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An Experimental Study of Strength Properties of Galvanized Iron (GI) Fiber Reinforced Concrete

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Abstract: Fiber Reinforced Concrete is one of the most quality construction techniques of modern times. The utilization of locally available galvanized iron or metallic fiber as a bridging material. The concrete with metallic or nonmetallic fiber is very useful and its enhanced concrete mechanical properties. Therefore, a research has been conducted to study the performance of locally available GI wire fiber reinforced concrete (GWRC). This paper presents the findings of the research that made an effort to explore several basic characteristics of GWRC primarily related to strength, ductility and durability. This research was, therefore, conducted to compare the concrete strength performance of GI fiber with different lengths and a control specimen. The objective of this study is to explore the effect of GI fiber in terms of compressive strength, splitting tensile strength, and flexural strength with 'Galvanized Iron' fiber using several cutting lengths of 25 mm and 35mm with various mix proportions including 1.0%, 1.5%, 2.0%, and 2.5% by weight of the concrete.
Keywords: Galvanized Iron, Fiber Reinforced Concrete, Compression, Tension.

I. INRODUCTION

Building construction materials such as concrete which is produced through a carefully proportioned mixture of cement, sand, gravel or other aggregates, and water and hardened in different forms and dimensions for the specified structure. The materials are amalgamated to ensure the voids within the aggregates are satiated to produce a consistent dense concrete. It is important to note that concrete has been the foremost widely used construction material throughout the planet with those made using hydraulic cement observed to be having certain characteristics while plain and unreinforced concrete is a friable material with a picayune strain capacity. Concrete is relatively sturdy in compression but languid in tension and tends to be fragile. This, therefore, makes it important from the engineering perspective and there has been a continuing effort to upgrade its performance. The greatest abridgment for concrete is the lack of ductility and the improvement of this aspect is a prime concern for civil engineers. This has, therefore, led to a considerable number of studies incorporating different fibers such as steel, jute, glass, and polymer in concrete the concept is generally known as the Fiber Reinforced Concrete (FRC) and has been found to be one of the foremost promising new construction materials due to its enhanced ductility and decreased brittleness. The inclusion of the fibers also modifies the behavior of the fibermatrix composite after it has cracked, thereby, upgrading its toughness. The real contribution of the fibers is to extend the toughness of the concrete which has been described to be an area under a load-deflection curve. This is due to the fact that plain concretes fail suddenly once the greatest strength is surpassed while fiber ferroconcrete continues under considerable loads even at deflections considered more than the fracture deflection in plain concrete. This means fiber reinforced concrete is in a position to sustain load or strain much greater than plain concrete.

Fiber ferroconcrete is also generally defined as a material made with hydraulic cement, aggregate, and incorporating discrete discontinuous. Galvanized steel wire or iron (GI) formed from zinc-plated steel is presently used as a reinforcement to improve concrete properties mainly due to the ability of the protective layer of zinc to inhibit corrosion. Several studies have been conducted to investigate the suitability of GI fibers as an alternative to steel or hybrid fibers. This is important considering the fact that steel fiber is the most prominent metallic fiber with the ability to augment concrete properties but it is expensive to be used in Bangladesh due to additional cost attached to its unavailability in the local market. Studies have also been conducted to determine the substitute reinforcing material to emulate steel fiber in improving the mechanical properties of concrete at a lower cost. Some others also focused on using different mix proportions of steel fiber to determine their effectiveness but there is no significant research on the use of GI fiber with different cutting length and at several mix proportions. This means it is considerably important to determine the influence of the effective utilization of galvanized iron (GI) fiber to produce ennobled concrete. Therefore, the foremost objective of the study was to develop galvanized iron (GI) fiber reinforce concrete composites, and determine the suitable length and content (volume fraction) of fibers based on concrete mechanical behavior.

As a matter of recent development, very little background knowledge about GI wire fiber reinforced concrete is available at present. A research has lately been carried out to investigate the properties of GI wire so that a proper comparison can be established between the properties of steel fiber and GI wire fiber. It was also studied if GI wire fiber conforms to the ACI and ASTM standards for steel fibers to be used in SFRC (Steel Fiber Reinforced Concrete). In addition, compressive strength of GWRC (Galvanized Wire Reinforced Concrete) was determined and was compared to compressive strength of SFRC to assess the performance of GI wire fiber as fiber in concrete. The study is regarded as one of the pristine attempts to incorporate GI wire fiber as a substitute for steel fiber in FRC. Therefore, the research followed the guidelines and specifications available in the literature concerning steel fiber reinforced concrete. Considering this study as a stepping stone, the present research attempts to move the current state of affairs forward and to lay the groundwork for future research in this field by exploring the prospects of GI wire fiber reinforced concrete.

