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

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Abstract
This experimental investigation explores the feasibility of utilizing sugarcane bagasse ash (SCBA) and granite waste (GW) as partial replacements for fine aggregate in concrete. The study aims to evaluate the mechanical properties, durability, and workability of concrete incorporating SCBA and GW. Concrete mixes were prepared with varying proportions of SCBA and GW, replacing 10%, 20%, and 30% of the fine aggregate. The experimental program included tests for compressive strength, tensile strength, and workability, as well as durability assessments through water absorption and permeability tests. Results indicated that SCBA and GW can be effectively used as partial substitutes for fine aggregate, with a notable enhancement in concrete's strength and durability at optimal replacement levels. The study provides a sustainable approach to utilizing industrial waste materials, potentially reducing the environmental impact and cost of concrete production.
Keywords: Sugarcane Bagasse Ash (SCBA), Granite Waste (GW), Fine Aggregate Replacement, Concrete, Mechanical Properties, Durability, Sustainable Materials.

INTRODUCTION

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 "gapgraded" 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.

It is believed that the use of necessary particle packing models, obtaining optimum proportions, such models are capable of predicting 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 computerbased 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 available which can be used to determine the void ratio resulting from different combinations of 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 the 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 satisfy technical 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 (20082009). 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 of 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.

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.

ENVIRONMENTAL ISSUES

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.

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. 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.

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.

EXPERIMENTAL INVESTIGATIONS

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

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.

Cement

Cement is one of the main ingredients to be used in the concrete. Different brands of cement have been found to possess different strength development characteristics and rheological 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

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).

a) Specific Gravity

The specific gravity of bagasse ash was determined using a density bottle. The weight of the empty bottle is taken as (W1). The bottle is filled with bagasse ash to its half around 20gm and weighed (W2). To this kerosene is added to the total of the bottle. The mixture is mixed thoroughly to remove the air bubbles. The density bottle with bagasse ash and kerosene is weighed (W3). The density bottle is emptied and re-filled with kerosene to its full and weighed (W4). The specific gravity of kerosene (Sg) is 0.79.

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).

a) Particle size distribution

The particle size distribution of river sand and granite waste is determined by taking 1000g of each sample, was mechanically sieved through a set of sieves starting from 4.75mm sieve at the top, 2.36mm, 1.18mm, 600µm, 300µm, 150µm, 75µm and pan at the bottom. The materials retained on each sieve were recorded. Fineness modulus of the sample was calculated as follows

b) Specific gravity and water absorption

The specific gravity of river sand and granite waste was determined using a pycnometer. A sample of 500g at a saturated surface dry condition was weighed (W1). The granite waste aggregate was placed in the pycnometer and filled with water. Trapped air was released by rotating the pycnometer on its sides. The pycnometer is topped with water and weighed (W2). The pycnometer was emptied and re-filled with water to the same level and then weighed (W3). River sand and Granite waste samples obtained after emptying the pycnometer were dried in an oven at 110ºC for 24 hours. Thereafter, the samples were cooled to room temperature and weighed (W4).

c) Bulk density

Bulk density of river sand and granite waste aggregate is conducted as per IS 2386 (part 3) -1963. A cylindrical metal measure of 3 liters capacity was taken and filled about one-third full by aggregate samples and tamped with 25 strokes. A further similar quantity is filled and tamped 25 strokes. Finally, be filled to overflowing,

tamped 25 times and surplus aggregate struck off and net weight of aggregate is measured and bulk density in the compacted state is calculated.

$$\text{Bulk density (Compacted)} = \frac{\text{Net weight of the granite waste aggregate (Compacted)}}{\text{Capacity of the cylindrical measure in litres}} \times 100$$

The cylindrical measure was filled to overflowing with granite waste aggregate and being discharged from a height not exceeding 5cm above the top of the measure. The surface of aggregate is leveled with a straightedge. The net weight of aggregate is measured and bulk density in the loose state is calculated

$$\text{Bulk density (Loose)} = \frac{\text{Net weight of the granite waste aggregate (Loose)}}{\text{Capacity of the cylindrical measure in litres}} \times 100$$

Coarse Aggregate

Crushed stone coarse aggregate was obtained from the local quarry. The maximum size of the coarse aggregate was 20mm. fineness modulus, specific gravity and water absorption of coarse aggregate were determined as per IS 2386 (Part III) – 1963. About 3kg of coarse aggregate was submerged in water for 24hours. Thereafter the samples were allowed to dry at room temperature until no free surface moisture was seen. The SSD aggregate sample was weighed (W1). Coarse aggregate was placed in a basket filled with water and weighed (W2). It was removed from the basket and dried in an oven at 110ºC for 24hours and then weighed (W3). Specific gravity and water absorption were calculated as follows.

