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A Study on Compressive, Impact, Flexural and Shear Strength of Steel Fiber Reinforced Concrete

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ABSTRACT
Concrete is a construction material composed of cement (commonly Portland cement) as well as other cementations materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water and chemical admixtures. This chapter presents the detailed experimental programmed of this investigation. It includes materials and fibres used a detailed methodology of experimental programmed, mix proportions, specimen details, reinforcement detailing and test set up. The details of the tests conducted to ascertain the basic properties of constituent materials, the tests conducted on standard specimens and the experiments conducted using structural components are also explained. This work presents the results of an experimental study investigating the effects of steel fibers on the mechanical properties of concrete. Experimental program consisted of shear, impact, compressive and flexural strength a test was carried out this study aims to investigate the shear strength of steel fiber reinforced concrete, incorporated with steel fibers at various dosages. For this, a drop weight test was performed on the 7 days and 28 days cured plain and fiber reinforced concrete samples as per the testing procedure recommended by ACI committee 544. Straight, Crimped and hooked steel fiber of length 50 mm and an aspect ratio equal to 50. The main aim of this experiment is to study the strength properties of steel fiber reinforced concrete of M20, M25 and M30 grade with steel fibers added to concrete in different proportions i.e. 0%, 0.5%, 1.0%, 1.5% and 2.0% with water cement ratio of 0.42. From the test results hence this fiber reinforced concrete with industrial waste fiber is doubly advantageous as it provides a superior performance without increasing the cost of the concrete.

Keywords: shear strength, durability, Steel Fibers composites, cracking, Compression, impact, Flexural strength

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INTRODUCTION

Concrete is a building material in the human history. It consists of cement, Coarse and Fine Aggregates and Water. It is no doubt that with the improvement of human civilization concrete will continue to be a governing construction material in the future. The hardened concrete was tested for compressive, shear, impact and flexural strength. Shear strength may be determined by subjecting the concrete to the three dimensional loading was also carried out this study aims to investigate shear strength of steel fiber reinforced concrete. Straight

Fiber (SF), Hooked Fiber (HF) and Crimped Fiber (CF) steel fibers of length 50 mm and an aspect ratio equal to 50. The shear strength of concrete is the resistance of one layer with respect of other during slip at common surface of contact. A compromise between strength and ductility can be obtained by using discontinuous fibers. Adding fibers to concrete makes it a homogenous and isotropic material and converts its brittle characteristics to ductile one. When concrete cracks, the randomly oriented fibers function to arrest micro cracking. Thus, improving the first-crack shear strength increased significantly. Improvements in ultimate shear strength. Adding fibers influences the ascending portion of the stress-strain curve only slightly but leads to a noticeable increase in the peak strain and a significant increase in ductility, as described by the area under the descending portion of the curve.

Reinforced concrete beam under bending load maintains its ductility by yielding of the reinforcing steel. However, it soon became clear that such reinforced concrete members can fail in shear, and that shear failure can be catastrophic. A case in point is the punching failure of bridge decks. In addition, shear failure can occur in anchor bolts embedded in concrete, in corbels and in shear keys of segmental bridges. The connection between beam columns and the base of shear walls are also likely to be subjected to intensive shear during earthquake loading. Shear transfer mechanism in FRC, **N.K. Bairagi and C. D. Modhera [1]** proposed an experimental set up for finding out shear strength in absence of any standard procedure to measure shear.

SHEAR

Reference to current engineering literature and discussions will show that there exist in the minds of engineers quite di-verse notions of the shearing resistance of concrete. Values as low as the tensile strength of the concrete are cited; others name as hearing resistance nearly as great as the compressive strength of the concrete. It seems evident that these divergent estimates must be due to inconsistent experimental methods or to improper conceptions of the nature of shearing action. Shear is defined to be the action of two equal and oppositely directed forces whose lines of action are in planes very close to-gather. Manifestly, in the actual application of forces to structures or even to test pieces, the applied forces are not in adjacent planes, and the shearing forces used in the analysis and calculation are forces which exist by virtue of the mechanics of the problem. The shearing stresses in concrete test pieces are discussed on the basis of some distribution throughout the section, generally a uniform or nearly uniform distribution. The importance of determining this distribution is not usually recognized. Shear should be differentiated from cutting action, in that the latter begins at the surface and involves, in some degree at least, a gradual tearing or detersive action and a concentration of the STATION force at a single point. Shear should also be distinguished from the phenomena which may accompany it, as bearing action, diagonal tension, etc. In fact, the difficulties surrounding the determination of the shearing resistance of concrete are due largely to the accompanying cutting action, bearing pressures, and beam stresses in-evolved in the test. In the breaking of reinforced concrete beams, shearing failures have been confused with diagonal tension failures and calculations made from the results of such beam tests are evidently a source of low values given in texts and in the building ordinances of many of the cities of the country.

