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Influence on Mechanical and Thermal Expansion Properties of Short Roselle Fibers-Reinforced Cement Base Composite Materials

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***Abstract* - This paper describes an experimental investigation on the mechanical, physical and thermal expansion properties of cement reinforced with Roselle fibres. The short discrete fibre length of (5-7mm) were used as reinforcement which were randomly oriented and uniformly distributed in the cement matrix and with various volume fraction of fibre cement ratio of (0-4%). The flexural strength, fracture energy, and thermal expansion of composites were found to increase as the fiber volume fraction was increased, while the elastic modulus was decreased, and also the results of the physical properties showed that a lightweight construction materials was obtained.**

Keywords: Roselle Fiber, Flexural strength, Fracture Energy, Elastic Modules, Thermal Expansion, Reinforced Cement Composites.

Symbols:

Sample width = b
Sample depth = d
Composer 's coefficient of elasticity =ε_{cf}
Maximum load=P
Fiber volume = V_f
Fiber weight = W_f
Composer 's breaking energy = ε_{cf}
Composer density = ρ_c
Fiber density =ρ_f
Maximum composer stress = σ_{cub}
Maximum applied stress = σmax
Composer 's percent thermal expansion = Ø%

I. INTRODUCTION

In recent years, many researchers have begun to pay attention to studying the use of natural fibres, for example palm tree husks, in the reinforcement process of some brittle construction materials such as cement and gypsum (1,2,3,4), due to their importance as an alternative to gravel and sand, which can be of great benefit in solving problems. There is a lot of waste, namely getting rid of accumulated waste, leftover palm oil husks near factories, and obtaining, Comparative study of the oretical concrete joisting investig(5).

Fibers as a successful reinforcement material with Ordinary Portland Cement (OPC) for use in building cheap housing. A recent study was also conducted on the behavior of the mechanical, thermal and physical properties of sawdust concrete [6,7,8,9]. The results of the examination showed the success of this reinforced concrete, which can be used in a number of It has many broad application fields that qualify it as an alternative construction material.

The behavior of sisal plant fibers in reinforcing thin concrete plates was studied [10]. The weight components of these concrete compositions were 30% of fine rice husk ash and 70% of cement (OPC), with the water to cement ratio constant, and the main variable factors were the length of fibers, and ratio of fine sand aggregate to cement [11]. The examination results of these works confirmed great success in increasing the coefficients of ductility (Resilience Modulus) and toughness. The results also confirmed that the presence of rice husk ash in concrete compositions leads to a noticeable improvement in the ductility of the composite[12]. The effect of natural reinforcement fibers on the basic components has recently been studied for cement using the Autocalve method [13].

As for the current study, the fiber of the Roselle plant was chosen, and its scientific name, as this fiber is characterized, was (Malvaceae) and it belongs to the mallow family (Hibiscus) SabdariffaL.) with small diameters ranging from (0.015 - 0.025 mm), the elastic modulus of the fiber between (10 - 17 GPa), and its strength rating is about (170 - 750 MPa), and it is available in large quantities in diameter [14]. The Roselle plant is grown in southern Iraq. Especially in Diwaniyah Governorate, and it can be obtained at the lowest costs. This research aims to study the mechanical and physical properties and thermal expansion of cement reinforced with fibers from the stems of the gujarat plant. To this end, different partial weight ratios of the fibers were used Short interruptions to cement with constant water to cement ratio.

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II. MATERIALS AND WORKING METHODS

Ordinary Iraqi Portland cement from the Al-Kubaisat area, with a specific gravity of (3.15), was used. The cement was laboratory-tested from both the physical and chemical aspects, as in Tables (1, 2). Ordinary drinking water was used, and the water to cement ratio (0.32) was chosen. This ratio is considered one of the low, fixed ratios of water to cement as a practical basis for obtaining a high value of strength. The density of the currant plant was made to (0.75 - 0.8 gm/cm^3) as a basic material in cement reinforcement, which was obtained from the Iraqi Atomic Energy Organization Department, Agricultural Research Department). Different weight percentages of short fibers to cement were used, ranging from (0, 0.5, 0.1, 1.5, 2.0, 3.0%). These weight percentages were converted. Fiber to volume ratios as shown in a table (3) as following equation:

$$(V_f = m_f \times p_f)$$

Where (V_f) represents the fiber volume, (m_f) the fiber weight, and (P_f) the fiber density.

pMothed reparing samples for fiber-cememt composites

In this study, the method of random mixing of fibers in cement was used. An appropriate weight quantity of ordinary dry Portland cement was placed in the bowl of a small mixer type (HOBER Mixer-3 - Speed). The mixer was operated at slow speed, with a certain weight percentage of fibers gradually added to the dry cement powder, while the mixer continued to move at slow speed until it was obtain a homogeneous mixture of fibers in the cement. Then the required percentage of water (0.32) was added to the mixture gradually until the required soft fibrous cement dough was obtained, with emphasis on the homogeneity of the dough and that it was free of any balling or bundling of the fibers Cement.

The soft dough mixture was transferred directly from the mixer to two sets of molds: the first set has dimensions of 40 x 40 x 160 mm) and is intended for physical tests (density, general absorbency, air voids) and mechanical (bending strength, fracture energy, and modulus of elasticity). As for the second set, it has dimensions (25 x 25 x 285mm) and special thermal expansion tests (Autoclave Thermal Expansion) for cement. Then the molds were filled with two layers of soft dough and manually leveled using the thumb of the hand and a manual trowel in order to hold the formed dough together and also get rid of some of the pores and air gaps formed inside the soft dough. Then the molds were covered with plastic covers for 24 hours to prevent water from escaping from the samples, to maintain their moisture, and to continue the annealing process.

