Assessment of Influence of Steel Fiber on the Improvement of Concrete's Mechanical Properties

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Abstract: In recent days concrete usage has been increased all over the world. Concrete is one of the most developed materials. Different types of waste materials used in concrete as fiber reinforcement to develop its mechanical performance. Steel fiber is such type of waste material used in concrete. The main focus of this paper is to improve the compressive and tensile strength of concrete using steel fibers as fiber reinforcement. In this paper, several number of normal concrete cylinders and several number of fiber reinforced concrete cylinders with addition of 1%, 2% and 3% of steel fiber are investigated. Several tests have been performed under UTM Machine. Compressive strength & split tensile strength of concrete are found better for 2% addition of steel fiber. This paper shows a summary of the improvement of concrete's mechanical performance including steel fiber as fiber reinforcement.

Keywords: Steel fiber, Compressive strength, Split tensile strength, Fiber reinforcement.

1. INTRODUCTION

Concrete is an indispensable building substance, it has been widely used in the applications of Civil Engineering such as building, bridges and roads. Behbahani H P et al. [11] stated that concrete is a fragile substance having low tensile & compressive strength. Hence it requires reinforcement to make it strong and be used as the widest construction material. To improve tensile and shear stress properties, steel bars are used as reinforcement placed in the concrete. In addition, fibers are basically short, sporadic & haphazardly placed in the concrete mixture. Steel fiber is the mostly used type of fiber as concrete reinforcement to improve plastic & drying shrinkage in concrete. A summary of the mechanical properties of steel fiber reinforced concrete was the reflection of this paper. In this study no laboratory experiments were performed.

When steel fibers are used in concrete as reinforcement, they act effectively as rigid incubations.

Shende A M et al. [3] investigated that M-40 grade of concrete (1:1.43:3.04) having water cement ratio 0.35 percent including fibers of 0%, 1%, 2% & 3% of hook tain to improve the several desired properties of steel fiber reinforced concrete (SFRC). With the increase of fiber percentage several concrete properties such as compressive strength, flexural strength & split tensile strength for M-40 concrete increase at 28 days. No investigation was done for several types of concrete grade & water cement ratio. Yuan J et al. [5] investigated that the flexural behavior of concrete. Continuous basalt has been added as fiber reinforced polymer in concrete. Under four-point bending cyclic loading 5 no concrete beams (150 × 300 × 2100 mm^3) were worked out & analyzed. Several reinforcement ratios (0.56%, 0.77%, 1.15% & 1.65%) used in basalt fiber reinforced polymer concrete were investigated. There was lack of preparing several concrete cubes or cylinders with different water cement ratio.

To resist flexure in structural members concrete does not belong to good tensile properties. Because of bending, cracks appear on the tension face of concrete. Designing uncracked sections of structural concrete of water retaining structures are well grounded. Heavy structural design is costly. For designing of concrete members with uncracked section Steel Fiber Reinforced Concrete is a low cost solution. The ability of structural members to carry significant stresses is enhanced using steel fiber reinforcement in concrete. The toughness of concrete under any type of loads increases with the use of fibers.

RAGAVENDRA S et al. [12] presented that the variation of mechanical properties and durability of fiber reinforced concrete. M25 concrete with several conditions were experimented. Cylindrical concrete with different grade was not investigated.

This paper is mainly focused on the assessment of influence of steel fiber on the improvement of concrete strength with addition of steel fiber as fiber reinforcement. The objective of this paper is to analyze the concrete's mechanical properties & workability using M20 concrete through several UTM tests, to compare the compressive strength, split tensile strength between steel fiber reinforced concrete & normal Concrete.

2. LITERATURE REVIEW

Kumutha R et al. [1] investigated that thirty cubes and ten flexure beams that were cast. Three cubes and a flexure beam having control mix were prepared. M15, M25 and M35 concrete were investigated with percentages of fibers (0.25, 0.50, and 0.75). A significant improvement in the ultimate strength was clearly seen due to the usage of fibers. Better condition on the basis of strength and ductility was found to be

0.5% addition of fibers. Chang D et al. [2] presented that the analysis of steel fiber reinforcement concrete containing fine aggregate, coarse aggregate, water, hydraulic cement, & steel fibers in an appropriate proportion. Steel fibers are defined as discrete, short lengths of steel having the desirable ratio (ratio of length to diameter) with respect to several cross-sections according to American Concrete Institution (ACI 544.IR, 1996). Steel fibers are portable enough to be spontaneously put out in fresh concrete mix having several concrete grades following traditional mixing methods.

