

USE OF SUGARCANE BAGASSE ASH AS A PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

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Abstract

Pakistan annually produces approximately 50 Million tons of sugar cane and most of it is used for production of sugar. The industrial waste of sugar cane, known as bagasse, is mostly used as fuel for power generation in the same sugar industry. We have to study the properties of sugar cane bagasse ash in concrete, the main variables in this study are the amount of sugar cane bagasse ash (0, 5, 10, 15, 20 and 25 percent by weight of cement) as a partial replacement of cement in concrete. We conclude that to improve the quality and reduce the cost of construction material. The importance of this work is to make sugar cane bagasse ash (SCBA) as a construction material.

Keywords: Artificial Pozzolan, SCBA, Compressive tests

I. Introduction

During the past years, concrete and cement technology have attained a lot of achievements. One of the achievements is the incorporation of industrial wastes as filler or additive in cement and concrete production with technical, economic and environmental advantages. Such waste materials was found to have either reactive or filler effect in cement and concrete production. Reactive materials are named pozzolanas and have been used widely worldwide where available. The use of inert fillers is also a common practice worldwide.

Inert fillers have been also used as aggregate fillers in concrete production to improve particle packing density thereby properties of concrete. These days, the increasing trend towards the use of filler types and amount has led to worldwide research and development in the area [1].

Ia. Pozzolans

Pozzolans are a broad class of siliceous or siliceous and aluminous materials which, in themselves, possess little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. The quantification of the capacity of a pozzolan to react with calcium hydroxide and water is given by measuring its pozzolanic activity. Pozzolans are naturally occurring pozzolans of volcanic origin. The Calcium Hydroxide formed by the process of the hydration of Dicalcium and Tricalcium silicate has no cementitious properties and is easily soluble in water. A stable insoluble cementitious product is formed by combination of CH and pozzolans in its finely ground state in the existence of water [II].



The reaction written above is called pozzolanic reaction. Durability of cement based mortars or concrete increase as the hydration process continues by consuming CH and result in more dense and impermeable material (Shetty,2005).

Ib. Natural Pozzolans

The natural pozzolan includes volcanic ashes, opalineshales and cherts, calcined diatomaceous earth, and burnt clays. According to ASTM C 618-94a, these materials are described as Class N type pozzolans (Neville 2000). These materials are processed for producing pozzolan which involves drying, grinding, and calcinations. The most common natural pozzolans used today are processed materials, which are especially treated in furnace and then properly grounded to a fine powder, such type of pozzolans contain calcined clay, calcined shale, and metakalcined clays are used in general purpose concrete structures similar to the other pozzolans. These pozzolans can be used as a partial replacement for the cement, usually in the range of 15 to 35% and to improve resistance to sulphate attack, control the reactivity of alkali and silica, and decrease the permeability [III].

Ic. Artificial Pozzolan

These are industrial and agricultural by-products such as silica fume, fly ash, blast furnace slag, metakaoline, rice husk ash, bagasse ash and other agricultural wastes. Due to ease of use and development of more active artificial pozzolans, the natural pozzolans have lost their fame.

Id. Sugarcane

Sugarcane is one of the major crops grown in irrigated areas of the Indus basin. Currently, it is grown on an area of around 2.5 million acres. The average production of cane during the last five years is around 49 million tones, with an average yield of 470 maunds per acre. The yield of sugarcane in Pakistan is almost half of the countries like Egypt, which is comparable in terms of agro-climates. Study show that for each 10 tons of sugarcane crushed, a sugar factory produces nearly 3 tons of wet bagasse. So if 49 million tons crushed then it produce approximately 14.7 million tones wet bagasse.

Ie. Sugarcane Bagasse

Bagasse is the fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice. It is used as a biofuel and in the manufacture of pulp and building materials.

For each 10 tons of sugarcane crushed, a sugar factory produces nearly 3 tons of wet bagasse. Since bagasse is a by-product of the cane sugar industry, the quantity of production in each country is in line with the quantity of sugarcane produced.

The high moisture content of bagasse, typically 40 to 50%, is detrimental to its use as a fuel. In general, bagasse is stored prior to further processing. For electricity production, it is stored under moist conditions, and the mild exothermic reaction that results from the degradation of residual sugars dries the bagasse pile slightly. For paper and pulp production, it is normally stored wet in order to assist in removal of the short pith fibers, which impede the papermaking process, as well as to remove any remaining sugar.

