Study on Sugarcane Bagasse Ash as a Partial Replacement of Cement in M60 Grade Concrete Exposed to Acidic Environment

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Abstract— *One of the main challenges now confronting the concrete industry in India is to meet the demand posed by enormous infrastructure needs due to rapid industrialization and urbanization. With the shrinkage of natural resources to produce Ordinary Portland cement (OPC), increased use of suitable industrial waste materials having pozzolanic characteristics that can replace cement clinker is one of the ways to meet the challenge. Sugarcane bagasse is one such cement replacing pozzolanic material. The positive effect of using sugarcane bagasse in concrete includes Producing concrete of better rheology, higher strength and enhanced durability. Preservation of lime stone and coal reserves Minimizing greenhouse gas emissions associated with manufacturing of OPC. Considering the above beneficial effects of using sugarcane bagasse in concrete, this should be considered as resource material rather than an industrial waste. The present experimental investigation was carried on bagasse ash and has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 10%, 15% and 20% by weight of cement in concrete. The variable factors considered in this study were concrete of grade M60 for a curing period of 28 days, 60 days and 90 days of the concrete specimens in 1%, 3%, 5% H_2SO_4 and HCl solution. Test for compressive strength at the age of 28days, 60days and 90days were conducted and results are presented.*

Keywords— *High Strength Concrete, M60 grade concrete, Sugarcane bagasse, Sulfuric Acid, Hydro Chloric Acid, Mix Design as Per ACI Code.*

I. INTRODUCTION

A. General

Day by day different structures have been designed and constructed. Long-term performance of such Structures have become vital to the economies of all nations. Concrete is a more essential material which is widely used for many kinds of structures. Concrete is composed of an inert matrix of sand, gravel, crushed rock, or other aggregates held together by a harden paste of hydraulic cement and water. The strength of concrete depends upon the strength of these components, their deformation properties, and the adhesion between the paste and aggregate surface. But for increasing performance of structures, strength of concrete should be high. This requirement leads the researchers and Engineers to invent High strength concrete (HSC). High strength concrete (HSC) provides economic benefits through thinner (lighter) construction. According to ACI 363, any concrete with a specified compressive strength of 6000 psi (41 MPa) or greater is "High strength concrete". Production of HSC may or may not require special materials, but it definitely requires materials of highest quality and their optimum proportions such as long term mechanical properties, early age strength, toughness, volume stability or service life in severe environment. With most natural aggregates, it is possible to make concrete with compressive strength up to 120MPa. This can be achieved by improving the strength of

Cement paste, which ca be controlled through the choice of water – cement ratio and type and dosage of admixtures. In the early 1960‟s, a super plasticizer was invented in Japan. By the inclusion of the super plasticizer, high-strength concrete could be realized by reducing W/C to fewer than 30%. The high strength concrete was however applied only to the factory products because it had a large loss in slump. Recent successful researches and developments on materials and construction methods have led to the cast-in place high-strength concrete with good workability, the strength of more than 150 N/mm2 and higher durability. The high-strength concretes have been applied to a lot of high-rise buildings or diaphragm walls (Toru KAWAI).his document is a template. An electronic copy can be downloaded from the conference website. For questions on paper guidelines, please contact the conference publications committee as indicated on the conference website. Information about final paper submission is available from the conference website.

B. High Strength Concrete or High Performance Concrete

As mentioned by Dr S.S Jain, according to paper by Aitcin and P.K. Mehta, what was known as high strength concrete in the late 1970s is now referred to as high performance concrete has one or more of the properties like low shrinkage, low permeability and high modulus of elasticity or high strength. According to Henry Russel, ACI defines high performance concrete as concrete that meets special performance and uniformity requirements that cannot always be achieved routinely by using only conventional materials and normal mixing, placing and curing practices. The requirements may involve enhancement of placement and compaction without segregation, long term mechanical properties, early age strength, toughness, volume stability or service life in severe environments.

A major criticism presented by P.K. Mehta (2004) against the ACI definition of HPC is that durability of concrete is not mandatory. It is one of the options. Earlier, it was assumption that high strength concrete is durable, probably this assumption lead to cracks in many structures. As per Indian Standard, the concrete having strength 60MPa or more are known as high strength concrete.

Typically, these mixtures are composed of a high cement content viz. 450-500 kg/m3 Portland or blended Port land cement containing relatively small amount of silica fume and fly ash or slag, a low water/cement ratio of the order of 0.3 (with the help of super plasticizer admixture) and an air entraining agent when it is necessary to protect the concrete from cycles of freezing and thawing. In this regard, an earlier definition proposed by Mehta and Aitcin stated that the term HPC should be applied to concrete mixtures possessing the following three characteristics: high workability, high strength, and high durability.