Super plasticizers in concrete (chemical admixture) may also be accumulated to improve the workability, toughness & durability of steel fiber reinforcement concrete (SFRC). Different types of steel fiber shapes have different diameters, lengths, and cross-sections. Steel fibers have different shapes because of engineering specifications. The Steel Fibers Reinforcement Concrete (SFRC) behavior can be categorized into three classes on the basis of its fiber effectiveness, fiber content & suitability. Steel fiber reinforced concrete can be analyzed depending on steel fiber volume content. Very little fraction of steel fiber containing less than 1% per volume of concrete was added in concrete to monitor plastic shrinkage for several years. To enhance the resistance property, flexural toughness, modulus of rupture & other important mechanical properties of concrete, adequate fraction of steel fibers percentage (1% - 2% per volume of concrete) are analyzed. Sufficient percentages of steel fibers (more than 2% per volume concrete) are also investigated. Practically steel fibers are used as the secondary reinforcement & main reinforcement as conventional steel bars. Steel fibers contain desirable mechanical properties with the variation of sufficient percentage of steel volume & also can be upgraded without other continuous reinforcement. Singn H et al. [4] investigated that brittle behavior of concrete was improved using reinforced concrete steel fiber. The analysis was the light weight concrete when investigated with the waste steel from reinforcement and formworks with different fiber contents. Manaf AFA et al. [6] investigated that the influence of micro fiber steel on slump height & the toughness of several concrete grades was investigated. With the increase of micro steel fiber in concrete (0.5% to 2%), the desirable strengths also increase. Eventually the toughness impact of self-compacting concrete has been reduced on the basis of several types of water used during the mixing procedure. With the addition of several percentages (0.5% to 2%) of micro fiber steel, tensile strength of self-compacting concrete and ultra-high performance concrete increases.

Mechanical properties of concrete have been investigated theoretically in some researches & lab tests were performed on the basis of different grade concrete having separate water cement ratio as well. In this paper steel fiber has been mixed with concrete to evaluate the mechanical properties & workability of concrete. Cold drawn wire has been used as steel fiber for these cases.

3. METHODOLOGY

This study has been investigated by collecting fine aggregate (Sylhet sand), coarse aggregate (Stone chips, Savar), steel fibers (cold drawn wire) and cement (Ordinary Portland cement). Sieve analysis of fine and coarse aggregates have been performed. 72 no cylinder molds (8" height & 4" dia) using M20 concrete (normal concrete & steel fiber reinforced concrete with 1%, 2% and 3% steel fiber addition) have been analyzed. Slump test is also performed for all cases. All concrete molds are cured for 7 days, 14 days and 28 days. Compressive test and Split tensile test have been performed by UTM machine.

Fig.1: Collection of steel fibers (cold drawn wire).

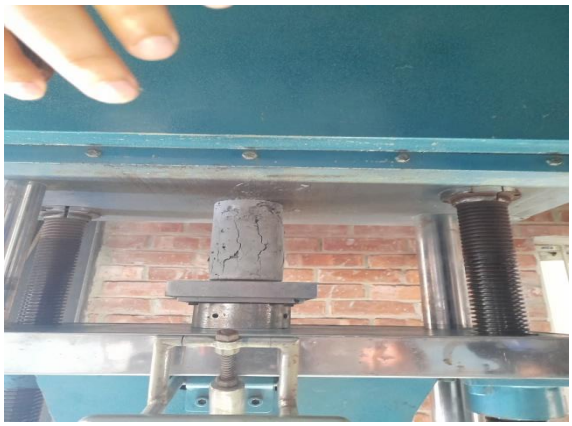

Fig.2: Compressive strength test by UTM machine.

Fig.3: Split tensile strength test by UTM machine.

Fig.4: Steel fiber mixing with concrete ingredients.

Sieve analysis

This test procedure complies with the ASTM standard specification C136 [18]. Stone chips & sylhet sand were collected and dried the sample to constant weight through oven. In order of decreasing size of opening from top to bottom the standard sieve was nested and placed the sample on the top sieve. The sieves were agitated by hand for 15 mins. After effective agitation the sample that was retained on each sieve was weighted by balance.

