

A BRIEF INVESTIGATION ON THE DURABILITY STUDIES OF CONCRETE MODIFIED WITH PARTIAL REPLACEMENT OF CEMENT WITH BAGASSE ASH AND FINE AGGREGATE WITH COPPER SLAG IN CONCRETE

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ABSTRACT: - *Present experimental program focuses on the partial replacement of OPC with 12% of sugar cane bagasse ash and natural fine aggregates with various proportions of copper slag. The use of industrial waste has focusing of research on waste reduction for environmental and economical reasons. In this investigation, a study on M25 grade of concrete with partial replacement of OPC with optimum percentage of sugar cane bagasse ash(12%) and natural fine aggregates with varying proportions(0,50,100) of copper slag is made. The cast specimens are subjected to different curing environments such as by curing in natural water and acid solutions like HCL, H₂SO₄ and Na₂SO₄ of 5% concentration. The strength properties calculated by various mechanical properties are studied for natural water curing. Strength deterioration and sorptivity tests for cubes and cylinders under acid curing at the age of 28days have also been investigated.*

Key Words: *Sugarcane bagasse ash, copper slag, HCL, H₂SO₄, Na₂SO₄, sorptivity test and mode-II fracture.*

1. INTRODUCTION

Since from the origin, concrete is viewed as a durable material required a small support, with the exception of when its mails subjected to quite competitive environments. In the past strength is the main aspect for designing the mix, but now durability is also one of the criteria. On other hand, cement is one of the durable materials used for infrastructural purposes. However, cement manufacture is responsible 3percentage of total worldwide waste products. Bagasse is a fiber waste product of the sugar factory. This waste material is causing serious environmental pollution, and so its alternative use is investigated. Sugarcane Bagasse ash (SCBA) mainly contains silica, iron, calcium & aluminum oxides. The sugarcane bagasse ash therefore becomes a factory waste and poses serious disposal effects. Similarly slag is used as a partial replacement for natural fine aggregates which is a waste product from mining factory and poses disposal problems. Durability of concrete structures in harsh environments is investigated by curing concrete specimens in HCL, H₂SO₄ and Na₂SO₄ solutions. From the study interesting results are observed.

2. LITERATURE REVEIW

In their work V. Bhaskar Desai and V. Raghavachar [1] investigated that bagasse ash can be mix as a required material by replacing cement. The strengths of the M25 mix can increase up to 10% with 20% partial replacement of cement by SCBA.

Prashant O Modania et.al [2] presented his work on replacing sugarcane bagasse ash as natural fine aggregates in between percentages of 10% to 20%.

Anurag shrivas et.al [3] examined the use of various agricultural waste ashes and Glass Powder in addition to the bagasse ash with 10% replacement with the cement.

Rambabu P.V et.al [4] studied effect of acidic environment on concrete with SCBA. Compressive strength is deterioration for concrete curing in 5% acid solutions when compared to the concrete curing in natural water.

Sumathy raju et.al [5] studied the effect of replacement of natural fine aggregates with copper slag for 0%, 10%, 20%, 30%, 40%, 50% and 60% and concludes that the strength would increase up to 50%.

Nataraja M.C et.al [6] stated that slag can be used as natural fine aggregate and both have more or less same compaction factor values.

From the brief literature review, it has been observed that less concentration has paid by the previous authors in the use of sugarcane bagasse ash and copper slag replacements in making concrete. Limited data is available on comparison of mechanical and durable properties. Hence research work is necessary to study the mechanical and durable

properties of concrete with partial replacement of copper slag in required proportions including 12% bagasse ash and to investigate their performance for several environmental exposures.

3. OBJECTIVE

1. To study the properties of concrete by partial replacement of cement with 12% of SCBA and natural fine aggregates with 0%, 50% and 100% of copper slag.
2. To find durability of specimens made with above mixes by using solutions with 5% concentration of HCL, H₂SO₄ and Na₂SO₄.

4. MATERIALS REQUIRED

The follow material is required to prepare the concrete mix. Physical properties of constituent materials are tabulated in table1.

- 1. Cement:** OPC of 53 grade (Ultratech) is use.
- 2. Fine aggregate (Sand):** Sand from local Chitravathi river which passing through 4.75mm IS sieve is used which conforms to grading zone-2 of IS: 383-1970[8].
- 3. Conventional Coarse aggregate:** Crushed granite coarse aggregates conform to IS: 383-1970[8] of 20mm maximum size, obtained from the quarry sources is used.
- 4. SCBA:** Bagasse ash is a repercussion of thermal power industries where pulped sugar cane fibres are used as a burning media. This sugar cane bagasse ash is very light weight material and contains very small size particles. This ash is obtained from Mayura Sugars Pvt. Ltd. (Sreekalahasthi, chittoor dist.).
- 5. Copper slag:** Copper slag is a repercussion of copper extracting by smelt. During smelt, impurities of copper slag flow on the molten metal. Slag used as a research studies. This copper slag is obtained from Sri Srinivasa Metalizers (Hyderabad).
- 6. Water:** Local available potable tap water has been use in this work for concrete mixing and cured specimens.
- 7. Distilled Water:** The distilled water used is obtained from Sree Srivari Enterprises (Anantapuramu). Its pH value is 6.5 to 7.
- 8. Chemicals (HCL, H₂SO₄ and Na₂SO₄):** Chemicals used are Na₂SO₄, HCL and H₂SO₄ with 5% concentration. They are obtained from Tirpala chemicals (Hindupur).