The samples were taken out of their molds 24 hours after casting, then immersed in a basin filled with normal drinking water for a period of 28 days in order to complete the rehydration and treatment processes.

Mechanical properties tests, (maximum bending strength, fracture energy and modulus of elasticity)

Bending strength tests were measured for samples with dimensions (40 x 40 x 160 mm) according to American specifications (ASTM-C192 - 88) [15] after they had been immersed in water for 28 days.

The examination device was of the type (Servopulser-300kg Model EHF-E series), Japanese-made. The speed rate of the device's twist was (0.5 mm/sec). Technology was used in conducting these tests-(Three Point Bending) for a lever length (100 mm) according to the following equation: $\sigma \max = pl/bd^2$

Whereas σ max - Maximum bending strength: unit of measurement (MPa)

Maximum load (P = Max. load (KN))
Sample space (mm)=L
Sample width (mm)=b
Sample Depth (mm)=d

From the results of the diagram of the ultimate flexural strength (stress - deflection) the fracture energy and elastic modulus were obtained graphically as shown in Figure (1).

Fracture energy: is defined as the work required to be done when deformed or crush the body to the point of breaking [16]. Its value is represented by the area under the (stress-diflection), and the unit of measurement (MPa), Figure (1)

Elastic Modulus: The elastic modulus of a body is defined as the ratio between (stress / strain) value is determined from the slope of the tangent curve (stress-strain) within the linear elastic region, and the unit of measurement is (MPa), figure (1).

Thermal Expansion test: Water samples were taken after 28 days of treatment and then intended for operations Test (ensure thermal expansion Autoclave: The samples were placed in a steam boiler under pressure and temperature of (220 - 215℃), for three hours, according to American specifications (ASTM -c157-88) [17]

The thermal expansion (stability - soundness) of the samples was found according to the following method: The dimensions of the samples after handling them in autoclaving operations) minus the dimensions of the samples before handling them in Autoclave operations) divided by the

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dimensions of the samples before they were treated in the autoclave operations) and multiplied by (100)For example, if (the dimensions of the sample before handling it in the autoclave device and (c,b,a) are the dimensions of the sample after handling it in the autoclave device, then the percentage increase in thermal expansion will be according to the following equation: Thermal Expansion

$$(\emptyset\%) = [(a'xb'xc')-(axbxc) / (a\times b\times c)]x100 \quad ....(2)$$

III. RESULTS AND DISCUSSION

1. Physical properties: (density, water absorption, and porosity.) Density and water absorption values were measured for samples with dimensions (160x40x40mm)According to American specifications (ASTM -C642-82)[18].the volume of air voids was calculated by multiplying the values Water absorption in the density of the composer in its dry state, as shown in Table (3). The content of the volumetric fraction of fibers (V_f) in the sample is considered the main factor affecting the change in the properties of the other factors of the sample. The volumetric fraction of fibers in the sample can be calculated from Two factors are: the weight fractional content of fibers (W_f) in the sample and its density (ρ_c). The mathematical expression that links the volumetric fractional content of fibers (V_f) and the fractional content The weight (W_f) for it in the sample is represented by the following relationship [19].

$$V_f = (\rho_c/\rho_f) \text{ x } W_f \text{ ....(3)}$$

Where pc and pf are the composition density and fiber density, respectively. The composer 's values of density, water absorption, and porosity depend on each other for any change. It occurs in the structural of the sample and that all of these properties depend on the free air voids resulting from the addition of fibers in the cement, as the movement of water between the cement particles also plays a primary role in the formation of the free voids and pores. Figure (2) shows the curves of density, water absorption, and volume of air voids of the compound, along with the partial volumetric percentage of fibers to cement. It appears from the figure that the density of the compound gradually decreases with an increase in the presence of fibers in the cement, while the water absorption and volume of free voids gradually increase with the increase in the addition of these fibers to Cement, except at the percentage by volume (0.66), the process here appears inverse, as it is noted that both the water absorption of the compound and the size of the free voids decrease with a modest increase in the density of the compound when adding this simple partial percentage of fibers (that is, the value of this percentage of water absorption The size of the free voids is less than its value in ordinary cement. Explaining the behavior of this ratio (0.66) volume of fibers to cement is considered an important physical condition, as this modest ratio of fibers can be considered as if it were dealing with cement as an impurity material, as it can behave like Materials that fill the free voids and pores within the structure of the sample instead of increasing the size of these voids and pores resulting during the formation of the soft fibrous cement paste, leading to a modest increase in the density of the composition at this ratio of fibers to cement. As for other percentages of fibers, their presence between the cement paste particles leads to an increase in volume, which exceeds the water absorption ratio of the sample (0.66), as well as free voids within the structure of the cement paste. With an increase in the sample density gradually decreases, and therefore a statistical regression analysis can be performed between the proportions. of fibers with composite density (ρ), which is represented by the following linear relationship, Figure (3).

$$\rho_c = 1.8992 - 0.0193V_f,\ R^2 = 0.9947 \text{............(4)}$$

The density ratio of the fibers compared to the density of cement is small, and the fibers themselves have free void folds in their fold, which leads to a reduction in the weight of the sample, and this property is one of the important properties in the classification of construction materials.

