Influence of Date Raceme Fibers on the Properties of Cement Mortar

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Abstract:

Natural fibers reinforced cement mortar materials have got increasing application in residential housing components. One of the natural fibers considered is Date raceme fibers which offer advantages such as availability, renewability, low cost and the established technology to extract the fibers. This study investigates the properties of cement mortar (density, compressive strength, tensile strength and impact strength) incorporated with different percents of short natural fibers (Date raceme fibers) (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5%) by weight of cement. An experimental work has been carried out to study the mechanical properties of Date raceme fibers-reinforced cement mortar. The results show that the tensile strength of cement mortar increases, (this increase in strength is about 94%), while the compressive strength decreases as the fiber percents is increased, as well as there is a corresponding increase in energy absorption capacity of reinforced slabs mortar with increased the percent of Date raceme fibers.

Keywords: Cement mortar, Compression, Mechanical Properties of Natural Fiber, Date raceme fibers, Strength, Tensile, impact.

الخلاصة:

ازدياد التطبيقات للاستعمال مونة الأسمنت المسلحة بالألياف الطبيعية في مجالات الحياة. أحد هذه الأنواع من الألياف الطبيعية هو ألياف عثق التمر، و الألياف الطبيعية و التي منها ألياف عثق التمر و التي تتميز بتوفرها بصورة كبيرة و كلفتها البسيطة و امكانية تجديدها و تحويلها إلى مادة هندسية يستفاد منها. في هذا البحث تم دراسة خواص مونة الأسمنت (الكثافة ، مقاومة الانضغاط ، مقاومة الشد و مقاومة الصدم) مع نسب مختلفة من ألياف عثق التمر (0 ، 0.5 ، 1.0 ، 1.5 ، 2.0 ، 2.5 ، 3.0 و 3.5%) من وزن الأسمنت . و تم دراسة الخواص الميكانيكية لمونة الأسمنت المسلحة بألياف عثق التمر. الفحوصات و النتائج أظهرت بأن مقاومة الشد لمونة الأسمنت المسلحة بألياف عثق التمر زادت بنسبة 94% مع نقصان مقاومة الانضغاط بزيادة النسب للألياف عثق التمر ، من ناحية أخرى زيادة مقاومة الصدم لمونة الأسمنت المسلحة بألياف عثق التمر .

الكلمات المفتاحية: مونة أسمنتية، ضغط، الخواص الميكانيكية للألياف الطبيعية، ألياف عصيدة التمر، القوة، الشد، التأثير.

Introduction:

Date raceme fibers extracted from fibrous tissues of raceme Palm tree, grows in very large areas in southern Iraq, their diameters of fibers vary from 0.15 mm to 0.25mm and their lengths depend on the fibrillation process as in the case with sisal or jute fibers.

The use of vegetable fibers such as sisal, jute and coconut in concrete or cement mortar poses an exciting challenge to the construction industry since they are a cheap and readily available form of reinforcement and require only a low degree of industrialization for their processing. In comparison to an equivalent weight of the most common synthetic reinforcing fibers, the energy required for their production is small and therefore, their costs are also low. Usually vegetable fibers have been used as reinforcement of cementitious matrices in the form pulp or short filament fibers. These composite systems present a tension softening behavior with low tensile ultimate strength, resulting in products which are more suitable for non-structural applications. For pulp fibers–cement based composites, although volume fractions as high as 8–10% can be used, the composites still present a tension softening behavior under direct tension due to the short fiber length. In addition, the matrix that is normally used in pulp fiber reinforced composites is a cement paste which presents high consume of cement, hence, elevated emission of CO2 to the atmosphere and high shrinkage[Roma Jr LC, Martello LS, Savastano Jr H.-2008].

The major advantage of fiber reinforcement is to convey additional energy absorbing capability and to transform a brittle material into a imitation ductile material. Fibers in cement mortar or in concrete serve as crack arrestor which can create a stage of slow crack propagation and gradual failure [Swamy,R.N. and Mangat,P.S.-1975].

Ismail observed that when the fiber content increased; the bulk density gradually decreases, while the tensile strength is increased. Although, the relationship between the fiber-cement ratio and tensile strength produce a slow increase in strength, the general partiality shows development in strength at 28 days age, and indicates a noticeable increase in the tensile strength [M. A. Ismail-2006].

[Augustine and Stephens 2005] has shown that higher sisal fiber volume reduces the compressive strength of concrete. The reduction in compressive strength is not surprising since the fibers themselves cannot resist axial compressive load and as such do not contribute to the compressive strength of blocks. Furthermore, it is difficult to compact higher sisal fiber content mix resulting in the increase of voids in the blocks.

The use of natural fibers for strengthing of brittle materials is very old, for example, reeds embedded in asphalt were used in the walls of ancient Babylon as a mortar binder for brick work [Raouf,Z.A.-1986].