Fig. 1 illustrates a common conception of shear. The shearing force is considered to act along the line AB, and the shearing resistance is assumed to be uniformly distributed over the section on this line. Evidently these assumptions do not give the real action. Cut-ting action begins at the surface. The fibers are pushed inward immediately in front of the cut-ting edge. As this impression is increased, the bearing pressure is extended over a greater surface of the tool, though not uniformly so distributed, and the resultants of the applied forces will be moved away from the line AB. This sep-aeration of the applied forces gives a couple, with resulting beam action and horizontal and diagonal tensile and compressive forces. It is evident that the bearing action and resulting impression modify conditions and also that the shearing stresses are not uniformly distributed over the section, and that cut-ting action may injuriously affect results. A little calculation will show that the bearing pressure for a thin tool would exceed the resistance of the concrete. Besides, a test piece could not be held in the position shown, and a further support will be necessary.

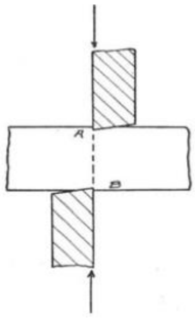


FIG.1 – COMMON CONCEPTION OF SHEAR

COMPRESSIVE STRENGTH

The compressive strength of concrete is one of the most important and useful properties of concrete. Strength is a measure of amount of stress acquired to fail a material. Concrete is strong in compression but weak in tension and the working stress theory for the concrete design also consider the concrete as a mostly suitable for bearing the compressive load ; that is why the compressive strength of the material is specified .Since the strength of concrete is a function of cement hydration process, which is relatively slow , traditionally the specification and the test for concrete strength are based on specimens cured under standard temperature humidity conditions for a period of 28 days.

IMPACT STRENGTH

Impact strength is of importance when concrete is subjected to repeated falling object, as pile driving, or a single impact of a large mass at a high velocity. The principal criteria are the ability of the specimen to with stand the high blows. It is interesting to point out that impact strength of concrete increases greatly with the rate at which impact stress is applied. It is generally assumed that the impact strength is directly related to compressive strength, since both are adversely affected by the micro cracks and voids. This assumption is not completely correct; it is found for the same compressive strength increased substantially with angularity and surface roughness of coarse aggregate.

In general the impact strength of concrete increases with compressive strength, but the higher the static compressive strength of concrete the lower the energy, energy absorbed per blow before cracking.

SHEAT STRENGTH

It is engineering is a term used to describe the strength of a material or component against the type of yield or structural failure where the material or component fails in shear. For shear stress τ applies.

$(\sigma_1 - \sigma_2) / 2$

Where

σ_1 is major principal stress

σ_2 is minor principal stress

Shear stress exists between 2parts of bodies in contact when the 2 equal opposite and opposite forces exert on each laterally

$$Q=P/A$$

Shear modulus (G) =shear strain / shear stress

Although pure shear is not encountered in concrete structures, an element may be subjected to the simultaneous action of compressive, tensile and shearing stress. Therefore the failure analysis under multi axial stress is carried out from a phenomenological rather than a material standpoint .Although the Coulomb-Mohr theory is not exactly applicable to concrete, the Mohr rupture diagram offers a way of representing the failure under combined stress state from which estimate shear strength can be obtained.

Shear strength may be determined by subjecting the concrete to the three dimensional loading in a trial axial compression test, the concrete is loaded in compression in two directions in right angles; whilst being loaded to failure in third direction. The result of such a test shows that resistance to failure increases as lateral loading increases by about 3 to 4 times , so that concrete which might fail at stress of 6000-7000psi with a lateral loading of 1000psi . The triaxial test measures the basic property of a material; it is difficult to carry out, however, it is easier to measure the strength of concrete by a tensile, flexural or compressive test, the most useful of which is compressive test.

FLEXURAL STRENGTH

Concrete as we know is relatively strong in compression and weak in tension in reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforced bars are provided to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons. Therefore, the knowledge of tensile strength of concrete is of importance.

