EXPERIMENTAL STUDY ON PROPERTIES OF STEEL FIBER REINFORCED CONCRETE

A thesis

Submitted in partial fulfilment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

With specialization in

STRUCTURAL ENGINEERING

Under the supervision of

MR. SAURAV

(Assistant Professor**)**

By

ROHIT HARBLA

(152658)

To

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173 234

HIMACHAL PRADESH, INDIA

May, 2017

CERTIFICATE

This is to certify that the work which is being presented in this project report titled **"EXPERIMENTAL STUDY ON PROPRERTIES OF STEEL FIBER REINFORCED CONCRETE"** in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in **"Structural Engineering"** and submitted to the Department of Civil Engineering, Jaypee University Of Information Technology, Waknaghat is an authentic record of work carried out by **Rohit Harbla (152658)** during a period from July 2016 to May 2017 under the supervision of **Mr. Saurav**, Assistant Professor, Department of Civil Engineering, Jaypee University Of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date: -

Dr. Ashok Kumar Gupta Professor and Head of Department Department of Civil Engineering JUIT Waknaghat	Mr. Saurav Assistant Professor Departmenet of Civil Engineering JUIT Waknaghat	External Examiner

ACKNOWLEDGEMENT

Above all else, I want to express my profound gratitude to my project guide Mr. Saurav, (Assistant Professor, Department of Civil Engineering) for giving me a chance to work under his watch and direction. He has always been my inspiration for doing this project. His steady support at each progression was a valuable advantage for me amid my work.

I also want to express my profound thankfulness and gratitude to Dr. Ashok Kumar Gupta, Head of the Civil Engineering Department for giving a wide range of creditable help and encouragement amid my project work.

I am appreciative to the faculty of Department of Civil Engineering, Jaypee University of Information Technology for giving me all facilities required to the experimental work.

I would also like to thank my family and friends for their nonstop support and motivation. At last, I would like to thank all who directly or indirectly helped me in finishing this project.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Concrete is derived from Latin word “concretus”. It is the second most used material after water. The use of concrete in construction has been increased many times in last few decades. Along with its advantages like high compressive strength, fire resistance, high water resistance, low maintenance and long service life, concrete also has many disadvantages for e.g. rebar corrosion, aggregate expansion, freezing of trapped water, moisture ingress, leaching, spalling etc. Such problems can decrease the durability of concrete and can increase the overall construction cost of the structure. This created the need of development of a new type of concrete, which is superior to the conventional concrete. Such concrete is known as steel fiber reinforced concrete which reduces the permeability of concrete, thus reduces the chances of moisture ingress. Such concrete also impact resistance, ductility, flexural strength etc. This examination incorporates the experimental investigation of properties of cement and steel fiber reinforced concrete and after that contrast these with properties of conventional concrete All the experiments included in this project have been performed at $(17 \pm 2)^o$ C and satisfy all the specifications given by Indian Standard Codes.

CHAPTER 1

INTRODUCTION

1.1 General

Now days, the most commonly used construction material used for almost all type of construction are concrete. Due to its many advantages like high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life, concrete is one of the most versatile construction material. During recent years the use of concrete in construction has been increased many times. The quality and durability of concrete not only depends upon the raw materials used to manufacture it but also on many factors like mixing, use of admixtures, placing, compaction and curing of concrete etc. Good quality concrete requires proper mixing, placing, compaction, curing and proper use of admixtures. Enhancement of structural properties of concrete is highly desirable. Pozzolanic materials like fly ash, silica fumes, rice husk ash, slag etc. or supplementary materials like steel bars, organic or inorganic fibres can be used to enhance the structural properties of concrete.

1.2 Conventional Concrete

Concrete is a Latin word "concretus", meaning of which is compact or condensed. It is a composite material composed of both coarse and fine aggregates bonded together with a fluid cement that hardens with time. Concrete can be easily poured and moulded into any shape. Additives like pozzolans or super-plasticizers can be added to improve the physical properties of green concrete. It is very poor in tensile strength as compared to its compressive strength. To overcome this problem it is usually reinforced with materials which are strong in tension. Concrete shrinks as it matures because of its very low coefficient of thermal expansion. Concrete can deteriorate due to rebar corrosion, aggregate expansion, freezing of trapped water, moisture ingress, leaching, spall etc. This created the need of development of a new type of concrete, which is superior to the conventional concrete. Different types of pozzolanic materials such as fly ash, silica fumes, GGBS, rice husk ash etc. can be used to improve the properties of concrete. Now days, fiber reinforced concrete is used in many fields as its properties are much better than conventional concrete.

