"ANALYSIS OF CHARACTERISTIC COMPRESSIVE STRENGTH OF CONCRETE USING GLASS FIBER AND STEEL FIBER"

[1]Rahul Singh, [2]Prof. Charan Singh Thakur, [3]Anil Sanodiya
Department of Civil Engineering, SRGI, Jabalpur, Madhya Pradesh, India

Abstract - Strengthening the fiber reinforced concrete (FRC) with steel fibers and glass fibers in structures is a major area of research for some time now. This paper focuses on study and analysis of plain concrete strengthen with steel and glass fibers by different volume fraction (i.e 0.4, 0.8 & 1.2%) In the place of fine aggregate. The conventional method of concrete strengthening with natural Fibers such as jute does not provides the satisfactory results. A lot of past researches have Established that SFRC and GFRC is a good substitute for the old methods for concrete structure.

Which gives the satisfactory results. Thesis work verifies the usability if steel fiber and glass fiber for M20 grade concrete The SFRC and GFRC specimens were loaded axially in a quasi-static manner. The ultimate load and stress resistance of theses specimans were found to have enhanced in SFRC when up to 0.8% steel fibers were mixed. similarly GFRC also shows the good bounding strength when 0.8% glass fiber were mixed into concrete. It is observed that the ductility of the concrete has increased when mixed these fiber up to 0.8% and also it's results the good resistance to the cracking growth. it is thus recommended by this thesis that the composition of steel and glass fibers in normal concrete gives the improvement in the ductile strength and provides the resistance to cracking growth.

Keywords: FRC, SFRC, GFRC, CRACKING, GROWTH, QUASI-STATIC LOADING.

1 INTRODUCTION

1.1 General

Plain concrete is known to have low strength and low strain capacity, however these structural properties could be improved by addition of fibers. There are different fibers that are used in the concrete namely glass fiber, steel fiber, synthetic fibers and natural fibers(jute fibers). The improvement in the material behaviour of the fiber reinforced concrete depends on dosage and characteristics of the used fibers.

The main important effect of fibers as reinforcement is to influence and control the tensile cracking of concrete. Yet, the fiber reinforced concrete is known to have considerable impact on the construction cost owing to reduced dimension needs, prolonged useful life and reduction in maintenance costs.

Amongst the fibers mentioned, steel fibers and glass fibers are the most researched and more practical. Steel fiber reinforced concrete (SFRC) and Glass fiber reinforced concrete (GFRC) are types of concrete that contains randomly oriented discrete steel glass fibers. The main aim of addition of these fibers to concrete is to control crack widening and crack propagation after the concrete matrix has cracked. By control of the cracking the strength and mechanical properties of the composite material as a result will be improved significantly.

The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cemetitious material, binding material (fine aggregate) by adding some special ingredients like steel and glass fibers. Hence concrete is very well suitable for a wide range of applications. However concrete has some deficiencies as listed below:

1) Low tensile strength
2) Low post cracking capacity
3) Brittleness and low ductility
4) Limited fatigue life
5) Incapable of accommodating large deformations
6) Low impact strength

The presence of micro cracks in the mortar-aggregate interface is responsible for the inherent weakness of plain concrete. The weakness can be removed by inclusion of steel and glass fibers in the mixture. Different types of fibers, such as those used in traditional composite materials can be introduced into the concrete mixture to increase its toughness, or ability to resist crack growth. The fibers help to transfer loads at the internal micro cracks. Such a concrete is called fiber-reinforced concrete (FRC).

