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Strength and Permeation Property of Concrete Made With Sugarcane Bagasse Ash and Granite Waste as Fine Aggregate Replacement

M. Sneha, RM. Senthamarai

Abstract: ***Use of agro and industrial wastes in concrete production will cause sustainable concrete era and greener habitat. In this study an endeavor has been made to discover the propriety of Sugarcane Bagasse Ash (SCBA) and Granite Waste (GW) as partial replacement for traditional river sand. The percentage substitute is calculated based on the particle packing approach. The properties such as compressive, splitting tensile, flexural strengths and modulus of elasticity, water absorption, sorptivity and rapid chloride penetration test of the concrete with bagasse ash and granite waste as a partial replacement for river sand and to evaluate them with those of conventional concrete made with river sand fine aggregate are investigated. The test results show that the strength aspects of bagasse ash-granite waste concrete are higher than those of the conventional concrete. Moreover, they suggest that the bagasse ash-granite waste concrete has higher strength characteristics and remains in the lower permeability level shows improvement in overall durability of concrete than the conventional concrete.***

Keywords: Granite waste, Permeation, RCPT, Sorptivity, Strength, Sugarcane bagasse ash.

I. INTRODUCTION

Agro or industrial wastes which include rice husk ash, fly ash, slag, silica fumes are well known mineral admixtures in concrete. The reactive silica in these wastes will prompt pore refinement and granule refinement in concrete, due to this concrete will be dense and durable. It is very much needed to evolve concrete with non-conventional aggregate due to environment tendencies in addition to cost-efficient problems. Now there is massive capability to increase the waste recycling with the aid of a systematic investigation of the possible use of these wastes in concrete making. Since the consumption of river sand is excessive in the rapid infrastructure growth, the need for the same is also high in growing countries.

Replacing natural river sand either partially or fully is being considered as an innovative view point. In sugar factories, sugar production process generates bagasse as waste, that is burnt to heat water in the boilers that produces steam for power cogeneration, the very last output of this burning is unused sugarcane bagasse ash (SCBA).

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* Correspondence Author
Sneha M*, department of Structural Engineering, Annamalai University, Chidambaram, India. Email: sneha.phdcivil@gmail.com
Senthamarai RM, department of Structural Engineering, Annamalai University, Chidambaram, India. Email: rmsenthamarai@yahoo.com

Ash stands out amongst agro industrial wastes as it outcomes from power generating processes 1. Using this ash in concrete production will pave way to improvement of properties and eco-friendly disposal.

Many researchers have discussed that SCBA has the potential to enhance the strength of concrete specifically due to the physical effects however infinitesimal chemical action is expected 2-4. According to 5 SCBA has dual influence which acts as pozzolan as well as filler in concrete. A very fine filler particle would be essential for the formation of C-S-H gel and because of this it will increase the rate and degree of cement hydration 6. Several fine fillers like limestone fine, marble fines, rock dust, recycled old concrete, tailings and sea shell waste are used as filler in concrete to enhance the properties of concrete. Granite waste particles have been finer than river sand and as a consequence would fill into the voids of inside the bulk volume of river sand to enhance the packing density and rectify the pore structure of the fine aggregate 7-9.

In general, packing is a feature of the particle forms and size distribution. EMMA (Elkem Material Mix Analyzer), a modelling software gives the required tools to assess the packing density of any material. In this software, we are able to visualize and adjust the particle size distribution of the concrete mix by remaking the proportion of each ingredient until the whole mix gets the best fit with the exemplary solid material with reference to the Andreassen Model. The very last grading curves were obtained using Modified Andreassen model by means of varying its distribution modulus (q) from 0.20 to 0.50 as a way to determine its most beneficial value for maximum packing density 10.

In this study, SCBA and GW are used as river sand alternative materials, with this EMMA tool is applied to get optimum packing density. Mechanical and Permeation properties of BAGW concrete is compared with conventional concrete.

II. EXPERIMENTAL WORK

A. Materials

Ordinary Portland cement of grade 53 was confirming to 11 locally available river sand (specific gravity 2.605 and fineness modulus 2.5) confirming to 12. Crushed granite coarse aggregate of maximum size of 20mm (specific gravity 2.8 and fineness modulus 6.5) are used. Super plasticizer (SP) is added to enhance the workability of fresh concrete. Sugarcane Bagasse ash (SCBA) was sourced from a sugar industry Tirukoilur, Tamilnadu (India).Granite waste (GW), which is a secondary product obtained from granite processing industry.

