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Experimental Study on Sand Replacement with Bagasse Ash & Crusher Stone Dust in Concrete Pavement

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Abstract: - This paper presents the findings on the strength and cost effects of using sugarcane bagasse ash and crusher dust blended in the concrete as sand replacement in pavement construction. Literature survey in line with this project shows a high potential for partial replacement of sand in concrete with bagasse ash and crusher stone dust which give the better results when these two materials are mixed up in the partial replacement of sand which gives a good cement concrete pavement for constructing a better strength pavement. In this project an attempt has been made, the concrete with the partial replacement of bagasse ash to the natural sand in concrete at 0%, 5%, 10%, 15%, 20% and 25%. An optimum value is taken into consideration and to these optimum value 10%, 20%, 30%, 40% and 50% values of crusher stone dust is added and the results are analyzed based upon the strength values occurred. Using the flexural strength values, pavement thickness is evaluated as per IRC: 58-2011, it is observed that there is a reduction in the pavement thickness when compared to conventional concrete

Keywords: - Natural sand, Sugar Cane Bagasse ash (SCBA), Crusher stone dust (SD), Compressive strength, Flexural strength, Workability

I. INTRODUCTION

Currently India has taken a major initiative on developing the infrastructures such as express highways, power projects, ports and harbor's, to meet the requirements of globalization, in the construction of pavements and other structures concrete plays the key role and a large quantum of concrete is being utilized in every construction practices. River sand, which is one of the constituents used in the production of conventional concrete, has become very expensive and also becoming scarce due to depletion of river bed. In view of this, there is a need to identify suitable alternative material from waste in place of river sand**.** Sugarcane bagasse (SCB) which is a voluminous by-product in the sugar mills when juice is extracted from the cane. It is, however, generally used as a fuel to fire furnaces in the same sugar mill that yields about 8-10% ashes containing high amounts of un-burnt matter, silicon, aluminium, iron and calcium oxides. But the ashes obtained directly from the mill are not reactive because of these are burnt under uncontrolled conditions and at very high temperatures. The ash, therefore, becomes an industrial waste and poses disposal problems.Today researches all over the world are focusing on ways of utilizing either industrial or agricultural wastes as a source of raw materials for the construction industry. These wastes utilization would not only be economical, but may also help to create a sustainable and pollution free environment.The main problem in the world is now or future existing is the downstream of the natural resources for building and constructing purpose. Basically in India like countries should concern with these developments to undergone by replacing the materials of the industrial by products and waste products to minimize the use of the natural sources in the building and construction. Concrete is the material mostly used in the construction field for building and pavement construction. Natural sand is a very fine material which can contribute for a concrete to solidify to give the necessary strength for a certain structure. Natural sand fill up the pores or voids inside the concrete which is also a contributing factor for the strength of the concrete. Today researchers all around the world are studying the properties of concrete with replacement of the materials which are naturally occurred with industrial wastes in order to decrease the land pollution as well as economical for the cost of construction in procuring the materials.

India is the second largest country in sugarcane production in the world with a 3, 41,200 TMT (Thousand Metric Tons), these sugarcane are converted to sugar and jaggery in large production and there is a large amount of bagasse ash is produced from the agro industries.

The present study was conducted to investigate the possible mechanism of actions underlying the usage of alternate material of sand in concrete with the bagasse ash and crusher dust. In this experimental study based upon the chemical properties as presented in the table, there is a common value ranges from each consistent which can be used as a substitute for natural sand in concrete. In order to overcome the depletion of the natural sand sources and environmental effects, the use of these two materials can replace the sand up to some extent in concrete based upon the experimental values.

In this paper comparison of the cost analysis for conventional concrete and experimental concrete has also been done, and also the results obtained and the strength characteristics also being included, based upon the optimum values occurred, the experiment values are taken into consideration and a concrete pavement is designed. This paper presents the findings on the strength and cost effects of using sugarcane bagasse ash and crusher dust blended in the concrete as sand replacement in pavement construction. Literature survey in line with this project shows a high potential for partial replacement of sand in concrete with bagasse ash and crusher dust which give the better results when these two materials are mixed up in the partial replacement of sand which gives a good cement concrete pavement for constructing a better strength pavement.