Addition of randomly distributed steel and glass fibers improves concrete properties, such as static flexural strength, ductility and flexural toughness. SFRC and GFRC has been largely used in airport pavements due to the extreme and damaging loads acting on the pavement and some other examples of the structural and non-structural applications of SFRC and GFRC are hydraulic structures, airport and highway paving and overlays, industrial floors, refractory concrete, bridge decks, concrete linings and coverings, and thin-shell structures. The elasticity modulus of steel fibers is as high as 210 MPa providing very high tensile strength with minimal deformation. The large number of fibers used for concrete members enables a uniform distribution of fibers through the compound, thereby creating a composite material possessing homogeneous mechanical behaviour. They provide a cohesive mix, creating a three dimensional reinforced net system. The important characteristic in FRC material is the bond between the fibers and the matrix. Fibers are designed in different geometries to increase the bond and interfacial friction between aggregates and cement paste. Steel fiber texture such as zig-zag shaped fibers improve the bond between the fibers within the matrix, thus increasing the necessary force required to pull out the fiber from the concrete. The forces induced in a SFRC and GFRC when subjected to load are redistributed within the concrete, which restrains the formation and extension of cracks. The result is a more ductile reinforced concrete which is able to maintain a residual capacity in the post-cracking phase. Thus resulting in an increased load-carrying capacity, improved shear and bending strength of concrete, superior flexural ductility, toughness, and fatigue endurance. In addition, SFRC has higher life cycle than the GFRC and the maintenance requirements are reduced resulting in lower costs. Another advantage of the SFRC and GFRC is that at an adequate volume fraction thet can replace conventional steel reinforcement when designed properly and it reduces the construction time since the steel fibers are added directly as one of the concrete mix constituents, hence no steel fixing or adjustment is required.

2 LITERATURE REVIEW

2.1 Previous Research Studies

A.M. Shende et. al.(2012), Critical investigation for M-40 grade of concrete having mix proportion 1:1.43:3.04 with water cement ratio 0.35 to study the compressive strength, flexural strength, Split tensile strength of steel fiber reinforced concrete (SFRC) containing fibers of 0%, 1%, 2% and 3% volume fraction of hook tain. Steel fibers of 50, 60 and 67 aspect ratio were used. A result data obtained has been analyzed and compared with a control specimen (0% fiber). A relationship between aspect ratio vs. Compressive strength, aspect ratio vs. flexural strength, aspect ratio vs. Split tensile strength represented graphically. Result data clearly shows percentage increase in 28 days Compressive strength, Flexural strength and Split Tensile strength for M-40 Grade of Concrete.

Experimental Investigation of the Compressive, Tensile and the Flexural Capacity of Beams made of Steel Fiber Reinforced Concrete (SFRC), **M. M. Islam, M. A. Chowdhury et. al.(2012)** has been studied under this research that customized enlarged end fibers are used with a volume fraction of 1.5%. Fibers consists of low aspect ratio are used and sufficient capacity enhancement is observed by experimental testing. Two different types of aggregate are used to make the concrete i.e. stone and brick and the effects of steel fibers on these two types of concrete specimens are also evaluated. Flexural test shows the increase in flexural capacity of about 8% to 60%, compressive strength is increased by about 8% to 19% and tensile strength by about 39% to 149%. This investigation proposes steel fibers as an additive for concrete to make flexural members of structures to increase the capacity as well as ductility which will reduce the risk of brittle failure during earthquake or any other load.

Reeta[1], Manoj[2], Karandeep[3], Mr. Amit Singhal[4](2016), Fiber Reinforced Concrete, under this research work the study has been carried out of using different types of fibers like steel, glass and synthetic fibers in concrete and analyze the mechanical properties. This research also finds the flexural-tensile strength, resistance to spitting, impact resistance and excellent permeability and frost resistance of concrete using the fibers in certain limits. The research result also shows that it is an effective way to increase toughness, shock resistance and resistance to plastic shrinkage cracking of the mortar. Steel fibers can improve the structural strength to reduce in the heavy steel reinforcement requirement.

Ahmad Bazgir (2016), a thesis on the behaviour of steel fiber reinforced concrete material and its effect on impact resistance of slabs, this study aims to investigate and examine the structural behaviour of steel fiber reinforced concrete material at different volume fraction of the fibers. Experimental work is conducted for this research to obtain results on the behaviour of SFRC. The experimental work consists of testing concrete under tension, compression and flexure.

