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MECHANICAL PROPERTIES OF NATURAL FIBER REINFORCED CONCRETE

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Abstract- It is well known that the mechanical properties of concrete can be improved by incorporating discrete fibers to produce more durable and sustainable concrete for construction industry. The purpose of the current research work is to investigate the effect of locally available mazri plant leaves in concrete to improve its mechanical properties. Mazri leaf straw of an average length of approximately 20 mm were mixed with concrete at a percentage of 0.5 and 1.0 by mass of wet concrete. For compressive and split tensile tests, standard cylindrical specimens were prepared, while flexural strengths were obtained from small beams. Test results showed that compared to the plain concrete the compressive strength was decreased with an increase in content of mazri leaf straw. On the other hand, both the split tensile and flexural strengths were found to be increased with the addition of natural mazri leaf straw. It is also interesting to note that the cracking pattern of mazri leaf straw reinforced concrete (MLSRC) exhibited improved ductile behavior compared to the reference specimens, however, in most of the cases pullout of straws was observed which needs further investigation on fiber-concrete bond behavior. In general, mazri leaf straw has the potential to be used in cement concrete composites for different non-structural applications.

Keywords- Mazri leaf straw reinforced concrete (MLSRC), Mechanical properties, Natural fiber.

1 Introduction

Conventional concrete shows less tensile strength and brittle failure. In order to enhance its tensile strength, adding fibers in concrete has proved to be very successful which not only improves its tensile strength but also imparts ductility to it. Previously, different fibers such as glass, steel, polypropylene and many other synthetic fibers have been added in concrete for this purpose. These fibers act as a crack-arresters to enhance the tensile behavior of concrete [1]. In recent decades, emphasis has been given to look for new materials based on renewable resources because of the increasing problem of resource reduction and global pollution. Also, the increase in cost of construction materials and environmental side effects made it necessary to think of new materials lower in cost and environmentally friendly. For this purpose, the development of natural fiber reinforced composites is based on the strategy of preventing the demolition of forest resources as well as producing good economic returns for the cultivation of these fibers [2].

Many natural fibers have been used in concrete for different applications which include sisal, coir, hemp, elephant grass, coconut fibers, wheat straw, jute, roselle fibers, palm oil, and date palm leaf [3-7]. The effect of wheat straw and hemp on the fracture energy of concrete was studied by [3] in which 40 mm long and 0.19% (by concrete mass) fibers were used. An increase of 70 and 2%, respectively, in fracture energy of hemp and wheat straw reinforced concrete was observed compared to plain concrete. The effect of different wheat straws i.e. SWSRC, BWSRC, and NWSRC was also studied by [5] in which 25 mm long wheat straw were added by 1, 2 and 3% of mass of wet concrete. An increase of 91, 92 and 105% in compressive, flexural and splitting tensile toughness indices, respectively, were observed. Roselle fibers in volume fractions of 0 to 4% were studied by [7]. The results indicated that the tensile strength was increased about 53% while compressive strength was reduced with an increase in fiber content. Palm oil fiber as discrete reinforcing fiber in concrete was studied by [8]. It was concluded that fiber reduces workability and compressive strength while splitting tensile strength is increased.

The overall aim of the present research program is to develop an economically efficient concrete for the improvement of pavements like parking pavements, footpaths and shoulders by using locally available natural fibers in concrete. For this purpose, the mazri plant leaf fiber which is abundantly available in the region of Kohat is used. The reason for using this fiber in concrete composites is its low price, local and abundant availability. The other reasons for using these fibers in concrete are their good tensile properties and rapid degradation of their plant forests. The mazri leaf are used in making mats, ropes, hats, baskets and are also used in roofs and huts [9]. Due to the introduction of polythene products in markets the farmers have lost their interest in cultivation of mazri plants leading to the rapid degradation of mazri plants forests. Thus, using these fibers in concrete will again open the markets for the farmers, hence it will also help to sustain mazri plant forests. To the best of authors' knowledge, no study has been carried so far on mazri plant leaf fibers for structural applications. Therefore, a pilot study is conducted to determine the effect of locally available mazri plant leaf fibers on the mechanical properties of concrete composites.