1.3 Steel Fiber Reinforced Concrete

Steel fiber reinforced concrete is a composite material made up of cements, aggregates, sand and steel fibers. The main function of steel fibers in concrete is to fill the cracks. Steel fibers reduces the permeability of concrete which reduces the chances of moisture ingress. Further, flexural strength, fatigue resistance, impact resistance of conventional concrete can be increased by the use of steel fibers. Also, the concrete becomes less porous and shrinkage cracks can be eliminated by the use of steel fibers. Steel fiber can give significant cost savings due to rapid construction, reduced labour cost etc. over conventional reinforced concrete. The main disadvantages of fiber reinforced concrete are corrosion of steel fibers, high cost, proportioning of exact amount of steel fibers in concrete, increase of specific gravity of concrete etc.

1.4 OBJECTIVE OF THE PROJECT

1. To study the properties of steel fiber reinforced concrete and compare them with the properties of conventional concrete.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Literature review is a critical summary of published research literature relevant to a topic under consideration for research. In this project, literature under-mentioned presents an objective and critical summary of work being carried out on evaluation of various properties of steel fiber reinforced concrete and its advantage over conventional concrete. The purpose is to know current thinking and research on this topic. Total of fifteen research papers has been referred in this project.

2.2 Response of steel fiber reinforced high strength concrete beams: Experiments and code predictions by Luigi Biolzi, Sara Cattaneo[1]

The main objective of the study was analyse the response of steel fiber reinforced high strength concrete beams. Randomly distributed steel fibers help in bridging the concrete cracks. Steel fibers also help in improving the flexural strength and ductility of concrete. Reinforced concrete beams with and without using conventional shear reinforcement were prepared and analysed. Four point loading machine was used for carrying out various experiments of compressive strength, flexural strength, ductility, crack control etc. Beams were prepared by using different percentages of steel fibers. Cubes of 150mm dimension were prepared for calculation of compressive strength. Beams having 200mm length and 100mm diameter were prepared for calculation of tensile strength of concrete. Prisms were casted with dimensions 150x150x600 mm for finding out bending strength of concrete with the help of three-point loading configuration. Fly ash and microsilica were used for the preparation of high strength concrete. Beams without stirrups and steel fibers showed brittle behaviour while reinforced beams showed more ductile nature. Beams without stirrups failed in flexure. Results showed that beams reinforced with steel fibers showed enhanced strength and ductility.

2.3 Compressive behaviour of FRP confined reinforced concrete columns by Rami Eid, Patrick Paultre[2]

The main objective of this study is to analyse the compressive behaviour of FRP confined reinforced concrete columns. In this modern world the demand of earthquake resistant structures is increasing. The structure should show ductile behaviour to counteract the earthquake forces. Fiber reinforced polymer composites are used to enhance the ductility of the column. Carbon fiber reinforced polymer is used as FRP. Circular, square/rectangular concrete columns were prepared. Columns having only transverse steel reinforcement, only fiber reinforced polymer and both were prepared. Steel bars having diameter of 8mm and 6mm were used and longitudinal and transverse reinforcement respectively. To provide external confinement to the columns carbon fiber reinforced polymer of thickness 0.381mm was used. After casting columns were kept in bath tub for 7 and 21 days for curing. Results showed that the axial compressive strength increases with the increase in number of layers of FRP. The compressive strength also increases with the increase in transverse reinforcement.

2.4 Investigation on flexural toughness evaluation method of steel fiber-reinforced lightweight aggregate concrete by Jing Jun Li, Chao Jun Wan, Yun Chao Wu[3]

The main objective of this study is to do investigation on flexural toughness evaluation method of steel fiber reinforced lightweight aggregate concrete. The popularity of light weight concrete has been increased over normal weight concrete due to its various properties like better resistance to fire, low density, improved seismic resistance etc. Although it has many advantages but many of its properties need to be improved. Light weight concrete has low shear strength, low tensile strength, low tension-compression ratio etc. To enhance the above properties steel fiber may be used with light weight concrete. Portland cement was used for casting of cubes. River sand was used having fineness modulus of 2.9 and bulk density of 1547kg/m^3 along with round shape coarse aggregates. Cubes and beams were prepared according to Chinese standards. Freshly prepared concrete is poured into moulds and after 24 hours these moulds were kept for curing for 28 days. Results showed that the workability of concrete is decreased due to the network of randomly distributed steel fibers. The steel fiber bridges the cracks of concrete. The optimal value of steel fiber for the enhancement of flexural strength of light weight concrete is 2 percent. The porosity between fibers and paste increases with the increase in amount of steel fiber content. So, only optimum amount of steel fiber should be used in concrete.

