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Experimental Investigation on the Use of Sugar Cane Bagasse Ash and Granite Waste as Fine Aggregate in Concrete

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ABSTRACT:
Due to the huge demand for the construction materials industry, particularly in the last era, because of this an increase in population leads to prolonged less availability of building materials, Civil engineers have been faced problems to transformation of industrial waste into beneficial building structure ingredients. Sugarcane bagasse is a fibrous waste product of sugar refining industry. This product causes severe environmental pollution, which calls for urgent ways of handling the waste. Bagasse ash mainly contains aluminum ion silica, iron &calcium oxides. The ash therefore becomes an industrial waste and poses disposal problems. So few studies have been reported that sugarcane bagasse ash as good pozzolanic material in partial replacement of cement.
This waste product (Sugar-cane Bagasse ash) is already causing serious environmental pollution, which calls for urgent ways of handling the waste. Bagasse ash mainly contains aluminium ion and silica. 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. Bagasse ash has been chemically and physically characterized, and partially replaced in the various percentages by weight of cement in concrete. Fresh concrete tests as well as hardened concrete tests were undertaken. The result shows that the strength of concrete increased as percentage of bagasse ash replacement increased up to certain percentage. Beyond that optimum level the strength of concrete begins to decrease drastically.

KEYWORDS: Sugarcane bagasse ash; fine replacement material; improved strength, compressive strength, Amorphous silica.

I. LITERATURE REVIEW

Dr. B. G. Nareshkumarinvestigated experimentally the fresh and hardened properties of lightweight concrete using sugarcane bagasse ash(SCBA) as replacement for cement by weight at 0%, 5%, 10%, 15% and 20% and expandedpolystyrene (EPS) beads as 100% replacement for coarse aggregate respectively. From the result it was found that there is marginal increase in workability with bagasse ash content up to 10% beyond that there is possibility of reduction in slump value. The compressive strength of lightweight concrete increases with bagasse content up to 15% and beyond this ,there is possibility of drastic reduction in strength and this 15% bagasse ash replacement strength is slightly less than OPC based lightweight concrete at 28 days but this value is comparable. He also added, If the bagasse is burnt again at controlled temp fineness of cement is increased hence it will improve the fresh and hardened properties of concrete.

Mr. H.S. Otuoze et al. had investigated on characterization of Sugar Cane Bagasse Ash (SCBA) and Ordinary Portland Cement (OPC) blends in concrete. The SCBA was obtained by burning Sugar Cane Bagasse (SCB) between 600-700 degrees Celsius. The sum of percentages of SiO2, Al2O3 and Fe2O3 is 74.44%.For strength test , mix ratio of 1:2:4 was used and OPC was partially replaced with 0% ,5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% by weight in concrete. Compressive strength values of hardened concrete were obtained at the ages of 7, 14, 21 and 28 days.

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Based on the tests conducted, it can be concluded that SCBA is a good pozzolanic material for concrete cementation and partial blends of it with OPC could give good strength development and other engineering properties in concrete. An optimum of 10% SCBA blends with OPC could be used for reinforced concrete with dense aggregate. Higher blends of 15% and up to 35% of SCBA with OPC are not acceptable. The values fell short of meeting requirements.

R.Srinivasan and K.Sathiyadone an experimental study on bagasse ash in concrete to analyze the performance of bagasse ash as a replacement of cement in concrete works. In his experimental work, a total of 180 numbers of concrete specimens were casted. The specimens considered in this study consisted of 36 numbers of 150mm side cubes, 108 numbers of 150mm diameter and 300mm long cylinders, and 36 numbers of 750mm x 150mm x 150mm size prisms. The mix design of concrete was done according to Indian Standard (IS) guidelines M 20 grade for the granite stone aggregates and the water cement ratio are 0.48.The results show that the SCBA in blended concrete had significantly higher compressive strength, tensile strength, and flexural strength compare to that of the concrete without SCBA. It is found that the cement could be advantageously replaced with SCBA up to maximum limit of 10%. Although, the optimal level of SCBA content was achieved with 1.0% replacement. Partial replacement of cement by SCBA increases workability of fresh concrete; therefore use of super plasticizer is not substantial. The density of concrete decreases with increase in SCBA content, low weight concrete produced in the society with waste materials (SCBA).

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 behaviour of reinforced BAGW concrete beams.

