Impact Energy Assessment of Steel Fibre Reinforced Concrete

Project report submitted in partial fulfilment of the requirement for the degree of Bachelor of Technology

in

Civil Engineering

by

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Student's Declaration

We hereby certify that the work which is being presented in the thesis entitled "**Impact Energy Assessment of Steel Fibre Reinforced Concrete**" in fulfilment of the requirements for the award of the degree of Bachelor of Technology under Jaypee University of information Technology, Waknaghat is an authentic record of our own work carried out during the session 2018-19 under the supervision of Dr Pankaj Kumar. The matter embodied in this thesis has not been submitted by us for the award of any degree of this or any other University/Institute.

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Certificate

We hereby declare that the work presented in this report entitled **"Impact Energy Assessment of Steel Fibre Reinforced Concrete"** in fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Civil Engineering** submitted in the Department of Civil Engineering**,** Jaypee University of Information Technology, Waknaghat is an authentic record of my own work under the supervision of **Dr Pankaj Kumar, Assistant Professor,** Department of Civil Engineering. The matter embodied in the report has not been submitted for the award of any other degree or diploma.

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This is to certify that the above statement made by the candidates is true to the best of my knowledge.

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Abstract

A structural system is exposed to various types of loading conditions during its whole life span. Reinforced concrete and plane concrete are the most suitable materials used to construct any structural system owing to their inherent properties. Mechanical property such as high compressive strength makes it usable for static compressive loading, but these properties can't be used to anticipate the failure of concrete when exposed to extreme loadings. The study focuses on behaviour of normal concrete as well as performance of fibre reinforced concrete having various percentage of steel fibre, under static loading and impact loading. Initially, the performance of steel fibre reinforced concrete performance has been examined under traditional concrete tests such as compressive strength test and flexural strength test. In addition, the drop weight impact test has been carried out on standard specimens to assess the performance of normal as well as steel fibre reinforced concrete. The test results demonstrate that the impact resistance of fibre reinforced concrete is enormously improved by including steel fibres. It has also evident that with higher volume expansion of what, a more noteworthy improvement of impact resistance has been accomplished.

Key words*: Steel fibre, Fibre reinforced concrete, Drop weight impact energy, Impact resistance.*

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List of Abbreviations

Ø	Diameter
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
FRC	Fibre Reinforced Concrete
FST	Final Setting Time
GFRC	Glass Fibre Reinforced Concrete
IST	Initial Setting Time
JSCE	Japan Society of Civil Engineers
NFRC	Natural Fibre Reinforced Concrete
SFRC	Steel Fibre Reinforced Concrete
SNFRC	Synthetic Fibre Reinforced Concrete
SFLWC	Steel Fibre Light Weight Concrete

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Chapter 1
Introduction

1.1 General

A structural engineer is required to predict the nature, duration and magnitude of loading on a structure. On the other hand he is also required to know the properties of materials he is working with.

Concrete is considered a brittle material. Although concrete has a very high compressive strength, it do lack behind when it comes to tensile strength. Over the years researchers have tried different additives, so as to improve the tensile strength of the concrete. The involvement of fibres in specimen, mortar and cement paste can improve a large number of the building properties of these materials, for example, crack durability, flexural quality, fatigue resistance, impact resistance. Elastic, flexure and ductile nature will increase in every aspect because of the addition of steel fibre.

There are number of types of loading to which a structure can be subjected. Loadings can be divided broadly into two categories dead load or quasi-static loads and suddenly applied load. These are generally referred to as static loading and dynamic loading, respectively. Load predictions for static conditions are fairly straightforward and do not pose any particular problem. As in the cases of dynamic types of loading, the accurate divination of loads and its variations with time can be fairly obtained. Dynamic loading itself can be subdivided into two class, single cycle and multi cycle. A case of single cycle dynamic loading is mass affecting against an auxiliary component. In any case, a structure experiencing a tremor would have its component exposed to multi-cycle dynamic loading. Single cycle dynamic loading is also called impact loading.

There are, further, two fundamental sorts of impact loading: single point impact loading and conveyed impact loading. A structure hit by rocket like item would experience a solitary point impact, while impacts or blasts would result in circulated impact load. The present work is concerned basically with single point impact loading. The size and mass of the affecting body are significant in a impact circumstance

Three particular circumstances can emerge:

• An exceptionally substantial object struck by a small impacting mass.

• An impact including equivalent masses.

• A little object struck by a large impacting mass.

While the third case is comparatively uncommon, the first and second cases are frequently experienced. In the primary case, as a result of the mass and size of the affected object impact is constrained fundamentally to the contact zone. In the instance of equivalent masses, the reaction of the affected mass is administered by shear and bending and a relatively large portion of impacted mass reacts to the impact.

Of all the major materials of construction used today, the behaviour of concrete under high rate of loading is the least understood. The inherently brittle nature of plain concrete, its extreme weakness in tension, and its heterogeneous structure are some of the reasons for its markedly low impact strength. Its' lack of toughness and tensile strength have meant that it is almost used in conjunction with conventional steel reinforcement. But the discovery of Fibre Reinforced Concrete (FRC) and FRC's greatly improved impact resistance over plain concrete, have triggered an interests in understanding the impact performance of both FRC and plain concrete.

With present design trends there are two reasons for the incorporation of fibres in cementations matrices: first, since the impact resistance of these components is higher they can withstand occasional shocks or over loadings without excessive damage. Secondly, the behaviour of FRC under load, which is characterized by large post-elastic deformations, means that failure if it occurs at all, generally does so only after sufficient warning.

1.2 Conventional Concrete

In the nominal concrete it is found that the cement have the tensile strength between (8%-15%) of its nominal compressive performance. Conventional concrete is the simple form of concrete with good compressive strength and less tensile strength, conventional concrete is way different in the other form of steel fibre reinforced concrete. The adding of additives is driving a great results in the ductile nature. In a segment, the ties opposes the shears, while the vertical bars oppose clasping stress and pressure, and give restriction to vertical bars. Just to make the nominal concrete more crack proof the additives like fibre will be added up to improve the load imparting capacity. Possibility of appearing of cracks will be very normal and then these cracks will get wider and finally the breaking stage will appear. In this way requirement for multidirectional and firmly dispersed steel reinforcement emerges.

1.3 Concrete Containing Fibres

Concrete containing fibres are also known as the fibre reinforced concrete and there are various types of fibres which are added up as an additive. Steel Fibre Reinforced Concrete (SFRC) is way different from the conventional concrete, these are the orientation and other things. In the orientation the fibre containing concrete structure be like 3-D oriented structure and all the fibres have the won shape in the 3-D structure while on the other hand the convention concrete doesn't have this type of any shape. Steel fibre can be added in the various percentages these are (0.5%, 1%,1.5%, and 2%) these are the various percentages in which we can add steel fibre in the concrete which is with the binder ratio as well. Starting percentage may give better strength than other high percentage because in the higher percentages the workability may reduce up to a great extent so that's why casting can be improper and we may not get accurate results.

Figure 1.1 Steel fibre of length 30 mm and diameter 0.5 mm.

1.4 Fibre Mechanism

The mechanism of fibre in the concrete containing steel fibres are that firstly, it provides the ductile nature in the concrete which is nominally brittle in nature. Basically, the fibre reduces the tension cracks in the concrete which ultimately deforms the structure in the last. The fibres in the structure reduces the cracking possibility which means that it reduces the micro-crack, which is the main reason for ultimate failure in small amount, micro-cracks will leads to the macro-cracking and the structure will easily loose its tension strength.

Fibres works until its pull out strength will be greater than the whole matrix. Mechanism tells us about, that if the pull out resistance of matrix is less than the fibre, then all loads will be carried by the fibres rather than the matrix.

Fibres containing concrete will also improve the energy absorption capacity in the concrete. Its impact bearing capacity will also increase up to mark because the fibre containing body imparts to carry more load than the nominal one, the energy is getting involved in such a manner that whole body containing matrix and fibres will acts as a single body and carry, more impact load than nominal. Even we can calculate it by certain methods of energy absorption. It also increases its durability, flexibility and toughness which is again even more than the nominal concrete.

1.5 Traits and Benefits of Steel Fibre Reinforced Concrete

There are several benefits of SFRC such as Elimination of fabrication, Elimination of extra work and labour. Also cycle time is reduced, resulting in increased percentages of production. It is also helpful in carrying heavy and sudden imparted loads. Brittleness is removed by fibres by certain extent, that’s why durability will increase. It saves our time by handling, manufacturing, transport and positioning or by the removal of bearing. No Impact to fixing because of support. Excellent erosion obstruction, spalling is completely rejected. Excellent break control, the fibres control and disperse the splits. The strands offer protection from tractable worries anytime in the shotcrete layer highly useful in industrial purposes for making a proper base at which the heavy machines are equipped. It makes the surface unscratchable and tough. It also makes the specimen containing Impact resistance properties.

1.6 Applications of Steel Fibre Reinforced Concrete

Steel fibre containing cement has increased across the board use in applications, for samples, the accompanying:

• Rock slant adjustment and backing of unearthed establishments, regularly related to move upward or downward and soil grapple frameworks.

• Industrial floor materials, street asphalts, distribution centres, foundation pieces.

• Channel linings, secure extension projections.

• Useful in salty type of water.

• Useful in yards and station (light).

- Useful in industries to carry more heavy equipment’s.
- It strengthens the structure to carry loads in every aspect like sudden load condition.
- Support of underground openings in passages and mines.

