EXPERIMENTAL STUDY ON STRENGTH PROPERTIES OF CONCRETE USING SUGARCANE BAGASSE ASH AND GRANITE WASTE AS FINE AGGREGATE

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ABSTRACT

In this experimental study, Sugarcane bagasse ash (SCBA) was used as a partial simulation for fine aggregate in concrete to reduce its cost, and different processing methods using agricultural/industrial waste were formed. The main focus of this research work was to examine the fresh property and mechanical (compressive strength and splitting tensile strength) concrete properties by replacing 0%, 10%, 20%, 30% and 40% of SCBA by dry weight of fine aggregates. A total of 60 concrete cylinders were prepared with 1:2:4 proportion with 0.50 water-cement ratio and immerged in water on 7 and 28 days. Finally, these concrete cylinders were tested on UTM. Three concrete samples were cast for each proportion and ultimately the average of the three concrete samples was taken as the final result. The slump value of concrete decreased with increases in the amount of SCBA in cement concrete. The results analyzed that the compressive and tensile strength of the concrete samples increased by 7.90 % and 14% at 10% of SCBA as sand substitute materials in cement concrete after 28 days..

Keywords: Sugarcane bagasse ash; fine replacement material; improved strength; reduced construction cost.

I. 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. Compare to all other 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% without compromising concrete performance (Anson-Cartwright 2011). Using multiple material aggregate blending is not only more cost-effective, but it is also more environmentally sustainable.

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 the 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% of 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 world for its use as a cement alternative material. The bagasse ash was found to enhance the properties 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 principle 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 different forms. 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.

1.4 NECESSITY OF THE PRESENT STUDY

Degradation of the environment takes place mainly due to the accumulation of industrial waste products becoming an environmental nuisance for the surrounding community and excessive use of natural resources, which are depleting gradually. There has been a growing trend in the utilization of industrial waste materials worldwide. Most of the research on SCBA has been targeted on its use as supplementary cementitious material. In a few research works sugarcane bagasse ash (untreated) has been targeted as fine aggregate in concrete and reported that they observe minimal pozzolanic activity in it. However, no significant effort has been made in the structural response of concrete made using bagasse ash and granite waste as fine aggregate in concrete. The combination of fine fillers such as SCBA and granite waste promotes better durability properties. The utilization of an industrial by-product has an important bearing on maintaining the ecological balance and economy of the country in general and construction industry in particular.

1.5 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 different cement content.
5. To evaluate the flexural behavior of reinforced BAGW concrete beams.
6. To validate the ultimate load-carrying capacity, the load-deflection behavior of experimentally tested beams using ANSYS software.

II. REVIEW OF LITERATURE

2.1 OVERVIEW

In this chapter, the benefits of using waste materials in concrete are presented. The previous studies on the properties and use of sugarcane bagasse ash and granite waste that were investigated for their incorporation in concrete, mixture design, and performance of beam elements were discussed.

2.2 INDUSTRIAL WASTE MATERIALS

Rapid industrialization has increased the production of solid waste materials. Disposal of these solid waste materials is a major environmental problem. The productive use of these solid waste materials is the best way to alleviate the problems associated with their disposal. It can be put in numerous uses depending on their physical and chemical properties. The construction industry has enormous potential for the use of waste materials as a construction material. Based on the properties of waste materials it can be either used as the supplementary cementitious materials or as aggregate replacement material in concrete or mortars.

In the published research work, waste materials such as Fly Ash (FA), Rice Husk Ash (RHA), Silica Fume (SF), Sewage Sludge Ash (SSA), Sugarcane Bagasse Ash (SCBA), Municipal Solid Waste Incineration (MSWI) fly ash, Titanium Fume (TF), glass residue and GROUNDED GRANULAR BLAST FURNAS SLAG (GGBFS) has been targeted for their use as a replacement of cement in concrete or mortar making. Waste material such as coal bottom ash, recycled aggregate, waste foundry sand, ceramic waste, plastic waste, marble dust, granite waste, crusher stone dust, copper slag, and demolished waste such as crushed bricks have been tried as aggregate replacement in concrete. A detailed review of the literature of industrial waste material as supplementary cementitious material and aggregate are discussed as follows.

Industrial Waste Materials as Supplementary Cementitious Material

Today several supplementary cementitious materials (SCMs) are widely used in concrete either in blended cement or added separately in the concrete mixes. In India use of fly ash started in the early ’90s in the manufacturing of cement. Metakaolin, ground granular blast furnace slag, and silica fumes have also been used as the replacement of cement in mortar and concrete.

