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EXPERIMENTAL INVESTIGATION ON THE USE OF SUGARCANE BAGASSE ASH AND GRANITE WASTE AS FINE AGGREGATE IN CONCRETE

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ABSTRACT

Cement usage has surged due to massive infrastructure projects, with 30 billion tonnes of cement concrete used annually to meet global demand. Scholars worldwide are devising novel carbon-neutral construction approaches to repurpose industrial pollutants, and they are disseminating their research outcomes on the internet.

Bagasse from sugarcane has a high proportion of amorphous silica and can be applied to the concrete-making process. The purpose of this study is to examine the physical and chemical properties of ash made from bagasse from sugarcane. The investigation focuses on the impact of sugarcane bagasse ash processing on concrete performance.

In this work, concrete treated with various concentrations of sugarcane bagasse ash (SCBA) is examined for its fresh and hardened qualities. The purpose of this study is to examine the physical and chemical properties of ash made from bagasse from sugarcane. The investigation focuses on the impact of sugarcane bagasse ash processing on concrete performance. In this work, concrete treated with various concentrations of sugarcane bagasse ash (SCBA) is examined for its fresh and hardened qualities. Recycling industrial and agricultural waste into concrete could bring in a more environmentally conscious future.

In this study, Granite Waste (GW) and Sugarcane Bagasse Ash (SCBA) were examined and evaluated as possible partial substitutes for river sand. % substitution is determined by particle packing. It is studied

whether river sand may be partially replaced with bagasse ash and granite debris. The concrete is put through tests such as compression and splitting.

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

Concrete is a commonly used building material in the world. Conventional concrete is a blend of cement, fine aggregate, coarse aggregate, and water. Compared to allother ingredients, aggregates occupy 75 to 80 % of the total volume of concrete and influence the fresh and hardened properties of concrete. In the total composition of concrete, 25 to 30 % was occupied by the fine aggregate in volume.

Most concrete mixtures use a combination of fine aggregate and coarse aggregate each meeting their required gradation envelopes, often resulting in what is defined as “gap-graded” mixtures because of the dearth of intermediate-sized particles. A well-graded combined aggregate blend can be accomplished by using optimization techniques (theoretical and empirical), or by adding waste aggregate materials (due to size) to pack in the intermediate size fractions. By optimizing the packing of the combined aggregate gradation of concrete mixtures, the required cement paste content is reduced. It is possible to lessen the cement paste content by 8-16% withoutcompromising concrete performance **(Anson-Cartwright 2011)**. Using multiple material aggregate blending is not only more cost-effective, but it is also more environmentally sustainable.

It is believed that the use of necessary particle packing models, obtaining optimum proportions, such models can predict the particle packing degree. Simple and more effective guidance for aggregate optimization and concrete mix design can be obtained. It is typically agreed that concrete overall performance can be progressed by means of decreasing capillary-sized voids and their interconnectivity.

Over the last few years, several computer-based mix constituent proportioning methods have been developed, such as Europack, MixSim98, EMMA, and Betonlab.Pro. These allow the engineer to decide the most beneficial combination of mix constituents that will provide a maximum packing density and minimize the voids. These mix design methods adopt one of several mathematical models availablewhich can be used to determine the void ratio resulting from different combinationsof materials, given their physical properties, and, thereby, their optimum combination, in terms of, minimum porosity and permeability, maximum strength.

Since the depletion of river sand is a burning problem in today’s scenario, the researchers are desperate to find the alternative material for sand replacement in concrete. Some alternative materials have already been used as a part of natural sand.Fly ash, Slag, limestone, manufactured sand, and siliceous stone powders were used in concrete mixtures as a partial replacement of river sand. However, scarcity in the required quality is the major limitation in some of the above materials. Now a day's sustainable infrastructural growth demands the alternative material that should satisfytechnical requisites of fine aggregate and at the same time, it should be available abundantly. Sugarcane Bagasse Ash (SCBA) is obtained as combustion byproducts from the boiler of sugar manufacturing industries. As per **Bahurudeen *et al.*, (2015)**, India is the second-largest country in sugarcane production in the world. Tamil Nadu is the leading state with average productivity of 108 tons/hectare (2008-2009). The total bagasse ash availability in the country is calculated to be about 44220tons/day in which Tamil Nadu alone produces 3060 tons/day.

