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Civil Engineering Journal

Vol. 3, No. 7, July, 2017

Mechanical Behavior of Normal Concrete Reinforced with Kantharo Suter Fiber

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Received 16 June 2017; Accepted 29 July 2017

Abstract

Physical characteristics of concrete can be enhanced by addition of different materials in various proportions. Fibrous substances, such as, steel, synthetic, glass, and natural fibers not only increase the structural and tensile strength but also cohesion of concrete by overcoming micro cracks and deficiencies in concrete. In this study, the effect of Kantharo suter fibers (animal hair) on compressive, flexural and split tensile strength, and workability of plain concrete was determined. For that, experiments were conducted on concrete cubes, beams and cylinders by adding different proportions of Kantharo suter fibers from 0.125 to 1.0 percentage by weight of cement. In each proportion of Kantharo suter fibers, three cubes, three cylinders and one beam were casted and cured for 28 days. The acquired results were compared with the plain cement concrete specimens. It was discovered from the results that 0.375 percentages of Kantharo suter fibers in normal concrete was optimum by weight of cement. The strength parameters and slump of concrete showed better results than control mixes even without using any admixture in the specimens. This study could also be enhanced using combinations of different fibers and other admixtures.

Keywords: Kantharo Suter Fiber; Slump Test; Strength; Fiber Reinforced Concrete; Curing.

1. Introduction

Concrete is the mixture of cement, water and aggregates. It is one of the most useful structure materials in all over the world. In early times, the stone and bricks were the common construction materials before introduction of concrete. At present, concrete is the only material preferred in every type of construction. Biological fibers, in recent times have become noticeable to researchers as substitute reinforcement for fiber reinforced polymer (FRP) complexes, due to their low-cost, acceptable properties and satisfactory strength [1]. The lesser weight and superior volume of the biological fibers as compared to the synthetic fibers improve the fuel competence and reduced discharge in auto application [2]. In contrast, there are some serious flaws in concrete, such as low tensile strength, flexural strength and micro-cracks. Such deficiencies in concrete can be reduced by adding different types of fibers in concrete.

Fiber reinforcement in concrete increases its tensile strength, resist post cracking capacity, and lower brittleness. Fiber reinforced concrete could be classified on the basis of type of fiber used, such as, steel fiber reinforced concrete, sisal fiber reinforced concrete, coconut fiber reinforced concrete, glass fiber reinforced concrete, oil palm trunk fiber reinforced concrete etc. Such fibers alter the properties of normal concrete. The properties includes the prevention of the cracking due to both plastic and dry shrinkage, reduction in the permeability (prevents the bleeding of concrete),

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accumulates greater impact and abrasion in concrete. Moreover, the fineness of fibers helps to reinforce the concrete strongly and thus reduces the formation and propagation of cracks, which ultimately improve the surface characteristics of concrete [2-8].

2. Literature Review

Thin threads of natural or artificial material typically used to make some other materials like cloth, paper, etc. are called fibers. The fibers obtained from natural sources are called natural fibers. For example, hair fiber, jute fiber, akwara fiber, sugarcane bagasse fiber, palm oil trunk fiber, cotton fiber etc. are natural fibers. On the other hand, the fibers got from artificial means are known as artificial fibers, which include steel fibers, glass fibers, and carbon fibers. In this study, fiber reinforced concrete was prepared from Kantharo suter fiber as shown in Figure 1. Kanthatro suter fibers are categorized as natural fibers, as these are obtained from natural source i.e., animals. Animal fibers are obtainable as silk, hair/fur (including wool) and feathers. These are commonly used as wool in industries. The local meaning of word Kantharo is "goat" and word suter means "treated hair of goat". It can generally say that Kantharo suter fibers are "hair of goat". Most goats have softer insulating hairs over the skin. In South Asia, cashmere is called "pashmina" (from Persian pashmina, "fine wool"). These fibers are attainable in large quantities at an affordable price (at Rupees 10/kg) due to local availability in Pakistan. These are commonly washed and dried after being removed from the body of goat, and then cut into desired lengths and finally mixed into concrete as reinforcing agent [3-17].