Bagasse is an extremely inhomogeneous material comprising around 30-40% of "pith" fiber, which is derived from the core of the plant and is mainly parenchyma material, and "best", "rind", or "stem" fiber, which comprises the balance and is largely derived from sclerenchyma material. These properties make bagasse particularly problematic for paper manufacture and have been the subject of a large body of literature [IV].

So according to literature, in Pakistan annually 14.7 million tones bagasse are produce. Bagasse is a waste which is produce in huge amount from the sugar mills and reuse as a fuel in the same sugar industry and form an ash which is known as sugarcane bagasse ash (SCBA).

Initiatives are emerging worldwide to control and regulate the management of sub-products, residuals and industrial wastes in order to preserve the environment from contamination. A good solution to the problem of recycling of agro-industrial residues would be by burning them in a controlled environment and use the ashes (waste) for more noble means. Utilization of such wastes as cement replacement

materials may reduce the cost of concrete production and also minimize the negative environmental effects with disposal of these wastes. Silica fume, rice husk ash, fly ash, met kaolin and ground granulated blast furnace slag are well established wastes with pozzolans because of high silica content in their chemical compositions. According to Sirirat and Supaporn (2010), the calcium hydroxide (unfavorable product from the cement hydration) released during the hydration of OPC reacts with silica present in the pozzolans and water to form additional calcium silica tehydrate which is responsible for the compressive strength in concrete.

If. Sugarcane Bagasse Ash (SCBA)

Ordinary Portland cement is recognized as a major construction material throughout the world. Researchers all over the world today are focusing on ways of utilizing either industrial or agricultural waste, as a source of raw materials for industry. 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. 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 also gives ash having amorphous silica, which has pozzolanic properties. 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 (SCBA) 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 [IX].

Thus, most of the bagasse ash is still disposed of as waste in landfills, causing environmental and other problems. An economical viable solution to this problem should include utilization of waste materials for new products which in turn minimize the heavy burden on the nation's landfills. Recycling of waste construction materials saves natural resources, saves energy, reduces solid waste, reduces air and water pollutants and reduces greenhouse gases. The construction industry can start being aware of and take advantage of the benefits of using waste and recycled materials [V].

II. Chemical Composition of (SCBA)

Sugarcane bagasse ash collected for experimental work was tested for the chemical compound at Pollucon laboratories PVT LTD, Surat. Chemical compound result of bagasse ash is follow:

Chemical compound	Abbreviation	%
Silica	SiO ₂	68.42
Aluminum Oxides	Al ₂ O ₃	5.812
Ferric Oxide	Fe ₂ O ₃	0.218
Calcium Oxide	CaO	2.56
Phosphorous Oxide	P ₂ O ₅	1.28
Magnesium Oxide	MgO	0.572
Sulphide Oxide	SO ₃	4.33
Loss on Ignition	LOI	15.90

Table 1. Chemical Composition of (SCBA)

IIa. Cement

Cement is a hydraulic binder and is defined as a finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes which, after hardening, retains its strength and stability even under water.

The history of making cementing material is as old as the history of engineering construction. Some kind of cementing materials were used by Egyptians, Romans and Indians in their ancient constructions. The early Greeks and Romans used cementing materials obtained by burning limestone. The remarkable hardness of the mortar used in early Roman brickworks, some of which still exist, presents sufficient evidence of the perfection which the art of cementing material had attained in ancient times.

The Greek and Romans had known the fact that certain volcanic ash and tuff, when mixed with lime and sand yielded mortar possessing superior strength and better durability in fresh or salt water. Roman builders used volcanic tuff found near Pozzuoli village near Mount Vesuvius in Italy. This volcanic tuff or ash mostly siliceous in nature thus acquired the name Pozzolana. Later on, the name Pozzolana was applied to any other material, natural or artificial, having nearly the same composition as that of volcanic tuff or ash found at Pozzuoli. The Romans, in the absence of natural volcanic ash, used powdered tiles or pottery as pozzolan [X].