C. *Sugarcane Bagasse Ash*

Sugarcane Bagasse is an abundant waste produced in sugar factories after extraction of juice from Sugarcane. The huge supply of bagasse needs meaningful disposal. In many countries this type of bulky waste usually used as the boiler fuel in the sugar mills. Increasing cost of natural gas and fuel oil resulting high prices of electricity, due to calorific properties of bagasse waste since last decade it is being used as the principal fuel in cogeneration plants to produce electric power. The burning of bagasse as fuel leaves bulk quantity of ash called sugar cane bagasse ash or SCBA. Sugar cane bagasse ash is recently accepted as a pozzolanic material; however, there is limited research data available on the effects of SCBA on the properties of concrete. Therefore, due to lack of research most of the bagasse ash is disposed in the landfills and only a few studies reported the use of bagasse ash as partial replacement of cement in concrete.

D. *Effect of Acids on Concrete*

1) *Effects of Sulfuric Acid (H_2so_4) On Concrete*

Concrete is susceptible to acid attack because of its alkaline nature. The components of the cement paste break down during contact with acids. Most pronounced is the dissolution of calcium hydroxide which occurs according to the
Following reaction:

$$2\,HX + Ca(OH)2 ==> CaX2 + 2\,H2O$$

(X is the negative ion of the acid)

The decomposition of the concrete depends on the porosity of the cement paste, on the concentration of the acid, the solubility of the acid calcium salts (CaX2) and on the fluid transport through the concrete. Insoluble calcium salts may precipitate in the voids and can slow down the attack. Acids such as nitric acid, hydrochloric acid and acetic acid are very aggressive as their calcium salts are readily soluble and removed from the attack front. Other acids such as phosphoric acid and hemic acid are less harmful as their calcium salt due to their low solubility, inhibit the attack by blocking the pathways within the concrete such as interconnected cracks, voids and porosity. Sulfuric acid is very damaging to concrete as it combines an acid attack and a sulfate attack.

2) *Effects of Hydro Chloric Acid (Hcl) on Concrete*

Hydrochloric Acid attack the chemicals formed as the products of reaction between hydrochloric acid and hydrated cement phases are some soluble salts and some insoluble salts, Soluble salts, mostly with calcium, are subsequently leached out, whereas insoluble salts along with amorphous hydrogels, remain in the corroded layer. Besides dissolution, the interaction between hydrogels may also result in the formation of some Fe-Si, Al-Si, Ca-Al-Si complexes which appear to be stable in pH range above 3.5.Compressive strength also has decreased with an increase in the concentration of HCl. Chemical equations when HCl is added in mixing water with cement are given below. The XRD pattern indicates that the lower peaks of CH which is responsible in decrease of compressive strength when compared with the control sample.

$$2HCl + Ca(OH)2 \rightarrow CaCl2 + 2H2O$$

$$CaCl2+3CaO.Al2O3+10H2O \rightarrow 3CaO.Al2O3.CaCl2.10H2.$$

E. *Objective of Work*

In this project objective is to study the influence of partial replacement of cement with Sugarcane bagasse in concrete subjected to different curing environments. Experimental investigation on acid resistance of concrete in H_2SO_4 and HCL solution. The variable factors considered in this study were concrete grade of M60 & curing periods of 28 days, 60 days and 90 days of the concrete specimens. The parameter investigated was the time in days to cause strength deterioration factor of fully immersed concrete specimens in fresh water & in 1%, 3% & 5% of H_2SO_4 and HCL solution. SCBA has been chemically and physically characterized and partially replaced in the ratio of 0%, 5%, 10%, 15%, and 20% by weight of cement for mix. Hardened concrete tests like compressive strength at the age of 28 days, 60 days and 90 days were obtained. The compressive strength test results of SCBA for 28days, 60days, and 90 days are observed.

II. MATERIALS

In the present experimental investigation Sugarcane Bagasse Ash has been used as partial replacement of cement in concrete mixes. On replacing cement with different weight percentages of SCBA the compressive strengths are studied at different ages of concrete exposed to different environments like 0%, 1%, 3%, 5% H_2SO_4 and HCl added.

A. Cement

Ordinary Portland cement of 53 Grade from a single batch was used for the entire work. The cement procured was tested for physical requirements in accordance with IS: 12269-1987 and for chemical requirements in accordance with IS: 4032-1985.The cement confirms to 53 Grade.

Table I : Properties of Portland Cement (53 Grade)

S.No	Property	Test Result
1	Normal consistency	32%
2	Initial Setting times	156
3	Final Setting times	297
4	Specific Gravity	3.1
5	Compressive strength of cement (28 days)	53Mpa

B. Fine Aggregate

The river sand, passing through 4.75 mm sieve and retained on 600 µm sieve, confirmed to Zone II as per IS 383-1970 was used as fine aggregate in the present study. The aggregate was tested for its physical requirements according to IS: 2386-1963.