Various studies have been conducted on the strengthening of concrete in the world using different materials; a few related works are given below. Shende et al. [3] examined mechanical properties of concrete using steel fibers as reinforcing agent. Steel fibers were used in concrete specimens up to 3% with an increment of 1% in each mix. The compressive strength of concrete cubes was found increased from 11% to 24%, split tensile strength of cylinders from 3% to 41% and flexural strength of beams from 12% to 49%. Mohod [4] used concrete cubes with the size of 150mmx150mmx150mm and beams with size of 500x100x100mm. These were casted with steel fiber content of 0.25%, 0.50%, 0.75%, 1%, 1.5% and 2% by volume of cement. The compressive strength of cubic specimens was found increased when the fibers were utilized up to 1% as compared to other added percentages. The flexural strength was found increased by adding fibers up to 0.75% as compared to other added percentages of fibers. It was established from the results that the specimens without steel fibers cracked quickly, whereas, the addition of fibers prevented it from the development of cracks. Shweta and Kavilkar [5] examined the behavior of fibers on strength parameters of specimen using different percentages of steel fibers from 0.5 to 2.5% by volume at an interval of 0.5%. The flexural strength of concrete was found increased significantly with the addition of steel fibers up to 1.5%. Its value was increased from 36.7% to 58.65% as compared to specimens casted without addition of fibers. Rahuman and Yeshika [6] used sisal fibers as reinforcement in concrete specimens to examine the effect of sisal fibers on workability and strength properties. Different mix proportions with different fiber percentages were casted for M-20 grade concrete specimens. A reduction in workability was noted with the increase of sisal fibers in mixes. However, compressive strength was found increased up to 50.53% as compared to control mixes with the addition of 1.5% fibers. Moreover, an increment of 3.41% in tensile strength was also observed. Garcia-Taengua [7] developed steel fiber reinforced concrete (SFRC) by adding steel fibers and rebar in concrete specimens. Different numbers of fiber slenderness and length were used to modify the effect of fiber content in the specimens. The results showed the increase of bond strength. In addition, the shorter fibers were found more effective in bond strength than the longer ones at the same fiber content. Ladole [8] used glass fibers as reinforcing agent in M-20 grade concrete mixes. The addition of fibers results the reduction in the workability of concrete and increment in its strength. The compressive strength escalated up to 29.33%, flexural strength 30.84% and split tensile strength 29.75% as compared to specimens without fibers.

Ravikumar et al. [9] observed that the blending of steel fibers and stirrups have a positive combined effect on the ultimate load, ductility and failure pattern of concrete beam. Zerrouk et al. [10] used human hair to reinforce cemented and un-cemented clayey-sand soils and to find out the ductility and strength parameters of soils. The properties of soils were improved with addition of hair fibers. Jain & Kothari [11] studied the effect of human hair on strength parameters of plain cement concrete. Investigations were made on concrete beams and cubes with various proportions of human hair fiber, like 0%, 1%, 1.5%, 2%, 2.5% and 3% by weight of cement. An increase of 22% in compressive strength and 8.6% in flexural was observed when 1.5% hair fibers were added in the amount of cement for M15 grade of concrete. Ahmad et al. [12] examined the influence of human hair and coconut fibers in mortar specimens. The addition of 4% and 6% coconut fibers showed better strength after 3 days and 28 days of curing at room temperature respectively, whereas the use of human hair up to 2 % gave higher strength. However, further increase of human hair fiber into the mix exhibited reduction in compressive strength in all mortar mixes. Patil and Harini [13] used human hair fibers in stability of soils. It was found by the authors that the addition of slight percentage of human hair fibers improving the strength of clayey soils. Moreover, the increase of fiber content increases the moisture content of soils might be due to absorption of moisture by the hair fibers. Gopi and Sateesh [14] added human hair fiber in M-35 grade of concrete to improve the stability of soil. The addition of 0.2% fiber was found suitable for improving stability of soils due to increase of its compressive, flexural and split tensile strengths. The compressive were found increased up to 8.18% and split tensile strength up to 26.88% after 28 days curing period as compared to mixes having no fibers.

