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Use of Sugarcane Bagasse Ash as partial replacement of cement in concrete - A Comparative Experiment.

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Abstract

As we know that the construction Industry is the most important industry for any country. It plays significant role in national economy. To develop the any country the major infrastructures required are schools, hospitals, offices, power system and other buildings, water supply, sewerage, drainage, railways, roads, airports, ports, irrigation system, etc. The consumption of Concrete is approximately thirty Billion tons per year that leads to high consumption of cement. As the concrete is the mixture of cement, aggregate (fine aggregate and coarse aggregate) and water & cement is the main ingredient of conventional concrete. The generation of cement causes major amount of air pollutants, which adversely affects the environment and is responsible for a major amount of greenhouse gases such as carbon-dioxide emission in the atmosphere. So, to reduce the emission of greenhouse gases in production of concrete, various types of modern sustainable concrete using industrial waste like rice husk ash, slag, silica fume, blast furnace slag fly ash. By Re-using these waste materials the harm to the environment can be decreased. In the present study partial replacement of Ordinary Portland Cement with Sugarcane Bagasse Ash in concrete will be done. The primary objective of this study is to determine properties of concrete in fresh (green) stage and in hardened stage. The concrete cubes (samples) of concrete (Cubes) were made for M30 (using IS codes 10262:2009 and 2016) with different mix Percentages of Sugarcane Bagasse Ash (i.e. 5%, 10%, and 15%) with this a normal mix of M30 concrete was also made. The innovation in the present study is to find replacement dose of Sugarcane Bagasse Ash for M30 grade of concrete by comparing the results of normal mixed concrete with SBA mixed concrete. By using of waste material will help the Society by providing pollution free environment and decreasing the problem of landfills for waste materials. Comparative results are satisfactory in case of fresh properties of concrete. However the Compressive Strength Test for M30 grade concrete the value of SBA percentage that can be added without adversely affecting the strength of concrete is only up to 5%.

Keywords- Strength, SBA(sugarcane bagasse ash), compressive Strength, Sieve analysis, W/C ratio, OPC cement, Workability test, CFA (Coal-Combustion Fly Ash), CBCs (Cement-Based Composites)

1 INTRODUCTION

Cement is the most important ingredient in both mortar and concrete. Due to its various properties like water resistance, including their ease of acquisition, thermal resistivity and mobility to be casted in various sizes and shapes However, the environmental aspect of cement has become a growing concern, as manufacturing of cement causes a great amount of greenhouse gases emission. Concrete is use in all types of construction works in civil engineering. The main components of concrete are cement, aggregates (fine aggregate and coarse aggregate), and water.

Cement is the third most energy-intensive material in worldwide after steel and aluminum. Cement manufacture process results in massive emissions ofpollutant as CO_2 into the air that causes climate change. Manufacture of cement alone generates 1350 million tons of greenhouse gases per year. Each ton of cement production requires approximately 80 units of electricity and raw materials of about 1500 kg.

Agriculture waste products such as sugarcane bagasse ash (SBA), sawdust ash, and rice husk ashas well as industrial by-products like fly ash, silica fume, red mud, tailingand slag, are presently being utilized as concrete in several applications. Non utilization of this products cause contamination of water, air and land. Using these materials as pozzolanic materials in concrete, these waste materials may improve durability and mechanical durability properties of the composites. Also, utilization of waste materials in concrete will promotes sustainability in construction. Sugarcane Bagasse Ash is a by-product of the sugar industry. After the sugar is extracted from sugarcane, a larger fibrous waste material called bagasse is left behind. When bagasse is burned at a specific temperature, a huge quantity of ash is produced, known as Sugarcane Bagasse Ash. After fibrous bagasse is burned at approximately 600–800 ◦C, the ash produced is rich in amorphous silica with excellent pozzolanic properties Bagasse ash’s amorphous silica content makes it an excellent cement substitute in concrete. The amount of silica in the ash varies depending on a variety of factors, including the burning method and temperature, the type of soil used to grow sugarcane, and raw material propertiesAfter sugarcane juice is extracted, sugarcane bagasse waste is left behind, which contains nearly 50% of the sugarcane’s quantity. Bagasse is frequently used as a fuel for power generation. SBA is the final waste product of this process. Thus, utilization of SBA is concrete would be a sustainable approach. In this study, experiment method has been adopted to find utilization of SBA in CBCs as a sustainable approach for construction materials.

