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Study of the Mechanical Properties of Jute Fiber Reinforced Cement Composites

Abstract-*The study results show the use of jute fibers to develop a low cost material for wall panels, roofs and other construction board. The study has been investigates the cement mechanical characteristics jute fibers reinforced concrete. Different lengths of fibers (2cm) and (4cm) were mixed to act as reinforcement for the concrete samples. The samples with different fiber percentages (0.5%, 1% and 1.5% by weight of cement) were tested in axial compression and splitting tensile strength. A total of (42) concrete cube samples (100mm*100mm*100mm) and (42) cylindrical samples (100mm*200mm) were used in the tests, these include compressive and splitting tensile strength and were conducted at (7) and (28) days of concrete age. The results showed that increasing the fiber content and length leads to a slight decrease (4.3% - 12.3%) in the compressive strength but it improves the splitting tensile strength which reached best value at the (1% by weight of cement) fiber content and (5cm) length. The increasing of splitting tensile strength was up to (19.4%) from the reference concrete strength.*

Keywords- *jute fiber, compressive strength, splitting tensile strength, concerts.*

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1. Introduction

Concrete is commonly used in the building and constructions due to its high compressive strength, need low maintenance unless exposed to harsh environment and very economic. Many researches and observations have been on increasing the concrete workability and strnegth by finding a new mixture or new additive materials to enhance the properties and durability of the concrete. The composite material has been used since many decades. The natural fiber was used in the first times to reinforce the brittle materials such as reeds reinforced asphalt was used in anceint Babylon for walls brick work while grass and straws employed in mud bricks [1].

Different types of fibers with different properties might be used to reinforce concrete; one of them is Jute fiber. The use of fiber enhances the concrete properties like increasing the toughness and tensile strength and decreasing cracking and shrinkage by stabilization of the micro cracks and improves the durability because of the permeability. Concrete is a brittle material because it rapidly propagates micro cracks when suffering from subjected stress while fibers are able to bear the loads after initial cracks, which highly increase the material toughness. Fibers increase the ductility and elasticity of the concrete by controlling the crack growth and increase the ductility [2].

Silva and Rodrigues [3] concluded that using natural fibers (sisal fiber) decreased the compressive strength of the concrete in result of the low workability, which makes its microstructure having different density of the plain concrete.

Ramakrishn and Sundararajan [4] conducted tests on cement mortar reinforced by sisal, jute, kenaf and coir fibers with various fiber dosages and fiber lengths. The results showed that the impact strength of the reinforced mortar is increased comparing to the plain mortar up to 18 times higher.

Kundu et al. [5] studied the sewage concrete pipes reinforced by jute fibers where the natural fibers treated by chemicals and chopped to homogeneous disperse natural fiber in the mortar. From the results, it has been concluded that the bearing capacity of the pipes was improved comparing to the plain concrete pipes which indicates that natural fiber can be excellent to reinforce concrete. Furthermore, the use of chemical compositions to treat jute fibers obviously costed and decreases sustainable score of final products.

Chakraborty et al. [6] investigated the mechanical properties and physical characteristics of concrete mortars are highly increased by the natural fiber reinforcements. Three various processes methods were considered to obtain homogeneous mix of the jute fiber with the mortar. By optimizing the fiber loading and processing condition, the

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toughness index, the cold crushing strength, flexural toughness and flexural strength of the mortar had highly been enhanced.

M.A. Mansur and M.A. Aziz [7] reported on the mechanical characteristics of the jute fibers reinforced concrete and plain concrete is studied in this research. Various lengths of fibers were mixed to reinforce the mortars, which were uniformly distributed in the mortar matrix. Samples with different fiber percentages were tested in direct axial compression, flexure, tension, and impact 3.

The aim of this research is to study the effect of low cost materials (jute fiber) with different percentages and length on the mechanical properties splitting tensile and compressive strength of cement.

2. Experimental Part

I. Material used

1. Cement

Ordinary Portland cement (OPC) manufactured by Al-kubaysa cement factory has been used in all mix batches in order to eliminate any effect of difference between them. The cement was stored the laboratory in dry environment. The chemical compositions and compounds of the cement are illustrated in table 1. The cement meets the requirements the Iraqi specifications (I.O.S) No.519.