II. 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 three stages, they are

(a) Characterization of material
(b) Strength studies
(c) Durability studies

a) Mix Proportion

Table 2.1: Mix Proportion for Suitability Study

Materials kg/m^3	**Trial mix 1**	**Trial mix 2**
Cement	425	435
Sugar Cane Baggasse ash	100	86
River Sand	582	566
Granite waste	50	65
Coarse Aggregate	1095	1120
Water	192	192

b) 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 de-moulded after 24 hours and cured under water at 27º ± 2º C.

Table 2.2:

Mix	Cement	River Sand	Coarse Aggregate	Water
	kg/m3	kg/m3	kg/m3	Lit /m3
C1	535	620	1120	192
C2	485	662	1120	192
C3	435	703	1120	192
C4	400	733	1120	192
C5	371	756	1120	192
C6	340	782	1120	192

c) Making Of Sugarcane Bagasse Ash-Granite Waste (Bagw) Concrete And Mix Design

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 blends of materials available and compare this optimum density with an ideal graph. The input required for this are 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. 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 litres 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.

Table 2.3:

Mix	Cement	Baggase Ash	River Sand	Granite Waste	Coarse Agg	Water
	kg/m3	kg/m3	kg/m3	kg/m3	kg/m3	Lit /m3
BAGW1	535	103	443	53	1120	192
BAGW2	485	93	492	57	1120	192
BAGW3	435	84	542	60	1120	192
BAGW4	400	77	574	63	1120	192
BAGW5	371	71	604	65	1120	192
BAGW6	340	65	634	67	1120	192

III. 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

a) Characterization Of Materials

The physical properties of bagasse ash and granite waste appear to have a greater influence on the performance of fresh concrete like workability, bleeding, segregation and setting time, etc. The specific gravity of the bagasse ash and granite waste is low when compared to the river sand fine aggregate. The particle size distribution of the granite waste is finer than the river sand, they were able to fill the voids between sand particles, similar to the way sand particles fill the voids between the coarse aggregate. From the chemical composition of the bagasse ash and granite waste, the major part of the composition was dominated by SiO_2.

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b) Properties of Cement

Table 3.1: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%	225 m2/kg
Specific gravity	3.15	-
Compressive strength at 28 days	54.6 MPa	27MPa 3days 37MPa 7days

c) 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.

Table 3.2:

Property	**Sugar cane Bagasse Ash**	**Granite Waste**	**River Sand**
Specific gravity	2.2	2.48	2.6
Water absorption by mass (%)	0.9	1.75	1.1
Fineness modulus	-	2.8	2.5
Bulk density kg/m3 (Loose)	386	1368	1547
Bulk density kg/m3 (Compacted)	555	1560	1760

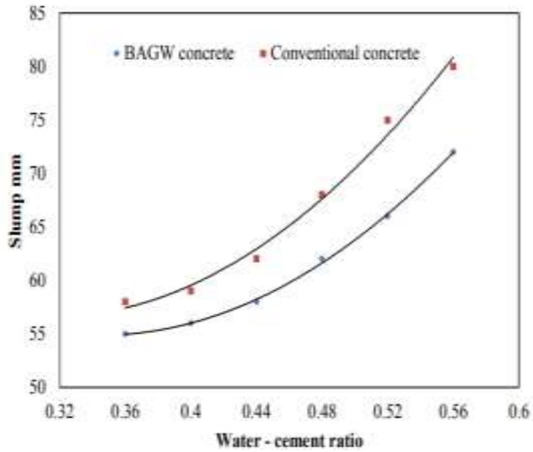
In this study, six BAGW concrete mixes, the volume of matrix and the volume of coarse aggregate were the same, but in the matrix, the volume of cement and volume of river sand was varying for different water-cement ratios.

d) Fresh Concrete Property

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. The slump value for all the mixes is in the range of 10mm to 30mm before adding super plasticizer. 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.

Table 3.3:

Mix ID	Super Plasticizer (kg/m³)	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



Graph: 3.1: Relationship between Slump and Water–Cement Ratio

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 super plasticizer. A super plasticizer 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.

IV. HARDENED CONCRETE PROPERTIES

Mechanical Properties

The strength test results of Bagasse ash and granite waste as fine aggregate replacement in concrete and conventional concrete are given in Tables 4.2 and 4.3 respectively. The results presented are average of three specimens. From the table, it indicates the use of SCBA and GW tends to enhance the strength properties of the concrete.