Table II : Properties of Fine Aggregate

S.No	Property	Test Result
1	Specific Gravity	2.64
2	Bulk density(kg/m3)	1600(loose state) 1750(dense state)
3	Fineness Modulus	2.74
4	Zone	II

C. Coarse Aggregate

Throughout the investigations, a crushed coarse aggregate of 20mm procured from the local crushing plants was used. The aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density etc. In accordance with IS: 2386-1963 and IS: 383-1970.

Table III : Properties of Coarse Aggregate

S.No	Property	Test Result
1	Specific Gravity	2.81
2	Bulk density(kg/m3)	1400(loose state) 1580(dense state)
3	Fineness Modulus	7.17

D. Water

Fresh potable water free from organic matter and oil is used in mixing the concrete. Water in required quantities were measured by graduated jar and added to the concrete. The rest of the materials for preparation of the concrete mix were taken by weight batching. The pH value should not be less than 6.

E. Properties of Sulfuric Acid & Hydrochloric Acid

Table IV : Physical Properties of H_2SO_4

Physical properties	Value
Molecular weight	64.06
Melting point (1013 mb)	−75.5 °C
Dynamic viscosity at 0 °C	368 Pa/s
Density at −10 °C	1.46 g/cm3
Boiling point (1013 mb)	−10 °C
Surface tension at 50 °C	51.7 mN/m

Table V : Chemical Properties of H_2SO_4

Chemical Properties	Value
pH(0.1N)	1.2
Dynamic viscosity at 0 °C	368 Pa/s
Density at −10 °C	1.46 g/cm3
Solubility	Miscible

Table VI : Properties of HCL

Properties	Value
Density, phase	1.18 g/cm³, 37% solution.
Solubility in water	Fully miscible.
Melting point	−26 °C (247 K) 38% solution.
Boiling point	110 °C (383 K), 20.2% solution; 48 °C (321 K), 38% solution.
Acid dissociation constant p*K*a	−8.0
Viscosity	1.9 mPa·s at 25 °C, 31.5% solution

F. Sugarcane Bagasse Ash

Sugarcane is a member of the grass family. Sugarcane is a tree-free renewable resource and one of the most important agricultural plants that grown in hot regions. Sugarcane is "carbon neutral" (i.e. emissions are equal to energy generated) and is the product of choice in the manufacture of bio-fuels due to its high energy conversion rate. Bagasse is lateral production of sugarcane that after treatment of sugarcane in the form of light yellow particles is produced. The chemical composition of this product are cellulous fibers, water and some soil soluble material such as cube sugar, by passing time cube sugar is converted into alcohol. Also the evaporation of bagasse fiber produce the methane gas which can cause fire in some circumstance. Bagasse is composed of fiber and pith, the fiber is thick walled and relatively long (1.4mm). Bagasse is a major by-product of sugar industry which finds a very useful utilization in the same industry as an energy source. Sugarcane consists of 25-30% bagasse whereas sugar recovered by the industry is about 10%. Bagasse is also used as a raw material for paper making due to its fibrous content and about 0.3 tons of paper can be made from one ton of bagasse. Bagasse is a byproduct during the manufacture of sugar and it has high calorific value. It is utilized as a fuel in boilers in the sugar mills to generate steam and electricity. The bagasse is used in the energy production (steam/electricity), fuel, hydrolysis, paper pulp, cellulose and wood veneer. 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 bagasse ash is the remains of fibrous waste after the extraction of the sugar juice from cane. In many tropical countries there are substantial quantities of bagasse and husks from rice both are rich in amorphous silica, which react with lime. The bagasse ash is a pozzolanic material that would otherwise require disposal.

The sugarcane waste, bagasse (300 g) was dried under sunlight to reduce the moisture content in bagasse. The dry bagasse was ground with a grinding machine and placed inside electric furnace. After firing at 1200^{o}C for 3h and 6h, bagasse ash was obtained. This bagasse ash was characterized by XRD (X-ray Diffraction). By observing the XRD spectrum, the XRD structure of bagasse ash at 1200^{o}C for 3h was formed to be better than that of bagasse ash 1200^{o}C for 6h. So, the bagasse ash for 1200^{o}C for 3h was chosen for further investigation. This bagasse ash was mixed thoroughly with silica gel, polyvinyl alcohol and distilled water. It was mould-pressed and bio-char pellet was formed. The samples were dried in an open air at 110^{o}C for 3h to expel any moisture. Bio-char disk (pellet) was then fired in a digital electric furnace at 600^{o}C for 1h.The bagasse ash ceramics were annealed at 1200˚C for 1h, 2h and 3h. Scanning Electron Microscope (SEM) characterization was performed to analyze their microstructural properties. The physical properties of bagasse bio-char ceramics will be investigated.

