International Journal of
Scientific Engineering and Technology Research

ISSN 2319-8885
Vol.06,Issue.06
February-2017,
Pages:1023-1029

www.ijsetr.com

Greener Concrete using Agro-Industrial Waste as a Partial Replacement of Cement

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Abstract: The utilization of industrial and agricultural waste produced by industrial processes has been the focus of waste reduction research for economic, environmental and technical reasons. Sugar-cane bagasse is a fibrous waste-product of the sugar refining industry, along with ethanol vapor. This waste product (Sugar-cane Bagasse Ash) is already causing serious environmental pollution, which calls for urgent ways of handling the waste. Bagasse Ash has mainly contains silica and aluminum ion. In this project, the Bagasse ash has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 10%, 15% and 25% by the weight of cement in concrete. Ordinary Portland cement was replaced by ground bagasse ash at different percentage ratios. The compressive strengths of different mortars with bagasse ash addition were also investigated. M30 concrete mixes with bagasse ash replacements of 0%, 5%, 10%, 15%, 20% and 25% of the Ordinary Portland cement were prepared with water-cement ratio of 0.42 and cement content of 378 kg/m^3 for the control mix. Wet concrete tests like slump cone test, as well as hardened concrete test like compressive strength, split tensile strength and flexural strength at the age of 7days, 28 days and 90 days were carried out. The test results indicated that up to 10% replacement of cement by bagasse ash results in better or similar concrete properties and further environmental and economic advantages can also be exploited by using bagasse ash as a partial cement replacement material.

Keywords: National Counsel for Applied Economic Research (NCAER), Bureau of Indian Standard (BIS), Ordinary Portland Cement (OPC).

I. INTRODUCTION

Concrete is the world's most consumed man-made material. To produce 1 ton of Portland cement, 1.5 tons of raw materials are needed. These materials include good quality limestone and clay. Therefore, to manufacture 1.5 billion tons of cement annually, at least 2.3 billion tons of raw materials are needed. Over 5-million BTU of energy is needed to produce one tone of cement. In the year 1914, India Cement Company Ltd started cement production in Porbandar with an output of 10,000 tons and a production of 1000 installed capacity. At the time of independence 1947, the installed capacity of cement plants in India was approximately 4.5 million tons and actual production around 3.2 million tons per year. The partial deep control in 1982 prompted various industrial houses to set a setup new cement plants in the country, capacity was nearly 30 million tons, which has now, increase to nearly 120 million tons during a period of 20 years. The full decontrol on cement industry in 1988 further provided momentum for the growth. India is the second largest producer of cement on the globe after China. In total, India manufactures 251.2 Million Tons of cement per year. The cement industry in India has received a great impetus from a number of infrastructure projects taken up by the Government of India like road networks and housing facilities. While the Indian cement industry enjoys a phenomenal phase of growth, experts reveal that it is poised towards a highly prosperous future over the very recent years.

The annual demand for cement in India is consistently growing at 8-10%. National Counsel for Applied Economic Research (NCAER) has estimated after an extensive study that the demand for cement in the country is expected to increase to 244.82 million tons by 2012. At the same time, the demand will be at 311.37 million tones if the projections of the road and housing segments are met in reality. The production of superior quality of Ordinary Portland Cement (OPC) in the country was primarily responsible for introducing the grading system in OPC by Bureau of Indian Standard (BIS) during 1986-87. The other varieties of structural cements, such as sulphate resisting Portland cement, Pozzolana cement and blast furnace slag cement found their way in the improve quality of prompted the structural engineers and major consumers to adopt higher grades of concretes in the construction work. This has been marked difference in the quality of concrete during this period primarily due to the availability of superior quality of cements in the market. The trend is continuing more and more varieties of cements are coming to the markets which help to the consumers to make appropriated grade quality of concrete to meet the specific construction requirement. The high performance fiber reinforced, polymer concrete composites and ready mixed concrete have been progressively introduced for specific applications. Cement and steel are available in the free market and the durability of concrete was guaranteed and was unquestionable. The reinforced concrete has become a common building material because of its inherent strengths such as

- High strength and durability
- Easy design procedures to suit any type of aggressive environmental conditions.
  - Modularity to required size and shape
  - Resistance to fire.
  - Flexibility to extend or reduce without serious efforts and side effects.
  - Cracking and damage control.
  - Easy maintenance.