Acda [15] employed waste chicken feather as reinforcement material in cement-bonded composites using various proportions of waste feather, cement, sand, and chemical admixtures. The workability of mixes was found decreasing with the increase of feathers proportion. The addition of 5% to 10% fiber/feathers by weight in mixes showed better strength properties. However, the flexural strength, modulus of elasticity and stiffness of the mixes were found decreased with the increase of feathers beyond 10%. Al-Mosawi [16] evaluated the mechanical properties of hybrid Palms-Kevlar fibers composites. Both fibers were incorporated in one mix with epoxy resin in different percentages ranging from 10% to 80%. The improvement in the impact, tensile and flexural strengths, and hardness were found with the addition of fibers as compared to composites without fibers. Gokulram and Anuradha [17] investigated the compressive, split tensile and flexural strengths of concrete composites reinforced with polypropylene fibers and supplementary cementing materials (SCMs). Polypropylene fibers with vol. fraction of 0.25% of total volume of concrete batch were added in the concrete specimens. The addition of fibers was found effective to reduce the shrinkage and brittleness of concrete.

It is discovered from the review that the mechanical properties of concrete can be improved and enhanced by addition of fibers of different types. Since Kantharo suter fiber is a locally available material in huge quantities at affordable price. It is not even examined for the improvement of concrete properties in Pakistan. Therefore, this study was conducted to examine the influence of Kantharo suter fiber in the modification of mechanical properties of concrete.

Figure 1. Pictorial view of Kantharo suter fibers

3. Materials and Methods

The experimental work was performed on the concrete incorporated with different proportions of Kantharo suter fibers. All tests were carried out under the recommendation of relevant ASTM standards in the Department of Civil Engineering, Mehran University of Engineering and Technology Jamshoro. The material used, methodology adopted and test specimens are discussed below.

3.1. Materials Used

- **Ordinary Portland Cement:**

Ordinary Portland cement (OPC) class of Lucky Cement Factory Pakistan confirming EN 196/197– 1, SABS, BIS, SLSI & PSS–232~1983 (R) [21] was purchased from local market of Jamshoro town.

- **Aggregates:**

The aggregates used in concrete, confirming the ASTM C33 and C136. Crushed hill sand of size less than 4.75mm and more than 0.075mm was used as fine aggregates and coarse aggregates size ranges from 4.75mm-20mm. The grading curve of aggregates is shown in Figures 2 and 3. The specific gravities of fine and coarse aggregates were measured as per ASTM C127 and C128 standards respectively. The measured specific gravities of fine aggregates were 2.60 and coarse aggregates were 2.62.

- **Water:**

Potable water was used for mixing of ingredients, hydration of cement and curing purposes.

- **Fibers:**

Kantharo suter fiber was purchased from district Tharparkar, Sindh. These were cut in the length of 5cm-7cm and mixed in concrete with different percentages by the weight of cement.

