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Study on Self Compacting Fiber Reinforced Concrete Using Alternative Materials - An Approach towards Sustainable Development

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Abstract: The present era is "THE ERA OF CONCRETE" because concrete is the most consumed material after water in developing countries. The huge demand of concrete requires large amount of cement which is the basic necessity for strength development of concrete. Large consumption of cement forces very high production to satisfy the demand. But production of cement produces CO_2 in the atmosphere. One ton of cement produces about one ton of CO_2 and hence it creates disturbance in natural global system. So, there is need of alternative materials which can replace cement. Previous researches shows number of materials such as Fly Ash, Silica Fume, and Sugarcane Baggase Ash etc may be used as a replacement of cement. India is second largest country which produce Sugar and hence sugar waste is also produced in very large quantity. Previous researches shows that Sugarcane Ash may be replaced by cement up to certain percentages. The higher percentage may lead the brittle failure of Concrete which may be overcomed by the addition of Steel Fiber and good range Super plasticizer to get Self Compacting nature of Concrete. Here an attempt is made to collect the detailed research overview for Sugarcane Baggase Ash as a replacement of cement along with the separate study of Steel Fiber reinforced Concrete. This would be helpful for fiber reinforced concrete using alternative materials.
Keyword: Cement, Fine Aggregate, Coarse Aggregate, Sugar Cane Baggase Ash, Superplasticizer (PC Base) and Steel Fibers

I. INTRODUCTION

Self compacting concrete (SCC) is defined as a concrete that has excellent deformability and high resistance to segregation and can be filled in heavily reinforced or restricted area without applying vibration [2,3,4,17]. SCC was developed in Japan in the 1980, and recently this concrete has gained wide use in many countries for different applications and structural configurations [2,3]. Several different approaches have been used to develop SCC. One method to achieve self-consolidating property is to incorporate a viscosity modifying admixture (VMA) to enhance stability. The use of VMA along with adequate concentration of super plasticizer (SP) can ensure high deformability and adequate workability, leading to a good resistance to segregation [3]. However, viscosity modifying admixtures are very expensive and can increase the cost of concrete [3]. One alternative approach to achieve self-consolidating property is to increase significantly the amount of fine materials such as bagasse ash without increasing the cost [3]. Self compacting concrete is not popular because its high cost compared to conventional concrete but now days several researcher institute and construction companies have undertaken research and development work on SCC [4].

In most of countries of the world, the construction activity is increased day by day. In most of the structure concrete plays very important role. The reason behind its popularity is its properties like durability, toughness and economy. Concrete is used everywhere from roads, dams, bridges, tunnel, industrial floor to parking slots, residential and commercial buildings and numerous other applications. Now as per need there is quite good quantity of concrete is available like high performance concrete, high strength concrete etc. Ordinary Portland cement is recognized as a major construction material throughout the world and in terms of its per capita consumption, it is second most consumed material in the country, next only to water. However, the production of Ordinary Portland cement, an essential basic of concrete, leads to the release of significant amount of CO_2, a greenhouse gas (GHG); production of one ton of Portland cement produces about one ton of CO_2 The objectives of this research were to make utilization of Sugar cane bagasse ash (SCBA) as replacement for cement is incorporated in concrete in order to achieve increase in strength and a better bonding between aggregate and cement paste. The environmental issues associated with GHG, in addition to natural resources issues, will play a leading role in the sustainable development of the cement and concrete industry during this century. 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 earnings and environmental pollution control.