When we come to more recent times, the most important advance in the knowledge of cements, the forerunner to the discoveries and manufacture of all modern cements is undoubtedly the investigations carried out by John Smeaton. When he was called upon to rebuild the Eddy Stone Light House in 1756, he made extensive enquiries into the state of art existing in those days and also conducted experiments

with a view to find out the best material to withstand the sever action of sea water. Finally, he concluded that limestone which contained considerable proportion of clayey material yielded better lime possessing superior hydraulic properties. In spite of the success of Smeaton's experiments, the use of hydraulic lime made little progress, and the old practice of mixture of lime and pozzolana remained popular for a long period. In 1766 hydraulic cement was made by calcining nodules of argillaceous limestone. In about 1800 the product thus obtained was called Roman cement. This type of cement was in use till about 1850 after which this was outdated by Portland cement.

i) **Portland Cement**

Portland cement was developed from natural cements made in Britain in the early part of the nineteenth century, and its name is derived from its similarity to Portland stone, a type of building stone that was quarried on the Isle of Portland in Dorset, England.

It is the chief ingredient in cement paste and the binding agent in Portland cement concrete. It is a hydraulic cement that, when combined with water, hardens into a solid mass. Interspersed in an aggregate matrix it forms Portland cement concrete. As a material, Portland cement has been used for well over 175 years and, from an empirical perspective, its behavior is well understood. The patent for Portland cement was obtained in 1824 by Joseph Aspdin. Chemically, however, Portland cement is a complex substance whose mechanisms and interactions have yet to be fully defined. The Portland Cement Association provides the following precise definitions:

- ii) **Hydraulic cement:** Hydraulic binder, i.e. a finely ground inorganic material, which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water.
- iii) **Portland cement:** Hydraulic cement composed primarily of hydraulic calcium silicates. As the use of Portland cement was increased for making concrete, engineers called for consistently higher standard material for use in major works. Association of Engineers, Consumer and Cement manufacturers has been established to specify standards of cement. The German standard specification for Portland cement was drawn in 1877. The British standard specification was first drawn up in 1904. The ASTM specification was issued in 1904 [VI].

IIb. Chemical properties

It is a Portland cement's chemical properties that determine most of its physical properties. Therefore, a basic understanding of Portland cement chemistry can help one understand how and why it behaves as it does.

The composition of Portland cement distinguishes one type of cement from another. The phase compositions in Portland cement are denoted as tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A), and tetracalcium aluminoferrite (C_4AF). The actual components are often complex chemical crystalline and amorphous structures, denoted by cement chemists as "alite" (C_3S), "belite" (C_2S), and various forms of aluminates. The behavior of each type of cement depends on the content of these components.

Iic. Concrete

Concrete is a composite material which is made up of a filler and a binder. The binder (cement paste) glues the filler together to form a synthetic conglomerate. The constituents used for the binder are cement and water, while the filler can be fine or coarse aggregate. The properties of concrete, workability, strength and durability, make it to be the most versatile and widely used manmade construction materials. The users of concrete usually need it to have such important properties in economical way.

The incorporation of different materials, like industrial wastes, in concrete production has been found to play role in achieving the required properties of concrete [XI].

Iid. Proportioning of Ingredients in Making Concrete

The key in achieving a strong, durable concrete rests in the careful proportioning and mixing of the ingredients. A concrete mixture that does not have enough paste to fill all the voids between the aggregates will be difficult to place and will produce rough, honeycombed surfaces and porous concrete. A mixture with an excess of cement paste will be easy to place and will produce a smooth surface; however, the resulting concrete is likely to shrink more and be uneconomical. There are different methods of mix designing such as: Arbitrary proportion, fineness modulus method, maximum density method, high strength concrete mix design, mix design based on flexural strength, Road note No.4 (grading curve method), ACI Committee 211 method, DOE method, mix design for pumpable concrete. Out of the above methods, some of them are not very widely used these days because of some difficulties or drawbacks in the procedures for arriving at the satisfactory proportions. ACI committee 211 method and DOE methods are commonly used [VII].

Iie. Workability

A high-quality concrete is one which has acceptable workability (around 6.5 cm slump height) in the fresh condition and develops sufficient strength. Basically, the bigger the measured height of slump, the better the workability will be, indicating that the concrete flows easily but at the same time is free from segregation. Maximum

strength of concrete is related to the workability and can only be obtained if the concrete has adequate degree of workability because of self-compacting ability. The workability of C0 and N series concrete are presented in Figure 2. The figure shows the influence of SCBA content on the workability of mixtures at constant water to binder ratio of 0.48. The results show that unlike the C0 series, all investigated SCBA mixtures had high slump values and acceptable workability. This may be due to the increasing in the surface area of sugarcane ash after adding SCBA that needs less water to wetting the cement particles.