1.1 Overview

While normal construction practice is generally guided by short term economic considerations, sustainable construction is focused on best practices which emphasize on long term affordability, durability and effectiveness. At each stage of the life cycle of the construction, it increases ease and quality of life, while minimizing the negative environmental impacts and increasing economic sustainability of the construction. Any infrastructure designed and constructed in a sustainable way minimizes the use of resources through the whole life cycle of the construction process in which the green concrete plays a vital role in achieving the sustainable construction. Having many of advantage has led to increased popularity in the construction world and is one of the emerging technologies in sustainable construction.

The present work is about studying the basic Characteristic of concrete mix using sugarcane bagasse ash as partial replacement of cement.

1.2 Research Motivation

In the terms of document count the top 3 most relevant area of research are engineering, material science and environment science. In this study by using of waste material such as Sugarcane Bagasse Ash as partial replacement of cement in concrete, we can contribute into all three of the research areas. A previous researcher has researched the replacement of 5%, 10%, 15%, and 20% as partial replacement of cement for M20-M25 concrete. The researchers have partiallyreplaced the cement for ratio of 5%, 10%, 15%, 20%, and 25% to find the optimum percentage of SBA. For this they have used SBA that was taken by mills directly. Here we have partially replacing the Ordinary Portland Cement of 43 grade for 5%, 10%, 15% with SBA that was produced by uncontrolled incineration, it is a byproduct of Sugar Mills and is cheaply available Use of SBA is yet to explored for use of making concrete.

Different Literature Reviews were studied and found that the researchers have explored partial replacement of Cement with some other materials or Aggregate with some different filler materials. After Literature Survey it was found that majority of researches were conducted for concrete of grade up to M25. For higher grade of concrete researches done are not very much. Design mixes using IS Codes 10262:2009 were prepared for M30 grade of concrete using SBA the objectives of the research is finalized the effects of SBA in the properties of fresh and hardened concrete.

The main reason for the research in this area is to recycle the waste product form sugar industries and power plantin our area and make the concrete economical as well as aid to the environmental friendly solutions. It is these days to use everything that can be used. It will also contribute in carbon dioxide emission in the environment. This can make an eco-friendly and ecological system for saving crucial space within the industrial boundary.

Another major significance of this study is that the Society will be benefitted as the concrete becomes economical; various Industries will be benefitted as management of the waste material can be done thus making space for storage of it and due to its ecofriendly nature Government will be benefitted as well. The major factor is that emission of CO_2 in the environment will be reduced as well as waste material management can be achieve by another making environment self-sufficient and the need for mining of exploration of different rocks for cement production will be reduced.

The global consumption of cement is very high; due to the fact that concrete is the most common use construction material. Thus the demand of cement is quite high in developing countries for rapid infrastructural growth, due to this developing country such as India facing increase in rate of cement in market. Particularly in India, due to this, a research to use of other materials to reduce the manufacturing cost of cement is increasing day by day.

In past decade the use of different waste materials in making cement to achieve the economical as well as ecofriendly cement has been increased. In this situation research began to find different waste material that has the properties to replace the cement in concrete making process. Some alternative materials have already been used as a part of concrete e.g. fly ash; slag limestone, rice husk ash, etc. used in concrete mixtures as a partial replacement of cement. However quality and quantity is the major limitation in many materials that mentioned above. Nowadays for sustainable growth of infrastructural demands the alternative material that should satisfy technical requisites of cement with availability as near as possible.

