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Experimental Investigation on the use of Sugarcane Bagasse Ash Granite Waste as Fine Aggregate in Concrete

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Abstract: 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.
Keywords: Compressive strength, splitting tensile strength, modulus of rupture, bond strength, Sugarcane bagasse ash, granite waste.

I. 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 "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.

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.

II. LITERATURE SURVEY

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.

High compressive strength is generally the first property associated with concrete made with SF content. Many reports are available (Tiwari and Momin 2000, Sellevold and Radjy 1983) showing that the inclusion of SF to a concrete mix will increase the strength of that mix by 30% to 100% depending on the type of mix, type of cement, replacement level of SF, nature, and dosage of superplasticizers, aggregate types and curing regimes.

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 at 28 days with a minimum cement content of 330 kg/m3, 10% silica fume by weight of cement, 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 necessity in 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.

III. MATERIALS USED

A. 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.

B. 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).

C. 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).

Table 1. Physical Properties of SCBA, GW and River Sand

Property	Sugarcane Bagasse Ash	Granite Waste	River Sand
Specific gravity	2.2	2.48	2.6
Water absorptionby mass (%)	0.9	1.75	1.1
Fineness modulus	-	2.8	2.5
Bulk density kg/m^3 (Loose)	386	1368	1547
Bulk density kg/m^3 (Compacted)	555	1560	1760

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D. 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.

E. 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.

F. Chemical Admixture

Superplasticizers (SP) are water reducer, which is capable of reducing water up to 30% was added to improve the workability of fresh concrete. Due to the inclusion of finer industrial by-products in concrete, there is a higher water demand to ensure the required workability. The superplasticizer also produces a homogeneous, cohesive concrete generally without any tendency for segregation and bleeding. In this investigation, chemical admixture based on sulfonated naphthalene formaldehyde condensate CONPLAST SP 430, conforming to IS: 9103-1999 and ASTM C494 was used. High-performance superplasticizer which is light brown, free-flowing liquid with a relative density of 1.18 was used in this investigation.

IV. MIX DESIGNATIONS

Table 2. Mix Proportion of Conventional Concrete

Mix	Cement		River sand		Coarse aggregate		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

V. RESULTS & DISCUSSIONS

A. *Slump Test*

The workability at the fresh state of the plain concrete and BAGW is determined through measuring the slump of the concrete. The concrete slump value for various mix proportions is shown in Table 4. The slump value for all the mixes is in the range of 10mm to 30mm before adding superplasticizer. The fluidity of concrete is reduced considerably subsequent to the addition of sugarcane bagasse ash. The higher the slump value indicates higher the concrete workability. The relationship between the slump and water-cement ratio shown in Fig. 1.

Table 4. Slump Value for BAGW Mix

Mix ID	Super Plasticizer (kg/m^3)	Slump value in mm	
		Before Adding SP	After Adding SP
BAGW 1	6.42	10	55
BAGW 2	5.82	13	56
BAGW 3	5.22	19	58
BAGW 4	4.80	25	62
BAGW 5	4.45	30	66
BAGW6	4.08	35	72

