Compressive and Tensile Strength of Natural Fibre-reinforced Cement base Composites

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Abstract:

This paper describes the effect of the addition of various volume fraction (0-٤%) of short natural fibres on the behavior of the composites. An experimental work has been carried out to study the mechanical properties of Roselle fibre-reinforced cement composites. The results show that the tensile strength of composite increases, (this increase in strength is about 53%), while the compressive strength decreases as the fibre volume fraction is increased.

Keywords: Cement , Composites ,Compression , Mechanical Properties Natural Fibre ,Roselle Fibre, Strength, Tensile.

مقاومة الشد والانضغاطية للمؤلفات الاسمنتية المسلحة بالياف الكجرات

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الخلاصة :

تصف هذه الدراسة تأثير النسب الحجمية الجزئية المضافة(٠-٤%) من الالياف الى الاسمنت على سلوك المؤلفات الاسمنتية. تم اعداد تجربة عملية لدراسة الخواص الميكانيكية للمؤلفات الاسمنتية المسلحة بألياف الكجرات، تبين من نتائج الفحص الميكانيكي أن مقاومة الشد تزداد تدريجيا الى ٥٣% عند زيادة وجود النسب الحجمية الجزئية من الالياف الى الاسمنت، بينما المقاومة الانضغاطية تقل تدريجيا.

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Introduction:

Roselle fibres extracted from fibrous tissues of Roselle plant trunk, grows in very large areas in southern Iraq, their diameters of fibres vary from 0.015 mm to 0.025mm and their lengths depend on the fibrilation process as in the case with sisal or jute fibres.

The major advantage of fibre reinforcment is to impart additional energy absorbing capability and to transform a brittle material into a pseudoductile material . Fibres in cement or in concrete serve as crack arrestor which can create a stage of slow crack propagation and gradual faillure [1].

The use of natural fibres for strengthing of brittle materials is very old, for example, reeds embeded in asphalt were used in the walls of ancient Babylon as a mortar binder for brick work [2].

It has been pointed out [3] , [4]. that low modulus fibres such as natural and synthetic organic fibres, when added to cement paste and concrete, do not produce composites with tensile or compressive strength significantly greater than that of the matrix as do high modulus fibres such as steel, carbon and glass.

Previous researchs have also referred to such advantages imparted by the natural fibres to the concrete material [5], [6].. Recent studies [7]. have described the results of a comprehensive exprimental evaluation of the fresh and mechanical properties of Coir-fibre composite with gravel-concrete as the matrix phase. An exprimental study was also carried out to improve the mechanical properties of gypsum hemihydrate joists reinforced with date palm fibres [8].

The present paper reports on the effect of the addition of various volume fraction of low modulus natural fibres on the behaviour of cement composites. Effects of Roselle fibres reinforcement in combination with cement to the ultimate compressive and tensile strengths behaviour are discussed . A cheap low modulus fibre may be used for the manufacture of structral units with cement-paste or cement-mortar composites have great potential, especilly for developing contries.

2-Experimeatal program

2-1 materials and specimens prepretion:

A locally manufacured (in kobaysat) ordinary portland cement (OPC) was used as the binding material. Sieve analysis for the grading curve and finenss test were conducted as well as the determination of its moisture and with specific gravity of (3.15). The chemical analysis of the cement used is shown in Table-1.

The natural fibres used in this investigation were Roselle fibres with an average length of (٨-١٠mm) and obtained from a Roselle plant trunk, whose scientific name is Hibiscus Subdariffa. L., it belongs to Malvaceas Family. The fibres soaked in water for four weeks, and afterwards the fibres were manually extracted into fine long fibres and their density is 0.75 gm/cm^3 . The fibre diameter varied from 0.015mm to

Table 1: Chemical Analysis of (OPC) Cement.