A concrete road slab is called upon to resist tensile stress from two principal sources wheel loads and volume change in the concrete. Wheel loads may cause high tensile stresses due to bending, when there is an inadequate sub grade support. Volume change, resulting from changes in temperature and moisture, may produce tensile stresses, due to warping and due to the movement of the slab along the sub grade.

Stresses due to volume changes alone may be high. The longitudinal tensile stress in the bottom of the pavement, caused by restraint and temperature warping, frequently amounts to as much as 2.5MPa at certain periods of the year and the corresponding stress in the transverse direction is approximately 0.9MPa These stresses are additive to those produced by wheel loads on unsupported portions of the slab.

FIBER REAINFORCED CONCRETE

The term fiber reinforced concrete (FRC) is defined by ACI Committee 544 as a concrete made of hydraulic cements containing fine or fine and coarse aggregates and discontinuous discrete fibers. Inherently concrete is brittle under tensile loading. Mechanical properties of concrete can be improved by reinforcement with randomly oriented short discrete fibers, which prevent and control initiation, propagation, or coalescence of cracks. FRC can continue to sustain considerable loads even at deflections exceeding fracture deflections of plain concrete. The character and performance of FRC changes depending on matrix properties as well as the fiber material, fiber concentration, fiber geometry, fiber orientation, and fiber distribution FRC can be regarded as a composite material with two phases in which concrete represents the matrix phase and the fiber constitutes the inclusion phase. Volume fraction of fiber inclusion is the most commonly used parameter attributed to the properties of FRC. Fiber count, fiber specific surface area, and fiber spacing are other parameters, which may also be used for this purpose. Another convenient numerical parameter describing a fiber is its aspect ratio, defined as the fiber length divided by its equivalent diameter. It is possible to make several classifications among fiber types. Fibers can be divided into two groups; those with elastic moduli lower than the cement matrix, such as cellulose, nylon, and polypropylene and those with higher elastic moduli such as asbestos, glass, steel, and carbon. Another classification can be made according to the origin of the fiber material such as metallic, polymeric, or natural.

Table 1: Materials and properties of common fibers

Type of Fiber	Tensile Strength (MPa)	Young's Modulus (GPa)	Ultimate Elongation (%)	Specific Gravity
Acrylic	210-420	2.1	25-45	1.1
Asbestos	560-980	84-140	0.6	3.2
Carbon	1800-2600	230-380	0.5	1.9
Glass	1050-3850	70	1.5-3.5	2.5
Nylon	770-840	4.2	16-20	1.1
Polyester	735-875	8.4	11-13	1.4
Polyethylene	700	0.14-0.42	10	0.9
Polypropylene	560-770	3.5	25	0.9
Rayon	420-630	7	10-25	1.5
Rock Wool	490-770	70-119	0.6	2.7
Steel	280-2800	203	0.5-3.5	7.8

LITERATURE REVIEW

N.K. Bairagi and C. D. Modhera (2004) [1] checked the feasibility and reliability of the test method proposed by them with the test method suggested by JSCE method. Results obtained by their proposed method were 10% higher than that of JSCE method. They concluded that by comparing the procedure of test methods and fabrication of test assemblies as well as the test specimen, their proposed method is simpler to handle compared to JSCE method. Different methods used to determine the shear strength using FRC specimens. The shear strength of concrete is the resistance of one layer with respect to other during slip at common surface of contact. There is questioned that two planes failing simultaneously in double shear doesn't happen in reality and hence shear strength calculated in this manner could be said to be erroneous. And there exists no standard reliable and simplified method getting shear strength of concrete specimens using compressive testing machine. During the performance of the test using the arrangement as suggested by Bairagi and Modhera, it was seen that the roller penetrates down in the specimen, not giving the correct picture of the failure. Also the results reported by them were on higher side compared to that of JSCE method in case of fiber reinforced concrete samples.

Banthia, N. & Soleimani, S. M. (2005) [2] Brief information about the development Flexural response of hybrid fiber Reinforced concrete and high-strength concrete with single fibers of either type does not offer a significant improvement in mechanical properties. Hence, in recent years there has been research on hybrid fiber reinforced concrete which incorporates the advantages of both types of fibers in a single matrix. One type of hybridization is to mix stiff and flexible fibers to enhance both the first crack strength and the post-crack toughness. Another type of hybridization is simply based on the geometry of the fibers. In this type there are two possible combinations in different sizes (micro- and macro-fibers) and in different shapes (straight and crimped/deformed).