Sample Designation	% of SCBA	Workability	
		Slump(mm)	Compaction factor
C0	0	60	0.95
N1	5	187	0.96
N2	10	200	0.96
N3	15	220	0.97
N4	20	225	0.97
N5	25	230	0.97

Table 2. FRESH CONCRETE

III. Strength of Concrete by Using SCBA

The strength test results obtained for concrete cube, cylinder and prism specimens with partial replacement of SCBA shown in Table 2.5 and 2.6. From the table, it is clear that the addition of SCBA in plain concrete increases its strength under compression, and tension up to 10% of replacement after that strength results was decreases [VIII].

Sample Designation	% of SCBA	Compressive Strength (MPa)	Split Tensile Strength at (MPa)
C0	0	13.80	0.693
N1	5	15.83	0.97
N2	10	12.33	0.90
N3	15	8.79	0.70
N4	20	8.30	0.65
N5	25	7.55	0.42

Table 3. Strength Result of SCBA Concrete at 7 DAYS

Sample Designation	% of SCBA	Compressive Strength (MPa)	Split Tensile Strength at (MPa)
C0	0	21.47	1.526
N1	5	29.50	1.94
N2	10	24.70	1.94
N3	15	19.32	1.45
N4	20	18.85	1.34
N5	25	17.73	1.24

Table4. Strength Result of SCBA Concrete at 28 DAYS

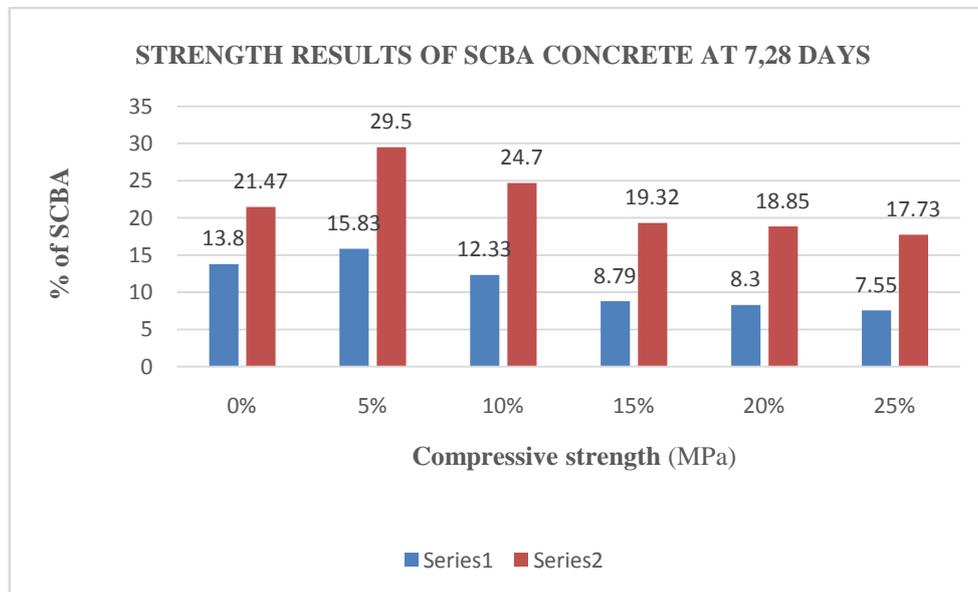


Figure 1. Chart Obtained from the Table 3 and 4

III. Results and Discussion

Ordinary Portland cement is the most extensively used construction material in the world. Since the early 1980's, there has been an enormous demand for the mineral admixture and in future this demand is expected to increase even more. Also in this modern age every structure has its own intended purpose and hence to meet this purpose modification in traditional cement concrete has become essential. This situation has led to the extensive research on concrete resulting in mineral admixture

to be partly used as cement replacement to increase workability in most structural application. If some of raw material having similar composition can be replaced by weight of cement in concrete then cost could be reduced without affecting its quality. The utilization of industrial waste 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.

In chapter 3, we study the chemical composition of sugarcane bagasse ash. For this reason sugarcane bagasse ash (SCBA) is one of the main byproduct can be used as mineral admixture due to its high content in silica (SiO_2). 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.

IIIa. Experimental work

In this experimental work, a total of 50 numbers of concrete specimens were casted. All the specimens are cylinder type, and the standard size of cylinder is 6 inch in diameter and 12 inch in height. For experimental work we select M 20 grade concrete, which is according to Indian Standard and the water cement ratio are 0.50. Based upon the quantities of ingredient of the mixes, the quantities of SCBA for 0, 5, 10, 15 and 20% replacement by weight were estimated.