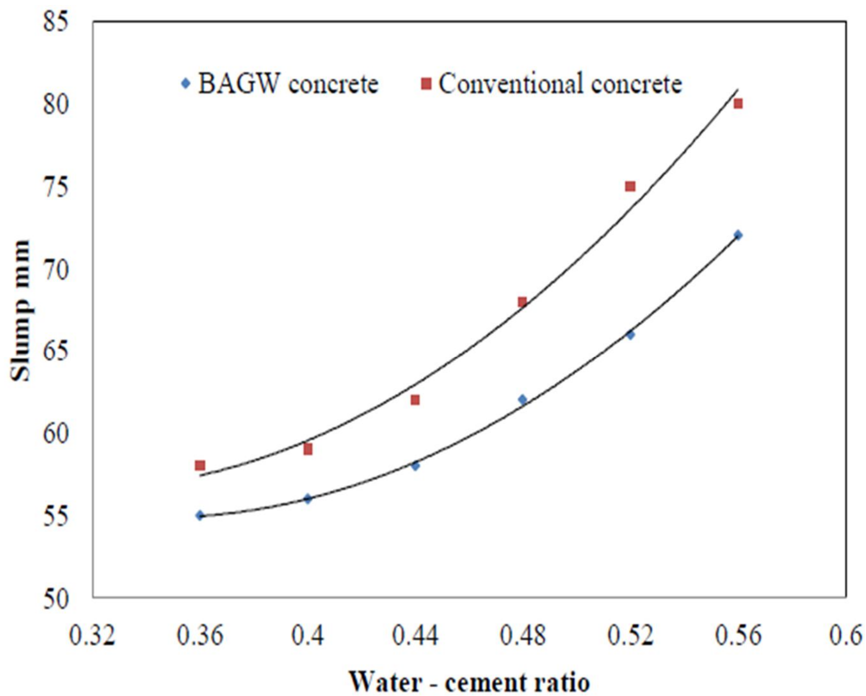

Figure 1. Relationship between Slump and Water–Cement Ratio

- *Discussions:* From the visual inspection and slump test results, it is revealed that adding bagasse ash to the concrete decreases the workability of the fresh mix, which is substantially enhanced by adding superplasticizer. A superplasticizer dosage of 12 ml per kg of cement was chosen based on the trial mixes. The slump values of all mixes are in the range of 50 to 75mm, after adding superplasticizer, which satisfies the workability requirements as per IS 456 – 2000. In the fresh concrete level, yield number of cubes planned to cast and number of cubes actually cast is also verified. The slump value of conventional concrete mixes C1,C2,C3,C4,C5 and C6 are 58, 59, 62, 68, 75 and 80mm respectively.

B. Compressive Strength Test

The compressive strength test is the most common test conducted because most of the desirable characteristic properties of concrete are qualitatively related to compressive strength. The cube compressive strength of conventional and BAGW concrete for six various cement content was determined. The compressive strength of the BAGW concrete varied from 11 to 21MPa at 7 days, 29 to 49MPa at 28 days. The concrete made with bagasse ash and granite waste as fine aggregate shows low early strength of 20 – 28% at 7 days compared to the conventional concrete. The relative elevation in the strength of 5-22% at 28 days curing compared to conventional concrete. It was observed that strength increases throughout all the mixes at later ages when compared to the conventional concrete. This confirms the filling potential of the SCBA and GW to make a thickly packed concrete matrix. This observation was constant with the findings of other research studies.

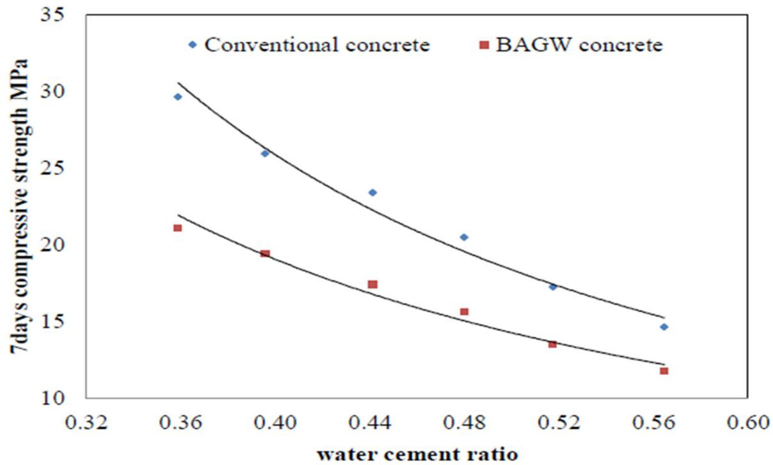

Figure 2. Relationship between Water-Cement Ratio and 7 days Compressive Strength

