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A BRIEF STUDY ON THE NEW GENERATION CONCRETE REPLACING CEMENT AND FINE AGGREGATE WITH SUGARCANE BAGASSE ASH AND ROBO SAND ALONG WITH ACID RESISTANT STUDIES.

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ABSTRACT:- Concrete is the most extensively used composite construction material in the world, which is made primarily from cement, water, fine aggregate and coarse aggregate. The present investigation is to find suitable alternative materials for fine aggregates and cement due to their scarcity and depletion of natural resources. Robo sand and sugarcane bagasse ash are such alternatives which are by-products from industries and these are ecofriendly. With the usage of these alternative products an attempt has been made to replace cement with 12% sugarcane bagasse ash and fine aggregate with artificial robo sand in required proportions (0%, 50%, 100%). Strength parameters such as compressive strength, split tensile strength, flexural Strength, In-plane shear strength by mode II fracture tests are conducted at the age of 28 days. The durability tests are also conducted by immersing specimens for 28 days in 5% concentrated Hydro Chloric Acid, Sulfuric Acid and Sodium Sulphate solutions. The results are analysed and reported.

***KEYWORDS**: Robo sand, Sugarcane Bagasse ash, Mode II fracture, Durability, Acid Curing, Hydro Chloric acid, Sulfuric acid, sodium sulphate.*

1. INTRODUCTION

Utility of concrete is increasing day by day in construction works. The use of by-products in the production of concrete has gained considerable interest among concrete technologists in the recent years. Sugarcane bagasse ash is most common type of by-product obtained, during the manufacture of sugar from sugarcane. Each tonne of sugarcane generates nearly 26% of bagasse. Burning bagasse results in bagasse ash which causes a great disposal problem. Due to increase in the consumption of concrete there is a scarcity of natural aggregate which is suitable for construction. In order to reduce dependence on natural aggregate in construction, artificially manufactured aggregate is used as an alternative. The use of robo sand as a replacement for fine aggregate in concrete will reduce the over consumption of natural river sand.

2. LITERATURE REVIEW

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

S Rukmangadhara Rao et.al [2] concluded that by partial replacement of robo sand by river sand the compressive, Split and flexural strengths have shown increased behavior with 12% to 15% compressive, 7% to 9% split and 20% to 22% flexural. It shown higher results than the normal conventional concrete.

P Bhanu Prakash Reddy et.al [3] discussed about the comparison on strengths of natural and robo sand and their durability tests. Stated that compressive strength of robo sand is to be 26.48% higher compared to natural sand.

Yajurved Reddy M [4] studied 60% replacement of robo sand by natural sand yielded good compressive, split and tensile strengths for M20 and M30 grade concrete and concluded that 60% replacement has shown good resistance to acid treatment.

Manjunatha M [5] stated by replacing the natural sand with 50% robo sand the percentage increase of compressive strength is 18.88%, Split tensile strength is 7% to 9% and flexural strength is 13.2% at the age of 28 days.

From the brief literature review, it has been observed that less attention has paid by the earlier researchers in the use of sugarcane bagasse ash and robo sand as alternatives in construction industry. 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 and to investigate their performance for several environmental exposures by replacing cement and fine aggregate with sugarcane bagasse ash and robo sand.

3. OBJECTIVE

1. To study the strengths of concrete by 12% use of sugarcane Bagasse ash as cement replacement and robo sand with fine river sand in required proportions.
2. Comparison of mechanical and durability properties of robo sand concrete in severe environmental exposure conditions.

4. MATERIALS USED

Cement: Ordinary Portland cement of 53 Grade (Ultratech)
Conventional Coarse Aggregate: Crushed stone aggregate of 20mm size conforming to IS:383-1970 is used which is obtained from the local sources.

Fine Aggregate: Natural sand which passes through 4.75 mm IS sieve and conforms to grading zone-II of IS: 383-1970. Locally available from chitravathi river near Batthalapally.

Sugarcane Bagasse Ash: The fibrous residue of sugarcane after crushing is known as bagasse and the residue of burning the bagasse in factories is called bagasse ash. It is obtained from the Mayura Sugars Pvt. Ltd. (Sreekalahasthi), Andhra Pradesh. It is sieved through 90microns IS sieve for replacement to cement.