Chapter 2
Literature Review

2.1 General

In this chapter, a detailed analysis is made about works done till date in this field as literature review. The fibre reinforced concrete with different amount of fibres and their behavioural analysis are discussed in the beginning. Working on impact tests are discussed in the later part of the chapter.

2.2 History and Development

The idea of utilizing fibres in matrix was first recorded with the antiquated Egyptians who utilized the hair of creatures and straw as reinforcement for mud blocks and dividers in lodging. This goes back to 1500 B.C. as indicated by *Balaguru et al, (1992).*

Zollo (1997) introduced an outline in regards to the history and advancement of Fibre Reinforced Concrete *30* years back. As indicated by this report, in the mid *1960s*, the works at fibre reinforced concrete had begun. A great deal of research work has been directed by numerous scientists on various styles. In any case, these tasks have learned about steel fibres alone. Up until now, there were just a couple of works which have contemplated different fibres like plastic, nylon, elastic and common fibres. In any case, those inquires about are totally unique in relation to the present investigation, since they have thought along the material quality properties not on their structural conduct.

As indicated by the wording received by *ACI Committee 544 (1999)*, Fibre reinforced concrete to be specified under four categories namely 1) Synthetic fibre reinforced concrete (SNFRC) , 2) Steel Fibre Reinforced Concrete (SFRC) , 3) Natural fibre reinforced concrete (NFRC) and 4) Glass fibre reinforced concrete (GFRC). It additionally gives the data about different mechanical properties and structure applications. Cement and Concrete Institute likewise distributed the classification of FRC in their site. In view of their characterization, Fibres are arranged into Glass, Steel, Synthetic (incorporates, Polyester, Carbon, Aramid, Nylon, Polyethylene, Acrylic, Polypropylene), and Natural Fibres.

2.3 Mechanical Properties

Kukreja et al. (1980) led a few analyses and announced that, in view of the consequences of three techniques, for samples, flexural test, direct tensile test and, split strain test, tensile (split) test was suggested for fibrous concrete. Likewise increment in post cracking strength and tensile strength, toughness were also documented.

Analysts like *Goash et al (1989)* examined tensile strength of steel fibre reinforced concrete and narrowed the consideration for report that with an addition of ideal short steel fibres increments the tensile strength of concrete even when, added in low faction of volume. Ideal aspect ratio of the proportion was found as *80* and the greatest increment in tensile strength was recorded as *33.14%* at a fibre mix *of 0.7%* by fraction of volume. Additionally it was also accounted that cylinder split tensile strength provided more uniform and consistent outcomes than provided by the direct tension and rupture test.

Sabapathi and Achyutha (1989) developed stress-strain attributes of steel fibre reinforced concrete when placed under compressive test. Initial tangent modulus and cube compressive strength were collected and an equation for stress-strain relation was developed. It was also proposed that distribution and orientation of fibres in FRC siginificantly affects the property of FRC.

In view of their idea, *Soroushian and Lee (1990)* completed some examination, by checking the quantity of fibres in a unit cross sectional territory of SFRC samples incorporating different volume fractions of various fibres. Hypothetical articulations were determined for the quantity of fibres per cross sectional region in fibre reinforce concrete as a component of length and volume fraction, as the main variables. The cross sectional boundaries were the only factor considered in distribution of fibres in 3-D random orientation. Comparisons were also made between the number of fibres and the reorientation fibres due to vibrations in concrete. To learn the tensile strength of the fibre reinforced concrete, a basic test set up was made to replace direct tensile apparatus as proposed by *Wang et al (1990)* as the equipment was costly. Testing procedure and methodology were given.

Ramana Murthy and Ganesan (1990) determined the stress-strain conduct of short, confined, reinforced concrete section with and without the addition of steel fibres. In tis experiment the volume proportion was taken as *1.5%* with an aspect ratio of *70* for steel fibres. The variable factor of the investigation was percentage reinforcement among lateral reinforcement.

Soroushian and Bayasi (1992) discovered that rheological property of SFRC is noteworthy. interlocking properties and Substantial surface area and of fibres leads to development of the balls during the concrete mixing which creates damage to hardened properties of the material. A test examination was directed so as to consider the fresh properties of concrete with addition of different amount of steel fibres. Conclusions were made that concrete workability property of FRC were no doubt affected by the fibre reinforcing index. At particular fibre reinforcing index, plain fibres performed slightly lower than crimped fibres.

Shah and Balaguru (1992) reported that fibres which are long and have higher volume fraction tends to ball together in mixing procedure. The procedure is referred as 'balling' happens to make the concrete stiff and also show reduction in workability of concrete with increment in the volume measurements of the fibres, which ultimately Impacts the quality and strength of the concrete.

Ashour and Wafa (1992) studied high strength FRC and their properties. They made and tested *504* test samples for various mechanical properties, as for example, compressive strength, flexural toughness, split tensile strength and also modulus of rupture. The mix was intended to accomplish compressive strength *of 94 N/mm2*. Three volume samples of steel fibres, *0.5%, 1.0% and 1.5%* were casted. It was reported that no genuine workability issues were experienced up to addition of *1.5%* volume fractions of fibres in the concrete. It was also reported that steel fibre improved ductility and post cracking load capacity of high strength concrete. Some observational conclusions were proposed among the volume fraction and compressive strength of conventional plain concrete.

Zeng and Bayasi (1993) led a few investigations on workability and mechanical strength property. Fibres (polypropylene) having length of *¼ and ½ inch* were taken at 3 volume fractions(V_f), *0.3%, 0.1%, and 0.5%* were used for concrete and workabilty properties, such as slump, air content and inverted slump cone.

Nataraja et al. (1998) did an investigation on SFRC under compressive loadings. Here the conduct of SFRC under compressive loadings for cylinder compression strength varied from *30 to 50* N/mm^2. Round crimped fibres with three different volume fractions(V_f) of *0.5 %, 0.75 %, and 1.0 %* were taken, also *2* aspect ratio of *55 and 82* are considered. It was also concluded that with the addition of fibre there was an increase in toughness and compressive strength.. It was reasoned that the expansion of strands expanded the compressive quality and durability. Empirical equation was proposed for compressive strength in terms of fibre reinforcing index.

Asteyate and Haddad (2001) found a fascinating way of foreseeing the job of synthetic fibre, for examples, nylon fibres and polypropylene in postponing corrosion cracks in steel and improving its blend with concrete. Different length of nylon fibres and polypropylene fibre with variation in volume were blended with concrete. Corrosion study and pull out test inferred that both the fibres contribute to delay corrosion and improve the bond strength. In addition it also pointed that the nylon fibres play less significant job than polypropylene fibres in improvement of the blend.

Kaushik and Mohammadi (2003) researched on Impact of mixed aspect ratios of fibre on mechanical property of concrete. *25mm -50mm* crimped steel fibre were mixed in different ratios with concrete and were tested for compressive and flexural tests. Compressive and flexural strength was acquired from test outcomes. It was discovered that *65* percent of long fibre and *35* percent of short fibre provided the ideal composite property in comparison with other mix. A significant note likewise was given in that writing that utilization of mixed aspect ratio of fibre had no apparent effect on static modulus of elasticity.

Yao et al. (2003) analysed the mechanical behaviour of hybrid FRC at a low fibre volume fraction (V_f). 3 hybrid composites, carbon and steel, polypropylene and steel, carbon and polypropylene fibre were picked and their mechanical strength such as split tensile strength, flexural toughness, compressive strength and modulus of rupture were calculated.

Ramasamy and Thomas (2007) did experimental examinations on mechanical properties of SFRC. 3 distinct strengths, normal strength (*35 MPa*), moderate strength (*65 MPa*) and high strength *(85 MPa*) concrete mixtures were chosen for this investigation.
30 mm long steel fibre (*aspect ratio 55)* with three distinctive volume fraction (V_f), *0.5%, 1.0% and 1.5%* were chosen and uniformly disseminated in mixture. Split tensile strength, flexural toughness, compressive strength, modulus of rupture and Poisson's ratio were contemplated. *60* test information relapse investigation was done and experimental relations were given, in view of the test consequences of *320* samples of mechanical quality properties of high strength FRC.

Sundararajan and Premalatha (2007) recommended that no noteworthy increment in compressive quality was gained past *1.5%* addition of volume fraction of steel fibre. Concrete mixture was intended to accomplish *60* N/mm^2 strength (high strength concrete) and its strengthening properties like Split tensile strength, flexural toughness, compressive strength and modulus of rupture were contemplated and observational relations were additionally found as far as *Fibre Reinforcing Index (FRI).*

The Impacts of aspect ratios and volume fraction of steel fibres on the mechanical property of SFRC was examined by *Yazici et al. (2007)*. 3 aspect ratio (l/d) of *45, 65, 80* and 3 volume fraction(V_f) *of 0.5%, 1.0%, 1.5%* hooked end packaged fibre were picked in the review. It demonstrated that an increment in the aspect ratio resulted in the workability. Also in compressive strength, *4-19%* increment, in split tensile test *11-54%* increment and in flexura test *3-18%* increment were recorded.

2.4 Fibre Reinforced Concrete Beams under Static Loading

Sukontasukkul et al. (2004) directed an exploratory examination on toughnesss of steel and polypropylene fibre reinforced solid beam under bending utilizing two unique techniques, for example, *ASTM C1018 (1997)* and *JSCE SF-4 (1994).* The conduct of SFRC demonstrated single peak response though polypropylene fibre reinforce concrete double peak response should twofold crest reaction. The deformation under two strategies was set side by side.