The ingredients of concrete were thoroughly mixed manually till uniform thoroughly consistency was achieved. Before casting, machine oil was smeared on the inner surfaces of the cast iron cylinder. Concrete was poured into the cylinder and compacted thoroughly using tamping rod. The top surface was finished by means of a trowel. The specimens were removed from the mould after 24h and then cured under water for a period of 7, 14 and 28 days. The specimens were taken out from the curing tank just prior to the test. The tests for compressive, split tensile strength were conducted using a 2000kN compression testing machine.

i) Experimental results

The strength results obtained from the experimental investigations are showed in tables. All the values are the mean of the two trails in each case in the testing program of this study. The results are discussed as follows.

ii) Compressive tests result

Compression testing of cylinder was done on compression testing machine having capacity of 3000kN. Compressive strength of sugar cane bagasse ash contain concrete cylinder was determined after 7, 14 and 28 days moist curing. Following are the compressive strength results of concrete cylinder having 0, 5, 10, 15, and 20% of sugarcane bagasse ash.



Figure 2. Concrete cylinder and result



Figure 3. Concrete cylinder

Table 4. Compressive strength of concrete specimen (psi)

Percentage of (SCBA)	After 7 days strength (psi)	After 14 days strength (psi)	After 28 days strength (psi)
0%	1821.08	2136.36	3056.28
5%	1912.07	2268.86	3222.63
10%	1485.35	1880.45	1970.7
15%	1103.39	1380.86	2055.85
20%	541.55	657.91	1031.13

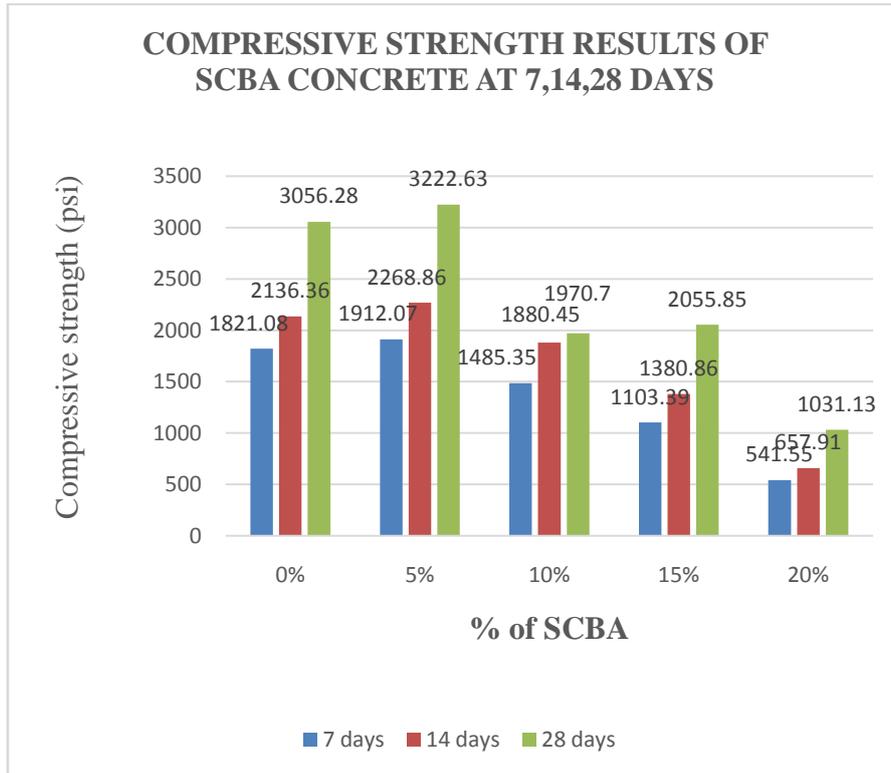


Figure 4. Compressive strength of concrete specimen

IIIb. Discussion

Results we obtained from the experimental work shows that sugar cane bagasse ash can be replaced with cement in concrete. Pulverized bagasse ash is a suitable pozzolanic material for use in concrete. From the experimental results we can partially replace of sugar cane bagasse ash with cement can be up to 5% by the weight of cement without significant loss in strength of concrete. With 5% replacement of sugar cane bagasse ash, compressive strength increase compare to normal concrete after 28 days of curing. After 5% replacement of sugar cane bagasse ash there is decrease in strength of concrete with increase of replacement of sugar cane bagasse ash.

