the slump value. This may due to the resistance to flow offered by the hardened cement mortar and also may due to absorption of the water due to the old mortar.

8.1.2 Effect of Bagasse Ash and RCA on Utilization of Concrete Mix

Fig 4 shows the pictorial representation of the slump by adding the bagasse ash to the normal concrete mix. The slump value of the concrete with the 30% of RCA with 5%, 10%, 15% and 20% of bagasse ash gets increased. This may be due to spherical shaped particles which are presented in the bagasse ash particles compared to cement particles.

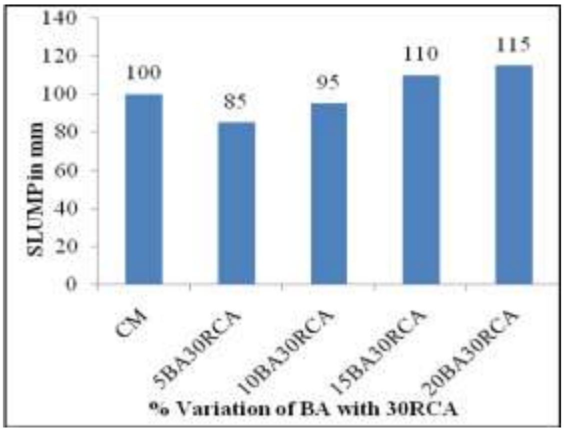

Figure 4: Effect of bagasse and RCA on slump

8.2 Compression Strength

8.2.1 Effects of RCA on the concretes compressive strength

Fig 5 shows the concrete compressive strength for different mixes. M20 grade of concrete is used. The RCA is replaced with the virgin aggregate in the range of 20%, 30% and 40%.

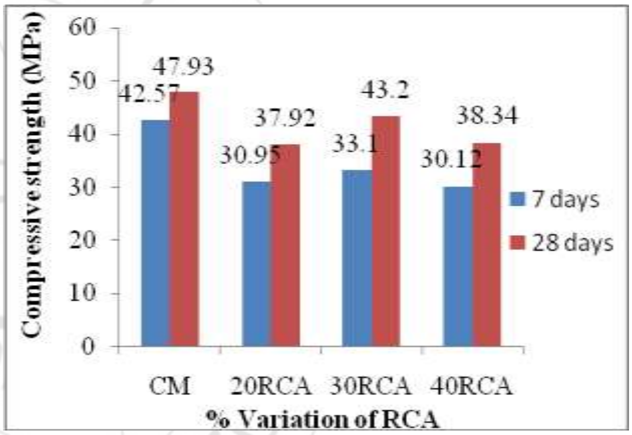

Figure 5: Effect of RCA on compressive strength of concrete

After the curing period of 7 and 28 days it was found that 27.29%, 22.24% and 29.24% strength was decreased compared to the control mix for 7 days and 20.88%, 9.86% and 20% strength decreased compared to control concrete for 28 days. In the 28th day 30% RCA cube strength reduction is less may be due to good gradation. Increasing the addition of RCA the strength reduction increased this may due to the adhered mortar presented on the surface of the RCA.

8.2.2 Effect of Addition of Bagasse Ash on RCA Concrete

Fig 6 shows the effect of the bagasse ash on RCA concrete. NCA was replaced with the RCA of 30% and cement replaced with the ash of 5%, 10%, 15% and 20% in concrete mix.

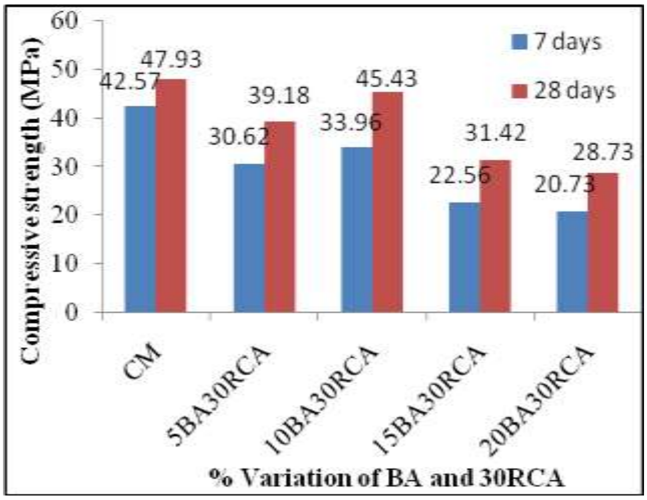

Figure 6: Effect of RCA on compressive strength of concrete

After the 7 and 28days of curing of the specimen in the curing tank the results was found that 28.07%, 20.22%, 47.00% and 51.30% for 7 days. For 28days the results found to be 18.25%, 5.21%, 34.44% and 40.05%. In both the cases the strength found to be decreased compared to the controlled concrete but up to 10% not that much reduction in strength. This may be due to rich in pozzalonic reaction. After 10% replacement of the ash the reduction in percentage of strength is more this may be due to quantity of pozzalonic material in the mix is greater than the quantity which is essential to blend with released lime at the time of hydration process causing the deficiency or reduction in the strength.