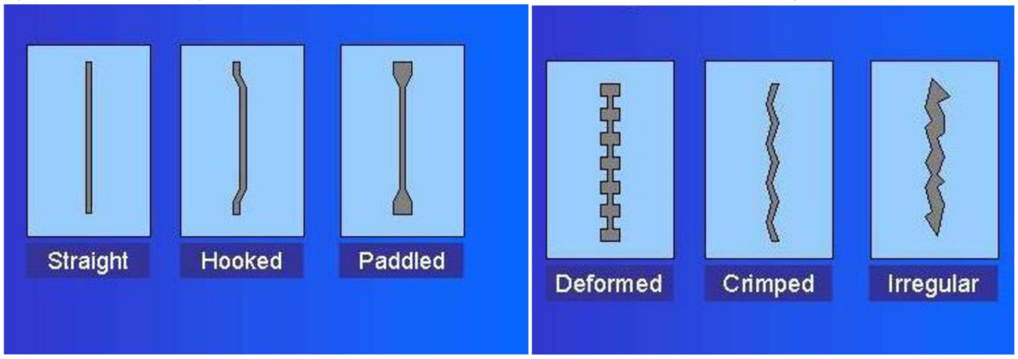
Industrial wastes, such as blast furnace slag, fly ash and silica fume are being used as supplementary cement replacement materials[13]. When this bagasse is burned under controlled conditions, it gives ash having amorphous silica, which has pozzolanic properties Therefore it is possible to use sugarcane bagasse ash (SCBA)) as cement replacement material to improve quality and reduce the cost of construction materials in concrete and also reduce the environment pollution .SCBA is used as fuel in the cogeneration process to produce steam and electricity in sugar industries [8-10]. When baggase is burnt in combustion boiler under controlled burning, reactive amorphous silica is formed in the residual ashes [8-10]. After burning baggase ash is collected as a by-product from cogeneration boiler and directly dumped to nearest disposal area. SCBA is generated in large quantities (67,000 tonnes/day) in India, because of the extensively developed sugar industry [8-10]. The total worldwide production of sugarcane was approximately 1794 million tons [6]. Disposal of baggase ash is a critical issue for sugar industries because of environmental constrains and land requirement [8-10]. Good pozzolonic properties are obtained in baggase ash heated between 700-1000 ºC [1,2,6,12]. After the extraction of all economical sugar from sugarcane, about 40-45% fibrous residue is obtained, which is reused in the same industry as fuel in boilers for heat generation leaving behind 8-10% ash as waste, known as sugarcane baggase ash (SCBA) [7,11]. The resulting Baggase Ash represent approximately 0.62% of the sugarcane weight [6]. The SCBA contains high amounts of un-burnt matter, silicon, aluminum and calcium oxides [1,7]. This bagasse ash has been chemically and physically characterized replaced in different proportion with cement and incorporated in concrete. For such application, the fresh concrete must possess high fluidity and good cohesiveness [4]. The use of fine material such as three different region Sugarcane Baggase Fly Ash (SCBA) ensure the required concrete properties [4]. Fresh concrete test such as slump cone test were carried out as well as hardened concrete test like compressive strength, tensile strength and flexural strength at the age of 3, 7 and 28 days will be carried out and the optimum limit of replacement of bagasse ash as replacement for cement in concrete is conducted[1,2,3]. Fresh concrete durability carried out at the optimum limit of replacement of baggase ash as replacement of cement in concrete is conducted[5]. The cost of self compacting concrete reduced by 36% by incorporating baggase ash along with the standard concrete in gradients [6].

Sugarcane Baggase and Sugarcane Baggase Ash

Fiber reinforced concrete (FRC) has been widely used for industrial pavements and small (non-structural) precast elements or sprayed in tunnels. Besides the non-structural elements (pipes, culverts and other small components), fiber reinforcement is particularly appealing for large structural elements. Here steel fibers may be successfully adopted in substitution, at least partly, of the conventional reinforcement (bars or welded mesh) to reduce labour costs (since the conventional reinforcement is placed manually [20].

Similar to normal weight concrete, addition of fibers to the lightweight concrete increases the load carrying capacity and control cracks [15]. It also increases the concrete resistance to dynamic and sudden loading, reduces crack width, increase tensile strength of concrete and its resistance against deformation [15-18]. Concrete technology now includes reinforcement in the form of polymeric fibers, steel fibers and glass fibers [15]. However, there is strong negative influence on the workability of concrete with addition of fibers to it. The toughness increases substantially with the contribution of the large fibers, but the peak stress remains almost constant [15, 16, 19].

