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Study of partial replacement of bagasse ash in concrete

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A B S T R A C T

As use Industrial and agricultural waste produced by various processes has been the focus of waste reduction research considering economic and environmental factors .Sugar cane bagasse ash is a fibrous waste product of the sugar refining industry with production of ethanol vapour. Such type of waste product hampering environment in very sever manner and increasing environmental pollution. Due to this we have to find different ways of handling the type of waste. In this paper, Bagasse ash has been chemically and physically characterized and partially replaced in the ratio by weight of cement in concrete. After replacing cement as percentage by Sugar Cane bagasse ash Fresh concrete test and hardened concrete test are done. The result shows that strength of concrete increased as percentage of bagasse ash replacement increased up to certain percentage. So test result shows that we can use Sugar Cane Bagasse Ash partially to prepare concrete.

Keywords:Sugarcane bagasse ash, concrete, fly ash

1. Introduction

The concrete industry is the largest consumer of virgin materials such as sand, gravel, crushed rock and fresh-water .It is consuming port land and modified port land cements at an annual rate of about 1.6 billion metric tons. The cement production consumes vast amounts of limestone's and clay besides being energy-intensive. Obviously, large amounts of energy and materials, in addition to financial resources, are wasted when structures deteriorate or fail prematurely which, in fact, has been the case with many recently built reinforced concrete bridge decks, parking garages and marine structures throughout the world. Traditionally, most concrete structures are designed for a service life of 50 years. With the advent of high performance concrete mixtures, some structures are now being designed and built for a service life of 100 years. In the long run, sustainable development of the concrete industry will not take place until we are able to make even more dramatic improvements in our resource productivity. In this context, it should be noted that the factor ten club, a group of scientists, economist, and business people have made a declaration that , within one generation, nations can achieve a tenfold increase in their resources productivity through a 90% reduction in the use of energy and materials.

Achieving a dramatic improvement in resource productivity through durability enhancement of products is, of course, a long term solution for sustainable development. A short term strategy that must be pursued simultaneously is to practice industrial ecology at a longer scale than is the case today. Simply defined, the practice of industrial ecology by a manufacturing industry involves there acclamation and re-use of its own waste products and, to extent possible, the waste products of other industries which are unable to recycle them in their own manufacturing process. Reportedly, over 1 billion tons of construction and demolition waste is generated every year. Cost-effective technologies are available to recycle most of the waste as a partial replacement for the coarse aggregate in fresh concrete mixtures. Similarly, industrial wastewaters and non-potable waters can substitute for municipal water for mixing concrete unless proven harmful by testing. Blended Portland cements containing fly ash from coal-fired power plants, and ground-granulated slag from the blast furnace iron industry provide excellent examples of industrial ecology because they offer a holistic solution for reducing the environmental impact of several industries. The construction industry already uses concrete mixtures containing cement replacement materials , such as 15% to 20% fly ash or 30% to 40% slag by mass.As discussed in this project , with conventional materials and technology, it is now possible to produce high-strength concrete mixtures containing 20% to 30% bagasse ash. Ash by mass of the blended cementious material. Note that fly ash is readily available in most of the world. China and India , the two countries that consume large amounts of cement , together produce over 300 million tons of bagasse ash per year.

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2. Literature Review

Sugarcane bagasse ash (SCBA) is generated as a combustion by product from boilers of sugar and alcohol factories. Composed mainly of silica, this by product can be used as a mineral admixture in concrete. In this investigation, conventional and high performance concretes (CCs and HPCs, respectively) were produced with 0, 10, 15, & 20% of a residual ultra-fine SCBA as cement replacement (in mass). For these concretes, rheological, mechanical, durability, and adiabatic calorimeter tests were performed. The results indicate that the mechanical properties of concretes were not significantly changed by the use of SCBA for all levels of replacement. The ultra-fine SCBA concretes presented superior performance in the rheological, water sorption capillary, and rapid chloride –ion permeability tests as compared with the reference mixture. The maximum adiabatic temperature rise of CC substantially decreased (11%) by replacement of 15% of cement by ultra-fine SCBA.