Robo Sand: Robo sand is manufactured at the stone quarries. It is an ideal substitute to fine aggregate. Robo sand contains more angular surfaces and its rough surface influences the workability and finishing ability in concrete. Robo sand which is used in this study, available locally in quarries near "Hindupur" Andhra Pradesh.

Properties of robo sand:
Specific Gravity of Robo Sand = 2.25
As per IS 383-1970 Robo sand is classified under grading zone II.

Water: In present study, locally available potable water which is free from organic substances and acids conforming to IS 3025-1986 is used for mixing and curing.
Mix Design: The mix design is done as per IS 10262-2009. Final proportions is concluded after casting several trial batchs of concrete. The final mix design is tabulated below.

Cement	Fine Aggregate	Coarse Aggregate	Water to cement ratio
1	1.59	2.61	0.45

Hydro Chloric Acid: For immersion of concrete cubes Hcl of 5% concentrated solution by weight of water with pH about 3 is used for a period of 28 days.
Sodium Sulphate: Na_2SO_4 with pH-7 and 5% concentration by weight of water is used.
Sulfuric Acid: 5% concentrated sulfuric acid by weight of water with pH-3 is used in this study.

Table 1: Properties of constituent materials in M25 grade concrete.

S.No	Name of the Material		Properties of the Material	
1	OPC-53 Grade		Specific gravity	3.15
			Initial setting time	29 minutes
			Final setting time	490 minutes
			Fineness	5.50%
			Normal consisitency	30%
2	Fine aggreagate passing through 4.75 mm sieve.		Specific gravity	2.64
			Fineness Modulus	2.46
3	Coarse aggregate passing through 20 mm Sieve	Natural Aggregate	Specific gravity	2.66
			fineness Modulus	6.99
			Bulk Density compacted	1620kg/m^3
		Bagasse Ash Passing through 90µ	Specific gravity	2.7
			Fineness Modulus	5.3
			water absorption	23%

5. Experimental Work

Mix design of M25 grade concrete is made according to Indian Standard 10262-1982. Concrete mix is well prepared with obtained mix proportions by using robo sand replacing natural river sand in proportions of 0%, 50%, 100% and with 12% of sugarcane bagasse ash replacing cement. These ingredients are mixed thoroughly. Mix is poured into the moulds in three layers each layer being well compacted and vibrated. Standard cubes, cylinders, beams and shear specimens are cast and tested after 28 days. 5% concentrated Hcl solution with pH about 3, H_2S0_4 with pH about 3 and Na_2So_4 with pH about 7 are prepared. After weighing, specimens are immersed in the prepared Hcl, H_2S0_4 and Na_2So_4 solutions for 28 days for acid resistance tests. After curing, concrete specimens are taken out and tested for their strength properties and weight loss.

1. **For Compressive test:**
- 3 Cube specimens of Size (150x150x150mm)
- 3 Cubes for acid curing of size (100x100x100mm)

2. For Split Tensile test:
- 3 Cylinder specimens of size 300x150mm (Dia)
- 3 Cylinders for acid curing of size 150x100mm (Dia)

3. For Flexural test:
- 3 Beam specimens of size 100x100x500 mm

4. For in-plane shear strength through mode II fracture test:
- 3 In plane shear specimens of size 150x150x150 mm with notches of a/w =0.3, 0.4, 0.5, 0.6.

Table 2: Designation details of specimen.

Name of the mix	% Weight of bagasse ash	% weight of natural fine aggregate and robo sand		No of Specimens Cast and tested									
				Cubes				Cylinders				Beams	In plane shear cubes
		Natural aggregate	Robo sand	Normal curing	Acid Curing			Normal curing	Acid Curing				
					Hcl	H_2SO_4	NA_2SO_4		Hcl	H_2SO_4	NA_2SO_4		
D0	0%	100%	0%	3	_	_	_	3	_	_	_	3	12
D1	12%	100%	0%	3	3	3	3	3	3	3	3	3	12
D2		50%	50%	3	3	3	3	3	3	3	3	3	12
D3		0%	100%	3	3	3	3	3	3	3	3	3	12
Sum of Specimens for 28 days				12	9	9	9	12	9	9	9	12	48
Total Specimens =													138