River sand was partially replaced by SCBA and GW. SEM and EDAX analysis were done to control the particle size and chemical composition of SCBA and GW.SEM image of the SCBA and GW are shown in Fig 1 and Fig 2.

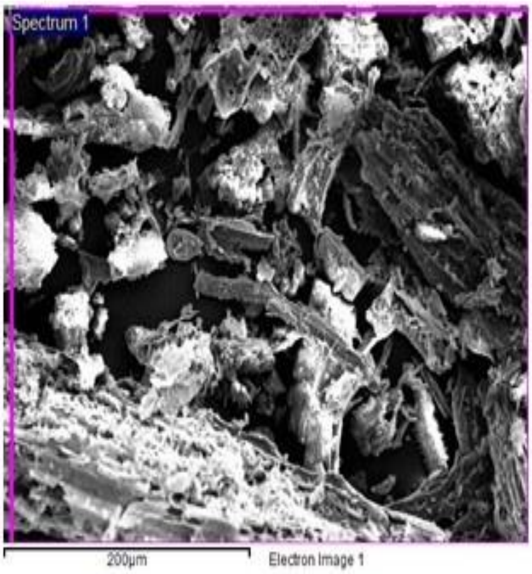

Fig 1 SEM image of SCBA

Fig 2 SEM image of GW

The properties of sugarcane bagasse ash and granite waste are presented in Table 1. It can be observed that specific gravity of SCBA and GW was nearly equivalent to the natural river sand. Grain size distribution of SCBA and GW ranging from 1mm to 0.045mm is used whereas granite waste falls in the distribution zone III. Grain size of SCBA and GW is less than the natural river sand and it results in better packing, higher density and strength similar findings were reported by 8, 13.

The chemical composition of SCBA and GW is containing maximum oxides like silica (SiO_2) and aluminium (Al_2O_3). According to 14 the summation of SiO_2, Al_2O_3 and Fe_2O_3 of SCBA more than 70% is considered as the same classification with the Class F fly ash. These waste residues are considered as the non-reactive pozzolanic filler that's specially governed by the particle packing 15.

Table 1 Physical and Chemical Properties (wt%) of SCBA and GW

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
LOI	8.87	2.37
Physical Properties	SCBA	GW
Specific gravity	2.20	2.48
Fineness modulus	-	2.8
Water absorption %	0.9	2.2
Bulk density (kg/m^3)		
Loose	386	1800.20
Compacted	555	1940.57

B. Mixture proportion

Over the years different particle packing optimization techniques have been applied in concrete mixing proportion 16. In this study the concrete packing was optimized using EMMA software. The Particle Size Distribution (PSD) of raw materials used in concrete is given as input. EMMA foreshows the optimum blend of the materials for preparing concrete. Andreassen aimed on the size distribution for particle packing with continual approach and initiated model, Andreasen and Andersen Model (A&A model) which presumes that the smallest particle could be infinitesimally small. Modified Andreassen Model, derived by Dinger and Funk, which considers the minimum particle size in the distribution into the Andersen Model 10, 17.

Originally M_{20} grade of concrete was proportioned as per 18, the materials and quantities were entered in EMMA and PSD curve following A&A grading and modified A&A grading is obtained. The designed mix follows as much as possible the PSD from the modified A&A grading. However, the PSD of the designed mixes cannot comply the A&A curve flawlessly and this is because A&A curve considers an unlimited distribution towards smaller and smaller particles only.

To optimise the composition by means of adjusting the quantity of a material manually to better fit the Modified Andreassen curve. By this, three other mixes were proportioned and test experiments were performed. It was able to discern that to get higher particle packing density, SCBA required was 27.5% the volume of 10-100µm (cement) particles and GW required was 9% the volume of 100-1000µm (river sand) particles as replacing material of total fine aggregate content.

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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 60mm slump. Therefore, the water content and the maximum size of coarse aggregate used were kept constant for both conventional concrete and BAGW concrete. Fig 3 shows conventional mix C1 there is clear drop at the fine particle sizes; Fig 4 shows mix BAGW 1 which comprises SCBA and GW that cover the fine particle size section. In this study, the Modified Andreassen Model was used and q value is taken as 0.30.