India accounts for over 20% of the world's resources in granite. Granite Waste (GW) is produced in granite factories while cutting and polishing granite rocks. As per **Lokeshwari *et al.*, (2016)** granite industries producing more than 150 tons of granite waste every day in the southern region of India. The waste disposal has been a major issue since it is dumped on land adjoining sites is becoming an environmental hazard to the surrounding community. The productive use of sugarcane bagasse ash and granite waste would be the best way to alleviate the problems associated with its disposal.

The present research work was aimed to explore the possibility to use the combination of sugarcane bagasse ash and granite waste as a construction material in place of river sand by using EMMA computer software to obtain the optimum combination of this material based on particle size distribution. The published research data which is confined to strength properties indicates that SCBA and GW are viable material as sand replacement in concrete. The main objective was to explore the feasibility of the use of SCBA and GW as filler material in structural concrete.

1.2 INDUSTRIAL WASTES AS FINE AGGREGATE

The traditional source of fine aggregate is natural river sand which is less available due to more usage of resources. The alternative waste materials are used as partial replacement of river sand fine aggregate. As several residual products have properties suited for concrete production, there is an increasing potential for material recycling by investigating the possible use of industrial waste in concrete making.

1.3 ENVIRONMENTAL ISSUES

1.3.1 Sugarcane Bagasse Ash

Sugarcane consists of about 30% bagasse whereas the sugar recovered is about 10%, and the bagasse leaves about 8% bagasse ash (this depends on the quality and type of the boiler) as a waste, this disposal of bagasse ash could be of serious concern. Sugarcane bagasse ash has been tested these days in some parts of the worldfor its use as a cement alternative material. The bagasse ash was found to enhance theproperties of the paste, mortar, and concrete including compressive strength and water tightness in certain replacement percentages and fineness. The higher silica content in the bagasse ash was suggested to be the principal cause of these enhancements. Although the silicate content may also range from ash to ash relying on the burning conditions and other properties of the raw materials including the soil on which the sugarcane is grown, it has been reported that the silicate undergoes a pozzolanic reaction with the hydration products of the cement (OPC) and results in a reduction of the free lime in the concrete.

1.3.2 Granite Waste

Granite is an igneous rock, which is broadly used as construction material in differentforms. Granite industries produce a lot of dust and waste materials. Granite quarry sludge is the waste from rock processing in quarries and crusher units. Tamil Nadu state has 45% of total granite reserves in India.

There are many granite stone cutting and polishing industries in Tamil Nadu. These industries produce significant amounts of waste in the form of slurry consisting of lime, granite powder, and bon fringes as residues. Presently, the dried slurry is disposed of by landfilling it in the low-lying areas. This leads to changes in soil fertility, pollution of the groundwater, and that of the surrounding environment. And also, all the processing units are disposing of this industrial waste by dumping it in open yards, occupying about 25% of the total area of the industry. Presently, the fines are disposed of with the aid of filling in barren land inflicting serious environmental problems. If this material is utilized in concrete making, it will lead to the sustainable improvement of concrete technology in addition to a secure environment. After a detailed investigation of all these factors, it was found that the utilization of granite waste in building blocks and special concrete was the best method of disposal. The utilization of granite waste will avoid disposal problems and related environmental issues. The utilization of granite waste will lessen using river sand and conserve natural resources.

1.1 OBJECTIVES AND SCOPE OF THE PRESENT STUDY

The objectives of the present study are kept as follows:

1. Characterization of two industrial waste materials: Sugarcane Bagasse Ash and Granite Waste fine aggregate.

2. To determine the mix proportion of the concrete mix based on the particle size which satisfies the requirement of the concrete in fresh condition and produces greater strength.

3. To study and compare the strength characteristics of BAGW concrete and control concrete.

4. To study the durability characteristics of BAGW concrete made with differentcement content.

5. To evaluate the flexural behaviour of reinforced BAGW concrete beams.

6. To validate the ultimate load-carrying capacity, the load-deflection behaviour of experimentally tested beams using ANSYS software.