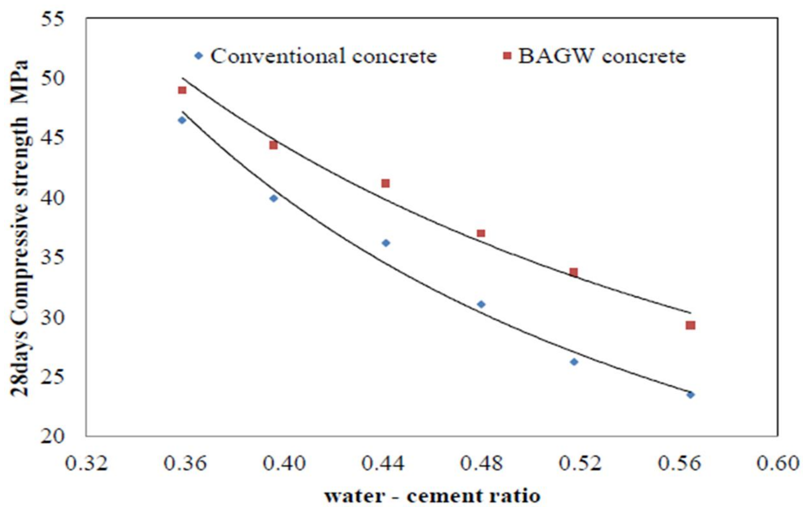

Figure 3. Relationship between Water-Cement Ratio and 28days Compressive Strength

- *Discussions:* It can be seen in Figs. 2 and 3, that the strength development is similar for both the conventional concrete and BAGW concrete. It is evident from the test results that with increasing curing age, the improvement in compressive strength of BAGW concrete mixture is continuous and significant. This may be due to presence of reactive silica content in the sugarcane bagasse ash which reacts with the alkali calcium hydroxide produced by hydration of cement and forms calcium silicate and aluminates hydrates. The chemical reaction between cement paste constituents and aggregates result in filling the voids in the interfacial transition zone and played its role in improving its compressive strength.

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C. Split Tensile Test

This is an indirect test to determine the tensile strength of cylindrical specimens. The addition of bagasse ash and granite waste in concrete as fine aggregate enhances the split tensile strength of concrete compared to the conventional concrete. The relation between the compressive strength and the split tensile strength can be obtained. A regression analysis was then performed, and the following expressions are proposed in terms of compressive strength. Fig. 4 represents the relation between the 28 days split tensile strength with the water-cement ratio of the concrete.