Komal Chawla et. al.(2013), studies of glass fiber reinforced concrete composites, this research paper outlines the experimental investigation conducts on the use of glass fibers with structural concrete. Cem-fill anti crack, high dispersion, alkali resistance glass fiber of diameter 14 micron, having an aspect ratio 857 was employed in percentages , varying from 0.33 to1 percentage by weight in concrete and the properties of this Fiber Reinforced Concrete (FRC) like compressive strength, flexure strength, toughness, modulus of elasticity were studied.

Samprati Mishra (2017), Glass Fiber Reinforced Concrete, under this study using alkali resistance glass fiber. Glass fiber falls under the economical class i.e. without any extra expenditure (out of the total cost of concrete) can be used. The used glass fibers are of 12mm in length and 14micron diameter. Total 10 groups were prepared with different percentage of glass fiber and grade of concrete. First trial test was conducted using different percentages of glass fiber in M25 grade concrete. Since high grade concrete has been used in various construction worldwide so this research work also kept the importance of investigate high grade concrete i.e. M40 with different fraction of glass fiber and analyzed the comparison study between the. The compressive strength test was conducted at 7days and 28days. The results shows the satisfactory enhancement in strength of fiber used concrete than plain concrete.

Pankaja B S et. al.(2018), the main aim of the study is to analyze the compressive strength of concrete, when concrete is mixed with glass fiber and Geogrid, to meet the demands of the modern construction. The addition of Glass fiber into concrete increases the compressive strength of concrete than Geogrid concrete. Tests are conducted by using glass fiber and Geogrid. For 1 m^3 of concrete, 612grams of glass fiber for M30 grade of concrete and for M40 grade of concrete 697 grams of glass fiber for 1m3 of concrete are used. Geogrids are placed at 2 layers (50mm interval each) in a 150*150mm cube in both M30 and M40 grade of concrete.The result shows GFRC gives good compressive strength whereas GFC records good improvement in tensile strength.

3 MATERIALS AND METHODOLOGY

3.1 Aim: Introduction

The experimental program involves tests of fiber reinforced concrete cubes, tested under static axial load equivalent applied uniformly in the vertical direction. Total 63 FRC cubes, conforming to Indian Standard were designed, built, instrumented and tested in the structure laboratory of the Civil Engineering Department at SRGI, JBP.A group of 27 no. cubes were strengthened with different volume percentage of steel fibers and 27 no. cube with glass fiber. This chapter presents the details of the experimental methodology. It consists of: (i) material characterization; (ii) fiber reinforcement and instrumentation, (iii) specimen preparation, including concrete casting and curing; (iv) FRP strengthening details.

3.2 Materials

3.2.1 Cement

Using Ordinary Portland Cement (grade 43) of specific gravity 3.14 conforming to IS 8112:2013, "ORDINARY PORTLAND

CEMENT- SPECIFICATION", has been used.

3.2.2 Aggregates

Fine aggregates conforming to IS383:1970, "SPECIFICATIONS FOR COARSE AND FINE AGGREGATES FROM NATURAL SOURCES FOR CONCRETE" has been used.

Coarse aggregates conforming to IS383:1970, "SPECIFICATIONS FOR COARSE AND FINE AGGREGATES FROM NATURAL SOURCES FOR CONCRETE" has been used

3.2.3 Water

Normal portable water fit for drinking purpose has been used to prepare fresh concrete. Specification confirming to IS 456:2000.

3.2.4 Concrete

The concrete is mixture of four main constituents: cement, water, coarse aggregate, and fine aggregate. The concrete was prepared of M20 for a characteristic compressive strength in 7,14 and 28 days from manufacturing. Ordinary Portland cement (Type 1) was used having specific gravity of 3.14 for the concrete preparation. The coarse aggregate used complied to 20mm grading (as per IS 383:1970).