With the advancement of technology and increased field of applications of concrete and mortars, the strength workability, durability and other characters of the ordinary concrete need modifications to make it more suitable by situations. Added to this is the necessity to combat the increasing cost and scarcity of cement. Under these circumstances the use of admixtures is found to be an important alternative solution. The use of Pozzolana materials in cement concrete paved a solution for

- Modifying the properties of the concrete
- Controlling the concrete production cost
- To overcome the scarcity of cement
- The economic advantages disposal of industrial wastes.

In the past continuous efforts were made to produce different kinds of cement, suitable for different situations by changing oxide composition and fineness of grinding. With the extensive use of cement, for widely varying conditions, the types of cement that could be made only by varying the relative proportions of the oxide compositions were not found to be sufficient. Recourses have been taken to add one or two more new materials, known as additives, to the clinker at the time of grinding, or to the use of entirely different basic raw materials in the manufacture of cement. The use of additives, changing chemical composition, and use of different raw materials have resulted in the availability of many types of cements to cater to the need of the construction industries for specific purposes. The most important Pozzolana materials are fly ash, silica fume and Metakaolin whose use in cement and concrete is thus likely to be a significant achievement in the development of concrete technology in the coming few decades. The trend is continuing and more and more varieties of cements are coming to the market which helps to consume to make appropriate grade and quality of concrete to meet the specific construction requirement. There has been a remarkable advance in the field of concrete technology also. The high Performance fiber reinforced, polymer concrete composites and ready mixed concrete have been progressively introduced for specific applications.

A. Objective Of The Work

The main objective of the work is studying the effect on the strength on partial replacement of cement with bagasse ash. In this work, we study the comparison between strength variation on NCC and bagasse ash replaced concrete. From the study we can find out how much economy can be attained on using bagasse ash as partial replacement for cement. The objectives of the work are as follows:

- To improve the strength properties of eco-efficient concretes in order to utilize them in major construction projects involving high strength requirements.
- Develop systems to mitigate and ultimately avoid industrial waste material.
- Develop industrial waste management systems.
- Develop ways to use industrial wastes as raw material for making construction material.
- To develop environmental friendly methods of construction.
- To make the best use of industrial waste.
- To establish strategies to find economical means of construction.
- To overcome the problem of waste disposal crisis caused due to industries.
- Determine the ways to utilize industrial waste in most effective, ecological, environmental, social and financially responsible manner.

B. Scope of the Work

The scope of present study includes the following aspects:

- Laboratory tests on cement, fine aggregate, coarse aggregate, bagasse ash, water.
- Whatever may be the type of concrete being used, it is important to mix design of the concrete. The same is the case with the industrial waste based concrete or bagasse ash replacement. The major work involved is getting the appropriate mix proportions.
- In the present work, the concrete mixes with partial replacement of cement with bagasse ash were developed using OPC 53 grade cement. A simple mix design procedure is adopted to arrive at the mix proportions. After getting some trail mix, cubes of dimensions 150mm *150mm *150 mm, cylinder of dimensions 150mm*300 mm and beams of dimensions 100mm*100mm*150mm was casted and cured in the curing tank. Compressive strength, Split tensile strength and Flexural strength of concrete were conducted to know the strength properties of the mixes. Initially, a sample mix design was followed and modifications were made accordingly while arriving at the trail mixes to get optimized mix which satisfies both fresh, hardened properties and the economy. Finally, a simple mix design is proposed.

- From previous experimental works, it was found that an optimal amount of 10%-15% of cement can be replaced with bagasse ash. So, to carry out further experimental studies, the cement was replaced by bagasse ash as 5%, 10%, 15%, 20%, and 25% by weight of cement. The changes in properties of concrete mix are studied.