A similar report had been led by *Ramaswamy and Padmarajaiah (2004)* on flexural loading on steel fibre reinforce high quality concrete in partially and completely pre-stressed beam samples. It was discovered that the ductility and toughness of pre-stressed high strength solid concrete beams have increment with increase of fibre content. The greatest increment in ductility was *18% - 68%* and rate increment in energy absorption was *25% - 88%* for completely pre-stressed beam.

Exploratory examination and Analytical displaying for flexural conduct of fibrous reinforced concrete solid beams utilizing synthetic fibres were performed by *Suji et al. (2006)*. Reviewed fibrillated polypropylene fibres were utilized in this examination. 1.8 metre long rectangular reinforced solid beam was cast with and without fibres at various volume divisions of *0.1%, 0.2%, and 0.3%*. Moment carrying capacity of solid beams were calculated and compared with equations. Additionally it was also proposed that the crack patterns continued as before for all specimens, however the crack width and length were diminished for fibre reinforce solid concrete beams.

Ganesan et al. (2006) conducted tests to calculate the ultimate strength of steel fibre reinforced self-compacting beams. *1.2* m reinforced concrete beams were made using self-compacting concrete mixture with addition of steel fibres at three volume fractions (V_f) of *0.25%, 0.5% and 0.75%*. It was discovered that ductility and strength of fibre reinforce self-compacting concrete solid specimens have expanded significantly over regular concrete.

Ramasamy and Thomas (2006), they researched on partially pre stressed T beams. With addition of steel fibres in complete and partial form they also developed the performance graph of load vs. deflection. They made three concrete mixtures *M 35*, *M 65 and M 85* which were mixed with steel fibre at a volume portion of *1.5* percent. *3.85* m long T-beams having span of *3.6 m* (simply supported) prestressed with *7 mm* wires were tested for 2 point bending. Expository models were proposed for calculation of load-deflection and moment curvature. The correlations were made between the trial and systematic outcomes.

Same creators, *Ramasamy and Thomas (2006)* announced the subtleties of finite element displaying and examination of some shear critical pre-stressed steel fibre reinforced solid concrete beams. An industrially accessible finite element software *ANSYS (Release 11.0, Ansys Inc, USA)* was utilized to examine the beams. The solid beams were modelled using *SOLID 65 (2003*) - an eight hub block model, which is fit for recreating the crushing conduct of brittle materials. The reinforcement was modelled utilizing the *LINK 8(1998)* - a 3D component.

2.5 Impact Resistance

The ability to absorb energy is known as toughness which is significant in genuine service condition of a structure. Due to that reason, an experiment was carried out by *Sundararajan and Ramakrishna (2005)* on Impact resistance of a couple natural fibres reinforced concrete slabs. Four sorts of fibre, like hibiscus cannebinus, coir, jute and sisal, with 4 diverse volume fraction (V_f), *0.5%, 1.0%, 1.5% and 2.0%* by weight of binder were utilized. Various tests were completed utilizing repeated projectile test apparatus and performance of samples was calculated on the basis of parameters such as Impact resistance, crack resistance ratio, residual Impact ratio. In conclusion it was found that coir fibre absorb maximum energy, *253.5 J* at *2 percent* volume fraction.

Tam and Ravindrarajah (1984) utilized *Ø 0.5 × 50 mm* hooked end fibre with fibre content *1.5* percentage to cast *200 × 400 × 1,020 mm* SFRC beams in flexural tests.

It was discovered that the steel fibre support in concrete will increment the ultimate strength capacity of solid concrete beam more than first crack strength, in flexure.

Indubhushan and Qian (1999), they used expanded end steel fibre with various aspect ratios from *38 - 46* which were blended to cast *120 × 150 × 2,000 mm* SFRC beam with *1 %* fibre addition. According to the researchers the fibre addition may increment the flexural rigidity of strengthened high strength solid beam before yielding, it may also increase displacement at failure and decrease the quantity and sizes of cracks.

Mitchell and Abrishami (1997) casted *95 × 170 × 1,500 mm* samples with rebar to test tensile strength. The materials were normal and high strength concrete with and without addition of *1 percent* fibre. The fibres were hooked end having *30 mm* length and *0.5 mm* diameter, thus making an aspect ratio equivalent to *60*. Conclusions were made, steel fibre gives phenomenal commitments to the control to cracks and post crack energy absorption.

Ashour and Wafa (2000) casted *504* samples to investigate the mechanical property of high strength SFRC with adding *Ø0.8 × 60 mm* hooked end steel fibre. Fibre content ranged from *0-1.5 %* by total volume. Cylindrical samples with measurement *Ø150 × 300 mm* were used in part pliable tested for split tensile tests, further *100 × 100 × 350 mm* beams were casted for flexure test. In conclusion the fibre addition increased the ductility, post crack load carrying strength and also the toughness of beams.

Reinhardt and Kormeling (1987) used steel fibre of dimensions *Ø0.4 × 25 mm* in the SFRC mix and assessed *Ø74 × 100 mm* samples for direct tension with rate of loading up to *20/s*. SFRC samples were casted with *1.5 and 3.0 percent* fibre. It was discovered that FRC had a fracture energy upto *100* times more compared to that of plain concrete.

Holschemacher et al. (2010) found that SFRC beam with high strength steel fibre showed better post peak ductility and residual strength compared to normal strength fibre, also the debonding of the fibres from the bond network was the essential for Impact mode. The result was consistent from the observations with the experimental studies that thought about three sorts of polymer fibre and straight flat finished steel fibre, in which it was discovered that under low Impact load, pull out of steel fibre pre dominant failure mode.

2.6 Impact Energy Assessment

Our present knowledge, and consequently our design practice as such, are still at least partly empirical in nature. For better understanding of the reactions the imparted structures to the external Impact load, nothing can be said with assurance. The stress distribution in an Impacted mass of plain concrete or fibre reinforced concrete is far from simple, due mainly to the unrelated internal structure, the irregular distribution of strains, the steep strain gradients, and the poorly defined factor interface between the cement and the aggregates. It is also worth noting that in many instances a correct estimation of the external load and its variation with time is also not possible. The input load function, which among other things depends upon the precise manner in which the Impacted body absorbs the incident energy and on the relative masses of the bodies colliding, forms an important area of study. The input in the form of the external load function and the output, in the form of the structural response, are thus highly interdependent. *Struck and Voggenreiter (1975)* have cited samples of Impact and impulsive loading that may possibly occur in practice and the consequences that may follow. They have also described the problems associated with the evaluation of the Impact response of structures. In the case of Impact loading, the response of the structure can be divided into two types: local response and overall response.

Depending on the relative masses of the Impacted and the Impacting bodies, the overall structural response may or may not be significant. The case of a very small object hitting a very large mass, which is particularly interesting from the military point of view, is a case in which the local response is critical.

Possibly the first experimental study was that of *Abrams (1917),* who subjected concrete cylinders to Impact compression loading and observed an increase in the Impact strength over the static strength. Abrams also observed that the rate at which the first *88%* of the ultimate load was applied did not have any effect on the compressive strength.

Green used the various type of cement, the type of coarse aggregate, shape of the coarse aggregate, curing conditions, sand grading, mix proportion and the age of the specimens as the independent variables in evaluating the performance of Concrete at variable rate of loadings. He found that the ratio of the impact to static strength increased with the static strength of concrete. Concrete with angular aggregates showed a greater Impact resistance than the concrete with rounded and smooth aggregates. The water-cured specimens showed higher impact strengths than the ones that were air cured.

Birkimer and Lindemann (26) have shown that the critical fracture strain energy theory provides a meaningful fracture criterion. They also found that the critical fracture strain is directly proportional to the rate of loading raised to the *one-third power*.

Many investigators have subjected structural elements made of cementitious materials (e.g. flexure members, compression members, tension members and slabs) to dynamic loading. Attempts have been made to calculate the energy absorbing capacity of the concrete specimen under dynamic loadings. The various methods used by these researchers are:

(i) Free fall drop weight test

(ii) Explosive tests

The extent to which useful information can be extracted from these tests depends on our understanding of the process of loading, energy transformation and energy loss (dissipations) occurring during these tests. The data obtained from these various tests can be often misleading if proper caution is not used.

Apart from these interpretations, efficiency of apparatus also holds a very high ground. Apparatus for these tests must be made very cautiously, with very little scope of error.

Zolfaghari et al. (2016) came to conclusion that impact resistance of structure was affected highly with rate of impact. With the decrease in water cement ratio, it leads to a higher quasi-static impact results. They also concluded that presence of fibres, results in better maintenance of consistency and intergrity of the specimens in quasi-static as well as dynamic Impact. For dynamic tests an index 'DISI' was proposed which accounted velocity and the length of fracture for the strike. This index was able to completely explain the dynamic impact resistance. A reduction of 'DISI' was observed with increase in brittleness of silica fume specimen. Highest dynamic strength was achieved with water-cement ratio of *0.45*.

Wang et al. (2009) in his study found that the Impact resistance, including the first-crack strength and the failure strength, can be determined corresponding to different failure probabilities. The $P–V_f$ *–lgN curves* and the Impact resistance formulae for different failure probabilities were developed. Thus, they will serve as a practical tool to estimate the impact resistance of SFLWC according to the specific design level of failure probability.