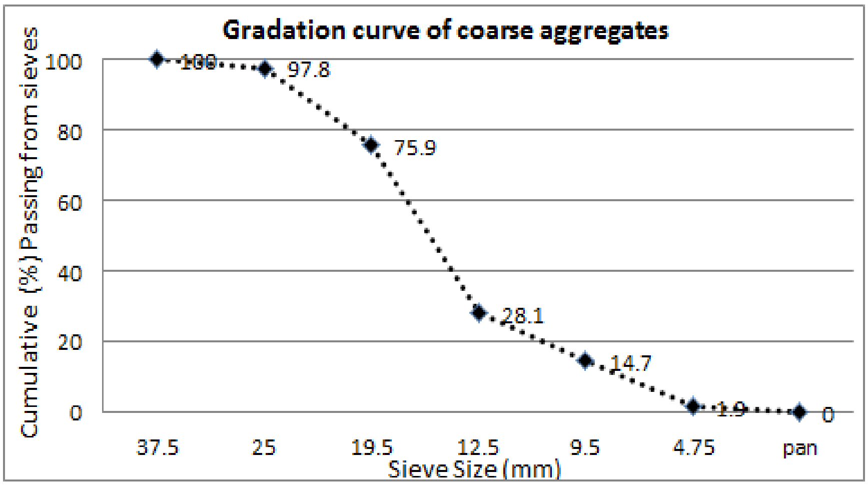

Figure 2. Gradation curve of coarse aggregates

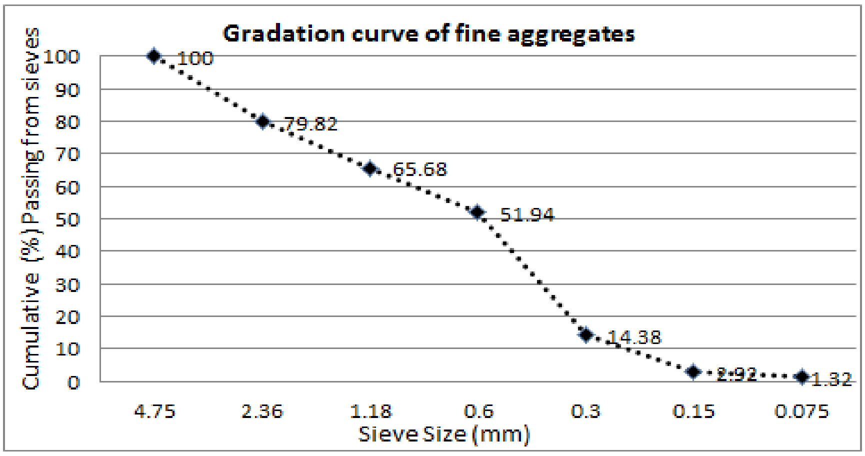

Figure 3. Gradation curve of fine aggregates

3.2. Research Methodology

The experimental work was carried out with different batch proportions by weight of ingredients. The ingredients of concrete were grouped on the ground in the laboratory. The required amounts of ingredients were first calculated from the mix design and then these were weighed separately in the laboratory for making batch of ingredients. The concrete mix was designed according to B.S code for compressive strength of 3000 psi after 28 days. The concrete mix proportion used was 1:1.28:3.28 with water/cement ratio of 0.55. The weighing was done by automatic weight balance available in the concrete laboratory. After weighing the ingredients of normal concrete, these were mixed in mixer for two (02) minutes in dry state. A total of nine mix batches were prepared for this work. Among them one batch was made without using fibers, known as control mix batch. In remaining eight batches, the fibers were used in different proportions, such as, 0.125%, 0.25%, 0.375%, 0.50%, 0.625%, 0.75%, 0.875% and 1.0% of by weight of cement. The detailed mix design is tabulated in Table 1. A total of twenty seven (27) numbers of cubes were casted from the above nine mix IDs, and three (03) numbers of cubes from each mix ID. Likewise, twenty seven (27) numbers of cylindrical specimens were casted from above nine mix IDs, and three (03) numbers of cylinders from each mix IDs. Besides, a total of nine (09) numbers of beams were casted from the above nine mix IDs, and one (01) beam from each mix ID.

Slump test was carried out to examine the workability of concrete mixes. After determining fresh properties, the molding process was carried out. Casting of test specimens was done as per ASTM C192. Before placing the concrete in molds, these were oiled so that these should not get patched with concrete. The concrete was placed in each mold with three layers and was compacted by compacting rod of diameter equal to 2.5cm and length 30cm. Twenty five (25) blows were applied in each layer for compaction. After that, the concrete specimens i.e. cubes, cylinders and beams were kept in concrete laboratory hall for setting and hardening up to 24hours. On the next day, all specimens were placed in water up to 28 days for curing purpose. Special care was taken during placement and movement of specimens so that these should be safe. After 28 days of curing periods, these were taken out from water and then strength parameters (compressive strength, split tensile strength and flexural strength) of specimens were determined. The compressive strength of cubic specimens were determined as per BS EN 12390-2: 2009/ BS EN 12390-3:2009, the split tensile strength as per ASTM C496 and flexural strength as per ASTM C78. All concrete specimens were casted without adding any special type of admixtures.