2.1. Research Significance

Sugarcane is one of the major crops grown in over 110 countries and its total production is over 1500 million tonnes. After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue is obtained, this is reused in the same industry as fuel in boiler for heat generation leaving behind 8-10% ash as waste, known as sugarcane bagasse ash (SCBA). The SCBA contains high amounts of unburnt matter, silicon aluminium and calcium oxide. It is very valuable pozzolana material if carbon free and amorphous ash could be obtained by further combustion. 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 but these ashes are produced under uncontrolled and non-uniform burning conditions with temperature rising above 1000°C resulting in crystallization of the matter. Present study was carried out on SCBA obtained by controlled combustion of sugarcane bagasse, which was produced from the Punjab province in India. Sugarcane sugarcane production in India is over 300 million tons/year leaving about 10 million tons of SCBA as un-utilised and hence waste material. This paper discusses the preliminary investigation results of test carried out on blended cementmortars and pastes by studying the pozzolanic reactivity of SCBA that was obtained by controlled burning of sugarcane bagasse. Pozzolanic and cementitious behaviour of SCBAwas evaluated by investigating the hydration reaction and strength development of SCBA-cement blended pastes and mortars.Some studies have shown that the SCBA presents potential for usage as a mineral admixture in paste and mortar. However there are few studies about its application in concrete. This work deals with fresh, mechanical durability, and calorimetric properties of SCBA concrete. This can yield interesting information regarding the production of green concrete with reduced environmental impact. Moreover, the use of ethanol tends to grow as an alternative to oil fuel. Thus, a high quantity of this by product can be generated in different parts of the world in the near future and its use as a mineral admixture can be an interesting alternative.(Bahurudeen & Santhanam, 2014) reported about theutilization of sugarcane bagasse ash as the pozzolanic material in concrete which can significantly improve its performance. Raw bagasse ash was ground up to cement fineness and used in the concrete for the performance evaluation.

2.2. Research Contribution by different Researcher related to Sugar cane Bagasse Ash

Development of Sugarcane bagasse ash based portland pozzolana cement and its influence on the durability performance of concrete are presented in this work. Durability performance such as rapid chloride penetration test, chloride conductivity test, water sorptivity test, and Torrent air permeability test were evaluated. The study shows that the use of Sugarcane bagasse ash in concrete significantly enhances its durability performance. [1] Apurva et al. (2013) described that Bagasse ash could be utilized by replacing it with fly ash and lime in fly ash bricks. In this work, Trial bricks of size 230 mm u 100 mm u 75 mm were tested with different proportions of 0 % to 60 % with 10 % increment with the replacement of fly ash and 0 % to 20 % with 5 % increment with the replacement of lime. These bricks were tested in compression and Water absorption test as per Indian Standards.[2] Aditya et al. (2013) investigated the usefulness of agricultural and industrial waste as a soil admixture to improve the engineering properties of soil to make it capable of the lower layer of road construction. This investigation describes the behavioral aspect of soils mixed with industrial waste materials such as Fly Ash (FA), Rice Husk Ash (RHA), Bagasse Ash (BA) and agricultural waste material Rice Straw Ash (RSA), which were used as a stabilizer to improve the load-bearing capacity of the soil. The physical and chemical properties of these stabilizers were ascertained and compared in this study. [3]Chaiyanunt et al. (2013) used Calcium Carbide Residue (CCR) which was a by-product of the acetylene gas production and Bagasse Ash (BA) obtained from the burning of bagasse for electricity generation in the sugar industry for the substitute for cement in concrete. The result shows thatthe concrete made with CCR and bagasse ash mixtures in Portland cement gave the compressive strength at the age of 28 days. These results also suggested that the use of CCR and BA combinations as a binder could reduce Portland cement consumption by up to 70 % compared to conventional concrete. Also, the mechanical properties of the alternative concrete including compressive strength, splitting tensile strength, and elastic modulus were also recorded same to that of conventional concrete. [4]Jimenez et al. (2013) investigated the effects of a sieved Sugar Cane Bagasse Ash (SCBA) and Fly Ash (FA) on the rheological properties of pastes and mortars. Cement pastes and mortar mixtures were designed such as single, binary and ternary systems. For the single ingredient system, only cement was used. For the binary system, FA was used to replace some of the cement. For the ternary systems, combinations of cement, SCBA and FA were used. The rheological tests were carried out with a stress control themeter equipped with a ball measuring system. The results obtained with the minislump cone and the flow/spread table tests showed a certain relationship with the rheological measurements, but this could not be completely identified. [5]

