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Developing a Sustainable Concrete using Sugarcane Bagasse Ash (SBA) with partial replacement of Fine Aggregate and Cement

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Abstract: There are lots of environmental impacts of cement on our ecology. Cement industry creating environmental problem by emission of CO2 during manufacturing of cement. Present time many researchers are more focusing towards the environment issue globally. Portland cement is the conventional building material that actually is responsible for about 5%-8% of global CO2 emissions. On the other side Sugarcane Bagasse ash (SBA) generated in sugar mill creating environment issue as most of the part is used as a land fill. In this research work the suitability of sugarcane bagasse ash (SBA) in concrete used as partial replacement with fine aggregate and cement as well. The cement and fine aggregate was partially replaced by SBA at 10%, 20%, 30% and 40%, by weight in normal strength concrete. Sugarcane bagasse ash which is taken from one of the sugar mill of Madhya Pradesh used in M 25 grade of concrete by replacing cement and fine aggregate in percentage by weight and compare with conventional concrete and to check the feasibility of sugarcane bagasse ash in concrete.

Fresh concrete tests like compaction factor test and slump cone test must examined as well as hardened concrete tests like compressive strength at the age of 7, 14 and 28 days , and flexural strength at the age of 7 and 28 days is to be obtained.

Keywords: Sugarcane Bagasse Ash (SBA), Concrete, Compressive Strength, Flexural Strength, Waste Material, Durability, waste utilization

I. INTRODUCTION

Concrete is the secondary most widely used material after water and over six milliard tons of concrete is produced each year. Concrete is specific to separate approach like new construction, repair, rehabilitation and retrofitting. Concrete building components in separate sizes and shapes include wall panels, doorsills, beams, pillars and more. Post-tensioned slabs are a select method for industrial, commercial and residential floor slab construction. It makes sense to order the uses of concrete on the basis of where and how it is manufacture, together with its techniques of application, since these have different requirements and properties. Concrete's versatility, durability, supportable, and economy have made it the world's most widely used construction material. About four tons of concrete are manufacture per person per year worldwide and about 1.7tons per person in the United States. The term concrete mentioned to a mixture of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementitious paste. The paste is typically made up of Portland cement and water and may also contain additional cementing materials (SCMs), such as fly ash or slag cement, and chemical admixtures.

Concrete under broad definition of this term, can be an excellent material for the encapsulation of hazardous wastes. Fundamentally, two types of encapsulation are possible. One is a condensed waste storage for those wastes, which can later re-processed and recycled and second is dispersed waste disposal system, in which low concentration of hazardous waste does not produce harmful effects in the encapsulating concrete which therefore can be used as building and construction material. The composition of Portland cement concrete can be optimized using mineral and chemical admixtures, which in themselves can be waste products, for the encapsulation of each particular hazardous waste. However, the best results in most cases can be obtained with concretes based on hydraulic cements other than Portland, or on the organic cements and sometimes with concrete based on the hybrid of two of the above types. Slag alkaline cements, geo polymer and silica water absorption suspension binder can be particularly effective for long term immobilization of hazardous waste in concrete.

II. LITRETURE REVIEW

Tayyeb Akram, et al (2009) This research is aimed at evaluating the usage of bagasse ash as viscosity modifying agent in SCC, and to study the relative costs of the materials used in SCC. In this research, the main variables are the proportion of bagasse ash, dosage of super plasticizer for flow ability and water/binder ratio.

The parameters kept constant are the amount of cement and water content. Test results substantiate the feasibility to develop low cost self compacting concrete using bagasse ash. In the fresh state of concrete, the different mixes of concrete have slump flow in the range of 333 mm to 815 mm, L-box ratio ranging from 0 to 1 and flow time ranging from 1.8 s to no flow (stucked). Out of twenty five different mixes, five mixes were found to satisfy the requirements suggested by European federation of national trade associations representing producers and applicators of specialist building products (EFNARC) guide for making self compacting concrete. The compressive strengths developed by the self compacting concrete mixes with bagasse ash at 28 days were comparable to the control concrete. Cost analysis showed that the cost of ingredients of specific self compacting concrete mix is 35.63% less than that of control concrete, both having compressive strength above 34 MPa.