IIIc. Split Tensile Tests Result

Split tensile test of cylinder was done on compression testing machine having capacity of 3000kN. Split tensile strength of sugar cane bagasse ash contain concrete cylinder was determined after 7, 14 and 28 days moist curing. Following are the split tensile strength results of concrete cylinder having 0, 5, 10, 15, and 20% of sugarcane bagasse ash.

Percentage	7 days(psi)	14 days(psi)	28 days(psi)
0%	209.52	287.33	318.62
5%	262.71	298.31	333.63
10%	201.52	239.07	319.69
15%	139.21	175.01	202.59
20%	99.44	141.54	156.36

Table 5. Split tensile strength of concrete specimen (psi)

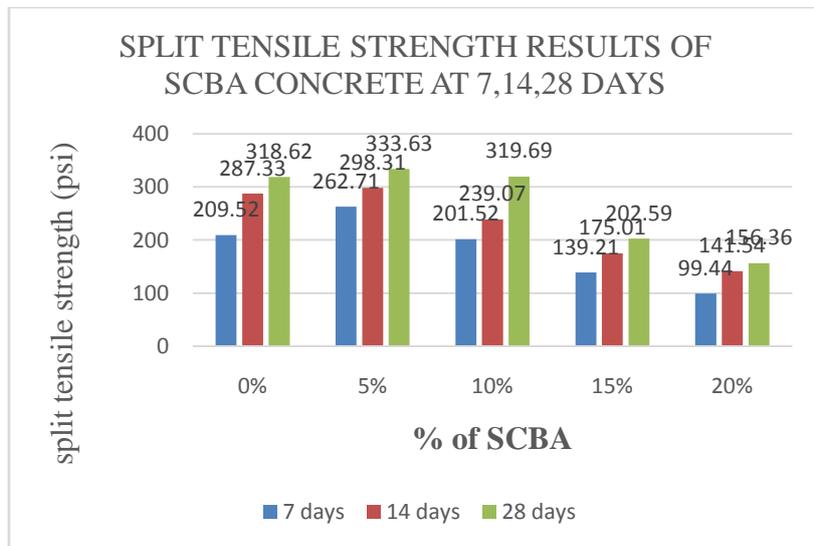


Figure 5. Split tensile strength of concrete specimen

III.d. Discussion

Results we obtained from the experimental workshws that sugar cane bagasse ash can be replacedwith cement in concrete. Pulverized bagasse ash is a suitable pozzolanic material for use in concrete. From the experimental results we can partially replace of sugar cane bagasse ash with cement can be up to 5% by the weight of cement without significant loss in strength of concrete. With 5% replacement of sugar cane bagasse ash, split tensile strength increase compare to normal concrete after 28 days of curing. After 5% replacement of sugar cane bagasse

ash there is decrease in strength of concrete with increase of replacement of sugar cane bagasse ash.

IV. Conclusion

The results which is obtained from the experimental work shows that sugar cane bagasse ash can be replaced with cement in concrete. Pulverized bagasse ash is suitable pozzolanic material for use in concrete. From the experimental results we can conclude that replacement of sugar cane bagasse ash with cement can be up to 5% by the weight of cement without significant loss in strength of concrete.

With 5% replacement of sugar cane bagasse ash, compressive strength increase compare to normal concrete after 28 days of curing. After 5% replacement of sugar cane bagasse ash there is decrease in strength of concrete with increase of replacement of sugar cane bagasse ash. Also split tensile strength increase with 5% replacement of sugar cane bagasse ash compare to normal concrete. Also sugar cane bagasse ash can be use as admixture in concrete due to high percentage of silica present in it. Partial replacement of cement by (SCBA) increases workability of fresh concrete, therefore use of super plasticizer is not essential. The above results show a beneficial application of the use of sugar cane bagasse ash and reduce the environment problem and also minimize the requirement of land fill area to dispose sugar cane bagasse ash.

V. Recommendation

From conclusion we recommended that, replacement of 5% of sugarcane bagasse ash (SCBA) in concrete give high strength then normal or conventional concrete. Replacement of sugarcane bagasse ash (SCBA) more than 5% reduce the strength of the concrete. So optimum replacement of sugarcane bagasse ash (SCBA) is 5% for the maximum strength of concrete. And the workability of 5% sugarcane bagasse ash (SCBA) is higher than conventional concrete at normal water cement ratio. It is also recommended that, it reduce the environment problem and also minimize the requirement of land fill area to dispose sugar cane bagasse ash (SCBA).

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