2.5Punching shear behaviour of lightweight fiber reinforced concrete slabs by Angelo Caratelli, Stefania Imperatore, Alberto Meda, Zina Renaldi[4]

The main objective of the study is to analyse the punching shear behaviour of lightweight fiber reinforced concrete slabs. Thin reinforced concrete structures for e.g. slabs are prone to failure in case of punching shear loads. Slabs without shear reinforcement fails in brittle way with some deflection and afterwards fails completely. Different type of steel fibers were used to analyse the behaviour of slabs under punching shear load. Three type of concrete mixes were prepared ordinary concrete, lightweight concrete having ash of solid waste of municipality, lightweight fiber reinforced concrete with ash of solid waste of municipality. For tensile strength beams were casted of size 150x150x600 mm. Results showed that the first crack was developed on the bottom surface underneath the loading area. The path of propagation of cracks was observed from centre to diagonally to the corner. The punching resistance of lightweight concrete with ash of municipal waste is slightly lower than slab of ordinary concrete. But the use of steel fibers in slabs has increased the punching resistance of lightweight fiber reinforced concrete slab having ash of solid waste of about 48% with respect to ordinary concrete slab.

2.6 Frost Resistance of the Steel Fiber Reinforced Concrete Containing Active Mineral Additives by S.N. Pogorelov, G.S.Semenyak[5]

The main objective of the study was to understand the frost resistance of steel fiber reinforced concrete containing active mineral additives. Steel fiber reinforced concrete can be used for construction of road pavements in areas having harsh environment. Frost and salt resistance of concrete are the essential requirements in such areas. Steel fibers are introduced in concrete mix to increase the impact and fracture toughness so as to increase the cracking resistance, tensile and bending strength of concrete. The most frost-resistant concrete proved to be steel reinforced concrete on Portland slag cement containing 50% of slag. This was confirmed by comparing the values of an open capillary porosity materials with different content of slag. Analysis of the results shows the beneficial effect of fiber reinforcement in the concrete on the durability of fine slag.

2.7 Fresh and hardened-state properties of self-compacting lightweight concrete reinforced with steel fibers by Thiago Melo Grabois[6]

The main objective of the study was to evaluate the properties of fresh and hardened state self-compacting lightweight concrete reinforced with steel fibers. Lightweight concrete is being used for construction because it reduces the dead weight of concrete components. It also has good durability and mechanical properties along with low handling cost. SCLC (self-compacting light weight concrete) has the properties of both self-compacting and light weight concrete. Portland cement, fly ash, natural sand, super plasticisers, viscosity modifying agent, hooked shaped steel fibers and water were used for concrete preparation. Two type of self-compacting lightweight concrete was prepared by using either coarse or coarse and fine lightweight aggregates. Results showed that the slump of both type of concrete was adequate for as per requirements of self-compacting light weight concrete. Flow time of the concretes was increased by 20 to 30 seconds with the incorporation of steel fibers. Concrete with fiber reinforcement and high lightweight concrete content showed decrease in compressive strength at 1 and 28 days due to rupture through lightweight aggregates. This showed that the lightweight aggregates are weaker than mortar. SCLC has better thermal insulation than NSCC (normal weight self-compacting concrete) concrete due to presence of porous lightweight aggregates. Drying shrinkage of SCLC with fly ash was higher than SCLC without fly ash due to higher w/c ratio of SCLC with fly ash.

2.8 Studies on carbon fiber polymer confined slender plain and steel fiber reinforced concrete Columns by Cengiz Dundar[7]

The main objective of the research was to study carbon fiber polymer confined slender and steel fiber reinforcement concrete columns. Increasing concrete strength makes the RC columns more brittle making retrofitting of RC columns is very common in recent times. The most common material used for retrofitting is CFRP (carbon fiber reinforced polymer) due to its low cost and rapid construction. The main purpose of this study is to investigate the effects of CFRP material on RC and SFRC columns. For column construction materials used were Portland cement, natural and clean aggregates, tap water and super plasticizer. Coarse aggregates having maximum size of 20mm were used. Steel fiber reinforced concrete columns were prepared by RC 65/35 BN-type hooked steel fibers. Test specimen for both type of columns were prepared in structural lab and mechanical vibrator was used for compaction. Diameter and length of prepared columns was 150mm and 300mm respectively. Columns were wrapped with zero, single and double layers of CFRP material. To avoid stress concentrations, the edges of columns were rounded. Tensile cracks and concrete crushing were observed on tension and compression sides respectively of the columns. It was observed that the strength capacity of both RC and SFRC columns was increased by the application of CFRP material. Ductility and deformability of both columns was improved due to CFRP material.