Contents (%)	(SiO_2)	(CaO)	(MgO)	(Fe_2O)	(AL_2O_3)	(SO_3)	(C_3A)	(L.S)
	21.36	60.08	4.7	3.14	5.24	2.25	8.58	0.86

Table 2: Comparison between Mechanical Properties for Roselle [9], Date-palm [8], Coconut [10], Reed [11], Sisal fibres [12].

Fibre Type	Density (kg/m^3)	Water Absorption (%)	Modulus Elasticity E(GPa)	Tensile Strength (MPa)
Roselle	800-750	40-50	10-17	170-350
Date Palm	463	60-65	70	125-200
Coconut	145-380	130-180	19-26	120-200
Reed	490	100	37	70-140
Sisal	800-700	56	15	268

0.025mm. Table-2; shows a comparison between Roselle fibres, Date-Palm fibers, Coconut fibres, Reed fibres and Sisal fibres, each material type being considered as a feasible reinforeing material.

The fibre-reinforcement with the cement past composites was used with low water to cement ratio (w/c) of 0.32 in order to minimise segragation of the low density natural fibres. Air dried fibres were used in weight fraction ranging from 0.25 percent to 3.0 percent(or in volume fraction ranging from (0.33-4) percent).The cement paste an fibres were mixed in this study using a regular Pan-Mixer of type (Mixer-3 speed HOBART).The mixing procedure for each weight fraction adopted was as follows:

(1). The required amount of cement (by weight) was put in pan-mixer and mixed at low speed (2).The required amount of fibres was added little by

little in cement as the mixer was running at low speed over a period of 10 minutes. until a uniform dry mixture is achieved.
(3). The required amounte of mixing water was gradually added into mixture as the mixer was running of low speed for about 2 minutes.
(4). The mixer was then turned to medium speed over a period of 2 minutes depending on the fibre content, taking care that no fibre balls are formed. (5) The mixing was finalized at high speed for 2 minutes. It has been noted that the fibre reinforced cement composites with relatively low fibre contents were used in this investigation and all fibres were uniformly distributed and randomly oriented with cement paste. The procedure aimed to achieve a uniform distribution of fibres between the specimens .

2.2 Experimental series :

Three Series of fibre – reinforced cement composites were casted :
Series 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)[13]. The number of specimens for each weight fraction was = 6
Series 2: (for temsil strength): The moulds were 25x25x75 mm casted and manually compacted. The number of Specimens for each weight fraction was = 3
Serie 3, (for density measurment): Three specimens of the 50x50x50mm sizes were taken from series 1 for density measurment which was obtained by methods Laid down in (ASTM-C220-75)[14].

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

2-3 Specimens Testing methods:

The ultimate compressive strenght test for specimens of 50x50x50 mm, was obtained by using a testing machine of type TONI TECHNICK of 600N Capacity while the direct tensile strength test for specimens of 25x25x75 mm was obtained by using a testing machine of type (MATR – 134 – 3 – 80 of RUM – 220Ib/in^2 (1.5 MPa)– 1100Ib (4.9 kN) Capacity .

3 - Result and Discussion:

3.1 Ultimate Compressive Strength test :

The results of series 1 and Series 2 for compressive strength and bulk density are shown in Fig-1(a). The compressive strength and bulk density are slightly increased in value with low fibre content in range (0.3 – 1.5%) as compared with the cement paste with no fibre, and the highest strength and density are obtained at the fibre–cement ratio of 0.3%. The increase in compressive strength and bulk density may be due to the good homogeny and high compaction between the fibres and the cement matrix. 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 fibre content exceeds the value of 1.5%, the compressive strength and the bulk density decrease. In general, when the fiber cement ratio exceeds the value of 1.5% , a reduction in compressive strength of about 8.5% for every 0.5% fiber volume increase occurred. This is very similar to a reduction in strength of about 10% for every 0.5% fibre volume increase occurred was reported by (Shimizo and Jorillo Jr,