On comparing experimental data of normal / conventional concrete with same amount of water / cement ratio and cement types, the concrete having optimum amount of SBA shows that in can improve characteristic strengths and durability. Design Mixes are prepared for production to find optimum percentage of SBA for partial replacement of cement for M30 grade of concrete. Mainly compressive strength and workability properties were considered. Different mixes are prepared for partially replacing Ordinary Portland Cement with SBA for and the results are compared with that of Conventional Concrete.

1.3 Research Objective

To contribute in the society environment majorly is to making efforts to help in sustainable ecofriendly development. Utilization of waste products (locally available) that can make ecofriendly concrete can also be economical. Therefore, the Literature reviews are studied and the main objectives are:

1. To compare the properties of fresh concrete produced by using Sugarcane Bagassae ash as partial replacement of Ordinary Portland Cement in different percentages with conventional concrete.
2. To compare the properties of hardened concrete produced by using Sugarcane Bagassae ash as partial replacement of Ordinary Portland Cement in different percentages with conventional concrete

2 METHODOLOGY

In this study waste materials used are sugarcane bagasse ash. The sugarcanebagasse ash is used to replace ordinary Portland cement by 5%, 10%, 15%, and 20% for every mixes that are prepared. These concrete mixes are prepared for M30 grade of concrete. For each grade replacement of mix concrete samples are made and nominal Mixis also made to compare the results. The Samples are prepared and tested for 7 Days and 28 Days Compressive Strength Tests.

2.1 Materials Used

1. **Cement:** Ordinary Portland Cement (OPC GRADE 43) was used.
2. **Sugarcane bagasse ash:** Sugar cane bagasse ash is used for partial replacement of OPC.
3. **Coarse Aggregate:** Normal or angular Crusher Stones passing 20 mm Sieve are taken into account for the study
4. **Fine Aggregates:** River Sand is taken for the study passing 4.75 mm
5. **Water:** As it is known that water plays animportant role in making concrete as the chemical reaction that occurs in between material that causes it cementious properties. Water having PH-7 is use for mixing purpose as well as for curing process.

2.1.1 Sugarcane Bagasse Ash

It is very important to understand the characteristics of sugarcane bagasse ash to ensure it role in the concrete when partially replacing cement. The hardened properties of concretes are determined by so many factors such as w / c ratio, chemical properties of the binding material (cement and SBA), the quantity of coarse and fine aggregate, type of cement, quantity of cement, and condition of the environment and the measures taken in quantity control during the concrete production process. The CaO content of SBA is approximately in between 1% and 12.6% of its overall composition. As pervarious research studies it is evident that ordinary Portland cement (OPC) comprises a greater percentage of CaOin its composition than SBA. Another main chemical composition of OPCis SiO_2, whose presence in SBA is used to determine its reactivity. The SiO_2 content in SBA is between 57.63% and 78.34% that shows thatit contains a high concentration of essential oxides appropriate to act aspozzolanic material.If sugarcane bagasse ash is used in the concrete manufacturing process; it has the potential to aid to act as pozzolanic material to contribute instrength development.

The physical properties of binding material (cement) and filling materials (aggregates) effects the hardened properties of concrete. The current study focuses on the physical properties of sugarcane bagasse and ordinary Portland cement, such as specific gravity, particle size, shape, color and specific surface area. These properties of ordinary Portland cementand sugarcane bagasse ash related

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to each other are shown in. Sugarcane Bagasse Ash is available in three different colors:

1. Reddish grey,
2. Black,
3. White.

Figure 1. SBA

This variation in colors due to both the degree in which the incineration process was done and the structural change of silica in the ash. Sugarcane bagasse Ash that is generated as waste material by power plants ranges in color from dark black to light. Dark black colors indicates a greater carbon amount because of inadequate incineration, gray color shows that incineration process was done at very high temperature (greater than 800ºC) and white colors when the incineration temperature is above 900ºC. After incineration process is done a prolonged heating is required to convert the sugarcane bagasse ash completely to white ash. A different researcher has found out that the specific gravity of sugarcane bagasse ash is significantly less that cement.