Sekar, T. (2004) [3] Almost all the studies were concentrated on commercially available fibers in developing countries; Proof that over half of their population is living in slums and villages. The earthquake damage in rural areas is multiplied mainly due to the widely adopted non-engineered constructions. On the other hand, the growth of various industries in developing countries leads to the production of waste materials. These industrial wastes include both metallic and non-metallic materials. Some research has been carried out on industrial waste fibers such as steel lathe waste.

Takashi Horiguchi et al (1997) [12]has studied the fracture toughness of fiber reinforced concrete in compression as well as in flexure and has used four different types of steel fiber with two types of polyvinyl alcohol (PVA). Hybrid effects of fracture toughness in compression as well as in flexure were investigated by mixing the steel and PVA fiber. The different types of fiber used in the study were steel fiber reinforced concrete (SFRC), PVA fiber reinforced concrete (VFRC) and hybrid fiber reinforced concrete (HFRC).

OBJECTIVE OF THE STUDY

The benefits of using mineral admixtures in cement are fairly established. They offer benefits with respect to the cost of manufacturing of cement because fly ash and silica fumes are by-products or waste materials replacing a part of OPC, hence fewer primary energy and raw materials are required in production of low cost concrete. This leads to more efforts towards the use of waste materials with lower environmental impact. The aim of the project is to estimate the shear strength of high strength steel fiber reinforced concrete using shear test 'L' specimen.

(1) To estimate the shear strength of concrete, using the shear, impact and flexural strength tests specimen for three different grades of concrete viz. M20, M25 and M30 grade with steel fibers added to concrete in different proportions i.e. 0%, 0.5%, 1.0%, 1.5% and 2.0% with water cement ratio of 0.42.

(2) The experimental investigation has to be conducted on steel fiber reinforced concrete using shear test 'L' specimen.

(3) Three different types of fibers to be used in the experimental investigation Straight, Crimped and hooked end steel fiber of length 50 mm and an aspect ratio equal to 50.

CONCREATE MIX DESIGN

Table 2: Mix proportion for M20 Grade Concrete

Water		Cement		Fine agg.		Coarse agg.
191.58 lit		426kg		583kg		1158kg
0.45	:	1	:	1.37	:	2.71

Hence the Mix is 1:1.37:2.71 (Designed for M20)

Similarly for M25 & M30 the mix proportions are as follows:

Table 3: Mix proportion for M25 Grade Concrete

Water		Cement		Fine agg.		Coarse agg.
182.25 lit		405kg		515kg		1028.7kg
0.45	:	1	:	1.274	:	2.54

Table 4: Mix proportion for M30 Grade Concrete

Water		Cement		Fine agg.		Coarse agg.
160 lit		380kg		437kg		855kg
0.42	:	1	:	1.15	:	2.25

EXPERIMENTAL INVESTIGATION

COMPRESSIVE STRENGTH TEST

The compression tests on cubes were conducted according to Indian Standard specifications (IS: 516 – 1959). The compressive strength data of cement based matrixes (table below), indicate that the fibers have negative effects of cement based matrixes; the presence of one fiber type was observed to reduce or eliminate the negative effects of the other one on compressive strength Francois de Garrard et al (1997) has presented a comprehensive theory describing the influence of aggregate on the compressive strength of concrete. The distinction of the aggregate is made between the topological and mechanical aspects. The topological effect also called as confining effect, includes the effect of the volume and the maximum size of the aggregate, which are described by means of a single physical parameter, the maximum paste thickness (MPT). MPT is defined as mean distance between two adjacent coarse aggregates. The second type of effect concerns the bond between paste and aggregate (bond effect), and a limitation of the strength that originates in the intrinsic strength of the rock. The aim of the research is to understand the role of aggregate in the compressive strength of structural concrete, from which semi-empirical mathematical models can be derived and incorporated in software for computer aided mix design and quality control. It has been concluded that the paste has a certain compressive strength, depending on mixture proportioning parameters (W/C ratio), time and curing regime.

Figure 2: Compressive Strength of cube

SHEAR STRENGTH TEST

So far, mechanical strength properties represented the compressive and tensile strength of concrete only. No much work on shear strength of concrete has been reported by researchers. But fiber reinforced concrete possesses significant improvement in shear strength (Baruah and Talukdar 2007). Bairagi et al (2001) proposed a method to determine the shear strength of fiber reinforced concrete.