1.2 RESEARCH METHODOLOGY

To achieve the above objectives the following methodology is adopted. The purpose of this research is to obtain an efficient way to produce concrete using industrial waste such as Sugarcane Bagasse ash and Granite waste as filler in concrete. An attempt has been made to find the optimum mix proportion of the bagasse ash and granite waste as a fine aggregate replacement, using EMMA computer modeling software. Preliminary test trials have been conducted on the fresh and hardened concrete to determine the workability and compressive strength of concrete. From the test results, the optimum mix for the dense concrete will be identified. Following those six concrete mixes arrived with and without Sugarcane bagasse ash – granite waste. In this research work, it was proposed to understand the behavior of BAGW concrete in fresh, hardened, and structural properties of concrete.

CHAPTER 2
REVIEW OF LITERATURE

Joshi, (2001) have studied the methods adopted for designing and optimizing the M60 grade HPC in the construction of a long bridge connecting Bandra – Worli sea link at Mumbai. He concluded that the target strength of 74 MPa could be achieved at28 days with a minimum cement content of 330 kg/m3, 10% silica fume by weight ofcement, and 3% of superplasticizer dosage.

Dilip Kumar Singha Roy, (2012) have studied the strength parameters of concrete made with partial replacement of cement by silica fume for low/medium-grade concretes (M20 and M25). They concluded that the use of silica fume is a necessityin the production of not only high strength concrete but also low/medium strength concrete at lower w/c ratio and better hydration of cement particles including strong bonding amongst the particles. The maximum compressive strength (both cube and cylinder) is noted for 10% replacement of cement with silica fume and the values are higher (by 19.6% and 16.82% respectively) than control concrete, whereas split tensile strength and flexural strength of the SF concrete are increased by about 38.58% and 21.13% respectively than by the control of concrete when 10% of cement is replaced by silica fume.

Bahurudeen and Santhanam, (2015) have comprehensively evaluated the pozzolanic activity of eight SCBA samples with different processing methods. The eight samples were (1) raw Bagasse Ash (raw BA); (2) Coarse Fibrous Unburnt (CFU) SCBA (74% LOI); (3) Fine Fibrous Unburnt (FFU) SCBA (72% LOI); (4) bagasse ash burnt to 700º C (B700); (5) bagasse ash ground to finer than 53 µm (G53); (6) (sieved) bagasse ash sieved through 300 µm sieve; (7) bagasse ash burnt at700 ºC and then ground to cement fineness (BG), i.e., 300 m2/kg; and (8) bagasseash sieved though a 300 µm sieve and then ground to cement fineness (SG). There are many methods to improve pozzolanic activity; it is difficult to achieve the desired SAI (Strength Activity Index) using only a single method. The integrated application of two or more processing methods is therefore necessary. With low LOI (B700) or increasing fineness (G53, sieved), the pozzolanic activity is slightly improved.

Praveenkumar *et al.*, (2020) have stated that Sugarcane Bagasse ash is an active pozzolan and investigated the production of bagasse ash with high specific surface area and pozzolanic activity using the laboratory ball milling and pulverize under controlled burning condition. The various properties of cement paste and mortar blended with processed bagasse ash were analyzed. The chemical and morphological characteristics were observed using various techniques like X-Ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), X-Ray Fluorescence (XRF), Electron Dispersive Spectroscopy (EDS) and Scanning Electron Microscopy (SEM). The behavior of cement pastes and mortars changed significantly up to 10% replacement level of treated sugarcane bagasse ash and reduce the water demand.

Dina M. Sadek *et al.*, (2016) have investigated the reuse of marble and granite wasteas mineral additive in the production of Self Compacting Concrete (SCC). The results revealed that the optimum percentage replacement of the waste powders as additives in SCC is 50% the weight of the cement content. SCC with waste powders had comparable or better performance than the control mix of the same cement content.

Li *et al.*, (2018) have studied the effects of adding Granite Waste (GW) as paste replacement on the durability and dimensional stability of mortar. A series of mortar mixes with varying GW volume and water/cement ratio but similar workability was achieved by adjusting the superplasticizer dosages. GW particles are finer than the fine aggregate particles and thus would fill into the voids in the bulk volume of fine aggregate to improve the packing density and refine the pore structure of the fine aggregate. The test results revealed that adding GW as paste replacement could substantially improve the carbonation and water resistances, reduce the ultimate shrinkage strain and shrinkage rate, and at the same time, reduce the cement content up to 25%. Some of the very fine GW particles could act as nuclei for precipitation ofCSH and thus increase the degree of cement hydration.