Table 1: Properties of materials in M25 grade mix.

S. No	materials		Properties	
1	Ordinary Portland Cement – 53		Specific gravity	3.14
			Initial setting time	27 minutes
			Final setting time	492 minutes
			Fineness	5.4%
			Normal consistency	29%
2	Fine aggregate	Natural fine aggregates	Specific gravity	2.64
			Fineness modulus	2.46
	Copper slag		Specific gravity	3.54
			Fineness modulus	2.53
3	Coarse aggregate		Specific gravity	2.66
			Fineness modulus	6.99
			Bulk density compacted	1620kg/m ³
4	Bagasse ash passing through 90μ		Specific gravity	2.7
			Fineness	5.3

5. EXPERIMENTAL PROCEDURES

An experimental study has been conducting on concrete mix with various percentage replacements (0, 50 and 100) of conventional fine aggregates by weight with copper slag and cement by 12% of bagasse ash. The experimental investigation has been carried out by casting the following specimens and testing after 28 days of curing for each proportion.

- 1) Three numbers of cubes (150X150X150mm) for compressive strength test
- 2) Three numbers of cylinders (dia 150X300mm) for split tensile strength test
- 3) Three numbers of beams (100X100X500mm) for flexure strength test
- 4) Three numbers shear cubes (with a/w ratios of 0.3,0.4,0.5and 0.6) and size being150X150X150mm for shear strength through mode-II fracture strength test
- 5) Three numbers of cubes (100X100X100mm) for compressive strength test for acid curing
- 6) Three numbers of cylinders (dia 100X200mm) for split tensile strength test for acid curing

5.1 Casting of specimen

Mix design:

The M₂₅ grade is designed using IS method i.e., IS 10262-2009[9] and IS 456-2000[10] the mix proportion of 1:1.59:2.62 with constant W/C ratio of 0.45. Three various mixes has studied and design as following,

Table 2: Design details for specimens

S. No	Name of the mix	Percentage weight replacement of cement with SCBA	Percentage weight replacement of fine aggregate		No. of specimen cast and tested					
			Natural fine aggregate	Copper slag	Cubes		Cylinders		Beams	In-plane shear cubes
					Normal water	Acid water	Normal water	Acid water		
1	R1	12	100	0	3	9	3	9	3	12
2	R2	12	50	50	3	9	3	9	3	12
3	R3	12	0	100	3	9	3	9	3	12
			Total Specimens		9	27	9	27	9	36

Therefore the total specimens which are cast and tested are 117

6. TESTING

6.1 Compressive strength for Cubes

The cubical specimens are place vertically between the plates of the compressive strength test machine. The apply load is continue at the rate of 130 kg/cm²/sec till the specimen failure and final ultimate loads are record. These ultimate loads are divides by the area of cross sectional to the cube obtained by the compressive strength of each cube. Ultimate load capacity of compression strength test machine is 2 MN (Mega Newton). The test values are in tables 3 and 4 respectively are in figure 1.

Table 3: Cube Compressive Strength test Results for normal water.

Name of the Mix	Percentage weight replacement of cement with SCBA (%)	Percentage weight replacement of fine aggregates		Cube compressive strength (N/mm ²)	% variation of compressive strength (%)
		Natural Fine aggregates (%)	Copper Slag (%)		
R0	0	100	0	34.55	0.00
R1	12	100	0	36.37	5.27
R2	12	50	50	40.15	16.21
R3	12	0	100	38.72	12.07

Table 4: Cube Compressive Strength test Results for Acids

Name of the Mix	Acids with 5% concentration	Percentage weight replacement of cement with SCBA (%)	Percentage weight replacement of fine aggregateS		Cube compressive strength (N/mm ²)	Percentage variation of compressive strength (%)
			Natural Fine aggregate (%)	Copper slag (%)		
R1	Na₂SO₄	12	100	0	25.93	0.00
R2		12	50	50	29.03	11.95
R3		12	0	100	26.17	0.90
R1	HCL	12	100	0	14.67	0.00
R2		12	50	50	22.77	55.23
R3		12	0	100	18.70	27.50
R1	H₂SO₄	12	100	0	12.70	0.00
R2		12	50	50	16.27	28.08
R3		12	0	100	13.80	8.66

6.2 Split Tensile strength for Cylinders

In this testing the cylinder specimens are keep horizontal. Specimens placed parallel axis to the compressive strength plates of the 3MN (Mega Newton) compression strength test machine. Slender plates of the packing material i.e., wood is

placed b/w the plates and the cylinder to received ultimate strength load. The apply load is uniform until the cylinder failure. Split tensile strength values of cylinders are in tables 5 and 6 respectively are in figure 2.