Out of the commonly used fibers, easily available low cost natural fibers are renewable source materials. Though these fibers are ecologically advantageous, they have some limitations such as lower durability and lesser strength. But recent research provides several treatment processes to enhance the durability of natural fibers. The durability of natural fibers such as coconut coir and sugarcane bagasse has been reported by conducting an experimental investigation. This investigation includes the determination of mechanical strength properties such as compressive, tensile, modulus of rupture and flexural properties of natural fiber reinforced concrete specimens once every 3 months for a period for 2 years under alternate wetting and drying conditions.[M Sivaraja, Kandasamy, N Velmani and M Sudhakaran Pillai-2010].

Concerning the composite mechanical behavior, it was observed a strong increase of the flexural strength for optimal fiber content. It can be seen that for a composite containing 16 vol. % of fibers, the flexural strength is maximal and about 40% higher than that of the cement paste. It is equally observed a decrease of the composite Young's modulus compared to the cement paste. Indeed, treatments applied on hemp fibers in this study improve only the flexural strength. An alkaline treatment improves this strength of about 84% compare to the cement paste [David Sedan, Cécile Pagnoux, Agnès Smith, Thierry Chotard-2001].

An investigational study was also carried out to develop the mechanical properties of gypsum hemihydrates joists reinforced with date palm fibers [Raouf,Z.A., AL-Ali,B.T.-1990].

The compressive strength of fiber reinforced concrete, increased due to the incorporation of 10% and 20% of bauxite as a partial replacement by weight of cement but it is still lower than plain concrete.[Kawkab H. Al Rawi, Moslih A. S. Al Khafagy-2009].

Many investigations have already been carried out on various mechanical properties and physical performance of concrete materials using natural fibers from coconut husk, sisal, hemp, sugar cane begasse, bamboo, jute, wood and other vegetable fibers. These investigations have shown encouraging commercial prospects of this new distinct group of materials for application in low cost housing construction [Aziz, M.A. and P. Lee, S. L-1988], [YONG NI.-1995].

2. Experimental Methods

2.1 Materials:

Ordinary Portland cement (OPC) (Tassluga trade mark) was used; it's conformed to Iraqi specification [IQS 5-1984] type II [ASTM C150-05]. The physical properties and chemical analysis are shown in **Table 1**. Testing of cement was conducted in the Laboratories of the consultant Engineering Bureau in Babylon University.

The natural fibers used in this investigation were Date raceme fibers with an average length of (8-12mm) and obtained from a Palm tree. **Figure 1** shows the Date raceme fibers. The fibers soaked in water for four weeks and dried it [Cam Yaremko-2012], and afterwards the fibers were manually extracted into fine long fibers and then soaked in sulphonated naphthalene formaldehyde condensate for two hours. This treatment decreases the fibers' abilities to absorb and retain moisture, since those very abilities promote the degradation of the fibers. The fiber diameter varied from 0.15mm to 0. 25mm and their density 0.83 gm/cm^3 and water absorption 40%. **Table-2** shows a comparison between Date raceme fibers, Date-Palm fibers, Coconut fibers, Reed fibers and Sisal fibers, each material type being considered as a feasible reinforcing material. [M. A. Ismail-2006].

Fine aggregate was natural sand from Al-Akaidur region. The specific gravity and absorption values and other properties are listed in **Table 3**.The grading is conformed to the Iraqi specification [IQS 45-1984].

The super plasticizer used for fibers treatment was a sulphonated naphthalene formaldehyde condensate. The aqueous solution contained 42% solids and had a density of 1200 kg/m^3. The chloride content was negligible. It is conformed to [ASTM C494-05].

A super plasticizer, Rheobuild SP1, was used throughout this work as a high range water reducing agent. It is used to achieve high workability. The dosage recommended by the manufacturer was (0.6-2.4) % by weight of cement, but it was used (1 %) by weight of cement to give workable mix with easy distribution fibers. This type of admixture conforms to the ASTM (C494 types D& G).

Fig. 1:Date raceme fibers

Table 1 Chemical Compositions and Physical Properties of Ordinary Portland Cement (OPC) (Tassluga trade mark).

Chemical Compositions		
Oxides	Content,%	Iraqi specification limits (I.Q.S. 5/1984)
CaO	62.31	----
SiO2	21.28	----
MgO	2.77	----
Fe2O3	3.60	----
Al2O3	5.31	----
SO3	2.45	Not more than 2.8% if C3A more than 5%
Free Lime	1.06	----
L.O.I	1.73	Not more than 4%
I.R	0.85	Not more than 1.5%
L.S.F	0.87	0.66%-1.02%
Compound composition		
C3S	39.60	----
C2S	31.12	----
C3A	8.51	----
C4AF	10.94	----