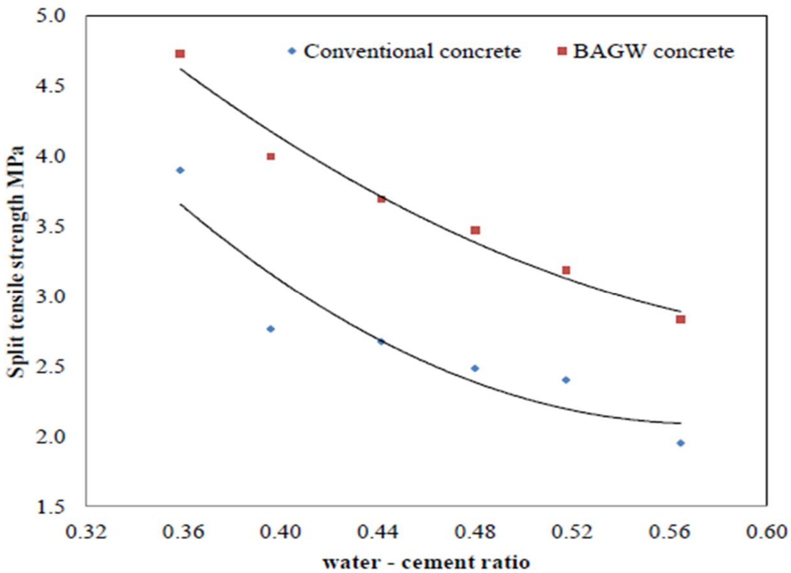

Figure 4. Relationship between the Water-Cement Ratio and Split Tensile Strength

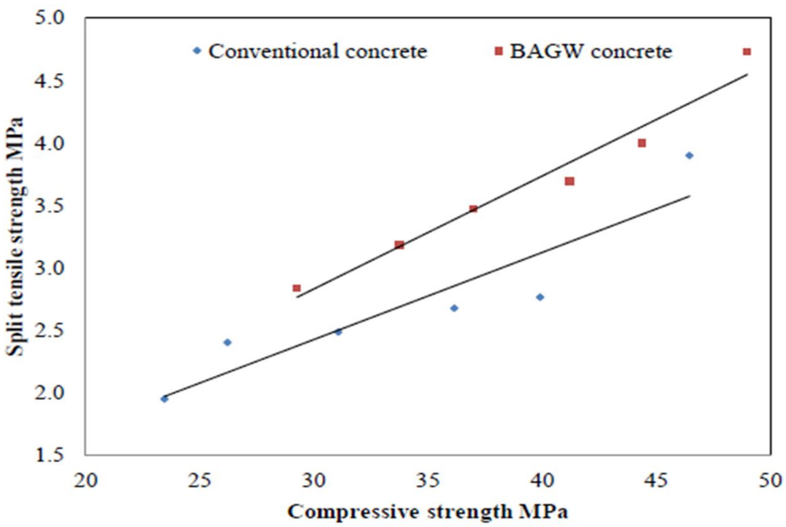

Figure 5. Relationship between Compressive Strength and Split Tensile Strength

- *Discussions:* The split-cylinder tensile strength of concrete varied from 4.73 to 2.83MPa. The splitting tensile strength of BAGW concrete is proportionately higher than the conventional concrete. Fig. 5 shows the variation of the split tensile strength of BAGW concrete and conventional concrete with compressive strength. The ratio of tensile to the compressive strength of concrete is roughly 8 to 9 percent which indicates the moderate strength concrete (Kumar Mehta 1986). For normal concrete, this ratio ranges from 8 to 14% (Mindess et al. 2003). The ratio of tensile strength to the compressive strength of BAGW concrete ranges from 9 to 10% is well within the range. The 28 days tensile strength of BAGW concrete is 17 to 31% higher than the conventional concrete.

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D. Flexural Strength Test

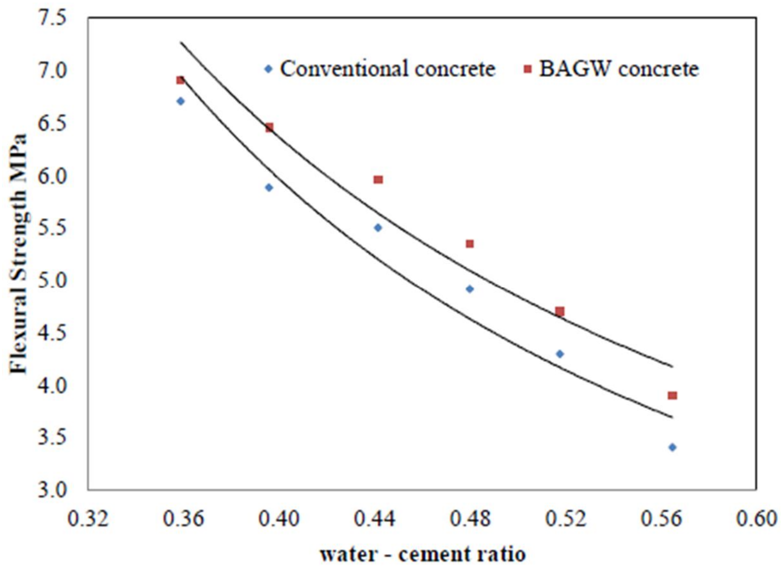

Figure 6. Relationship between the Water-Cement Ratio and 28 days Flexural Strength