Table VII : Physical Properties of SCBA

S.No	Property	Test Result
1	Colour	Reddish Grey
2	Bulk Density(Kg/m3)	994
3	Specific Gravity	2.88
4	Moisture(%)	3.14
5	Mean particle size(μm)	0.1-0.2
6	Particle shape	Spherical
7	Specific Surface area(m2/Kg)	514

III. METHODOLOGY

A. *Preparation of Testing Specimens*

1) *Mixing*

Mixing of ingredients is done in concrete mixer. The cementitious materials are thoroughly blended and then the aggregate is added and mixed followed by gradual addition of water and mixing. Wet mixing is done until a mixture of uniform color and consistency are achieved which is then ready for casting.

2) *Casting of Specimens*

The cast iron moulds are cleaned of dust particles and applied with mineral oil on all sides before concrete is poured into the moulds. The moulds are placed on a level platform. The well mixed concrete is filled into the moulds and kept on vibration table. Excess concrete was removed with trowel and top surface is finished level and smooth as per IS 516-1959.

Fig1 Cast specimens

3) *Curing of Specimens*

The specimens are left in the moulds undisturbed at room temperature for about 24 hours after casting. The specimens are then removed from the moulds and immediately transferred to the different curing environment tubs i.e. cubes are exposed to fresh water and in different percentages of H_2SO_4 and HCl added to water.

Fig.2 Specimens Exposed to H2SO4 & HCl Solutions

Fig.3 Specimens After Curing in Solutions

B. *Testing of Specimens*

A time schedule for testing of specimens is maintained to ensure their proper testing on the due date and time. The casted specimens are tested as per standard procedures, immediately after they are removed from curing tubs and wiped off the surface water, as per IS 516-1959.

Fig.4Testing of Specimen After Curing in Compression Testing Machine

1) *Compressive Strength Test on Concrete Specimens*

In most structural applications, concrete is used primarily to resist compressive stresses. In most cases where the strength in tension or in shear is of primary importance, the compressive strength is frequently used as a measurement of these properties. Specimens were removed from the moulds after 24 hours and cured. After curing, cube specimens of different percentages of sugarcane bagasse ash were tested under compression testing machine in accordance with IS: 516 for 28 days, 60 days and 90 days.

2) *Durability*

The durability of sugarcane bagasse ash concrete was tested for resistance against inorganic salt like sulfuric sulphate and hydrogen chloride. The response of chemical effect on different percentage replacement of cement with sugarcane bagasse ash in concrete was studied by conducting compressive strength test. For conducting this test, concrete specimens with ordinary and different percentage replacement of cement with Sugarcane bagasse ash were cast. These specimens were immersed in normal water and 1%, 3%and 5% H_2SO_4 and HCl added to fresh water solution for 28 days, 60 days, and 90 days.

3) *Durability Studies on Cement Conventional Concrete and SCBA Concrete*

Concrete is the most versatile material of construction in the world over. It is achieved that the distinction of being the "largest man-made material" with the average per capita consumption exceeding 2 kg. Concrete is the material of choice for a variety of applications such as housing, bridges, highway pavements, industrial structures, water carrying and retaining structures etc. The credit for this achievement goes to well-known advantages of concrete such as easy availability of ingredients, adequate engineering properties for a variety of structural applications, adaptability, versatility, relative low-cost etc. Moreover, concrete has an excellent ecological profile compared with other materials of construction.

With the continuing expansion of infrastructure and housing construction, especially in the developing countries of Asia, Africa, and South America, the rate of consumption of cement and concrete is rising and is bound to go further. In India, concrete construction scenario has been witnessing considerable growth in recent years.

4) *Problem of Durability*

While the spectacular growth has been occurring in concrete production, the problem of early deterioration of some of the reinforced and pre-stressed concrete structures has also come to the forefront in recent years. It has been observed that some recently constructed structures - even those built confirming to the latest specifications - has shown early signs of distress and damage, sometimes within a few years of commissioning, while quite a few structures built more than half a century ago are still in a good serviceable condition. The phenomenon of early deterioration of concrete structures is tending to assume alarming proportions in some countries, especially those spacing hostile weather conditions. The seriousness of the problem is reflected with the high cost of repairs in these countries. It has been estimated that in the USA alone, the overall cost of repairing and replacing all deteriorated concrete structures would a staggering $200 billion! In the most of the advanced countries, nearly 40% of the construction industries budget is spent on repair, restoration and strengthening of the damaged concrete structures. All this has tarnished the image of concrete as a "durable, maintenance-free" material. Thus, durability of concrete has become an important issue today.