Table 1: Specific gravity of cement and SBA

Material	**Specific gravity**
Cement	2.9-3.15
Sugarcane bagasse ash	1.78-2.88

It shows that to replace a unit weight of cement a greater amount of sugarcane bagasse ash is required. The concrete samples prepared by partial replacement of cement with sugarcane bagasse ash will lower density compare to normal concrete, in the proportional to the replacement of cement with sugarcane bagasse ash. It is evident that pozzolanic materials such as sugarcane bagasse ash have a lower bulk density compare to ordinary Portland cement. As density is ratio of mass and volume it suggests that the decrease in density will increase the volume that occupied by a given mass, because of this small voids of the matrix will be filled by these particles, which will reduce its permeability. As several researchers, the specific surface area of ordinary Portland cement varies from 309 to 373 m^2 / kg, which is so much less than that of sugarcane bagasse ash, which is between 514 and 1250 m^2 / kg. A specific surface area of sugarcane bagasse ash is very high to produce the same workability as normal mix greater amount of water, super plasticizer and air entraining admixtures are required. As sugarcane bagasse ash has a finer particle size compare to cement, it has glassy texture as fly ash particles that can increase workability

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2.2 Primary Tests Done

1 Sieve Analysis

1. For Fine Aggregates:
2. For Coarse Aggregates:
3. For cement.

2Specific Gravity of Coarse Aggregate

3 Specific Gravity of Fine Aggregate

4 Compaction Factor Test

5 Slump Cone Test

Table 2 Primary tests results

TESTS	VALUE/ RESULT
Fineness modulus of CA	7.359
Fineness modulus of FA	3.009
Fineness of Cement (Average)	0.950%
Specific Gravity of Sand	2.60
Specific Gravity of Coarse aggregate	2.80
Specific Gravity of Cement	3.17

2.3 Process

The Cubes are casted for M30 grade of concrete for which Mix Designs are done and the ratio for M30 is (1: 1.5058: 2763) found. After that weight of materials are calculated

1. In a pan take the weighted materials i.e. fine aggregate (sand), coarse aggregate, cement and sugarcane bagasse ash as in ratio found for mix design.
2. Mix the materials in dry state thoroughly.
3. Dry mix all the materials. After thoroughly mixing the materials make a hollow as crater in the Centre.
4. Start adding water in the mix at small amount at a time and start mixing them, water should be added as per the water cement ration taken in mix design.
5. After concrete is mixed start placing it inoil polished Cube moldsup to 1 / 3 of its part.
6. Now after this start temping the placed mixture in mould for 25 times, fill themouldup to 2 / 3 and repeat the tempingprocess.
7. Now completely fill the mould and temping it for 25 times in last portion, level it then put on Table Vibrator for compaction.
8. Then keep for 24 hours.After 24 hours take the specimen out of the moulds and keep for Curing in curing tanks.
9. After 7 & 28 Days take out the specimens of curing tanks and leave them for some time to surface dry them.After this perform the Compressive Strength tests.

FIGURE 2. MIXING, MOULD FILLING. COMPACTING AND CUBES IN MOULD

3.Result and discussion

The main objective of this chapter is to discuss the results of the tests done in this study and to find how ecofriendly and economical it will be to use SBA mixed concrete compared to conventional concrete and the use of mixes in various constructions. The tests did showspromising results that if an optimum value of 5% of SBA is achieved. If complete incinerated SBA were use the value can be increase up to 15% to 20%. So that it can be uses as fly ash in cement.The SBA used was burnt in uncontrolled manner because of which carbon content were high that has decreased the value of optimum value to 5%. The use of SBA has workability is decreased as compared to fresh concrete but the tests results shows partially replaced concrete can achieve higher compressive strength.