2.9 Evaluation of mechanical properties of steel fibre reinforced concrete exposed to high temperatures by double punch test by Jihwan Kim, Gyu Pil Lee, Do Young Moon[8]

The main objective of the study was evaluation of mechanical properties of steel fibre reinforced concrete exposed to high temperatures by double-punch test. Factors responsible for influencing the mechanical properties of SFRC has been studied. Due to high accuracy of double punch test, the properties of SFRC are evaluated with the help of double punch test. Concrete is fire resistant but when concrete is exposed to very high temperature degradation of concrete starts which results rapid increase of vapour pressure and thermal stresses, spalling and perforation of concrete, induction of cracks etc. Steel fibers are incorporated in concrete to improve its properties. SFRC has good resistance to high temperature and controls cracking. Two type of steel fiber are used i.e. twisted or hooked in three different percentages. Specimen were prepared for 14 and 28 days and tested. The specimen were heated in electric furnace upto 1000 degree Celsius. The required temperature was maintained in the furnace 1 hour before testing. Test specimens were heated for 2 hours and then allowed to cool naturally at room temperature for 24 hours before testing. The results showed that loss of tensile strength of SFRC was higher than compressive strength.

2.10 Flexural strengths and fibre efficiency of steel fibre reinforced, roller compacted, Polymer modified concrete by Karadelis J. N.[9]

The main objective of the study was to study the flexural strength and fiber efficiency of steel fiber reinforced, roller compacted and polymer modified concrete. Concrete is used for pavements at a large scale. Due to its low tensile strength it is very prone to cracking and the repair work increases the cost of project. To overcome this problem new type of concrete, roller compacted, polymer modified concrete is introduced with steel fibers. According to the study to reduce the structural repairs of concrete, steel fibres are used with SFR-RC-PMC. Results have shown that the flexural strength of SFR-RC-PMC is much greater than conventional steel fiber reinforced concrete. SFR-RC-PMC can be used for concrete pavement repairing by just spreading over the degraded surface. Two type of steel fibers, polymers and super plasticizers are used for casting beams. Compaction was done in two layers, thickness of each layer was about 40 to 50mm. Flexural strength of test specimen was carried out by three and four point bending. Due to presence of more airvoids in roller compacted concrete the fiber efficiency of concrete may decrease. According to the results, it can be concluded that SFR-RC-PMC has very high flexural strength and can be used to worn concrete pavement rehabilitation. The fibers used in SFR-RC-PMC have much higher efficiency than that of conventional fiber reinforced concrete.

2.11 Behavior of steel fiber reinforced high strength concrete filled FRP tube columns under axial compression by Tianyu Xie, Togay Ozbakkaloglu[10]

The main objective of the study was to study the behaviour of steel fiber reinforced high strength concrete filled FRP tube column under axial compression. Many circular unreinforced and SFRHSC filled FRP tube columns has been tested and analysed. 27 controlled specimens were casted with the help of same materials that were used to cast fiber reinforced specimens. FRP tubes were prepared by using four layers of aramid FRP. The thickness of aramid FRP on FRP tubes is 0.3mm. Different type of steel fibers were used with different volume fraction for different specimens. According to results steel fiber reduces the formation of isolated major cracks. Under axial compression, steel fiber helps in control cracking of concrete under axial compression which helps in reduction of stress concentration on FRP jackets.

2.12 Study of Flexural Strength in Steel Fibre Reinforced Concrete by Shweta Patil[11]

The main objective of the study was to study flexural strength in steel fiber reinforced concrete. Concrete has very low tensile strength. It has low resistance to cracks and has limited ductility. To make concrete more popular, effective and efficient construction material, its properties should be analysed and enhanced. Use of steel fiber in concrete makes it economical by reducing the dose of fibers. SFRC concrete is less permeable and is more effective in case of moisture penetration. OPC 43, sand of zone 1, aggregates having size 20mm or less has been used to conduct tests of concrete. Tests for compressive strength, flexural strength, workability etc. has been conducted. Concrete specimens having different amount of steel fiber and grade mix are prepared and tested. Amount of steel fibers ranged from 0.5% to 2.5% with an interval of 0.5%. It was observed that there was significant increase in flexural strength of conventional concrete with the use of steel fibers. The maximum deflection is observed with 2.5% fibre and 70 aspect ratio and it was 3.2mm. Steel fibers does not impart much compressive strength. According to the study, steel fiberreinforced concrete can be used for the design of curvilinear forms.

