

Natural Roselle Fiber Reinforced Cement Based Composite Materials

Dr. Mahmood A. Ismail

Department of Chemical Engineering and Petroleum Industries, Al-Amarah University College, Iraq

Abstract - This paper describes an experimental study on strength properties, and the physical performance of cement-based composite materials reinforced with Roselle fibers. Two different fiber lengths of volume fraction were used as reinforcement with cement paste composites, which were uniformly distributed and randomly oriented in the cement matrix. Specimens with varying fiber volume fractions were tested for strength properties in tensile, flexure, compressive, and impact. Samples were also tested for bulk density and thermal properties. The results of this study have shown the feasibility of using Roselle fibers in developing low-cost building materials, which indicated that making Roselle fiber reinforced cement composite enhanced the strength properties of cement composite. Roselle fibers are readily available in Iraq and also in many other neighboring countries.

Keywords: Natural Roselle Fibers, Cement, Composite Materials, Strength, Reinforcement, Impact.

I. INTRODUCTION

The natural fibers have been used to reinforce the brittle materials, and pottery, since the very beginning of civilization. For example, reed embedded in asphalt was used in walls of ancient Babylon as a mortar binder for brickwork, and the same principle was used in the construction of boats in the marshes of southern Iraq [1]. However, only in the last years have the principles of fiber reinforcement with brittle matrices begun to be scientifically understood.

Composite materials of cement-natural fibers have been in use since ancient times because of the disadvantage of the synthetic, fiberglass and asbestos. The health problems associated with asbestos and its related products necessitated finding the alternative resource of fiber. Over the last two decades, natural fiber (mainly wood pulp fiber) [2] has emerged as the most acceptable alternative reinforcement for the fiber cement product. Many countries in the Asia-Pacific region face acute problems of having tough, robust, cheap, and durable materials for housing construction for low-income families. The use of natural fiber-reinforced composite materials can provide a solution to some extent to these problems of low-income housing of money. Several previous

research has already been carried out on the use of natural fibers, bamboo, coconut, jute, sisal, and wood pulp fibers, in cement paste, mortar, and concrete [3,4,5,6,7]. Also, recent developments in the field of composites have been conducted on the strength properties, physical performance, and durability aspects of cement-based composites reinforced. This evaluation of the potential use of glass powder residue as partial replacement of cement in the fibers cement industry was experimentally investigated by [8]. The results showed that the partial replacement of cement by 50% by weight of glass powder residue increases the flexural strength of composites at 8 days after of 30 days durability tests. The shear capacity of reinforced concrete beams strengthened with cement-based composite materials was investigated by [8].

It was found that The use of the PBO-FRCM (in FRCM composites, different types of fibers such as carbon, glass, asbest, steel and polyparaphenylene benzobisoxazole, PBO can be used) strengthening system allows improving the shear capacity of reinforced concrete beams significantly if an adequate strengthening configuration is adopted [9]. Experimental work was also studied on the mechanical properties of the pseudo-stem banana woven fabric reinforced epoxy composite [10]. It was prepared by hand layup method, and the test results showed that the strength properties of composite materials were significantly improved. Also, very early research was reported on the bamboo fiber-reinforced cement-based composite materials [11]. The test results showed that the mechanical properties of the composite were significantly improved. A number of recent developing investigations have been conducted on several types of natural fibers such as Sisal, Coir, Bamboo, etc. Reinforcement with cement mortar composite materials due to several reasons [12].

In addition, some of these investigations were conducted on the development of bio-composite materials based on biopolymers and natural fibers. Some of these materials have been made through the fabrication of natural fiber powdered material of (Sisal, Banana, and Roselle) reinforced polymer composite plate material by using bio-epoxy resin [13]. The present investigation reports an addition of the effect of two different fiber lengths of various volume fractions of natural

Roselle fibers (*Hibiscus Subdariffa*. L., it belongs to Malvaceas Family on the behavior of cement-based composites materials [14]. The objective of this paper is to study the tensile, compressive, flexural, impact, bulk density, and thermal conductivity of natural Roselle fiber reinforced cement paste composites. Roselle fibers extracted from fibrous tissues of Roselle plant trunk grows in extensive areas in Iraq, their diameter and density are varied (0.015-0.025 mm) and (0.75-0.80 gm³ respectively, and their lengths depend on the fibrillation processes in the case with jute and sisal fibers. Table (1) shows a comparison between Roselle, Coconut, Jute, and Sisal fibers, each material type being considered as a feasible reinforcing material.