II. LITERATURE REVIEW

R.Srinivasn, Vol. 5, 2010, International Journal for service learning in Engineering, examine a review on "Experimental study on use of bagasse ash in concrete". Bagasse ash mainly contains aluminum ion and silica. In this paper, Bagasse ash has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 15% and 25% by weight of cement in concrete. Fresh concrete tests like compaction factor test and slump cone test were undertaken was well as hardened concrete tests like compressive strength, split tensile strength, flexural strength and modulus of elasticity at the age of seven and 28 days was obtained. The result shows that the strength of concrete increased as percentage of bagasse ash replacement increased. This paper reviews the use of bagasse ash as replacement of cement material in concrete. Yashwanth M.K, Maharaja, Institute of Technology, Mysore, Vol.3 January 2014, International Journal of Latest Trends in Engineering and Technology (IJLTET). He examined that "An Experimental study on bagasse ash as replacement for cement in light weight concrete". The present study is to investigate experimentally the fresh and hardened properties of lightweight concrete using sugarcane bagasse ash(SCBA) as replacement for cement by weight at 0%, 5%, 10%, 15% and 20% and expanded polystyrene (EPS) beads as 100% replacement for coarse aggregate respectively. From the result it was found that there is marginal increase in workability with bagasse ash content up to 10% beyond that there is possibility of reduction in slump value.

The compressive strength of lightweight concrete increases with bagasse content up to 15% and beyond this there is possibility of drastic reduction in strength and this 15% bagasse ash replacement strength is slightly less than OPC based lightweight concrete at 28 days but this value is comparable. Prashant O Modania, M.R Vyawahareb, Vol.4 2013 Procedia Engineering. He examined "Utilization of bagasse ash as a partial replacement of fine aggregate in concrete". In this paper, untreated bagasse ash has been partially replaced in the ratio of 0%, 10%, 20%, 30% and 40% by volume of fine aggregate in concrete. Fresh concrete tests like compaction factor test and slump cone test were undertaken along with hardened concrete tests like compressive strength, split tensile strength and sorptivity at the age of 7 days and 28 days. The result shows that bagasse ash can be a suitable replacement to fine aggregate up to 20%. AbdolkarimAbbasi and Amin Zargar, Middle-East Journal of Scientific Research 2013. He examined a review on "Using bagasse ash in concrete as pozzolanic". The aim of this research is to use bagasse ash as pozzolan. In this research the moisture percent and the method of burning bagasse, physical characteristics, chemical combination (XRF test), crystal fixtures (XRD test) and specific area of bagasse ash were investigated and compared with cement and micro silica. Replacing cement by 10% of bagasse ash by fine grade (specific area of 9000cm /gr), the workability and flow ability is optimized and their compressive strength 7 at 28 days is increased by 25% in comparison with normal concrete specimens. Using bagasse ash has no effect on the setting time and absorbing water. Due to wastage nature of bagasse the producing cost is predicted to be low and can be replaced as cement.

M. Siva kumar and N. Mahendran, Vol.2 2013, International Journal of Engineering Research & Technology. He examined "Experimental studies of strength and cost analysis of concrete using bagasse ash". The Bagasse ash mixture provides strength equal to the nominal strength of the concrete and reduces the cost at a large & scale. Various moulds were casted for the different properties of bagasse ash and Cement concrete i.e. replacement of cement with various percentage of Bagasse ash. The various specimens were tested for the compressive strength and the most optimum value was found out. Cost analysis was done on the account of optimum replacement of the account of optimum replacement of the cement. The tests reveal the cost to be lesser than the initial cost. Use of Bagasse ash also contributes to the reduction of waste disposal by the industries which reveal that the environmental hazards from the waste materials.