6. Testing

6.1 Compressive Strength for Cubes:

Compressive strength test is performed by using digital CTM having a capacity of 2000 KN. Cubes are placed between the plates. Load is applied gradually at the rate of 140 $kg/cm^2/sec$ until the specimen fails. The ultimate loads are recorded. The results are tabulated in table 3 and graphed in fig .1

Table 3: Cube Compressive Strength Results

Mix	Percentage weight replacement of cement with Sugar cane Bagasse ash (%)	Percentage weight replacement of fine aggregate		Cube compressive strength in (N/mm^2)	Percentage increase of compressive strength (%)
		Natural Fine aggregate (%)	Robo sand (%)	28 Days	
D0	0	100	0	34.55	0
D1	12	100	0	36.37	5.27
D2		50	50	38.61	11.75
D3		0	100	37.90	9.70

6.2 Split Tensile Strength of Cylinders: Cylindrical specimens are kept horizontally such that its axis is parallel to the compressive plates of the CTM (3000 KN). A packing material i.e., plywood is kept in between the plates so that the cylinder to receive compressive load. Load is applied uniformly until the specimen fails by compression. Obtained results are tabulated below and graphically represented in fig 2.

Table 4: Split Tensile Strength of cylinder Results

Mix	Percentage weight replacement of cement with Sugar cane Bagasse ash (%)	Percentage weight replacement fine aggregate		Cylider Split Tensile strength in (N/mm$^{2)}$	Percentage increase of split tensile strength (%)
		Natural Fine aggregate (%)	Robo sand (%)	28 Days	
D0	0	100	0	3.1	0
D1	12	100	0	3.23	4.19
D2		50	50	3.60	16.13
D3		0	100	3.49	12.58

6.3 Flexural strength for Beams:

Flexural strength is also a measure of tensile strength of the concrete specimens. In this test two point loadings is adopted. Here deflections are obtained through dial gauges. The obtained test results are tabulated in Table 5 and values are presented graphical in fig 3.

Table 5: Flexural Strength of Beams

Mix	Percentage weight replacement of cement with Sugar cane Bagasse ash (%)	Percentage weight replacement fine aggregate		Beam Flexural strength in (N/mm$^{2)}$	Percentage increase of Beam flexural strength (%)
		Natural Fine aggregate (%)	Robo sand (%)	28 Days	
D0	0	100	0	3.64	0
D1	12	100	0	3.90	7.14
D2		50	50	4.35	19.51
D3		0	100	3.98	9.20

6.4 Mode-II Fracture test: To calculate the in plane shear strength the notched cube specimens using different notch depths are cast with size of specimen being 150x150x150mm. These DCN cubes are tested on 3000KN digital compression testing machine. Uniform load is applied over the central one third part between the notches, so that the central part gets punched through all along the notches. The test setup and its loading pattern is represented in following figure:

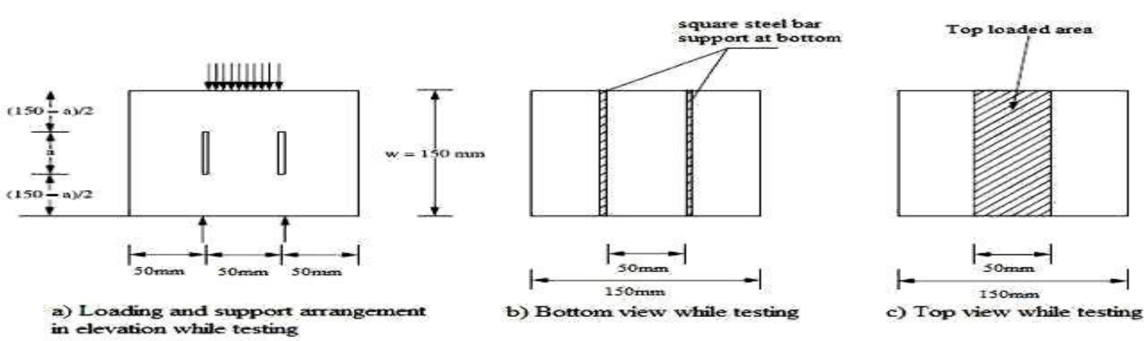

Plate1. Loading Diagram of Ultimate Shear DCN Specimens

In-Plane shear strength: In plane shear strength can be calculated by using given formula

In plane shear strength = $\frac{P}{2d(d-a)}$ N/mm^2

Here P= Ultimate load in mode II Shear

d = size of the cube = 150mm

a = depth of the notch in mm.