In general, it is clear from Figure (2) and Table (3) that the partial volumetric percentages of fibers added to the cement, which exceed (0.66) volume of fibers, lead to a gradual reduction in the density of the samples, and the opposite is true for the values of water absorption and the size of free voids. In the sample, both of them increase with the increase in the addition of fibers in the cement [20].

2. Mechanical properties, ultimate bending resistance, fracture energy and modulus of elasticity

Ultimate Flexural Strength (Maximum bending strength)

Bending resistance properties are important properties in determining many static mechanical parameters, such as fracture energy and modulus of elasticity. The flexural resistance was calculated from the maximum value of the resistance of the first crack to the failure of the specimen according to the (stress-deflection curves) (Figure 1). The results of the mechanical examination of the flexural resistance showed a clear improvement in the resistance of the cement compositions reinforced with fibers of the Roselle plant , due to the clear increase in the peak strain, especially in the exposed part. For the tensile strength of the sample, Figure (4) shows the effect of the partial volumetric ratios of fibers on the bending resistance. The composer states that the large increase in the peak strain of the sample led to a high increase in strength values, and this increase is due to the high mechanical efficiency in the tensile stress system of the

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sample compared to the compressive stress system. It appears that the gradual addition of volumetric proportions of fibers to the cement led to a direct increase in the maximum bending strength, and that this increase in strength amounted to about (82%) compared to the bending strength of ordinary fiber-free cement, and that the reason for this increase in strength is also due to its properties. The mechanics of the fibers, as well as their homogeneity and strength of adhesion to the cement bonding material. Therefore, a statistical regression analysis can be performed between the partial ratios

The volumetric size of the fiber with the composer's maximum bending strength (σcub) as shown in the following equation:

$$\sigma_{cub}=5.7705+1.0832Vf,\ R^2=0.9811\ldots\ldots\ldots\ldots (5)$$

Fracture Energy: The fracture energy of cement compositions reinforced with Roselle fibers was calculated from the area Enclosed under the bending strength(stress-deflection curves). It was found that the areas under the (stress-deflection) curve increase directly with the increase in the partial volume ratios of the fibers, as shown in Table (3) and Figure (1). This increase in the area under the curve is due to several reasons, including:first Crack Strength Failure

1. Increase in strength of the first crack to failure.

2. Increase in effective (Composite Strain).

3. The increase occurring in the post-cracking stage, i.e. in the stage of the plastic region of composite and when the percentage of the volume fraction of fibers increases at its critical size, there is a significant increase in the post-cracking strength of the fibers, and the fibers are responsible for the remaining load after the first crack of failure, which adds a new area to the stress-deflection curve, and this added area represents the amount of energy absorbed by the composite after cracking. Which depends mainly on the type of reinforcing fibers, on the volumetric and aspect ratios, especially on the tensile strength of the fiber and on its specific surface area, as well as on how the adhesion stresses are distributed between the surface of the fiber and the cement (interface zone). Figure (5) shows the effect of the volume fraction of fibers in cement on composer's fracture energy. According to the composite, the increase in fracture energy amounted to about (650%) compared to regular cement without fibers. This large increase in fracture energy, according to the composer , confirm the effectiveness of these fibers in suppressing cracking and their ability to absorb the largest possible energy when they are withdrawn from the bonding cement without breaking. Accordingly, a statistical regression analysis can be performed between the partial volume ratios.

For fibers (V_f) in cement with fracture energy, which is represented by the following linear equation:

$$\varepsilon_{cf} = 0.2159+0.3509V_f\ R^2 = 0.9447\ldots\ldots.(6)$$

It follows from the above that both the maximum bending resistance and the fracture energy of the composite are directly proportional to the increase in the addition of the partial volume ratios of fibers in the cement, as any increase in the composite (strain-stress) or in its maximum bending strength is accompanied by an increase in its fracture energy. Accordingly, it is possible to derive a linear mathematical relationship or perform a statistical regression analysis between the composite maximum bending strength and his breaking energy for the partial volumetric fiber-to-cement ratios in Figure (6), which is represented by the following linear equation:

$$\varepsilon_{cf} = -0.1609+0.31820\ \sigma_{cub},\quad R^2 = 0.9299\ldots\ldots.(7)$$

This equation indicates the extent of the appropriate linear relationship between the factors of bending strength and the composite fracture energy for the volume fractions added from fibers to cement.

This equation indicates the appropriate linear relationship between the two bending strength factors. The composite breaking energy for the volume fractions added from fibers to cement.

Modulus of elasticity

It is one of the important variable parameters in static mechanical properties in compressive and tensile behavior is the modulus of elasticity, which can calculated from the stress-strain curve. This variable factor is considered one of the distinctive mechanical properties in practical applications. The static modulus of elasticity was calculated from the (slope of the elastic linear portion), (Slope of Stress - Strain Curve).