Kawee et al. (2013) used two different sources of bagasse ash with low and high Loss On Ignition (LOI) for their experiment. The effects of loss on ignition, fineness, and cement replacement of bagasse ash on the compressive strength of concrete were investigated. The results revealed that the compressive strength of concrete containing bagasse ash was much lower than that of control concrete. Concrete mixed with low loss on ignition ground bagasse ash had resulted in a slightly higher compressive strength than the mixture with high loss on ignition ground bagasse ash. [6]Loh et al. (2013) summarized a review of current research on the extensive studies that have been undertaken in an attempt to explore plausible applications and potentials of sugarcane bagasse for the composite material. The author, specified that the natural, bio-degradable features and chemical constituents of the sugarcane bagasse have been attracting attention as a highly possible and versatile ingredient in composite materials. They also indicated that eco-friendly and low-cost considerations had set the momentum for material science researchers to identify green materials that give low pollutant indexes. [7]

Prashant et al. (2013) focused on the ways of utilizing industrial or agricultural wastes as a source of raw materials for the construction industry. They pointed that these wastes utilization would not only be economical but may also help to create a sustainable and pollution free environment. 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 state properties such as compaction factor value and slump value were undertaken along with hardened concrete properties such ascompressive strength, split tensile strength, and sorptivity. The result shows that bagasse ash can be a suitable material for the replacement to fine aggregate. [8]Cordeiro et al. (2012) were carried out an experimental investigation to find out the influence of residual sugar cane bagasse and rice husk ashes in the properties of concretes. Experiments were performed to investigate the rheology, compressive strength for different ages, Young's modulus and rapid chloride ion penetrability. The joint influence of both ashes allowed reaching benefits in rheology and kept constant or increased the compressive strength when compared to the reference mixtures. Moreover, the ternary concrete presented lower electric charges and the replacement of cement by 40 % sugar cane bagasse and rice husk ashes decreased significantly. [9]Rattapon et al. (2012) studied the effect of Ground Fly Ash (GFA) and Ground Bagasse Ash (GBA) on the durability of recycled aggregate concrete. Recycled aggregate concrete was produced with the addition of recycled aggregate instead of coarse aggregate in this study. Compressive strength, water permeability, chloride penetration depth, and expansion by sulfate attack on concretes were investigated. The results revealed that the use of GFA and GBA to partially replacing cement in recycled aggregate concrete was highly effective in improving the durability of recycled aggregate concrete. The suitable replacement of GFA or GBA in recycled aggregate concrete to obtain the adequate compressive strength, low water permeability, high chloride penetration resistance, and high sulfate resistance was derived as 20 % by weight of the binder. Rattapon et al. (2012) pointed that the bagasse ash, which is a large disposal landfill waste from sugar mill industr ies, is utilized as a pozzolanic material to improve the mechanical properties and durability of recycled aggregate concrete. Compressive strength, modulus of elasticity, water permeability, and chloride penetration depth of the concretes were determined in this study. The results showed that the modulus of elasticity of recycled aggregate concrete with and without GBA was lower than that of 31 conventional concrete. This paper also highlighted that the GBA could be used effectively to reduce the water permeability of recycled aggregate concrete. Besides, the mechanical properties and durability of recycled aggregate concrete were efficiently improved by adding 20 % of GBA to cement in the concrete mixtures. [10]Sumrerng et al. (2012) presented the use of Bagasse Ash (BA) as a pozzolanic material for producing high-strength concrete. Bagasse ash was partially replaced with Portland cement in concrete. The compressive strength, porosity, coefficient of water absorption, rapid chloride penetration and chloride diffusion of concretes were determined. The test results indicated that the incorporation of BA up to 30 % replacement level increases the resistance to chloride penetration and the use of 10 % of BA results concrete with good strength and low porosity. [11]