Table 2. Mix proportion for different concrete specimens

Specimens	Ingredients	Kantharo suter fiber/ hair used in mixes (%)									Specimens ratio	w/c ratio
		0	0.125	0.25	0.375	0.50	0.625	0.75	0.875	1.0		
		Wt. of different ingredients used in concrete specimens (grams)										
Cubes (6"x6"x6")	Cement	1760	1760	1760	1760	1760	1760	1760	1760	1760	1:1.28:3.28	0.55
	F.A	2240	2240	2240	2240	2240	2240	2240	2240	2240	1:1.28:3.28	0.55
	C.A	5700	5700	5700	5700	5700	5700	5700	5700	5700	1:1.28:3.28	0.55
	Hair/fiber	0	2.20	4.40	6.60	8.80	11.00	13.20	15.40	17.60	1:1.28:3.28	0.55
Cylinders (6"x12")	Cement	2760	2760	2760	2760	2760	2760	2760	2760	2760	1:1.28:3.28	0.55
	F.A	3530	3530	3530	3530	3530	3530	3530	3530	3530	1:1.28:3.28	0.55
	C.A	9080	9080	9080	9080	9080	9080	9080	9080	9080	1:1.28:3.28	0.55
	Hair/fiber	0	3.45	6.90	10.35	13.80	17.25	20.70	24.15	27.60	1:1.28:3.28	0.55
Beams (24"x6"x6")	Cement	7000	7000	7000	7000	7000	7000	7000	7000	7000	1:1.28:3.28	0.55
	F.A	10000	10000	10000	10000	10000	10000	10000	10000	10000	1:1.28:3.28	0.55
	C.A	23000	23000	23000	23000	23000	23000	23000	23000	23000	1:1.28:3.28	0.55
	Hair/fiber	0	8.75	26.25	35.00	43.75	52.50	61.25	70.00	78.75	1:1.28:3.28	0.55

Figure 4. Fresh state of concrete when Kantharo suter fibers were added in mix

Figure 5. Slump test of fresh concrete

4. Results and Discussion

4.1. Compressive Strength of Cubes

A total of twenty seven (27) cubes were casted, among these 24 cubes were casted by adding eight (08) different percentages of fibers and three without any fibers. The results were recorded to see effect of Kantharo sutter fibers on compressive strength of specimens. The average compressive strength of cubes is shown in Table 3. and Figures 6 and 7. The bar chart between compressive strength and fiber percentage indicates the increase in compressive strength up to the 0.375% of fiber, and then keeps on decreasing with increase in percentage of fibers in the mixes. The optimum results were got at 0.375% fibers by weight of cement, which was 33.34 MPa as compared to control mix specimen of 20.9 MPa.

Table 4. Average compressive strength of cubes

Sr. No.	Fibers (%)	Avg. load (N)	Avg. compressive strength (N/mm^2)	Avg. compressive strength (Psi)
1	0.000	484964	20.90	3031
2	0.125	590564	25.43	3689
3	0.250	682030	29.34	4256
4	0.375	775460	33.34	4836
5	0.500	692383	29.81	4324
6	0.625	655700	23.49	3407
7	0.750	469940	20.23	2935
8	0.875	439617	18.92	2745
9	1.000	414697	17.85	2589

Figure 6. Compressive strength test of cubic specimens under UTM

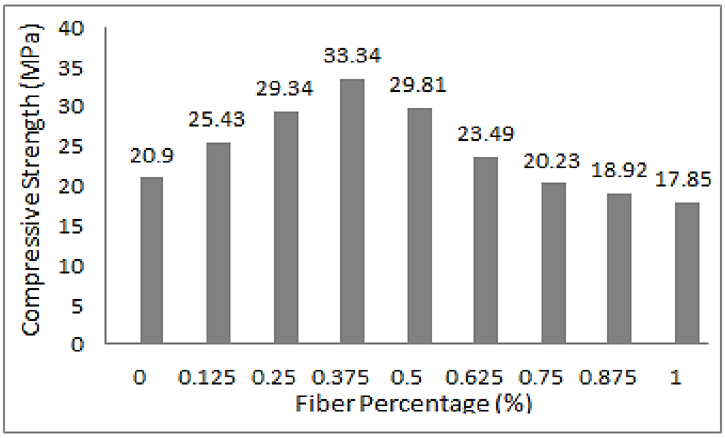

Figure 7. Compressive strength versus fiber percentage in specimens

4.2. Split Tensile Strength of Cylinders

Effect of fiber is also seen in tensile strength of concrete specimens. For this purpose, a total of twenty seven (27) cylindrical specimens were casted, among these 24 with 8 different percentages of fiber and 3 without any fibers were casted. The average split tensile strength of cylinders is shown in Table 5. and Figure 8. The bar chart between split tensile strength and percentage of fiber indicate increase in split tensile strength up to 0.375% of fiber and then decrease in split tensile strength with increase in percentage of fiber. The optimum results were obtained at 0.375% of fiber by weight of cement. Its value was 40% more than the split tensile strength of normal concrete.