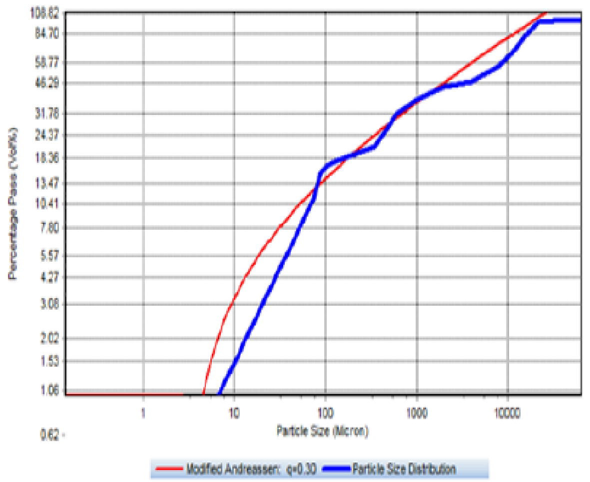

Fig 3 PSD

of Conventional Concrete C1

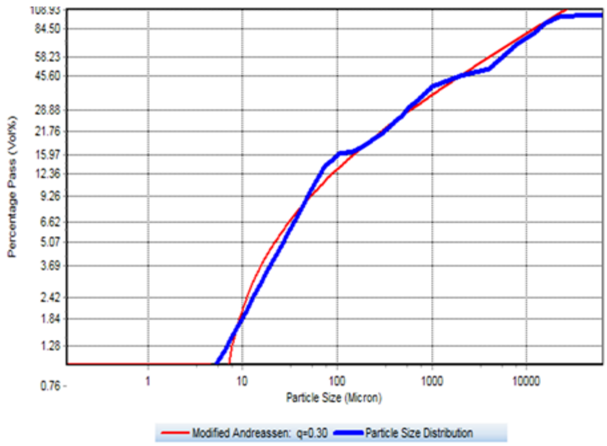

Fig 4 PSD of Bagasse ash Granite waste concrete BAGW 1

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 10-100µ and 9% of 100-1000µ particles). The volumes of cement, filler and water are same in both the conventional concrete and BAGW concrete for the respective mixes. To fulfill the expected workability, Super plasticizer (SP) of 12ml per weight of binder was mixed to BAGW concrete to get equal workability of comparable conventional concrete mix. The mix proportions are characterized in Table 2.

Sample preparation and testing

The concrete components such as cement, river sand, SCBA, GW, and coarse aggregate were weighed in dry state and mixed homogeneously. To comprehend the workability of BAGW concrete and conventional concrete the slump cone test was conducted in accordance with 19. For each mix, eighteen concrete cubes of 100mm size were cast to determine the compressive strength and water absorption of concrete. Twelve cylinders of 150mm diameter and 300 mm height were cast to determine the split tensile strength and modulus of elasticity of concrete and six prisms of 100x100x500mm long were cast to determine the flexural strength. The specimens were demoulded after 24 hours were cured under water up to the specified age of test. The compressive strength, flexural strength and modulus of elasticity of concrete were tested in accordance with 20. The splitting tensile strength test was done as per 21.

In addition six cylinders of 100mm diameter and 200mm height were casted for sorption and chloride ion penetration test. The cylindrical specimen were sliced into 50mm thick and 100 mm diameter were used for sorption and chloride penetration test. As per 22 and 23 the specimens were preconditioned in oven and sides of the specimen were sealed using suitable electrical sealant.

III. RESULT AND DISCUSSION

A. Effect of BAGW in fresh property of concrete

The slump cone test is the test which assesses the parameters close to workability. Additional information about the workability is observed from the drop from the top of the slumped concrete as per 19 is followed. The Slump of the conventional concrete is better than the BAGW concrete. The fine aggregate particles of 0.075 to 1 mm sizes were considered as the water fixation point by 24. SCBA and GW has lower density than the cement and fine aggregate which results in the improvement in the paste volume also this combination improves the resistance towards the flow of mix therefore the need of super plasticizer is essential to sustain the equivalent workability as the conventional concrete. The use of SCBA and GW as fine aggregate replacement enhances the stability of the concrete.