CHAPTER 3

EXPERIMENTAL INVESTIGATIONS

3.1 OVERVIEW

Several non-conventional materials are used as the aggregate in concrete making.In the present study, Sugarcane bagasse ash and Granite waste were used as the partial replacement of river sand fine aggregate in concrete. The materials used and their properties, concrete mix design, preparation of test specimens, and various testing methods have adopted to examine the behavior of the specimens are highlighted in this chapter. The experimental investigation has been done in four stages; they are

a) Characterization of material

b) Strength studies

c) Durability studies

d) Flexural behavioural studies

3.2 TESTS FOR CHARACTERIZATION OF MATERIALS

The process by which the structure and properties of the material are probed and measured is characterization. It is a fundamental process in the field of materials science without which no scientific understanding of engineering materials could be ascertained. It is essential to select the proper ingredients, evaluate the properties, andunderstand the interaction among different materials for optimum usage. The ingredients used for this investigation were cement, river sand fine aggregate, crushed granite coarse aggregate, water, chemical admixture (superplasticizer), Sugarcane Bagasse ash and Granite

3.2.1 Cement

Cement is one of the main ingredients to be used in concrete. Different brands of cement have been found to possess different strength development characteristics andrheological behavior due to the variations in the compound composition and fineness.Hence, it was decided to use the cement from a single supplier. For the present investigation, Ordinary Portland Cement of 53 grade conforming to IS: 12269 - 2013 was used.

To find the properties of the selected cement the following tests were carried out.

1. Fineness test
2. Specific gravity test and
3. Setting time test

3.2.2 Sugarcane Bagasse Ash

In sugar industries after the extraction of juice from the sugarcane plant the waste obtained was bagasse which is burned around 600ºC to heat water in a boiler to produce steam that will be used to drive power plants. The combustion process generates bagasse ash that has a grey-black color. Sugarcane Bagasse ash (SCBA) was obtained from Madras Sugar mill, Tirukoilur, Tamil Nadu (India). The dry sieving was conducted on 90 µm and 45 µm sieves to determine the particle size and chemical composition of bagasse ash was also determined using Energy Dispersive X-ray (EDX) analysis with Scanning Electron Microscope (SEM).

3.2.3 River Sand and Granite Waste

Locally available river sand was conforming to zone II as per IS 383-2006. Particle size distribution, specific gravity, water absorption, and bulk density were determined as per procedure given in IS 2386 (Part-I and II) 1963.

Granite waste is obtained from the crusher units in the form of finer fraction in slurry form. This is a physical mechanism owing to its spherical shape and very small in size, granite powder disperses easily in presence of superplasticizer and fills the voids between the river sand, resulting in a well-packed concrete mix. The particle size distribution and the Chemical composition of Granite powder were determined. The chemical composition of the granite waste was determined using Energy Dispersive X-ray (EDX) analysis with Scanning Electron Microscope (SEM).

3.2.4 Mix Design

Several models have been presented in Chapter 2 on particle packing to obtain high (or low) density. Proper design of the particle size distribution is essential in obtaining a dense particle packing. The two classical equations for particle size distributions are those of Furnas and Andreassen. In particle packing theory, the Particle Size Distribution (PSD) of the materials used is presented as a cumulative finer fraction. In 1907 Fuller and Thompson proposed the gradation curve for maximum density also known as the fuller ideal curve.

$$CPFT = (d/D)^n \times 100$$

CPFT is the cumulative percentage finer than and n = 0.5 was later revised to 0.45.

Andreassen proposed the "Andreassen Equation" for ideal packing assuming that the smallest particles would be infinitesimally small. Dinger and Funk recognized that the finest particles in real materials are finite in size and modified the Andreassen equation considering the minimum particle size in the distribution.

$CPFT = (d/D)^q \times 100$ Andreassen Model

$CPFT = [(d-d_O) / (D-d_O)]^q \times 100$ Modified Andreassen Model

Where,

CPFT = Cumulative percent finer than (volume)d =
Particle size in µm
D = maximum particle size of distribution in µm
d_O = minimum particle size of distribution in µmq =
modulus of particle size distribution

The exponent q is distribution coefficient or exponent or distribution modulus, so generally, q value varies from 0.20 to 0.37 depending on the various workability requirements. Increase in q value, the mix will be coarser and less workable whereas decreases in q value, fine contents will be increased and more workable. As the waterdemand and water holding capacity of the mixture is controlled by the volume of fines. This exponent gives a reasonable basis for choosing the amount of water and rheology modifying agents like superplasticizer to be added to the mixture. For high- performance concrete and conventional concrete depending upon the slump range theexponent q value may be taken as 0.25 – 0.30. For self-compacting concrete q < 0.23 and for roller-compacted concrete, q >0.32 mat be taken.