<table>
<tr><th colspan="4">Chemical Compositions</th></tr>
<tr><th>Oxides</th><th>Content,%</th><th colspan="2">Iraqi specification limits (I.Q.S. 5/1984)</th></tr>
<tr><th colspan="4">physical properties</th></tr>
<tr><th>Property</th><th>Result</th><th colspan="2">Iraqi specification limits (I.Q.S. 5/1984)</th></tr>
<tr><td>Fineness by air permeability method (Blaine)</td><td>348 m2/kg</td><td colspan="2">Not less than 230 m2/kg</td></tr>
<tr><td>Initial setting</td><td>125 min.</td><td colspan="2">Not less than 45 min.</td></tr>
<tr><td>Final setting</td><td>230 min.</td><td colspan="2">Not more than 600 min.</td></tr>
<tr><td>Soundness (Autoclave Method)</td><td>0.28%</td><td colspan="2">Not more than 0.8%</td></tr>
<tr><td rowspan="2">Compressive strength</td><td>3-day age</td><td>22.8 MPa</td><td>Not less than 15 MPa</td></tr>
<tr><td>7-day age</td><td>31.5 MPa</td><td>Not less than 23 MPa</td></tr>
</table>

Table 2 Comparison Between Mechanical Properties for Different Fibers

[M. A. Ismail-2006]

Fiber Type	Density (kg/m3)	Water Absorption(%)	Tensile Strength(MPa)
Date raceme	**830**	**40**	**281**
Roselle	750-800	40-50	170
Date Palm	463	60-65	125
Coconut	145-380	130-180	120
Reed	490	100	70
Sisal	700-800	56	268

Table 3 Physical Properties of Fine Aggregate from Al-Akaidur region

Properties	Test results	Iraqi specification limits (I.Q.S. 45/1984)
Grading Zone	Second	----
Fineness Modulus	2.80	----
Sulfate content (SO3)	0.38%	Not greater than 0.5%
Materials finer than sieve No. 200,%	2%	Not greater than 5%
Sieve size (mm)	**Passing (%)**	**Iraqi specification limits (I.Q.S. 45/1984)**
10	100	100
4.75	99	90-100
2.36	85	75-100
1.18	68	55-90
0.60	46	35-59
0.30	14	8-30
0.15	2	0-10

2.2. Tensile Test Of Fibers

Tensile tests of individual technical fibers were carried out for Date raceme fibers with an average length of (12mm) for three fibers specimens.

The specimens were prepared in the following manner: The fibers were randomly selected. Then the length and the weight of the fibers were measured. By assuming that the cross sectional area of a fiber is constant along its length and using the density, the area was determined. This method is rather blunt, but still believed to give a reasonable estimation of the size of the cross sectional area [Nur H. BtAbd Khalid, Jamaludin M. Yatim-2010]. Attachment of fibers to the tensile loading machine (universal testing machine) was arranged by gluing the end parts of the fibers between washers. The fibers with clamps were placed in the testing device (universal testing machine).Load and elongation was recorded during the tests. The stroke rate was 0.1mm/min and the time to failure in the order of 30-60 seconds. The tests were made at temperature 22 °C and relative humidity 50%. The result of average tensile strength for three fibers specimens of Date raceme fibers was 281MPa and that value of tensile higher than compared with the other natural fibers as shown in **Table 2.**

2.3. Mix Proportions

Preliminary mixed design serves the purposed of determining the suitable mix design to be used. The objective of the mixed design is to have a workable mix with certain proportion of natural fiber. [M.Hashim 2005].

A few trial mixes were prepared in order to determine the most workable mixture of cement mortar with different percent of natural fibers (Date raceme fibers) used by weight of

cement. The water - cement ratio of 0.45 was selected. It was found that mixing the Date raceme fibers for the length between (8-12mm) was easier than the longer ones.
Air dried fibers were used in different percents (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5%) by weight of cement. The mixtures number and their proportion listed in **Table 4.**
The mixing procedure adopted for all mortar mixes involve the following:

a) Measure sand and cement and mix them thoroughly until homogeneous mix is achieved.
b) Add required quantity of fiber and mix carefully to a point of uniformity.
c) Add measured quantity of water and mix the whole lot until a workable mix is obtained. All mixing and compaction were done manually.

It has been noted that the fiber reinforced cement mortar with relatively low fiber contents were used in this investigation and all fibers were uniformly distributed and randomly oriented with cement mortar.

2.4. Experimental Series

Three groups of fiber – reinforced cement mortar were casted:

Group 1, (for compressive strength): The cubic moulds of the 50 x 50 x 50 mm were casted into two layers and manually compacted, according to methods (ASTM-C109-88). The number of specimens for each weight fraction was = 3

Group 2: (for tensile strength): The moulds were 25x25x75 mm casted and manually compacted. The number of Specimens for each weight fraction was = 3

Group 3, (for density measurement): Three specimens of the 50x50x50mm sizes were taken from group 1 for density measurement which was obtained according to (ASTM-C220-75).