Barbant and Charron (2018) in their experiment found out that theoretical estimation of fibre arrangement from regular fibre distribution and density can't provide the accurate prediction of experimental observation in samples. Bending strength, residual stress and tensile strength are mostly affected by the arrangement of fibre. Thus they concluded that for such important Impact density and fibre arrangement on shear, tensile and bending characteristic of SFRC highlights the necessity to take them in consideration for the design of structure.

2.7 Scope and Need of the Study

Concrete, with its heterogeneous composition and inelastic behavior, behaves quite differently from other materials such as metals. The distribution of fine aggregates and coarse aggregates particle throughout the tough cement matrix and the nonlinear behavior under loading, separate concrete from the much more homogeneous metals. It is the very structure and composition of concrete which impart its rate of loading sensitive characteristics.

The present knowledge of the behavior of concrete under high rates of loading is inadequate to explain its performance as a structural material when subjected to impact loadings. The rate of loading sensitivity of concrete makes it improper to use its statically determined properties under high rate of loading or impact loading. Moreover, the results obtained at low or intermediate rate of loadings may not be used to predict the behavior under impact loading because, (a) no universally accepted rule exists for such an extrapolation, and (b) Impact may not be regarded simply as a case of extreme rate of loading application. Not only don't we understand plain concrete, we can't even begin to predict the behavior of fibre reinforced concrete, and of conventionally reinforced concrete at high stress rates.

Concrete is a conglomerate of randomly distributed aggregate particles bound together by hydrated portland cement. The overall properties of concrete depend upon the properties of the paste and on its bond with the aggregates. Thus, as a first step in the study of the rate of loading sensitivity of concrete the behavior of paste itself under Impact loading was studied. The effect of stress rate on the behavior of plain concrete was also studied by subjecting plain concrete beams to stress rates associated with static loading and those associated with impact. The most important properties studied were the strength and the fracture energy.

The use of fibres has proven to be of importance in improving the ductility of concrete. This desirable contribution of fibres and making it slightly ductile in nature, where a large amount of energy is suddenly imparted to the structure, demanding a high energy absorption capacity from its elements. Steel and polypropylene fibre reinforced beams were subjected to different state of load and it is expected that the steel fibre containing beams will act in a way better form rather than the conventional, thus obtained were compared with those obtained under static loading. Comparison was also made with beams without fibres.

Compressive and flexural strength of concrete has been always a burning topic along the Researchers in the field of civil Engineering. Although very little work has been done on adding additives in the concrete to gain other features. For example very few work has been done in the field of impact Resistance. Impacts are a part of our day to day life. From slow velocity Impacts such as vehicle Collision, sudden fall of heavy equipments in industries to high velocity impact such as a missile collision. Impact resistance is an important aspect of concrete properties. Thus this paper tries to cover the advantages of adding steel fibre in concrete to give a boost to the impact resistance of the concrete.

The output from the testing program is more in the form of trends, and less in the form of basic material properties, although an attempt has been made to evaluate the basic material properties wherever possible.

2.8 Objectives

- To assess the compressive strength of steel fibre reinforced concrete with different volume fractions substitution over standard plain concrete.
- To assess the flexural strength of steel fibre reinforced concrete with different volume fractions substitution over standard plain concrete.
- To assess the impact resistance of steel fibre reinforced concrete with different volume fractions substitution over standard plain concrete.
- To determine the difference between the crack initiation and the ultimate failure under drop weight test with the change of volume fraction.

Chapter 3
Materials and Methodology

3.1 Materials

The requisite materials for the concrete mix proportioning are cement, fine and coarse aggregates, water, and superplasticizer. The physical and mechanical properties of these materials are discussed below.

3.1.1 Cement

We used Portland pozzolanic cement (ultratech). Its consistency was 32%. The initial and final setting time for respective is 90 minutes and 220 minutes. The specific gravity was found to be 3.14.

3.1.2 Aggregates

The coarse aggregates of size less than 19 mm and fine aggregate classified as zone II sand were used in current study. Various tests were conducted to obtain the physical and mechanical properties and the results were discussed in section 3.2.

3.1.3 Water

Regular tap water was used for all experimentation purpose.

3.1.4 Superplasticizer

Due to workability issues, we used a BASF product: Masterglenium 51. It was added as 0.8 % of the binder weight. Further the physical and chemical properties of above mentioned super plasticizer are mentioned in Table 3.1

Table 3.1 Properties of super plasticizer Masterglenium 51

Structure of the material	Polycarboxylic ether based
Color	Amber
Density	1.082-1.142kg/liter
Chlorine content% (EN 480-10)	< 0.1
Alkaline content% (EN 480-12)	< 3

3.1.5 Steel Fibre

Steel Fibre used in our Experiment were Crimped of Diameter 0.5 mm and length 30mm. Thus making the aspect ratio ({length (l)/diameter (d)} = 30/0.5 = 60.

3.2 Material Testing Results

Different tests were performed for testing PPC and the results obtained from these tests were compared to specification of PPC along with testing of coarse aggregate and fine aggregate. The results are included in the Table 3.2. The apparatus used for sieve analysis of fine aggregate is shown in Figure 3.1. Table 3.3 represents the sieve analysis results of fine aggregates and Table 3.4 confirms aggregate zone of obtained perecentage passing results in accordance with IS 383 (2016). The graphical representation of sieve analysis is shown in Figure 3.2 .Further, Table 3.5 represents various apparatus used to perform physical and mechanical properties tests on materials.

Table 3.2 Initial properties of materials used for concrete mix proportioning

Name of Experiments	**Values of Experiment**
Consistency of cement	32 %
IST of Cement	90 minutes
FST of Cement	230 minutes
Soundness of Cement	3 mm(millimeter)
Specific Gravity of Cement	3.14
Specific Gravity of Fine Aggregates	2.52
Specific Gravity of Coarse Aggregates	2.59
Zone of Fine Aggregate	II

Figure 3.1 Standard test apparatus for sieve analysis of fine aggregates

Table 3.3 Sieve analysis of fine aggregate.

Size of sieve (mm)	Retained weight (gm)	Passing weight (gm)	Percentage passing (%)
4.75	11.9	1986.6	99.23
2.36	419.5	1567.1	79.46
1.18	517.7	1049.4	57.63
0.60	293.5	755.9	37.48
0.30	193.3	562.6	28.28
0.15	496.8	65.8	3.19
Pan	65.8	-	-
Total	1998.5	-	-

Table 3.4 Sieve analysis of fine aggregate.as per IS 383 (2016)

Size of Sieve (mm)	Percentage passing as per test (%)	Percentage passing as per IS 383 for zone II (%)	Remark
4.75	99.23	90-100	
2.36	79.46	75-100	
1.18	57.63	55-90	zone II
0.6	37.48	33-59	
0.3	28.28	8-30	
0.15	3.19	0-20	

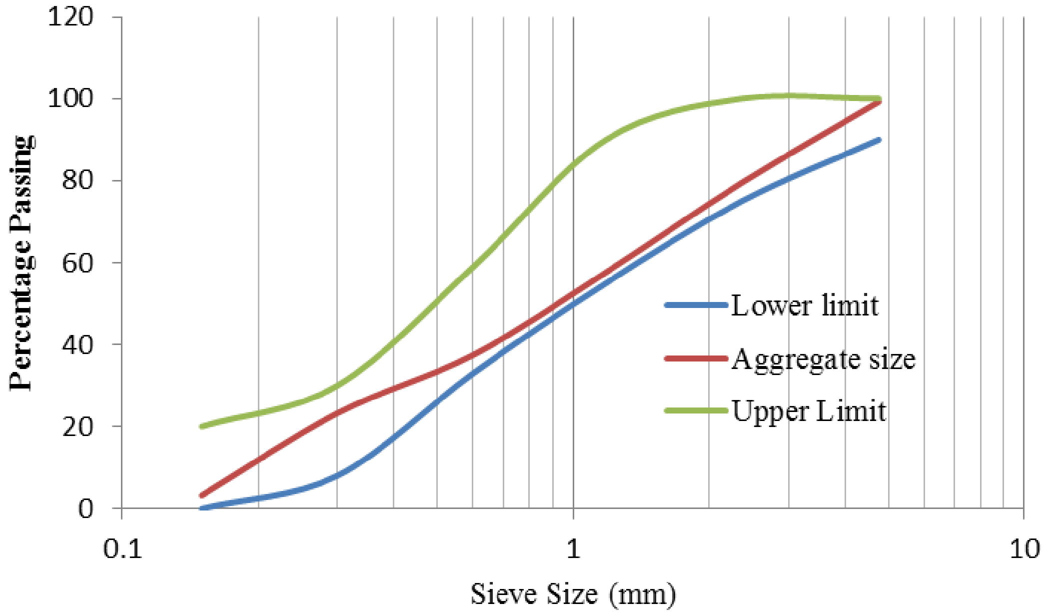


Figure 3.2 Sieve analysis of fine aggregates

Table 3.5 Apparatus used in testing of concrete Materials.

Apparatus	**Usefulness**
Vicat apparatus “IS: 4031(4)-1988” & “IS: 4031(5)-1988”	For cconsistency, IST and FST time of cement
90 micron sieve “IS: 4031(1)-1996”	Fineness of cement
Le-Chatelier’s mould “IS: 4031(3)-1988”	Soundness of cement
Density bottle or Specific gravity bottle	Specific gravity of cement
Pycnometer	Specific gravity of fine aggregate
Wire basket	Specific gravity of coarse aggregate

3.3Specimen Preparation

3.3.1 Methodology

3.3.1.1 Preliminary Study

Several trial mixes were carried in order to achieve desired strength. Apart from Strength several other factors such as workability, placement etc were also considered. To achieve such goal several changes were also made in the original trial mix such as change in the water cement ratio. Five tested samples were casted and then cured for 7 days.