Particle size distribution has been analyzed for cement, fine aggregate, and coarse aggregate This software requires an input of material name, description, origin, price,particle size distribution (PSD) of material from the sieve analysis test, and particle density. The software gives the PSD of the concrete mix the line above the ideal grading indicates too much material of that size and the line below ideal grading indicates shortage material of that size. By mixing appropriate proportions of different granular materials, the medium size particles would fill up the gaps betweenthe larger size particles and the smaller size particles would fill up the gaps between the medium size particles and so forth.

3.2.5 Mix Proportion

The mix has been proportioned according to the IS:10262–2009 method for a design compressive strength of 20MPa.The materials and quantities were entered in the EMMA (Elkem Material Mix Analyzer) and PSD curve following Andreassen grading and modified Andreassen grading is obtained. It is then adjusted to meet the Modified Andreassen curve for optimization keeping w/c ratio as constant. EMMA (Elkem Material Mix Analyzer) software has been used for the study. After adjustment, it is found that there is ample scope for optimizing the material for particular design strength.

Likewise, two fine waste matervial such as sugarcane bagasse ash and granite wasteis incorporated as a filler agent. The optimum quantity of bagasse ash and granite waste is taken from research work of Almir sales et al, Prasanth O Modani et al, Aukkadet Rerkiboon et al, Rajasekar et al, Elisabeth et al, Vijayalakshmi et al, such as 20% and 10% by volume. These percentages of materials were entered as filler in EMMA to check the grading gap in the trial mix. To optimize the mixture manually the quantities were adjusted and the better of two mixtures are presented in Table 3.1

Table 3.1 Mix Proportion for Suitability Study

Materials kg/m^3	Trial mix 1	Trial mix 2
Cement	425	435
Sugarcane Bagasse ash	100	86
River sand	582	566
Granite waste	50	65
Coarse aggregate	1095	1120
Water	192	192

3.2.6 Casting and Curing of Specimens

The standard laboratory batching and mixing procedure is adopted in this study. Then the freshly mixed concrete was placed into the moulds and compaction was done using a vibrating table to ensure adequate compaction. The specimens were demoulded after 24 hours and cured under water at 27^o ± 2^o C.

3.3 MAKING OF SUGARCANE BAGASSE ASH – GRANITE WASTE(BAGW) CONCRETE AND MIX DESIGN

3.3.1 Overview

In this study, an attempt has made to develop concrete using Bagasse ash and Granitewaste as filler material to make the concrete denser using particle size distribution technique.

3.3.1 Mix Proportions

Particle packing optimization in concrete mixture design covers the selection of the right sizes and quantity of various materials. To optimize the packing density of concrete using a different blend of materials available and compare this optimum density with an ideal graph available in EMMA software. The input required for this software; material properties include particle size distribution, specific gravity, and the quantity of material. Modified Andreassen equation takes into account a minimum particle size and gives a downward curvature therefore it is used with the particle distribution coefficient 'q' as 0.30. It was observed that the optimum requirement of sugarcane bagasse ash was 27.5% of 10-100µm (cement) particle sizein graph and granite waste required was 9% of 100-1000µm (river sand) particle size in a graph.

To find the effect of bagasse ash and granite waste in concrete in terms of strength, durability, and structural properties, six concrete mixes were prepared with varying the water-cement ratio 0.36 to 0.56 with a difference of 0.04. It was also observed that the operating water needed was 192 liters per cubic meter of concrete for 20 mm maximum size of aggregate to get a 60mm slump. Therefore, the water content and the maximum size of coarse aggregate used were kept constant for both conventional concrete and BAGW concrete.