Figure (7) shows the effect of the partial volume ratios of fibers in cement on the composite modulus of elasticity. It appears with the increase in the addition of aggregate percentages of fibers to cement, and this decrease in the value of the elastic modulus is attributed to the gradual decrease in the curved curvature that the value of the static elastic modulus increases. The ascending straight part in the region of the elastic linear part of the (stress-strain) curves. Likewise, the increase in the composite strain is that the high increase in the composite strain is due to the high mechanical efficiency of the fibres. The results of the extracted values showed a clear improvement in the increase in the effective composite strain, especially in the part subjected to tension, and this in turn led to a gradual decrease in the elastic modulus of the

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composite. The largest decrease in the composite modulus of elasticity was about (50%) compared to the modulus of elasticity flexibility of ordinary cement. Accordingly, it is possible to conduct a statistical regression analysis between the volume percentages of fibers and the composite elastic modulus, which is represented by the following linear equation:

$$E_{cf} = 145.85\text{-}12769V_f R^2 = 0.728................(8)$$

3. Properties of the thermal expansion coefficient

Cement Soundness is considered one of the most important physical properties on which the success of cement hardening and its suitability in construction work depends, because the stability of cement depends on its ability to expand, meaning that lack of stability in the case of cement hardening during the processes of chemical reactions of hydration leads to the occurrence of cracks. Microcracking occurs in the texture of hardened cement, which leads to its failure as a bonding building material. This is a result of the sudden and inappropriate expansion in the cement texture. This sudden expansion may be accompanied by the lumpy disintegration of the cement as a result of the free calcareous hydration processes (CaO) [21] present between the cement particles. Perhaps after cement hardening processes, the limestone material may be exposed to immediate hydration as a result of its exposure to moisture, or when limestone expansions of various shapes occur through the influence of a large thermal force resulting from chemical reactions to hydrate the cement. Therefore, the cement must harden slowly and gradually. One of the advantages of slow hardening of cement is that it gives sufficient or appropriate time to complete the hydration processes for the limestone materials in the cement components so that the soft cement mass gradually turns into a solid material without any microscopic cracks occurring in the solid mass. Another reason for the lack of stability of the cement during the hardening processes is the amount of high levels of magnesium oxide (MgO) and other alkaline oxides with gypsum [22]. Figure (8) shows the effect of the partial volume ratios of the cut fibers Short Discrete Fiber in cement affects the thermal expansion of the samples. It appears from this figure that the partial volumetric addition of fibers in the cement leads to a gradual increase in the thermal expansion of the composition and thus leads to an increase in the stability of the composition. The increase in thermal expansion of the samples with the cinder fibers reached about (69%) compared to ordinary fiber-free cement. Accordingly, a statistical regression analysis can be performed between the volume fractions of fibers in the samples, and the following linear equation is calculated: The percentage thermal expansion for it.

$$\emptyset\% = 0.3269+0.2165V_f\ R^2=0.9937..... (9)$$

This increase in thermal expansion is due to the physical and mechanical properties of the fibers and to the good state of homogeneity between these fibers with the cement bonding material, as well as to the strength of their adhesion In the (Interface Zone) which has a fundamental role in increasing resistance to the high thermal stress resulting from autoclave process. It is known that the change in the dimensions of a rod, for example, may not be achieved by stress force alone, but temperature may perform the same work as an alternative in the event of a deficiency Mechanical stress about it. When cement compositions reinforced with natural fibers are exposed to external stress such as pressure at high temperatures, the presence of these fibers in cement is effective because of their ability to elongate and have high strength to these compressive and thermal stresses, which prevents any cracks from occurring in the solid cement block reinforced with these fibers. In contrast, unreinforced cement blocks, when exposed to these high thermal or compressive stresses, lead to To its cracking or disintegration, and on the other hand, the presence of these fibers adds some ductility to the properties of the brittle cement material, so that the cement turns into a semi-brittle material capable of elongation and expansion. For example, when these compositions are exposed to turbulent climates, especially in hot areas that are exposed to High temperatures may reach more than 70 degrees Celsius in the summer and below zero degrees Celsius in the winter, which puts these buildings in an unstable situation. Accordingly, the presence of these fibers in the structural mass leads to their stability.

IV. CONCLUSIONS

It was shown from the results of this study that the process of reinforcing ordinary Portland cement (OPC) with short intermittent Roselle fibers led to a significant improvement in the maximum bending strength and fracture energy and a decrease in the modulus of elasticity. It also led to an increase in the thermal expansion of the cement and thus to an improvement in its strength and stability. In general, cement reinforced with these fibers has created lightweight construction materials with load-bearing capabilities that outperform hard cement in locations requiring high strength and ductility performance. Therefore, fracture energy is one of the most desirable mechanical properties in production. Construction materials because they bring greater safety to the facility in the event of sudden collapses and cracks such as earthquakes.

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Mechanical properties and thermal expansion of Gujarat fiber reinforced cement

Table (1): Results of physical and mechanical tests according to the report of the national center for structural laboratories for Baghdad structural laboratory Directorate -concrete department

Method and type of examination	According to Iraqi standard specification	The result	Type of cement (OPC).
(Blaine) method	230kg/cm² minimum	459	Softness
(Vicat) method	45minutes minimum 10 hours minimums	2:15 4:30	2 Hardening time (minutes: hours)initial and final compressive strength rate (Mpa/cm²) 3days 7days
	Minimum(Mpa/cm²) 15 Minimum (Mpa/cm²)23	18.9 28.5	

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Road (فرن الضغط) (Autoclave)	0.8 maximum limit	%0.33	Stability (extensibility)
	Ordinary Portland cement (OPC)		Cement type

Table (2): Results of chemical analysis of cement according to the construction laboratories of the Baghdad Laboratory Directorate