II. MATERIALS AND MIX DESIGN

A. Materials

1) Cement:

Ordinary Portland cement (Grade 43) was used. Its physical properties are as given in Table I

Table I: Physical Properties of Cement

Physical property	Results obtained
Fineness(retained on 90 micron sieve/100gm)	8 %
Vicat Initial Setting Time (Minutes)	205
Vicat Final Setting Time (Minutes)	305
Specific Gravity	3.13

2) Sugarcane Bagasse Ash :

The bagasse ash used in the investigation is obtained from a Corporate Sugar Factory in the nearby vicinity. The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemicellulose and 25% of lignin. Each ton of sugarcane generates approximately 26% of bagasse (at a moisture content of 50%) and 0.62% of residual ash. The residue after combustion presents a chemical composition dominates by silicon dioxide (SiO2). Table II gives the chemical composition of bagasse ash.

Table II: The Chemical Composition of Bagasse Ash

Component	**Mass (%)**
SiO_2	62.43
Al_2O_3	4.28
Fe_2O_3	6.98
CaO	11.8

K_2O	3.53
MgO	2.51
SO_3	1.48
Loss of ignition	4.73

3) Aggregates:

Locally available natural sand with 4.75 mm maximum size was used as fine aggregate, having specific gravity, fineness modulus as given in Table 2 and crushed stone with 20mm and 10mm maximum size having specific gravity, fineness modulus and as given in Table III was used as coarse aggregate. Both fine aggregate and coarse aggregate confirmed to Indian Standard Specifications IS: 383-1970 [6]. The sugarcane bagasse ash is obtained from the jaggery point which is separated from other materials and high supervision is taken while producing the ash and collecting from them. The crusher dust is collected from the locally available crushing points

Table III: Physical properties of Coarse and Fine Aggregates

Physical tests	**Coarse Aggregate**	**Fine Aggregates**		
		River Sand	**Bagasse Ash**	**Crusher Dust**
Specific Gravity	2.8	2.6	2.2	2.61
Fineness Modulus	7.91	2.4	2.21	---

B. Mix Design:

Samples are prepared for M-40 grade. For the mix design of the concrete pavement IS: 44-2008 recommendations are adopted. Mix proportions of M-40 are given in the following table IV

Table IV: Concrete Mix-proportions

Material	**Cement (kg/m^3)**	**Sand (kg/m^3)**	**Coarse Aggregate (kg/m^3)**	**W/C Ratio**	**Admixture (lit/m^3)**	**Water (lit/m^3)**
Weight	415	726	1187	0.38	1.10	157.7

III. EXPERIMENTAL WORK AND TESTS CONDUCTED

A. Work Executed:

The experimental work consists of performing the sieve analysis of bagasse ash as per the Indian standard procedure and using the results for the mix design to achieve the concrete of required strength and quality. Based upon the quantities of ingredient of the mixes, the quantities are replaced by volume of sand was estimated. The water cement ratio was kept 0.40 and the dose of super plasticizer was kept constant at 1.18 lit/m^3. The casted concrete specimens were cured under standard condition in the laboratory and tested for 7 days and 28 days compressive strength, workability, and flexural strength.

Table V: Properties of Fresh Concrete with SCBA

Specimen	Material Combination (Kg/m^3)				
	Cement	W/C Ratio	Fine Aggregate	SCBA	Coarse Aggregate
CC	415	0.38	726	--	1187
SC 5%	415	0.38	689.7	36.3	1187
SC 10%	415	0.38	653.4	72.6	1187
SC 15%	415	0.38	617.1	108.9	1187
SC 20%	415	0.38	580.8	145.2	1187
SC 25%	415	0.38	544.5	181.5	1187

Table VI: Properties of Fresh Concrete with SCBA & Crusher stone dust

Specimen	Material Combination (Kg/m^3)					
	Cement	W/C Ratio	Fine Aggregate	Crusher stone dust	SCBA 15%	Coarse Aggregate
CC	415	0.38	726	--	--	1187
SD 10%	415	0.38	555.39	61.71	108.9	1187
SD 20%	415	0.38	493.68	123.42	108.9	1187
SD 30%	415	0.38	431.97	185.13	108.9	1187
SD 40%	415	0.38	370.26	246.84	108.9	1187
SD 50%	415	0.38	308.55	308.55	108.9	1187