In this study, six conventional concrete mixes were proportioned with different cement content. Similarly, six more BAGW concrete mixes were prepared with partial replacement of river sand fine aggregate by SCBA and GW (27.5% of 10- 100µm and 9% of 100-1000µm particles). The volumes of cement, filler, and water are the same in both the conventional concrete and BAGW concrete for the respective w/c ratio mixes. To fulfill the expected workability, Superplasticizer (SP) of 12ml per kg of cement was mixed to BAGW concrete to get equal workability of comparable conventional concrete mix. The mix proportions of conventional concrete and BAGW concrete are presented in Table 3.2 and Table 3.3 respectively. The details of the number of specimens prepared for different mixes are given in Table 3.4.

Table 3.2 Mix Proportion of Conventional Concrete

Mix	Cement		River sand		Coarse aggrega		Water
	kg/m3	m^3/m^3	kg/m3	m^3/m^3	kg/m^3	m3/m3	liters/m3
C 1	535	0.170	620	0.238	1120	0.4	192
C 2	485	0.154	662	0.254	1120	0.4	192
C 3	435	0.138	703	0.270	1120	0.4	192
C 4	400	0.127	733	0.281	1120	0.4	192
C 5	371	0.118	756	0.290	1120	0.4	192
C 6	340	0.108	782	0.300	1120	0.4	192

Table 3.3 Mix Proportion of BAGW Concrete

Mix	Cement		Bagasse ash		River sand		Granite waste		Coarse aggregate		Water
	kg/m3	m3/m3	kg/m3	m3/m3	kg/m3	m3/m3	kg/m3	m3/m3	kg/m^3	m3/m3	lt/m3
BAGW 1	535	0.170	103	0.047	443	0.170	53	0.021	1120	0.4	192
BAGW 2	485	0.154	93	0.042	492	0.189	57	0.023	1120	0.4	192
BAGW 3	435	0.138	84	0.038	542	0.208	60	0.024	1120	0.4	192
BAGW 4	400	0.127	77	0.035	574	0.220	63	0.025	1120	0.4	192
BAGW 5	371	0.118	71	0.032	604	0.232	65	0.026	1120	0.4	192
BAGW 6	340	0.108	65	0.030	634	0.243	67	0.027	1120	0.4	192

Table 3.4 Details of the Number of Specimens for Each Mix

Size of specimen	Nature of test	Curing period	Test Standards	Total number of specimens*
100mm cube	Compression	7,28 days	IS 1199 - 1959	144
150mm diameter 300mm height cylinder	Split tension	28 days	IS 516 – 1959	48
100mmx100mmx500mm Prism	Flexure	28 days	IS 5816 – 1999	48
150mm diameter 300mm height cylinder	Modulus of Elasticity	28 days	IS 516 – 1959	48
100mm cube	Bond Strength	28 days	IS 2770 – 1967	36
100mm cube	Water absorption	28 days	ASTM C642 – 2006	36
100mm cube	Sulphate attack	56 days	ASTM C1012 – 2015	36
100mm cube	Acid resistance	56 days	ASTM C267 – 2001	36
100mm cube	Salt attack	56 days	Literature	36
100mm diameter 50mm thick slices	Sorptivity	28 days	ASTM 1585 – 2013	36
Same specimens of Sorptivity	RCPT	28 days	ASTM C1202 – 2015	-

*** Total number of specimens includes all the twelve concrete mixes**

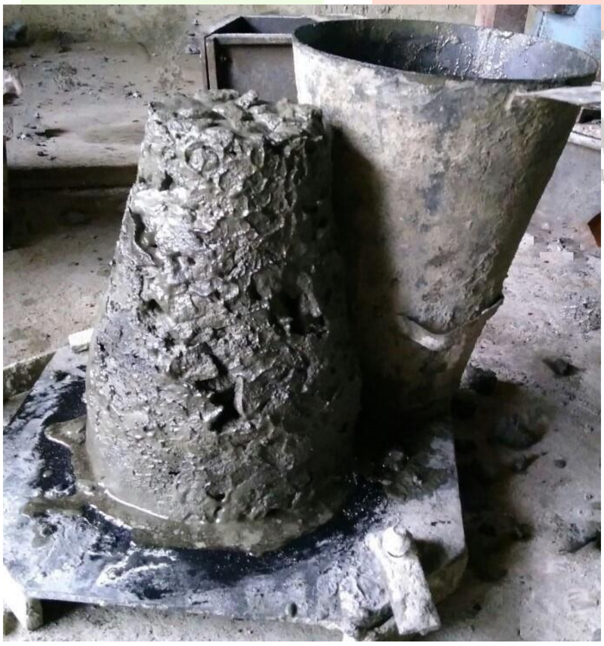
3.3.2 Test Procedure on Fresh Concrete

Overview

The proportioning of ingredients of concrete is governed by the required performanceof two states namely- the fresh state and hardened state. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability therefore becomes of vital importance.

