STRENGTH OF SISAL FIBER CONCRETE WITH FINE CONSTRUCTION WASTE AGGREGATE

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Abstract

For long lasting of natural construction materials including natural sand and aggregate, due importance should be given for sustainable development in the construction field. As it is well known fact that concrete is hugely consumed by the humans for construction activities, making concrete as sustainable material is unavoidable. Although concrete has enough flexibility to use range of materials in its production, understanding performance of concrete with different materials is important for its end use. In the present investigation an effort was made to produce concrete with fine aggregate from construction waste and natural sisal fiber (instead of regular fibers like glass, carbon and polypropylene) and thereby to make concrete as more sustainable and environmentally friendly construction material. Concrete mixes were produced by replacing natural sand with fine construction waste in quantities of 20, 50, 80 and 100 per cent by weight of natural sand and added 1 per cent sisal fiber by weight of cement in all the mixes. The mixes were tested for fresh properties such as slump and strength properties such as compressive strength, split tensile strength and modulus of elasticity. This paper describes behavior of the concretes under the tests performed.

Keywords: *construction waste, sisal fiber, compressive strength and split tensile strength.*

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1. INTRODUCTION

Infrastructure development is important for countries like India to transform the country as developed. However, such development should emphasis on sustainable and environmentally friendly construction. As concrete is one of the predominant construction materials used in construction industry, making concrete as sustainable and environmentally friendly is unavoidable. Therefore, it is necessary to identify substitutes for concrete ingredients like cement and natural aggregates. In recent years, the use of recycled and secondary aggregates (RSA) has become increasingly important to sustainable construction by reducing demand for primary aggregates in few parts of the world [1]. Although coarse aggregate-sized RSA are successfully used to replace primary aggregates to produce normal weight concrete [2-4], the silt/sand-sized phase is problematic owing to its high water absorption and particle shape. Therefore, there is a need for study to overcome problems associated with recycled fine aggregates when used in concrete production. It is well known fact that plain concrete is brittle. Addition of fibers in concrete can decrease brittle fracture of concrete. Many researchers used different fibers like steel, glass, carbon and polypropylene in concrete to understand behavior of concrete [5]. Sisal fiber is a natural fiber and is very easily cultivated. It has short renewal times and grows wild in the hedges of fields and railway tracks. Furthermore, in comparison to the most common synthetic reinforcing fibers, natural fibers require less energy to produce and are the ultimate green products. Therefore, using such natural fiber in concrete in place of regular fibers could be an alternate option to improve ductility of concrete. In the present investigation an effort was made to produce concrete with fine aggregate from construction waste and natural sisal fiber (instead of regular fibers like glass, carbon and polypropylene) and thereby to make concrete as more sustainable and environmentally friendly construction material.

2. MATERIALS AND MIX PROPORTIONS

The constituent materials used in this investigation were procured from local sources. Ordinary Portland cement of C53 grade conforming to the requirements of IS: 12269 were used. Class F fly ash conforming to IS: 3812–2003 was used. Chemical composition and physical properties of both cement and fly ash is presented in Table 1. Well-graded river sand finer than 4.75 mm was used. Crushed blue granite of maximum size of 20 mm and 12mm aggregate types was chosen as coarse aggregate. Coarse and fine aggregates were suitably proportioned to obtain well graded combined grading. Locally available potable water was used for mixing and curing. Construction waste was collected locally, the waste was from demolition of a building and it was exclusively from demolition of cement brick wall of a building (Figure 1). The waste was sieved through 4.75 mm, the material retained on the sieve was discarded and material passing through the sieve was considered for mix proportions. Sieved construction waste was then tested for properties like aggregate grading, specific gravity and water absorption. Grading, water absorption and specific gravity of the aggregates is shown in Table 2. Locally available manual processed sisal fiber was used for the investigation (Figure 2). Sisal fiber was chopped into 20-25mm pieces and used for the investigation.

Table 1 Composition & Specific Gravity of the Materials

Chemical Composition (%)	Cement	Fly Ash
SiO_2	21.8	58.3
$Al_2 O_3$	6.6	31.7
$Fe_2 O_3$	4.1	5.9
CaO	60.1	2
MgO	2.1	0.1
$Na_2 O$	0.4	0.8
$K_2 O$	0.4	0.8
SO_3	2.2	0.2
Others	-	-
LOI	2.4	0.3

The Specific gravity of cement and fly ash was 3.15, 2.0.6 respectively

Fig 1 Demolition waste (i) landfill site and (ii) sieved material

Table 2 Properties of Aggregates

Sieve Size (mm)	Cumulative Percentage Passing		
	Coarse Aggregate Grading	Fine Aggregate Grading	Grading of Demolition Waste
20	100	-	-
10	97.83	-	-
4.75	96.79	100	100
2.36	92.32	98	99.44
1.18	76.78	83	89.01
0.6	50.88	32	57.19
0.3	18.61	8	11.6
0.15	3.84	3	1.9
Pan	0	1	0
SSD density	2.71	2.62	2.25
Water absorption, %	0.5	1.0	16