The durability tests have been conducted to check the durability parameters to withstand for the environmental attacks. So, in the present thesis work the test was conducted on H_2SO_4 and HCl attack on concrete.

IV. RESULTS AND DISCUSSION

A. General

In the previous chapter, the properties of materials determined based on the various laboratory tests are presented. In the present chapter strength and durability characteristics of SCBA replaced concrete are studied and discussions on the results obtained from the tests are done.

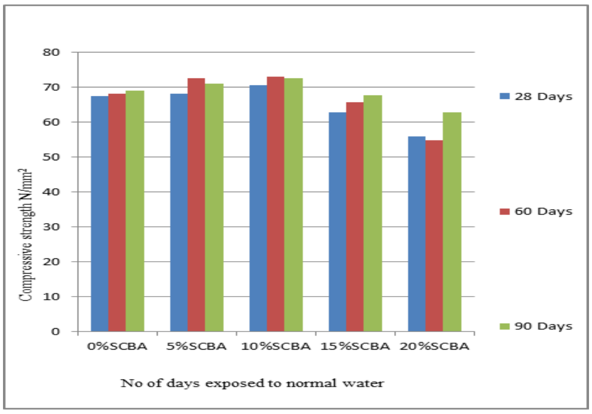
B. Compressive Strength and Durability Charecteristics of SCBA Replaced Concrete.

In accordance with IS-516 the compressive strengths of SCBA replaced concrete in different percentages exposed to water and different percentages of H_2SO_4 and HCl for 28, 60, 90days are determined by testing the cube specimens in compression testing machine.

1) Compressive Strength of Conventional Concrete Cubes Cured in Water and Solutions

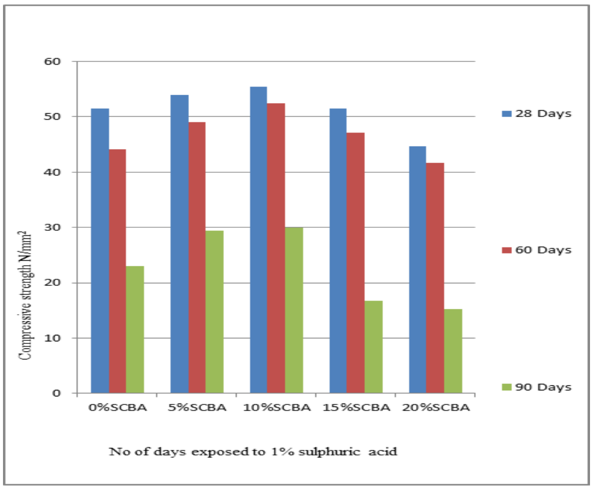
The SCBA replaced concrete cubes are prepared in the moulds for estimating the compressive strength values. The tests were conducted as per IS-516. Cube specimens were prepared using cement, replaced with varying percentages of SCBA. The tests were conducted after 28, 60 and 90 days of curing.

Graph 1 infers that compressive strengths of 0% SCBA replaced concrete cubes cured in water and 1%, 3% and 5% H_2SO_4 solutions and 1%, 3% and 5% HCl solutions for all curing periods. The compressive strengths of 0% SCBA replaced concrete cubes cured in water increased with increase in curing period. But the compressive strengths of 0% SCBA replaced concrete cubes exposed to H_2SO_4 and HCl solutions decreases with increase in curing periods for all percentages of solutions. It is also observed that when compared to compressive strengths of cubes exposed to HCl solutions, compressive strengths of cubes exposed to H_2SO_4 solutions have lesser values.