With addition of steel fibers to concrete, its properties are altered from brittle to ductile [15]. Addition of high strength steel fibers to concrete results in better ductility and higher load carrying capacity, compared to concrete with normal strength steel fibers in the absence of main reinforcement bars [15]. Use of optimal steel fiber weight ratio in high strength concrete produces high performance bending elements having elastic–plastic behavior similar to that of normal strength concrete members.



Steel Fiber

II. FORMAR EXPERIMENTAL WORK

The sugarcane bagasse consists of approximately 50% of cellulose, 25% of hemi cellulose 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) [14]. The detailed chemical composition is as shown below [1,2] and also physical property of SCB [14]

Chemical Composition of SCBA

Chemical Composition	Residual Baggase Ash (%)
SiO_2	78.34
Al_2	8.55
Fe_2O	3.61
CaO	2.15
Na_2O	0.12
K_2O	3.46
MnO	0.13
TiO_2	0.50
BaO	<0.16
P_2O_5	1.07
Loss of Ignition	0.42

Table-1 [1,2]

Physical Property of SCB

Component	Mass (%)
Density	2.52
Blaine Surface Area (cm^2/gm)	5140
Particle size (μm)	28.9
Colour	Reddish Grey

Table-2 [14]

Due to its favorable chemical composition for concrete it has been used number of times for research purpose. The detailed survey gives following remarkable technical output

A. Workability

1) Partial replacement of cement by SCBA increases workability of fresh concrete.
2) The fraction of fine aggregate 10% and 20% can be effectively replaced with a baggase ash without a considerable loss of workability [7].
3) To achieve superior workability and placeability, high range water reducing concrete admixture used [3].
4) In the fresh state of concrete the different mixes of concrete have slump flow in the range of 333 mm to 815 mm [3].
5) L-box ratio ranging from 0 to 1 and flow time ranging from 1.8 s to no flow [3].
6) The slump and weight density of concrete decrease monotonically as the replacement percentage of cement with SCBA increases. The workability increase when cement is replaced partially with SCBA.
7) As a conclusion, all the objectives of this study are achieved; concrete with using waste SCBA has a very high workability from control sample. This result achieved from the slump test that use of SCBA will increase the workability of concrete.
8) The slump of concrete containing SCBA as fine aggregate replacement decreased with increases in the SCBA content, but in spite of this decline in the slump, the mixes remained good workability.

B. Compressive Strength

1) The Replacement of cement by SCBA gives increased compressive strength upto 15% after 15% compressive strength may decrease.
2) The Replacement of Cement by SCBA give maximum Compressive Strength upto 10% further increase in SCBA percentage results in decreasing Compressive Strength and they will replaced up to 20% of SCBA [2,4,5].
3) The fraction of fine aggregate 10% and 20% can be effectively replaced with a baggase ash without a considerable loss of strength property [7].
4) Prashant and Vyawahare shows that the compressive strength of results of specimens at 10% replacement of SCBA were higher than those at 0% SCBA. Further increase in SCBA percentage results in decreasing compressive strength along with significant fall in properties of fresh concrete.
5) Prashant and Vyawahare shows that the the compressive strength of results of specimens at 7 and 28 days increases with 10% and 20% SCBA replace by fine aggregate.
6) Deepak, Bahurudeen and Santhanam shows compressive strength of concrete for different SCBA blended cements was determined at 3, 28 and 56 days of curing. compressive strength of SCBA blended concrete were greater compared to control concrete up to 20% replacement and then a marginal reduction was observed for 25% replacement.
7) Sinde and Angalekar shows compressive strength of result of specimens at 10% replacement of SCBA were maximum and up to 20% replacement of SCBA give higher strength compare to 0% SCBA.
8) Tayyeb, Shazim and Humayun shows compressive strength of concrete increase upto 15% replacement of SCBA and 10% replacement of SCBA give maximum compressive strength.
9) Shahid, Ahsan and Thomas shows the compressive strength of concrete is slight decrease with increase of Steel Fiber content.
10) The 7 days, 28 days and 60 days compressive strengths of concrete increase initially as the replacement percentage of cement SCBA increases, and become maximum at about 20% and later decreases.