Group4, (for the impact tests):Three specimens of the (250x250x25mmthickness) sizes were cast in wooden moulds placed on a wooden platform for each fibers percent used (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5%) that mean the total numbers of cast slabs are 24samples.

2.5. Curing Of Test Specimens

All specimens in groups 1, 2 and 3, were covered in the moist room (23 ˚C and relative humeditiy of over 95%) until demoulding 24 hours later, after which the specimens were kept in a controlled temperature water tank (21± 2˚C) until testing at 28 days.

Table 4 The mixtures number and their proportion

Mixture No.	SP (Liter/100kg cement)	Fiber/Cement Ratio F/C % By weight	W/C Ratio	Cement: Sand: W/C
M-0	1	0	0.45	1:3:0.45
M-0. 5	1	0.5	0.45	1:3:0.45
M-1.0	1	1.0	0.45	1:3:0.45
M-1.5	1	1.5	0.45	1:3:0.45
M-2.0	1	2.0	0.45	1:3:0.45
M-2. 5	1	2.5	0.45	1:3:0.45
M-3.0	1	3.0	0.45	1:3:0.45
M-3.5	1	3.5	0.45	1:3:0.45

2.6. Specimens Testing Methods:

The cubes and prism specimens were tested for compressive and mortar flexuralstrength respectively at 28 days and the results presented in **Table 5**. The impact test was conducted on the test and control specimens after 28 days of curing using a drop weight set up, as per the procedure demonstrated in previous studies of [**P.B. Sakthivel**, 2012]. The drop weight was a steel mass of 1 kg and the mass has been dropped on to the slab in the centre from a predetermined height of 600 mm. A rope and pulley arrangement with a pipe guide, which enables a central impact in the vertical direction, was used to manually liftthe steel mass to the required height and repeatedly drop it on the specimen surface. The number of blows required to cause the first visible crack at bottom of the specimen was recorded as the first or initial crack. After the appearance of the first crack, the impact test was continued by dropping the steel mass till the ultimate failure stage has been achieved. At the time when final cracks were noticed, the impact loading exercise was stopped, and the total numbers of blows received are noted down; and this stage is treated as the ultimate failurestage of the specimen. The calculations of energy absorption at initial and final crack stages are given below.

Energy Absorption

The total energy absorbed by the cementitious composite slabs when struck by a steel mass depends onthe local energy absorbed both in contact zone and by the steel mass, and the energy absorption iscalculated from the following formula in equation (1) from the studies of [Sakthivel et al., 2012]:

E = n x (w x h) Joules ……………………………………………………………………..(1)

Where

E = energy (absorbed by the specimen on impact) in Joules

n = number of blows (on impact specimen)

w = weight (of steel mass) in Newton

h = height (from where steel mass is dropped on the specimen) in meter

In equation (1), constant values are w=9.81 N (weight of the ball) and h=0.6 m (height of fall), but thenumber of blows are based on the initial and final cracks. **Table 6** gives the energy absorption capacities of slabspecimens cast with plain cement mortar and fibrous mortar.

3. Discussion Of Test Results

3.1 Density Test :

The results of density are shown in **Fig-2** and listed in **Table-5.**The density are slightly increased in value with low fiber content in range (0 – 0.5%) as compared with the cement mortar with no fiber, and the highest density is obtained at the fiber–cement ratio of 0.5%. The increase in bulk density may be due to the good homogeny and high compaction between the fibers and the cement mortar. The bulk density gradually decreases due to difficult to compacted with fibers and resulting in increase of voids in the cement mortar.

3.2 Compressive Strength Test :

The results of group 2 for compressive strength are shown in **Fig-3** and listed in **Table-5.** The compressive strength is slightly increased in value with low fiber content in range (0.0 – 1.5%) as compared with the cement mortar with no fiber, and the highest strength is obtained at the fiber–cement ratio of 0.5%. The increase in compressive strength and bulk density may be due to the good homogeny and high compaction between the fibers and the cement mortar. However, the compressive strength of specimens increased with the increase in density, this can be explained by the fact that the composites have higher density, and this might be due to the

decrease in air void and low porosity. However, as the fiber content exceeds the value of 1.5%, the compressive strength decreases. In general, when the fiber cement ratio exceeds the value of 1.5%, a reduction in compressive strength occurred.
Such reduction in strength and density may be recognized to increasing porosity and air void which brought about not enough compaction of the high fiber content mixture. However, from the values listed in **Table 5**, it can be seen that compressive strength and the density of mortar are progressively decreased with increasing fiber content; therefore, the compressive strength of the Date raceme fibers-cement mortar is a function of the density. During the test it was observed that the failure of specimen was gradual, and in spite of the occurrence of excessive vertical cracks, the specimen still did not break into pieces when compared with the cement mortar with no fiber.