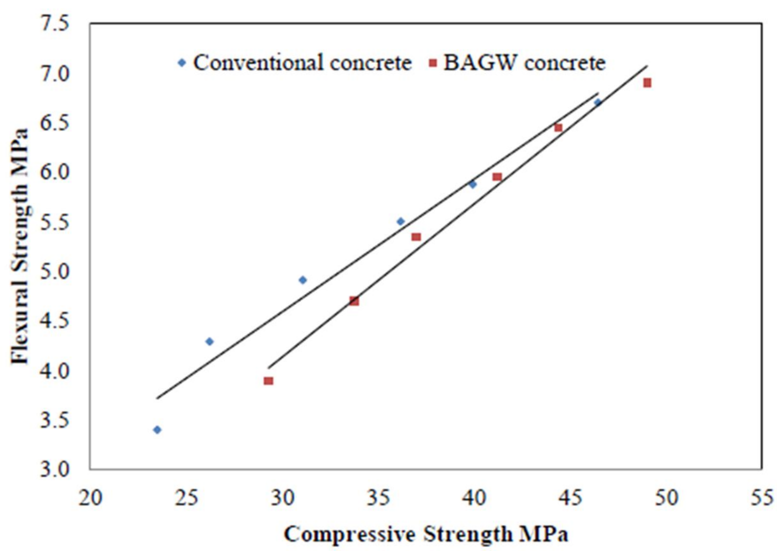

Figure 7. Relationship between 28 days Compressive Strength and Flexural Strength of Concrete

- *Discussions:* Flexural strength is defined as a material's ability to resist deformation under load. The determination of flexural strength is essential to estimate the load at which the concrete members may crack. The flexural strength (Modulus of rupture) was moderately increased when the river sand was replaced by bagasse ash and granite waste. The flexural strength of BAGW concrete varied from 6.9 to 3.9 MPa whereas the conventional concrete is 6.7 to 3.4 MPa. The ratio of flexural strength to the compressive strength of conventional concrete ranges from 11 to 23%, for BAGW concrete this value ranges from 13 to 14%. The Flexural strength of BAGW concrete is 2.9 to 12.8% higher than conventional concrete. The relation between the water-cement ratio and flexural strength of concrete for BAGW concrete and conventional concrete are shown in Fig. 6. The basic trend in the relationships of flexural strength with water-cement ratio and compressive strength is similar to the conventional concrete. The flexural strength of BAGW concrete is 3 to 4.7 % higher than the conventional concrete. As shown in Fig. 7, the relation between the flexural strength and compressive strength of concrete is given below which is slightly higher compared to the relation given in IS 456-2000.