Table 5: Cylinder Tensile strength results for Normal Water

Name of the Mix	Percentage weight replacement of cement with SCBA (%)	Percentage weight replacement of fine aggregates		Split Tensile strength (N/mm ²)	Percentage variation of split tensile strength (%)
		Natural Fine aggregate (%)	Copper Slag (%)		
				28 Days	
R0	0	100	0	3.10	0.00
R1	12	100	0	3.23	4.19
R2	12	50	50	4.06	30.97
R3	12	0	100	3.63	17.10

Table 6: Cylinder Tensile strength results for Acids

Name of the Mix	Acids with 5% concentration	Percentage weight replacement of cement with SCBA (%)	Percentage weight replacement of fine aggregateS		Split Tensile strength (N/mm ²)	Percentage variation of compressive strength (%)
			Natural Fine aggregate (%)	Copper slag (%)		
					28 Days	
R1	Na2SO4	12	100	0	3.03	0.00
R2		12	50	50	3.90	28.77
R3		12	0	100	3.28	8.42
R1	HCL	12	100	0	2.47	0.00
R2		12	50	50	3.94	59.23
R3		12	0	100	3.59	45.06
R1	H2SO4	12	100	0	2.57	0.00
R2		12	50	50	2.94	14.46
R3		12	0	100	2.71	5.37

6.3 Flexural Strength for Beams

Flexural tensile strength is a measure of a concrete specimen to with stand failure in bending. The flexural tensile strength test is done by typical method of 2-point load method. In this observation, 3 beams 100*100*500 mm are use to evaluate the flexural tensile strength. The flexural tensile strength values are in table 7 are in figure 3.

Table 7: Flexural Strength results for Beams

Name of the Mix	Percentage weight replacement of cement with SCBA (%)	Percentage weight replacement of fine aggregate		Flexural strength (N/mm ²)	Percentage variation of flexural strength
		Natural Fine aggregate (%)	Copper slag (%)		
				28 Days	
R0	0	100	0	3.64	0.00
R1	12	100	0	3.90	7.14
R2	12	50	50	4.65	27.75
R3	12	0	100	3.98	9.34

6.4 Mode II shear test: A doubled central notched specimens 150*150*150mm, notches are placed at (1/3)rd portion centrally during casting. The shear test on the doubled central notched specimens is conducted on 3 Mega Newton (MN) compression strength machine. Test results are shown in table 8. UDL is applied over the central (1/3)rd parts b/w the notch and steel supports of square cross sectional area are provide at outer edge along the bottom edge of the notches, so

that the center portion could get shear along the notches on the application of load. The test place and loading pattern is presented below plate 1.

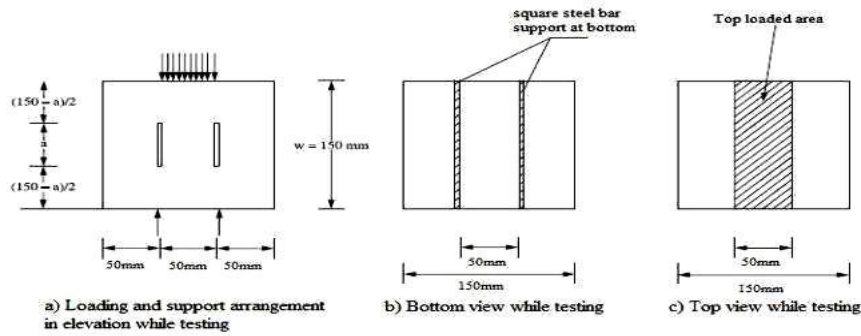


Plate1. Loading Diagram of DCN specimen

In-Plane shear strength: The in plane strength of modified concrete was calculated using the formula

In plane shear strength = $(P/(2*D*(D-d)))$ N/mm²

Where P= Ultimate load in mode-II shear

D= cube size = 150mm

d= notch depth in mm

The value of In-plane shear of concrete for different a/w ratios in mode-2 shear are present in Table 8 and results are present in figure 4.

Table 8(a): Ultimate load and In Plane Shear Stresses in mode II shear test values (a/w =0.3 & a/w=0.4)

Name of the mix	Percentage weight replacement of cement with SCBA (%)	Percentage weight replacement of fine aggregates		a/w=0.3			a/w=0.4		
		Natural Fine aggregate (%)	Copper slag (%)	Ultimate load (KN)	In-plane shear stress (N/Sq.mm)	Percentage variation of shear stress	Ultimate load (KN)	In-plane shear stress (N/Sq.mm)	Percentage variation of shear stress
				28 days			28 days		
R0	0	100	0	140	4.44	0	127	4.7	0
R1	12	100	0	144	4.571	2.93	134.67	4.988	6.17
R2	12	50	50	175	5.556	25.14	169.47	6.284	33.7
R3	12	0	100	138	4.381	-1.33	137.33	5.086	8.21

Table 8(b): Ultimate load and In Plane Shear Stresses in mode II shear test values (a/w =0.5 & a/w=0.6)