3.3 Tensile Strength Test:

The results of group 3 for tensile strength are shown in **Fig.4**and listed in **Table-5.** The tensile strength is increased in value with increase the fiber content in range from (0.5-3.5) %. However, when the fiber content exceeds density gradually decreases as shown in Fig.1, while the tensile strength is increased as mention. Although, the typical relationship between the fiber-cement ratio and tensile strength produce a quite low increase in strength, the general tendency shows improvement in strength at 28 days age, and indicates a noticeable increase of about 94% in the ultimate tensile strength. This is very similar to the 48% in the ultimate tensile strength reported by**[Shimizo and JorilloJr, 1992]**. Increasing the tensile strength with increasing the Date raceme fibers due to the strong bond between the fibers and cement mortar and also due to the Date raceme fibers have the highest tensile strength compared with the others natural fibers.

3.4 Relationship Between Compressive And Tensile Strengths

The typical relationship between Compressive and tensile strengths is shown in **Fig.5**. It seems that the lower fiber content in range (0-1.5%) has approximatelythe same high values of compressive strength, while the tensile strength increases.When the fiber content exceeds the value of 1.5%, the compressive strength indicatesa marked decrease, while the tensile strength marginally increases.

3.5 Impact Strength Tests:

From **Table 6** and **Fig. 6**, it is seen that the energy absorption at first crack is 11.77(for plain cement mortar) and increases from 17.65 J to 47.08 J for increase in Date raceme fibers percentage from 0.5% to 3.5%.From **Table 6** and **Fig. 6**, it is observed that for plain cementations slabs (with 0% fibers), the ultimate failure has occurred after receiving energy absorption of 17.65 J. It can also be incidental that for every 0.5% increase in fiber percentage inDate raceme fibers percentage in slabs, i.e., there is an increase in energy absorption. This means that when the fiber percentage was increased from 0 to 0.5%, 0.5 to 1%, 1% to 1.5%, 2%, 2.5%, 3% and 3.5% there is a jump in value of energy absorption. In general, it can be recognized from this study that as the percentage of Date raceme fibers increases, there is a corresponding increasein energy absorption capacity of reinforced slabs mortar.**Fig. 7** shows comparisonthe observed failure cracks of slabs mortar (with and without) Date raceme fibers after impact test.

Table.5. The Mechanical and Physical Properties of Reinforced Cement Mortar.

Mixture No.	Fiber/Cement Ratio F/C % By weight	Density gm/cm^3	Compressive Strength MPa	Tensile Strength MPa
M-0	0	1.882	34.5	5.4
M-0. 5	0.5	1.9	36.4	5.81
M-1.0	1.0	1.87	35.7	6.5
M-1.5	1.5	1.851	34.6	7.65
M-2.0	2.0	1.832	32	8.15
M-2. 5	2.5	1.83	29.6	9.5
M-3.0	3.0	1.815	27.3	10.1
M-3.5	3.5	1.81	24.2	10.5

Table 6. Energy Absorption of Cement mortar Slabs with different fibers percent.

Fiber/Cement Ratio F/C % By weight	First Crack number of blows	Ultimate Failure number of blows	Energy Absorption at first crack based on equation (1)	Energy Absorption at Failure crack based on equation (1)
0	2	3	11.77	17.65
0.5	3	5	17.65	29.43
1.0	3	6	17.65	35.31
1.5	4	9	23.54	52.97
2.0	5	12	29.43	70.63
2.5	6	16	35.31	94.17
3.0	7	19	41.20	111.83
3.5	8	20	47.08	117.72