	Percentage %	Basic component of cement
	20.22	Silica Oxide (Sio2)
	59.58	Calcium oxide (CaO)
5% Maximum	4.40	Magnesium Oxide (MgO)
	2.91	Iron Oxide (Fe2O3)
	6.39	Aluminum Oxide(AL2O3)
2.8% maximum limit	2.56	Sulfur Oxide(SO3)
4% maximum limit	2.41	Loss by burning (Loss)
1.5% maximum limit	1.46	Insoluble Substances (Ins)
5% Minimum	12.02	Calcium triluminate (C3A)
%1.02-%0.66	0.87	Lime Saturation factor (L.S.F)

Table (3): Showing the mechanical and physical properties of cementitious composites reinforced with jute fibers

Fibre - Cement Ratio F/c%			Flexural StrengthM Pa	Fracture Energy Mpamm	Elastic Modulus Mpa	Thermal Expansion I O(C⁻¹)%	Density Po (gm/cm³)	Water Absorpti On %	Composite volume		
SP NO.	By Weight Wf%	By Volume Vf%							Fibre Volume Vf%	Air Voids Volume%	Cement volume %
1	0	0	5.5	0.335	157.5	0.335	1.897	15.10	0	28.65	71.35
2	0.5	0.66	6.62	0.381	142.9	0.478	1.889	15.03	1.18	28.39	70.5
3	1.0	1.33	7.3	0.543	113	0.582	1.872	15.40	2.34	28.83	68.86
4	1.5	2.0	7.95	0.865	110.9	0.747	1.863	15.62	3.49	29.10	67.26
5	2.0	2.67	8.94	1.334	109	0.945	1.848	15.83	4.6	29.25	66.24
6	3.0	4.0	9.86	1.583	105.7	1.182	1.821	16.18	6.8	29.46	63.74

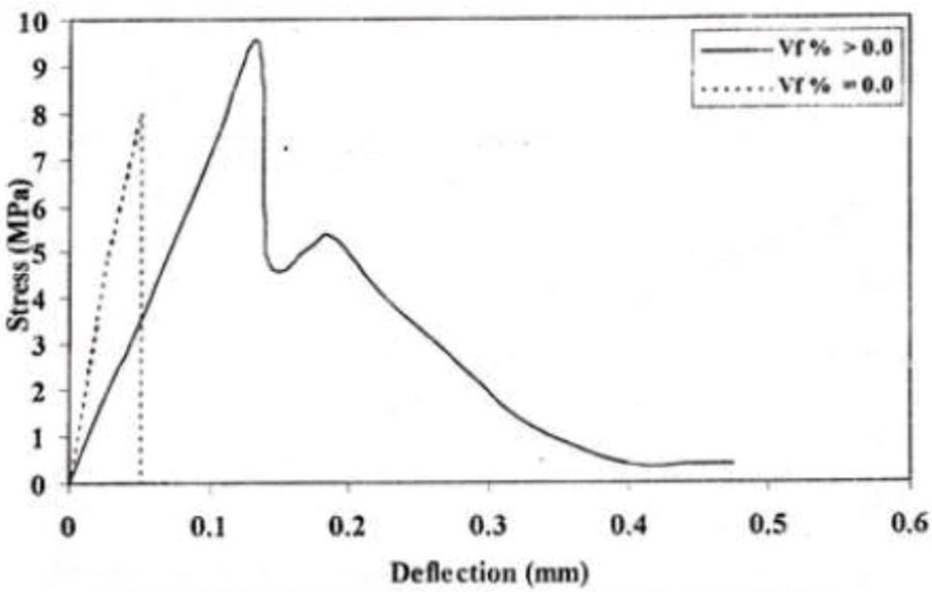

Figure 1: The relationship between stress and deviation

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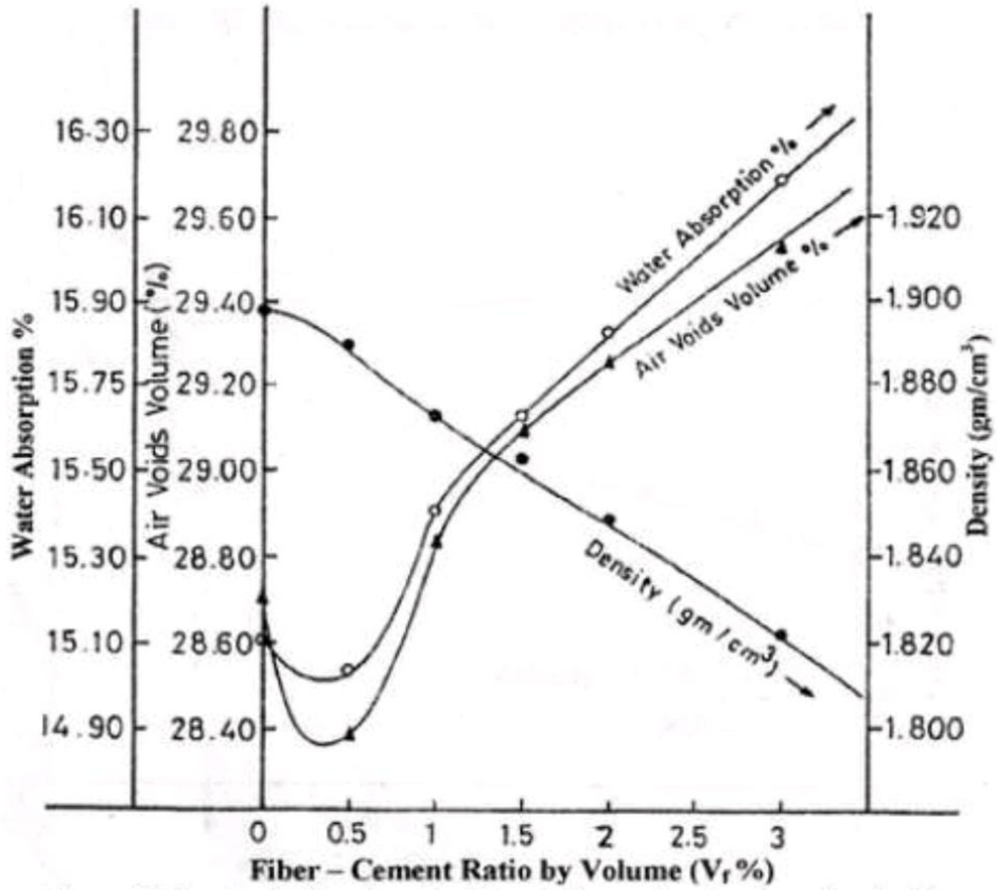