Kawee Montakarntiwonga, et al (2013) Two different sources of bagasse ash with low and high loss on ignition (LOI) were used in this experiment. Ordinary Portland cement was replaced by bagasse ash at the levels of 20%, 30%, and 40% by weight of binder. The effects of LOI, fineness, and cement replacement of bagasse ash on the compressive strength of concrete were investigated. Additionally, the heat evolution of concrete mixed with ground bagasse ash with low LOI was also measured. The results revealed that the compressive strength of concrete containing unground bagasse ash was much lower than that of control concrete (CON). Concrete mixed with low LOI ground bagasse ash had a slightly higher compressive strength than the mixture with high LOI ground bagasse ash. The replacement of cement by ground bagasse ash with low and high LOI at 30% and 20% by weight of binder, respectively, result in a compressive strength at 28 days as high as that of CON concrete. Finally, the temperature of bagasse ash concretes could be reduced by 13–37% relative to CON concrete, depending on the level of cement replacement by ground bagasse ash with low LOI.

Y.R. Loh, D. Sujan, M.E. Rahman and C.A. Das (2013) The natural, bio-degradable features and chemical constituents of the sugarcane bagasse (SCB) have been attracting attention as a highly potential and versatile ingredient in composite materials. Eco-friendly and low cost considerations have set the momentum for material science researchers to identify green materials that give low pollutant indexes. Various components of SCB is shown to possess the ability of being applied as raw material for manufacturing of composite materials at multiple levels of properties and performances. Studies on the impacts, performances and applications of SCB in its original condition; transformed forms; treated with appropriate chemicals and/or processes; in combination with materials of distinct properties and manipulation of manufacturing methodologies have been duly considered. This paper attempts to summarize a review of current literature on the extensive studies that have been undertaken in an attempt to explore plausible applications and potentials of SCB for composite material.

Gritsada Suaiam and Natt Makul (2013) Bagasse ash is an abundantly available combustion by-product in the sugarcane industry. We examined the effect of adding limestone powder to self-compacting concrete mixtures in which large amounts of bagasse ash were employed as a fine aggregate replacement. A Type 1 Portland cement content of 550 kg/m3was maintained in all of the mixtures. The fine aggregate was replaced with 10, 20, 40, 60, 80, or 100% bagasse ash and limestone powder by volume. Mixtures were designed to yield a slump flow diameter of 70 ± 2.5 cm. The workability (slump flow, T50cm slump flow time, V-funnel flow time, and Jring flow) and hardened properties (ultrasonic pulse velocity and compressive strength) of each mixture were measured, and blocking assessments were performed. The volumetric percentage replacement of 20% limestone powder in fine aggregate incorporating 20% bagasse ash effectively enhanced the workability and hardened properties of selfcompacting concrete.

Aukkadet Rerkpiboon, et al (2015) This research examines the strength and durability properties of concrete containing up to 50% ground bagasse ash (GBA) replacing ordinary Portland cement (OPC) by weight of binder. The setting times, compressive strength, modulus of elasticity, chloride resistance, and expansion due to a 5% Na2SO4 solution of concretes containing ground bagasse ash were investigated. The results showed that concrete with 50% of GBA produced at least 90% compressive strength as compared to control concrete at the age of 28 days. The rapid chloride ion penetration in term of charge passed (Coulombs) was at a very low level when 20-`50% of GBA was used to replace OPC in the concrete. Moreover, the same trend of chloride penetration depth was found by the immersion test, i.e., the chloride resistance increased with the increase of GBA replacement. The results suggest that the use of GBA of up to 50% to replace OPC by weight of binder can increase the durability properties of concrete, especially its chloride penetration resistance.

Eduardo Gurzoni Alvares Ferreira, et al (2017) Sustainable development has been growing concern worldwide, with special emphasis to its effects on climate change. An important action to reduce the environmental damage is the decrease of cement use. In this study the pozzolanicity of Sugarcane Straw Ashes (SCSA), thermal treated, at different curing times was investigated. Synchrotron Xray Powder Diffraction measurements allowed the quantification of several phases of the cement pasts through Rietveld analysis.

The properties of cement paste are directly related to the concentrations of Alite, Belite, Portlandite, Brownmilite and amorphous phases. Tomography technique was also used to study the differences amongst the pore structures according to type of ash used.