2 Experimental Program

2.1 Materials

The constituents used in the preparation of plain concrete (PC) and mazri leaf straw reinforced concrete (MLSRC) are ordinary Portland cement (OPC), locally available sand, aggregates, tap water and straw from mazri plant leaves available locally in southern regions of Pakistan (i.e. Karak).The maximum size of aggregates used is 19.5 mm.

2.2 Preparation of mazri leaf straws

The natural fibers used were extracted from the leaves of mazri palm trees. Firstly, the leaves were cut from the plant and were air dried for 4-5 days. Secondly, the dried leaves were split into fibers by hand tools locally used for making such fibers. After that the fibers were cut manually into an average length of 20mm, width of 3mm and thickness of 1-1.2mm. Finally, before mixing into the concrete the fibers were dipped in water for an hour to remove the dust on the surface of the straws. After that, the straws were air dried for 10-15 minutes. Figure 1 shows the straws obtained from the mazri plant.

Figure 1: a. Mazri plant [9], b. dried mazri leaves, and c. prepared mazri straw

2.3 Mix proportions and casting procedure

The mix proportion for PC was 1:2:4 (cement: sand: aggregate). For making MLSRC, the straw contents were added in 0.5 and 1% by mass of wet concrete. The w/c ratio of 0.6 is kept same for both PC and MLSRC. For the preparation of

PC mix all the ingredients were simultaneously put into the drum type mixer and the mixer was rotated for one minute. The water in required quantity was then poured into the mixer and the mixer was rotated again for five minutes until a homogeneous mixture was obtained. In case of MLSRC, one-third of cement, sand, aggregates and straw were put in the mixer in four layers. The remaining quantities were then added using the same layering technique. After that, two-third of water was added, and the mixer was rotated for about four minutes. The one-third of the remaining water was added, and the drum mixer was again rotated for two minutes. Slump test was performed for both PC and MLSRC; values of slump noted are 75, 25 and 5mm for 0, 0.5 and 1% straw reinforced concrete. The less value of slump for MLSRC is due to absorption of water by the straws which resulted in reduced workability. For preparation of MLSRC specimens, the prepared homogeneous mixture is then poured in the respective molds. Each mold is filled in three layers with compaction of 25 blows per layer with the help of temping rod.

2.4 Specimens

For compressive and split tensile strength tests, cylinders with height of 300mm and diameter of 150mm were cast for both PC and MLSRC. However, for flexural strength test, 100 mm wide, 100 mm deep and 500 mm long beams/prisms were cast. Table 1 shows details of specimens cast for different testing.

Table 1-Details of specimens cast

S.no	**Testing**	**Number of specimens casted**		
		0% Fiber	**0.5% Fiber**	**1.0% Fiber**
1	Compressive	3	3	3
2	Split tensile	3	3	3
3	Flexure	2	2	2

3 Test Methodology

Ultra-sonic pulse velocity (UPV) test is one of the non-destructive tests used to check the quality of concrete and estimate the strength without damaging the concrete. UPV test was performed following the standard procedure of ASTM C597 [10]. For determination of compressive strength of concrete cylinders, universal testing machine (UTM) of CONTROLS with a capacity of 5000 kN was used following the ASTM C39 [11]. Since the finished surfaces of MLSRC specimens were not smooth, all cylinders were capped with plaster of paris to ensure uniform compression. PC and MLSRC concrete cylinders for split tensile strength were tested conforming to ASTM C494/496M-11 standard [12]. ASTM C78/C78M standard is adopted for performing flexural strength using small sized beams with third point loading [13]. Testing setup for above mentioned tests is shown in Figure 2.