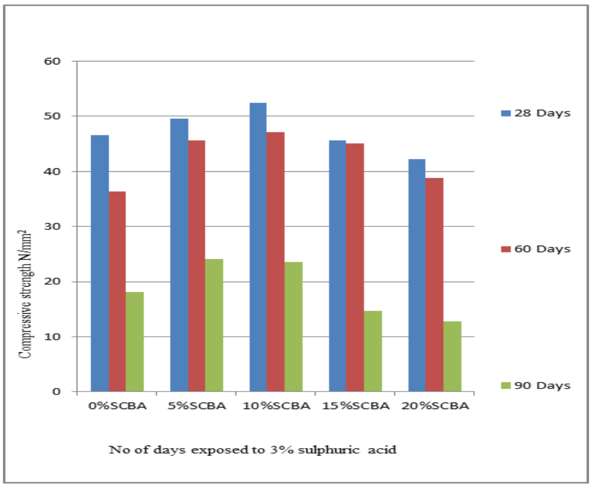


Graph.1: Compressive Strength Results of SBCA Concrete Cured in Normal Water

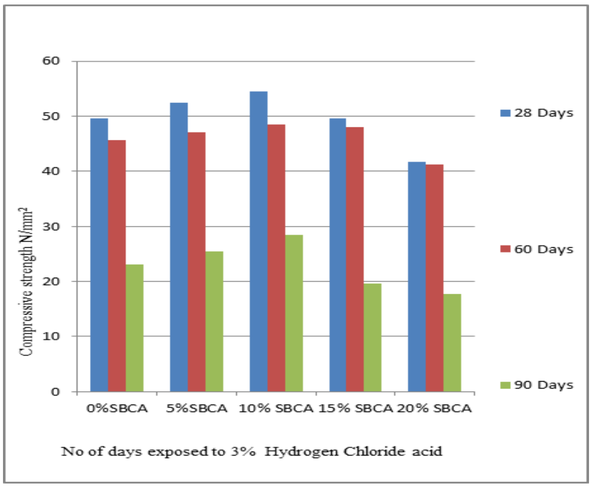
Graphs 2 to 7, Shows the results for 5%, 10%, 15% and 20% SCBA concrete cubes cured in water and 1%, 3% and 5% H_2SO_4 solution and 1%, 3% and 5% HCl solution. From the graphs it can be seen that the compressive strength of SCBA replaced concrete cubes decreases with in the increasing period of exposure for all percentages of solutions. It is observed that when compared to compressive strengths of cubes exposed to HCl solutions, compressive strengths of cubes exposed to H_2SO_4 solutions have lesser values.



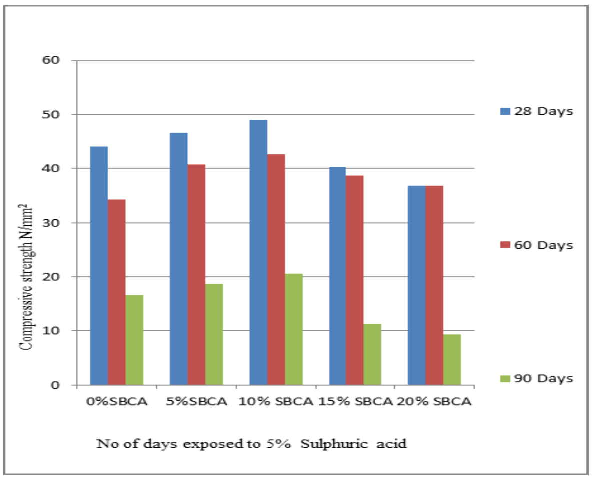
Graph.2: Compressive Strength Results for Cubes Exposed to 1% Sulphuric Acid



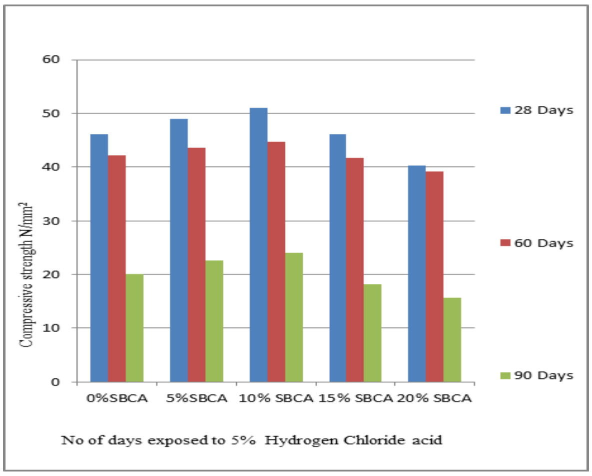
Graph.3: Compressive Strength Results for Cubes Exposed to 3% Sulphuric Acid



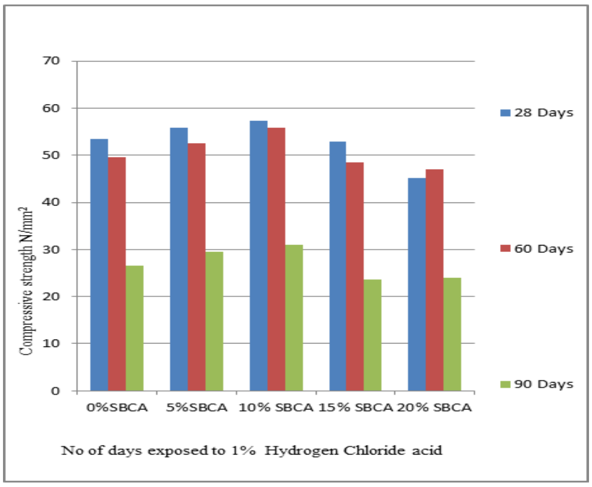
Graph.6: Compressive Strength Results for Cubes Exposed to 3% Hydrogen Chloride Acid