Tekram Bais, et al (2020) The addition of complex chemical compound in form of polymer in the form of binding and plasticizing agent, to the concrete mix also introduces the desired plasticity and strength to enhance the property of concrete w.r.t. the normal conventional concrete. Fresh concrete tests like compaction factor test and slump cone test was examined as well as hardened concrete tests like compressive strength, rebound hammer test and flexural strength at the different ages of days is obtained according to feasibility. Results show that there is decrease in slump value and compaction factor.

III. MATERIALS AND METHODOLOGY

A. *Materials Used*

1) *Cement:* Ordinary Portland Cement 43 grade having properties as mentioned in Table No.3.1 was used.

Table No. 3.1 – physical Properties of cement

Physical Properties	IS Specification
Soundness value (mm)	2.0
Fineness (cm^2/gm.)	2850
Standard Consistency (%)	30
Initial setting time (minutes)	120
Final setting time (minutes)	200
Specific gravity	3.15

2) *Fine Aggregate:* The locally available natural sand with 4.75 mm maximum size was used as fine aggregates, having specific gravity, fineness modulus, bulk density, water absorption as given in the Table No. 3.3 The grading must be uniform throughout the work. Both fine aggregate and coarse aggregate validating to Indian Standard Specifications IS: 2383-1963
3) *Coarse Aggregate:* The maximum nominal size of coarse aggregate is taken as 20 mm. Well graded cubical or rounded aggregates are desirable. The sample used is of uniform quality. Crushed aggregates of less than 20 mm size produced from local crushing plants were used. The aggregate absolutely passing through 20 mm sieve size and retained on 10mm sieve is selected. The mix coarse aggregate size (10 mm and 20 mm size) in a well maintained proportion according to concrete mix design is taken. The individual aggregates were mixed in a definite proportion to induce the required combined grading. The coarse aggregate with 20 mm maximum size having specific gravity, fineness modulus, water absorption and bulk density as below.

Table No. 3.3 - Properties of fine aggregate and Coarse Aggregate

Physical properties of coarse and fine aggregates	Coarse Aggregates		Fine Aggregates
	10 mm	20 mm	
Specific gravity	2.66	2.71	2.58
Bulk density (kg/m^3)	1620	1580	1740
Water Absorption (%)	0.55	0.60	0.92
Impact value (%)	12.5	-	-
Fineness modulus (mm)	-	-	2.70

4) *Sugarcane Bagasse Ash (SBA):* This waste, utilization would not only be economical, but may also result in foreign exchange earning and environmental pollution control. Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as supplementary cement replacement materials. Along with industrial wastes; agricultural wastes like rice husk, wheat hay, sugarcane bagasse are also being tried to be supplement material.

Currently, there has been an attempt to utilize the large amount of bagasse ash, the residue from an in-line sugar industry and the bagasse-biomass fuel in electric generation industry. When this waste is burned under controlled conditions, it produces ash having amorphous silica, which has pozzolanic properties.

The potential production capacity of burnt sugarcane bagasse residue is around 7-8% of total bagasse consumed. A few studies have been carried out on the ashes obtained directly from the industries to study pozzolanic activity and their suitability as binders, partially replacing cement. Therefore it is possible to use sugarcane bagasse ash (SBA) as cement replacement material to improve quality and reduce the cost of construction materials such as mortar, concrete pavers, concrete roof tiles and soil cement interlocking block.

Figure No. 3.4-Sugarcane Bagasse Ash (SBA)

Table No. 3.4 - Composition of Sugarcane Bagasse Ash

S. No	Chemical compound	Abbreviation	Percentage (%)
1	Silica	SiO_2	68.42
2	Aluminum Oxide	Al_2O_3	5.812
3	Ferric Oxide	Fe_2O_3	0.216
4	Calcium Oxide	CaO	2.554
5	Phosphorous Oxide	P_2O_5	1.258
6	Magnesium Oxide	MgO	0.572
7	Sulphide Oxide	SO_3	4.327
8	Loss on Ignition	LOI	15.86

5) *Concrete Mix Proportion:* Table 3.4 shows the batch descriptions of all the specimen of different proportioned concrete produced during the experimental work of project M25 Grade of concrete were used.
Abbreviation used: FA- Fine aggregate, CA- Coarse aggregate, SBA- Sugarcane Bagasse Ash