Srinivasan et al. (2010) in this experimental investigation studied the Bagasse ash characters were studied physically and chemically, and it replaced fractions in the ratio of 0 %, 5 %, 15 % and 25 % by weight fractions of cement. Hardened concrete tests such as compressive strength, split tensile strength, flexural strength and modulus of elasticity at the age of 7 days and 28 days was obtained. The result shows that the strength of concrete increased as the percentage of bagasse ash replacement increased. [12]Guilherme et al. (2009) described that bagasse ash, a byproduct of sugar and alcohol production is having excellent pozzolanic characteristics. However, its useful application in mortar and concrete fir st requires the control use of grinding and classification processes to allow it to achieve the fineness and homogeneity. This paper describes the pozzolanic activity of the ground ash which was directly related to its fineness, characterized by its 80 % passing size or specific surface area. Incorporation of a finely-ground ash in a high-performance concrete in partial replacement of Portland cement resulted in no measurable change in mechanical behavior but improved rheology and resistance to penetration of chloride ions. [13]Nuntachai et al. (2009) investigated the physical properties of concrete such as compressive strength, water permeability and heat evolution by the addition of Bagasse Ash (BA) in concrete. The results indicate that at 28 days of age, the concrete samples containing 10 % to 30 % ground bagasse ash by weight of binder had greater compressive strengths than the control concrete, same while the water permeability was lower than the control concrete. It was noted that the concrete containing 20 % ground bagasse ash had the highest compressive strength compared to control concrete. The permeability of concrete reduced as the replacement of ground bagasse ash was increased. For the heat evolution, the maximum temperature rise of concrete containing ground bagasse ash was lower than the control concrete. The results showed that ground bagasse ash could be used as a pozzolanic material in concrete with an acceptable strength, lower heat evolution, and reduced water permea bility of the control concrete. [14]Ganesan et al. (2007) stated that the utilization of waste materials in concrete provides a satisfactory solution to some of the environmental concerns and problems associated with waste management. Agro wastes such as rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash 33 are used as pozzolanic materials for the development of blended cement. In this study, the effects of bagasse ash content as the partial replacement of cement on physical and mechanical properties of hardened concrete are presented. The properties of concrete such as compressive strength, splitting tensile strength, water absorption, permeability characteristics, chloride diffusion and resistance to chloride ion penetration were investigated. The test results are proven that bagasse ash is an effective mineral admixture, with 20% as optimal replacement ratio of cement. [15]Singh et al. (2000) studied hydration of bagasse ash blended Portland cement by employing some experimental techniques. By the experimental investigation, they found that in the presence of bagasse ash setting time are increased, and free lime was decreased. In the same while, the compressive strength values get increased with hydration time in the presence of bagasse ash and also in this paper they stated that the blended cement was found to be more resistant in an aggressive environment. [16]

2.3. Need For The Present Study

From the literature review, it is observed that numerous researches were carried out to standardize the light weight concrete. The mineral admixtures such as fly ash and bagasse ash are used to increasing volume in the light weight concrete due to their long-term performance by replacing with cement. The need for the present study arises that as on today's scenario, the fine aggregate is the fastest depleting natural resources and to preserve this the optimum replacement possibilities of the waste products such as bagasse ash and fly ash; both are obtained as a waste product from the sugarcane industry and thermal power plant respectively, are needed to be studied. The utilization of these admixtures are beneficial in solid waste management point of view. Hence in this assessment, an effort is made to make use of the bagasse ash and fly ash for the replacement of fine aggregate through mechanical and durability studies.

3. Methodology

Concrete mix design for M20

Table 1: Design Description for M20

	Description	**For M20**
A.	Design Description	
	1.Characteristics compressive strength required in the field at 28 days	20N/mm2
	2.Max.Size of aggregate	20mm
	3.Degree of workability	0.9 compaction factor
	4.Degree of quality control	Good
	5.Type of exposure	Mild

Table 2: Test data for Material

B.	**Test Data For Material**	
	Cement	**Ordinary Portland cement**
	I. Specific Gravity Of Cement	3.15
	II.Comp.Strength Of Cement At 7 Days	Satisfies The Requirement Of Is269-1989
	III.A.Specific Gravity For C.A. B.Specific Gravity Of F.A.	2.60 2.70
	IV.Water Absorption A.C.A. B.F.A.	 0.5% 1.0%
	V.Free Surface Moisture A.C.A. B.F.A.	 Nil 3.09%