II. EXPERIMENTAL PROCEDURE

2.1 Materials and Method

1. Cement (using Ordinary Portland Cement, OPC) locally manufactured (in Iraq) was used as a matrix binder. Sieve analysis for the grading curve and fineness test were conducted as well as the determination of its moisture and with a specific gravity of (3.12).
2. The natural fibers used in this investigation were Roselle fibers. The fibers soaked in water for four weeks, and afterward, the fibers were manually extracted into fine long fibers and dried in sunlight for more than 10 hours until all the moisture was removed from the fibers.

The fiber-reinforcement with the cement past composites was used with low water to cement ratio (W/C) of 0.33 in order to minimize the segregation of the low density of natural fibers. In this experiment, fibers were cut into 7mm and 15 mm separately and were used as reinforcement with a varying fiber weight fraction of (0, 1, 2, and 3 percent) or in the volume fraction of (0, 1.5, 2.5, and 4 percent). In this investigation, the cement paste and dried fibers were mixed together by using a regular Pan-Mixer of Type (Mixer-3 Speed HOBART) and then the required amount of mixing water of (c/w= 0.33) was gradually added into the mixture as the mixer was running on low Speed for a few minutes until to get for a uniformly distributed mixture, taking care that no fiber balls are formed (for more detail about this mixing procedure, see the last research work) [12]. It has been noted that all the fibers reinforced cement paste composite materials were uniformly distributed and randomly oriented, although, with relatively low weight fiber content was used in this study. The procedure aimed to achieve a uniform distribution of fibers between the specimen of cement composites.

2.2 Experimental series

Six series of fiber-reinforced cement composites were cast and manually compacted. In each series, the number of specimens for each weight fraction was 3.

Series 1, (for compressive strength): The cubic molds of the (50x50x50 mm) were cast according to methods (ASTM-C109-88) [15]. The ultimate compressive strength test for specimens was obtained by using a testing machine of the type (TONY TECHNICK of 600 N) Capacity.

Series 2, (for tensile strength): The moulds of the (25x25x75 mm) were cast according to methods (ASTM-C190-82) [16]. The direct Tensile strength test for specimens was done by using a testing machine of the type (MATR-134-3-80 OF RUM-220Ib/in2 (1.5 MPa) -1100 Ib (4.9 KN) Capacity.

Series 3, (for flexural strength): The moulds of the (40x40x160 mm) were cast according to methods (ASTM-C192-88) [17]. The Ultimate flexural strength test for specimens was obtained by using a testing machine of the type (TONY TECHNICK-TYPE 25 Kg) and was using a simple beam with the third point Bending.

Series 4, (for Impact strength): The circular moulds of the diameter 40 mm and with thickness 10 mm were cast and manually compacted. The impact strength test for specimens was obtained by using a test machine of the type (Izod Pendulum Impact).

Series 5, (for bulk density measurement): The moulds of dimension (40x40x160 mm) were cast and the density measurement was obtained by the method laid down in (ASTM-C220-75) [18].

Series 6, (for thermal conductivity measurement): The circular disc moulds of the (Diameter 40 mm and with thickness 10 mm) were cast and the thermal Conductivity test for Specimens was obtained by using a test machine of the type (Lee, s Disc Apparatus) [19].

All the specimens in series 1, 2, 3, 4, 5 and 6 were covered in the moist room at (23°C and RH of over 95%) until demoulding 24 hours later, after which the specimens were kept in a controlled temperature water tank (21± 3 °C) until testing at 30 days.

III. RESULT AND DISCUSSION

3.1 Ultimate compressive strength

The results of the test series (1) for ultimate compressive strengths are shown in Figure 1. The compressive strength is found to reduce as fiber volume fraction and fiber lengths are increased. This might be due to the increased porosity and air

void, which brought about insufficient compaction of the high fiber content mixture. In other words, the compressive strength is a function of fiber volume fraction, aspect ratio, properties of the constituent materials, and casting pressure of composites. However, from the values listed in Tables 2 and 3, it can be seen that the compressive strength Rewrite this sentence and the bulk density of composites are gradually decreasing with increasing fiber volume fraction. These may be due to balling, and low compaction of fibers with cement paste occurred, therefore, when the cement paste was mixed with long length Roselle fiber (15mm) in the mixing process.