2.13 Steel Fibre reinforced concrete and its properties by Shrikanth Harle[12]

The main objective of the study was to understand steel fiber reinforced concrete and its properties. Concrete with application of steel fibers becomes much stronger in tensile strength and its application in day to day life has been increased many times. Conventional concrete is brittle and weak in tension. This makes the concrete less durable, increases the tendency of high shrinkage cracking. To overcome this problem, steel fibers can be used with concrete. Steel fibers increase the ductility, crack arrest, tensile strength, shock resistance and flexural strength of concrete. The study is based on accumulation of information about GFRC (glass fiber reinforced concrete) and the research work which is already carried out by other researchers. It was observed that steel fiber increases various properties ofconcrete.

2.14 Mix Design of Fiber Reinforced Concrete (FRC) Using Slag & Steel Fiber by Gadge N. A.[13]

The main objective of the study was to study mix design of fiber reinforced concrete (FRC) using slag & steel fiber. Concrete, most widely used material for construction requires cement as its raw material for being manufactured. Cement manufacturing requires huge amount of natural resources and is responsible for emission of carbon dioxide at a large scale which causes pollution. So, it is much needed to find out a replacement of cement. There are many pozzolanic materials like fly ash, silica fume, rice husk ash, GGBS etc. which can be used as partial replacement. Studies have shown that concrete prepared with the help of blended cement is quite better than the ordinary one. To get rid of from frequent maintenance of concrete, steel fibers can be used along with pozzolanic materials to enhance the properties of concrete. This study is based upon the use of pozzolanic materials and steel fibers together in concrete. Steel fibers increase the tensile strength and crack resistance of concrete. According to IS specifications several tests has been conducted for the evaluation of various properties of concrete blended with GGBS and steel fibers. Concrete cubes and beams were prepared of control mixes for grades M20, M30 and M40. Cubes were tested for varying amount of steel fiber and GGBS for 3, 7 and 28 days. It was observed that there was no significant increase in compressive strength of concrete by using GGBS and steel fibers. 20% slag as partial replacement of cement and 1.5% of steel fiber is the optimum amount to be usedfor obtaining maximum flexural strength. Results for tensile strength were same. The optimum dosage of steel fibers in concrete is 1% and 20% of cement can be replaced by GGBS for best results.

2.15 Studies on Steel Fibre Reinforced Concrete – A Sustainable Approach. Dr. Vishnuram B. G.[14]

The main objective of the study was to research and improve different properties of steel fiber reinforced concrete. The demand of fiber reinforced concrete is increasing day by day due to its various advantages. SFRC has great advantage over conventional concrete. This study mainly focuses on the efficient use of industrial waste. Steel fibres used in this study were steel scraps, industrial waste from lathe shops. Concrete cubes, beams and cylinders were casted by using varying percentage of steel fibers according to IS specifications. M20 and M30 grade of concrete mix are adopted in this study. Tests for splitting tensile and compressive strength for 7 and 28 days has been conducted. Results showed that there is significant increase in splitting tensile strength of concrete. Always optimum percentage of fibers in concrete is preferable.

2.16 A Study on the Shrinkage Control of Fiber Reinforced Concrete Pavement by Choi S. Y.[15]

The main objective of the study was shrinkage of fiber reinforced concrete pavement. Cement concrete is widely used for rigid pavement because of its service long service life for heavy traffic. It is cheaper than asphalt but the repair of cement concrete pavement is much more costly than asphalt concrete. Cracking of cement concrete is its main disadvantage as pavement material. This study involves the use of fibers in cement concrete pavement to reduce the tendency of cracking of concrete so as to make the pavement more durable and to increase its economic efficiency. The bending tensile performance of concrete increases with the use of fiber reinforcement. Drying shrinkage and autogenous shrinkage strains of fiber reinforced concrete has been evaluated in order to reduce the cracking of concrete pavement. Many specimen has been prepared by the use of three different kind of fibres to evaluate drying and autogenous shrinkage of concrete. Several tests has been conducted. Results showed that S-00-PV2 with single fiber reinforcement and hybrid fiber reinforcement mix H-N1-ST1 shows most remarkable performance against autogenous shrinkage. The use of fiber reinforcement can control concrete cracking.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 GENERAL