CALCUALTION:

a) Target mean strength of concrete the target mean strength for specified characteristic cube strength is

$= F_{ck}+1.65x(\delta)$

$=20 + 1.65 \times 4.6$

$= 27.59\ N/mm^2$

b) Selection of water cement ratio:

The water cement required for the target mean strength of 27.59 N/mm^2. So corresponding to this strength w/c ratio came as 0.5.

c) Selection of water and sand content for max. size of aggregate 20mm sand conforming to grading zone II, equal to 186 kg.

d) water content per m3 of concrete and sand content as % of total aggregate by absolute vol.are water content ,sand content came as 35%.

e)

Table 3 : Change in condition and % Adjustment Required

Change In Condition	% Adjustment Required	
	Water Content	Sand In Total Aggregate
	For M20	For M20
I.For Decrease In W/C Ratio By (6-0.92) For M20 (0.6-0.5=0.10)	0	-2.0
II.For Increase In C.F.	+3	0
III.For Sand Conforming To Zone	0	-1.5
III Of Tables IS 383-1970	+3	-3.5

Therefore required sand content as % of total aggregate by

a) Absolute vol.=35—3.5=31.5%

b) Required water content=186+5.58=191.58 kg/m

c) Determination of cement content

Water cement ratio = 0.50

Water Content = 191.58

Therefore Cement content = 191.58/0.50 =383.16 kg/m^3

d) Determination of C.A. & F.A. content for specified max. size of aggregate of 20 mm the amount of entrapped air in the wet concrete is 2%.

e) V=(w+c/s_c+f_a/ps_{fa})x1/1000

0.98m^3 = (191.58+383.16/3.15+f_a/945)1/1000

f) C_a=1-p/p xf_a x s_{ca}/s_{fa}

=1126.84 kg/m^3

Table 4 : Actual Quantities Required For Mix Per Bag Of Cement

The Min Proportion Then Becomes **Water** **Cement** **Fine Aggregate** **Coarse Aggregate**	 **0.50** **1.0** **1.64** **2.94**
I. Actual Quantities Required For Mix Per Bag Of Cement	
1. Cement	50 Kg
2. Sand	82 Kg
3. Coarse Aggregate	147 Kg Fraction I=60% =88.2 Kg Fraction Ii=40% =58.8 Kg
4. Water	
A. For W/C Ratio	25 Lit
B. Extra Quantity Of Water To Be Added For Absorption In Case Of Ca At 0.5% Mass	0.73 Lit
C. Qty Of Water To Deducted For Moisture Present In Sand At 2.56% By Mass.	2.10 Lit
D. Actual Quantity Of Water Required To Be Added	25.0+0.73-2.10 = 23.63 Lit

Therefore actual quantity of material required is for M20
Water = 23.63 lit
Cement= 50 kg
Sand = 84.10 kg
Coarse Aggregate=147.0 kg