Based on the literature, L-shaped shear test specimens were prepared from 150 mm cubes by inserting a wooden block of 90 mm 60 mm in cross section and 150 mm high into the cube moulds before casting of concrete. The details of the shear test specimen are shown in Figures 10 and 11. All the test specimens were cast and cured for 28 days. The loading arrangement for shear test is shown in Figure 12. The specimens were placed on compression testing machine. A 150*85*10 mm size MS plate was placed on left side portion of 90 mm face. Mild steel bar of 12 mm diameter was placed over the centre of the plate. Another MS bar of 22 mm diameter was placed at the edge of the plate. Over these bars, another MS plate of size 150*110*10 mm was placed. Load was applied on the top plate which forms shear plane below the centre of 22 mm diameter bar. The loading was continued until the specimen failure. The shear strength was obtained using

$$f_s = \frac{P}{A}$$

Where

fs – Shear strength

P – Applied compression load

A – Shearing area

Figure.3: Shear Test on ‘L’ Specimen

IMPACT STRENGTH TEST

Impact strength is of importance when concrete is subjected to repeated falling object, as pile driving, or a single impact of a large mass at a high velocity. The principal criteria are the ability of the specimen to with stand the high blows. It is interesting to point out that impact strength of concrete increases greatly with the rate at which impact stress is applied. It is generally assumed that the impact strength is directly related to compressive strength, since both are adversely affected by the micro cracks and voids. This assumption is not completely correct; it is found for the same compressive strength increased substantially with angularity and surface roughness of coarse aggregate. In general the impact strength of concrete increases with compressive strength, but the higher the static compressive strength of concrete the lower the energy, energy absorbed per blow before cracking.

Figure.4: Impact strength Specimen

FLEXURAL STRENGTH

Concrete as we know is relatively strong in compression and weak in tension in reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforced bars are provided to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons. Therefore, the knowledge of tensile strength of concrete is of importance. A concrete road slab is called upon to resist tensile stress from two principal sources wheel loads and volume change in the concrete. Wheel loads may cause high tensile stresses due to bending, when there is an inadequate sub grade support. Volume change, resulting from changes in temperature and moisture, may produce tensile stresses, due to warping and due to the movement of the slab along the sub grade. Stresses due to volume changes alone may be high. The longitudinal tensile stress in the bottom of the pavement caused by restraint and temperature warping, frequently amounts to as much as 2.5MPa at certain periods of the year and the corresponding stress in the transverse direction is approximately 0.9 MPa. These stresses are additive to those produced by wheel loads on unsupported portions of the slab.

Modulus of rupture Fb = Pl/bd2 (2)

Where,

b = measured width in cm of the specimen,

d = measured depth in cm of the specimen at the point of failure,

l = length in cm of the span on which the specimen was supported, and

P = maximum load in N applied to the specimen

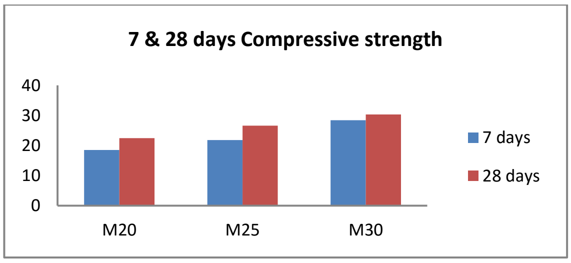
Test Set Up

Tests were carried out at room temperature. Structural properties are ascertained by conducting middle third loading test. The testing arrangement is shown in Figures 21 AND 22 was applied on steel fiber concrete beams of beam span 0.5m through hydraulic jack of capacity 50 KN. The specimens were placed on a simply supported arrangement of 100 T Loading frame. The beams were suitably instrumented for measuring deflections at several locations including the mid span deflection with dial gauges and LVDTs. To avoid the excessive deformation at the support locations, additional dial gauges were placed at the top and bottom face of ends. DEMEC (demountable mechanical strain gauge) was used to measure the concrete strain readings at top as well as the bottom fiber on mid-section of the beam.