After 7 days compressive strength was tested for cubes. Which involved a total four number of trial mixes. The opted mix proportioning ratios are shown in Table 3.6, 3.7, 3.8, and 3.9.

Table 3.6 First trial mix proportioning

Material	Cement	Water	Aggregates	
			Fine	Coarse
Weight (kg)	*400*	*167.4*	*675*	*1135*

This mix attained *19.45 MPa* compressive strength in *7* days. Which was not suitable as per our design proportioning strength of *38.25 MPa*. Thus it was discarded.

Table 3.7 Second trial mix proportioning

Material	Cement	Water	Aggregates	
			Fine	Coarse
Weight(kg)	*400*	*160*	*675*	*1135*

This mix attained *23.24 MPa* compressive strength in *7* days. Which was not suitable as per our design proportioning strength of *38.25 MPa*. Thus it was discarded.

Table 3.8 Third trial mix proportioning

Material	Cement	Water	Aggregates		Superplasticizer
			Fine	Coarse	
Weight(kg)	*400*	*152*	*675*	*1135*	*0.912*

This mix attained *22.35 MPa* compressive strength in *7* days. This was not suitable as per our design proportioning strength of *38.25 MPa*. Thus it was discarded. Also this mix had workability problems due to very less water cement ratio (*0.38*).

Table 3.9 Fourth trial mix proportioning

Material	Cement	Water	Aggregates		Superplasticizer
			Fine	Coarse	
Weight(kg)	*430*	*168*	*670*	*1120*	*1.344*

This trial mix gave the compressive strength of *27.48 MPa* which was according to our Design Strength. So it was chosen as the Final Mix.

3.3.1.2 Mixing of Paste, Casting in Moulds, and Curing

All components are weighed independently according to the mix subtleties. Mixing is completed by concrete blender to cast 8 solid cubes and 5 solid cylinders for each mix. To perform mix proportioning, tilting mixture is used. The schematic of tilting mixture is shown in Figure 3.3. After this point steel fibres are mixed with hand. The consistency of concrete and appropriate dispersion of fibres primarily relies upon the blending methodology. Cement and components of aggregates are blended completely and after that steel fibres are included physically. While the mixing activity is in advancement, 75% of water is included first and blended for around 5 min then the rest of the water is included and mixed completely. For each blend, an aggregate for 8 cubes of size 150 mm and 5 cylinders of 150 mm diameter and 64 mm thickness are casted. The moulds used for casting the cylinders are shown in Figure 3.4. Figures 3.5 and 3.6 show cast beam specimens and cube specimens, respectively. After 24 h the samples are demoulded, drenched in tap water and restored until testing. The demoulded plain concrete cubes and concrete cubes with 0.5% of steel fibre are shown in Figures 3.7 and 3.8, respectively. Standard impact test cylindrical specimens are shown in Figure 3.9.

Curing is the way toward keeping up palatable dampness on specimens and temperature on freshly created concrete for a positive timeframe promptly following arrangement. The procedure fills two noteworthy needs:

- It avoids or renews the loss of dampness from the solid
- It keeps up an ideal temperature for hydration to happen for a known period

We cure fresh concrete specimens to boost its quality of strength i.e. to increment auxiliary strength factor and decrease splits.**Error! Reference source not found.**The specimens kept for curing are shown in Figure 3.10.

3.4 Final Casting

When appropriate mix design was found, through the series of trial mixes, which gave desired strength at 7 days. That trial mix was finalised. Eight Cubes, Four beams and Five cylindrical specimens were then casted with the finalised mix Proportioning.

Table 3.10 Details of mixes used in the present study

Materials	Proportion(kg)
Water	168.000
Cement	430.000
Fine aggregate 1. Crusher dust	502.500
2. Natural sand	167.500
Coarse aggregate 1. 10 mm	504.000
2. 20 mm	616.000
Super plasticizer	1.344

Figure 3.3 Concrete mixer used for preparing the concrete mix

Figure 3.4 Cylindrical moulds used in casting of standard concrete specimen for impact test

Figure 3.5 Casted concrete beams specimen for flexural testing

Figure 3.6 Fresh concrete cubes for compression test

Figure 3.7 Demoulded marked concrete cubes before curing

Figure 3.8 Cubes of 150 mm diameter containing 0.5 % Steel fibre

Figure 3.9 Standard concrete specimens for drop weight impact test

Figure 3.10 Concrete specimens placed for curing in curing tank

3.5 Experimental Procedures

3.5.1 Introduction

Destructive tests on concrete have been in use for many years. However, strength is not a fundamental material property; it depends upon how it is measured. The mechanical properties of concrete have been found to depend upon, amongst other things, the geometry of the specimen, the stiffness and type of testing machine, loading configuration, moisture content, temperature, and the rate of loading.

High stress rate testing on any material is based on suddenly imparting a large amount of energy to the test specimen. In most Impact machines potential energy is stored in a spring, a pendulum, a hammer, or a simple ball, and this stored energy is transferred to the specimen over an extremely short interval of time. The specimen deforms in response to this energy transfer, leading to the development of high stresses in the specimen over a very short length of time. But, there is a limit to the amount of energy any material can absorb as strain energy before failing. If the externally available energy exceeds this limit, failure will result.

ACI Committee 544 (1999) has recommended an impact test in which a 4.54 kg ball is dropped repeatedly through a standard height of 457mm (18 inches) on a 152.4mm diameter by 63.5mm thick concrete test specimen. The number of blows to a predetermined failure criterion is noted. In actual the differences are being noted down between the initial and final stage which is the distortion stage. The number of blows can also be converted to an energy value by multiplying the energy given to the specimen with each blow by the total number of blows to failure. There are several major problems with this type of testing. The selection of the failure criterion is completely arbitrary, and not all of the energy goes in to the specimen, being dissipated in the test device itself.

3.6 Testing Program

The basic aim of the testing program was to develop a valid testing technique to test concrete under Impact, and to measure the effect of stress rate on the performance of plain and fibre containing Cylinders. The tests carried out may be broadly classified into two categories: static and dynamic.

3.6.1 Static Testing

3.6.1.1 Compressive Strength

Concrete is considered as a heterogeneous mixture. A concrete specimen contains some micro cracks. These micro damages increase under compressive loading and thus lead to cracks which in term lead to structure failure. After the ultimate strength there is a decrease in stress whereas the strain continue to increase, it is called the softening phase. Uniaxial compressive loadings show the structural aspect of softening. We note that the material is damaged and that its stiffness is reduced.

The concrete proportioning mix were casted in cubes of dimension (150 mm x150 mm). Eight cubes were casted for 0%, 0.5%, 1%, 1.5%, and 2% of steel fibres respectively. The moulds were demoulded and were put for curing for 7 and 28 days. The compressive tests for cubes were carried out by help of compression testing machine of capacity 2000 kN at a constant loading. The machine schematic is shown in Figure 3.11

Figure 3.11 Load control Compression Testing Machine of capacity 2000 kN for compression testing

3.6.1.2 Flexure strength

Flexural strength is defined as utmost stress at the outermost fiber on either the compression or tension side of the sample. Flexure strength is property of material to check its flexure ability i.e. modulus of rupture or modulus of elasticity in bending. Its result is denoted in MPa. If the sample is projected under tensile stress it expands. If the extreme fibre is loose or the casting is not properly done then flexural test value decreases Calculation of flexural strength is considered crucial in structural mechanics.

For this test 4 beams of various percentages of steel fibre i.e. 0%, 0.5%, 1%,1.5%, and 2.0% were casted of dimension 100mm×100mm×500mm. the machine used is flexural testing machine. The experiment was conducted till the beams showed failure. The apparatus used for 2 point bending test is shown in Figure 3.12.