Workability

A slump test is the most commonly used method for measuring the consistency of concrete. The test is popular owing to its simplicity. The apparatus for conducting a slump test consists of mould in the form of a frustum of a cone having internal dimensions as per IS 1199-1959. The slump cone is placed on a clean non-absorbent tray. The concrete mix is filled in the slump cone in three layers, compacting each layer by tamping 25 times using the standard tamping rod. Care is taken to distribute the strokes evenly over the cross-section. After filling the fourth layer, the top surfaceis leveled off using a trowel. Immediately, the slump cone mould is removed from the concrete by raising it slowly in a vertical direction. This allows the concrete to subside. The subsidence is referred to as the slump of concrete. The difference in level between the height of the mould and the highest point of the subsided concreteis measured in millimeters. This difference in height in “mm” is referred to as the slump of concrete shown in Fig. 3.1.



3.3.3 Test Procedures on Hardened Concrete Properties

Overview

The following tests were conducted to assess the strength of the BAGW concrete.

3.3.3.1 Compressive strength test

3.3.3.2 Split tensile test

3.3.3.3 Flexural strength test

3.3.3.4 Modulus of Elasticity test

3.3.3.5 Bond strength test

The methodology adopted to conduct the above experiments.

CHAPTER 4

RESULTS AND DISCUSSIONS

In this chapter, characterization of ingredients used in concrete, development of BAGW concrete mix design, properties of fresh, mechanical, durability and flexural behavior of concrete made with SCBA and conventional concrete are discussed

4.1 CHARACTERIZATION OF MATERIALS

4.1.1 Properties of Cement

The test results of the properties of cement are presented in Table 4.1. The ordinary Portland cement used in this study fulfilled the requirements as per IS: 12269 – 2013.The fineness of cement was measured by 90µm sieve.

Table 4.1 Properties of Cement

Property	Test Result	IS 12269-2013
Normal consistency	31 %	29-33%
Initial setting time	90 minutes	60mins *Min*
Final setting time	325 minutes	600mins *Max*
Fineness	8%	225m^2/kg
Specific gravity	3.15	-
Compressive strength at 28 days	54.6 MPa	27MPa 3days 37MPa 7days

4.1.2 Properties of Sugarcane Bagasse Ash

The sugarcane bagasse ash received from the industry is initially screened to remove the coarser particle size. The chemical composition may vary for materials received from a different source. The chemical composition of SCBA depends on the type of sugar mill, temperature, and time of burning.

Sugarcane bagasse ash was collected from Madras Sugar mill Pvt ltd, Tirukoilur, Tamilnadu, India. The chemical composition and physical properties of sugarcane bagasse ash are presented in Table 4.2 respectively. The chemical composition shows that bagasse ash is mainly composed of silica, alumina and iron with a small amount of magnesium, sulphate, calcium, etc. The total composition of silicon dioxide, aluminum oxide, and iron oxide present altogether in bagasse ash was 73.5% and such bagasse ash used in this study conformed to ASTM C 618-2005 class F fly ash. Energy Dispersive Spectroscopy (EDS) spectra and Scanning Electron Micrograph (SEM) image of sugarcane bagasse ash are shown in Figs. 4.1 and 4.2 respectively. As shown in SEM image the majority of the particles in bagasseash are irregular in shape, porous with only a minor number of spherical particles.

Table 4.2 Chemical properties of Sugarcane Bagasse Ash and Granite Waste

Chemical Component	SCBA %	GW %
SiO_2	56.01	53.55
Al_2O_3	12.67	9.69
Fe_2O_3	4.81	11.53
CaO	2.18	4.38
SO_3	0.10	-
MgO	1.01	2.09
Na_2O	0.35	0.87
K_2O	1.3	0.72
P_2O_5	0.59	-
TiO_2	0.03	1
Others	12.08	13.8
LOI	8.87	2.37

CHAPTER 5

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