3.2.5 Steel Fiber

Steel fiber is a metal reinforcement. Steel fiber for reinforcing concrete is defined as short, discrete lengths of steel fibers with an aspect ratio (ratio of length to diameter) from about 20 to 100. They are generally of larger cross-section, with an 'equivalent diameter' of 0.5-1.2 mm and lengths varying between 20 and 60 mm. In this research work crimped steel fiber is used as shown in figure. Carbon steels are normally used; where a greater degree of corrosion resistance is required (e.g., in marine applications), alloy steels, stainless steels or galvanised steels may be substituted. Galvanized steel fiber is used in this research. The mechanical properties of the steel fibers are :

Table 1 Mechanical Properties of Steel Fiber used

Sr.No.	Property	Description/Approximate values
1	Shape	Crimped
2	Diameter(mm)	0.5
3	Length(mm)	20-60
4	Specific Gravity	7.9
5	Tensile Strength (MPa)	500-2000
6	Resistance to Alkalies	Good
7	Heat Resistivity	good
8	Aspect Ratio	20-100
9	Young Modulus (MPa)	2.1×10^5
10	Elongation(%)	5-35

Source: Properties-of-steel-fiber_tbl1_307775640

Note: The cost of the above Steel Fiber was Rs 190/- per kg.

Figure 3 Crimped Steel Fiber

3.2.6 Glass Fiber

Glass fibers are the most common type of reinforcement used in PMCs; they generally have good specific strength and stiffness properties and are inexpensive. Glass fiber is made by melting the constituent materials together and drawing the melt into a fiber. They have a diameter of 5–25 µm and are coated with a "sizing" to improve the adhesion with the matrix material. Size is a thin surface coating of mainly organic materials applied to nearly all types of man-made fibers during their manufacture. Sizing is the process of coating fibers with a size. The predominant constituent of glass fiber is silica (silicon dioxide, SiO_2), or sand; however, there are different types of glass fiber, each with slightly different compositions and properties. The three most common types of glass fiber are E-glass, C-glass, and S-glass; there are others available but they are usually associated with a particulars manufacturer.

Glass fiber is used for enhancing the tensile strength in structure and thus the glass fiber of following characteristics are used:

Table 2 Properties of Glass Fiber used

Sr.No.	Property	Description/Approximate Values
1	Shape	Straight
2	Length(mm)	10-15
3	Sp. Gravity	2.68
4	Tensile Strength(MPa)	1600-1800
5	Resistance to Alkalies	Good
6	Chemical Resistance	Good
7	Electrical conductivity	Poor
8	Softening Point(^oC)	700-900
9	Aspect Ratio	800-900
10	Modulus of Elasticity(GPa)	70-80

Source: Properties-of-glass-fibers_tbl4_283188657

3.2.7 Specimen layout

A total of 63 fiber reinforced concrete cube specimens were prepared and tested in the experimental program. Each cube specimen consists of a 150 mm square cross section and a depth of 150 mm. The concrete specimen was reinforced with steel and glass fiber in different volume percentage with respect to binding material (sand). Steel fibers of 15-30 mm length and 1 mm diameter and glass fiber of 20-30mm length and 10µ (approximate) diameter is used for the research. Specimen were prepared with M20 grade concrete.27 specimens were strengthened with steel fiber of desired characteristics as mentioned in above section and 27 specimens were strengthened with copped glass fiber of above mentioned characteristics. The other 9 were used as control specimens (no strengthening). These specimen were prepared for 7, 14 and 28 days of curing respectively. The specimens were numbered as PC_{11},SC_{11}, ,GC_{11} and so on, where the letter "P" indicates plain and "S" and "G" are indicating steel fiber reinforcement and glass fiber reinforcement respectively while "C" indicates concrete which is the second word in abbreviation and the numeric value indicates the sequence in which they were tested in different group. The specimens were divided into three groups according to the fiber reinforcement used as indicated in Table 4. The specimen groups were: (i) Group G-I for 7 days curing concrte, which included specimens PC_{11},PC_{12}, PC_{13}, SC_{11}, SC_{12}, SC_{13}, GC_{11}, GC_{12} and GC_{13}; (ii) Group G-II for 14 days curing concrete which included specimen PC_{21},PC_{22}, PC_{23}, SC_{21}, SC_{22}, SC_{23}, GC_{21}, GC_{22} and GC_{23} ; (iii) Group C-III for 28 days curing concrete, including specimens PC_{31},PC_{32}, PC_{33}, SC_{31}, SC_{32} SC_{33}, GC_{31} GC_{32} and GC_{33}. The steel and glass fiber reinforcement is used in concrete specimens in the volume percentage of 0.4%, 0.8% and 1.2% in the replacement of binding material i.e. sand.