Table No. 3.5 – Batching Description

Batch Description		Cement	FA	Coarse Aggregate	SBA
For conventional concrete					
Sample 1	Proportion	1	1.68	2.86	0
	Wt. (kg/m^3)	394.32	658.26	1123.62	0
10% replacement of Fine Aggregate by SBA					
Sample 2	Proportion	1	1.58	2.86	0.10
	Wt. (kg/m^3)	394.32	592.44	1123.62	65.82
20% replacement of Fine Aggregate by SBA					
Sample 3	Proportion	1	1.38	2.86	0.20
	Wt. (kg/m^3)	394.32	526.61	1123.62	131.65
30% replacement of Fine Aggregate by SBA					
Sample 4	Proportion	1	1.08	2.86	0.30
	Wt. (kg/m^3)	394.32	460.78	1123.62	197.48
40% replacement of Fine Aggregate by SBA					
Sample 5	Proportion	1	0.68	2.86	0.40
	Wt. (kg/m^3)	394.32	394.96	1123.62	263.30
10% replacement of both Cement and FA by SBA					
Sample 6	Proportion	0.90	1.49	2.84	0.20
	Wt. (kg/m^3)	354.89	592.44	1123.62	39.43+65.82
20% replacement of both Cement and FA by SBA					
Sample 7	Proportion	0.80	1.32	2.84	0.40
	Wt. (kg/m^3)	315.43	526.61	1123.62	78.86+131.65
30% replacement of both Cement and FA by SBA					
Sample 8	Proportion	0.70	1.16	2.84	0.60
	Wt. (kg/m^3)	276.02	460.78	1123.62	118.30+197.48
40% replacement of both Cement and FA by SBA					
Sample 9	Proportion	0.60	0.99	2.84	0.80
	Wt. (kg/m^3)	236.59	394.96	1123.62	157.73+263.30

IV. RESULT AND DISSCUSION

A. Results Of Slump Cone Test And Compaction Factor Test

The results of slump test value and compaction factor tests are shown below in Table No. 4.1.1 and represented in graphically form.

Table No. 4.1.1- Results of slump test and compaction factor test

Sample	Abbreviation	Slump Value (mm)	Compaction Factor (C.F.)
Sample 1	Conventional	90	0.92
Sample 2	10FA	85	0.90
Sample 3	20FA	79	0.88
Sample 4	30FA	74	0.87
Sample 5	40FA	68	0.85
Sample 6	10C10FA	86	0.91
Sample 7	20C20FA	81	0.88
Sample 8	30C30FA	76	0.87
Sample 9	40C40FA	69	0.85

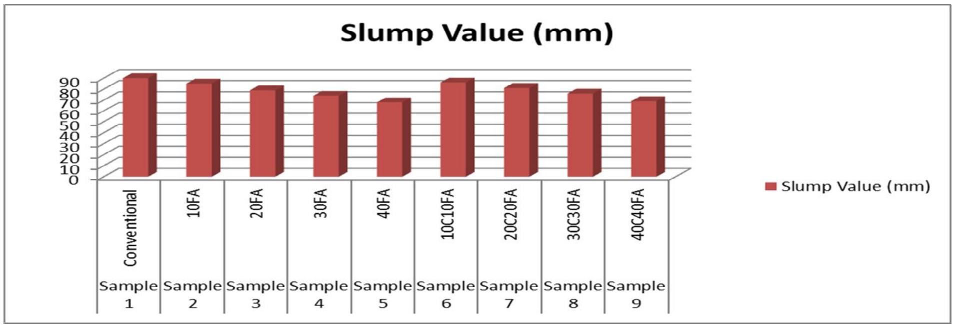

Figure No 4.1.1: Graphical representation of Slump Value (mm)