Graph.4: Compressive Strength Results for Cubes Exposed to 5% Sulphuric Acid



Graph.7: Compressive Strength Results for Cubes Exposed to 5% Hydrogen Chloride Acid



Graph.5: Compressive Strength Results for Cubes Exposed to 1% Hydrogen Chloride Acid

V. CONCLUSIONS

[1]. The compressive strengths of conventional concrete cubes exposed to 1%, 3% and 5% concentrations of Sulphuric acid solutions decreases by 23.63%, 30.9% and 34.54% for 28 days period of exposure, 35.25%, 46.76% and 49.64% for 60 days period of exposure, 66.67%, 73.76% and 75.89% for 90 days period of exposure respectively when compared to compressive strengths of conventional concrete cubes cured in water.

[2]. The compressive strengths of 5% replaced SCBA concrete cubes exposed to 1%, 3% and 5% concentrations of Sulphuric acid solutions decreases by 20.86%, 27.34% and 31.65% for 28 days period of exposure, 32.43%, 37.16% and 43.92% for 60 days period of exposure, 58.62%, 66.21% and 73.79% for 90 days period of exposure respectively when compared to compressive strengths of 5% replaced SCBA concrete cubes cured in water.

[3]. The compressive strengths of 10% replaced SCBA concrete cubes exposed to 1%, 3% and 5% concentrations of Sulphuric acid solutions

decreases by 21.53%, 25.69% and 30.56% for 28 days period of exposure, 28.19%, 35.57% and 41.61% for 60 days period of exposure, 58.78%, 67.57% and 71.62% for 90 days period of exposure respectively when compared to compressive strengths of 10% replaced SCBA concrete cubes cured in water.

[4]. The compressive strengths of 15% replaced SCBA concrete cubes exposed to 1%, 3% and 5% concentrations of Sulphuric acid solutions decreases by 17.97%, 27.34% and 35.94% for 28 days period of exposure, 28.36%, 31.34% and 41.04% for 60 days period of exposure, 75.36%, 78.26% and 83.33% for 90 days period of exposure respectively when compared to compressive strengths of 15% replaced SCBA concrete cubes cured in water.

[5]. The compressive strengths of 20% replaced SCBA concrete cubes exposed to 1%, 3% and 5% concentrations of Sulphuric acid solutions decreases by 20.18%, 24.56% and 34.21% for 28 days period of exposure, 24.11%, 29.46% and 33.04% for 60 days period of exposure, 75.78%, 79.69% and 85.16% for 90 days period of exposure respectively when compared to compressive strengths of 20% replaced SCBA concrete cubes cured in water.

[6]. The compressive strengths of SCBA replaced concrete cubes exposed to sulphuric acid of concentrations of 1, 3 and 5 percentage solutions decreases with the increase in period of exposure for all percentages of replacements. For different periods of curing an increase in compressive strength is observed up to 10% replacement and a decrease in compressive strength is observed at 15% and 20% replacements and a slight increase is observed at 10% replacements for all curing periods.

[7]. The compressive strengths of conventional concrete cubes exposed to 1%, 3% and 5% concentrations of Hydrogen Chloride acid solutions decreases by 20.72%, 26.54% and 31.63% for 28 days period of exposure, 27.34%, 33.09% and 38.13% for 60 days period of exposure, 61.70%, 66.67% and 70.92% for 90 days period of exposure respectively when compared to compressive strengths of conventional concrete cubes cured in water.

[8]. The compressive strengths of 5% replaced SCBA concrete cubes exposed to 1%, 3% and 5% concentrations of Hydrogen Chloride acid solutions decreases by 17.99%, 23.02% and 28.06% for 28 days period of exposure, 27.70%, 35.14% and 39.86% for 60 days period of exposure, 58.62%, 64.14% and 68.28% for 90 days period of exposure respectively when compared to compressive strengths of 5% replaced SCBA concrete cubes cured in water.

[9]. The compressive strengths of 10% replaced SCBA concrete cubes exposed to 1%, 3% and 5% concentrations of Hydrogen Chloride acid solutions decreases by 18.75%, 22.92% and 27.78% for 28 days period of exposure, 23.49%, 33.56% and 38.93% for 60 days period of exposure, 57.43%, 60.81% and 66.89% for 90 days period of exposure respectively when compared to compressive strengths of 10% replaced SCBA concrete cubes cured in water.

[10]. The compressive strengths of 15% replaced SCBA concrete cubes exposed to 1%, 3% and 5% concentrations of Hydrogen Chloride acid solutions decreases by 15.63%, 21.09% and 26.56% for 28 days period of exposure, 26.12%, 26.87% and 36.57% for 60 days period of exposure, 65.22%, 71.01% and 73.19% for 90 days period of exposure respectively when compared to compressive strengths of 15% replaced SCBA concrete cubes cured in water.