Table 1: Chemical composition and compounds of the cement *

Compound	% by weight	Limit of Iraqi specification
Lime saturation factor L.S.F	0.85	0.66 - 1.02 (Max)
Insoluble residue	1.1	1.5 (Max)
Loss on ignition	1.5	4.0 (Max)
SO_3	2.3	2.8 (Max)
MgO	1.5	5.0 (Max)
Fe_2O_3	3.0	-
Al_2O_3	5.69	-
SiO_2	19.9	-
CaO	60.8	-
C_4AF	9.12	-
C_3A	10	5.0 (Min)
C_2S	21.76	-
C_3S	47.14	-

* Both chemical and physical tests on cement were made by the National Center for Constructional Laboratories (NCCL).

2. Fine Aggregate

Ordinary Al-Ekhadir region is the source of the fine aggregate. Sieve analysis and sulfate content tests have been made to of fine aggregate. The results conforms to the Iraqi specifications (I.O.S) No.45 1984, zone 3 which are shown in Table. 2.

Table 2: Sieve analysis of fine aggregate

Sieve size (mm)	Percentage passing %	Limit of Iraqi specifications
4.75	100	90-100
2.36	92.1	85-100
1.18	82.0	75-100
0.60	64.8	60-79
0.30	21.0	12-40
0.15	7.2	0-10

3. Coarse Aggregate

Crushed irregular shape gravel used as coarse aggregate was obtained from Al-Sodour source, maximum size (10mm) was used in all mix patches. This size was selected in order to achieve acceptable fibers dispersion and workability in the mix batches [8]. The sieve analysis of the coarse aggregate is showed in Table 3 and it meets the requirements of the Iraqi specifications No.45 1980.

Table 3: Sieve analysis of fine aggregate

Sieve size (mm)	Percentage Passing %	Limit of Iraqi specifications
10	100	85-100
5	12.2	0-25
2.36	0	0-5

4. Jute Fiber

Tap water used to wash the jute fibers several times in order to remove dust from the surfaces and left to dry in the air then it was cut into (2cm-4cm) and spread out randomly during the mixing procedure.

II. Procedures

1. Mixing Method and Preparation of Specimens

A rotary mixer was used to prepare the (0.1) m3 mix patches. The coarse aggregate, fine aggregate and cement are mixed at first for two minutes after that the water content is added and mixed until reaching a homogenous mix then fibers are added in small proportions for a period ranging from (1-3) minutes each time to spread it out. Over mixing is avoided because the fibers will loss of strength and suffer damage, such

procedure results in prevent balling problems and good dispersion of fibers.
All the molds were thoroughly oiled before casting to get a fair face of the specimens and to demold the samples easily.
The concrete was casted into the molds in three layers. Each layer is vibrated by using a large table vibrator for about 3 minutes until no more air bubbles emerged from the top surface of the concrete. The samples were leveled by hand trawling and marked.
Nylon sheets were used to cover the top face in order to prevent mixing water from evaporating. The specimens were stored for 24 hours in a place far from sun light. After that, they were demolded and placed in water tanks prepared for curing procedure.

2. Curing Method

The demolded specimens were cured in tap water at laboratory temperature for (7) and (28) days. Large storing tanks were used for this purpose and the level of water was kept constant throughout the curing periods.

II. Tests

1. Compressive Strength Test

The compressive strength test was conducted based on B.S.1881: part 116/1989 by using 100mm cubes which were tested by using digital compressive machine (ELE-Digital Elect.) which shown in Figure 1. The tests were carried out at the days of (7, 28). The average of three cubes was taken for all tests.

$$\sigma = P / A \quad (1)$$

Where:
σ: Compressive strength (MPa)
A: Surface area in contact with the platens (mm^2)
P: Ultimate compressive load of concrete (N)

Figure 1: ELE Dig. Elec. compressive machine.