Figure 2: The effect of the volume fractions of fibers on the, Density, Water obsebtion and the air volume of the composite

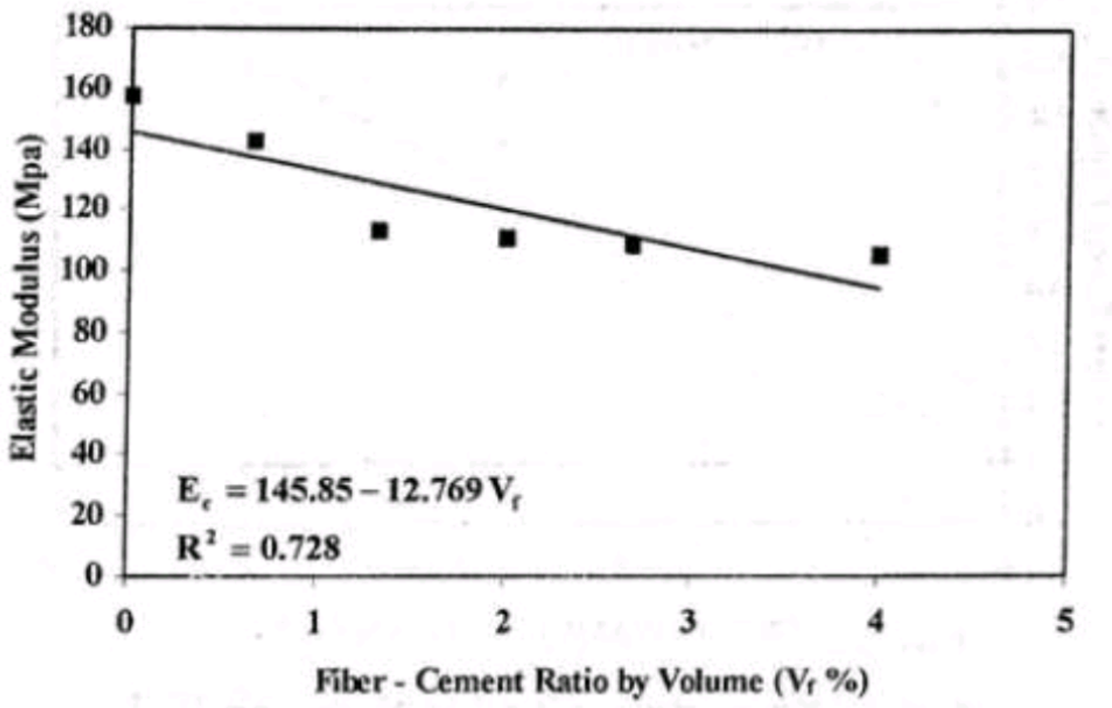

Figure 3: The effect of volume fractions of fiber in cement on density of the composites

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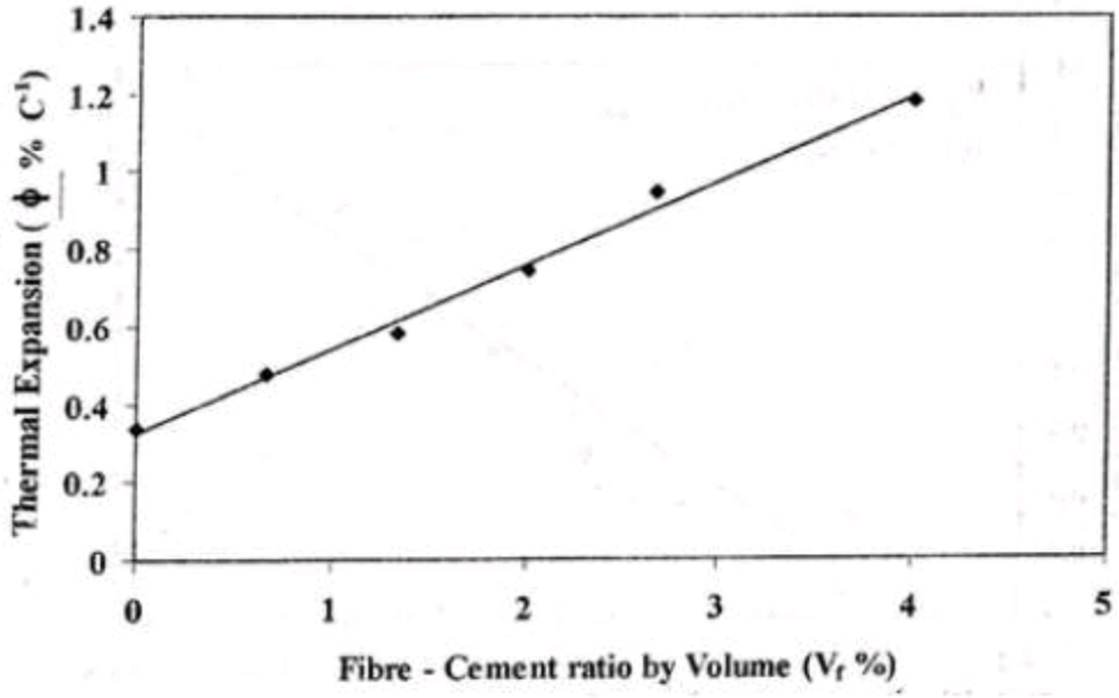