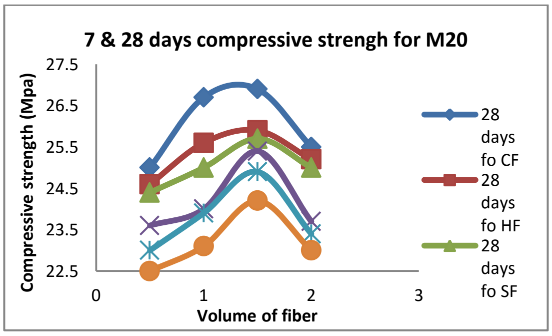
Figure.5: Loading Arrangement of Flexural Test

TEST RESULTS

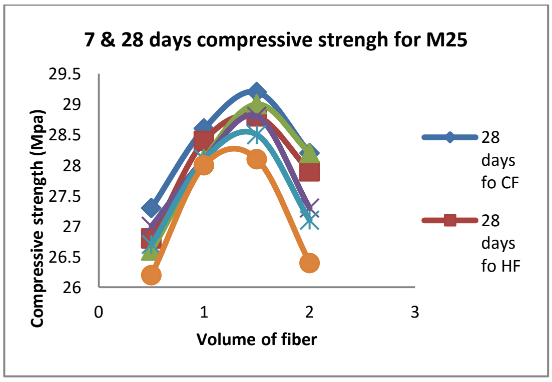
Test results of Compressive strength for M20, M25 and M30



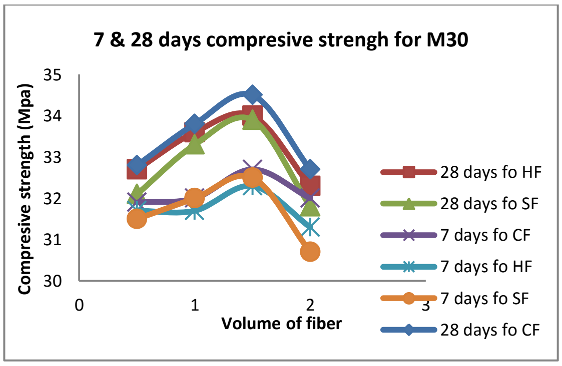
Test results of Compressive strength with fibers for M20



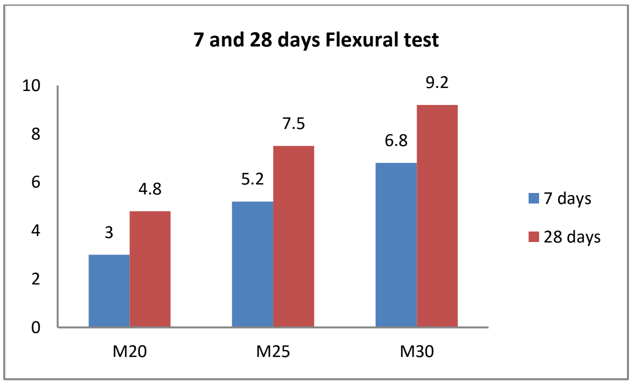
Test results of Compressive strength with fibers for M25



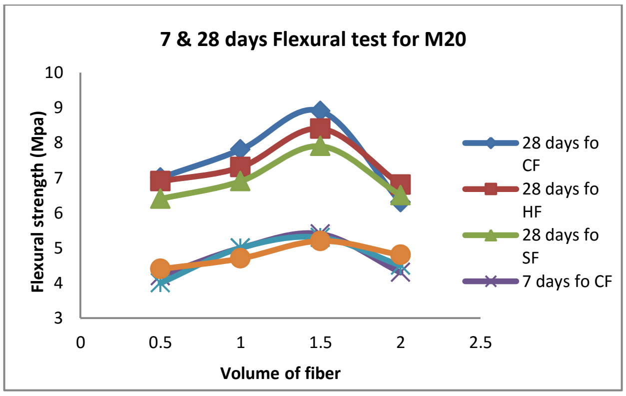
Test results of Compressive strength with fibers for M30



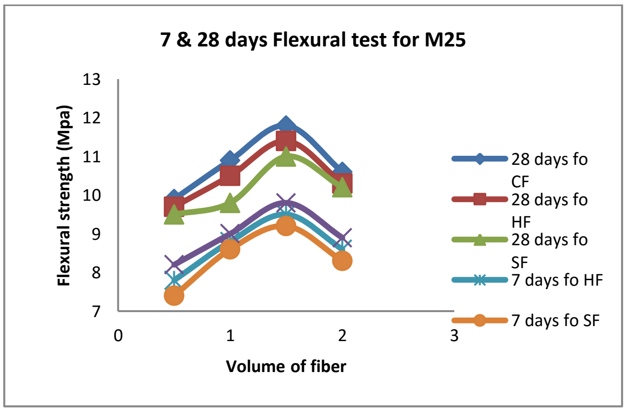
Test results of Flexural test for M20, M25 and M30