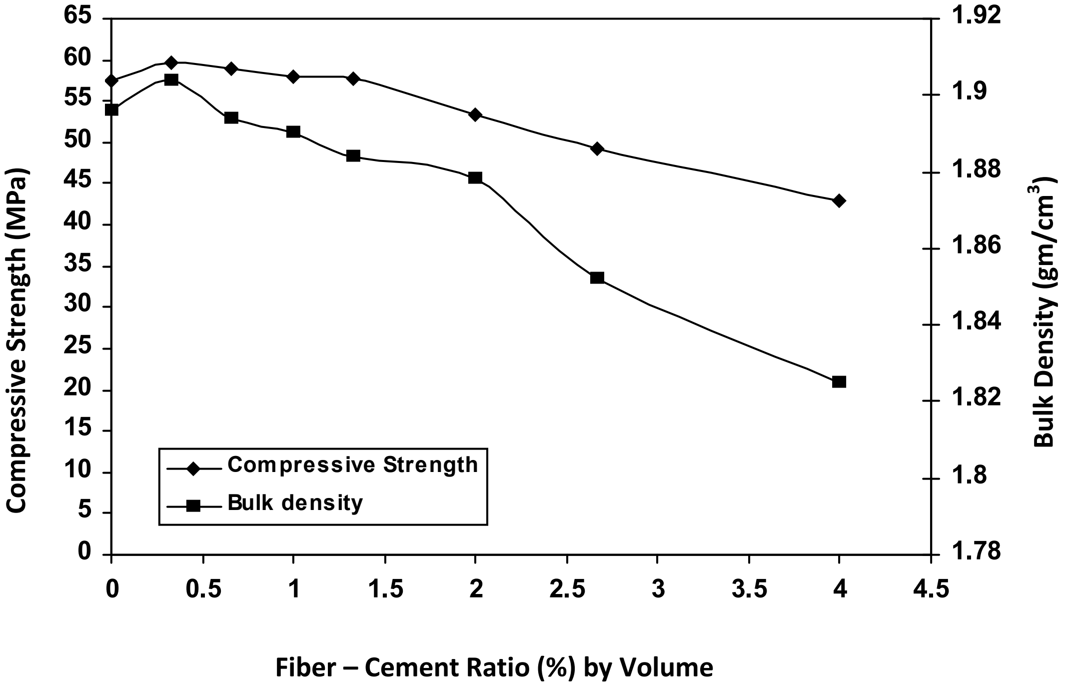
Table.3. The Mechanical and Physical Properties of Composites.

Fibre-Cement Ratio ($F/_c$)%		Bulk density (gm/cm^3)	Compressive Strength (MPa)	Tensile strength (MPa)
By Weight	By Volume			
0	0	1.896	57.5	6.4
0.25	0.3	1.904	59.7	5.6
0.5	0.66	1.894	58.9	7.15
0.75	1.0	1.890	57.9	7.5
1.0	1.33	1.884	57.7	8.6
1.5	2.0	1.878	53.3	9.2
2.0	2.67	1.852	49.2	9.64
3.0	4.0	1.825	42.9	9.8

1992).Such reduction in strength and density may be attributed to increasing porosity and air void which brought about insufficient compaction of the high fibre content mixture. However, from the values listed in Table 3, it can be seen that compressive strenght and the bulk density of composites are gradually decreased with increasing fibre content, therefore, the compressive streagth of the Roselle fibre-cement composite is a function of the bulk 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 (i.e retain its integrity) when compared with the cement paste with no fibre. A regression analysis correlating the composite compressive strength (σ_{Cc}) was correlated with the fibre reinforcing volume (V_f) in the form of composite mechanics approach. The correlation coefficient (R) of the best fit-line shown in Fig.1(b) is 95.5%

$$\sigma_{Cc}=60.925 - 4.1952\ V_f \qquad (R=0.955)\ldots\ldots(1)$$

Where the subscripts c and f refer to a particular property of the composite and fiber respectively.