[11]. The compressive strengths of 20% replaced SCBA concrete cubes exposed to 1%, 3% and 5% concentrations of Hydrogen Chloride acid solutions decreases by 19.30%, 25.44% and 28.07% for 28 days period of exposure, 27.19%, 28.57% and 29.01% for 60 days period of exposure, 66.32%, 71.88% and 75.00% for 90 days period of exposure respectively when compared to compressive strengths of 15% replaced SCBA concrete cubes cured in water.

[12]. The compressive strengths of SCBA replaced concrete cubes exposed to hydrogen chloride acid of concentrations of 1, 3 and 5 percentage solutions decreases with the increase in period of exposure for all percentages of replacements. For different periods of curing an increase in compressive strength is observed upto 10% replacement and a decrease in compressive strength is observed at 15% and 20% replacements and a slight increase is observed at 10% replacements for all curing periods.

[13]. The compressive strengths of SCBA replaced concrete cubes cured in water increased with increase in curing period for all percentages of replacements. An increase in compressive strength is observed up to 10% replacement and a decrease in strength is observed at 15%, 20% and a slight increase is observed at 10% replacements for all curing periods.

REFERENCES

[1] Dr M.P.S. Chauhan, Dr S.S Jain, Sanjay Srivastava, High Strength Concrete of M60 Grade for Highway Pavements for Heavy Vehicles, International Journal of Scientific and Research Publications, Volume 4, Issue 11, November 2014 1 ISSN 2250-3153.

[2] N.Vidya Sagar Lal, G.Naveen, B.SomeswaraRao, Durability studies on concrete and comparison with partial replacement of cement with rise husk ash and sugarcane bagasse ash in concrete, International Journal of Engineering research and applications (IJERA), ISSN: 2248-9622, Vol. 5, Issue 11, (Part-4) November 2015,pp. 52-58.

[3] Sagar W. Dhengare, Dr.S.P.Raut, N.V.Bandwal, Anand Khangan, Investigation into Utilization of Sugarcane Bagasse Ash as Supplementary Cementitious Material in Concrete, International Journal of Emerging Engineering Research and Technology Volume 3, Issue 4, April 2015, PP 109-116 ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online).

[4] T. Shafana, R.Venkatasubramani, A study on the Mechanical Properties of Concrete with partial replacement of Fine aggregate with Sugarcane bagasse ash, International Journal of Advanced Structures and Geotechnical Engineering ISSN 2319-5347, Vol. 03, No. 01, January 2014.

[5] G. Sireesha, M. Kanta Rao, P. Kanta Rao, An Experimental Study on Strength Properties of Concrete When Cement Is Partially Replaced With Sugar-Cane Bagasse Ash, IOSR

Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 9, Issue 3 (Sep. - Oct. 2013), PP 35-38.

[6] Shruthi H R,Dr.H Eramma,Yashwanth M K,Keerthi gowda B S A Study On Bagasse Ash Replaced Plain Cement Concrete, International Journal of Advanced Technology in Engineering and Science www.ijates.com Volume No.02, Issue No. 08, August 2014 ISSN (online): 2348 – 7550.

[7] Jayminkumar A. Patel, Dr. D. B. Raijiwala, Experimental study on compressive strength of concrete by partially replacement of cement with sugar cane bagasse ash, Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 5, Issue 4, (Part -7) April 2015, pp.117-120.

[8] Mrs.U.R.Kawade, Mr.V.R.Rathi, Miss Vaishali D. Girge, Effect of use of Bagasse Ash on Strength of Concrete, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 7, July 2013.

[9] Mohananganga Raju Puppala , M K M V Ratnam, An Experimental Study on Concrete with Sugarcane Bagasse Ash as a Partial Replacement of Cement under Sulphate Attack Using Mgso4 Solution ISSN ONLINE(2319-8753)PRINT(2347-6710).

[10] Nasir Shafiq, Muhd Fadhil Nuruddin, Asma Abd Elhameed, Effect of Sugar Cane Bagasse Ash (SCBA) on Sulphate Resistance of Concrete, International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463 Vol. 3 Issue 4, April-2014, pp: (64-67).

[11] P. R. Wankhede , V. A. Fulari, Effect of Fly ASH on Properties of Concrete, International Journal of Emerging Technology and Advanced Engineering Journal, Vol- 4 July 2014 PP 284- 289.

[12] Sidramappa S I, Shivakumar S A, Karthik M N, Studies on mechanical properties of concrete using Sugarcane bagasse ash, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN: 2320-334X PP 33-37.