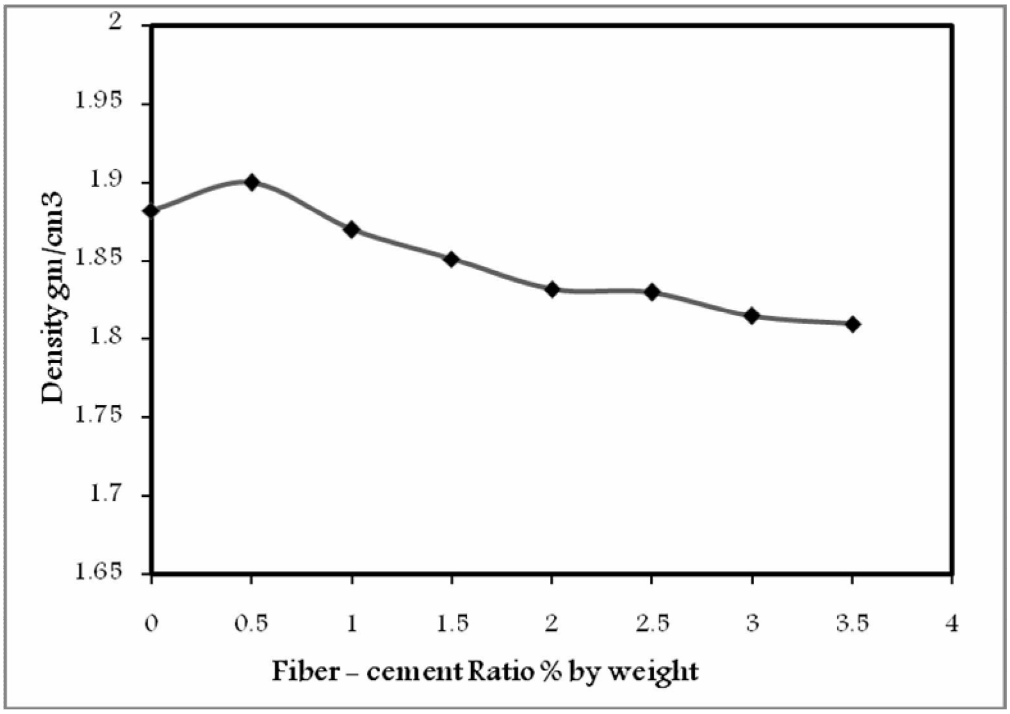

Fig-2:Influence of Fiber-Cement Ratio on Bulk Density of Fiber-Cement mortar.

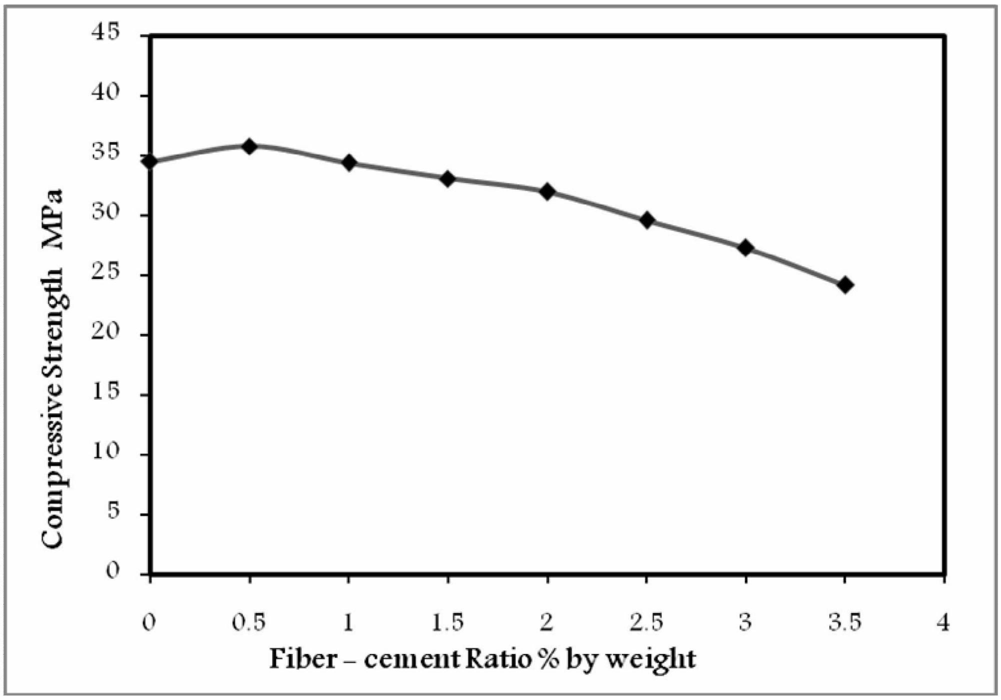

Fig-3: Influence of Fiber-Cement Ratio on Compressive Strength of Fiber-Cement mortar.