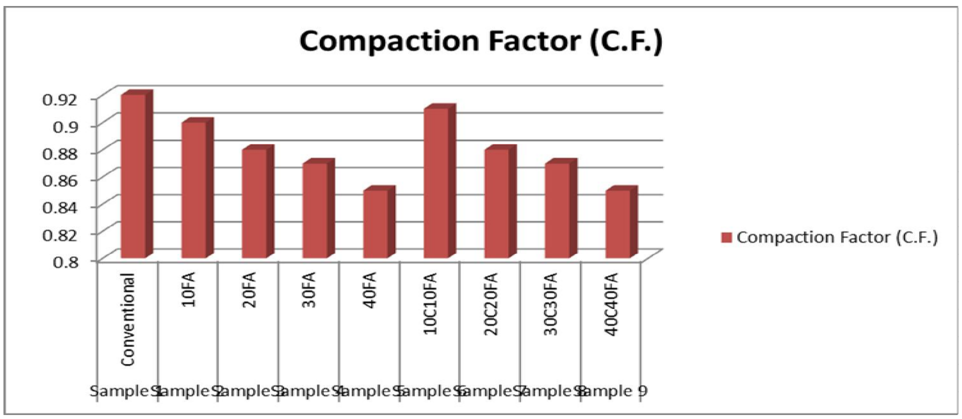

Figure No 4.1.2: Graphical representation of Compaction Factor Value

It can examined from the Graph No. 4.1.1, when replacement of cement by sugarcane bagasse ash (SBA) is increased by percentage (10%-40%), with increase in sugarcane bagasse (SBA) in the concrete mix there is decrease in slump value. There is an indication of less water cement ratio and hence value of slump decreases with increase in sugarcane bagasse ash (SCBA).This can be explained as, more the sugarcane bagasse ash (SBA) in concrete mix; less will be the water in the concrete mix. This can clarified with the fact that sugarcane bagasse ash (SBA) is more porous than cement, which requires more amount of water for lubrication process.

Similar trends of result obtained when replacement of fine aggregate by sugarcane bagasse ash (SBA) is used in concrete mix. As sugarcane bagasse ash (SBA) is more permeable than sand, so the slump value obtained are quite higher than case of cement replacement for the same proportioning.

Similarly, Graph No. 4.1.2 shows the results of compaction factor test for all different sample or parameters used in the experimental study. The result of compaction factor tests also determines the similar behavior of fresh concrete as in slump test.
Same trends of result obtained from slump test are followed in compaction factor test,which clarifies or confirms the accuracy of results so obtained.

B. Results Of Compressive Strength Test Of Concrete Cubes

The Compressive Strength test was carried out by obtaining compressive strength of concrete at 7, 14 and 28 days. The cubes of dimension 150×150×150mm are tested using Universal Testing Machine of 2000KN capacity. The table below represents the variation of compressive strength with age for M25 grade Concrete.
The characteristic compressive strength of concrete at 7 days, 14 days and 28 days was found in N/mm^2. The results are shown below in tabular form in Table No. 4.2.1 and are represented graphically in Graph No. 4.2.1 respectively for all the specimens. Average results of 3 samples for each parameter (specimen/days of test) are evaluated by using universal testing machine.

Table No. 4.2.1- Compressive strength of cube specimen

Specimen	Abbreviation	Average Compressive Strength of Cubes (N/mm^2)		
		7 days	14 days	28 days
Sample 1	Conventional	22.43	29.70	32.95
Sample 2	10FA	22.86	29.55	32.65
Sample 3	20FA	21.10	27.48	30.52
Sample 4	30FA	20.15	26.61	29.46
Sample 5	40FA	19.39	25.97	28.79
Sample 6	10C10FA	22.52	28.99	32.15
Sample 7	20C20FA	20.92	27.44	30.25
Sample 8	30C30FA	20.88	26.26	29.13
Sample 9	40C40FA	19.30	25.90	28.60

Result showed a continuous decrease in the strength with addition of SBA in the concrete. Decrease in compressive strength with the increase SBA can be justified by the fact that SBA does not have such binding property as compared to cement. At the same time, SBA imparts more strengthen properties comparing to sand because it is finer than sand thus results in less voids in the concrete specimen.