C. Split Tensile Strength

1) The Replacement of cement by SCBA gives increase tensile strength upto 20% after 20% tensile strength may be decrease gradually.
2) Prashant and Vyawahare shows when the influence of SCBA on the tensile strength of concrete was examined, it was observed that the development of tensile strength of mixes decrease as the replacement of SCBA increase.
3) Sinde and Angalekar shows the split tensile strength of concrete increase upto 10% replacement of SCBA after 10% split tensile strength may be gradually decrease. Self compacting concrete has attained lesser split tensile strength than that of the conventional concrete, it is due to the use of percentage of SCBA replaced in the cement and to the slower Pozzolonic action of SCBA that decrease the split tensile strength at early stage.
4) Shahid, Ahsan and Thomas show the adding of Steel Fiber in concrete they will increase the split tensile strength of concrete. Result show that the there is around 37% increase in split tensile strength of concrete compare to control concrete.
5) The split tensile strength of concrete increases initially as the replacement percentage of cement with SCBA increases, and becomes maximum at about 20% and later decrease.

D. *Flexural Strength*

1) The Replacement of cement by SCBA gives increase flexural strength upto 20% after 20% flexural strength may be decrease gradually.
2) Replacement of SCBA in cement by 5%,10% and 20% increases the flexural strength by 22.97%, 31.45% and 41.34% respectively.
3) Sinde and Angalekar show the flexural strength and graph, it is found to be increasing flexural strength with the addition of 10% SCBA in river sand. But it reduce when an increasing SCBA was added.
4) Shahid, Ahsan and Thomas show the result an increase in flexural strength of concrete with the increase in steel fiber content. The first crack load increase by around 32% while there is an increase of around 110% in peak load, once the fiber content is increased from 0% to 1.25%.
5) Experimented on replacement of cement by SCBA and concluded that a Considerable improvement in the flexural strength was seen at 20% replacement of cement**.**

III. DURABILITY

Durability performance was investigated by the different method

1) Oxygen Permeability Method
2) Rapid Chloride Penetration Test
3) Chloride Conductivity Test
4) Water Sorptivity Test
5) DIN Water Permeability Test and
6) Torrent Air Permeability test
7) Water absorption decrease with increase SCBA aggregate ratio. The highest reduction was obtained with 20% of SCBA aggregate replacement with a reduction of 14.68% at 28-day age compared to control concrete.
8) They were conducted the study on the effect of 15% and 30% replacement of cement by silica fume, fly ash, and glass powder, SCBA on compressive strength and durability in the form of capillary absorption.

IV. CONCLUSION

Based on the critical review of the research papers following conclusion can be drawn

A. When the proportion of SCBA increase in concrete then make light weight concrete.
B. When the proportion of Steel Fiber add in concrete then concrete convert into brittle to ductile. Steel Fiber improve the ductility of concrete.
C. As per study I can clearly seen that SCBA replacing by cement than workability of concrete increase and relative density decrease.
D. As per study I can clearly seen that 5%, 10% and 15% SCBA replacement of cement compressive strength increase for 7,28 and 56 days.
E. As per Study I can clearly seen that SCBA replace with Cement they will increse tensile strength and of concrete Increase.
F. As per study I can clearly seen that Steel Fiber add in concrete they will increase flexural strength of concrete.
G. As per study I can clearly seen that the compressive strength, tensile strength and flexural strength of concrete increase up to 20% replacement of SCBA with cement If SCBA replace more than 20% compressive strength, tensile strength and flexural strength is decrease.