Table 3 Classification of Specimens

Sr. No.	Specimen Group	Specimen Name	Plain Concret Specimen	SFRC Specimen			GFRC Specimen		
			No. of Specimens in 7,14 & 28 Days	No. of Specimens in 7,14 & 28 Days			No. of Specimens in 7,14 & 28 Days		
				0.4%	0.8%	1.2%	0.4%	0.8%	1.2%
1	G-I	PC_{11}, PC_{12}, PC_{13}, SC_{11}, SC_{12}, SC_{13} GC_{11}, GC_{12}, GC_{13}	3	3	3	3	3	3	3
2	G-II	PC_{21}, PC_{22}, PC_{23}, SC_{21}, SC_{22}, SC_{23} GC_{21}, GC_{22}, GC_{23}	3	3	3	3	3	3	3
3	G-III	PC_{31}, PC_{32}, PC_{33}, SC_{31}, SC_{32}, SC_{33} GC_{31}, GC_{32}, GC_{33}	3	3	3	3	3	3	3

3.2.8 Specimens Details

The specimens were reinforced with steel and glass fiber of length 20-30mm both and diameter 1mm and 10μ(app) respectively. These specimens were cast in cube form of mould having dimension 150X150X150mm. Manufacturing of specimen has been done by mixing ordinary portland cement, aggregate of size 20mm , sand passing through the 4.76mm sieve and water having drinking quality with water cement ratio of 0.5. M20 grade concrete was used. The specimenss were cured for 7, 14 and 28 days.

4 RESULT & DISCUSSION

4.1 Introduction

This chapter provides the results of the experimental activity, which involves tests of 63 concrete specimens under one directional axial load under compression testing machine. The tests were performed at the construction material laboratory of the SRGI, JABALPUR. They were tested to study the effects of using steel and glass fiber which are good in tensile strength and also analyze the compressive strength when replaced these material with fine aggregate (sand). The tests were conducted under constant axial load and increasing this load until the failure of specimens does not occurs. The following section provides stress-deformation relationships i.e. stress-strain relationship and observed damages for all the specimens. The specimen performance and comparisons of the effects of test parameters are presented at the end of the chapter.

4.2 Compressive Strength of Plain Concrete, Steel Fiber & Glass Fiber used Concrete

The different concrete specimen gave the following results during the application of direct axial compression load under compression testing machine (2000KN capacity) and 22500 mm^2 surface area:

4.3 7 Days Curing Results

Table 5: Results obtained of different specimens

S.No.	Specimen Name	% Replacement	No. of cubes	Avg. P_{ult}(KN)	Avg. σ_{ult} (Pult/A) (MPa)
1	PC_{11}	0	1	520	23.11
	PC_{12}	0	1	560	24.89
	PC_{13}	0	1	520	23.11
2	SC_{11}	0.4	3	530	23.56
	SC_{12}	0.8	3	535	23.85
	SC_{13}	1.2	3	550	24.59
3	GC_{11}	0.4	3	530	20.15
	GC_{12}	0.8	3	540	24.15
	GC_{13}	1.2	3	530	23.70