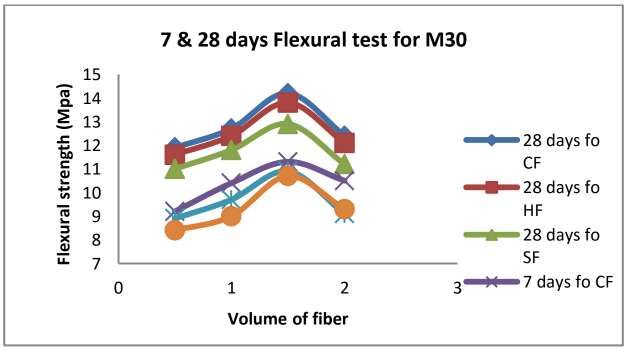
Test results of Flexural test with fibers for M20



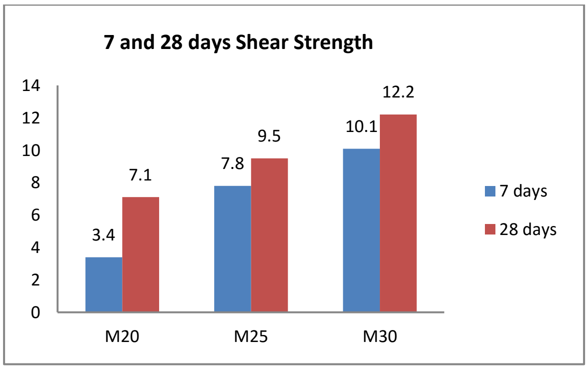
Test results of Flexural test with fibers for M25



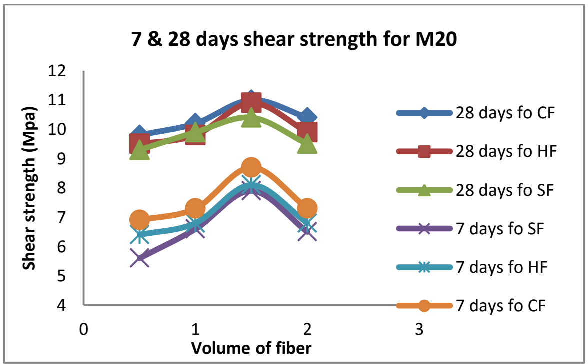
Test results of Flexural test with fibers for M30



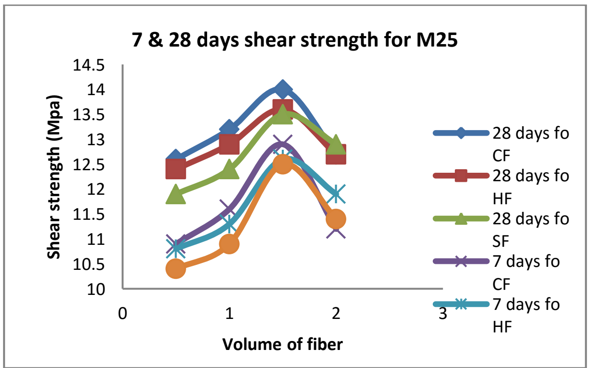
Test results of Shear Strength for M20, M25 and M30



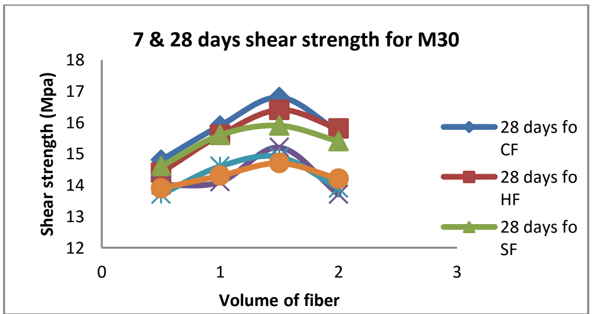
Test results of Shear strength with fibers for M20