Name of the mix	Percentage weight replacement of cement with SCBA (%)	Percentage weight replacement of fine aggregate		a/w=0.5			a/w=0.6		
		Natural Fine aggregate (%)	Copper slag (%)	Ultimate load (KN)	In-plane shear stress (N/Sq.m m)	Percentage variation of shear stress	Ultimate load (KN)	In-plane shear stress (N/Sq.m m)	Percentage variation of shear stress
				28 days			28 days		
R0	0	100	0	115.66	5.14	0	102	5.66	0
R1	12	100	0	125.33	5.57	8.37	106	5.889	4.05
R2	12	50	50	137.67	6.119	19.04	130.67	7.259	28.25
R3	12	0	100	127	5.644	9.8	113	6.278	10.91

6.5 Sorptivity test

The sorptivity can be measure by the measurement of capillary rise water absorption rate on reasonably material. Water is used as the test fluid. A specimen after taking out from the acid are placed in a glass tub with water level not exceeding 5mm for 30 min and then the quantity of water is it absorbed by the cubes and cylinders through capillary action is found by taking the weight of the specimens before placing and after removing the specimen from the glass tub with water. By using this change in weight the sorptivity is calculated. Sorptivity(s) is a material property which character to tendency of the pour to absorb and transfer water by capillarity action. The cumulative water absorption increases as the square root of elapsed time (T). From the earlier research [7] the sorptivity can be calculated by the equation

$$I = S \cdot t^{1/2}$$

$$(or) S = Y/T^{1/2}$$

Where,

S= Sorptivity in mm.

T= Elapsed time in min.

$$Y = \Delta x / AD$$

Δx = weight difference = $X_2 - X_1$

X_1 = weight before place in water.

X_2 = weight after remove from water.

A= Surface cross sectional area of the specimen through which water penetrating.

D= water density.

Hence, sorptivity test values are tabulated in table 9 are in figure 5 in graphical form.

Table 9: Sorptivity test values

Table 9(a): Sorptivity test values for cubes.

Name of the Mix	Acids with 5% concentration	Percentage weight replacement of cement with SCBA (%)	Percentage weight replacement of fine aggregates		Sorptivity value (mm/min ^{0.5})
			Natural Fine aggregate (%)	Copper slag (%)	28 Days
R1	NA ₂ SO ₄	12	100	0	0.0001551
R2		12	50	50	0.0002714
R3		12	0	100	0.0001938
R1	HCL	12	100	0	0.0006590
R2		12	50	50	0.0009691
R3		12	0	100	0.0005815
R1	H ₂ SO ₄	12	100	0	0.0002714
R2		12	50	50	0.0003489
R3		12	0	100	0.0002326

Table 9(b): sorptivity test results for cylinders.

Name of the Mix	Acids with 5% concentration	Percentage weight replacement of cement with SCBA (%)	Percentage weight replacement of fine aggregates		Sorptivity value (mm/min ^{0.5})
			Natural Fine aggregate (%)	Copper slag (%)	28 Days
R1	NA ₂ SO ₄	12	100	0	0.00019382
R2		12	50	50	0.00042641
R3		12	0	100	0.00023259
R1	HCL	12	100	0	0.00050394
R2		12	50	50	0.00058147
R3		12	0	100	0.00046518
R1	H ₂ SO ₄	12	100	0	0.00023259
R2		12	50	50	0.00050394
R3		12	0	100	0.00031012