2. Splitting Tensile Strength Test

The tensile splitting strength tests conducted based on B.S.1881: part 117/1989 by using (100*200) mm cylinders. The tensile splitting strength cylinder was tested by using digital compressive machine (ELE-Digital Elect.) which shown in Figure 1 above. The tests were carried out at days of (7, 28). The average of three cylinders samples was taken for each test.

$$\tau = (2\ P) / (\pi\ l\ d) \quad (2)$$

Where:
P is the failure load (N)
*l*the length (mm)
d the specimen diameter (mm). compressive

3. 3.Results and Discussions

I. Splitting Tensile Strength

Table 4, Figure 2 and Figure 3 shows the results of the tensile strength for the cylindrical specimens with jute fiber lengths (2 and 4) cm with (0.5, 1 and 1.5) % percentages referenced to non-reinforced mix. The maximum improvement is (19.4) % for (4) cm fiber with (1) % percentages in reference to unreinforced concrete. The concrete tensile strength increased up to 1 % then decreased after that due to more fiber content leads to more voids in the concrete because of the nonhomogeneous desperation of fibers in the concrete matrix and balling effect during mixing and casting of the specimens. The reinforced specimens showed several small cracks at failure while the non-reinforced ones showed single failure crack.

Table 4: Splitting tensile test results

Mix	Fiber Length (mm)	Fiber Percentage (%)	7 days (MPa	28 days (MPa)
C	-	-	2.5	3.1
M_{11}	2	0.5	2.7	3.2
M_{12}	2	1	2.9	3.4
M_{13}	2	1.5	2.8	3.3
M_{21}	4	0.5	2.9	3.3
M_{22}	4	1	3.3	3.7
M_{23}	4	1.5	3.1	3.4

* 1 : 1.8 : 2.4 : 0.58 Mix proportion for all mixes

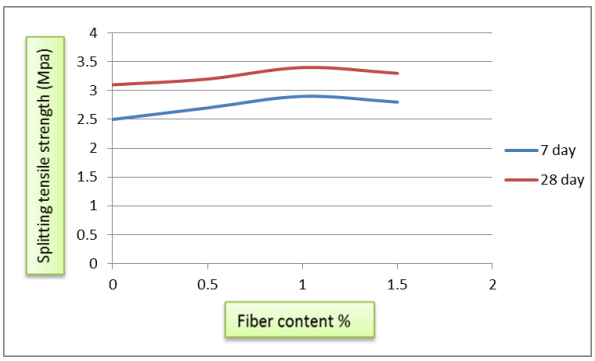

Figure 2: Effect of fiber percentage on splitting tensile strength at (7, 28) day for (2) cm fiber length

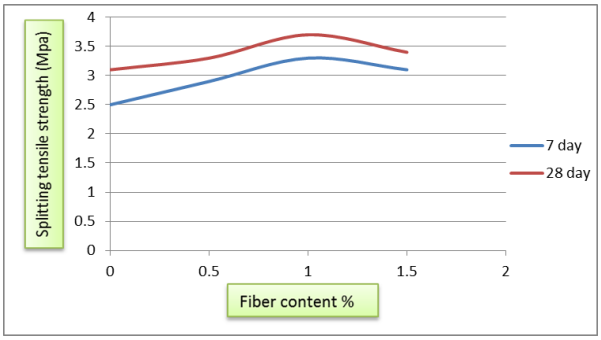

Figure 3: Effect of fiber percentage on splitting tensile strength at (7, 28) day for (4) cm fiber length

II. Compressive Strength Test

Table 6, Figures (4, 5, 6, and 7) show a slight reduces in the compressive strength of Jute Fiber Reinforced Concrete Compared to non-reinforced one with reference to three various volumetric percentages of jute fibers. Decreasing in compression strength may be attributed to more voids as a result for exciting of reinforcing material. Increasing jute fibers content in the concrete can lead to reduce the composite specific gravity in a result for the high porosity, inadequate mixing and low specific gravity of the mix. The compressive strength is decreased with reference to the non-reinforced concrete by high increase of the fibers content and larger lengths of fiber to be added.