II. REVIEW OF LITERATURE

F. Akter, S. S. Das, A. Rahman at all (2022): - An Experimental Study On Compressive Strength Of Fiber Reinforced Concrete Using Gi Wire. This paper principally focused on the compressive strength enhancement due to the addition of the Galvanized Iron Wire Fiber (GIWF) to concrete. Galvanized Iron Wire Fiber Reinforced concrete (GIWF) is a concrete in which small doses of galvanized iron wires are added as a fiber component to the concrete mix. GIW is a low-cost material and usually accessible in the local market of Bangladesh. However, the concept of GIW as fiber to improve the strength and properties of concrete is very new in the domain of fiber reinforced concrete technology. For these reasons and in order to enhance knowledge, an experimental investigation was carried out to study the effectiveness of galvanized iron wire as a fibrous material. For this purpose, a total of 18 concrete cylinders were cast with two different volume fractions of GI wire fiber contents with 0.7% and 1.4% of the total composite. The cylinder specimens were tested statically loaded under compression until crushed. It was found that the addition of 0.7% GIWF significantly increased 28 days compressive strength of the concrete by 22.5% whereas 1.4% GIWF enhanced 29.85% compressive strength with respect to the reference cylinder specimens (0% GIWF). Finally, the test results were analyzed with respect to the available published literature and concluded that the Galvanized Iron Wire Fiber with 0.7% and 1.4% volume fractions may be a potential alternative and safe fibrous material in the fiber reinforcement concrete technology, especially for Bangladesh

R. Sadi at all (2022): - An Experimental Investigation Of The Mechanical Behavior Of Galvanized Iron Wire Fibers In Reinforced Concrete The behavior of concrete is strong in compression but weak in tensile strength. Various methods and materials have been utilized to improve its tensile strength, which has been introduced as reinforced concrete. The characteristics of concrete have been improved because of fiber reinforcement.

A case study has been carried out to improve concrete quality in Bangladesh through the use of locally available, inexpensive galvanized iron (GI) wire fibers that alter the concrete's behavior in terms of compressive and tensile strength. Specimens were cast with fibers of 0%, 0.5%, 1.0%, and 1.5% of the total concrete weight to find the mechanical properties of concrete in a cylinder (150 mm x 300 mm) test. In the results, compressive strength (20.12 N/mm2) and tensile strength (1.92 N/mm2) without fibers were shown, whereas maximum compressive and tensile strengths were shown in 1.0% fiber using concrete (26.74 N/mm2) and (3.52 N/mm2) on 28 days. Compared to these results, the better improvement is in tensile strength (83.33%), and the slight upgrade is in compressive strength (32.90%).

It has been seen that galvanized iron (GI) wire fiber-reinforced concrete (GFRC) is much better than standard concrete. Additionally, it has been found that, for the specific mix design, a fiber component of 1% by weight provides substantially better results. According to the results of the slump test, the galvanized iron wire reinforcement had a substantial impact on workability. The workability declined as the fiber concentration increased.

III. MATERIAL AND METHOD

A. Portland Cement

Ordinary hydraulic Cement containing 95–100% and 0–5% of clinker and gypsum respectively at a precise gravity of 3.12 was used in this study.

B. Coarse and Fine Aggregates

River sand was utilized as the fine aggregate while crushed stone chips were treated as the coarse aggregate using a grading consistent with IS 383(1970). The aggregates were collected from Sylhet and their physical properties are presented in Table.

Table 1: - Physical characteristics of aggregates.

Property	Sand	Stone Chips
Bulk Specific Gravity (OD Basis)	2.54	2.66
Absorption Capacity (%)	1.34	0.69
Fineness Modulus (FM)	2.62	-
Dry Rodded Unit Weight (kg/m3)	1590	1550

C. Galvanized Iron Fiber

Galvanized iron (GI) fiber has a circular section with the diameters varying from 0.37 mm to 5 mm but those with 1mm diameter were used in this study. According to the manufacturers, the materials are resistant to high temperature and corrosion and also provide high strength considering the properties shown in Table. Two different cut lengths including 25 and 35 mm as presented in Fig were used in this study at different weight percentages of 1%, 1.5%, 2%, and 2.5% in the concrete mixture.