8. GRAPHS

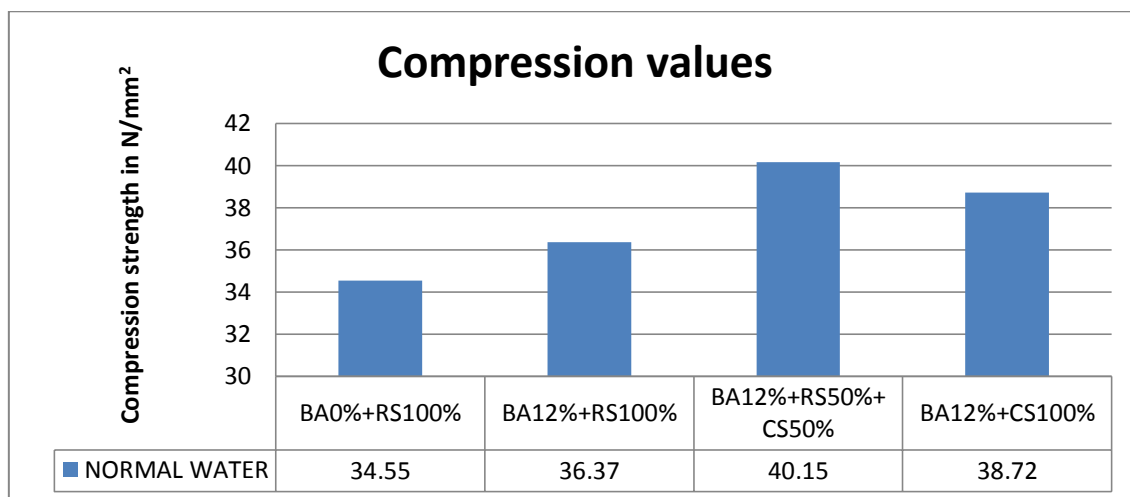


Fig.1 (a) Compressive strength test of cubes in normal water

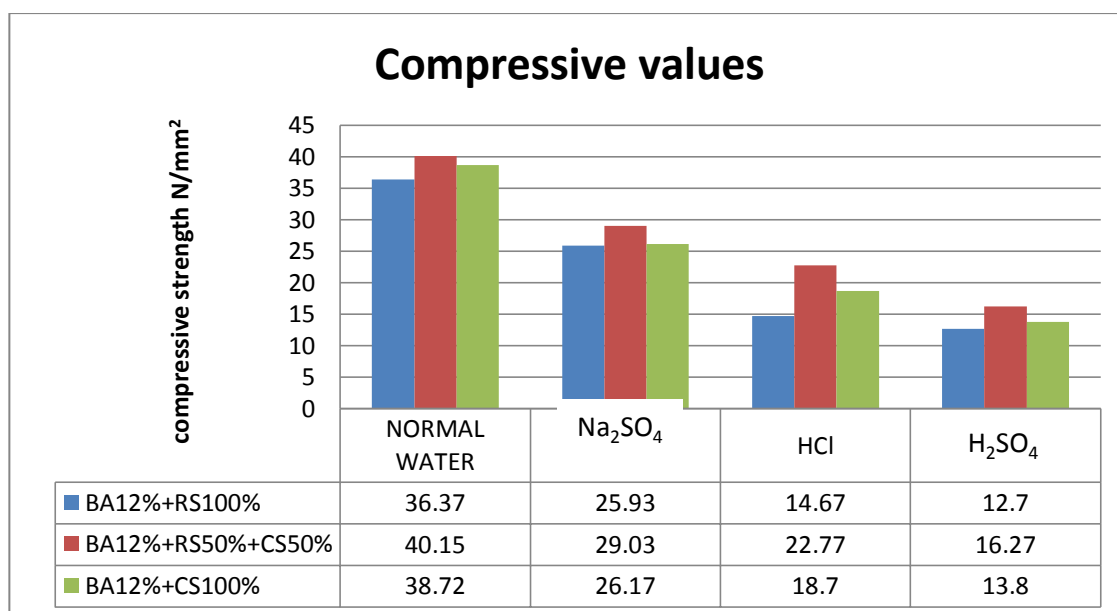


Fig.1 (b) Compressive strength test of cubes in normal water and acid solutions