Water

Water reacts with cement and forms the binder, which binds the aggregate together. Also, it is accountable for the process to form the hydration product, calcium-silicate- hydrate (C-S-H) gel. Water conforming to the requirements of IS: 456-2000 is found to be suitable for making concrete. For the present investigation, the Laboratory tap water was used for making concrete.

Table 1: 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 2: 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

Table 3: 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**

Test Procedure on Fresh Concrete

The proportioning of ingredients of concrete is governed by the required performance of 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 surface is 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 concrete is measured in millimeters. This difference in height in "mm" is referred to as the slump of concrete shown in Fig. 3.1.

Fig. 3.1 Slump of the Concrete

Test Procedures on Hardened Concrete Properties

Overview

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

i) Compressive strength test
ii) Split tensile test
iii) Flexural strength test
iv) Modulus of Elasticity test
v) Bond strength test

The methodology adopted to conduct the above experiments is explained in the following section.

Compressive strength test

The test was carried out as per IS 516- 1959 to determine the compressive strength of the concrete at the age of 7 and 28 days on 100 x 100 x 100mm size concrete cube specimen. The testing was done on a compression testing machine with a maximum capacity of 2000kN. The load was applied at a constant rate of 140kg/cm^2 per minute until the specimen fails. The compressive strength had been calculated using the following expression and the test setup is shown in Fig. 3.2

Fig. 3.2 Test setup for Compression Test on cubes

Splitting tensile strength test

The test was carried out as per IS 5816-1999 to determine the tensile strength of the concrete at 7 and 28 days on 150mm diameter and 300mm height cylinder. The concrete cylinders were placed longitudinally between the plates and subjected to the load constantly at the rate of 1.4MPa/min until the cylinders split into two halves. The tensile strength had been calculated using the following expression and the test setup is shown in Fig. 3.3

Fig. 3.3 Test setup for Split Tensile strength

Flexural strength test

The test was carried out as per IS 516-1959 to determine the flexural strength of the concrete at 28 days on 100 x 100 x 500mm prisms. The test was done on a CTM machine of maximum capacity 1000kN. The two-point load was applied at the rate of 1.8kN/min. the appearance of the fractured face of concrete failure was noted. The flexural strength had been calculated using the following expression and the test setup is shown in Fig. 3.4.

Fig. 3.4 Test setup for Flexural Strength

Modulus of elasticity test

The test was carried out as per IS 516-1959 to determine the modulus of elasticity of concrete at 28 days on 150mm diameter and 300mm height cylinders in the compression testing machine with the capacity of 2000kN. The specimen was subjected to uniaxial compression and by measuring deformation by means of a dial gauge fixed between the gauge length of 200mm. Applying the load gradually at the rate of 14MPa/min the corresponding deformation was recorded. The modulus of elasticity derived from a true elastic response is the initial tangent modulus, which is the slope of the tangent to the curve at the origin. The test setup is shown in Fig. 3.5.

Fig. 3.5 Test setup for Modulus of Elasticity

Pull out test

The test was carried out as per IS 2770 (part 1) 1967 to determine the bond strength of the concrete at 28days on 100 x 100 x 100mm cube specimen embedded with a 12mm diameter rod projected for a length of 10mm at the bottom of the cube. The bar embedded in concrete is pulled until failure occurs by splitting, excessive slip or pullout. The cube was reinforced with a helical spring of 6mm diameter with 25mm pitch the outer diameter of the spring is equal to the cube shown in Fig. 3.6. To confirm the concrete confinement the test was carried out in a UTM of capacity 1000kN and load applied gradually at the rate of 22.5kN/min. The specimens were placed vertically on a platen and reacted against a 25mm thick steel bearing plate by applying a tensile load to the reinforcing bar. The slip of the reinforcement was measured relative to concrete using 2 linear variable displacement transducers. The bond strength was calculated from the load at which the slip was about 0.25mm. The failure of test specimen is shown in Fig. 3.7.

Fig. 3.6 Casting of Pullout Cube Specimen

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

CHARACTERIZATION OF MATERIALS

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

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 and Table 4.3 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 The mass loss and the strength loss of BAGW concrete immersed in hydrochloric acid ranges from 2.1 to 4.3% and 5.1 to 8.2% respectively. The mass loss and the strength loss of conventional concrete immersed in hydrochloric acid ranges from 2.97 to 4.79% and 6.8 to 9.6% respectively.