8.3 Tensile Strength

By adding the RCA to the NCA the split tensile strength reduced with the bagasse ash combination up to the 10% the strength is comparable with the control concrete.

8.3.1 RCA effect on the Tensile Strength of Concrete for 7 And 28 Days

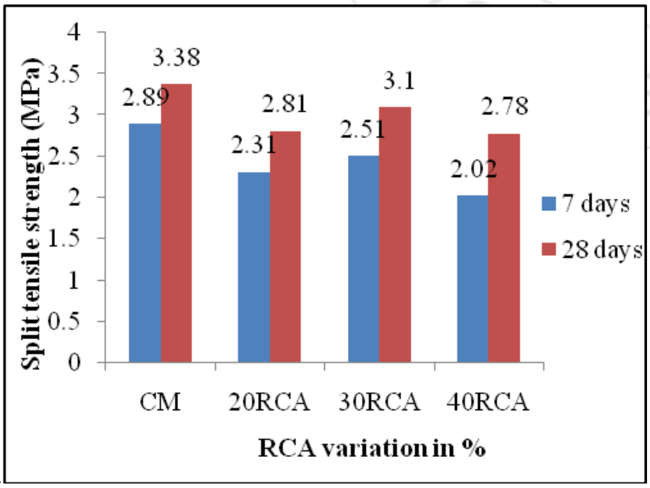

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Figure 7: RCA effect on split tensile strength of concrete

Fig 7graphically represents the effect of the RCA in split tensile strength. The cylinder was casted for 7 and 28days. The addition of RCA in the range of 20%, 30% and 40% the strength of 20.41%, 13.14% and 30.10% was reduced for 7days. The strength of 16.86%, 8.28% and 17.75% reduced for 28days.the strength reduced due to the adhered mortar

8.3.2 Bagasse Ash and RCA effect on the Tensile Strength of Concrete for 7 and 28days

Fig 8 shows the pictorial representation of the effect of ash and RCA on the concrete. 30% RCA and 5%, 10%, 15% and 20% addition of the bagasse ash, concrete cylinder was casted for a curing period of 7 and 28 days.

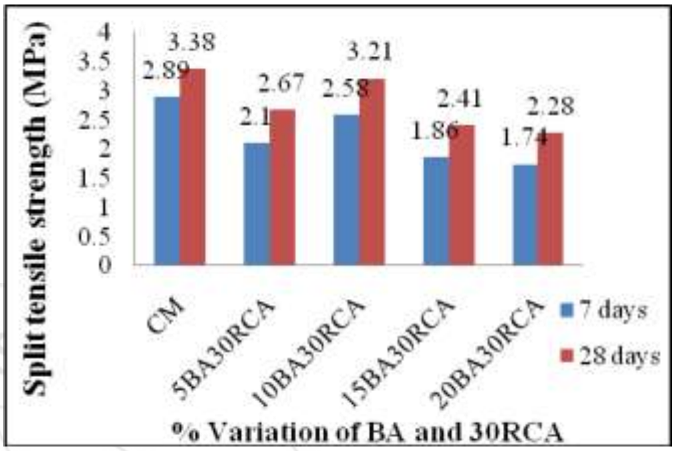

Figure 8: Bagasse ash and RCA effect on split tensile strength

It was found that 27.33, 10.72, 35.64 and 39.79% of strength decreased for 7 days and 21, 5.02, 28.64 and 32.54% strength decreased for 28 days. Up to 10% strength is comparatively good compared to the control concrete after that strength was decreased due to the more amount of pozzalonas availability compared to the lime availability after the hydration process in cement particles.

8.4 Flexural Strength

Adding the RCA with the various percentages the Flexural strength was decreased up to a certain limit. After addition of bagasse ash with 30% RCA the strength up to 10% bagasse level is performed significantly better. The strength decreased after the increasing in the bagasse ash percentage.