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E. Modulus of Elasticity

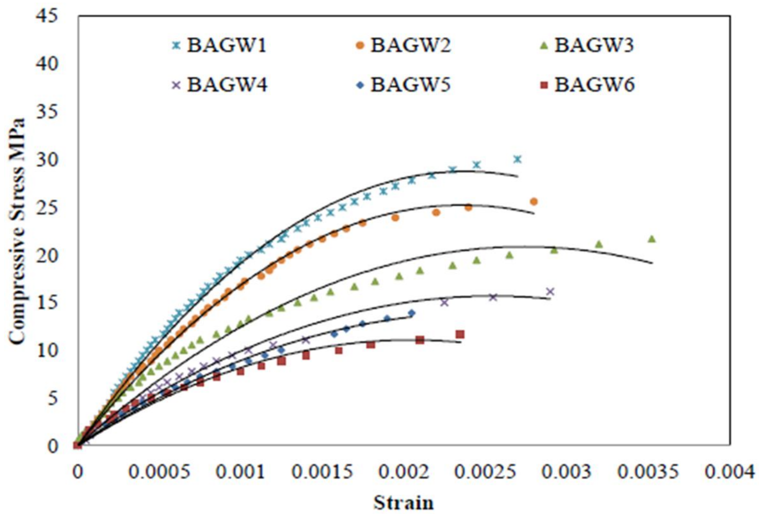

Figure 8. Relationship between Compressive Stress and Strain for BAGW Concrete

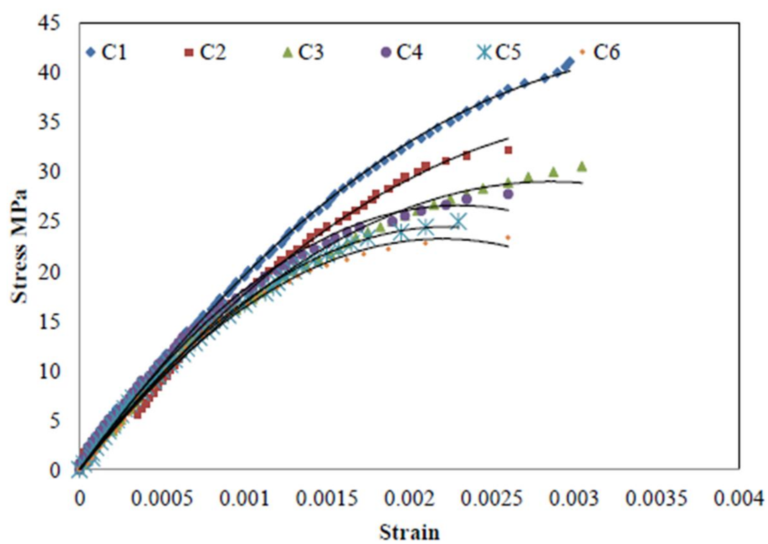

Figure 9. Relationship between Compressive Stress and Strain for Conventional Concrete

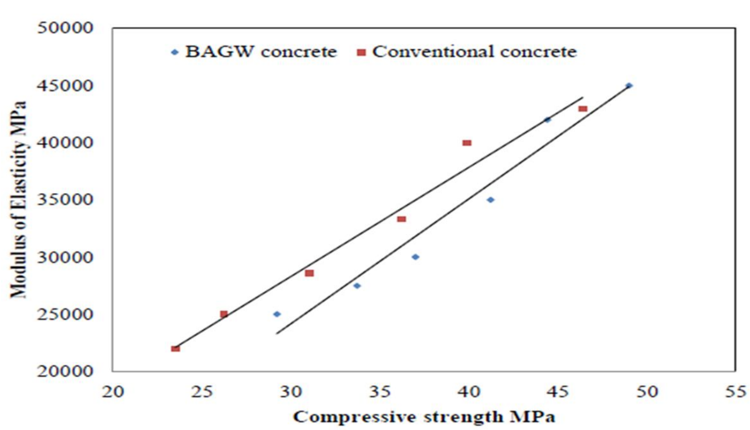

Figure 10. Relationship between Modulus of Elasticity and 28 days Compressive Strength

- *Discussions:* Modulus of elasticity in direct compression of concrete was calculated with initial tangent modulus from the stress-strain curve of BAGW and conventional concretes. Fig. 8 and 9 shows the compressive stress-strain behavior of the BAGW and conventional concretes respectively. The modulus of elasticity of BAGW concrete ranged from 45-25GPa and for conventional concrete is 43-22GPa. The value of BAGW concrete is 5-13.6% higher than the conventional concrete. The stress-strain behavior of Bagasse ash and granite waste as fine aggregate concrete is slightly higher than the conventional concrete. The expression for determining the modulus of elasticity for BAGW concrete using 28 days compressive strength is presented. For determining the modulus of elasticity depending on the compressive strength at 28 days obtained from the test results are given below. From the experimental results, it is revealed that the modulus of elasticity affects the concrete compressive strength as shown in Fig. 10. The modulus of elasticity increases when the compressive strength is increased.