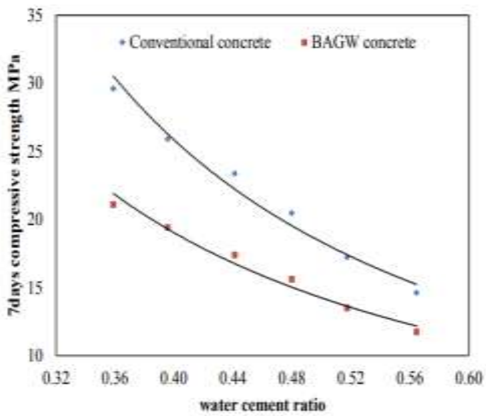
a) Compressive strength

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.

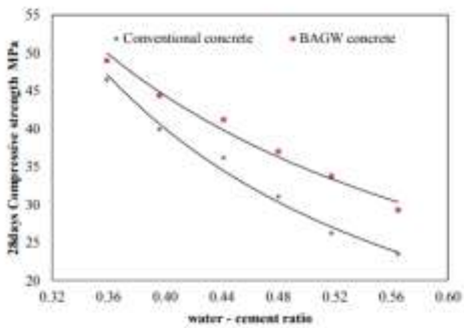
International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 2505-2514 www.ijaem.net ISSN: 2395-5252

Table 4.1:

BAGW-1	21.1	49.0	4.73	6.90	45
BAGW-2	19.4	44.4	4.00	6.45	42
BAGW-3	17.4	41.2	3.69	5.95	35
BAGW-4	15.6	37.0	3.47	5.35	30
BAGW-5	13.5	33.7	3.18	4.70	27.5
BAGW-6	11.7	29.2	2.83	3.90	25



Graph: 4.1: Relationship between Water-Cement Ratio and 7 days Compressive Strength



Graph: 4.2: Relationship between Water-Cement Ratio and 28days Compressive Strength

It can be seen in Graph 4.1 and 4.2, 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. Fig. 4.20 shows the average compressive strength of BAGW concrete and conventional concrete for each mix.

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Table 4.2:Mechanical Properties of BAGW Concrete

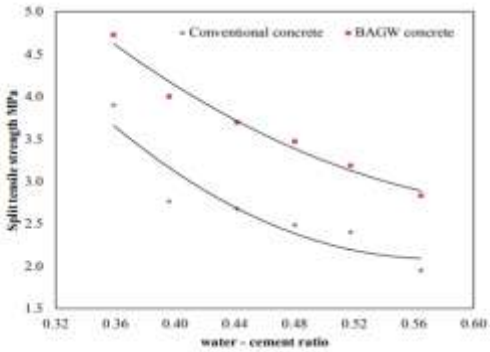
Mix	Average Compressive Strength (MPa)		Average Split Tensile Strength (MPa)	Average Flexural Strength (MPa)	Average Modulus of Elasticity (GPa)
	7 days	28days	28days	28days	28days
C 1	29.60	46.4	3.90	6.70	43
C 2	25.90	39.9	2.76	5.88	40
C 3	23.36	36.2	2.68	5.50	33.3
C 4	20.46	31.0	2.48	4.91	28.6
C 5	17.23	26.2	2.40	4.29	25
C 6	14.60	23.5	1.95	3.40	22

Table 4.3:Mechanical Properties of Conventional Concrete

Mix	Average Compressive Strength (MPa)		Average Split Tensile Strength (MPa)	Average Flexural Strength (MPa)	Average Modulus of Elasticity (GPa)
	7 days	28days	28days	28days	28days
BAGW 1	21.1	49.0	4.73	6.90	45
BAGW 2	19.4	44.4	4.00	6.45	42
BAGW 3	17.4	41.2	3.69	5.95	35
BAGW 4	15.6	37.0	3.47	5.35	30
BAGW 5	13.5	33.7	3.18	4.70	27.5
BAGW 6	11.7	29.2	2.83	3.90	25

b) Split tensile strength

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. Graph 4.3 represents the relation between the 28 days split tensile strength with the water-cement ratio of the concrete.