8.4.1 Bagasse Ash and RCA effect on the Flexural Strength of Concrete for 28days

Fig 9 graphically presents the flexural strength of concrete with addition of bagasse ash and RCA at 28 days of curing. With the percentage increasing in the RCA the strength level decreased about 18.25, 12.85 and 19.5% compared to controlled concrete, this may be due to the adhered mortar presented in the RCA. With constant 30% RCA by varying the ash the strength is good up to 10%. The percentage was decreased only by 10.83%. After that the strength reduction will be more. This is due to the excess available of bagasse compared to lime presented in the mix.

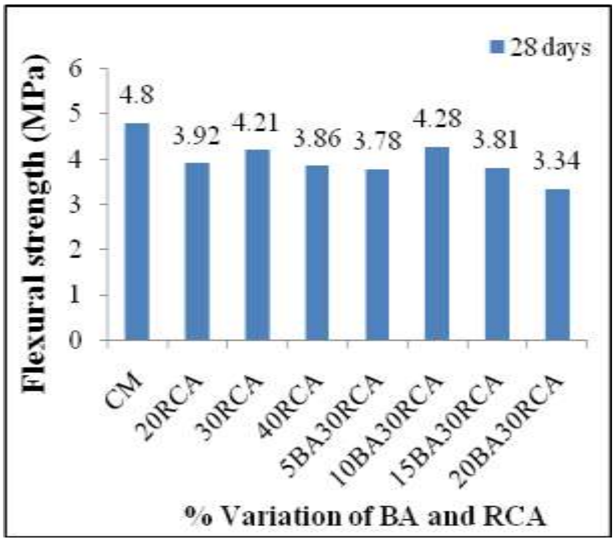

Figure 9: Bagasse ash and RCA effect on the flexural strength of concrete

8.5 Microstructural Analysis By Sem

Micro structural analysis of control concrete, 30%RCA and 30%RCA with 10% bagasse ash concrete was carried out by using the SEM analysis at 28days of curing. By using this technique interfacial zone, C-S-H formation, CH which are identified these are plays a major role in the strength aspect of the concrete. Fig 10 to 12 shows the control concrete, 30RCA and 30RCA10BA morphology. By this one can observe the concrete property with only NCA, RCA and also by combination of both RCA and pozzalonic material.

8.5.1 Control Concrete

Fig 10 represents the formation of the interfacial transition zone (ITZ). It is the gap length, between the aggregate and cement paste. The formed calcium silicate hydrate can also see in the figure. From the figure observed that microstructure is not homogenous. The paste was densely packed this resembles the strength of the concrete

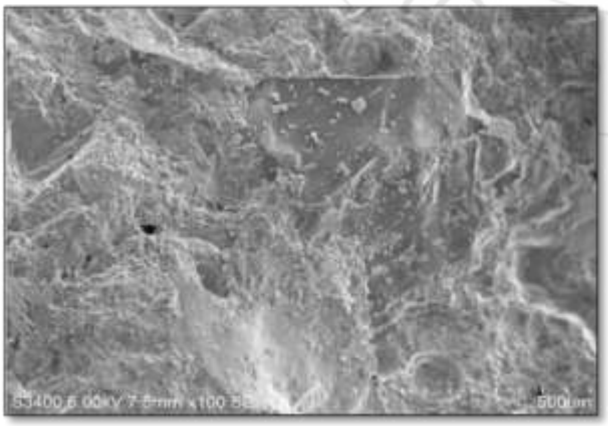

Figure 10: Microstructure of control concrete

8.5.2 RCA Concrete

Fig 11 represents the SEM analysis of 30% RCA concrete. The adhered mortar was observed on the face of the RCA. The formation of the new ITZ zone was observed where the calcium silicate hydrate is observed in the figure. From this CSH the concrete gets strength.