Fig:1 GI Cutting

Fig:2 GI Wire

Table 2: - Characteristics of Galvanized iron (GI) fiber

GI Fiber	Feature
Cutting Length (mm)	25
Cutting Length (mm)	35
Diameter (mm)	1
Aspect Ratio (l/d)	25
Aspect Ratio (l/d)	35
Density (kg/m3)	6000
Tensile Strength (MPa)	250
Color Silver	Silver
Elastic Modulus (GPa)	6.0

Method

D. Concrete Mix Proportions

Trial mixtures were prepared to obtain the targeted strength of 25 MPa at 28 days with a target slump value of 75–100 mm. The concrete mix was designed according to the standards of the India standard (IS 10262:2019). The fibers added reduced the slump value due to the interweaved arrangement of fibers in the concrete matrix. Therefore, additional water was needed compare to control concrete to keep the slump within the mix design range. The detailed mix proportions of the constituent materials, with the SSD condition where applicable, to produce the concretes used in this study are presented in Table.

Fig:3 Mixing Of GI Wire

Fig:4 Mixer Of Sand Cement Aggregate

E. Concrete Mixing, Casting, and Curing

The concrete mixture was prepared with different parameters including the length and volume fraction of the iron fiber content while the cut lengths of the fiber were 25 and 35 mm at 1%, 1.5%, and 2% proportion. The fibers were truncated to the desired length using a wire cutting machine while the concrete was prepared through a machine mixer by considering a 50- liter volume for each trial blend. The process involved mixing the appropriate quantity of coarse aggregates, fine aggregates, and cement followed by the inclusion of the iron fibers to obtain congruous distribution in every part of the concrete after which water was added with four minutes of vigorous mixing to achieve consistency. A slump cone was used to measure the workability of the mixture while a 150 mm cube specimen was set and placed in a circumambient temperature for 24 hours to conduct laboratory strength tests. Subsequently, the specimens were extracted from the mold and placed in a curing tank to determine the strength at 7 and 28 days.

Fig:5 Specimen Of Cube

Fig:6 Curing Of Cube

Table3: - Mixing composition of concrete utilized in laboratory works (Galvanized iron)

PROPORTION	WATER (KG/M3)	CEMENT (KG/M3)	FA (KG/M3)	CA (KG/M3)	GI (KG/M3)
CONTROL CONCRETE GIF(0.0%)	221	403.20	604.80	1209.60	0.00
GALVANIZED IRON (25MM)					
GIF 1(1.0%)	221	403.20	604.80	1209.60	15.584
GIF 2(1.5%)	221	403.20	604.80	1209.60	23.472
GIF3 (2.0%)	221	403.20	604.80	1209.60	31.168
GIF 4(2.5%)	221	403.20	604.80	1209.60	38.961
GALVANIZED IRON (35MM)					
GIF5 (1.0%)	221	403.20	604.80	1209.60	15.584
GIF 6(1.5%)	221	403.20	604.80	1209.60	23.472
GIF7 (2.0%)	221	403.20	604.80	1209.60	31.168
GIF 8(2.5%)	221	403.20	604.80	1209.60	38.961

F. Compression Test

The compression of the concrete was tested using compression test machine. The compressive strength has been considered the most prominent feature of concrete compared to other physical properties due to its structural significance and the provision of a limpid repercussion on how the increment of fiber proportions influence the concrete strength. Moreover, the load was implemented with a strain rate of 1.5mm/min up to the period the specimens reached their fracture point. The highest load received by the concrete specimen throughout the test was inscribed. The experimental set up is, therefore, shown in the following Figure.


Fig: 7 Compression Test

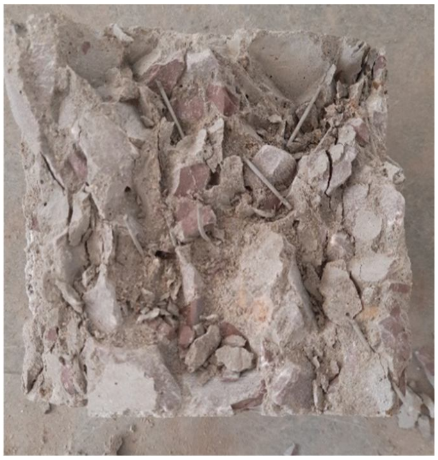
Fig:8 Broken Cube

G. Tensile Strength Testing

The friableness and modicum tensile strength of concrete make it callow to flounder with the direct tension. Therefore, assessing concrete tension is imperative to ascertain the load required for fracture through the use of a splitting experiment in accordance with the tensile strength test. The tensile strength was, however, measured using Equation (1)

$Fct = 2F/\pi Ld$ (1)

where

Fct : - The Tensile Strength In N/Mm2,

F : - The Maximum Load In Newtons (N),

L : - The Length Of The Specimen In Millimeters (Mm).