B. Tests Conducted:

At the end of each curing period, a total of 3 specimens were tested for each concrete property. The concrete is tested for workability parameters by performing the slump cone test on it, followed by casting the cubes of dimension 100x100x100 mm were casted and were tested on compression testing machine as per I.S.516-1959. For flexural strength test beam specimens of dimension 500x100x100 mm were casted. These flexural strength specimens were tested under four point loading as per I.S.516-1959, using universal testing machine

Fig 1: Compressive Strength Test

Fig 2: Flexural Strength Test

IV. RESULTS AND DISCUSSION

A. Workability:

Slump cone test was performed to determine the slump of the mixes. The slump values for various mixes are shown in the following figure 3

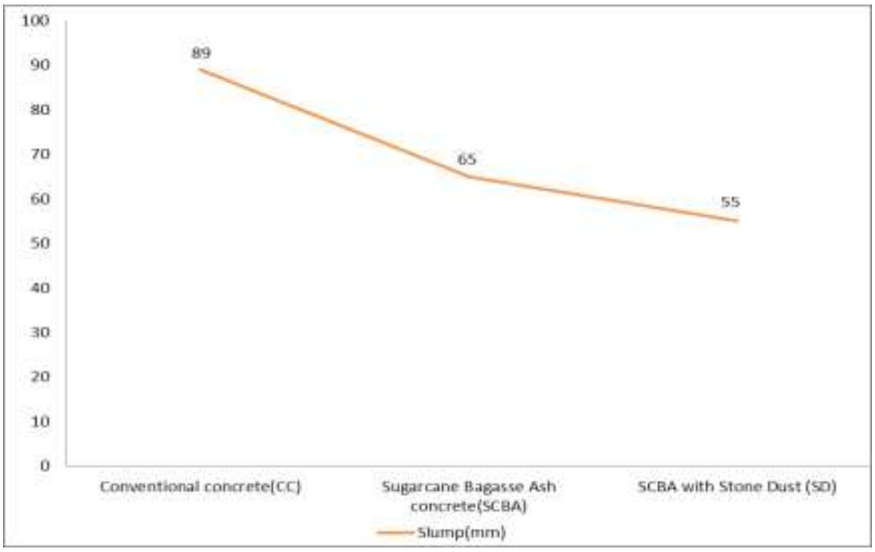

Fig 3: Workability Results

B. Compressive Strength:

Compressive strength values of cube specimens were at 7&28 days testing given in below Figure 4. From the figure 4, it was observed that rate of increment in compressive strength of the SCBA concrete at age of 7&28 days respectively compared to conventional concrete. From the graph it was clear that there is an improvement in compressive strength of the SCBA with Crusher stone dust at age of 7&28 days respectively compared conventional concrete.