The obtained mode II fracture test results period of 28 days curing are shown in table 6(a) and table 6(b) respectively, and presented graphically in fig 4

Table 6(a): Ultimate Load (KN) and In Plane Shear Stress Results for a/w ratio 0.3 and 0.4

Name of the Mix	% weight replacement of Sugarcane Bagasse ash	No of Days	% weight replacement of robo sand (%)	a/w ratio = 0.3			a/w ratio = 0.4		
				Ultimate Load in KN	In Plane Shear Stress in N/mm^2	% increase in shear stress	Ultimate Load in KN	In Plane Shear Stress in N/mm^2	% increase in shear stress
D0	0	28	0	140.00	4.44	0.00	127.00	4.70	0.00
D1	12	28	0	144.00	4.57	2.95	134.67	4.99	6.13
D2			50	173.00	5.09	14.68	142.67	5.28	12.43
D3			100	153.33	4.87	9.64	139.00	5.15	9.53

Table 6(b): Ultimate Load (KN) and In Plane Shear Stress Results for a/w ratio 0.5 and 0.6

Name of the Mix	% weight replacement of Sugarcane Bagasse ash	No of Days	% weight replacement of robo sand (%)	a/w ratio = 0.5			a/w ratio = 0.6		
				Ultimate Load in KN	In Plane Shear Stress in N/mm^2	% increase in shear stress	Ultimate Load in KN	In Plane Shear Stress in N/mm^2	% increase in shear stress
D0	0	28	0	115.66	5.14	0.00	102.00	5.66	0.00
D1	12	28	0	125.33	5.57	8.37	106.00	5.89	4.06
D2			50	135.00	6.00	16.73	116.33	6.46	14.13
D3			100	128.33	5.70	10.89	108.00	6.00	6.01

6.5 Results of Concrete Specimens which are simultaneously cured in normal water and Hydro Chloric Acid, Sodium sulphate and sulfuric Acid solutions for 28 days are compared and tabulated below in table 7 and Table 8 and graphically presented in fig 5 and fig 6.

Table 7: Comparison in Compressive Strength of Cubes

Name of the Mix	Treated with	% weight replacement of cement by sugar cane bagasse ash	% weight replacement of fine aggregate		cube compressive strength in (N/mm^2)	% variation of compressive stress
			Fine aggregate (%)	Robo sand (%)	28 Days	
D1	Normal Water	12	100	0	36.37	0.00
D2			50	50	38.61	6.16
D3			0	100	37.9	4.21
D1	Na_2So_4	12	100	0	25.93	0.00
D2			50	50	28.2	8.75
D3			0	100	26.1	0.66
D1	HCL	12	100	0	14.67	0.00
D2			50	50	21.33	45.40
D3			0	100	15.23	3.82
D1	H_2SO_4	12	100	0	12.7	0.00
D2			50	50	15.73	23.86
D3			0	100	14.1	11.02

Table 8: Comparison in Split Tensile Strength of Cylinders

Name of the Mix	Treated with	% weight replacement of cement by sugarcane bagasse ash	% weight replacement of fine aggregate		Split Tensile strength in (N/mm^2)	% variation of Split Tensile stress
			Fine aggregate (%)	Robo sand (%)	28 Days	
D1	Normal Water	12	100	0	3.23	0.00
D2			50	50	3.6	11.46
D3			0	100	3.49	8.05
D1	Na_2So_4	12	100	0	3.03	0.00
D2			50	50	3.57	17.82
D3			0	100	3.28	8.25
D1	HCL	12	100	0	2.47	0.00
D2			50	50	3.26	31.98
D3			0	100	2.77	12.15
D1	H_2SO_4	12	100	0	2.57	0.00
D2			50	50	3.35	30.35
D3			0	100	2.71	5.45