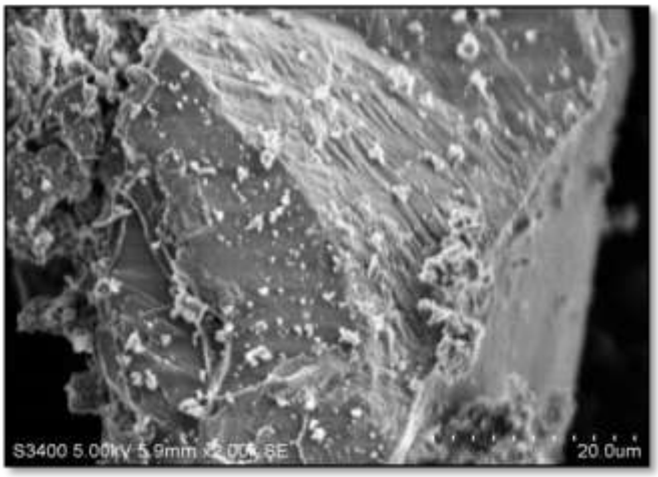

Figure 11: Microstructure of RCA concrete

8.5.3 Bagasse Ash Concrete

Fig 12 represents the SEM analysis of the bagasse ash concrete of 10BA30RCA. The adhered mortar was observed on the aggregate. The new ITZ zone clearly sees in the figure. The formed CSH and the CH was noticed. Bagasse ash concrete reduces the formation of CH by forming that to calcium silicate hydrate.

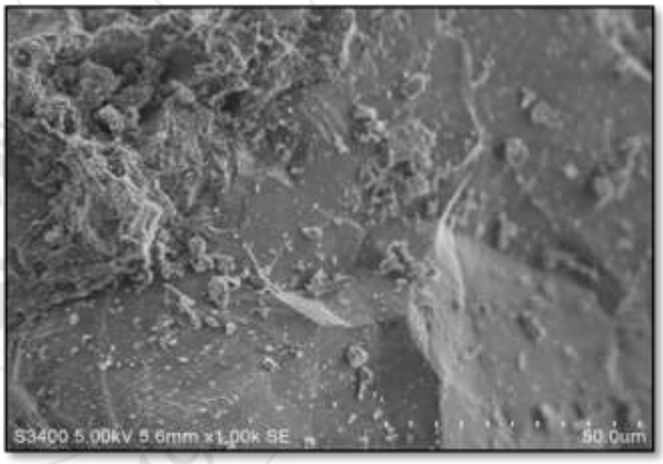

Figure 12: Microstructure of bagasse ash with RCA concrete

8.6 Durability Test

Durability test was conducted for a specimen of controlled concrete, 30% RCA concrete and 10% bagasse ash with 30% RCA concrete, after casting the concrete cubes it was kept for a curing period of 28 days in the curing tank. Later it was immersed for both acid and base attack. The chemical used here was HCL and $NaSo_4$, about 3% of chemical was added to water which is used for the immersion of the cubes.

Table 10: Acid attack test result

Mix Designation	*Compressive strength (N/mm^2)*			*Weights (kg)*		
	Actual strength	*Reduced strength*	*Strength Loss (%)*	*Actual weight*	*Reduced weight*	*Weight loss (%)*
CC	47.93	45.28	5.52	8.68	8.58	1.15
30RCA	43.20	40.43	6.41	8.30	8.12	2.16
10BA 30RCA	45.43	42.72	5.96	8.38	8.24	1.67

Table 11: Base attack test result

Mix Designation	Compressive strength (N/mm^2)			Weights (kg)		
	Actual strength	Reduced Strength	Strength loss (%)	Actual weight	Reduced weight	Weight loss (%)
CC	47.93	46.86	2.23	8.61	8.57	0.46
30RCA	43.20	41.73	3.40	8.35	8.28	0.83
10BA 30RCA	45.43	44.21	2.69	8.41	8.36	0.59

8.6.1 Effect of Acid on Strength and Weight of the Concrete Cubes

Fig 13 graphically represents the strength and weight losses due to the acid attack on the concrete specimens. Both the strength and weight reduction is observed more in 30RCA and 30RCA10BA compared to the controlled concrete. In the controlled concrete not that much porous compared to the 30RCA and 30RCA10BA so it's not much gets detoriated. Due to the porous by the adhered mortar in the 30RCA the reduction of both strength and weight more observed in 30RCA. In the 30RCA10BA strength and weight reduction was less compared to 30RCA. Because the Pozzalonic action is observed in the bagasse ash mixed concrete.