It became more difficult to disperse the cement paste uniformly, while, for the specimens of the same fiber-cement ratio, the compressive strength of composites with long length fiber of (15 mm) is decreasing quite higher than for short length fiber of (7 mm). These are shown in Figure 1 and Table 2.

However, the reduction in compressive strength of composites with short length fiber of (7mm) is about 35% and with long length fiber of (15 mm) is about 87%.

3.2 Direct tensile strength

Figure 2 shows the results of test series (2) for ultimate tensile strength (for plain cement and fiber-reinforced cement composites). It has been found that the ultimate tensile strength of composites gradually increased as fiber volume fraction and fiber length was increased, while the density of composite decreased (Table 2). This increase in strength of composites was slightly higher for long length fiber than for short length fiber in the same volume fraction of composite. The tensile strength test produce a slightly high increase in strength and the general tendency show a significantly enhancement in strength at 30 days age. However, the tensile strength result of composite indicates that a marked increase in the ultimate tensile strength of composites for short length fiber of about 44% and long length fiber of about 68%.

3.3 Flexural strength

Figure 3 shows the results of the test series (3), for ultimate flexural strength, (for plain cement and fiber-reinforced cement composites). In this test, was found that the behavior properties of flexural strength of composites as same as in case of tensile strength. Therefore, both the tensile and flexural strengths were substantially increased as the Roselle fibers content in cement increased. Likewise, the typical relationship between the fiber-cement ratio and flexural strength, produce a quite high increase in strength. However, Figure 3 and Table 2 show that the flexural strength of composites increase while the fiber volume fraction and fiber

length are increased, this increase in strength for a long fiber length is slightly higher than for a short fiber length in the same fiber-cement ratio, and indicates a market increase of about 78% for short fiber length, and about 83% for long fiber length.

3.4 Impact strength

Figure 4 shows the results of a series (4) for impact strength, (for plain cement and Roselle fiber reinforced cement composite materials). The well known Izod impact test instrument, which uses the energy stored in the composite materials, and the work fracture test results of specimens are shown in Figure 4 and Table 2. However, when the volume fraction of composites increases, the impact strength is increased. The impact strength result of composites indicates that the market increase of about 277%.

3.5 Density and thermal conductivity measurement

Table 3, shows the results of a series (5) and (6) for density and the thermal conductivity measurement (for plain cement and fiber-reinforced cement Composites). The result shows that, when the fiber volume fraction of composites increases, the bulk density and thermal conductivity are decreased. Therefore, the density and thermal conductivity are interrelated in so far as the magnitude depends upon the porosity and void volume or free space, which are produced by the presence of fiber content in composite materials.

IV. CONCLUSIONS

It is evident that low modulus natural Roselle fibers reinforced cement paste with a suitable choice of fiber lengths, fiber type, fiber volume fraction, and cement matrix, give remarkable improvements in compressive strength and tensile, flexural, impact strengths and in bulk density and thermal conductivity properties. Also the results indicate that the use of Roselle fiber reinforcement with cement paste improves the ductility and plasticity of composites and its superiority in certain applications. In general, the results of this investigation have shown the feasibility of using Roselle fibers in developing suitable construction and low-cost building materials.

REFERENCES

- [1] Raouf, Z. A. (1986), Examples of Building Constructions, Using Reeds, in the Use of Vegetable Plants and their Fibers as Building Materials. *RILEM.NCCL.CIB. Joint Symposium, Baghdad, Iraq*, PP. A35- A40.