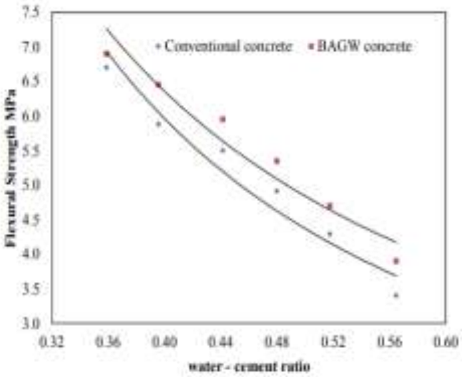


Graph: 4.3: Relationship between the Water-Cement Ratio and Split Tensile Strength

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.

c) Flexural strength

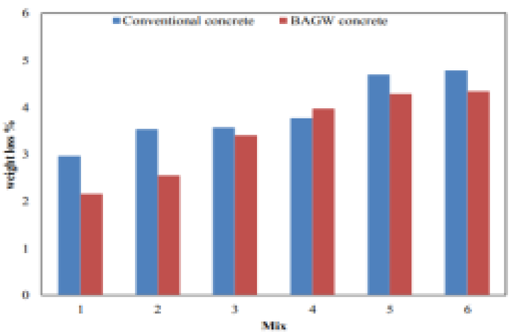
Flexural strength is defined as a material's ability to resist deformation under load. The determination of flexural strength is essential to estimate the load at which the concrete members may crack. The flexural strength (Modulus of rupture) was moderately increased when the river sand was replaced 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 watercement ratio and flexural strength of concrete for BAGW concrete and conventional concrete are shown in Graph 4.4 The basic trend in the relationships of flexural strength with watercement 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. 4.24, 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.



Graph: 4.4: Relationship between the Water-Cement Ratio and 28 days Flexural Strength

d) Acid Resistance Test (HCl and H2SO4)

Results of the acid resistance tests for Hydrochloric acid (HCl) and Sulphuric acid (H2SO4) on the conventional concrete and BAGW concrete specimens are discussed below. The acid attack leached away the calcium compounds of cement paste formed in concrete through the hydration process, as well as the calcium in calcareous aggregate. Acid attack weakens the concrete structurally and reduces its durability and service life. The percentage of mass loss and strength loss of the 56 days cured concrete specimens are shown in Fig. 4.36 and 4.37 for HCl and Graph 4.6 and 4.7 for H2SO4 respectively. 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 thestrength 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.



Graph: 4.5: Percentage of Mass Loss under HCl Environment

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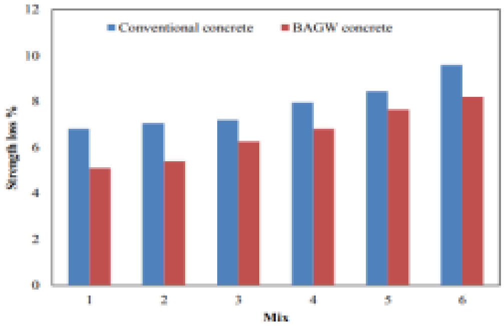
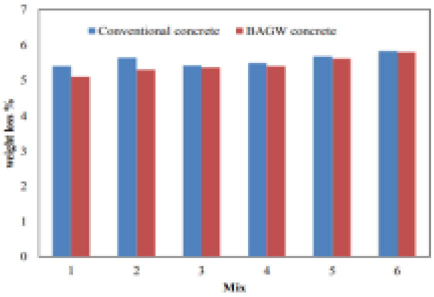
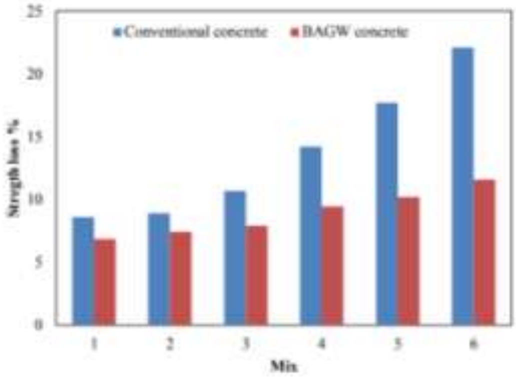


Fig. 4.6 Percentage Strength Loss under HCl Environment



Graph: 4.7: Percentage of Mass Loss under H2SO4 Environment



Graph: 4.8:Percentage Strength Loss under H2SO4 environment

V. CONCLUSIONS

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.

a) Effect Of Combined Sugarcane Bagasse Ash And Granite Waste As Fine Aggregate On The Strength Characteristics Of Concrete

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, super plasticizer 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 136 development of strength of BAGW concrete is varying from the conventional concrete.
5. The relationships have 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.

b) Effect Of Combined Sugarcane Bagasse Ash And Granite Waste As Fine Aggregate On The Durability Performance

1. All the specimens of BAGW concrete immersed in HCl, H2SO4 acids there is a decrease in weight loss and compressive strength loss compared to the conventional concrete.
2. 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 matrixes of concrete mixes containing waste materials are denser and more impermeable when compared to that of conventional concrete.

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