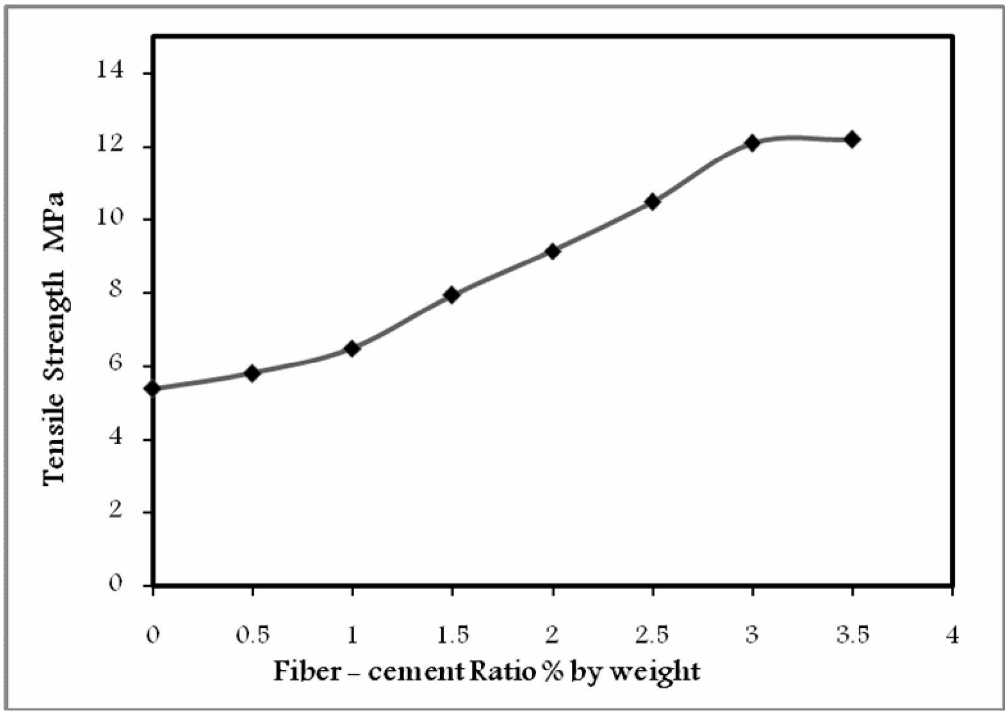

Fig-4: Influence of Fiber-Cement Ratio on Tensile Strength of Fiber-Cement mortar.

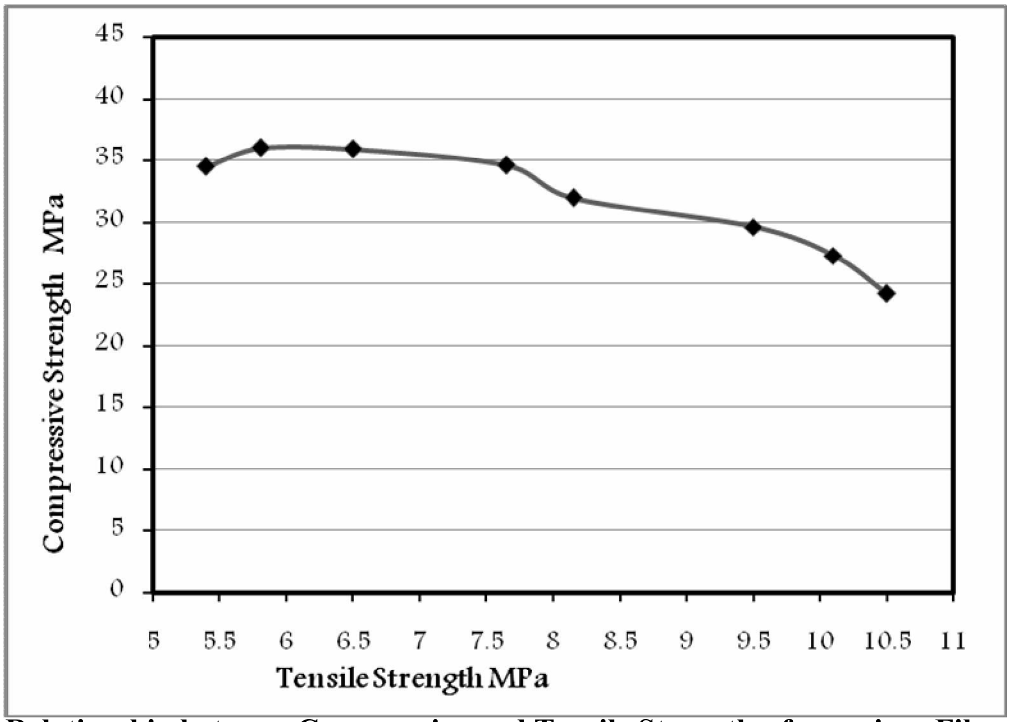

Fig. 5: Relationship between Compressive and Tensile Strengths, for various FiberCement Ratios