B. Effect of BAGW in strength properties of concrete

The strength test results of conventional and BAGW concrete were given in Table 3. The results presented were average of six specimens. From the table it indicates the use of SCBA and GW tends to enhance the strength properties of the concrete.

a. Compressive strength

Table 2 Mix Proportions

Mix Designation	Cement Content kg/m^3	Bagasse Ash kg/m^3	River Sand kg/m^3	Granite Waste kg/m^3	Coarse Aggregate kg/m^3	Water kg/m^3	SP kg/m^3
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	-
BAGW 1	535	103	443	53	1120	192	6.42
BAGW 2	485	93	492	57	1120	192	5.82
BAGW 3	435	84	542	60	1120	192	5.22
BAGW 4	400	77	574	63	1120	192	4.80
BAGW 5	371	71	604	65	1120	192	4.45
BAGW 6	340	65	634	67	1120	192	4.08

The cube compressive strength of conventional and BAGW concrete for six various cement content was determined. The compressive strength varied from 49 to 29MPa for BAGW concrete. The relative elevation in strength of 5-25% compared to conventional concrete for 28 days curing. It was observed that strength increases throughout all the mixes when compared to the conventional concrete. This confirms the filling potential of the SCBA and GW to make thickly packed concrete matrix. This observation was constant with the findings of other studies

b. Split tensile strength and Flexural strength

Indirect method of finding the tensile property of concrete. The split-cylinder tensile strength of concrete differed from 4.73 to 2.83MPa.The splitting tensile strength of BAGW concrete is proportionately higher than the conventional concrete. The ratio of tensile to compressive strength of concrete is roughly 8 to 9 percent which indicates the moderate strength concrete 27.

The flexural strength (Modulus of rupture) varied from 6.9 to 3.9MPa whereas; the ratio of flexural strength to compressive strength is lower for BAGW concrete. The value of BAGW is 3-14.7% higher than conventional concrete.

c. Modulus of elasticity

Elastic modulus in direct compression of concrete having different cement content is presented. E was calculated via the initial tangent modulus method from the stress strain curve of BAGW and control concrete. Fig 5 shows the stress strain behaviour of the BAGW concrete. The modulus of elasticity of BAGW concrete ranged from 45-25GPa. The value of BAGW concrete is 5-13.6% higher than the conventional concrete.

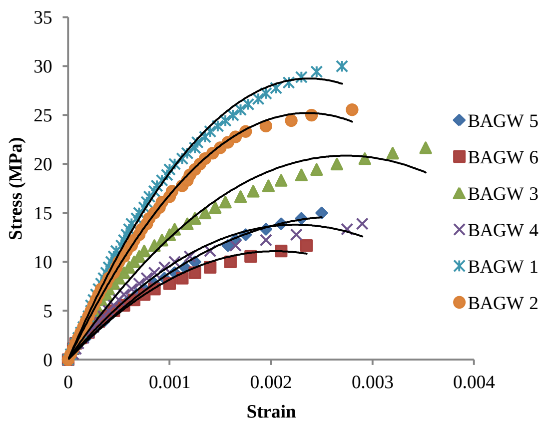

Fig 5 Relationship between Stress and Strain of BAGW concrete

C. Effect of BAGW in permeable properties of concrete

The Permeation test results of conventional and BAGW concrete are tabulated in **Error! Reference source not found.**. The results given are average of three specimens. From the table it indicates the use of SCBA and GW tends to enhance the durability of the concrete.

Table 3 Strength Properties of conventional and BAGW concrete at 28 days

Mix	Compressive strength MPa		Split tensile strength MPa		Flexural strength MPa		Modulus of elasticity GPa
	Mean	C.V	Mean	C.V	Mean	C.V	Mean
C1	46.4	2.07	3.9	3.63	6.7	4.22	43
C2	39.9	3.41	2.76	3.82	5.88	2.89	40
C3	36.2	3.47	2.68	3.97	5.5	2.57	33.33
C4	31	2.90	2.48	3.42	4.91	5.3	28.57
C5	26.2	3.33	2.40	5.89	4.29	3.29	25
C6	23.5	4.05	1.95	3.29	3.4	4.29	22
BAGW 1	49	2.86	4.73	4.73	6.9	1.02	45
BAGW 2	44.4	1.35	4	4.07	6.45	3.29	42
BAGW 3	41.2	2.52	3.69	3.83	5.95	3.57	35
BAGW 4	37	4.60	3.47	5.30	5.35	3.97	30
BAGW 5	33.7	1.90	3.18	3.56	4.70	3.01	27.5
BAGW 6	29.3	2.56	2.83	3.50	3.90	3.93	25

a. *Saturated water absorption*

It is the measure of porosity in the hardened concrete that is occupied by fluid in saturated condition as per 28. The disparity between saturated mass and oven dry mass of cubical concrete sample is water absorption. It is observed that percentage of water absorption slightly increased compared to the conventional mix but in later stage percentage water absorption is gradually decreased for BAGW concrete. This shows the alleviation in structural pore volume.

b. *Sorptivity*

Sorptivity is determined by the measurement of the absorption rate of capillary rise on a concrete specimen. Increase in mass was determined at required time intervals. The efficacy of sorptivity (S) is used to estimate the calibre of the concrete whereas the elevation in sorptivity value decreases the longevity of concrete. The sorptivity values of BAGW and conventional concrete specimens after 28 days damp curing were estimated as per 22 is observed from that lower the water cement ratio decreases the sorptivity value of the both BAGW and conventional concrete shown in Fig 6 and Fig 7.

c. *Rapid chloride penetration test*

Resistance to chloride ion penetration in concrete was calculated based on the test strategy described in 23.