For sugarcane bagasse ash to be replaced in mixed by 5%, 10%, 15%, of weight of cement.The 7 Days Compressive ofMix for M30 grade is between 20.00 to 24.18Mpa and for 28 Days it is between 29.55 to 37.5 MPa. It is also observed thatdue to high carbon present on SBA the optimum value was 5%, if complete incineration process will be done that it can be increase up to 15%.

The Workability is decreased will increase in percentage of replacements as seen from the results.

For M30 Grade:

Table 3: Compressive Strength Test Results for M30 Grade of Concrete

%age Mix (Cement partially replaced SBA)	7 Days Compressive Strength (MPa)	28 Days Compressive Strength (MPa)
0%	25.55	39.00
5%	24.80	37.50
10%	22.56	34.22
15%	20.00	29.55

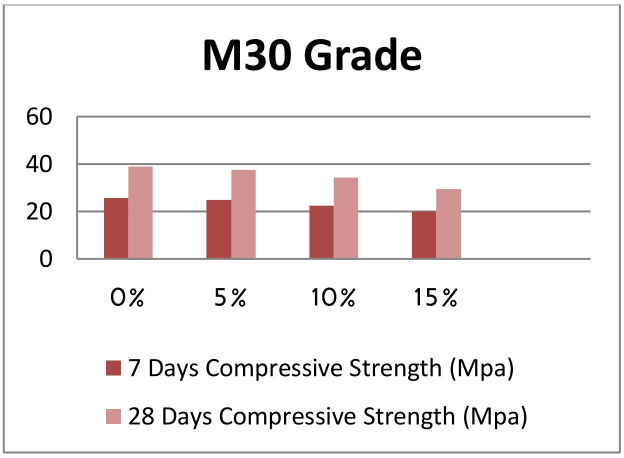

Fig.3: Compressive Strength of M30 grade of Concrete

Table 4 Slump Cone Test Results

%age Replaced	For M30 (in mm)
0%	40
5%	40
10%	30
15%	30

As the table above indicates that the slump value of M30 grade of concrete decrease with the increase of percentage of SBA partially replacing cement in mix.

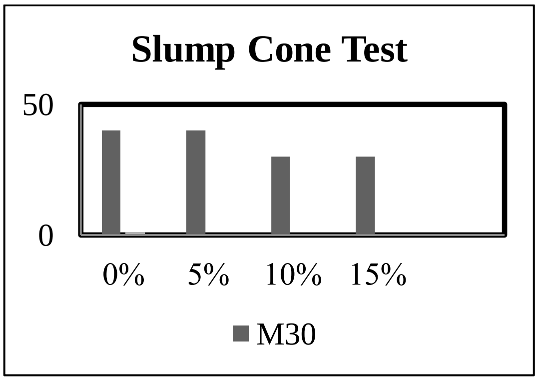

Fig. 4 Slump Cone Test

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Table 5 Compaction Factor Test Results

%age Replaced	For M30
0%	0.90
5%	0.90
10%	0.89
15%	0.88

As the table above indicates that the compaction factor test result of M30 grade of concrete decreases with the increase of percentage of partial replacement of cement with SBA in concrete that shows that workability of concrete decreases.