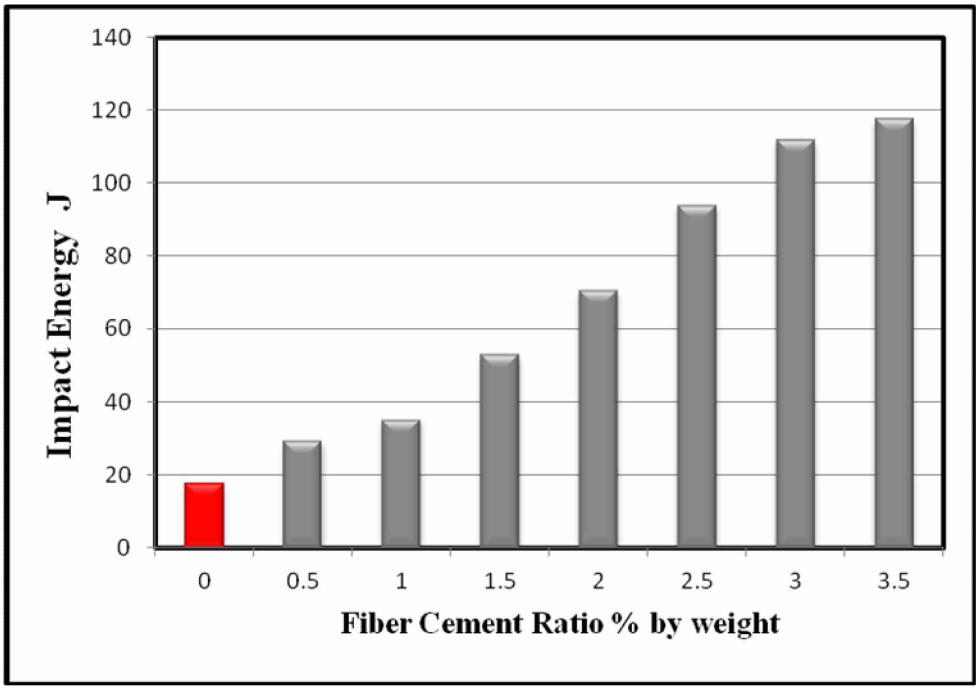

Fig. 6: Impact Energy of Slab Mortar reinforced with different Date raceme fibers percentage

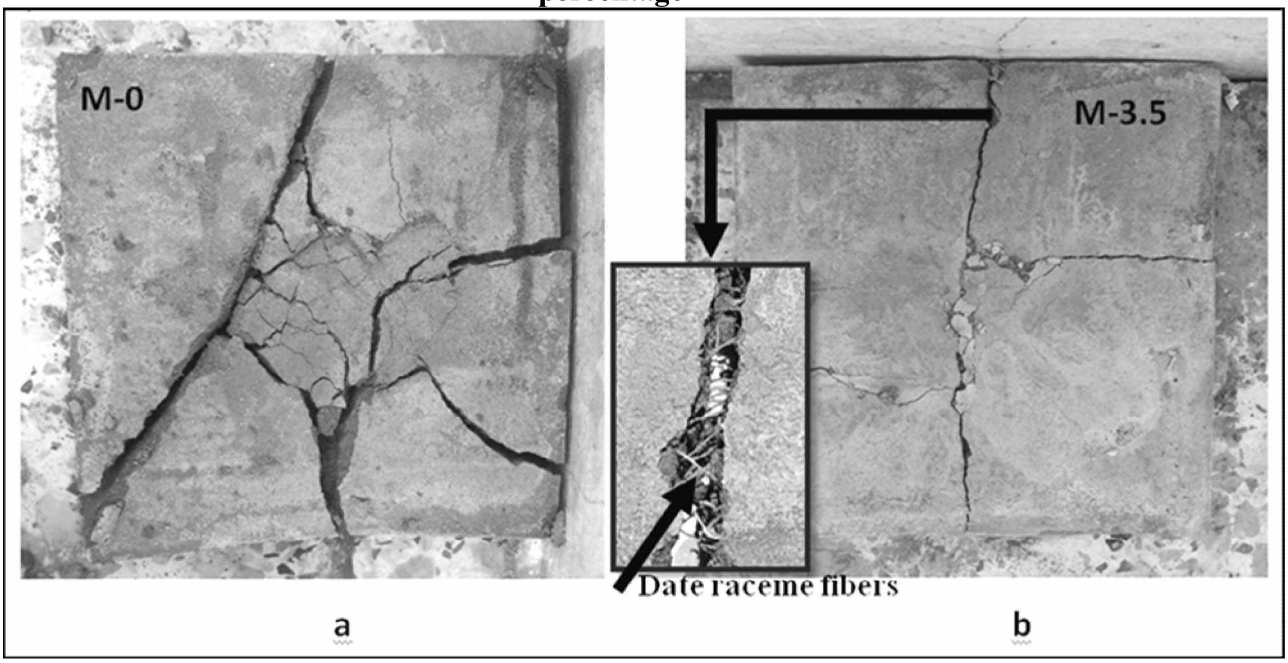

Fig. 7 Mortar slab reinforced a. with 0% of Date raceme fibers b. with 3.5% of Date raceme fibers by weight of cement

4. Conclusions:

Based on the results of this research, the following conclusions were made:

1. Date raceme fibers possess high physical–mechanical properties, such as higher tensile strength, attractive for their application as reinforcement for cement mortar.
2. Application of Date raceme fibers as a reinforcement results in a ductile behavior in both compression and tensile tests.
3. Simple addition of short efficient natural Date raceme fibers to cement mortar overcomes their brittle behavior permitting a ductile behavior in both compression and tensile tests, while retaining the very high strength of the cement mortar. The composites of Date raceme fibers -reinforcement improve the avoidance of bulk crushing required in the presence of the external load, and also improve its advantage in certain applications. In general, the addition of Date raceme fibers improved the tensile strength of cement mortar. The increase in tensile strength at age of 28 day represented by (94%) for cement mortar reinforced with Date raceme fibers with (3.5%) by weight of cement.
4. The impact resistance of cement mortar slabs improved by the addition of Date raceme fibers and increased with the increase of fiber content. The improvement can be represented by 117.72 J for cement mortar mix reinforced with 3.5% fiber.

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