Concrete specimen preparation

Normal concrete & steel fiber reinforced concrete were prepared following proper mixing ratio of M20 concrete. Ordinary Portland cement, sylhet sand, stone chips & cold drawn wire were mixed with water cement ratio 0.55 to make concrete cylinder. Molds having height 8" and diameter 4" was used for these cases. The total number of 72 concrete cylinders was prepared.

Slump Test

For checking the consistency and workability of the concrete mix prepared at the construction site slump test is most prominent & effective method.

After completing concrete mix the internal surface of the standard slump cone was properly cleaned and the slump cone was placed on a smooth, horizontal waterproof base plate. Then the slump cone was then filled with concrete in 4 layers for each percentages of steel fiber and each layer was tampered 25 times with the help of a tamping rod. After completing the top layer tampering, the excess concrete was pulled out and the surface was leveled with a trowel. Finally, the slump cone was brought out by lifting it slowly and carefully in the vertical direction that permits the concrete to subside. This subsidence is referred to as a slump of concrete. This test was performed for all cases. The slump test method complies with the ASTM standard specification C143/C143M [8].

UTM Machine Test

The total number of 72 cylindrical concrete was prepared. Moreover, 3 number of cylindrical concrete was prepared for every case. 24 hrs. later all cylindrical concrete were immersed into water & cured for 28 days. After 7 days, 14 days, 28 days all specimens were investigated by UTM machine. The compressive strength & split tensile strength was found for all cases in N/mm^2. The strength test method complies with the ASTM standard requirements of specifications C39/C39M [9] and C192/C192M [10] for cylinders.

4. RESULTS AND DISCUSSIONS

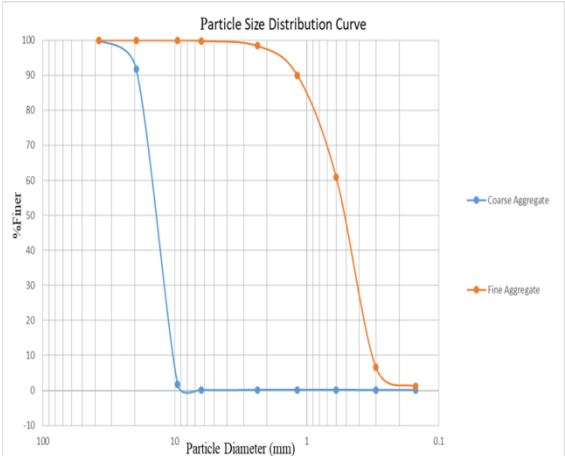

Fig.5: Graphical representation of percentage of finer with the variation of particle diameter for Sylhet sand & stone chips.

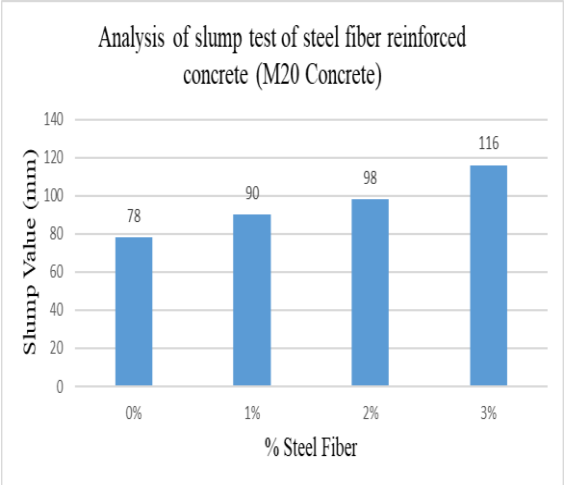

Fig.6: Variation of slump value with respect to percentage of steel fiber in concrete.

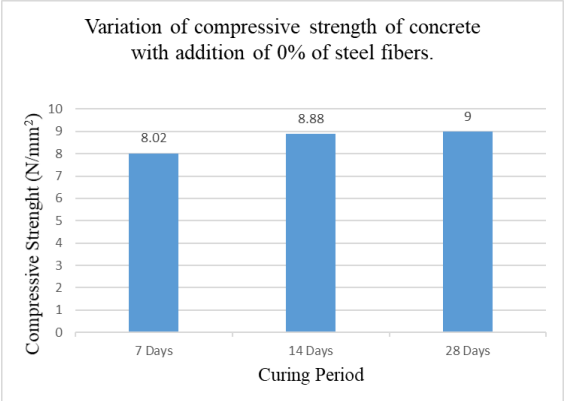

Fig.7: Variation of compressive strength with respect to curing period of concrete.