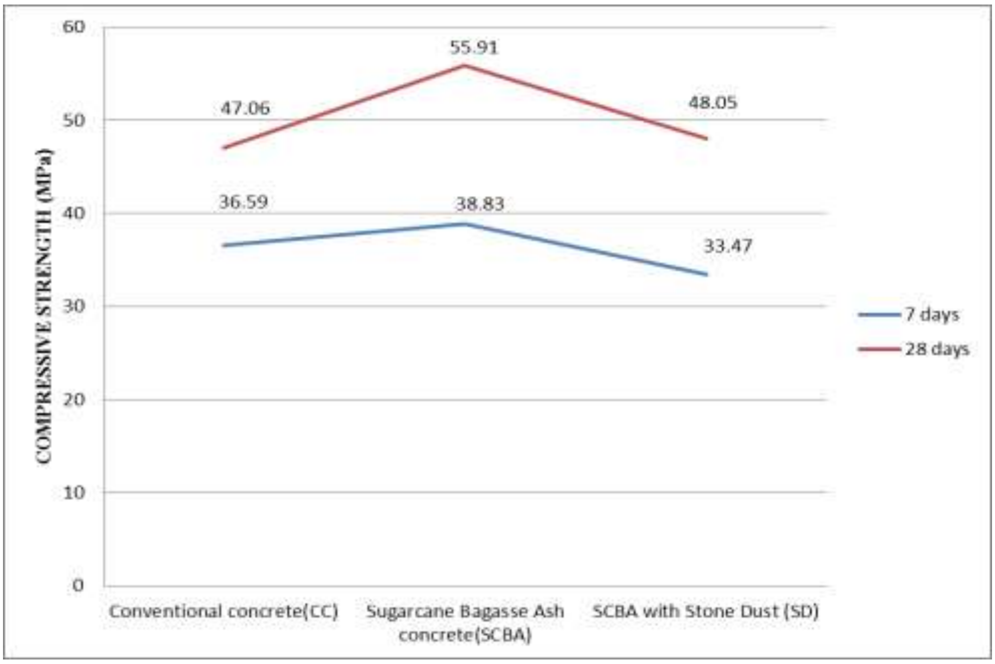

Fig 4: Compressive Strength Results

C. Flexural Strength:

Flexural strength values of cube specimens were at 7&28 days testing given in below Figure 5. From the figure 5, it was observed that rate of increment in flexural strength of the SCBA concrete at age of 7&28 days respectively compared to conventional concrete. From the graph it was clear that there is an improvement in flexural strength of the SCBA with Crusher stone dust at age of 7&28 days respectively compared conventional concrete.

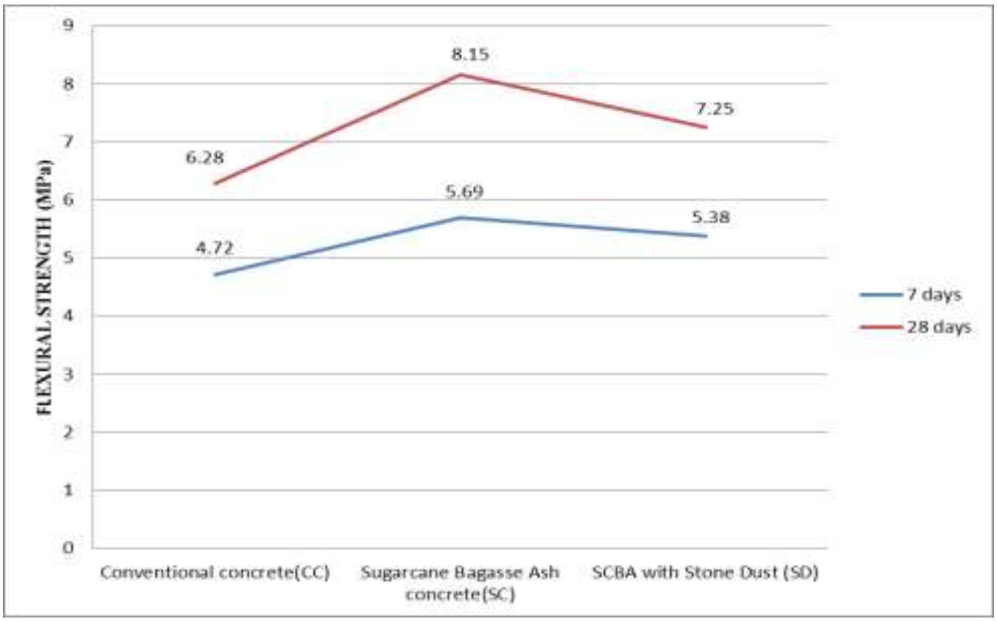

Fig 5: Flexural Strength Results

V. PAVEMENT SLAB DESIGN AND ANALYSIS

Pavement slab was designed as per IRC 58:2011. The flexural strength is directly taken from the beam flexural test. The axial load spectrum is taken from IRC: 58-2011 and other data used in this design are given below. A cement concrete pavement was to be designed for a four lane divided National Highway with two lanes in each direction in the state of Bihar. The total two-way traffic is 6000 commercial vehicles per day at the end of the construction period. The concrete pavement is designed without tied concrete shoulder and doweled joint