VI. CONCLUSIONS

1) 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.
2) 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.
3) The mechanical properties of BAGW concrete are comparable to those of conventional concrete.
4) 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.
5) The relationships has been proposed between cube compressive and split tensile strength and cube compressive and flexural strength of BAGW concrete.
6) 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.
7) 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.
8) 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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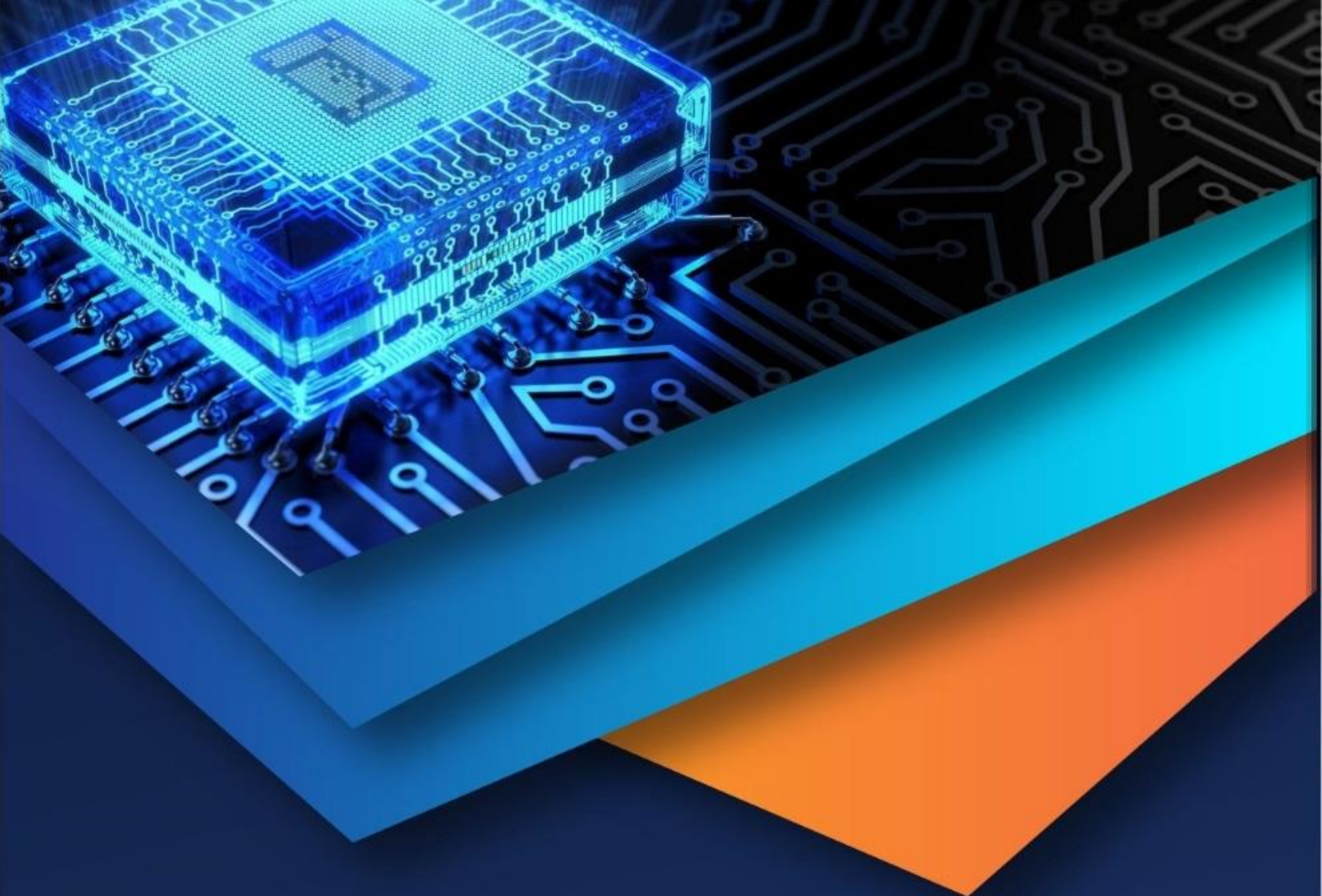

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