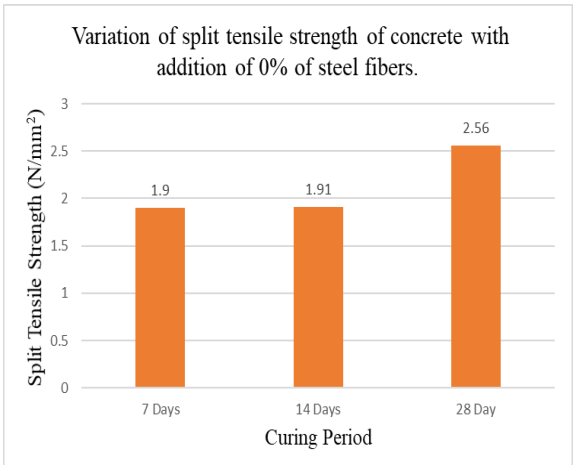

Fig.8: Variation of split tensile strength with respect to curing period of concrete.

It can be seen that maximum slump value was found for 3% addition of steel fiber in concrete & degree of workability high. It has been observed that the addition of steel fiber slump value increases simultaneously. The porosity inside the concrete decreases with the increase of steel fiber addition in concrete. Moreover, the increase of percentage of steel fiber improves the binding property & durability of concrete. Therefore the workability of concrete gains better.

There was a significant change in compressive strength and split tensile strength with 0% addition of steel fiber in concrete. Moreover from 0 to 28 days, there was a dramatic rise in the quantity of compressive strength as well as split tensile strength.

Compression Strength Test

Table 1: Variation of compressive strength of concrete (M20 Concrete) with addition of several percentages of steel fibers.

SL. No	% Steel Fiber	Compressive Strength (N/mm^2)		
		7 (Day)	14 (Day)	28 (Day)
1	0%	8.02	8.88	9.00
2	1%	11.47	14.18	15.54
3	2%	11.10	15.91	17.51
4	3%	10.24	13.57	14.55

Split Tensile Strength Test

Table 2: Variation of split tensile strength of concrete (M20 Concrete) with addition of several percentages of steel fibers.

SL. No	% Steel Fiber	Split Tensile Strength (N/mm^2)		
		7 (Day)	14 (Day)	28 (Day)
1	0%	1.9	1.91	2.56
2	1%	1.79	2.04	2.65
3	2%	1.97	2.10	2.78
4	3%	1.91	2.16	2.62

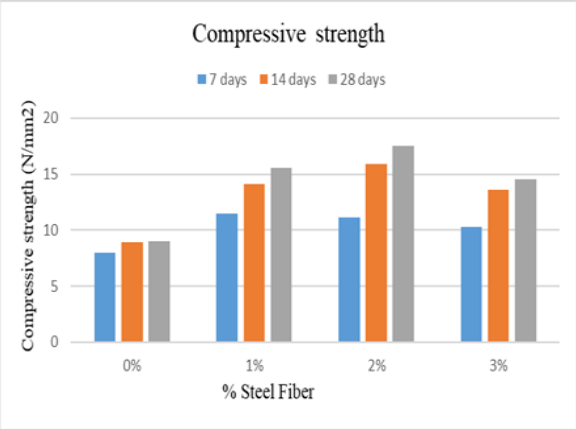

Fig.9: Graphical representation of compressive strength of concrete with the variation of percentage of steel fibers at 7, 14 & 28 days.

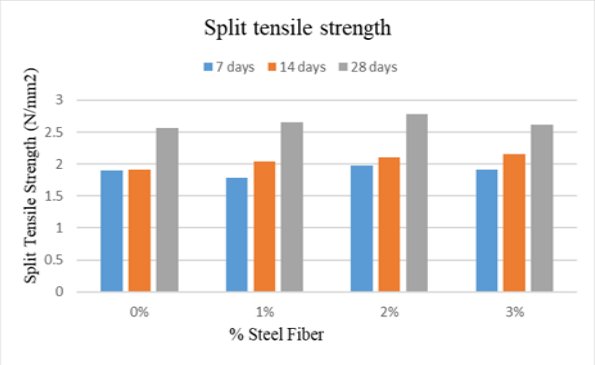

Fig.10: Graphical representation of split tensile strength of concrete with the variation of percentage of steel fibers at 7, 14 & 28 days.