4.4 14 Days Curing Results

S.No.	Specimen Name	% Replacement	No. of cubes	Avg. P_{ult}(KN)	Avg. σult (Pult/A) (MPa)
1	PC_{21}	0	1	620	27.56
	PC_{22}	0	1	710	31.56
	PC_{23}	0	1	640	28.44
2	SC_{21}	0.4	3	655	29.04
	SC_{22}	0.8	3	545	25.63
	SC_{23}	1.2	3	630	28
3	GC_{21}	0.4	3	510	22.67
	GC_{22}	0.8	3	690	30.67
	GC_{23}	1.2	3	600	26.67

4.5 28 Days Curing Results

S.No.	Specimen Name	% Replacement	No. of cubes	Avg. P_{ult}(KN)	Avg. σult(Pult/A) (MPa)
1	PC_{31}	0	1	840	37.33
	PC_{32}	0	1	900	40.00
	PC_{33}	0	1	850	37.78
2	SC_{31}	0.4	3	797	35.41
	SC_{32}	0.8	3	610	27.26
	SC_{33}	1.2	3	613	27.26
3	GC_{31}	0.4	3	610	27.11
	GC_{32}	0.8	3	923	41.04
	GC_{33}	1.2	3	723	32.15

The results of tested specimens were tabulated above, these results were recorded in ultimate loads at which the failures of specimens occurred and further these loads are converted in ultimate stress that is ultimate load divided by cross sectional (surface area) area in which the load was applied. And the minimum value of these stresses is considered as the final stress value of that particular specimen for which the test was conducted, the similar values are also considered for other specimens.

The graphical presentation is also plotted with the help of recorded results of tested specimens and made the comparison between the plain concrete specimen and steel and glass fiber used concrete specimens.

The above results can be interpreted in the following statements:

- Since steel and glass fiber have the good strength in tension hence it improves the flexural strength of concrete. Due to the bondage between the particles and fibers, it also improves the compressive strength of concrete as well.
- In steel fiber used concrete specimens, the strength increases as we replace sand with steel fiber by 0.4% and 0.8% in 7 and 14 days curing period when compared to the plain concrete specimens. But when we just go beyond the 0.8% replacement, strength of the SFRC starts to fall. 1.2% addition of steel fiber in concrete shows the significantly decrement in strength with respect to plain concrete specimen. So we can conclude that steel fiber can be mixed in concrete up to 0.8% for higher strength performance.
- In case of glass fiber used concrete, when we mix 0.4% glass fiber into the concrete, it records reduction in strength but as we increase this glass fiber volume up to 0.8%, concrete gives the higher strength than plain concrete specimens. Further increment of glass fiber i.e. up to 1.2%, again concrete shows the decrement in strength. So basis on this observed results we can conclude that 0.8% replacement of glass fiber is best suited for achieving the good strength in concrete.