A. Materials and Their Properties

Raw materials required for the concrete use in the present work are

- Cement
- Coarse Aggregates
- Bagasse ash
- Fine aggregate
- Water

B. Ordinary Portland Cement

Ordinary Portland cement is used for general constructions. The raw materials required for manufacture of Portland cement are calcareous materials, such as limestone or chalk and argillaceous materials such as shale or clay. The manufacture of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon their purity and composition and burning them in a kiln at a temperature of about 1300^0C to 1500^0C at which temperature, the material sinters and partially fuses to form nodular shaped clinker. The clinker is cooled and ground to a fine powder with addition of about 2 to 3% of gypsum. The product formed by using the procedure is a "Portland cement".

C. Testing on Cement

The following tests as per IS: 4031-1988 is done to ascertain the physical properties of the cement. The results of the tests are compared to the specified values of IS: 4031-1988.

Consistency: The standard consistency of cement paste is defined as consistency, which will permit the Vicat plunger to penetrate to a point 5-7 mm from the bottom of the mould, this test is done to determine the quantity of water required to produce cement paste of standard consistency. For determining the setting time, compressive strength and soundness, the percentage of water required to produce cement paste of normal consistency is used. Consistency depends upon the composition of cement, this test was conducted as per the procedure given in IS: 4031-1988.

Initial and Final Setting Time: Lower the needle gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the needle may penetrate only to a depth of 33-35mm from the top. The period elapsing between the times when water is added to the cement at the time of which the needle penetrates the test block to a depth equal to 33-35mm from the top is taken as initial setting time.

D. Aggregates

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregates occupy 70 to 80 percent of volume of concrete. Aggregates are obtained either naturally or artificially. Aggregates can be classified on the basis of size as fine aggregate and coarse aggregate.

Fine Aggregate (Sand): The size of the fine aggregate is below 4.75mm.Fine aggregates can be natural or manufactured. The grade must be throughout the work. The moisture content or absorption characteristics must be closely monitored. The fine aggregate used is natural sand obtained from the river Godavari conforming to grading zone-II of table 3 of IS: 10262-2009. The results of various tests on fine aggregate are given in table 3.2.The fine aggregate shall consist of natural sand or, subject to approval, other inert materials with similar characteristics, or combinations having hard, strong, durable particles. The use of concrete is being constrained by urbanization, zoning regulations, increased cost and environmental concern.

E. Coarse Aggregate

The material whose particles are of size are retained on IS sieve of size 4.75mm is termed as coarse aggregate and containing only so much finer material as is permitted for the various types described in IS: 383-1970 is considered as coarse aggregate. Aggregates are the major ingredients of concrete. They constitute 70-80% of the total volume, provide a rigid skeleton structure for concrete, and act as economical space fillers. Because at least three-quarters of the volume of the concrete is occupied by aggregate, it is not surprising that its quality is of considerable importance. The properties of aggregate greatly affect the durability and structural performance of concrete. Aggregate was originally viewed as an inert material dispersed throughout the cement paste largely for economic reasons. It is possible, however, to take an opposite view and to look on aggregate as a building material connected in to a cohesive whole by means of the cement paste, in a manner similar to masonry construction. In fact, aggregate is not truly inert and its physical, thermal and sometimes also chemical properties influence the performance of concrete. Aggregate is cheaper than cement and it is, therefore, economical to put in to the mix as much of the former and as little of the later possible. But economy is not only the reason for using aggregate, it confers considerable technical advantages on concrete, which has a higher volume stability and better durability than hydrated cement paste alone. Aggregates should be of uniform quality with respect to shape and grading. The size of coarse aggregated depends upon the nature of the work. The coarse aggregate used in this experimental investigation is 20mm and 10mm size, crushed and angular in shape. The aggregates are free from dust before used in the concrete.

F. Sugarcane Bagasse Ash

The sugarcane bagasse ash consists of approximately 50% of cellulose, 25% of hemicelluloses 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 (SiO_2). In spite of being a material of hard degradation and that presents few nutrients, the ash is used on the farms as a fertilizer in sugarcane harvests. In this sugarcane bagasse ash was collected during the operation of boiler operating in the KCP Sugar Factory, located in the vuyyuru, Krishna District, Andhra Pradesh.