Figure 4: The effect of volume fractions of fiber in cement in cement on the compressive of composites

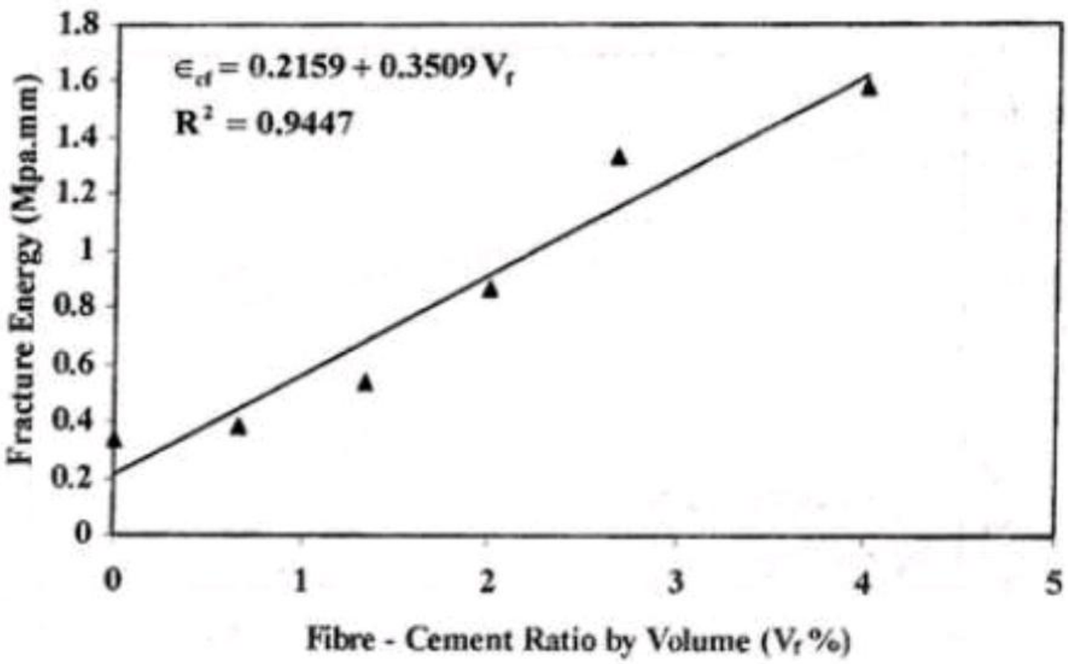

Figure 5: The effect of the volume fractions of fiber in cement on the fracture energy of the composites

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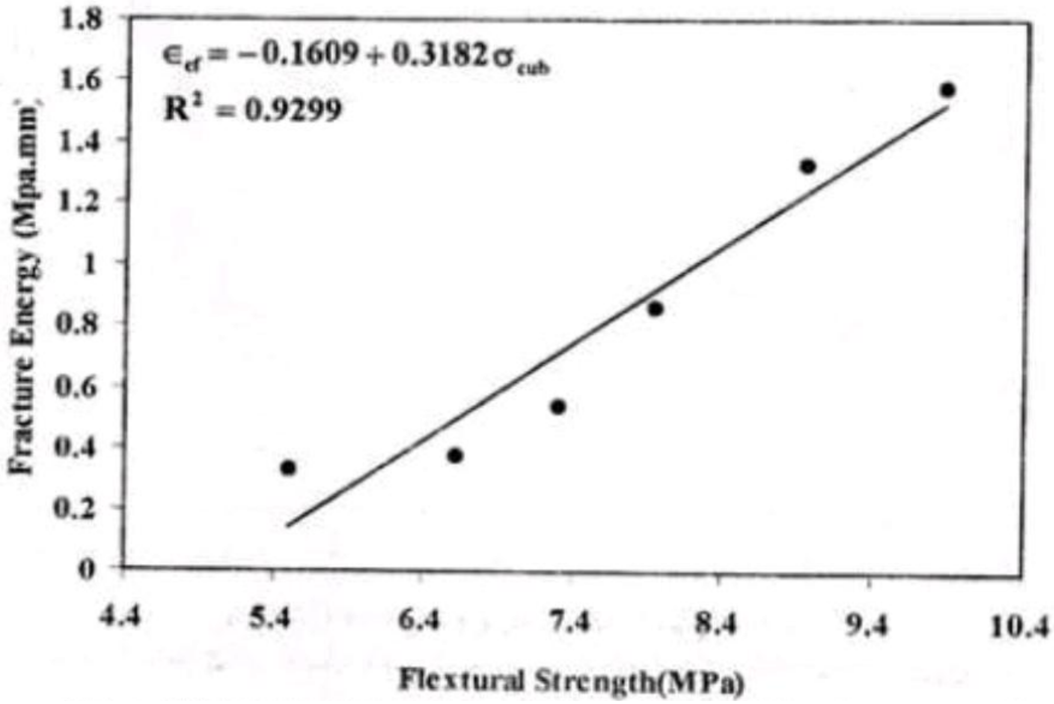