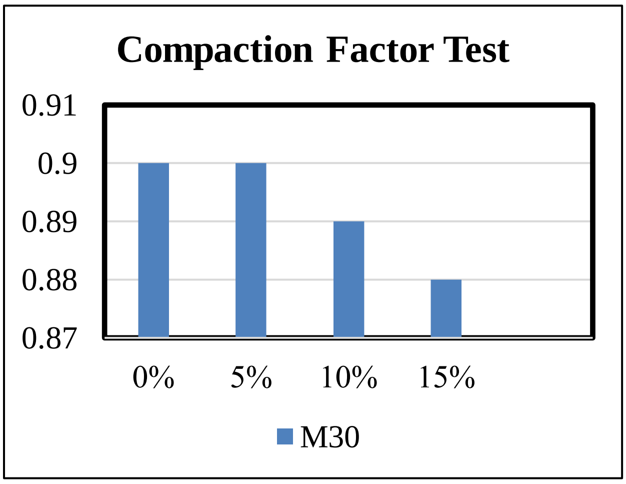

Fig.6: Compaction Factor Test

CONCLUSION

The present study was carried out to aim of this study was to carry out to use industry by-product Sugarcane bagasse ash to produce a sustainable, strong and durable concrete. It was an experimental approach for use of sugarcane bagasse ash in concrete production as a step towards sustainability in construction.SBA was used in experiment of production of concrete as secondary cementitious material (SCM) as to get the effect of SBA on the performance of concrete. In fresh concrete the slump cone test and compaction factor tests were performed to find the effect of SBA in workability of concrete. In hardened concrete 7 days and 28 days compressive strength test was performed. Test results shows that the workability of concrete decrease with the increase of SBA content in concrete as the specific surface area of SBA is very high compare to cement. Thus it requires more water. The compressive strength test result shows that the strength in compression in concrete mix decreases as the SBA content in mix increases more than 5% of cement.

SBA can make a good pozzolanic material as it has a higher amount of amorphous silica in it. Because of which, it can decreasing cement demand thus reduce CO2 emissions, protect various natural resources and solve waste management problems. These reasons can make SBA a sustainable construction material product in concrete with lower cost.

The strength properties of concrete improved with SBA addition up to an optimal amount, after which addition of SBA can decrease the strength of concrete. The optimal replacement of cement with SBA concrete lies within the range of 5–15% of cement. In this study it was found out that increase in SBA content more than 5% negatively affects the compressive strength of concrete

1. The lower workability is due to the higher specific surface area of SBA which increases the water requirement thus decreasing the fluidity thus the slump value and compaction factor is reduced.
2. Another reason of low workability is that SCBA contains no spherical glass grains but many porous grains thatdecrease the workability of fresh-state cement-based materials.
3. The design mix for M30 grade of concrete made with SBA partially replacing cement in concrete for 5%, 10% and 15%that shows that compressive strength of concrete decreases for 10% and 15%.

4. To achieve higher percentage of SBA replacement superplasticizerspolycarboxylic ether based is more compatible compare to sulphonated naphthalene based superplasticizer.
5. SBA contains more unburned carbon and potassium, as vegetable ash formed under a lower combustion temperature. That is a main reason of lower value of percentage replacement of cement with SBA; by incineration with higher temperature for complete incineration we can achieve white colored SBA that poses lower value of carbon content and higher pozzolanic properties.
6. With the use of sugarcane well-burnt bagasse Up to 20% of ordinary Portland cement can be optimally replaced with without any adverse effect on the desirable properties of concrete.
7. The use of SBA as partial replacement of cement in reduction in water permeability andresistance to chloride permeation and diffusion up to some percentage can be achieved.
8. As sugarcane bagasse ash is a waste material, its utilization as a cement replacing material reduces the levels of CO_2emission by the cement industry and also the material consumption for making of cement and at the same time it helps in disposal problem of the sugar industries.
9. Due to the lower density of SBA, concrete with partial replacement of cement by SBA has slightly less density so that it can be used at the place at which strength is of less importance and low density concrete density is required.
10. In the economic point of view, the cement partially replaced by SBA can be economical.

The reason for reduced strength that the exceed amount of pozzolanic material that required to combine with $Ca(OH)_2$. Another reason in decrease in strength can be due to defects generated during SBA dispersion that causes weak zones in concrete. Therefore it is recommended to use the SBA as replacement of cement in concrete in lower proportion i.e., 5-25% by weight of concrete.

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