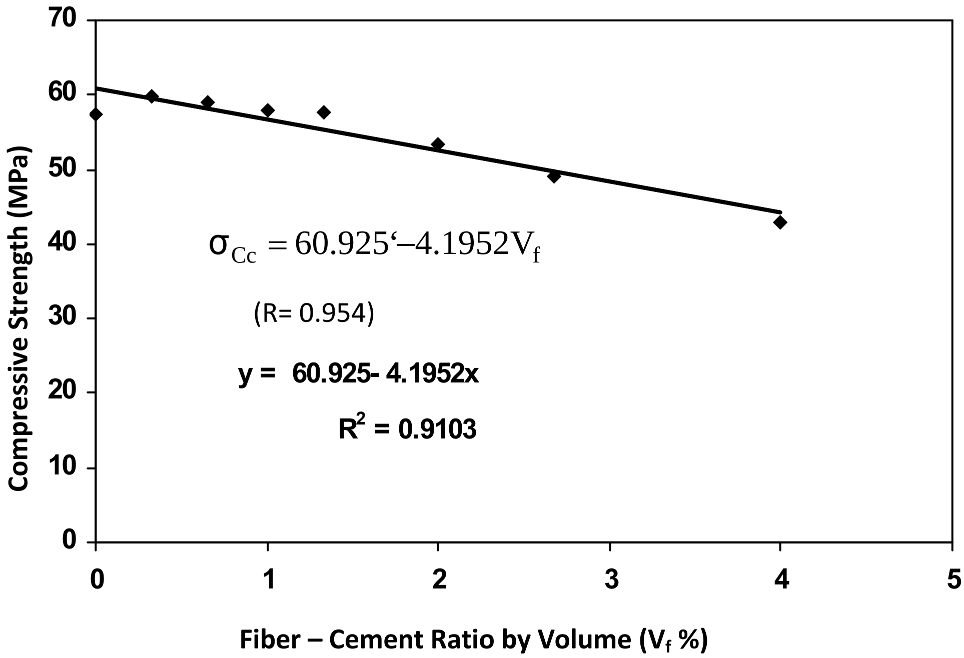


Fig. 1(a): Influence of Fibre-Cement Ratio on Compressive Strength and Bulk Density of Fibre-Cement Composite.

Fig. 1(b): Correlation between Compressive Strength and Fibre Reinforcing Volume in the form of Composite Mechanics Approach .

3.2 Direct tensile strength test:

The results of series 2 and series 3 for tensile strength and bulk density are shown in Fig.2(a). At lower fiber volume content of 0.3%, the tensile strength seemed to decrease,while the bulk density is increased to the maximum, possibly due to the high compaction between the fibre and the cement. However, when the fibre content exceeds the value of 0.3% the bulk density gradually decreases, while the tensile strength is increased. Although, the typical relationship between the fibre-cement ratio and tensile strength produce a quite low increase in strength, the general tendency shows enhancement in strength at 28 days age, and indicates a marked increase of about 53% in the ultimate tensile strength.This is very similar to the 18% in the ultimate tensile strength reported by (Shimizo and Jorillo Jr, 1992)[13]. Hence, a regression analysis using a linear fit- line equation was carried out to correlate the ultimate tensile strength (σ_{tc}) with fiber reinforcing volume (V_f) in the form of composite mechanics approach. The correlation coefficient (R) of the best fit-line showen in Fig.2(b) is 89.8%