It can be clearly seen that with the increase of percentage of steel fibers, compressive strength of concrete increases up to 2% mixing of steel fiber. Moreover, from 7 to 28 days, the quantity of compressive strength for 2% addition of steel fiber dramatically rose from 11.10 to 17.51. Conversely, there was a significant reduction in the quantity of compressive strength with 3% addition of steel fiber in concrete. It can also be observed that with the increase of percentage of steel fibers, split tensile strength of concrete increases up to 2% mixing of steel fiber. Moreover, from 7 to 28 days, the quantity of split tensile strength for 2% addition of steel fiber dramatically rose from 1.97 to 2.78. Conversely, there was a significant reduction in the quantity of split tensile strength with 3% addition of steel fiber in concrete. The voids in concrete decreases with addition of steel fiber. Moreover, steel fiber reinforced concrete gives more workability, compressive strength and split tensile strength.

5. CONCLUSION

In this study, waste material steel fiber used in concrete as fiber reinforcement is successfully employed & investigated. Several tests are performed for these cases. There is a dramatic & significant change in quantity of compressive strength & split tensile strength of concrete with the variety of percentages of steel fibers. The compressive strength & split tensile strength of concrete are found maximum for 2% mixing of steel fibers in concrete. Eventually, it can be concluded that steel fiber reinforcement concrete gains better strength & workability than that of normal concrete.

References

[1] Kumutha R, Vijai K, “Effect of Steel Fibers on the Properties of Concrete” Journal of Reinforced Plastics and Composites, Vol 29, Issue 4, pp. 531–538,2009.

[2] Chang D, Chai WK (1995), “Flexural fracture and fatigue behavior of steel-fiber-reinforced concrete structures”, Vol. 156, Issue 1-2, pp. 201-207, 1995.

[3] Shende AM, Pande AM, “Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade”, International Refereed Journal of Engineering and Science (IRJES), Vol. 1, Issue, 2012.

[4] Singn H, Kaur R, “Steel Fibre Reinforced Light weight Aggregate Concrete”, International Journal of Recent Technology and Engineering (IJRTE), Vol. 9, Issue1, 2020.

[5] Yuan J, Zhu H, “Flexural Performance of Concrete Beams Reinforced with Continuous FRP Bars and Discrete Steel Fibers under Cyclic Loads”, Vol. 14, Issue 7, 2022.

[6] Manaf AFA, Shahidan S, “Strength Capacity of Concrete Using Micro Steel Fiber: A Review”, IOP Conf. Series: Materials Science and Engineering, 1144 (2021) 012023, 2021.

[7] Thomas J, Ramaswamy A, “Mechanical Properties of Steel Fiber-Reinforced Concrete”, Journals of Materials in Civil Engineering, Vol. 19, Issue 5, 2007.

[8] Minde PR, Deepak D, “Exploration of Characteristics of Steel Fiber Reinforced Concrete and Its Influence on Regular Concrete”, International Journal of Recent Technology and Engineering (IJRTE), Vol. 9, Issue 2, 2020.

[9] Huang Y, Gu H, “Fatigue behavior assessment for steel fiber reinforced concrete beams through experiment and Fatigue Prediction Model”, Vol. 27, pp. 1105-1117, 2020.

[10] Liu Y, Liu S, Xiang D, ”Improvement of flexural and cyclic performance of bridge deck slabs by utilizing steel fiber reinforced concrete (SFRC)”, Vol. 329, 2022.

[11] Behbahani H P, Nematollahi B, Farasatpour M, “Steel Fiber Reinforced Concrete: A Review” Proceedings of the International Conference on Structural Engineering Construction and Management (ICSECM2011), 2011.

[12] RAGAVENDRA S, REDDY S P, DONGRE A, “FIBRE REINFORCED CONCRETE- A CASE STUDY”, 33rd national Convention of Architectural Engineers and National Seminar on "Architectural Engineering Aspect for sustainable building envelopes, 2017.

[13] Gul A, Alam B, Shahzada K, Ahmed W, “Impact of length and percentage dosage of recycled steel fibers on the mechanical properties of concrete”, Civil Engineering Journal, 2021.

[14] Binglin Y, “Research status and prospect of waste steel fiber reinforced concrete”, E3S Web of Conferences 248, 03039, 2021.

[15] Jaral M, Firdous E S, “A REVIEW STUDY ON THE STEEL FIBER REINFORCED CONCRETE PAVEMENT”, JSDR, Vol. 3, Issue 4, 2018.