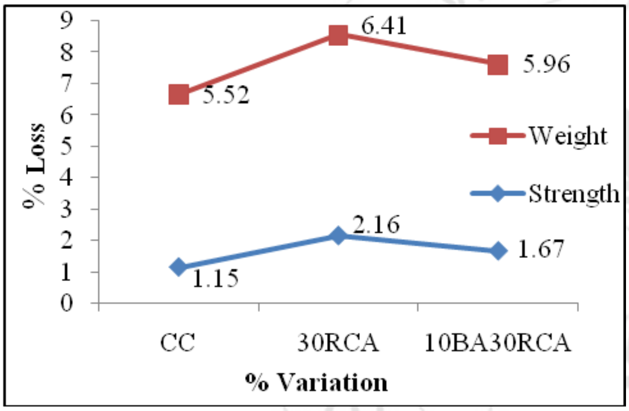

Figure 13: Strength and weight losses due to the acid attack

8.6.2 Effect of Base Attack on Strength and Weight of the Concrete Cubes

Fig 13 graphically represents the strength and weight losses due to the acid attack on the concrete specimens. Both the strength and weight reduction is observed more in 30RCA and 30RCA10BA compared to the controlled concrete. In the controlled concrete not that much porous compared to the 30RCA and 30RCA10BA so it's not much gets detoriated. Due to the porous by the adhered mortar in the 30RCA the reduction of both strength and weight more observed in 30RCA. In the 30RCA10BA strength and weight reduction was less compared to 30RCA. Because the Pozzalonic action is observed in the bagasse ash mixed concrete.

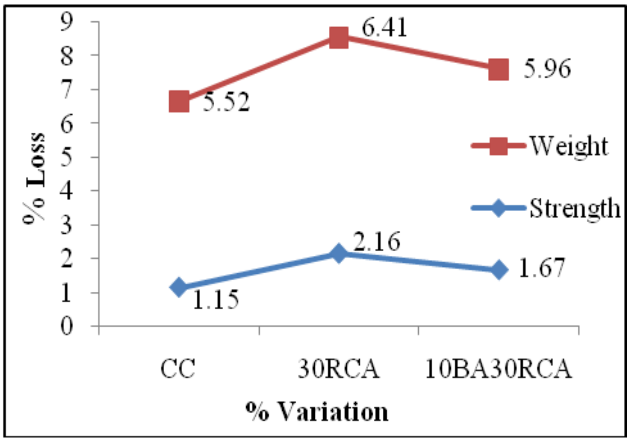

Figure 13: Strength and weight losses due to the acid attack

8.6.3 Effect of Base Attack on Strength and Weight of the Concrete Cubes

Fig 14 graphically represents the strength and weight loss due to the base attack. Strength and weight loss was seen less compared to the acid attack. Controlled concrete strength and weight loss is less as noticed in the acid attack. The strength and weight loss is more in the 30RCA due to the adhered mortar this makes the concrete porous. In the bagasse ash concrete the strength and weight loss is less compared to the 30RCA. Because of the bagasse ash the formed calcium hydroxide which makes the concrete porous converted to the CSH gel. Avoids leach out effect.

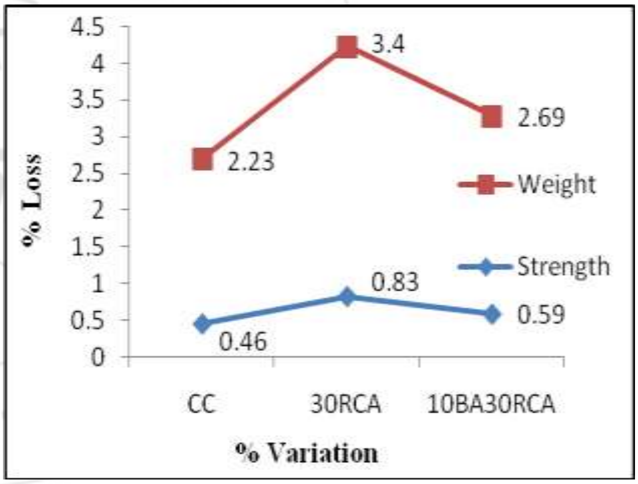

Figure 14: Strength and weight loss due to the base attack

9. Conclusions

From the current study, which was carried out with bagasse ash and RCA following conclusion is made.

1) From the test of oxide composition i.e. $SiO_2+Al_2O_3+Fe_2O_3$ gives the values of about 86.19% which indicates that collected bagasse from pandavpura sugar factory classified as class F pozzalona.
2) Water absorption of RCA is more than conventional concrete with NCA because of adhered mortar to improve the workability Pozzalonic material bagasse ash can be used.
3) By the SEM analysis lot of spherical shaped particles were observed in bagasse ash this made the concrete workable.

4) Strength parameter of BA10 with 30RCA was good which is comparable with controlled concrete, which is recommended.
5) Durability aspect of bagasse ash with RCA concrete is good compared to RCA concrete because of Pozzalonic reaction of ash made reaction with CH forms CSH gel so to make concrete durable SCBA is suggested.

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