Fig 2 Manual processed sisal fiber

3. MIX PROPORTIONS

Six mixes were employed to understand behavior of recycled fine aggregate concrete with sisal fiber. The mix proportions are presented in Table 3. Before selecting final mix proportions, several trial mixes were employed to arrive at suitable w/c ratio for cement content of 350kg/m3 and for well graded all-in-aggregate. From the trial mixes it was noticed that effective w/c ratio of 0.6 would be suitable for uniform concrete mix. Apart from effective water, extra water was added to the concrete mixes based on aggregate water absorption value to bring the aggregates to SSD condition. Natural sand replaced with demolition waste in 20, 50, 80 and 100%. Sisal fiber was kept constant at 1% of cement weight in all the mixes.

Table 3 Concrete Mix Proportions

Mix	Cement (kg/m^3)	Coarse Aggregate (kg/m^3)		Sand (kg/m^3)	Demolition Waste (kg/m^3)	Sisal Fiber (kg/m^3)
		20 (mm)	12 (mm)			
M1	350	756	863	431	0	0
M2	350	756	863	431	0	3.5
M3	350	756	863	344	86	3.5
M4	350	756	863	215	215	3.5
M5	350	756	863	86	344	3.5
M6	350	756	863	0	431	3.5

3.1 Mixing, Compaction, Specimen Preparation and Curing

The concretes were mixed in a planetary mixer of 100 l capacity. The mixing time was kept to about 3–4 min. Mixing of the materials was in a sequence: (i) a portion of design water poured into the mixture drum; (ii) coarse aggregate placed and spread to the boundaries of the mixture drum; (iii) cement and fly ash gently placed over the aggregate; and (iv) sand spread over the powder, after which, started mixing. During mixing, the remaining design water poured into the mixture so that the concrete ingredients could combine thoroughly. After thorough mixing of these materials for 4 to 5 minutes sisal fiber was added such that, the fiber spread uniformly in the concrete mixes. Specimens were then prepared by placing fresh concrete into the moulds. The moulds were covered with wet gunny bags to prevent water loss and kept for 24 h. The specimens were removed from moulds after 24 h and immersed in normal water for curing until the test age. The hardened properties of the concretes discussed in this paper for 1, 7 and 28 days of normal water curing.

4. TEST PROGRAM

The main objective of the present investigation was to develop concrete with fine aggregate from demolition waste with sisal fiber and with no chemical admixtures in the mixes and study performance of the concretes. The performance of the concretes was assessed through: fresh properties, compressive strength, split tensile strength and stress strain behavior.

4.1 Properties of Fresh Concrete

Visual inspections were conducted to assess appearance, segregation and uniformity in the concretes during mixing and compaction. Furthermore, broken compression and split tensile test specimens were also inspected for evaluating fresh concrete parameters such as segregation; uniformity in the mixes and fiber distribution in the concretes. Workability of the concretes was assessed based on slump test.

4.2 Compressive Strength Studies

The compressive strength test on the concretes was conducted on a compression testing machine of capacity 2000 kN. For the compressive strength test, a loading rate of 2.5 kN/s was applied as per IS: 516–1959. The test was conducted on 100mm cube specimens. The test was performed at 1, 7 and 28 days. The specimens were completely water cured until test age. The specimens were then tested immediately after taking the cubes from curing tank in wet condition.

4.3 Split Tensile Strength

Split tensile strength test was conducted in accordance with IS5816. Cylinders of 100 x 200 mm size were used for this test, the test specimens were placed between two platens with two pieces of 3 mm thick and approximately 25 mm wide plywood strips on the top and bottom of the specimens.

4.4 Stress Strain Behavior

Stress strain behavior of the concretes was conducted in according to ASTM C-469.Two cylinders of size 100 x 200 mm were tested for each concrete mix to get the stress-strain relationship. The cylinders were cured in normal water up to age of testing. The loading surfaces of the cylinders were made plane by grinding to have uniform contact to the loading plates and thereby to have uniform load distribution on the testing specimen. The axial deformation was measured by a longitudinal compressometer.