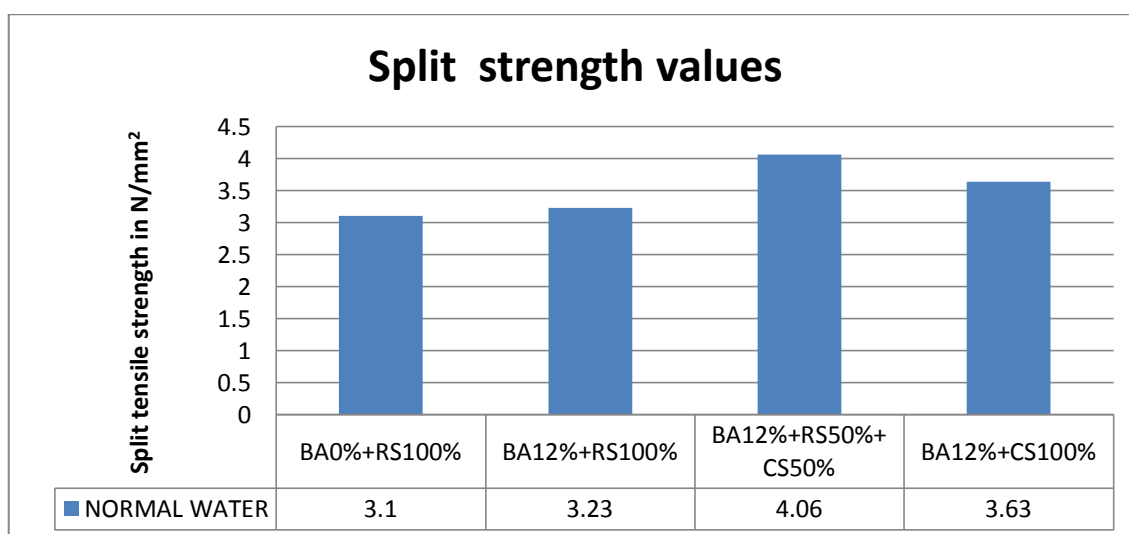


Fig.2 (a) Split tensile strength test of the cylinders in normal water

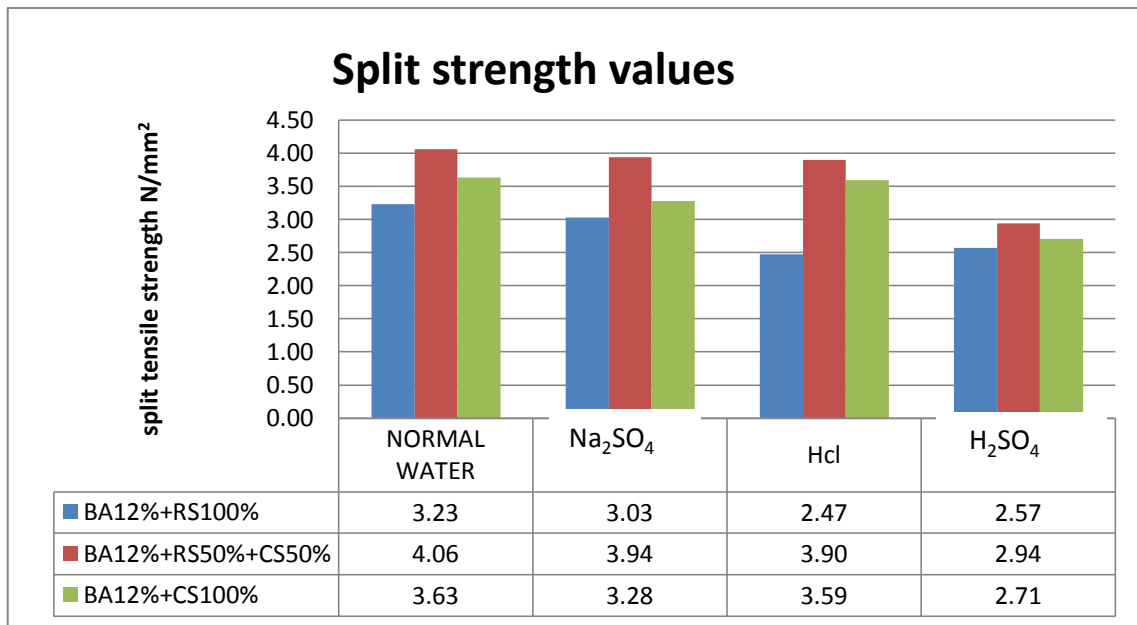


Fig.2 (b) Split tensile strength test of the cylinders in normal water and acid solutions