- [2] Young, Ni, (1995), Natural Fiber Reinforced Cement Composites. *PhD thesis, Victoria University of Technology*.
- [3] Pakotiprapa, B., Pama, R. P. And Lee, S. L. (1983), Behavior of Bamboo Fiber-element Paste Composites. *Journal of Ferrocement*, 13, 235-243.
- [4] Paramasivam, P., Nathan, G. K. And Das Gupta, N. C. (1984), Coconut Fiber Reinforced Corrugated Slabs. *International journal of Cement Composites and Lightweight Concretes*, 6, 19-27.
- [5] Mansur, M.A. and Aziz, M. A. (1982), A study of Jute Fiber Reinforced Cement Composites. *International Journal of Cement Composites and Lightweight Concretes*, 4, 75-82.
- [6] Burachat Chatveera and Pichai Nimityongskul, (1994), ‘Sisal Fiber –Mortar Composites’, *J. Natl. Res. Council Thailand*, 26 (10).
- [7] Andonian, P., Mai, Y. M. And Cotterell, B. (1979), Strength and Fracture Properties of Cellulose Fiber Reinforced Cement Composites. *International Journal of Cement Composites and Lightweight Concretes*, 1,151-158.
- [8] Loïc Rodier, Viviane da Costa Correia, Holmer Savastano Junior. (2020). Elaboration of eco-efficient vegetable fibers reinforced cement-based composites using glass powder residue, *Cement and Concrete Composites*, PP, 1-9.
- [9] Luciano Ombres. (2015), Structural performances of reinforced concrete beams strengthened in shear with a cement based fiber composite material, *Composite Structures*, PP, 316-329.
- [10] Maleque, M. A., Belal, F. Y. And Sapuan, S. M. (2007), Mechanical Properties of Pseudo-Stem Banana Fiber Reinforced Epoxy Composite, *The Arabian Journal for Science and Engineering*. Volume 32, Number 2B.
- [11] Liu Yu , Zhou Aiguo, and Lin Zhenyu (2011), Study of the Mechanical Properties of the Bamboo Fiber Reinforced Cement Composite Materials, *International Conference on Agricultural and Natural Resources Engineering Advances in Biomedical Engineering*, Vol.3-5.
- [12] Ramakrishna, G., Sundararajan, T. and Kothandaraman, S. (2010), Evaluation of Durability of Natural Fiber Reinforced Cement Mortar Composite-A New Approach, *ARPJ Journal of Engineering and Applied Sciences*, Vol.5, No.6, PP.44-51.
- [13] Chandramohan, D. And Marimuthu, K. (2011), Drilling of Natural Fiber Particle Reinforced Polymer Composite Material, *International Journal of Advanced Engineering Research and Studies, IJAERS/ Vol. I/Issue I/October- December*, 134-145.
- [14] Ismail, M. A. (2007), Compressive and Tensile Strength of Fiber-reinforced Cement Based Composites, *AL-Rafidain Engineering*, Vol.15, No.2, PP. 42-51.
- [15] Test method for Compressive Strength of Hydraulic Cement Mortars Using (50x50x50mm) *Cube Specimens*, (1988), Vol. 04.01, PP 31-32.
- [16] Standard Test Method for Flexural Strength of Concrete Using Simple Beam with Third-Point Loading, (1988), Vol. 04. 01, PP. 31-33.
- [17] Standard Test Method for Specific Gravity, Absorption and Voids in Hardened (1982), Vol. 04. 02, PP. 305-306.
- [18] Akrill, T. B., Bennet, G. a. And Miller, C. J. (1979), “Thermal Properties in Physics” *Published by Eduard Arrol Ltd*. PP. 118.

ANNEXURE

Table 1: Comparison between Typical Properties of Fibers for Roselle [11], (Jute, Coconut)[8]and Sisal [6]

Fiber Properties	Fiber Type			
	Roselle	Jute	Sisal	Coconut
Specific gravity	1.25-1.30	1.02-1.04	1.00-1.0025	1.12-1.22
Bulk density (Kg/m ³)	750-800	120-140	0.05-0.22	145-280
Fiber diameter (mm)	0.015-0.025	0.1-0.2	0.05-0.22	0.1-0.4
Fiber length (mm)	-----	180-800	-----	50-350
Ultimate tensile strength (N/mm ²)	170-350	250-350	275.43	120-200

Modulus of elasticity (KN/mm ²)	10-17.5	26-32	15	19-26
Elongation at break (%)	1.7-7.45	2-3	-----	10-25
Water absorption (%)	40-55	25-40	56.25	130-180