5. RESUSTS AND DISCUSSION

5.1 Fresh Properties

Fresh properties of the concretes were assessed based on visual observations and through slump test. During mixing and mould preparation visual observations were carried out. From the observations it was noticed that the mixes were uniform and has no bleeding. It was also observed that sisal fiber distributed uniformly within the mix. Slump values shown in Table 4 suggest that there is no marked difference in workability with addition of demolition waste in sisal fiber concrete mixes, when compared with the normal concrete. The mixes were easily compactable. Smooth surface finish was noticed on hardened concrete specimens, no honeycombing Structure was observed in any of the specimens. Distribution of sisal fiber in hardened concretes was examined on failure specimens of compression and split tensile strength, the observations suggests that the sisal fiber uniformly distributed across the specimens in all the concretes.

Table 4 Properties of Sisal Fiber Concrete

Mix	Slump Value (mm)	Comp Strength (N/mm2)			Split Tensile Strength (N/mm2)		
		1d	7d	28d	1 d	7 d	28d
M1	60	5.90	8.70	26.50	0.89	1.59	1.85
M2	78	6.44	9.50	28.93	0.72	1.38	1.99
M3	3 71	9.99	14.98	31.02	0.88	1.83	2.08
M4	73	10.5	17.12	35.95	1.00	2.04	2.23
M5	78	6.76	13.08	31.48	0.57	1.61	1.66
M6	85	6.73	13.78	25.78	0.37	1.59	1.31

5.2 Compressive Strength

The results obtained for compressive strength test for 1, 7 and 28 days are shown in Table 4. When compared M1 and M2 it can be noticed that addition of sisal fiber increases compressive strength of normal concrete, this can be attributed to composite action that exists such that the fibers bridge the matrix cracks and transfer the loads, allowing a distributed micro crack owing to tensile nature of sisal fiber. Furthermore, use of demolition waste in sisal fibre concrete increased compressive strength upto 80 % replacement and at 100 % replacement the compressive strength decreased. From the result it is clear that maximum strength can be obtained at 50 % replacement, suggesting optimum demolition waste replacement. Increased strength with fine Demolition waste in concrete was also reported by Jones et al (2012) [6]. Strength of all the concretes increased with curing age. The strengths at 28 days are 3.11 – 4.65 times higher than corresponding concretes one day strengths. Maximum rate of strength gain is observed for M5 concrete.

5.3 Split Tensile Test

The results obtained for split tensile strength test for 1, 7 and 28 days are shown in Table 4. When compared M1 and M2 it can be noticed that addition of sisal fiber also increases split tensile strength of normal concrete, as in compressive strength. Demolition waste in sisal fiber concrete increased split tensile strength upto 80 % replacement and at 100 % replacement the split tensile strength decreased. From the result it is clear that maximum strength can be obtained at 50 % replacement, similar to that of compressive strength of all the concretes increased with curing age. The strengths at 28 days are 2.08 – 3.54 times higher than corresponding concretes one day strengths. The maximum rate of strength gain is observed for M6 concrete. On the whole the split tensile strength behavior of the concretes is in line with the compressive strength.

5.4 Bond between Fibre and Concrete Matrix

Bond between the sisal fiber and concrete matrix was assessed on the specimens failed in compression and split tensile strength tests. The bond strength was arbitrarily assessed by pulling the exposed fibers with fingers on surfaces of failed specimens. Few fibers were broken suggesting a good bond between the matrix and few fibers slipped from the matrix could be due to weak bond or insufficient embedded length of fiber. Further research is clearly needed to understand bond between sisal fiber and concrete matrix.

5.5 Stress Strain Relationship

Stress strain behavior of the concretes was assessed after 28days of normal water curing. Stress strain behavior of the concretes is shown in Table 5. From the table it can be observed that for lower strength concretes M5 and M6 at same stress higher strains were recorded when compared with higher strength concretes.

Table 5 Stress Strain Behavior of the Concretes

Stress	Strain, x10-4					
(MPa)	M1	M2	M3	M4	M5	M6
3.18	0.5	0.4	0.9	0.9	1	1.1
6.37	0.9	0.9	1.4	1.6	2	2.5
9.55	1.4	1.6	2.7	2.3	3	3.2
12.73	1.9	2.6	3.9	4.2	4	4.6
15.92	2.4	3.8	4.9	5.8	5.2	4.9
19.10	3	4.8	5.8	7.2	7.8	8.2
22.28	5.2	6.8	7.15	9	9	9.2
25.46	6.2	7	8	11.2	11	11.2
28.65	-	8.5	9.5	12.6	13.8	-
31.83	-	-	-	14	-	-

6. CONCLUSION

The data show that use of sisal fiber improves concrete properties and fine demolition waste with simple process can be used in place of natural sand in concrete production. Addition of sisal fiber and demolition waste has no influence on workability of the concretes. Sisal fiber in concretes increased performance of the concretes. Addition of fine recycled demolition waste in place of natural sand improved strength up to 50 % replacement. Furthermore, it was possible to get nearly equal strength as that of normal concrete up to 80 % replacement.

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BIOGRAPHIES

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