Table 5: Compressive strength test results

Mix	Fiber Length (mm)	Fiber Percentage (%)	7 days MPa	28 days MPa
C	-	-	27.6	39.1
M_{11}	2	0.5	24.9	36.2
M_{12}	2	1	25.7	36.0
M_{13}	2	1.5	24.4	34.3
M_{21}	4	0.5	26.1	36.9
M_{22}	4	1	25.6	37.4
M_{23}	4	1.5	24.8	35.1

* 1 : 1.8 : 2.4 : 0.58 Mix proportion for all mixes

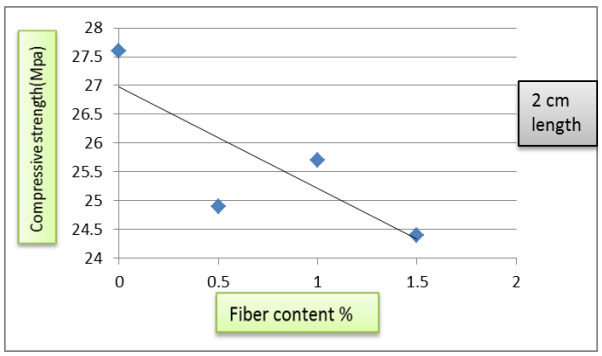

Figure 4: Effect of fiber percentage on compressive strength at (7) day for (2.5) cm fiber length.

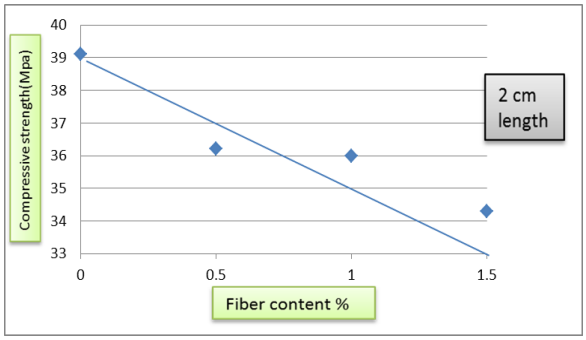

Figure 5: Effect of fiber percentage on compressive strength at (28) days for (2.5) cm fiber length.

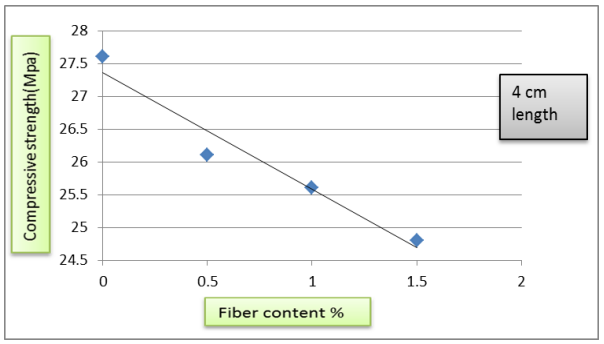

Figure 5: Effect of fiber percentage on compressive strength at (7) day for (4)cm fiber length.

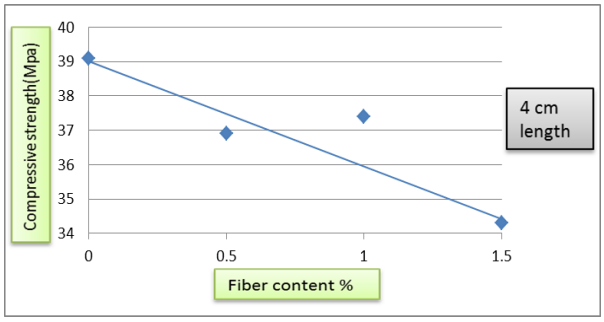

Figure 5: Effect of fiber percentage on compressive strength at (28) days for (4) cm fiber length.

4. Conclusions

1- The results showed (4.3% - 12.3%) decrease in compressive strength with the increase in fiber percentage in the mixes.

2- The results showed an increase in the splitting tensile strength with the increase in fiber length and percentage until (1%) fiber percentage, the increasing reached (19.4%) from the reference concrete mix.

3- The results also showed that increasing the fiber percentage more than (1%) reduces the splitting tensile strength.

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