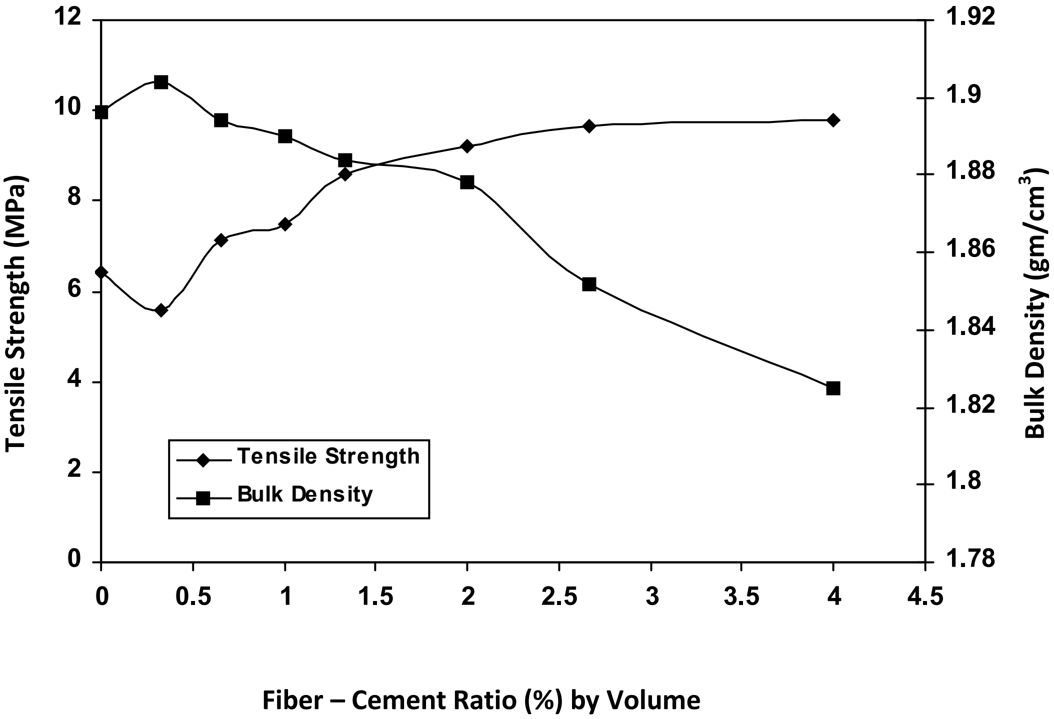
$$\sigma_{tc} = 6.4134+1.0494\ V_f \qquad (R=0.898) \quad \ldots\ldots\ldots(2)$$

3.3 Relationship between Compressive and tensile strengths

The typical relationship between Compressive and tensile strengths is shown in Fig.3. It seemes that the lower fibre content in range (0-1.5%) has approximately the same high values of compressive strength, while the tensile strength increases. When the fibre content exceeds the value of 1.5%, the compressive strength indicates a marked decrease, while the tensile strength marginally increases.

4. Conclusions:

Simple addition of short efficient natural low modulus fibres to cement matrix overcomes their brittle behaviour permitting a ductile behaviour in both compression and tensile tests , while retaining the very high strength of the cement paste. The composites of Roselle fibre-reinforcement improve the avoidance of bulk shattering required in the presence of the external load, and also improve its superiority in certain applications.In general, the increase in tensile strength of composites is found about 53%.