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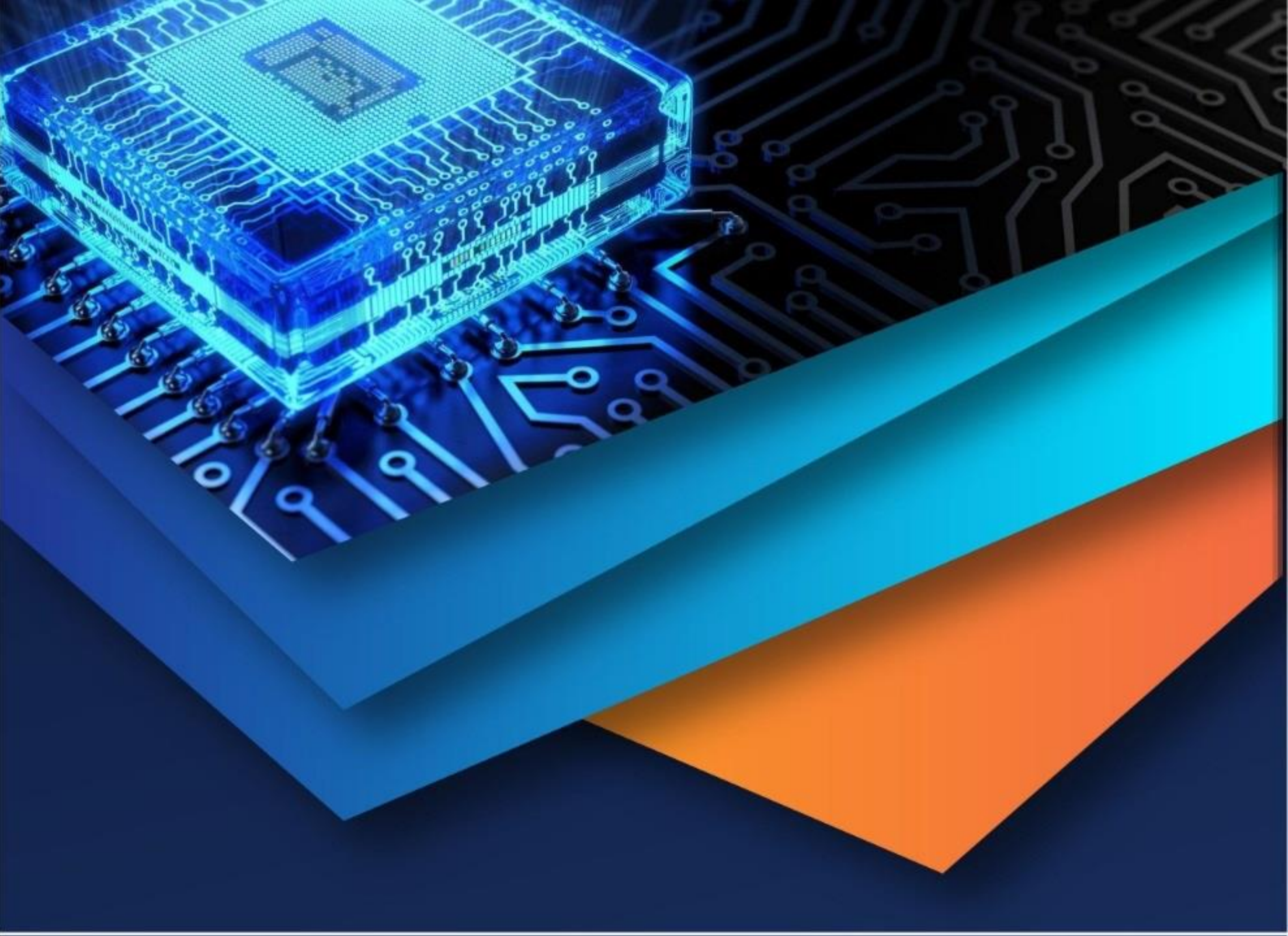

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