D : - The Size Of A Designated Cross-Section In Millimeters (Mm).

IV. RESULT AND DISCUSSION

A. Compressive Strength

Compressive strength is the most fundamental property of concrete due to its main function of withstanding compressive stress. The behavior of concrete under compression load due to the utilization of galvanized Iron metallic fiber is presented in Figures Meanwhile, the results presented in Table showed the integration of galvanized iron fiber in concrete enhanced the compressive strength.

Table 4:- Experimental outcomes of concrete compression

Length (mm)	Concrete Composition	Compressive strength at 7 days (MPa)	Compressive strength at 28 days (MPa)	28 days strength increment(%)	Steel Fiber(%)
	Control concrete	14.22	22.66		0
25 mm	GIF1	15.55	22.81	0.97	1
	GIF2	16.88	23.77	4.89	1.5
	GIF3	17.77	24.67	8.89	2
	GIF4	16.22	23.33	2.95	2.5
35 mm	GIF5	17.33	24.88	9.79	1
	GIF6	18.22	25.33	11.78	1.5
	GIF7	19.11	26.77	18.13	2
	GIF8	18.66	25.88	14.22	2.5

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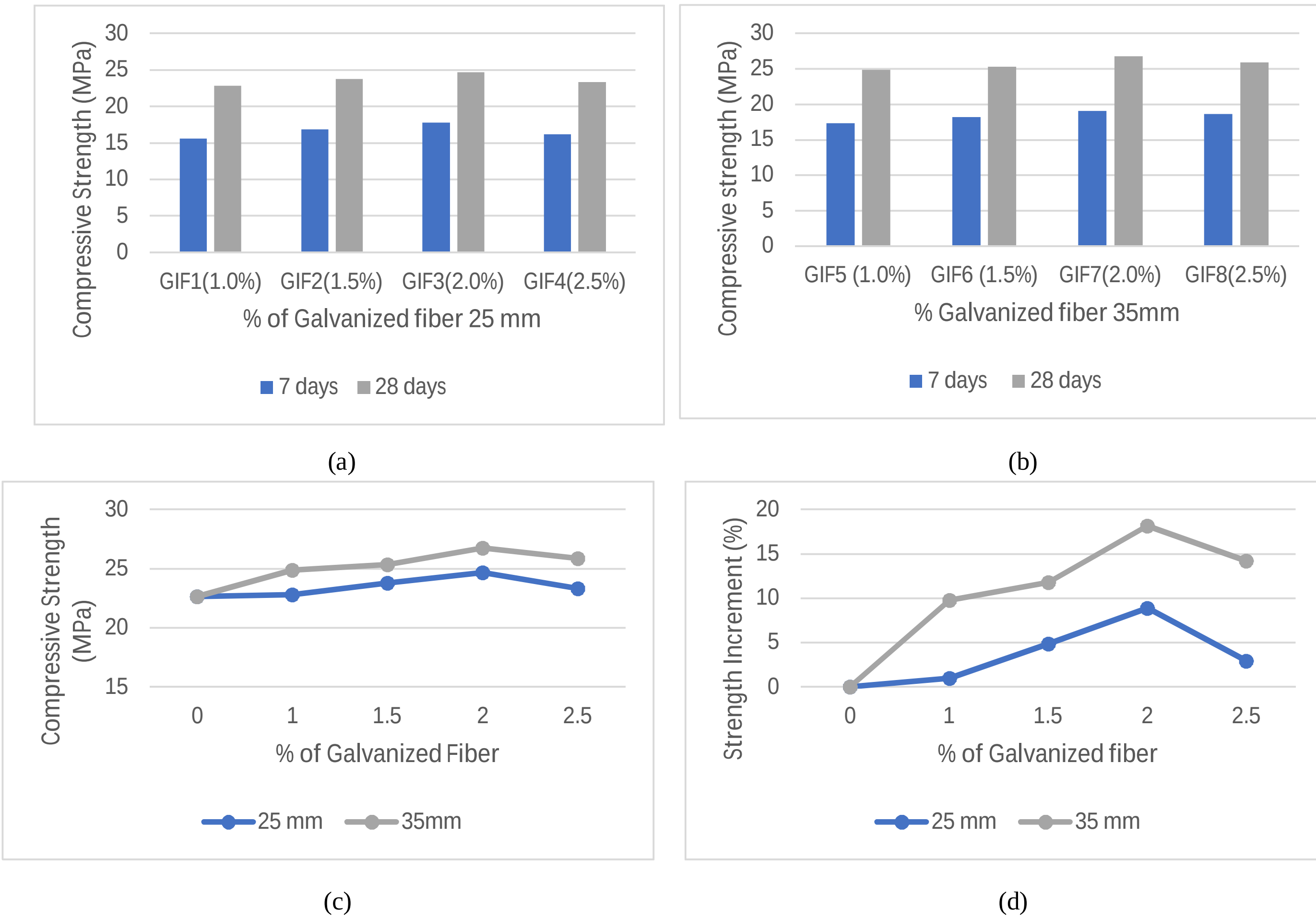