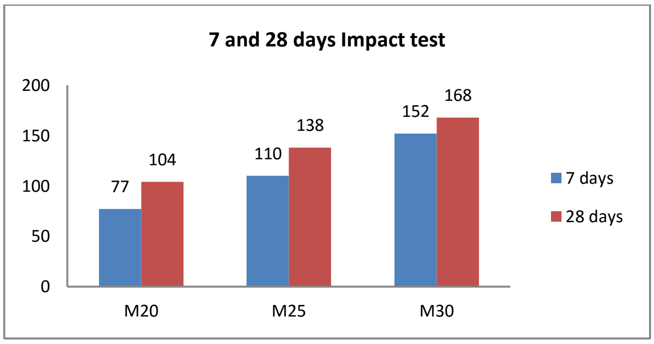
Test results of Shear strength with fibers for M25



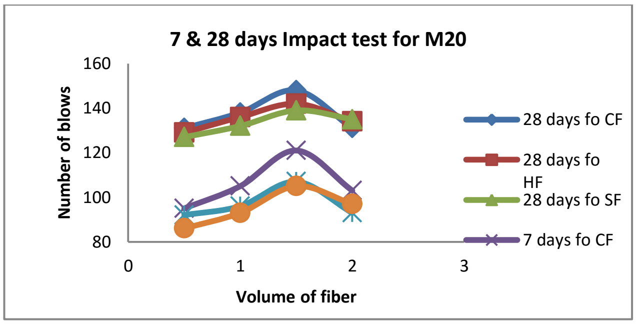
Test results of Shear strength with fibers for M30



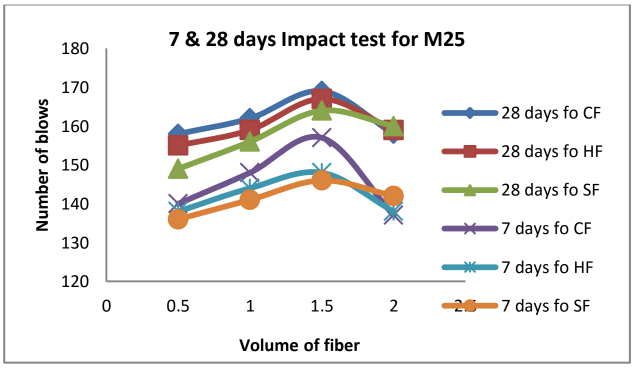
Test results of Impact test for M20, M25 and M30



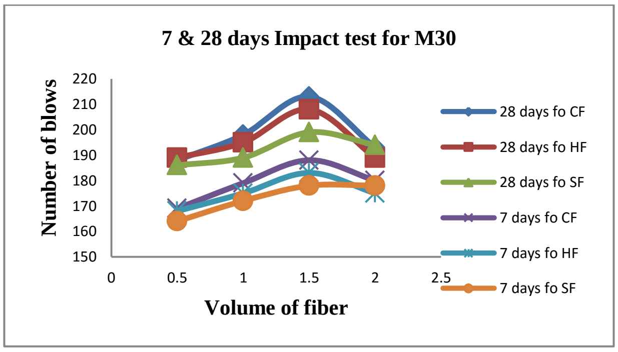
Test results of Impact test with fibers for M20



Test results of Impact test with fibers for M25



Test results of Impact test with fibers for M30



CONCLUSIONS

1 Maximum shear strength obtained in Straight Fibers, Hooked Fibers and Crimped Fibers is quite high than ordinary concrete However, results of Straight Fibers, Hooked Fibers and Crimped Fibers are much scattered as most of

the specimens failed by fracture control after a formation of first crack, steel fibers being very strong and stiff in shear make it possible to resist large amount of load if fibers are available in the resisting plane.

2 Due to presence of fibers, ductile failure is observed .In fact crack get arrested by fibers does not get fractured but pulling out of fibers from matrix is observed.

3 In compressive strength, the strength was observed and it is more than 1.37 times than conventional concrete.

4 In the flexural strength aspect we observed the incremental change, which is 1.6617 times more than the conventional concrete.

5 In shear strength aspect we observed the drastically incremental change, which is 1.9411 times more than the actual conventional concrete.

6 In impact strength, the strength was observed and it is more than 1.5714 times than conventional concrete.

7 By adding 1.5% of straight, hooked and crimped fibers to the concrete, the compressive, flexural, impact and shear strength is increased.

8 By this project we can able to convert the waste materials in to useful building materials.

9 As an Engineer it is our duty that to convert waste products into useful building, products to introduce the innovative ways in construction field.

10 As a Civil Engineer we have construct the constructions with most economically and with high strength.

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