The prepared concrete specimens were arranged in the migration cells with 3.0 % NaCl solution as cathode and 0.3 N NaOH solutions as anode. The system was then connected and an incessant potential of 60 V was applied for six hours to speed up the chloride ingress. Total charge passed every half-hour up to six hours as specified in the standard at 28 days were calculated. Based on the category specified the conventional concrete specimens had moderate resistance towards the chloride ion penetration. Almost all the mixes of the BAGW concrete suggests low chloride penetration. This indicates that chloride ion penetration is significantly diminished because of the presence of the fine fillers.

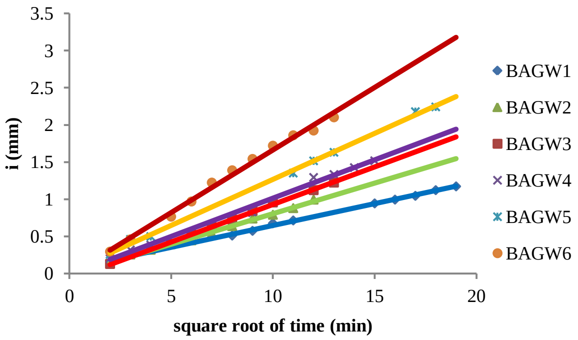

Fig 6 Sorptivity of BAGW concrete

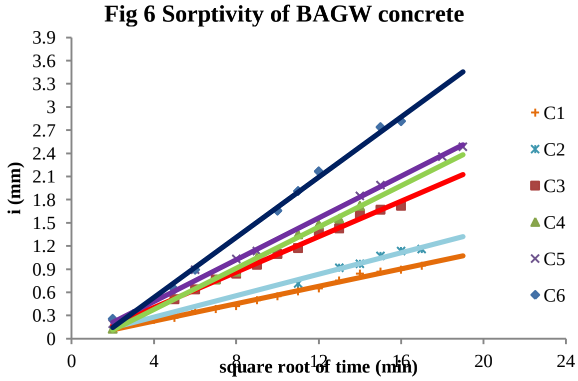

Fig 7 Sorptivity of Conventional concrete

Table 4 Permeability Properties of Concrete

Mix	BAGW concrete				Conventional concrete			
	Water Absorption %		**Sorptivity (S) mm/√min**	**RCPT charge coulombs**	**Water Absorption %**		**Sorptivity (S) mm/√min**	**RCPT charge coulombs**
	28days	56days			28days	56days		
1	4.50	3.38	0.056	1448	4.20	3.76	0.064	2457
2	4.72	3.55	0.082	1640	4.42	4.00	0.084	2509
3	4.86	3.75	0.101	1707	4.65	4.21	0.114	2597
4	5.12	4.08	0.103	1727	4.88	4.40	0.133	2854
5	5.25	4.31	0.124	1821	5.10	4.65	0.135	2862
6	5.45	4.55	0.168	2793	5.31	4.85	0.194	3933

IV. CONCLUSION

SCBA and GW are the two waste materials from the sugar and granite cutting industry. Both the waste materials were triumphantly used as sand substitution material in concrete and attain better performance than the conventional. There are also diverse benefits from the usage of both residues including resources and energy conservations. The following deductions were drawn based on the test results:

- EMMA software helps to reduce the number of iteration of trial mixes when using more than two admixtures in concrete production based on particle size distribution.
- It additionally gives dense and durable concrete which can also be fruitful to produce high performance and high strength concrete.
- The substitution of sand by SCBA and GW enhanced the stableness parameters in all the mixes are because of filler effect and contribute a condensed matrix.
- The permeation properties of BAGW concrete were low due to the fact that the particle size of SCBA and GW ought to block the bridged paths of micro pores.
- It is approved that SCBA and GW can be used as aggregates to produce more durable and economical concrete mix.

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