Table 2: Strength Properties of Plain Cement and Roselle Fiber Reinforced Cement Composites

Fiber-Cement Ratio (F/C) % (By Volume Fraction)	Fiber Length (mm)±1	Ult. Compressive Strength (MPa)	Ult. Tensile Strength (MPa)	Ult. Flexural Strength (MPa)	Impact Strength (MPa)
Plain Cement,0.0	0.0	59.0	6.3	5.9	8.0
1.5	7.0	52.0	7.5	9.27	13.0
2.5	7.0	46.5	8.6	9.74	17.0
4.0	7.0	43.0	9.1	10.2	26.0
1.5	15.0	44.0	8.6	9.7	-----
2.5	15.0	37.5	9.5	10.1	-----
4.0	15.0	31.5	10.6	10.8	-----

Table 3: Bulk density and Thermal conductivity of Plain cement and Roselle fiber reinforced cement Composites

Fiber-Cement Ratio (F/C) % (By Volume Fraction)	Fiber Length (mm)±1	Bulk Density (Kg/m ³)	Thermal Conductivity (W/K.m)
PlainCement0.0	0.0	1926	0.910
1.5	7.0	1891	0.710
2.5	7.0	1867	0.630
4.0	7.0	1822	0.625

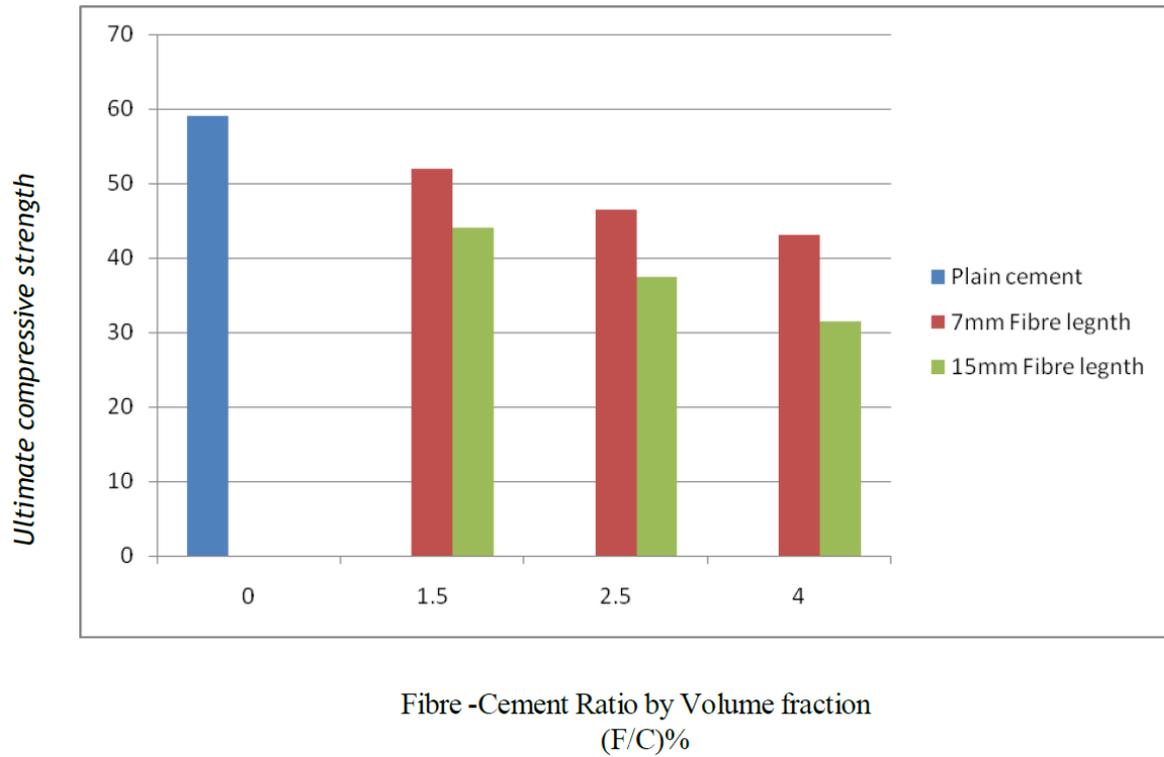


Figure 1: Ultimate compressive strength of plain cement and fiber reinforced cement composites