6.6 Sorptivity test for Acid treated specimens:

Sorptivity is the measurement of capillary rise absorption rate on reasonably homogeneous material. Water is used as the test fluid. The specimens after removing out from the diluted acid solutions are placed in a glass tub with water level not exceeding 5mm for 30 min, taking the weight of the specimens before and after placing a specimen in glass tub containing water. By calculating the difference in weights will get the sorptivity values. The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t). From reference [6]

$I=S.t^{1/2}$ therefore $S=I/t^{1/2}$

Where, S = sorptivity in mm,

t =elapsed time in minutes,

$I = \Delta w/Ad$

Δw = change in weight = W_2-W_1

W_1 = weight before placing in water.

W_2 = weight after removing from water.

A = Surface area of the specimen through which water penetrated.

d = density of water.

The obtained sorptivity test results are tabulated in table 9(a) and table 9(b) and the values are presented in figure 7 and fig 8 in graphical form.

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

Name of the Mix	Name of Acids	% volume replacement of cement with sugarcane	% volume replacement of fine aggregate		Sorptivity value in $mm/min^{0.5}$
			Fine Aggregate (%)	Robo sand (%)	28 Days
D1	NA_2SO_4	12	100	0	0.0001551
D2			50	50	0.0002093
D3			0	100	0.0001473
D1	HCL	12	100	0	0.000659
D2			50	50	0.0009691
D3			0	100	0.0003101
D1	H_2SO_4	12	100	0	0.0002714
D2			50	50	0.0002869
D3			0	100	0.0001628

Table 9(b): Sorptivity test results for cylinders

Name of the Mix	Name of Acids	% volume replacement of cement with sugarcane	% volume replacement of fine aggregate		Sorptivity value in $mm/min^{0.5}$
			Fine Aggregate (%)	Robo sand (%)	28 Days
D1	NA_2SO_4	12	100	0	0.0001938
D2			50	50	0.0002714
D3			0	100	0.0001783
D1	HCL	12	100	0	0.0005039
D2			50	50	0.0005117
D3			0	100	0.0003877
D1	H_2SO_4	12	100	0	0.0002326
D2			50	50	0.0002714
D3			0	100	0.0002326