Figure 3.12 Flexure testing machine

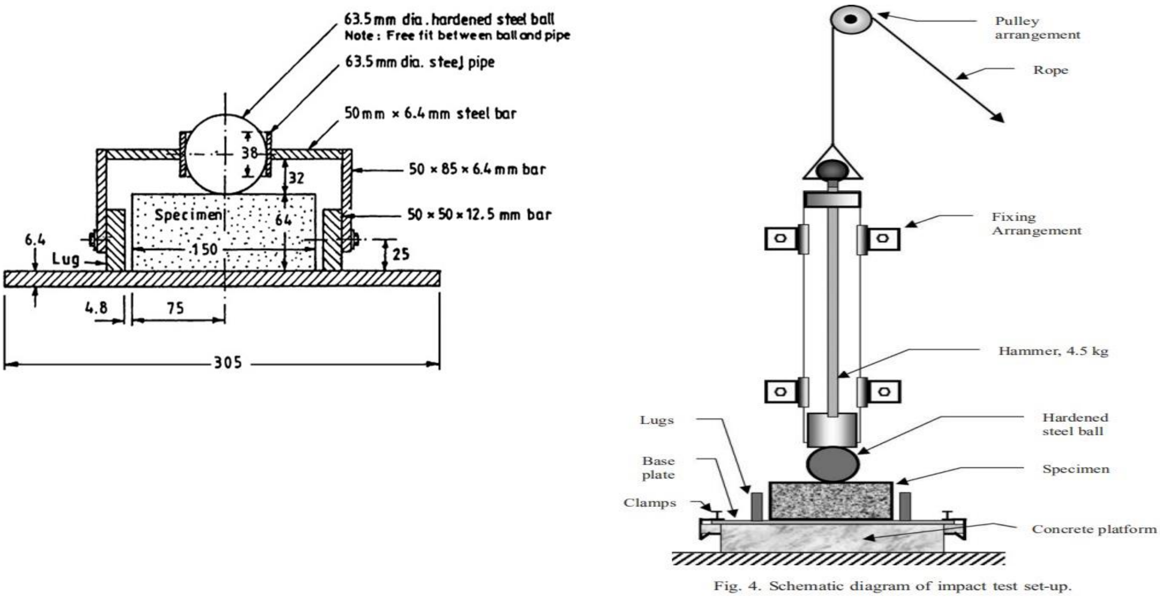
3.6.2 Dynamic Testing

3.6.2.1 Impact Test

For impact test, we used a Drop weight test which is specified in ACI 544 (1999). In this test a cast iron ball weighing 4.5 kg was dropped from a height of 18 inch (457 mm). The energy was exchanged from the iron cast ball to the specimen through a 63.5 mm steel ball set at the centre point of the plate. This test was performed on both the plain concrete and the fibre reinforced concrete containing steel fibres of volume fraction (V_f) 0.5%, 1%, 1.5%, 2%. The specimen used in this test were casted with dimension 150 mm diameter and 64 mm height. The specimens also adhered to the guidelines given by ACI 544 committee. Specimens were taken out of the water tank and then dried for 1-2 hours before the tests were done. For every given percentage, 5 specimens were casted. The specimens were kept on the base plate and arranged inside four hauls, so that there was no displacement of the specimen and thus no irregularity in results.

In this test the heavy iron cast ball hits the low weight steel ball which ultimately transfers that energy to the specimen. The number of blows are counted for the ball drop. At first there is a little crack visible which corresponds to the N_1 number of blows. Then again the test is continued and after some blows ultimate failure can be seen in the form of multiple cracks. These multiple number of cracks contacts any three of the four hauls.

Further the difference between N_2 and N_1 is calculated. This shows us the impact resistance of the concrete specimens.



(a) (b)

Figure 3.13 Graphical representation of drop weight equipment in accordance with ACI Committee 544 (1999); (a) cylindrical specimen, (b) apparatus

Figure 3.14 Drop weight test apparatus base plate with steel ball and casted cylinder

Figure 3.15 steel ball(1.054kg), cast iron ball(4.500 kg) according to ACI 544

Figure 3.16 Drop weight test apparatus used for impact test

Chapter 4

Results and Discussions

4.1 Concrete Results

4.1.1 Compressive tests results

4.1.1.1 Discussion of 7 days results

We see a gradual increase of compressive strength at 7 days. Although the increment of strength gain is less, which suggests that addition of steel fibres does very less increment in compressive strength of concrete. The concrete gained around 73% of strength in 7 days. The readings for which are given in Table 4.1. Maximum increment was recorded for 1.5 % as 1.27 % increase over the conventional plain concrete. A detailed comparison of the compressive strength at different volume fractions is given in Figure 4.1. Although we also see a decrease in the compressive strength for 2%, which can be due to many reasons, improper compaction, workability issue or improper mixing for instance.

4.1.1.2 Discussion of 28 days results

Here also we see a gradual increase of compressive strength at 28 days. Although the increment of strength gain is again less, which also suggests that addition of steel fibres does very less increment in compressive strength of concrete. The concrete gained around 99% of strength in 28 days. The readings for which are given in Table 4.1. Maximum increment was recorded for 1.5 % as 2.40 % increase over the conventional plain concrete. A detailed comparison of the compressive strength at different volume fractions is given in Figure 4.2. Although we also see a decrease in the compressive strength for 2%, which can be due to many reasons, improper compaction, workability issue or improper mixing for instance. The failure of concrete cube under compressive loading is shown in figure 4.3.

Table 4.1 Compressive test results

Volume fraction V_f %	Average compressive strength in MPa	
	7 days	28 days
0	27.48	37.91
0.5	27.57	38.01
1	27.63	38.23
1.5	27.83	38.82
2.0	27.28	37.42

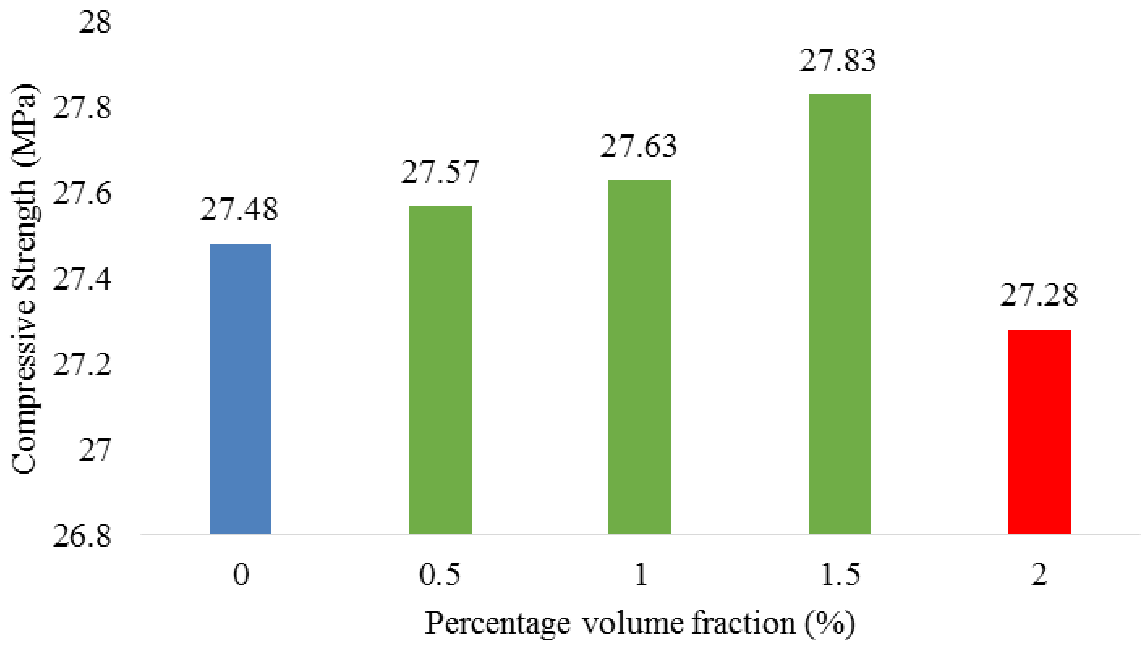
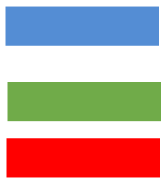


Figure 4.1 Comparative compressive strength results of concrete cubes at 7 days



Compressive strength of conventional concrete

Compressive strength more than conventional concrete

Compressive strength less than conventional concrete

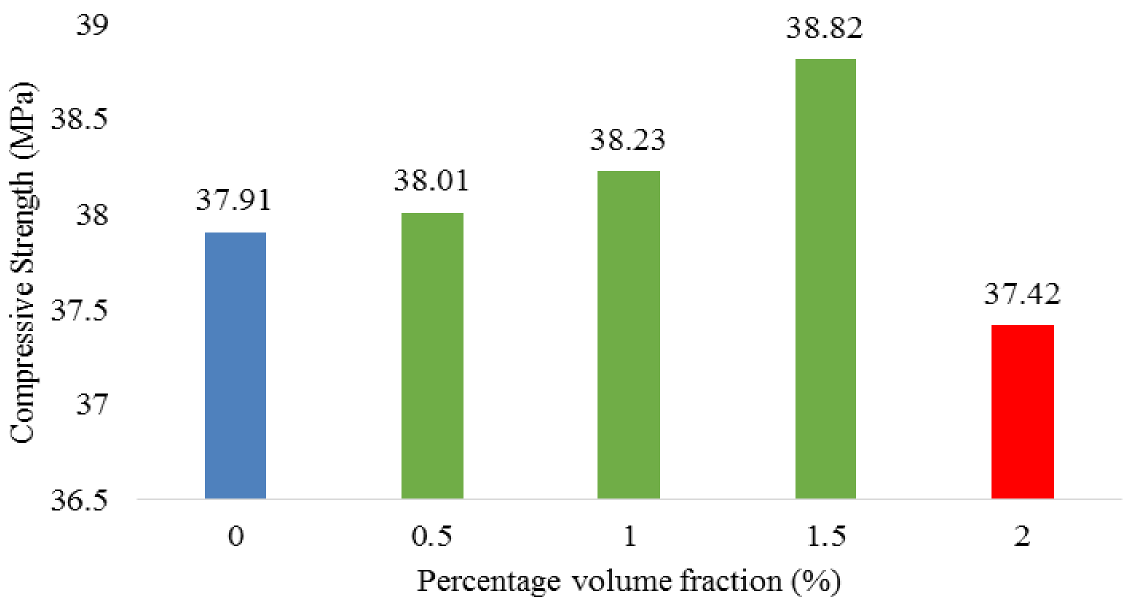


Figure 4.2 Comparative compressive strength results of concrete cubes at 28 days

Compressive strength of conventional concrete

Compressive strength more than conventional concrete

Compressive strength less than conventional concrete

Figure 4.3 Failure of concrete cube under compressive loading.