Rice Husk Ash (RHA)

Saraswathy and Song, (2007) have investigated the mechanical properties and corrosion resistance properties of rice husk ash blended concrete. OPC was replaced by rice husk ash at 5%, 10%, 15%, 20%, 25% and 30% replacement levels. The results were compared with conventional Portland cement concrete. The mechanical properties and corrosion-resistant properties were investigated. They concluded that RHA up to 30% replacement level improves strength and corrosion resistance properties and reduces the chloride penetration, decreases permeability.

2.3 MIX DESIGN

Jones et al., (2002) discussed the basic concept of the four established models, particularly how each model defines the particle size distribution of the solid particles such as modified Toufar, Dewar, De Larrards Linear Packing Model (LPM) and Compressible Packing Model (CPM). The models have been applied to both the aggregate (sand and gravel) and the cement phase (PC, PFA, GGBS, and limestone fines) and the estimated voids ratio was compared with that measured in the laboratory. They found that the models give broadly the same output and suggest similar combinations of materials to give the minimum voids ratio. Using the materials considered, it was found that the largest improvement in the voids ratio was achieved with the aggregate phase. The particle sizes of the cement considered here were similar and, as a result, only small improvements in voids ratio is achieved. The results of this analysis suggest that individual suitability varies depending on the mean sizes of particles being considered and the ratio of mean size with the particles with which it is being combined. The comparison of the models was then extended to ternary combinations of three different particle groups, both for mono-sized steel balls and for concrete aggregates tested in the laboratory. Again discrepancies occurred in the suggested proportions of each of the particle groups, although the calculated voids contents were found to be similar. Proportioning concrete mix constituents to minimize voids ratio did tend to produce a harsher mix than normal to offset this mix suitability factor is proposed by Day, (1999), which reduced that coarse/ fine aggregate ratio.

III. 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 behavioral 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, and understand 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 waste.

3.3 STEPS TO STUDY THE SUITABILITY OF BAGASSE ASH AND GRANITE WASTE AS FINE AGGREGATE IN CONCRETE

3.3.1 Overview

To determine the suitability of the waste materials such as bagasse ash and granite waste as fine aggregate in concrete.

3.3.2 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

do = minimum particle size of distribution in µm q = 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 water demand 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 the exponent 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 between the larger size particles and the smaller size particles would fill up the gaps between the medium size particles and so forth.

3.3.3 Mix Proportion

Likewise, two fine waste matervial such as sugarcane bagasse ash and granite waste is 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 .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

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

3.4.1 Overview

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

3.4.2 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 size in graph and granite waste required was 9% of 100-1000µm (river sand) particle size in a graph.

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 .2 Mix Proportion of Conventional Concrete

Mix	Cement		River sand		Coarse aggrega		Water liters/m^3
	kg/m^3	m^3/m^3	kg/m^3	m^3/m^3	kg/m^3	m^3/m^3	
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 Mix Proportion of BAGW Concrete

Mix	Cement		Bagasse ash		River sand		Granite waste		Coarse aggregate		Water lt/m^3
	kg/m^3	m^3/m^3	kg/m^3	m^3/m^3	kg/m^3	m^3/m^3	kg/m^3	m^3/m^3	kg/m^3	m^3/m^3	
BAGW1	535	0.170	103	0.047	443	0.170	53	0.021	1120	0.4	192
BAGW2	485	0.154	93	0.042	492	0.189	57	0.023	1120	0.4	192
BAGW3	435	0.138	84	0.038	542	0.208	60	0.024	1120	0.4	192
BAGW4	400	0.127	77	0.035	574	0.220	63	0.025	1120	0.4	192
BAGW5	371	0.118	71	0.032	604	0.232	65	0.026	1120	0.4	192
BAGW6	340	0.108	65	0.030	634	0.243	67	0.027	1120	0.4	192

3.5 SUMMARY

The raw materials used for concrete making and substitute material such as SCBA and GW are characterized by using different test procedures provided in the Indian standard codes. The mixes are designed with particle packing concept using EMMA modeling software. The concrete mixes were proportioned using volumetric method. Six different mixes were arrived with varying water cement ratio for BAGW and conventional concrete. Workability, strength, and durability tests procedures are given. The reinforced concrete beam of grade M30 and M40 were designed to study the flexural behavior of BAGW and conventional concrete. Further the reinforced concrete beam has been analyzed using ANSYS software.