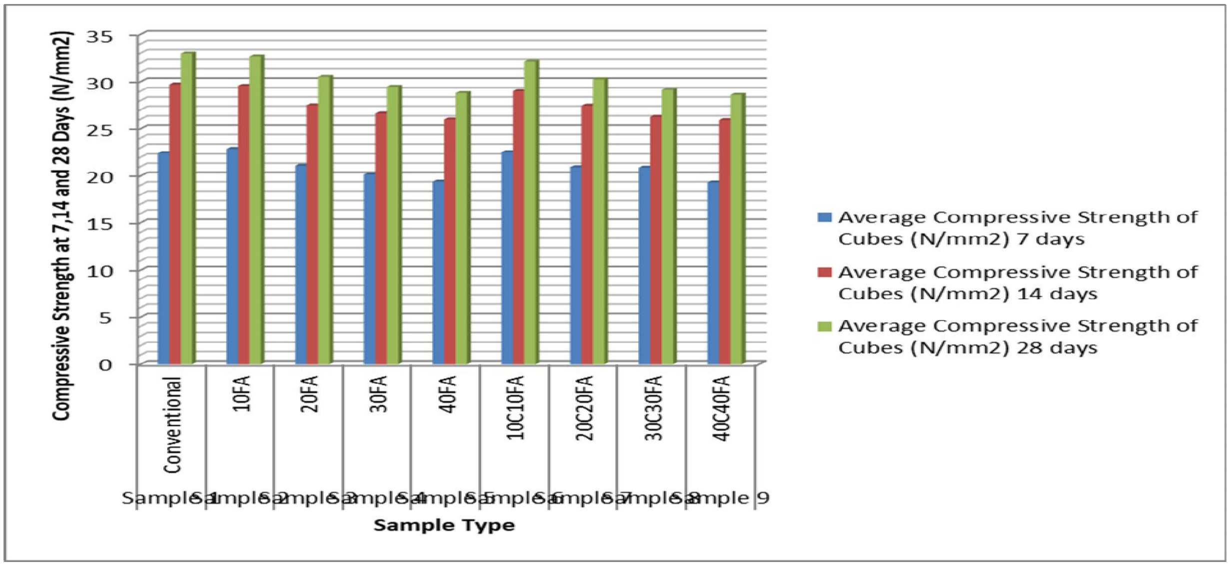

Figure No 4.2.1: Graphical Arrangement of Compressive Strength at 7,14 and 28 Days (N/mm2)

C. Results Of Flexural Tensile Strength Test Of Concrete Beam

The flexural strength of concrete beam at 14 days and 28 days was found in N/mm^2. The results are shown below in Table No. 4.3.1 and are represented graphically in Graph No. 4.3.1 & Graph No. 4.3.2 respectively for all the specimens. Average results of 3 samples for each parameter (specimen/days of test) are evaluated by using BIS: 456-2000 specification.

Table No. 4.3.1- Flexural strength of concrete beam specimen

Specimen	Abbreviation	Flexural Strength of Beam (N/mm^2)	
		14 Days	28 Days
Sample 1	Conventional	4.89	5.39
Sample 2	10FA	4.78	5.35
Sample 3	20FA	4.69	5.20
Sample 4	30FA	4.64	5.13
Sample 5	40FA	4.59	4.99
Sample 6	10C10FA	4.78	5.33
Sample 7	20C20FA	4.67	5.19
Sample 8	30C30FA	4.59	4.99
Sample 9	40C40FA	4.46	4.97