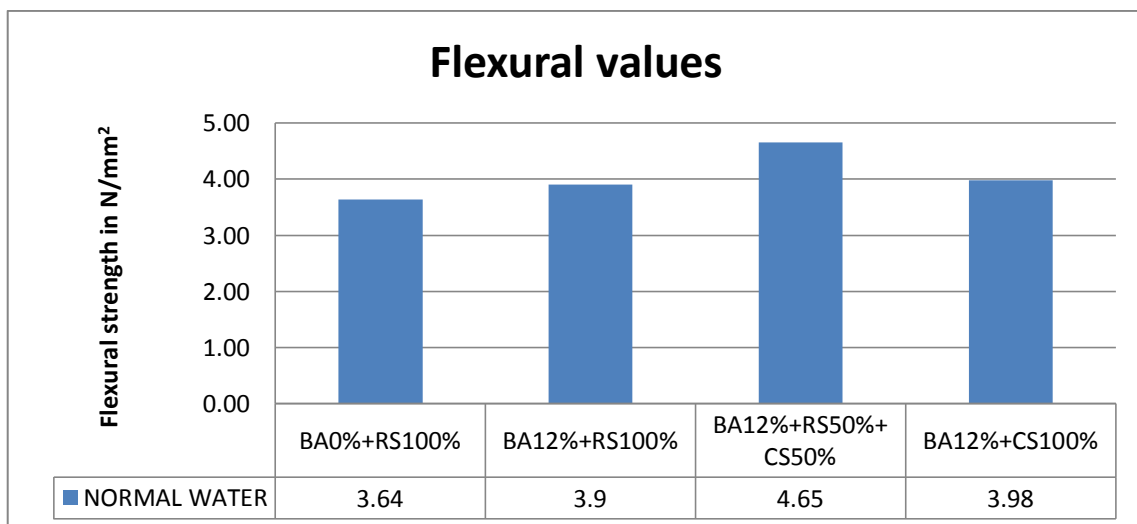


Fig.3 Flexural tensile strength test of beams

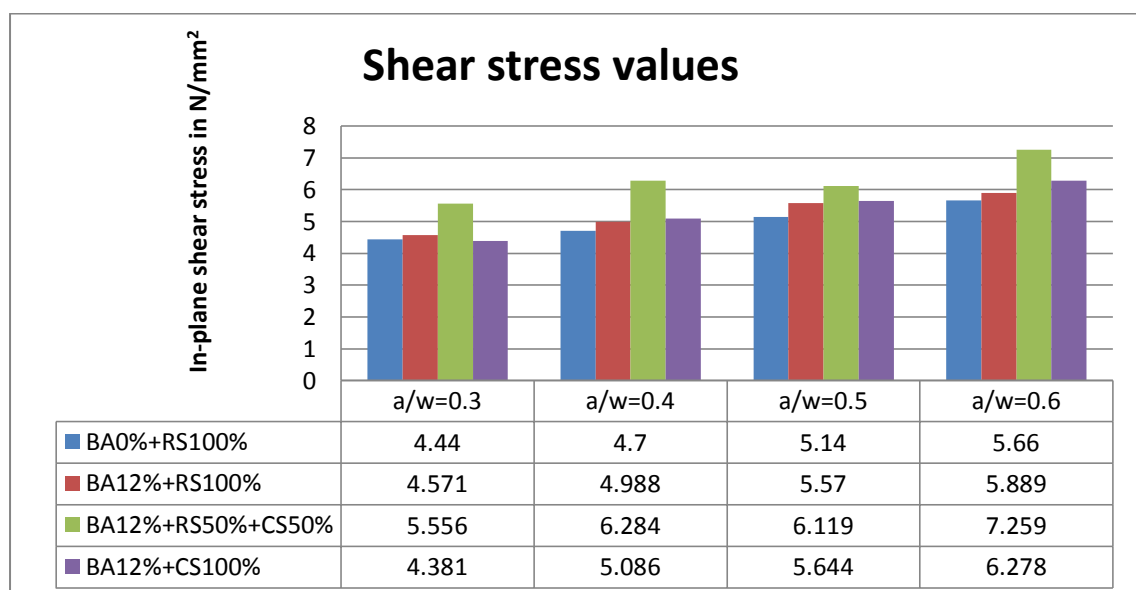


Fig.4 Shear stress test as per a/w ratio

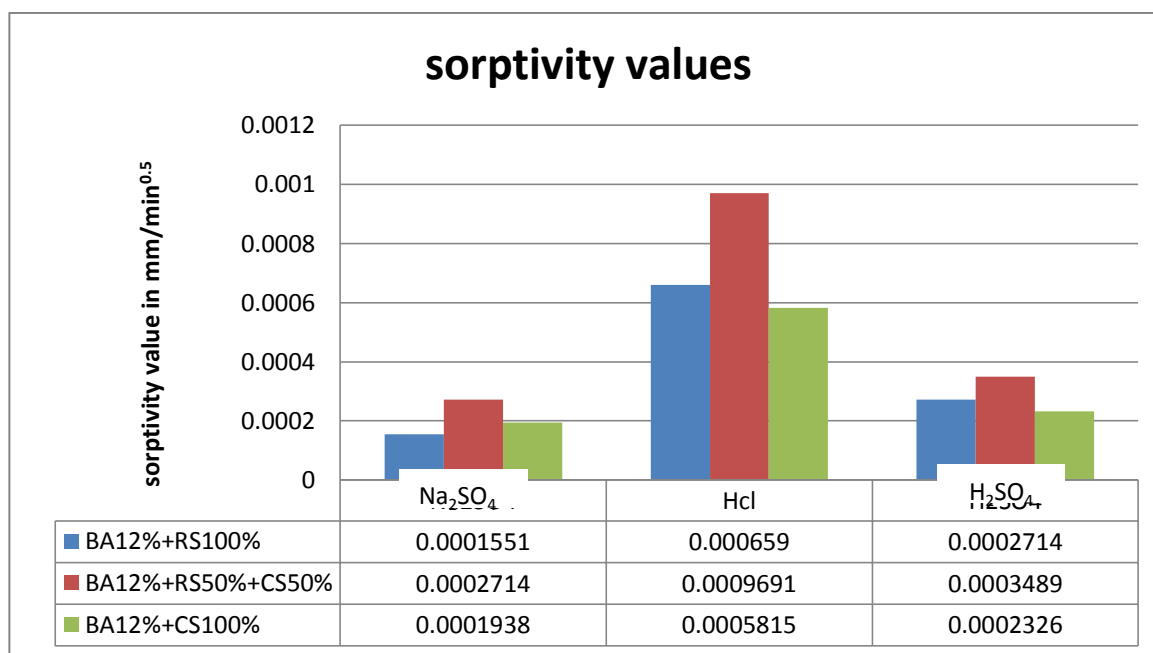


Fig.5 (a) Sorptivity test results for cubes

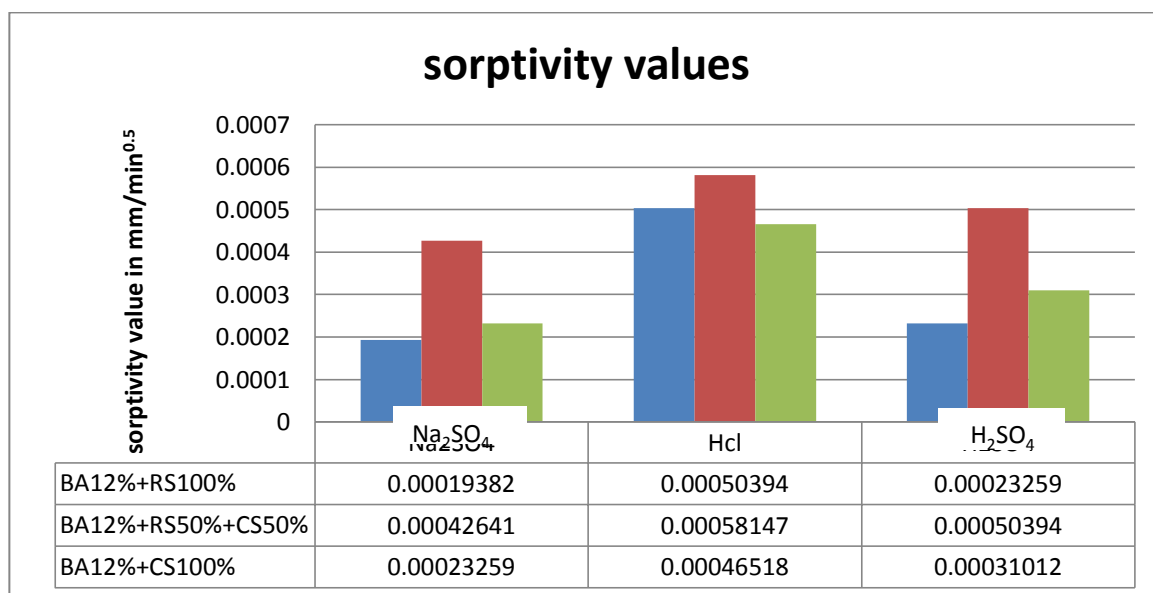


Fig.5 (b) sorptivity test results for cylinders

9. DISCUSSION ON TEST RESULTS

9.1 Influence of 12% of bagasse ash and copper slag on cube compressive strength

The cube compressive strength test versus percentage replacement of natural fine aggregates with copper slag for 28 days curing in normal water and acid solutions are shown in figure 1. In all the curing cases the strength has increased with the natural fine aggregates replacement by copper slag up to 50% and decreased thereafter. Hence the optimum strength is obtained when the replacement is 50%.

At optimum replacement of natural fine aggregates (50%) the 28 days strength with normal water curing is 40.15 N/mm² where as it is 29.03 N/mm², 22.77 N/mm² and 16.27 N/mm² with 5% concentration solutions of Na₂SO₄, HCL and H₂SO₄ solutions respectively.

9.2 Influence of 12% of bagasse ash and copper slag on split tensile strength

The split tensile strength test versus percentage replacement of natural fine aggregates with copper slag for 28 days curing in normal water and acid solutions are shown in figure 2. In all the curing cases the strength is optimum when the natural fine aggregates replacement with copper slag is 50% and decreased thereafter.

At optimum replacement of natural fine aggregates (50%) the 28 days split tensile strength in normal water curing is 4.06 N/mm² where as it is 3.94 N/mm², 3.9 N/mm² and 2.94 N/mm² in 5% concentration solutions of Na₂SO₄, HCL and H₂SO₄ respectively.

9.3 Influence of 12% of bagasse ash and copper slag on flexural strength

The flexural strength test versus replacement of natural fine aggregates with copper slag for 28 days curing in normal water is shown in figure 3. As in other cases the strength is optimum when the fine aggregate replacement with copper slag is 50% and decreased thereafter.

9.4 Influence of 12% of bagasse ash and copper slag on in plane shear stress.