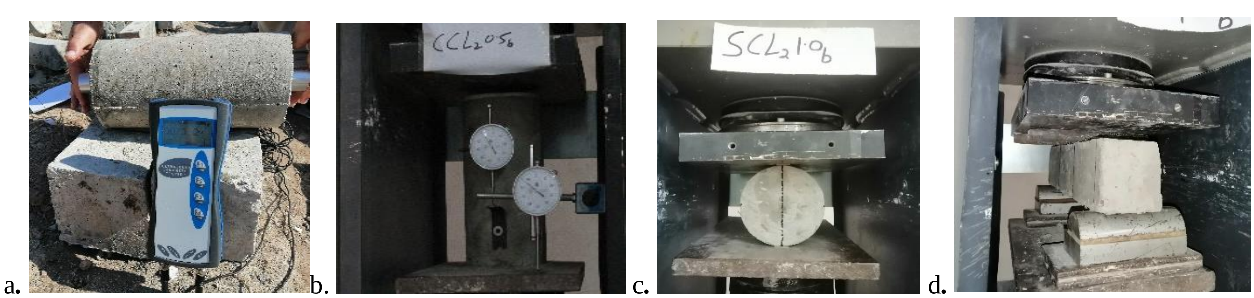

Figure 2: Testing setup, a. ultra-sonic pulse velocity test (UPV), b. compressive strength test, c. split tensile strength test, and d. flexural strength test

4 Results and Discussion

4.1 Ultra-sonic pulse velocity

Figure 3 shows the average of four readings of UPV for cylinders and three readings for beams. Several studies had concluded that there is a relation between UPV and compressive strength [14,15]. The present results of UPV indicate a decrease in the UPV with the addition of discrete fibers, however, the overall difference is small. The maximum value of 4 km/sec at 0 and 0.5% fiber content indicates that the concrete is of excellent quality while all the values in case of beams are greater than 3.5 km/sec showing overall good quality of concrete.

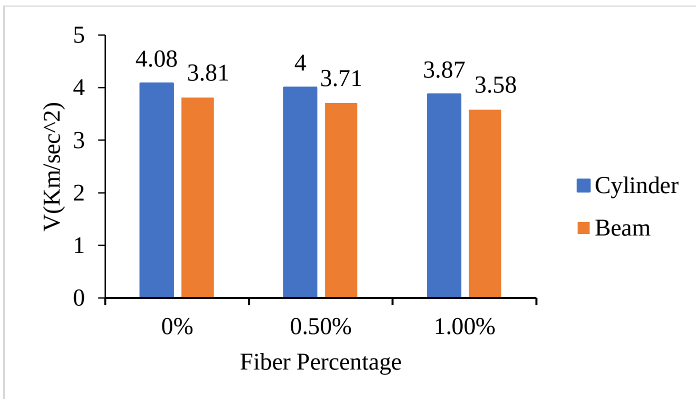

Figure 3: Results of ultrasonic pulse velocity in cylinders and beams

4.2 Compressive strength

It can be observed in Figure 4 that the compressive strength of MLSRC was decreased with an increase in content of mazri palm fibers. Similar observation of strength reduction in natural fiber reinforced concrete had also been reported in many other studies [5,7,8]. For specimens with 0.5% content of mazri fibers, the compressive strength was observed to be reduced by 10% compared to the control specimen. Similarly, a decrease of about 31% was observed in specimens with 1% fiber content. This strength loss might be due to the weak bonding between fibers and concrete as the fibers were easily pulled out from the failed specimens. However, it needs further investigation into the bonding behavior of mazri fibers with concrete.

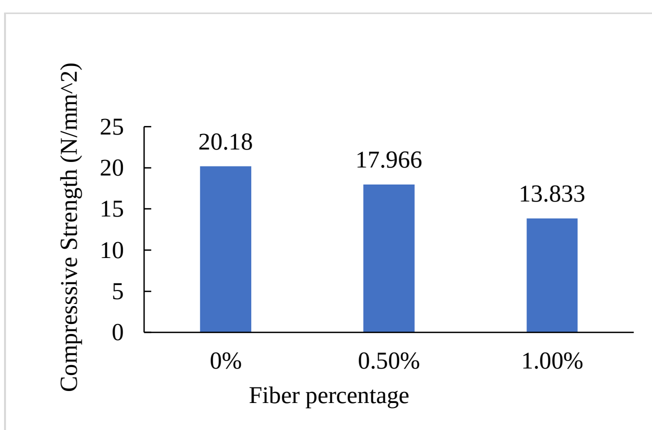

Figure 4: Average compressive strengths at 28 days

4.3 Splitting tensile strength

Figure 5 shows that the tensile strength of MLSRC was increased by 23.5 and 5.7% for 0.5 and 1.0% fiber content, respectively, compared to PC. This increase in tensile strength of MLSRC might be due to the better tensile properties of mazri leaf straws. During the test, it was observed that unlike the splitting of PC specimens into two halves, MLSRC specimens did not exhibit sudden brittle failure mode and only cracks are observed as the maximum load is reached. It shows that the mazri fibers performed well a bridging action among the cracks. Similar observation was also reported by [5].