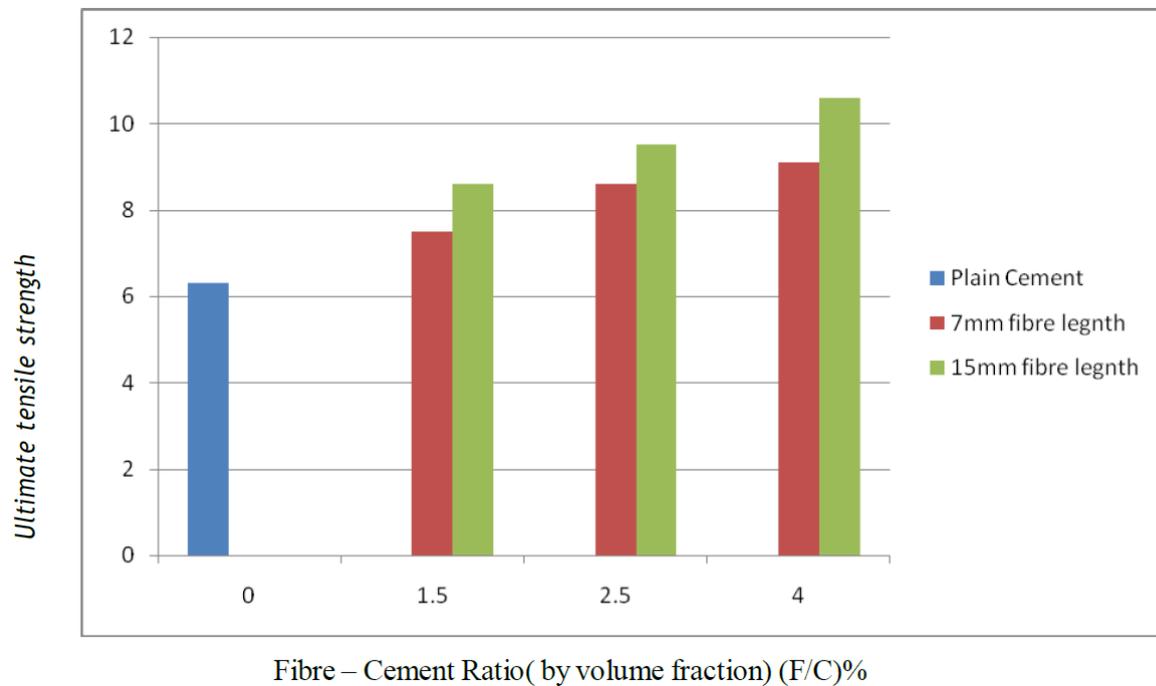


Figure 2: Ultimate tensile strength of plain cement and fiber reinforced cement composites