M20= 1:1.68:2.94

4. Experimental Result

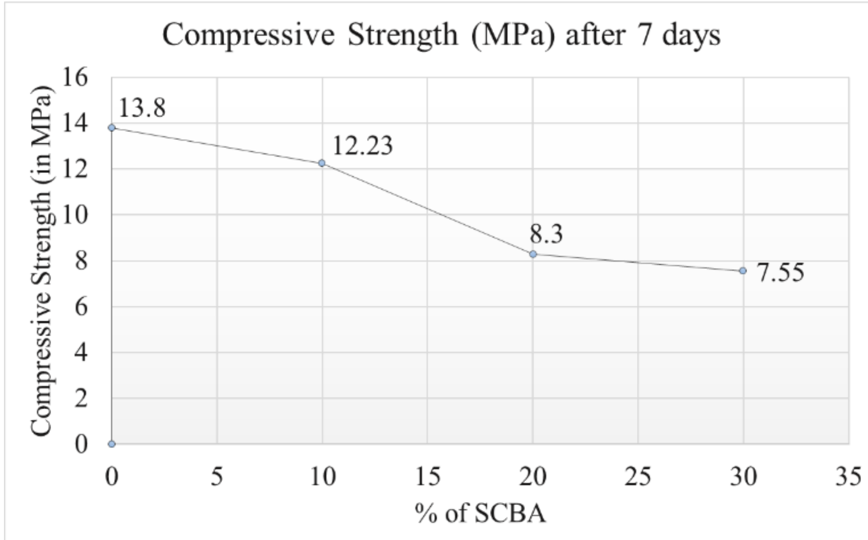

Fig 1 : Compressive Strength Result of SCBA Concrete after 7 days

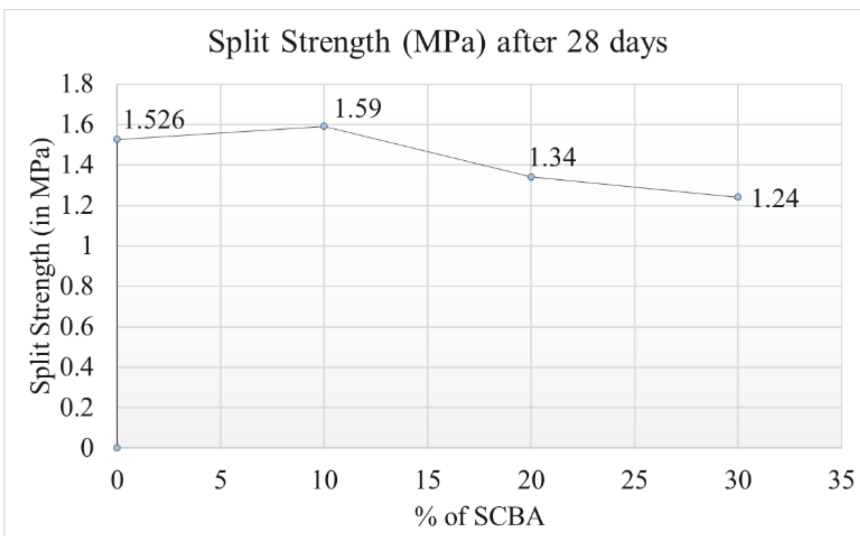

Fig 2 : Split Strength Result of SCBA Concrete after 28 days

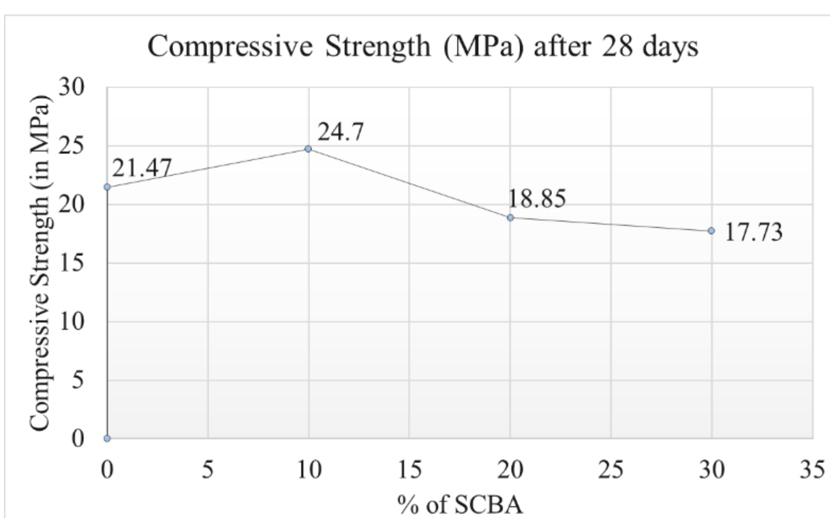

Fig 3 : Compressive Strength Result of SCBA Concrete after 28 days

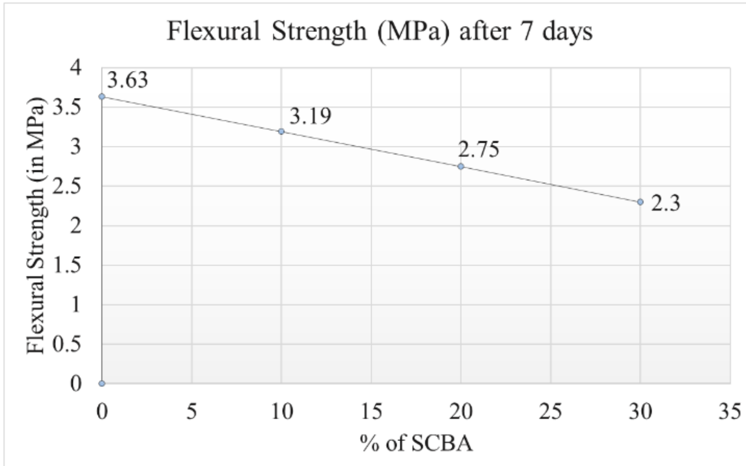

Fig 4 : Flexural Strength Result of SCBA Concrete after 7 days

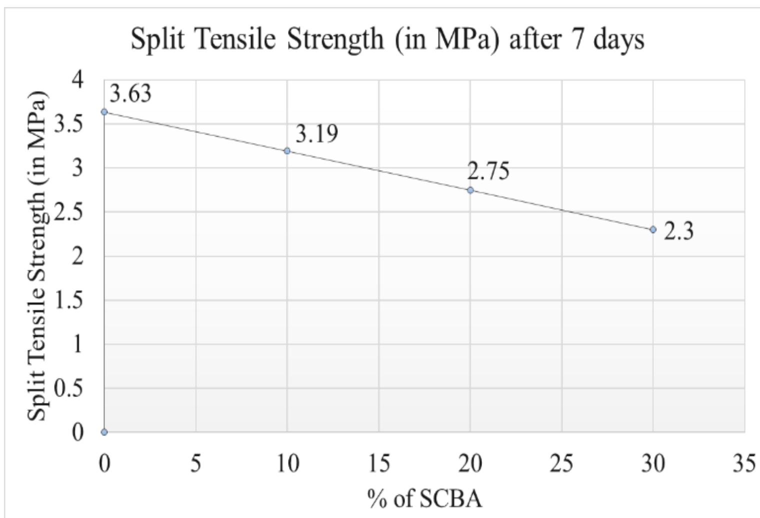

Fig 5 : Split Strength Result of SCBA Concrete after 7 days

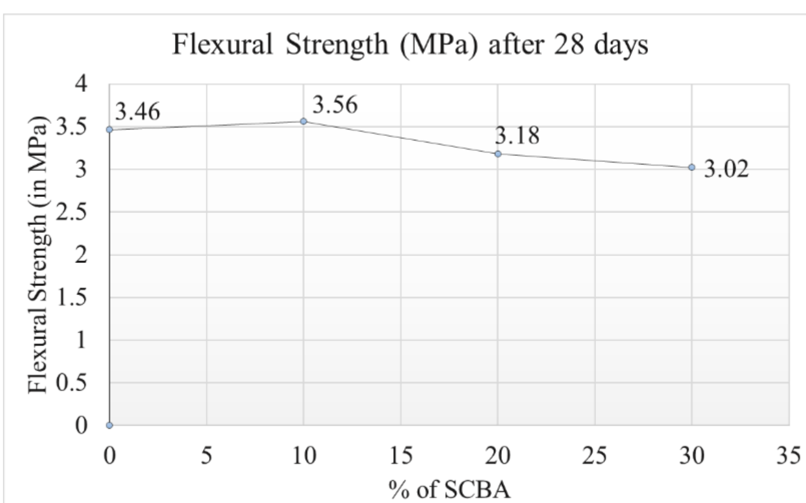

Fig 6 : Flexural Strength Result of SCBA Concrete after 28 days

Comparison of the results from the 7 and 28 days samples shows that the compressive strength, tensile strength and also flexural increase with SCBA up to 1.0% replacement and then it decreases, although the result of 2.0% replacement is still higher than those of the plain cement concrete. It was shown that the use of 2.0% SCBA decrease the compressive strength to a value which is near to the control concrete. This may be due to the fact that the quantity of SCBA present in the mix is higher than amount required to combine with liberated lime during the process of hydration thus leading to excess silica leaching out and causing a deficiency in strength as it replaces part of the cementitious material but does not contribute to strength.

5. Conclusion

The result shows that the SCBA in blended concrte had significantly higher compressive strength, tensile strength and flexural strength compare to that of the concrete without SCBA.It is found that cement could be advantageously replaced with SCBA up to maximum limit of 10%.Although, the optimal level of SCBA content was achieved with 1% replacement.Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not substantial.

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