The mass loss and the strength loss of BAGW concrete immersed in sulphuric acid ranges from 5.1 to 5.8% and 6.8 to 11.6% respectively. The mass loss and the strength loss of conventional concrete immersed in sulphuric acid ranges from 5.4 to 5.8% and 8.6 to 22.1% respectively.

Sulphate Resistance

Permeability of concrete plays an important role in protecting it against external sulphate attack. Sulphate attack can take the form of expansion, loss in compressive strength, and loss in weight of concrete. It may be due to the formation of ettringites and gypsum. Up to 56days of immersion in sulphate solution, no cracks and spalling were observed in BAGW concrete. The percentage loss in strength and percentage loss in mass of the bagasse ash and granite waste (BAGW) fine aggregate concrete is less compared to the conventional concrete shown in Fig. 4.40 and 4.41. The mass loss for BAGW concrete and conventional concrete ranges from 0.5 to 0.8% and 0.7 to 0.9%. The strength loss for BAGW and conventional concrete ranges from 0.9 to 1.45% and 0.95 to 1.9%.

Crack Patterns and Failure Mode

The flexure cracks got initiated in the pure bending zone. As the load increased, the existing cracks propagated and new cracks developed along the span. The width and the spacing of cracks varied along the span. In all, the crack patterns observed for reinforced BAGW concrete are similar to those reported in the conventional reinforced beam. Near peak load, the beams deflected significantly, thus indicating that the tensile steel must have yielded at failure. The final failure of the beam occurred when the concrete in the compression zone was crushed, accompanied by buckling of the compressive steel bars. The failure mode was typical of that of an under reinforced concrete beam. During the test, the crack width in the beams is measured using a crack detector microscope shown in Fig. 4.50 and the crack patterns are closely analyzed.

Fig. 4.50 Measuring Crack Width using a Crack Detector Microscope

The maximum crack width occurs at the point of the ultimate load. The width of crack gradually increased at the tension zone, the cracks are perpendicular to the beam axis. The crack in the bending zone (application of loading place is mostly vertical cracks and the shear zone is inclined cracks. The crack width for tested reinforced BAGW 30, BAGW 40, C 30, C 40 are 1.36mm, 1.22mm, 1.16mm, 1.14mm respectively. It exhibits that reinforced conventional concrete carries a higher load with lesser crack widths. The crack patterns at the collapse of all the reinforced beams are shown in Figs. 4.51 – 4.54 respectively. The crack width and spacing of cracks are given in Table 4.14.

Ductility characteristics

Ductility is the property that allows the structure to undergo large deformation without losing its strength. Ductility is quantified by the ductility factor. The experimental results exhibit that the effect of adding Sugarcane bagasse ash and granite waste as filler in concrete influences the behavior of beams with an increase in the ductility characteristics when compared to the conventional beam. The deflection ductility index gives an estimation of the lack of ductility of these beams. It was also observed that BAGW concrete beams showed slightly higher deflection ductility as compared to the conventional RC beam. The maximum deflection prior to the final failure of the beam and it indicates that the BAGW concrete was more ductile compared to conventional concrete. The lower value of the

The deflection ductility was calculated using the following formulaDeflection ductility, $\mu\rho = \Delta u / \Delta y$

Table 4.15 Ductility and Stiffness Value for all the Tested Beams

Beam ID	Deflection Ductility	Stiffness (kN/mm)
C 30	1.468	3.12
BAGW 30	1.201	3.17
C 40	1.333	3.74
BAGW 40	1.258	2.94

If the desired ductility is not available, premature failure is likely (due to crushing of the concrete in the compression zone at the plastic hinge forming region) at a load that is less than the ultimate load. By enhancing ductility the induced seismic forces can be reduced, and a more economical structure obtained, or the probability of collapse reduced.

Stiffness Characteristics

The stiffness is the ratio between the load and deflection of a concrete member, which indicated the flexible property and inelastic action, which has occurred during constant loading. Fig. 4.50 shows the variation in stiffness of the reinforced C30 and BAGW 30 concrete beams ductility index for the beams indicates the lacking of ductility of such beams.

SUMMARY

The FEA is compared with the experimental results and it is found that a good correlation is obtained between the experimental results and the results obtained from ANSYS. The percentage of difference in ultimate deflection between experimental and analytical results is within 10%. The FEA predicted the load-deflection response and load-carrying capacity similar to the experimental results.

CONCLUSION

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.

- 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.

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