The Graphical Presentation of Result Analysis

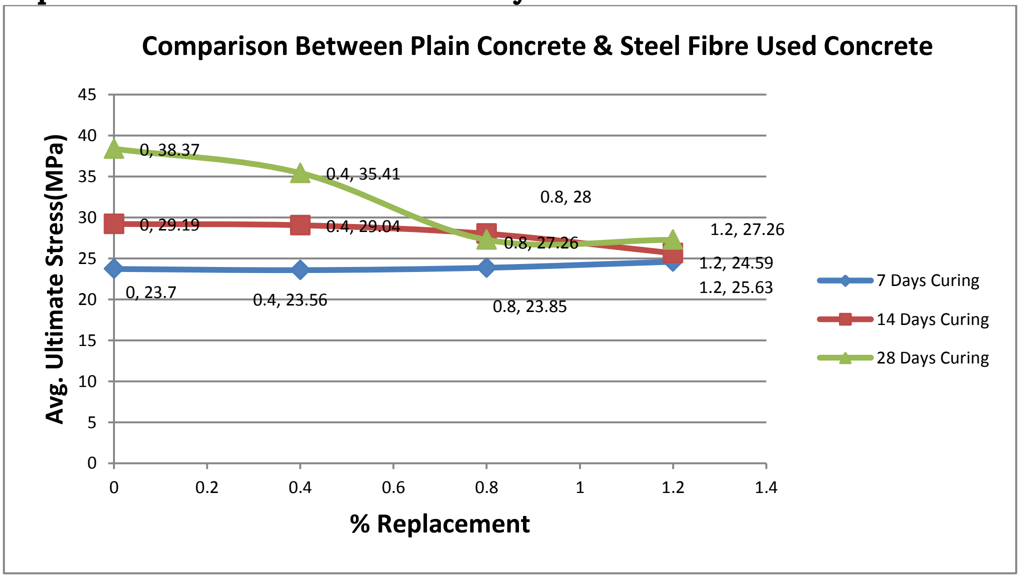
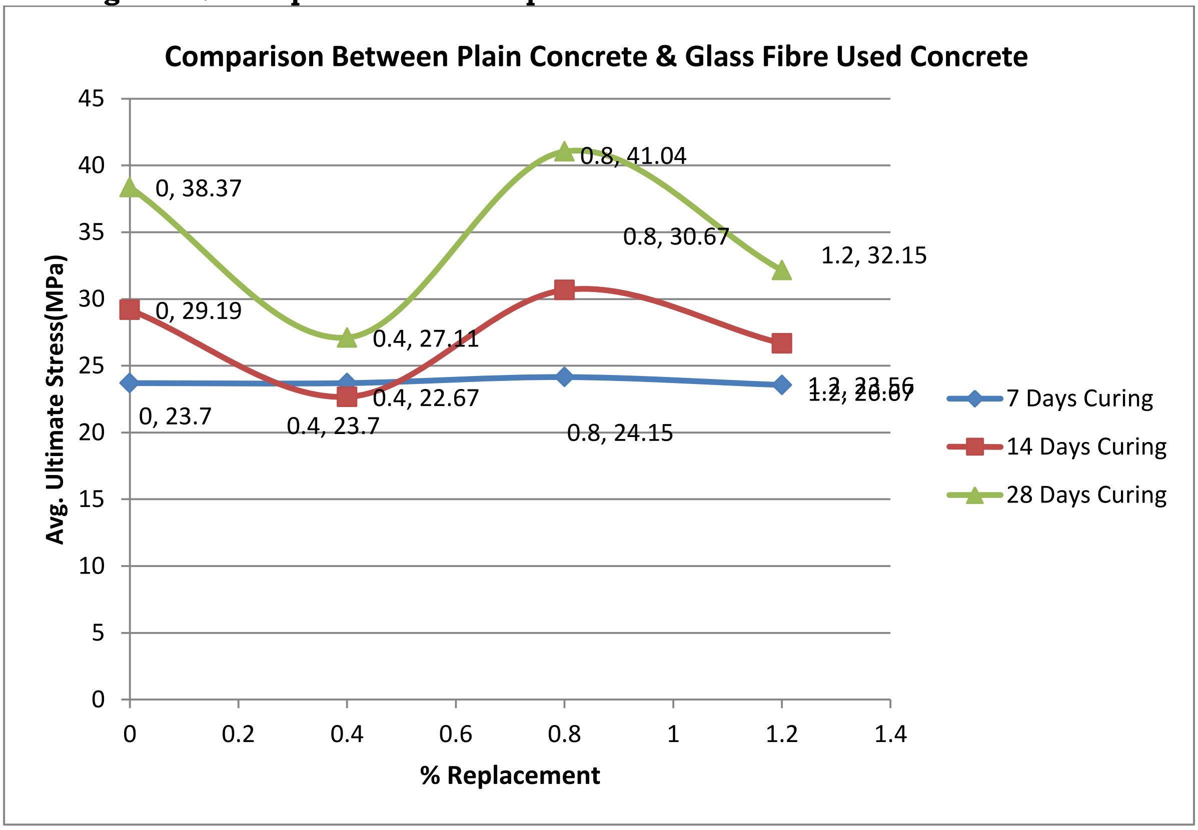