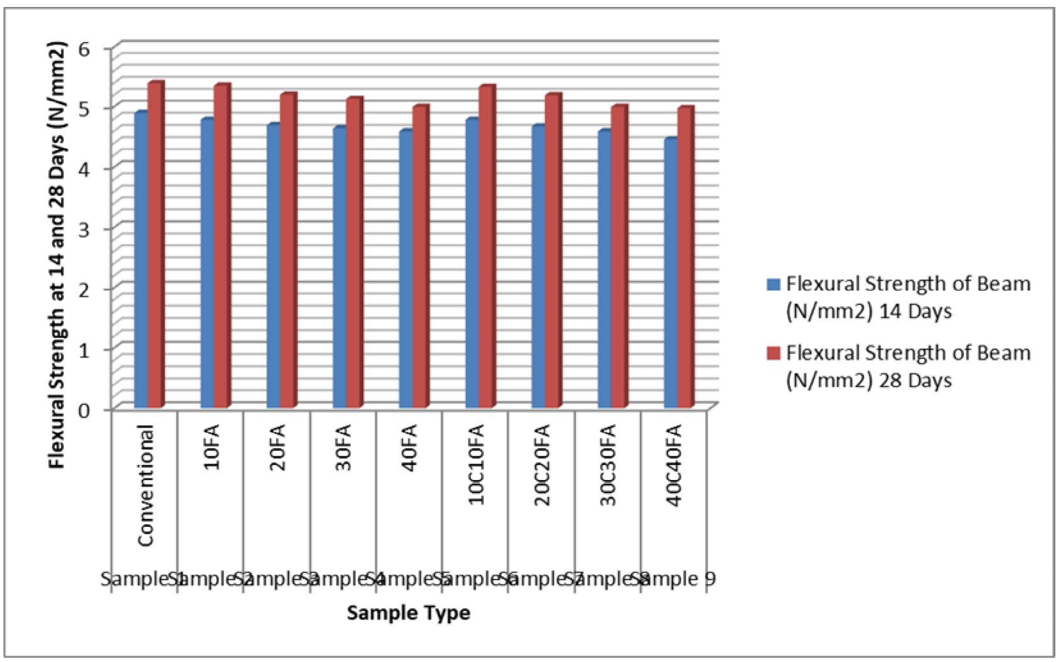

Figure No 4.3.1: Graphical Arrangement of Flexural Strength at 14 & 28 Days (N/mm2)

Result showed a continuous decrease in the flexural strength with addition of SCBA in the concrete beam. Decrease in flexural strength with the increase SBA can be justified by the fact that doesn't have tensile properties. SCBA provides minimum voids in the concretedue to finer than sand thus helpful in decreasing cracks on concrete beam.

The test results of 14 and 28 days are represented above in Graph No. 4.3.1.

D. Results Of Rebound Hammer Test On Cubes

The rebound hammer test of cube at 28 days was found. The results are shown below in tabular form in Table No. 4.3 and are represented graphically in Graph No. 4.11 &Graph No. 4.12respectively for all the specimens. Average results of 15measurements for each parameter (specimen/days of test) are evaluated by using BIS: 13311:1992 (part 2) The same trend was observed in case in Rebound hammer test as in compressive strength test which confines the accuracy of test and surface quality of specimen.

Table No. 4.4- Average Rebound Value of Cube specimen

Specimen	Abbreviation	Rebound Value
Sample 1	Conventional	29.70
Sample 2	10FA	24.60
Sample 3	20FA	30.50
Sample 4	30FA	27.60
Sample 5	40FA	25.95
Sample 6	10C10FA	29.05
Sample 7	20C20FA	27.30
Sample 8	30C30FA	26.30
Sample 9	40C40FA	25.90

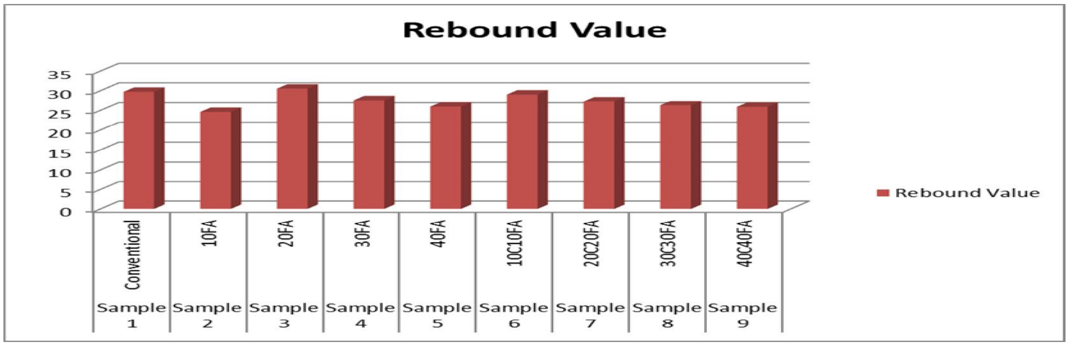

Figure No 4.4: Graphical arrangement of Rebound Value of Beam

V. CONCLUSION

The result of the present study shows that there is great potential for the utilization of waste sugarcane bagasse ash (SBA) in concrete as replacement of fine aggregate as well as cement and fine aggregate.

1) Decrease in slump value by 25% and compaction factor by 9% is examined when the replacement of sand by SBA in the concrete mix from 0% to 40%
2) Compressive strength of concrete cube at 7 days, 14 days and 28 days are decreased by 20%, 19% and 18% respectively when 40% SBA was used to replace cement.
3) Compressive strength of concrete decreases initially with the inclusion of SBA.
4) Flexural strength of concrete at 14 days and 28 days are decreased by 6% and 5% respectively when 40% SBA was used to replace fine aggregate.

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