Figure 6: The relationship between flexural bending strength and fracture energy of the composites

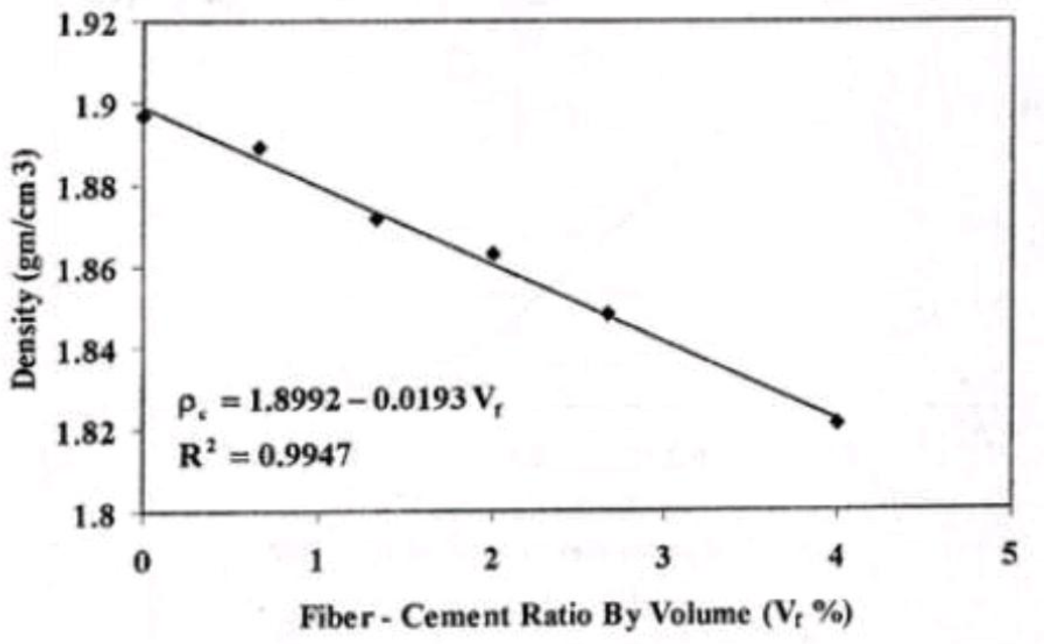

Figure 7: The effect of volume fractions of fibers on the elasticity modulus

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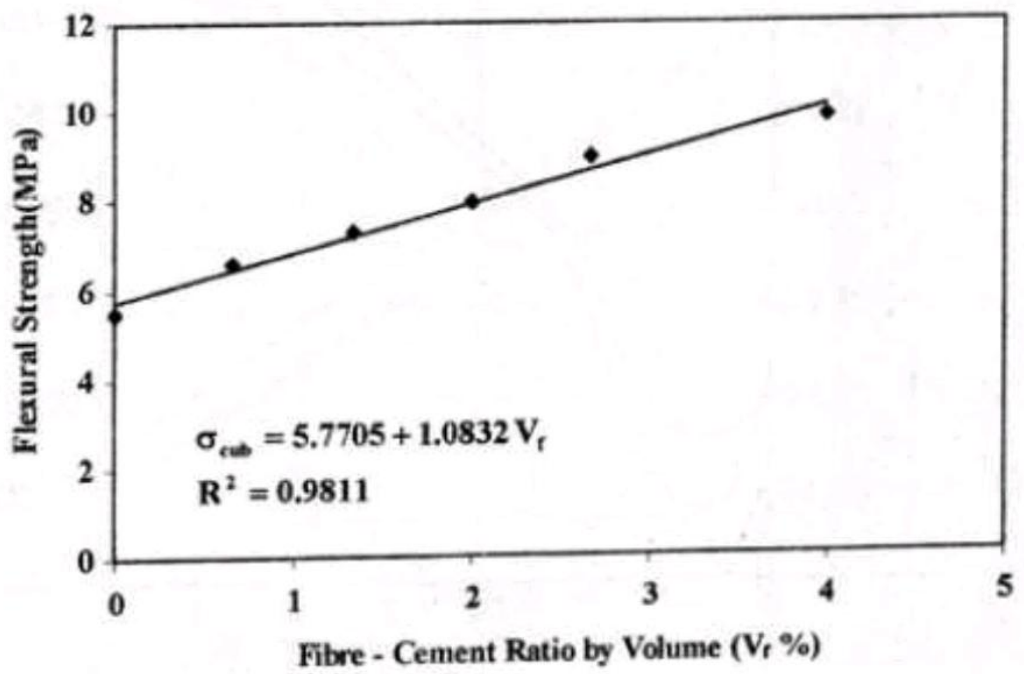

Figure 8: The effect of volume fractions of fibers on the thermal expansions

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