Fig.1.

III. MIX DESIGN

A. Design of M25 Grade Concrete

Stipulations for proportioning:

a) Grade designation : M25

b) Type of cement: OPC 53grade confirming IS: 12269

c) Minimum Cement content : 300 kg/m³

d) Maximum nominal size of aggregate : 20 mm

e) Maximum water – cement ratio : 0.5

f) Workability : 100 mm (slump)

g) Exposure condition : Moderate

h) Method of concrete placing : Non Pumpable

i) Degree of supervision : Good

j) Type of aggregate : Crushed angular aggregate

B. Test Data for Materials

a) Cement used : OPC 53 grade confirming IS: 12269

b) Specific gravity of cement : 3.10

c) Mineral admixture : -----------

d) Specific gravity of
Coarse aggregate : 2.69
Fine aggregate : 3.08
Bagasse Ash : 2.3

e) Water absorption
Coarse aggregate : 0.5%s
Fine aggregate : 1.0%

f) Free (Surface) moisture
Coarse aggregate : NIL
Fine aggregate : NIL

g) Sieve analysis
Fine aggregate : Confirming to grading Zone II of Table 4 of IS: 383

C. Target Strength For Mix Proportioning

$f'_{ck} = f_{ck} + 1.65S$
$= 25 + 1.65 \times 4$
$= 31.60$ N/mm²

Where
f'_{ck} =target average compressive strength at 28 days
f'_{ck} = characteristic compressive strength at 28 days
S = standard deviation

From Table 1of IS 10269:2009, standard deviation(s) = 4 N/mm²

Target strength = 31.60 N/mm²

D. Selection of Water-Cement Ratio

From Table 5 of IS456, maximum water cement ratio = 0.45

Based on experience, adopt w/c=0.42

0.42< 0.45 hence O.K

E. Selection of Water Content

From Table 2 of IS 10262: 2009 maximum water= 186 litres (for 25 to 50 mm Slump range) for 20mm aggregate

Estimated water content for 100mm slump = $150 + \frac{6}{100} \times 150$
= 159 litre

F. Calculation of Cement Content

Water-cement ratio = 0.42

Cement content $= \frac{159}{0.42}$
=378.57kg/m³

From Table 5 of IS 456 minimum cement content

For 'Moderate' exposure condition = 300kg/m³

378.57kg/m³> 300 kg/m³, hence, O.K

G. Proportion of Volume Of Coarse Aggregate And Fine Aggregate Content

From Table 3 of IS: 10262-2009

Volume of coarse aggregate corresponding to 20mm size aggregate &fine aggregate (Zone 2)

For water-cement ratio of 0.50= 0.62

But our water content is 0.42. Therefore water cement ratio lovers by 0.08, the proportion of

Volume of coarse aggregate is increased by 0.02 (@ of -/+ 0.01 for every 0.05 change in w/c ratio)

Volume of Coarse aggregate for the water - cement ratio 0.42 = 0.64

Volume of fine aggregate = 1-0.64

= 0.36

H. Mix Calculations

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m³

b) Volume of cement $= \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \times \frac{1}{1000}$
$= \frac{378}{3.10} \times \frac{1}{1000}$
$= 0.122$ m³

c) Volume of water $= \frac{\text{Mass of water}}{\text{Specific gravity of water}} \times \frac{1}{1000}$
$= \frac{159}{1} \times \frac{1}{1000}$
$= 0.159$ m³

d) Volume of admixture = Nil

e) Volume of all in aggregate = [a – (b + c + d)]
= 1-(0.122+0.159)
= 0.719m³

f) Mass of coarse aggregate = e × Volume of CA × Specific gravity of CA x 1000
= 0.719 × 0.64 × 2.69 × 1000
= 1238 kg

g)Mass of fine aggregate = e × Volume of FA× Specific gravity of FA × 1000
= 0.719 × 0.36 × 3.08 × 1000
= 797 kg