Table 6. Average split tensile strength of cubes

Sr. No.	Fibers (%)	Avg. load (N)	Avg. split tensile strength (N/mm^2)	Avg. split tensile strength (Psi)
1	0.000	161917	2.22	322
2	0.125	183447	2.51	365
3	0.250	206040	2.82	409
4	0.375	233370	3.12	452
5	0.500	197383	2.72	392
6	0.625	181217	2.48	360
7	0.750	156723	2.14	310
8	0.875	145770	1.99	289
9	1.000	117493	1.61	233.5

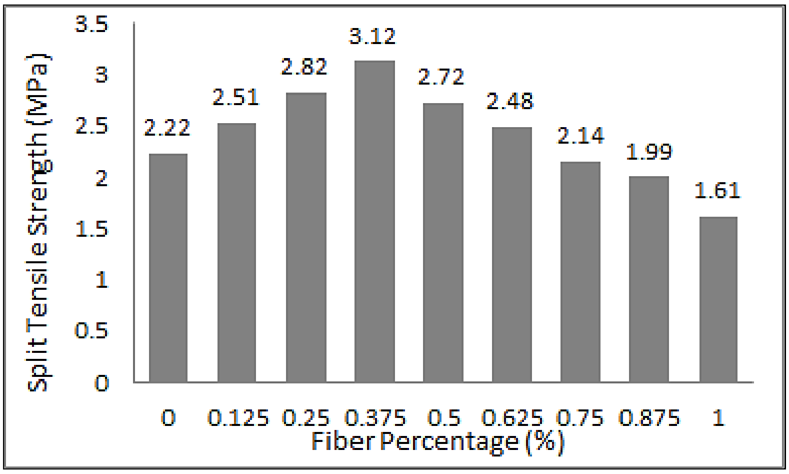

Figure 8. Split tensile strength versus fiber percentage in specimens

4.3. Flexural Test of Beams

A total nine (9) beams were casted for flexural test of beams. Among these, 8 beams were casted with 8 different percentages of fibers and 1 beam without any fibers. The results were recorded by applying two point loads at one feet c/c distance. The results of flexural test of beams casted with different proportions of hairs are given in Table 7. and Figure 9. The bar chart between flexural strength and percentage of fiber shows increase in flexural strength with increase in percentage of fiber up to 0.375% and then decrease in flexural strength with further increase in percentage of fibers from 0.375%. The rise of curve indicates increase in flexural strength with increase of percentage of fiber. The optimum results were obtained at 0.375% fiber by the weight of cement. It indicates 9% more value than flexural strength of normal concrete.

Table 8. Flexural test of beams casted with different proportions of hairs/fibers

Sr. No.	Fibers (%)	Failure load (N)	Flexural strength (MPa)	Flexural strength (Psi)
1	0.000	17524	3.01	436.5
2	0.125	18260	3.14	455.4
3	0.250	18780	3.23	468.5
4	0.375	19180	3.30	478.6
5	0.500	17800	3.06	443.8
6	0.625	16260	2.80	406.1
7	0.750	15400	2.65	384.3
8	0.875	15200	2.61	378.5
9	1.000	14760	2.54	368.4