All the double central notched cubes with different a/w ratios, 0.3, 0.4, 0.5 and 0.6 and with different percentages of copper slag as natural fine aggregates are tested with load in shear strength. The different of ultimate loads versus % replacement of normal fine aggregate with copper slag are presented in figure 4. The various a/w ratios for 28 days curing period. The results are increased from 0% to 50% replacement of natural fine aggregates with copper slag and deterioration thereafter.

9.5 Influence of 12% of bagasse ash and copper slag on sorptivity test.

The sorptivity value has increased when the replacement of copper slag as natural fine aggregates replacement is increased from 0 to 50% and deterioration thereafter. The specimens cured in HCL solution have shown high sorptivity value when compared to H_2SO_4 and Na_2SO_4 solutions.

10. CONCLUSIONS

- 1) From the present investigations it can be understood that the modified concrete can be generated by using copper slag as natural fine aggregates replacing river sand & sugarcane bagasse ash replacing cement to optimum extent.
- 2) As copper slag granules are small and rounded in shape they fill the voids, therefore it shows increase in strength up to the optimum replacement. From this project investigation the optimum percentage is found out to be 50%.
- 3) From the experimental investigation, it can be observed that the concrete has attained the maximum compressive, split tensile, flexural and in-plane shear stress when the replacement of natural fine aggregates with copper slag is 50% at an optimum replacement of cement with 12% bagasse ash. Hence it can be explained that the optimum percentage of copper slag for natural fine aggregates replacement is 50%.
- 4) With the curing in acidic solutions the strength is found to decrease. The worst condition for compression and split tensile tests is noticed for H_2SO_4 .
- 5) Among the acid solutions Na_2SO_4 has comparatively lesser effect on concrete strength when compared to HCL and HCL shows lesser effect when compared to H_2SO_4 .
- 6) The specimens cured in different acid solutions have different sorptivity values. The worst condition for sorptivity test is noticed for Na_2SO_4 .

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