4.1.2 Flexure tests results

4.1.2.1 Discussion of 7 days results

We see a gradual increase of flexural strength at 7 days. The concrete gained around 71% of flexural strength in 7 days. The readings for which are given in Table 4.2. Maximum increment was recorded for 2% volume fraction as 9.71 % increase over the conventional plain concrete. A detailed comparison of the compressive strength at different volume fractions is given in Figure 4.4.

4.1.2.2 Discussion of 28 days results

We see a gradual increase of compressive strength at 28 days. The readings for which are given in Table 4.2. Maximum increment was recorded for 2% volume fraction as 13.80% increase over the conventional plain concrete. A detailed comparison of the compressive strength at different volume fractions is given in Figure 4.5.A failed beam specimen under flexural loading is shown in figure 4.6

Table 4.2 Average flexure test values

Volume percentage(V_f)	Average flexure strength In MPa	
	7 days	28 days
0%	2.78	3.84
0.5%	2.83	4.02
1%	2.93	4.13
1.5%	3.01	4.30
2.0%	3.05	4.37

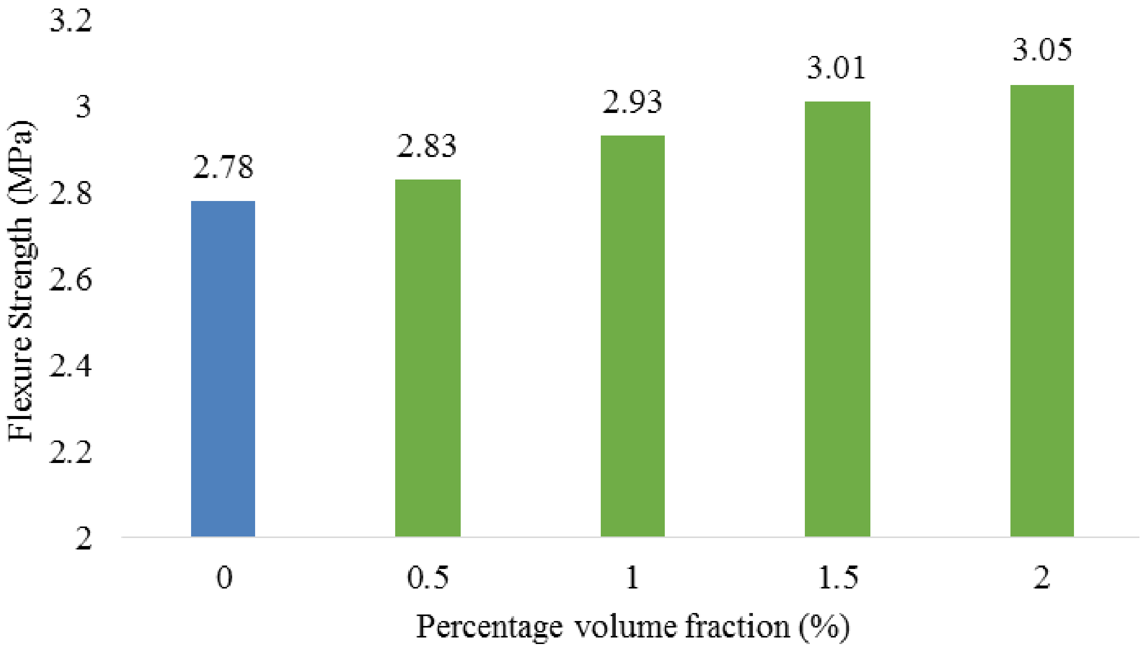


Figure 4.4 Comparative flexural strength results of concrete cubes at 7 days.

Flexural strength of conventional concrete

Flexural strength more than conventional concrete

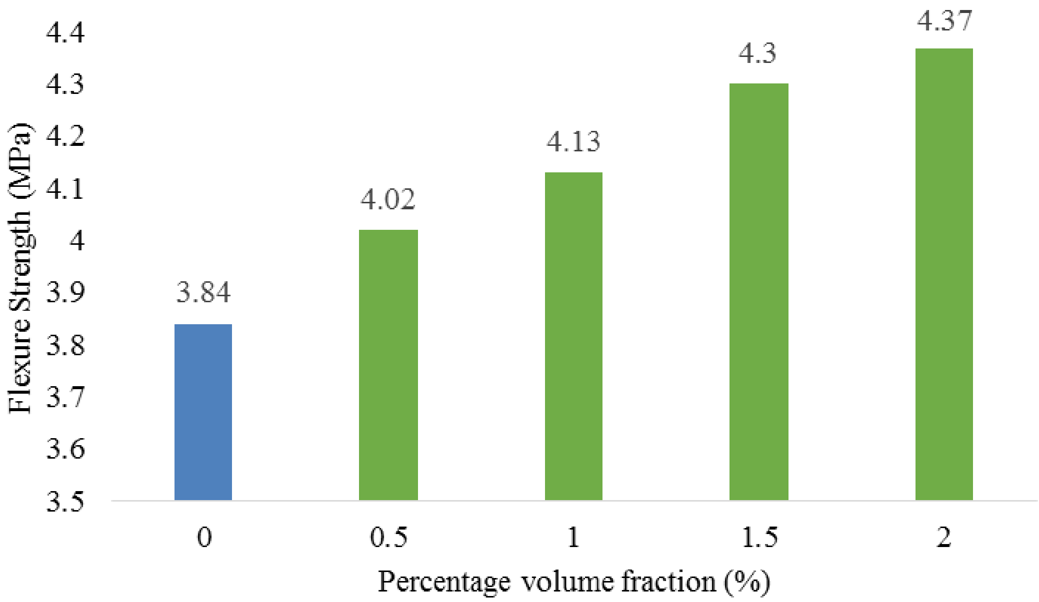


Figure 4.5 Comparative flexural strength results of concrete cubes at 28 days.

Flexural strength of conventional concrete

Flexural strength more than conventional concrete

Figure 4.6 Failed beam under flexural loading

4.1.3 Impact Test Results

In this test we see a sharp increase in the value of number of blows for the first crack N_1 with the increase of fibre content in the mix. Similarly we also see an increase in the number of blows for the ultimate failure N_2. The readings for which are given in Table 4.3. Maximum increment was recorded for 2% volume fraction as 56.42%, and 93.07%, increase over the conventional plain concrete for the first crack and the ultimate failure respectively. A detailed comparison of the impact resistance at different volume fractions is given in Figure 4.7. Also the propagation and pattern of cracks in a cylindrical specimen can be seen in Figure 4.8.

Table 4.3 Impact testing results

Percentage volume in fraction (V_f %)	Development of First Crack N_1 (blows)	Development of ultimate failure N_2 (blows)	N_2 - N_1 (blows)	Percentage increase (%)	(SFRC/PC)
0	296	303	7	2.36	-
0.5	337	429	83	24.63	1.14
1.0	354	445	91	25.70	1.20
1.5	415	523	108	26.02	1.40
2.0	463	585	122	26.35	1.56

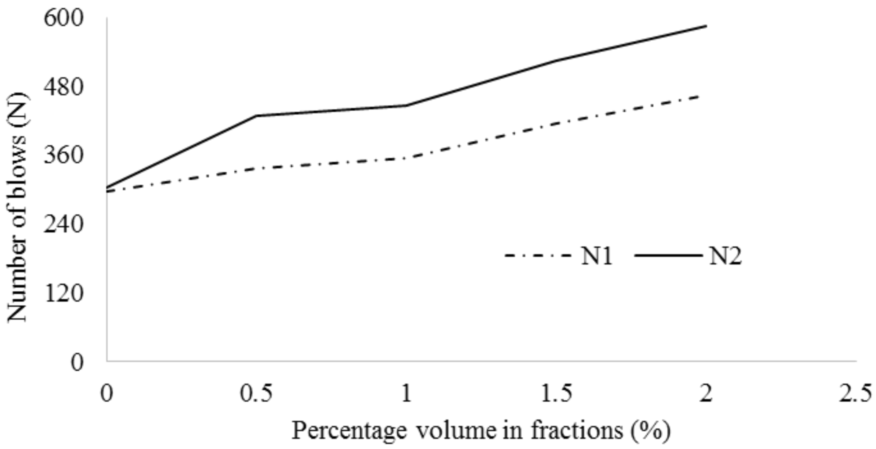


Figure 4.7 Comparative impact resistance of concrete cylinders under drop weigh impact test

Crack initiation at 0%

Crack failure at 0%

Crack initiation at 0.5%

Crack failure at 0.5%

Crack initiation at 1%

Crack failure at 1%

Crack initiation at 1.5%

Crack failure at 1.5%

Crack initiation at 2%

Crack failure at 2%

Figure 4.8 Crack initiation and Crack failure of impact test cylinders after drop weight test

Chapter 5

Conclusion

The following observations can be concluded.