I. Mix Proportions for Trail

Cement = 378 kg/ m³

Water = 159litre

Fine aggregate: = 797kg

Coarse aggregate = 1238kg

Water Cement ratio = 0.42

IV. TEST RESULTS

A. Introduction

In this chapter, the experimental observations discussed are presented. Observations of slump and compaction factor in respect of fresh concrete are noted. The test results such as compressive strength, split tensile strength and flexural strength of hardened concrete of M25 grade replacement of cement with bagasse ash in the ratio of 0%, 5%, 10%, 15%, 20% and 25% proportions mixes at the ages of 7 days , 28 days and 90 days are detailed**.** Compressive strength of concrete tested on cubes at different partial replacement of bagasse ash was tested in water curing tank and the test results were shown in below Fig.2.

B. Slump Cone Test

The slump cone test was conducted for all the six mixes. Slump for different mixes are shown below.

TABLE I:

S.No	Mix Id	Slump (mm)
1	NORMAL MIX	86
2	SCBA 5%	83
3	SCBA 10%	82
4	SCBA 15%	79
5	SCBA 20%	74
6	SCBA 25%	70

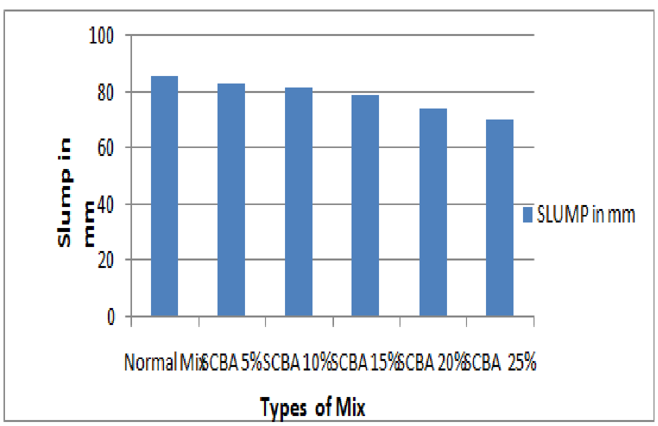

Fig.2.Slump tests mixes.

C. Compressive Strength

The compressive strength of the concrete was done on 150 x 150 x 150 mm cubes. A total of 54 cubes were cast for the five mixes. i.e., for each mix 9 cubes were prepared. Testing of the specimens was done at 7 days, 28 days and 90 days, at the rate of three cubes for each mix on that particular day. The average value of the 3 specimens is reported as the strength at that particular age shown in below Fig.3. The compressive strength test was conducted for all the mixes and the results are shown in the table below.

TABLE II: Compressive Strength Test Results

S.No	Mix id	Compressive Strength (N/mm²)		
		7 Days	28 Days	90 Days
1	NORMAL MIX	29.13	36.18	37.93
2	SCBA 5%	28.15	36.89	38.67
3	SCBA 10%	27.26	37.52	39.85
4	SCBA 15%	24.44	33.93	35.41
5	SCBA 20%	21.93	30.07	31.56
6	SCBA 25%	19.26	24.85	26.52

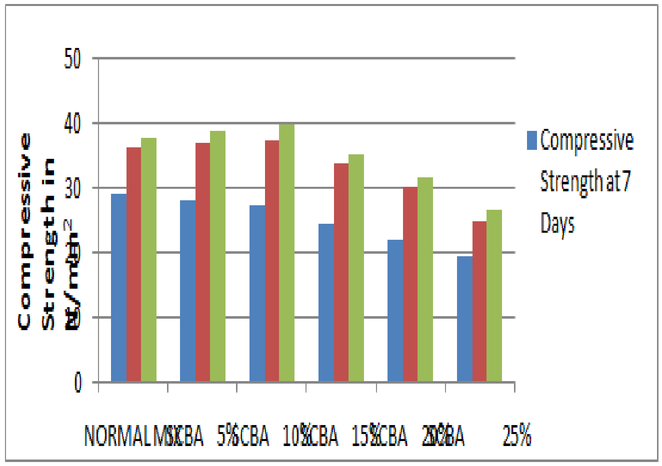

Fig.3.