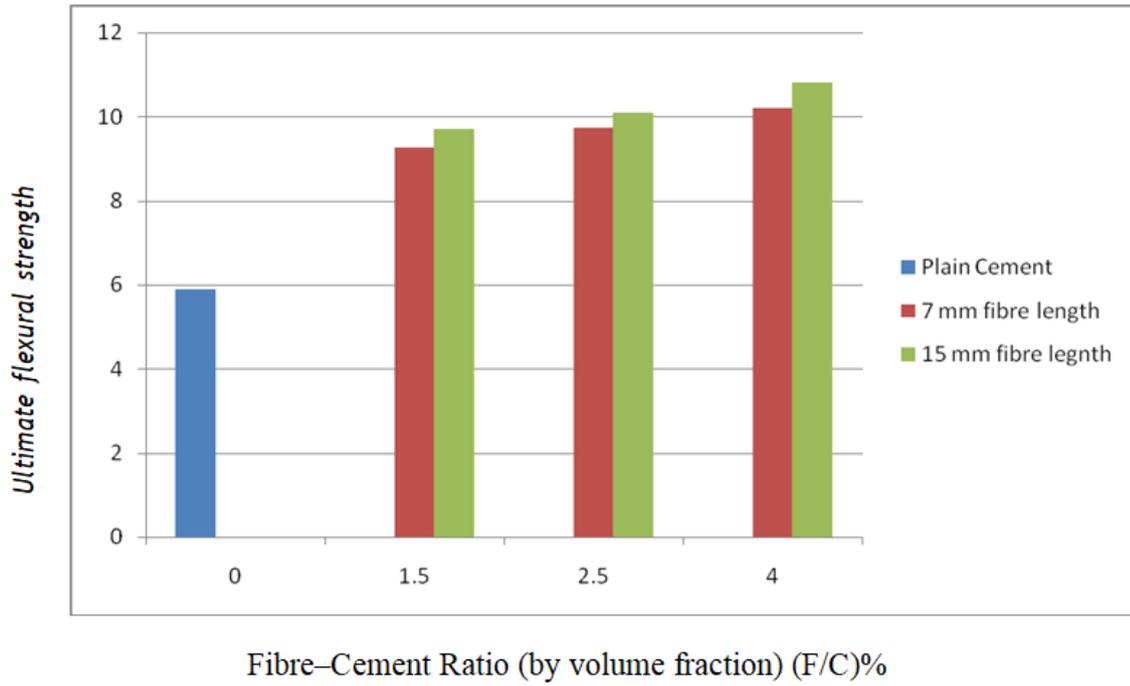


Figure 3: Ultimate flexural strength of plain cement and fiber reinforced cement composites

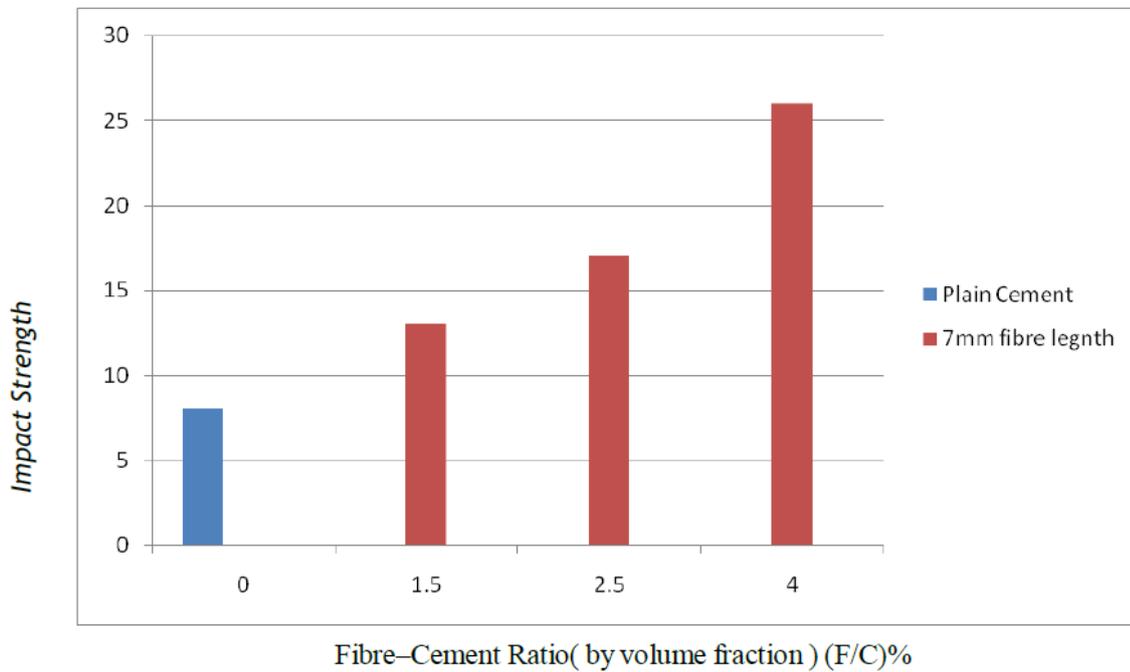


Figure 4: Impact strength of plain cement and fiber reinforced cement composites



Citation of this Article:

Dr. Mahmood A. Ismail. (2025). Natural Roselle Fiber Reinforced Cement Based Composite Materials. *International Current Journal of Engineering and Science (ICJES)*, 4(11), 6-13. Article DOI: <https://doi.org/10.47001/ICJES/2025.411002>