- Steel fibre reinforced concrete shows greater compressive strength as compared to plain concrete. The maximum of which was observed as 38.82 MPa at a volume Fraction of 1.5% in 28 days which was an increase of 2.40% over conventional concrete.
- Steel fibre reinforced concrete showed a greater flexural strength as compared to plain concrete. The maximum of which was observed as 4.37 MPa at a volume Fraction of 2% in 28 days which was an increase of 13.80% over conventional concrete.
- The specimens containing no steel fibres i.e. plain concrete, failed in a brittle manner. This suggests that plain concrete do not exhibit ductile behaviour. On the other hand specimens containing fibres showed a ductile failure.
- Maximum first crack impact resistance N_1 of steel fibre reinforced concrete was seen at 2% which was 463 which was an increase of 56.42% over conventional concrete.
- Maximum ultimate impact resistance N_2 of steel fibre reinforced concrete was seen at 2% which was 585 which was an increase of 93.07% over conventional concrete.
- Addition of steel fibre in plain concrete showed an increment of blows for the first crack failure. Similarly the steel fibre reinforced concrete showed a great improvement in the number of blows for the ultimate failure. However the increase in the number of blows for ultimate failure N_2 was greater than that of first crack failure N_1.
- Compressive strength, flexural strength and impact resistance increased with the addition of steel fibre to the plain concrete. However the rate of increase of impact resistance was comparatively higher than the compressive and flexural strength.
- The slope of increase of N_2 is greater than the slope of N_1. This shows that with the increase in volume fraction of steel fibres, ultimate failure is delayed in a significant manner. This is because of the steel fibre, which reduces the development of micro-cracks which further delayed the ultimate failure.

References

Zollo, R. F. (1997). Fiber-reinforced concrete: an overview after 30 years of development. *Cement and Concrete Composites*, *19*(2), 107-122.

Kukreja, C. B., Kaushik, S. K., Kanchi, M. B., & Jain, O. P. (1980). Tensile strength of steel fibre reinforced concrete.

Agarwal, R., & Tiwari, A. (2017). Fortifying of Concret by Fibre Reinforcement. *International Journal of Engineering Science*, *4658*.

Sabapathi, P., & Achyutha, H. (1989). Stress-strain characteristics of steel fibre reinforced concrete in compression. *Journal of the Institution of Engineers. India. Civil Engineering Division*, *69*, 257-261.

Soroushian, P., & Lee, C. D. (1990). Distribution and orientation of fibers in steel fiber reinforced concrete. *Materials Journal*, *87*(5), 433-439.

Ganesan, N., & Murthy, J. R. (1990). Strength and behavior of confined steel fiber reinforced concrete columns. *Materials Journal*, *87*(3), 221-227.

Bayasi, M. Z., & Soroushian, P. (1992). Effect of steel fiber reinforcement on fresh mix properties of concrete. *Materials Journal*, *89*(4), 369-374.

Balaguru, P. N., & Shah, S. P. (1992). *Fiber-reinforced cement composites*

Ashour, S. A., Hasanain, G. S., & Wafa, F. F. (1992). Shear behavior of high-strength fiber reinforced concrete beams. *Structural Journal*, *89*(2), 176-184.

Bayasi, Z., & Zeng, J. (1993). Properties of polypropylene fiber reinforced concrete. *Materials Journal*, *90*(6), 605-610.

Atahan, H. N., Pekmezci, B. Y., & Tuncel, E. Y. (2012). Behavior of PVA fiber-reinforced cementitious composites under static and Impact flexural effects. *Journal of Materials in Civil Engineering*, *25*(10), 1438-1445.

Mohammadi, Y., & Kaushik, S. K. (2003). Investigation of mechanical properties of steel fibre reinforced concrete with mixed aspect ratio of fibres. *Journal of ferrocement*, *33*(1), 1-14.

Deng, Z., & Li, J. (2006). Mechanical behaviors of concrete combined with steel and synthetic macro-fibers. *International Journal of Physical Sciences*, *1*(2), 57-66.

Perumal, R. (2014). Correlation of Compressive Strength and Other Engineering Properties of High-Performance Steel Fiber–Reinforced Concrete. *Journal of Materials in Civil Engineering*, *27*(1), 04014114.

Yazıcı, Ş., İnan, G., & Tabak, V. (2007). Effect of aspect ratio and volume fraction of steel fiber on the mechanical properties of SFRC. *Construction and Building Materials*, *21*(6), 1250-1253.

Sukontasukkul, P. (2004). Toughness evaluation of steel and polypropylene fibre reinforced concrete beams under bending. *Thammasat Int. J. Sc. Tech*, *9*(3), 35-41.

Padmarajaiah, S. K., & Ramaswamy, A. (2004). Flexural strength predictions of steel fiber reinforced high-strength concrete in fully/partially prestressed beam specimens. *Cement and Concrete Composites*, *26*(4), 275-290.

Vijayanand, M., ANGELESCU, N., Muthu, K. U., & RAO, C. P. H. S. (2010). Flexural characteristics of steel fibre reinforced self compacting concrete beams. *The Scientific Bulletin of Valahia University–Materials and Mechanics*, *8*(5), 96-102.

Khan, M. I., Abbas, Y. M., & Fares, G. (2017). Review of high and ultrahigh performance cementitious composites incorporating various combinations of fibers and ultrafines. *Journal of King Saud University-Engineering Sciences*, *29*(4), 339-347.

Perumal, R. (2014). Correlation of Compressive Strength and Other Engineering Properties of High-Performance Steel Fiber–Reinforced Concrete. *Journal of Materials in Civil Engineering*, *27*(1), 04014114.

Ramakrishna, G., & Sundararajan, T. (2005). Impact strength of a few natural fibre reinforced cement mortar slabs: a comparative study. *Cement and concrete composites*, *27*(5), 547-553.

Ravindrarajah, R. S., & Tam, C. T. (1984). Flexural strength of steel fibre reinforced concrete beams. *International Journal of Cement Composites and Lightweight Concrete*, *6*(4), 273-278.

Abrishami, H. H., & Mitchell, D. (1997). Influence of steel fibers on tension stiffening. *Structural Journal*, *94*(6), 769-776.

Ashour, S. A., Wafa, F. F., & Kamal, M. I. (2000). Effect of the concrete compressive strength and tensile reinforcement ratio on the flexural behavior of fibrous concrete beams. *Engineering Structures*, *22*(9), 1145-1158.

Körmeling, H. A., & Reinhardt, H. W. (1987). Strain rate effects on steel fibre concrete in uniaxial tension. *International journal of cement composites and lightweight concrete*, *9*(4), 197-204.

Holschemacher, K., Mueller, T., & Ribakov, Y. (2010). Effect of steel fibres on mechanical properties of high-strength concrete. *Materials & Design (1980-2015)*, *31*(5), 2604-2615.

Abrams, D. A. (1917). Effect of rate of application of load on the compressive strength of concrete. In *Proceeding of ASTM*(Vol. 17, pp. 364-377)

Schuler, H., Mayrhofer, C., & Thoma, K. (2006). Spall experiments for the measurement of the tensile strength and fracture energy of concrete at high strain rates. *International Journal of Impact Engineering*, *32*(10), 1635-1650.

Doyon-Barbant, J., & Charron, J. P. (2018). Impact of fibre orientation on tensile, bending and shear behaviors of a steel fibre reinforced concrete. *Materials and Structures*, *51*(6), 157.

Tai, Y. S., Pan, H. H., & Kung, Y. N. (2011). Mechanical properties of steel fiber reinforced reactive powder concrete following exposure to high temperature reaching 800 C. *Nuclear Engineering and Design*, *241*(7), 2416-2424.

Nili, M., Azarioon, A., Danesh, A., & Deihimi, A. (2018). Experimental study and modeling of fiber volume effects on frost resistance of fiber reinforced concrete. *International Journal of Civil Engineering*, *16*(3), 263-272.

Birkimer, D. L., & Lindemann, R. (1971, January). Dynamic tensile strength of concrete materials. In *Journal Proceedings*(Vol. 68, No. 1, pp. 47-49).

Struck, W., & Voggenreiter, W. (1975). Examples of impact and impulsive loading in the field of civil engineering. *Materials and structures*, *8*(2), 81-87.

BIS, I. (1970). 383 (1970) Specification for Coarse and Fine Aggregates from Natural Sources for Concrete. *Bureau of Indian Standards, New Delhi, India*.

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Annexure

Mix proportioning as per IS 10262 (2016)

M 30 = 30 N/mm^2
Formula Used = Target Strength
F=30+(S×1.65)
= 30+(5+1.65)
=38.25 MPa

Water/cement ratio = 0.39 (to be used)
For 20mm coarse aggregate
Max. Water content
= 186 h (Reduction of 10% plasticizer)
= 167.40 kg

Cement
W/C = 0.39 [C=167.40/0.42]
Cement(c) = 429.23 kg/m^3
= 430.00 kg/m^3

Calculation of sand of course aggregate
Volume of concrete = 1m^3
Volume of concrete
= 430 / (3.14×1000)
=0.137m^3

Volume of water
= 167.40/1000
=0.1674

Course aggregate + Fine aggregate
= 1 - (0.1674 + 0.137)
=0.6956m^3

Volume of course aggregate = 0.62 × 0.6956
= 0.431 m^3

In the Fine types of Aggregates = 1-0.62
= 0.38
= 0.38 × 0.6956
=0.264 m^3

Coarse Aggregates mass
= Volume of coarse aggregate × Specific gravity ×1000
= 0.431 × 2.59 × 1000
=1116.29 kg/m^3

Mass of Fine aggregate
= Volume of fine aggregate × Specific gravity × 1000
= 0.264 × 2.52 × 1000
= 665.20 kg/m^3

Rounding off
Mass of cement = 430.00 kg/m^3
Mass of water = 168.00 kg/m^3
Coarse aggregate = 1120.00 kg/m^3
Fine aggregate = 670.00 kg/m^3

Water	Cement	Coarse	Fine
168 kg	430 kg	1120 kg	670 kg
0.39	1	2.60	1.56