D. Flexural Strength

Flexural strength of the concrete was determined from modulus of rupture test on beam specimens of 100 x 100 x 500 mm size. Here also, a total of 54 specimens were cast out of which three specimens were tested for each mix at 7days, 28 days and 90 days shown in below Fig.4.

TABLE III: Flexural Strength Test Results

S.No	Mix id	Flexural Strength (N/mm²)		
		7 Days	28 Days	90 Days
1	NORMAL MIX	4.67	5.87	6.25
2	SCBA 5%	4.53	6.13	6.52
3	SCBA 10%	4.53	6.43	6.92
4	SCBA 15%	3.33	5.75	5.85
5	SCBA 20%	3.20	4.93	5.22
6	SCBA 25%	3.07	4.13	4.66

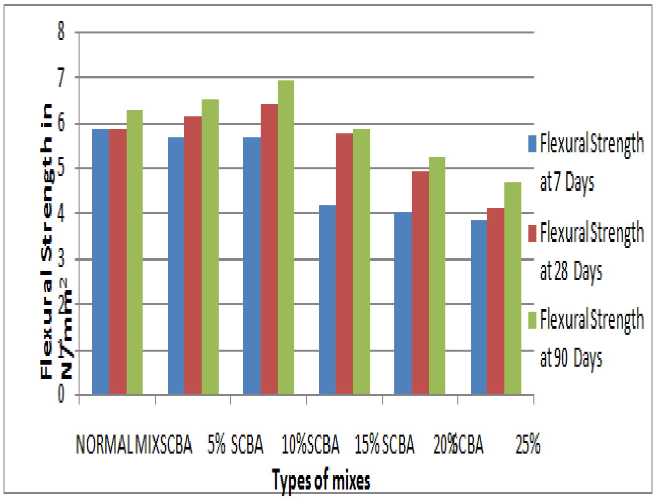

Fig.4.Flexural Strength graph vs Age.

V. CONCLUSIONS

Based on the study, following conclusions can draw.

- There is a change in slump for SCBA 5% has decreased 3.5% when compared with normal mix.
- The slump for SCBA 10%, SCBA 15%, SCBA 20% and SCBA 25% has reduced by 4.7%, 8.2%, 14% and 18.7% respectively when compared with the normal mix.
- The compressive strengths of SCBA mixes at the age of 7 days was gradually decreases its strength when compared with normal mix.
- It was observed that the compressive strength of SCBA 5% and SCBA 10% at the age of 28 days has reached its target mean strength; however the compressive strength was increased by 2.04% and 6.55% when compared with normal mix.
- It was observed that the compressive strength of SCBA 15%, SCBA 20% and SCBA 25% at the age of 28 days has decreases its compressive strength by 6.15%, 16.92% and34.13% respectively when compared with the normal mix.
- The split tensile strength of mixes SCBA 5% and SCBA 10% at the age of 28 days has increases its strengths by 4.42% and 9.5% respectively when compared with the normal mix.
- The split tensile strength of mix SCBA 15%, SCBA 20%, SCBA 25% at the age of 28 days has decreases it strengths by 11.8%, 24.8% and 32.7% when compared with the normal mix.
- The flexural strength of SCBA 5%, SCBA 10% at the age of 28 days has increases its strength by 4.42%, 9.5% when compared with the normal mix.
- Cement can be replaced with bagasse ash up to 10% without much loss in compressive strength.
- Considerable decrease in compressive strength was observed from 15% cement replacement. It has been shown in this study that 10% sugarcane bagasse ash can be used as a partial cement replacement material with technical and environmental benefits. Concerned stakeholder, such as sugar industries, cement industries and relevant government institutions, should be made aware about this potential cement replacement material and promote

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