Figure. Change in the compressive strength of concrete at different fiber proportions (a) 25 mm length of Galvanized Iron (b) 45 mm length of Galvanized Iron (c) the comparison between compression for 25 mm and 35 mm length (d) comparison between the strength improvement between 25 mm and 35 mm length.

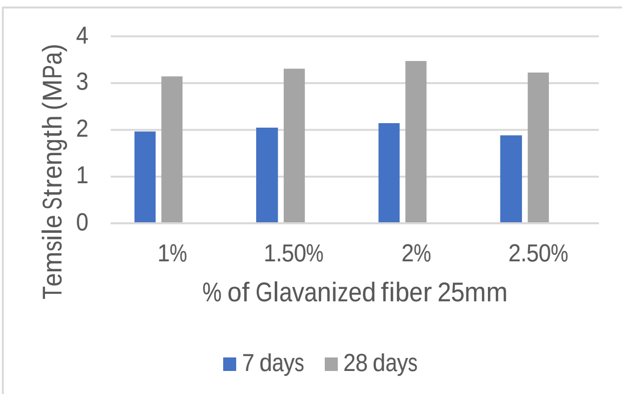
Figures a and b compare the compressive strengths on the 7th and 28th day for 25 mm and 35 mm fibers respectively and the values were observed to have aggravated up to 2% GI fiber and later reduced as the proportion increased. This was associated with the confining effect of fibers in the concrete matrix which holds the materials together. Meanwhile, this effect depends mainly on the difficulty in controlling the orientation of fibers due to its random distribution in the concrete matrix. Figure , however, shows the holding capacity of GI fiber to be lucid with the increment in the strength of the reinforced concrete found in the range of 0.97 % to 8.87% for 25 mm length and 9.79% to 18.13% for 35 mm. A slight decrease was observed in the two specimens for 2.5% proportion and this Is associated with the high dosage of fiber which affects the concrete's cohesiveness. The best result was, however, recorded at 2% proportion with 40 mm length as observed with the 18.13% increment in the compressive strength of the concrete.

B. Tensile Strength

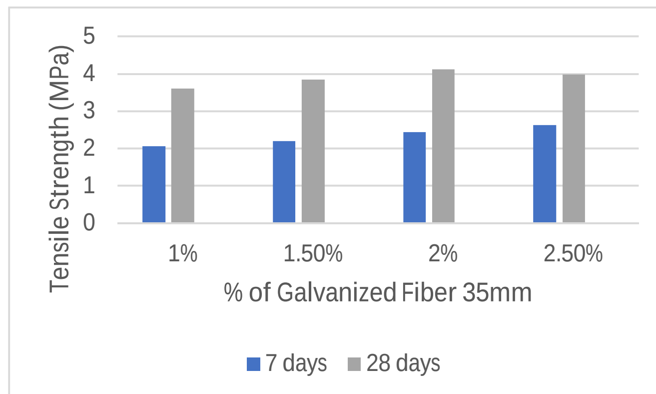
Split tensile strength is the ability of concrete to withstand tension with the effect of the GI fiber incorporated determined using a split tensile test and the results obtained are presented in Table 5 and the changes recorded are demonstrated in Figure. The incorporation of GI fibers was observed to have increased the split tensile strength of the reinforced concrete compared to the control specimen. Figure represents the effectiveness of the splitting tensile strength for the specimens at 28 days with the galvanized Iron fiber reinforced concrete observed to have increased significantly compared to the plain concrete. Moreover, the splitting tensile strength of the reinforced concrete was found to have increased in a range of 47.88% to 62.91% for 25 mm length as the fiber content increased while 35 mm length was observed to have shown a better performance with 69.01% to 93.89%.