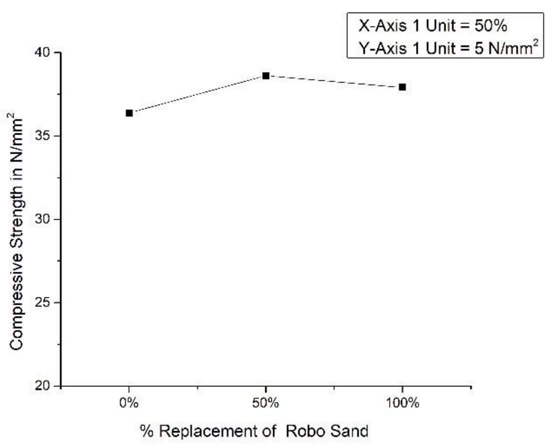

Fig 1: Compressive Strength of cube

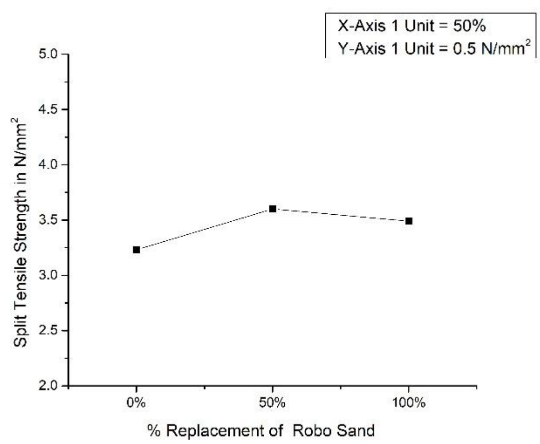

Fig 2: Split Tensile Strength of Cylinder

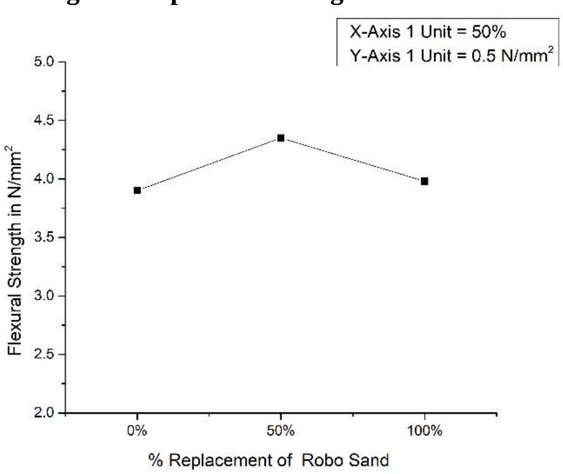

Fig 3: Flexural Strength of Beam

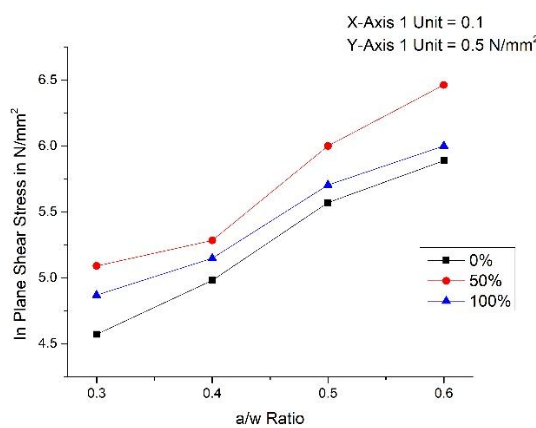

Fig 4: In-Plane Shear strength

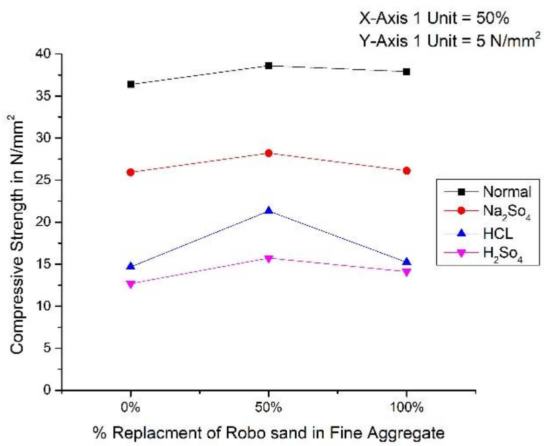

Fig 5: Compressive Strength of Acid Cubes

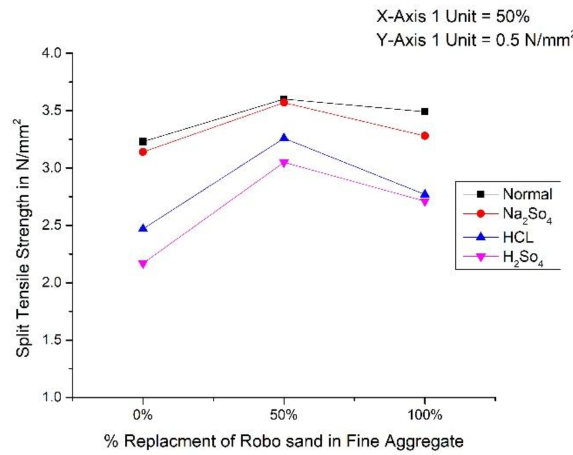

Fig 6: Split Tensile strength of Acid Cylinders

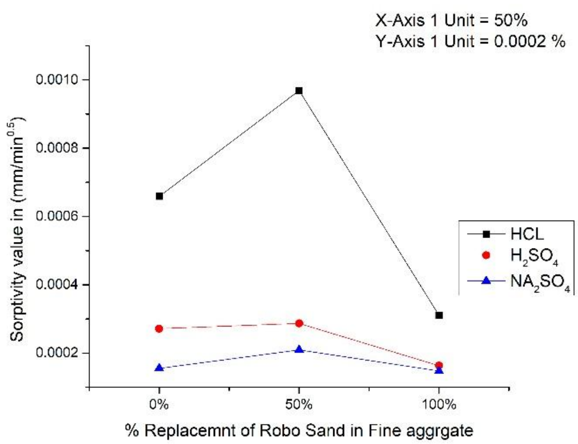

Fig 7: Sorptivity for Acid Cubes

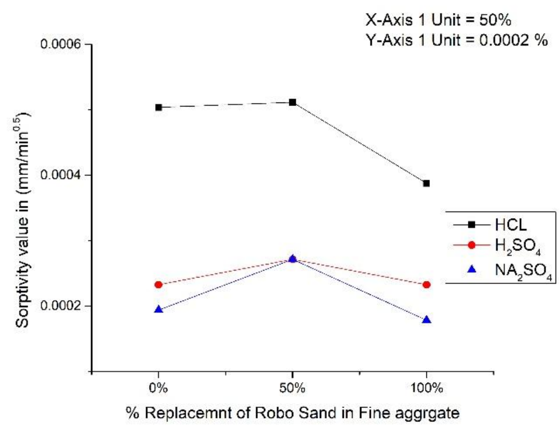

Fig 8: Sorptivity for Acid Cylinders

7. Discussion on Test Results

1. Influence of 12% sugarcane bagasse ash and robo sand on compressive strength:
From the compressive strength results given in table 3 and fig 1, it is observed that use of 12% sugar cane bagasse ash and 50% of robo sand replacing the natural fine aggregate there is 11 to 12 % increase in its strength after 28 days of curing. From this investigation it can be observed that for 50% replacement, optimum strength is obtained.

2. Influence of 12% sugarcane bagasse ash and robo sand on split tensile strength:
From the values of table 4 and fig 2, split tensile strength shows that there is increase of tensile strength about 15 to 16% for 28 days of curing. It clearly shows that by using robo sand and sugarcane bagasse ash replacements there is always increase of strength compared to conventional mix. Use of complete robo sand in fine aggregate shows little increase of 7%.

3. Influence of 12% sugarcane bagasse ash and robo sand on Flexural strength: From the results of table 5 and fig 3, flexural strength of beams with 50% robo sand and 12% sugar cane bagasse ash shows maximum increase of 19% is achieved for 28 days. Hence 50% of robo sand is acceptable for optimum strength.

4 Influence of 12% sugarcane bagasse ash and robo sand on Ultimate mode-II shear:
Double central notched specimens with different a/w ratios i.e., 0.3, 0.4, 0.5, 0.6 and with varying percentage of robo sand are tested with load in mode-II. From table 6a & 6b and fig 4 the percentage variation of shear stress with varying ultimate loads for 28 days of curing shows is found to increase from 0% to 50% of robo sand. Hence it can be concluded in DCN specimens for 50% replacement, optimum strength is obtained.

5. Influence of 12% sugarcane bagasse ash and robo sand on Acid treated specimens:
From the comparison of results of normal cubes and acid treated specimens from table 7&8 and fig 5 & 6, only 50% replacement of robo sand resists more deformation in Hcl, H_2SO_4, and Na_2SO_4 acids for 28 days of curing. It is also observed

that specimens treated with H_2SO_4 have lesser strength due to its more surface deformation. Therefore 50% replacement is more acceptable for all severe environmental exposure of concrete.

8. CONCLUSIONS

- From the present study it is possible for new generation of concrete with the use of robo sand and sugarcane bagasse ash in required proportions replacing fine aggregate and cement.
- From this study it is noticed that robo sand is one of the best alternatives to replace fine aggregate. It is clearly evident that 50% replacement has given good results in strength compared to all robo sand mixes. Robo sand has particles with angular shape which influences the finishing surface and strength of the concrete.
- When the acid treated specimens are tested, the compressive strength and split tensile strength in table 7&8 are found to decrease. From the present investigation it can be concluded that, the specimens with 50% replacement of robo sand has shown good resistance to acid treatment for M25 grade concrete.
- Use of sugarcane bagasse ash upto 12% and robo sand upto 50% increases strength and its durability properties. Hence 50% robo sand is acceptable for optimum strength.
- Replacement of sugarcane and robo sand in cement and fine aggregates, shows lower water absorption and lower sorptivity values.
- By using replacement of natural sand with robo sand and cement with sugarcane bagasse ash the cost of construction can be reduced to 10%.

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