The design parameters are

CBR value for Sub grade	=	8%
Modulus of subgrade	=	50.3 MPa/m
Effective modulus of sub grade reaction of	=	285 MPa/m
Unit weight of concrete	=	24.46 KN/m^3
Elastic Modulus of concrete	=	32,500 MPa
Poisson’s ratio	=	0.15
Rate of traffic increase	=	0.075
Maximum Day time temperature differential in slab	=	16.8^{o}C
Maximum Night time temperature differential in slab	=	13.4^{o}C
Percentage of predominant direction	=	50%
Spacing of transverse joints	=	4.5 m
Width of slab	=	3.5 m
Design life	=	30 years
Present traffic	=	6000 cvpd
The Average number of axles per Commercial Vehicle	=	2.43

Table VII: Axle Load Spectrum

Single Axle		**Tandem Axle**		**Tridem Axle**	
Axle Load Class (KN)	**Frequency (% of Single Axles)**	**Axle Load Class (KN)**	**Frequency (% of Tandem Axles)**	**Axle Load Class (KN)**	**Frequency (% of Tridem Axles)**
185-195	18.15	380-400	14.15	530-560	5.23
175-185	17.43	360-380	10.5	500-530	4.85
165-175	18.27	340-360	3.63	470-500	3.44
155-165	12.98	320-340	2.5	440-470	7.12
145-155	2.98	300-320	2.69	410-440	10.11
135-145	1.62	280-300	1.26	380-410	12.01
125-135	2.62	260-280	3.9	350-380	15.57
115-125	2.65	240-260	5.19	320-350	13.28
105-115	2.65	220-240	6.3	290-320	4.55
95-105	3.25	200-220	6.4	260-290	3.16
85-95	3.25	180-200	8.9	230-260	3.1
<85	14.15	<180	34.23	<230	17.58
	100		100		100

Taking the above design parameters and expected repetition values into considerations and design the slab thickness according to IRC- 58:2011 for conventional, SCBA, SCBA with Crusher stone dust concrete

Table VIII: Designed Slab Thickness for the Pavement

Grade of concrete(M40) (1)	**28 days Flexural strength (N/mm^{230}) (2)**	**Slab thickness (cm) (3)**	**CFD for Bottom-Up cracking (4)**	**CFD for Top-Down cracking (5)**	**Total Cumulative fatigue damage(CFD) (6)=(4)+(5)**
CC	6.28	26	0.889	0.000	0.889
SC	8.15	22	0.864	0.000	0.864
SD	7.25	24	0.492	0.000	0.492

VI. Cost Comparison of Pavements

Cost comparison has been made for each concrete pavement to be laid with 26cm, 22cm, and 24cm. Cost comparison has been for each individual material and the cost for the each thicknessed slab was calculated with the dimensions of 1m length and 3.5m width of the pavement

Table IX: Cost of Each Material

S.no.	**Material**	**Rate per Kg in Rs.**
1	Cement	6.6
2	Fine Aggregate	0.79
3	Coarse Aggregate (20mm)	1.35
4	Coarse Aggregate (10mm)	1.02
5	Super Plasticizer	62
6	Sugarcane Bagasse Ash	0.125
7	Crusher stone dust	0.15

Table X: Cost Analysis for Each Pavement

Pavement type	Thickness (cm)	Cost (Rupees)
CC	26	4392.12
SC	22	3555.91
SD	24	3789.51

It is observed from the above cost analysis sand replacement alone with SCBA reduce the cost of Rs.836.21/- and sand replacement with SCBA and crusher stone dust reduce the cost of Rs.602.61/- when compared with conventional concrete

VII. CONCLUSIONS

Optimum dosage of replacement of sand by SCBA and Crusher stone dust was 45%. Increment in flexural strength was found by using SCBA with and without Crusher stone dust at age of 28 days compared to conventional concrete. Material cost of the pavement is reduced with inclusion SCBA alone, and with SCBA & Crusher stone dust in the concrete when compared to the conventional concrete. Thickness of pavement is reduced by replacement of sand with SCBA and addition of Crusher stone dust in concrete. Material cost of the pavement is reduced up to 19.03%, by partial replacement of sand with SCBA and Crusher stone dust and 13.72% by replacement of sand with SCBA only.

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