Table:- 5 Experimental outcomes of concrete tension :-

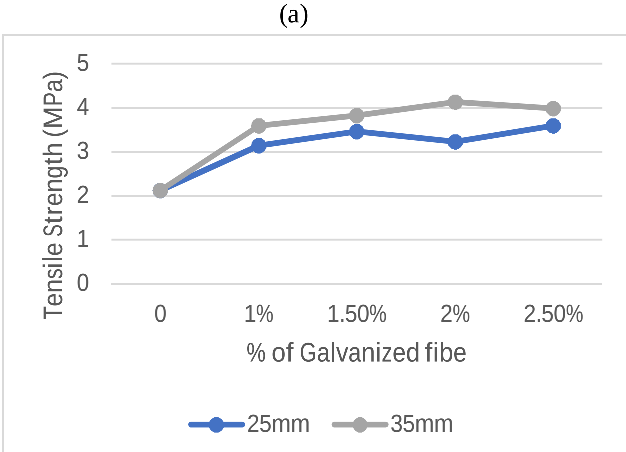
Length (mm)	Concrete Composition	Tensile Splitting Strength at 7 Days (MPa)	Tensile Splitting Strength at 28 days (MPa)	28days Strength Increment(%)	Steel Fiber (%)
	Control concrete	1.17	2.13		0
25mm	GIF1	1.96	3.15	47.88	1
	GIF2	2.05	3.31	55.39	1.5
	GIF3	2.14	3.47	62.91	2
	GIF4	1.89	3.23	51.64	2.5
35mm	GIF5	2.06	3.60	69.01	1
	GIF6	2.20	3.85	80.75	1.5
	GIF7	2.44	4.13	93.89	2
	GIF8	2.63	3.98	86.85	2.5



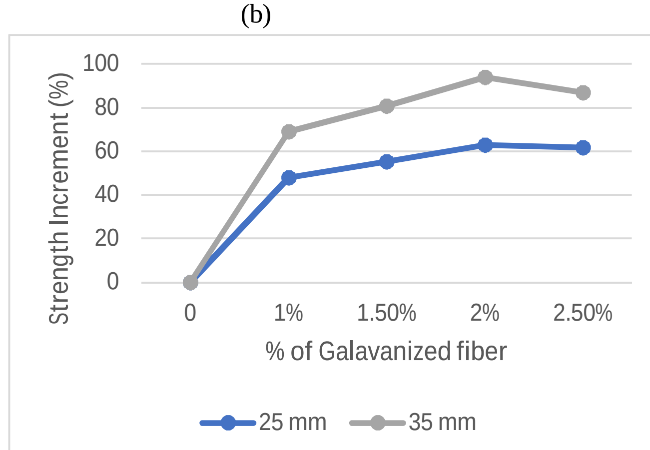
(a)



(b)



(c)



(d)

Figure. Change in concrete tension due to the fiber proportion in (a) 25 mm length (b) 35 mm length (c) comparison in the tension between 25 mm and 35 mm length (d) comparison with the strength increment between 25 mm and 35 mm length.

The most effective result indicated by an 93.89% increment in the tension was found with a 2% mix proportion for 35 mm length. This means a lengthy fiber with averagely ≤ 2% of GI leads to the production of a concrete mixture which is able to withstand cracking under a tensile load as shown in Figure. Meanwhile, more proportion of GI fiber which is >2% were found to have produced an incongruous mixture due to the deficiency caused by the free rearrangements of the concrete elements. The incorporation of 2.5% GI fiber was, however, discovered to have provided a superior contribution to tensile strength than the control specimen.

V. SUMMARY AND CONCLUSION

Laboratory experiments were conducted to determine the compression, and tension of the concretes reinforced with 'Galvanized Iron' fiber. The results showed 25mm length galvanized iron fiber was able to aggravate concrete compressive strength by 0.97 % - 8.87%, increased tension by 47.88% to 62.91%. The use of a 35 mm length for 2% GI fiber proportion was found to be the best mixture as observed in its effect on the compression with a 18.13% increase, tension with 93.89% increase. In comparison with steel fiber, the utilization of GI fiber showed a bit smaller enhancement in concrete compression and tension and has the potential to be used as a substitute for the expensive imported steel fiber in India. This is due to the local availability of the GI fiber in the country which makes it a viable low-cost substitute in fiber reinforced concrete and its ability to improve the mechanical properties of concrete.

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