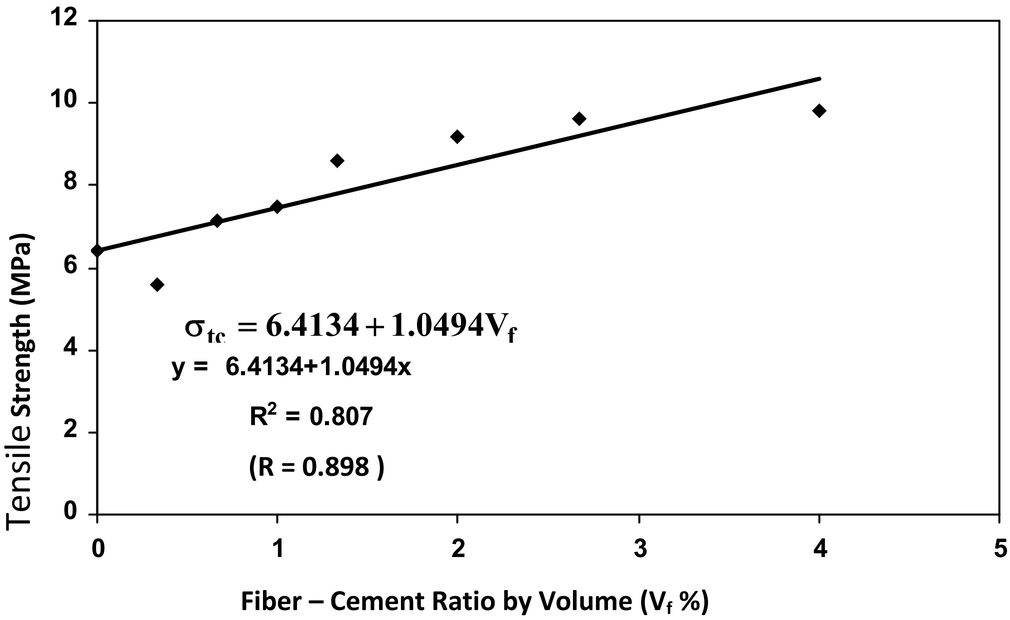


Fig. 2 (a): Influence of Fibre-Cement Ratio on Tensile Strength and Bulk Density of Fibre-Cement Composite

Fig. 2(b): Correlation between Tensile Strength and Fibre Reinforcing Volume in the Form of Composite Mechanics Approach

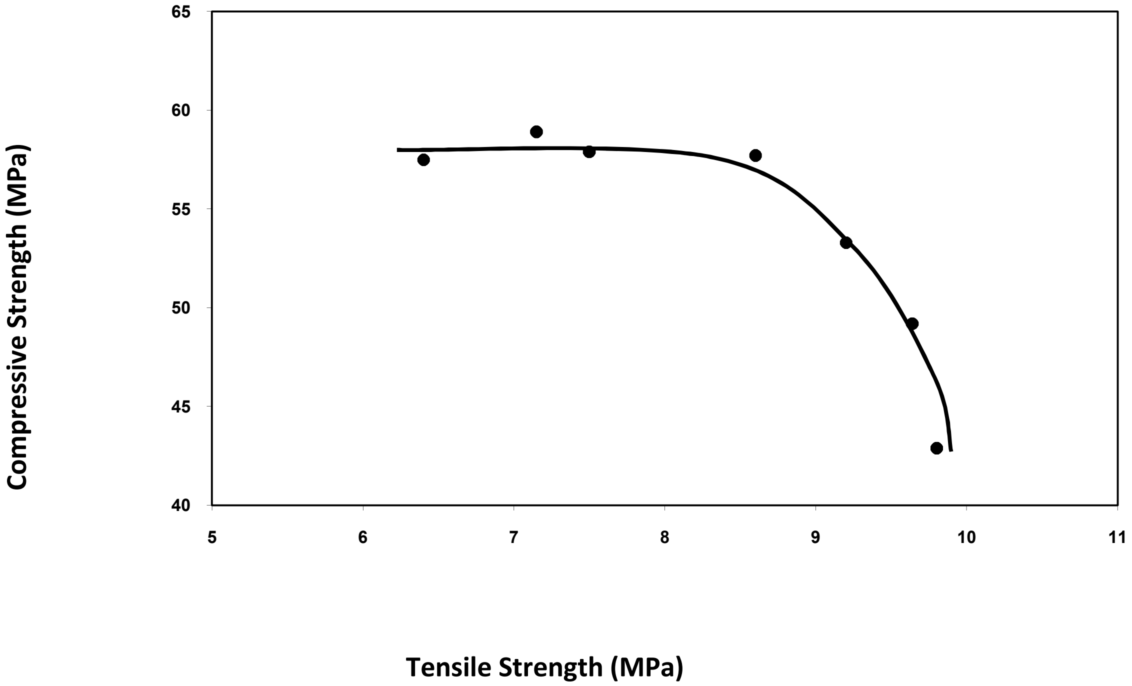


Fig. 3: Relationship between Compressive and Tensile Strengths, for various Fibre Cement Ratio (V_f%)

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