Figure 12: Comparison between plain concrete and steel fiber used concrete



5 CONCLUSIONS

Comparison of Plain Cement Concrete with Steel Fiber and Glass Fiber used Concrete

The analyses were conducted for plain cement concrete, steel fiber used concrete and glass fiber used concrete. Comparison has been carried out between these concrete specimens. Steel fiber used concrete gives the satisfactory good compressive strength than plain cement concrete strength when we use 0.8% replacement of steel fiber. But as we further increase the steel fiber volume beyond 0.8%, it records the decrement in strength In case of glass fiber used concrete only 0.8% replacement gives the higher strength result when compared with plain cement concrete strength. Beyond this 0.8% replacement, it reduces the strength of glass fiber used concrete.

6 SUMMARY

In this research work the effectiveness of fiber materials as a replacement of fine aggregate in concrete was investigated experimentally. The experimental program consisted of total 63 concrete specimens, tested under axial compression and applied statically. 27 were mixed with steel fiber, 27 were mixed with glass fiber and 9 were plain concrete specimens. The tests were performed under static load conditions and compared these replaced concrete specimens with plain concrete specimens.

The specimens were analyzed under incrementally increasing static loads, the monotonically axial load is applied to the cross sectional area under the compression testing machine. The load was continuously applied until the specimens failed and observing the strain patterns which were occurred during the application of load. At the failure point of the specimen, the maximum value of load is recorded. This sequence of process was followed for all concrete specimens and recorded the maximum load value and further this load converted into the ultimate stress. Finally these stresses of different material mixed (i.e. waste marble and shredded tyre) concrete compared with plain concrete specimens (no replacement) and these all analysis is presented by graphical charts. This result can be concluded that the steel and glass fiber can be used up to 0.8% of fine aggregate volume for achieving the high strength in concrete.

6.1 Conclusion

The results obtained for the fiber materials replaced concrete and plain concrete specimens with the discussed test setup were analyzed keeping in view the pre decided objectives. The analysis concluded as enumerated below:

1. Steel Fiber and Glass Fiber can be used for making the concrete.
2. Observed variation in strength according to the replacement percentage used with different fiber material.
3. The enhancement in the ultimate load or stress of the replaced concrete specimens verifies the past work suggests that the using fiber material like steel and glass fiber as a replacement in concrete improves the load bearing capacity of the concrete.
4. Size ad shape of these materials affects the bonding of particles in concrete.
5. Using these materials in concrete affects the homogeneity of whole concrete.
6. As we increases the percentage of glass fiber, firstly we observe the improvement in strength up to certain limit. After this limit, the further increment of glass fiber reduces the strength of concrete. In case of steel fiber, concrete strength falls in initial stage but after certain limit of mixing, concrete records a satisfactory good strength.
7. Steel fiber used concrete gives the good strength, when 0.4% and 0.8% volume is replaced by steel fiber in the place of fine aggregate (sand). Further increment of the fiber beyond 0.8% starts reducing the strength of concrete.
8. The concrete mixed with glass fiber gives the higher strength than plain concrete and steel fiber used concrete, when added this material up to 0.8% in concrete. Beyond this 0.8% limit concrete starts losing its bonding strength.
9. When we compare between cost and strength of these fiber materials used concrete, we observed that glass fiber (0.8%) mixed concrete gives the higher strength but its cost is also too high (i.e.60%) than plain concrete. In case of steel fiber used concrete, results shows the satisfactory strength but again it also takes high cost(i.e.40%) than its strength when compared with plain concrete.

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