IV. RESULTS AND DISCUSSIONS

4.1 OVERVIEW

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

4.2 CHARACTERIZATION OF MATERIALS

4.2.1 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: 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

4.2.2 Properties of Sugarcane Bagasse Ash

Table .5: 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

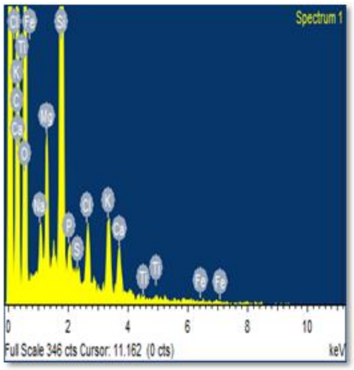

Fig. 1 EDS Spectra of Sugarcane Bagasse Ash

Fig. 2 SEM Image of Sugarcane Bagasse Ash

4.3 COMBINED SUGARCANE BAGASSE ASH AND GRANITE WASTE FINE AGGREGATE CONCRETE MIX DESIGN

4.3.1 Overview

The main objective of the concrete mix design is to find the optimum proportion of individual ingredients to satisfy the requirement concerning workability, strength, and durability. Here separate mix proportioning method is described, since the specific gravity of the sugarcane bagasse ash and granite waste are less when compared to the natural river sand. The relationship between water-cement ratio and slump using SP, the variation of compressive strength at 28days with cement-water ratio, the volume of cement content, the volume of cement-fine aggregate ratio, and the volume of cement-total aggregate ratio have been developed for BAGW concrete. By using this relationship, the following guidelines are proposed to arrive at trial mixes.

4.3.2 EMMA Modeling

EMMA, as modeling software, gives the required tools to evaluate the packing density of any material. EMMA is a very useful tool to visualize and adjust the particle size distribution of the entire mix by modifying the quantity of each ingredient until the whole mix gets the best fit with the perfect solid material model. Fig. 4.6 shows the user interface of Elkem Material Mix Analyzer (EMMA) where we can feed the materials which are used for proportioning in a material library and the new recipe is initiated shown in Fig. 4.7.

The M20 mixes have been prepared using IS 10262-2009. The proportions of each mix were entered into EMMA to produce visualized curves of the particle size distribution for the entire mix. However, an area of improvement in particle packing can be identified within the graph.

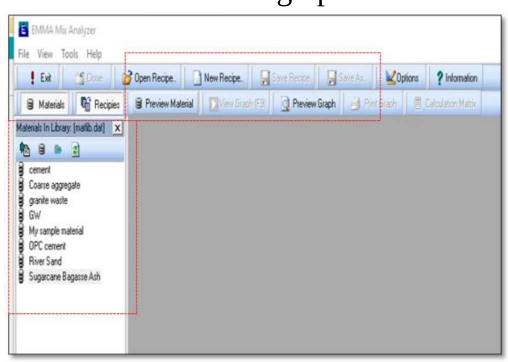

Fig.3: EMMA Mix Analyzer User Interface

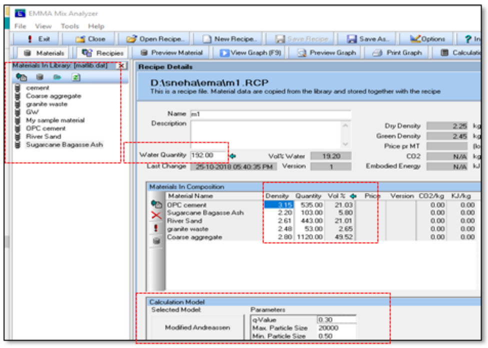

Fig.4: Mix Design Input in EMMA

The particle size distribution of the C1 mix is close to the modified Andreassen model as shown in Fig. 4.8, and the mix is well graded. 10-100µm area (cement) can be improved significantly by adding sugarcane bagasse ash and 100-1000µm area (fine aggregate) gap was improved using granite waste. Fig. 4.9 shows the particle size distribution of the BAGW 1 mix using EMMA.

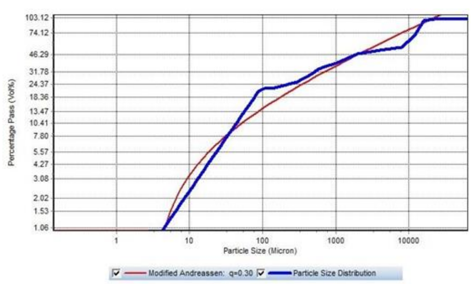

Fig. 5. PSD of Conventional Concrete C1 using EMMA

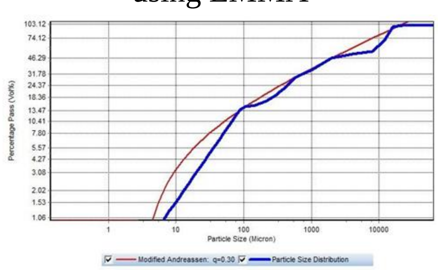

Fig. 6. PSD of BAGW 1 Concrete using EMMA

V. CONCLUSION

OVERVIEW

Many kinds of research have been carried out on the possible utilization of industrial waste in concrete making. One such attempt is made on this to examine the usage of sugarcane bagasse ash and granite waste as fine aggregate in concrete. The study was carried out to characterize the sugarcane bagasse ash and granite waste and to study the properties of BAGW concrete and the flexural behavior of reinforced BAGW concrete beams. The following conclusions are drawn based on experimental studies.