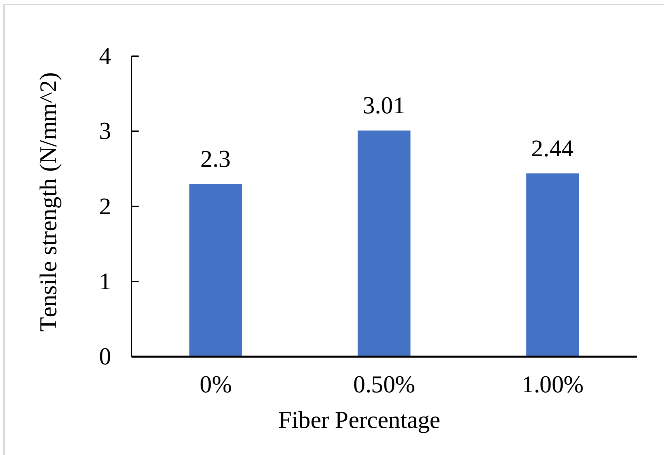

Figure 5: Average split-tensile strength of cylinders at 28 days

4.4 Flexural strength

The results of flexural strength test are shown in Figure 6 which show that the flexural strength of MLSRC was increased by 9.6 and 6.6% for 0.5 and 1.0% fiber addition, respectively. This increase in flexural strength might be due to the tensile properties of the mazri leaf fibers and better interlocking between concrete and straw. It was also observed from the cross section of failed specimens that a proportion of 80:20 existed in fiber pull out and fracture failure. The pull out of straw was observed where less straw length was embedded in concrete. A similar behavior was also observed by [5].

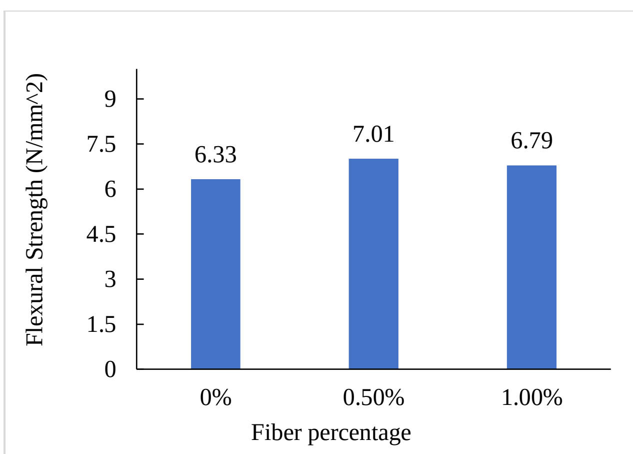

Figure 6: Average flexural strength of concrete beams at 28 days

5 Implemenation of Current Research

Results of current study shows that these fibers has the potential to be used to increase the tensile and flexural strength of concrete, however further research is required to improve the bonding of these fibers with concrete by surface treatment using different techniques.

6 Conclusions

An experimental work was done to study the effect of mazri leaf straw on the mechanical properties of concrete. The following conclusions were made from the results obtained:

- The ultrasonic pulse velocity was slightly decreased by the presence of natural mazri plam fibers.
- The compressive strength was reduced with an increase in fiber content which might be due to the presence of low-density straws causing improper compaction and making concrete less workable.
- Incorporation of mazri leaf straw increased the tensile strength of concrete due to the bridging behavior. A higher increment was observed for 0.5% fiber content compared to 1.0%.
- Like tensile strength, flexural strength is also improved. A higher increment was observed for 0.5% fiber content than for 1.0%.

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