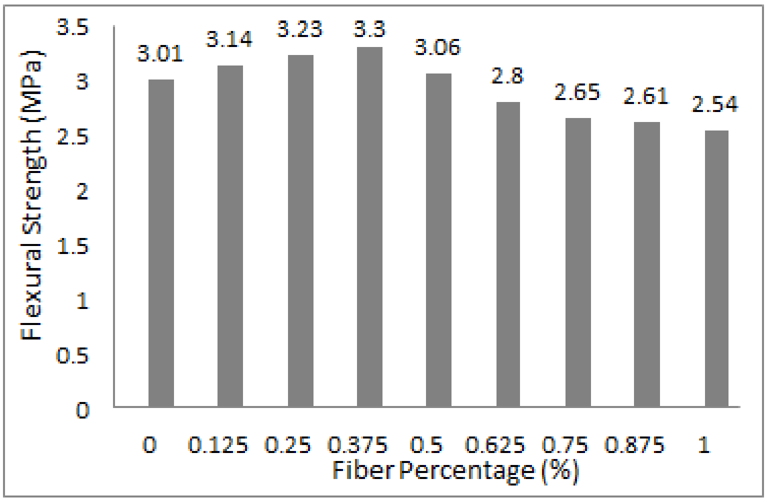

Figure 9. Flexural strength versus fiber percentage in specimens

4.4. Slump Test

Slump test of each sample was done and was seen that with increase in percentage of fibers there was a decrease in slump value. Hence it was observed that the fibers used in the specimens were beneficial as because of reduction in slump which minimizes the water-cement ratio to a suitable limit. The results of slump test are given in Table 9. and Figure 10. The bar chart between slump values and percentage of fiber shows decrease in slump value with the increase of percentage of fiber. Fall of the curve in in the graph indicates decrease of slump value so of the workability of concrete with increase in percentage of fiber. Slump value of concrete decreased from 2inches to 1inch with 0%-1% increase in percentage of fiber.

Table 10. Slump values of specimens added with different percentage of fibers

Sr. No.	Fibers (%)	Slump (inches)	Slump (mm)
1	0.000	2.00	50.8
2	0.125	2.00	50.8
3	0.250	1.75	44.5
4	0.375	1.70	43.2
5	0.500	1.60	40.6
6	0.625	1.50	38.1
7	0.750	1.25	31.7
8	0.875	1.20	30.5
9	1.000	1.00	25.4

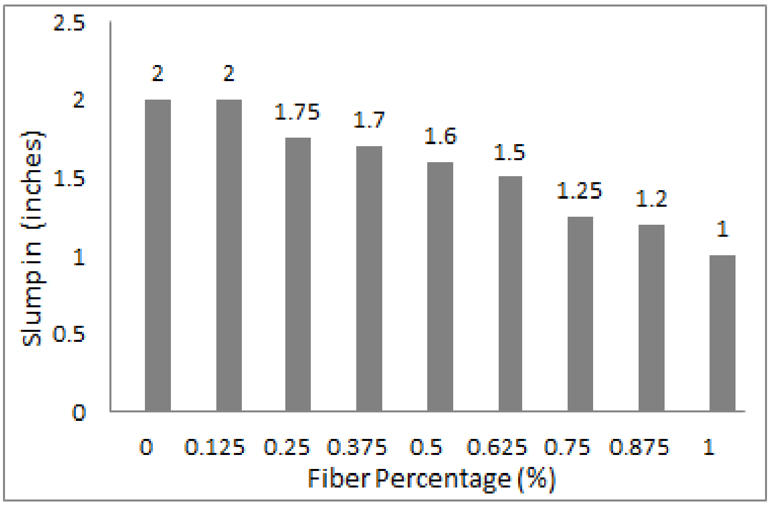

Figure 10. Slump test results versus fiber percentage in specimens

5. Conclusions

- It was found from the study that mixing of Kantharo suter fibers in concrete influence the compressive strength, split tensile strength and flexural strength of hardened concrete, and workability of fresh concrete.
- The compressive strength of concrete obtained was 33.3MPa as compared to the strength of control mix of 20.9MPa. An increment of 12.44MPa in compressive strength of concrete was achieved as compared to control mix specimen. It was achieved with the addition of fibers up to 0.375% by weight of cement.
- The maximum tensile strength was found by addition of fibers up to 0.375% by weight of cement with 3.12MPa as compared to 2.22MPa of control mix specimen. The tensile strength was found decreasing after 0.375% fibers addition by weight of cement.
- The flexural strength of concrete was observed maximum with the addition of fibers up to 0.375% with 3.30MPa as compared to 3.01MPa of control mix specimen.
- A 15% loss in slump value of concrete was noted with the addition of 0.375% of Kantharo suter fiber with respect to weight of cement.
- It is established from the analysis that Kantharo suter fiber improves the mechanical behavior of concrete and could be utilized in proper proportions with cement. The length of Kantharo suter fibers for this work was kept 5cm-7cm with the water/cement ratio of 0.55. No other admixture was added to concrete to vary its properties in fresh as well

as in hardened state. However, different admixtures could be added to concrete with Kantharo suter fiber to resolve the problem of workability and loss.

6. Acknowledgements

The authors would like express profound gratitude to the doctoral students of Hanyang University, Seaoul South Korea, the faculty of Mehran University of Engineering and Technology (MUET), Jamshoro, Sindh, Pakistan for funding the research work and The COMSATS Institute of Information Technology (CIIT) Sahiwal, Punjab, Pakistan and Hanyang University Seoul, South Korea for technical contributions to make the work possible.

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