EFFECT OF COMBINED SUGARCANE BAGASSE ASH AND GRANITE WASTE AS FINE AGGREGATE ON THE STRENGTH CHARACTERISTICS OF CONCRETE

• The slump value of the concrete mixture was decreased when river sand is replaced with combined Bagasse ash and granite waste, because of the fine particle content in SCBA It shows that concrete is significantly stiff and hard to compact to improve the workability of BAGW concrete, superplasticizer should be used without increasing the water.

• The basic trend in the variation of the strength of BAGW concrete with the water cement-ratio is similar to that of the conventional concrete. So, SCBA and GW can be used as the fine aggregate in concrete making. The basic water-cement ratio law can be applied to BAGW concrete.

• The mechanical properties of BAGW concrete are comparable to those of conventional concrete.

• Because of the pozzolanic nature of SCBA, the early age strength is lower than that of the conventional concrete but later age strength of BAGW concrete is higher than that of the conventional concrete. So the rate of development of strength of

BAGW concrete is varying from the conventional concrete.

• The relationships has been proposed between cube compressive and split tensile strength and cube compressive and flexural strength of BAGW concrete.

• At 28days split tensile strength of BAGW concrete is 17 – 31% increase in strength than the conventional concrete. The tensile to compressive strength ratio was higher for BAGW concrete compared to the conventional concrete.

• The ratio of flexural strength (Modulus of rupture) to compressive strength is lower for BAGW concrete. The flexural strength of BAGW is 2.9-12.8% higher than the conventional concrete.

• The trend in stress-strain behavior of BAGW concrete at compression is similar to conventional concrete up to ultimate load. The modulus of elasticity of BAGW concrete is slightly higher than the conventional concrete.

• Bond strength steel rod and concrete in BAGW concrete is more than that of conventional concrete for all mixes.

EFFECT OF COMBINED SUGARCANE BAGASSE ASH AND GRANITE WASTE AS FINE AGGREGATE ON THE DURABILITY PERFORMANCE

- The saturated water absorption of BAGW mixes was lower when compared with that of the conventional concrete mixes.
- Transport mechanism in BAGW concrete due to permeation characteristics values decrease with a decrease in the water-cement ratio for both BAGW and conventional concrete. BAGW concrete shows better permeation characteristics.
- Incorporating sugarcane bagasse ash and granite waste into the concrete causes minimum interconnecting voids. The Volume of Permeable Voids ranges from 10% to 15% for all the concrete mixes and found to be ‘good’ as per ASTM C642 – 2006 durability classification.
- All the specimens of BAGW concrete immersed in HCl, H2SO4 acids and Na2SO4 and marine solution, there is a decrease in weight loss and compressive strength loss compared to the conventional concrete.
- From the durability studies, it is found that the concrete containing bagasse ash and granite waste are more durable than conventional concrete. It reveals that the hardened matrix of concrete mixes containing waste materials are denser and more impermeable when compared to that of conventional concrete

BEHAVIOR OF REINFORCED BAGASSE ASH AND GRANITE WASTE FINE AGGREGATE CONCRETE BEAM IN FLEXURE

- The flexural behavior of reinforced BAGW concrete beams has an increase in ultimate load over the conventional RC beam.
- The crack patterns observed for BAGW beams are found to be similar to the conventional concrete beams. At the early load stages, flexural cracks appeared in the central portion and gradually spread

towards supports. All the beams failed in flexural mode by yielding of reinforcement and crushing of concrete in the compression zone.

LIMITATION AND SUGGESTIONS FOR FUTURE WORK

• The BAGW as fine aggregate has decreased in the early age strength of concrete. As such further research to explore the possible ways to enhance the early age strength of BAGW concrete is needed.

• By varying the Particle Size Distribution of the Sugarcane Bagasse Ash and Granite Waste materials in concrete can be studied.

• The effect of creep and shrinkage of reinforced concrete with BAGW can be studied.

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