In the very first stage of research, many tests of ordinary Portland cement were performed for the evaluation of various properties of cement. These tests were conducted to find out the fineness, initial/final setting time of cement, specific gravity and consistency of cement. Compressive and tensile strength of cement mortar cubes was also calculated. Concrete cubes were casted of M40 grade concrete to find out the compressive strength of cement. To find out the tensile strength of cement mortar, briquettes were prepared and the tests were conducted with the help of tensile strength testing machine. In the second stage, concrete cubes were prepared with cement, sand, aggregates and water. Concrete cubes and beams with different percentage of steel fibres were prepared. Various test were conducted to compare the property of steel fibres reinforced concrete cubes and ordinary concrete cubes. Results were calculated and compared.

Stage 1 – In this stage different test were performed to find out the properties of cement. Controlled specimens of cement mortar were prepared and allowed to cure for 7, 14, 28 days. Cubes and briquettes were tested to find out the compressive and tensile strength of cement mortar. Sieve analysis for evaluating sand zoning and aggregates specifications were also carried out during this phase.

Stage 2 – Mix design of M40 grade concrete were prepared according to Indian standard. Concrete cubes and beams for different percentages of steel fibres were casted and different tests were conducted and results were compared and analysed to evaluate compressive strength and tensile strength at 7 days, 14 days and 28 days.

3.2 MATERIALS

Cement, sand and water are mixed together to form a paste known as cement mortar. This paste is uniformly mixed with aggregates to wet concrete mix. This mix on solidification becomes a rock hard like structure called concrete. The reason behind the hardening of concrete is the reaction between cement, water and other ingredients. The constituents of concrete can be organized into two groups, one being named as active which includes cement and water. The other group is being named as inactive which comprises coarse and fine aggregates and these do not participate in chemical reactions within the concrete.

***Cement*–**It is a well-known binding material and has been widely used in this modern world due to its various properties. Cement used in construction works are of two types, hydraulic and non-hydraulic cement. Non-hydraulic cement does not set in wet conditions while hydraulic cement reacts with water and chemical reactions are carried out. This cement paste binds the aggregates with the help of adhesive bond and on drying it forms rock hard like structure called concrete. The function of cement is also to fill the voids between to form a compacted mass. The cement used in this report is Ordinary Portland cement of 43 grade (OPC 43) as per IS 8112:1989[20]. The ordinary Portland cement used here (Figure 3.1) satisfies all the standards listed in IS 8112:1989.

Fig No. 3.1 - OPC 43 Cement

Fine aggregates **–** Fine aggregates is naturally occurring sand which may be easily found at river beds and coastal areas. These aggregates should be washed and cleaned before being used as they may have many impurities which may be the reason behind deterioration of concrete. According to Indian Standards, fine aggregates passes through 4.75 mm sieve and the coarser quantity retained should be according to specification. Fine aggregates are described natural sand, crushed stone sand, crushed gravel sand on the basis of its particle size. On the basis of particle size, IS 383:1970 has classified fine aggregates into four zones of grading from zone-1 to zone-4. As the zone increases the fineness of the aggregates also increases. For carrying out this experimental work, locally available river sand having fineness modulus of 2.874 (listed in Table 3.1) confirming to Zone II as per IS 383:1970 is used.

Table 3.1 – Sieve Analysis of Fine Aggregates

Size of Sieve	**Retained weight (grams)**	**Cumulative weight Retained (grams)**	**Cumulative %age of weight Retained**
4.75 mm	0	0	0
2.36 mm	102	102	10.20
1.18 mm	212	314	31.40
600 microns	315	629	62.90
300 microns	200	829	82.90
150 microns	171	1000	100.00
			Total = 287.40
Weight of sample taken = 1000 grams			

Fineness Modulus = (Total of cumulative % age of weight retained)/100.

= 287.40/100

= 2.874

Coarse aggregates – Aggregates which are retaining on 4.75 mm IS sieve and the retained portion contains only that much of fine particles which is specified in code standards. Coarse aggregates are formed by the disintegration of rock due to different environmental conditions. These aggregates have their chemical and mineral properties similar to their parent rock. The coarse aggregates are also described as uncrushed, crushed and partially crushed stones. The nominal size of coarse aggregates is described according to the grading of coarse aggregates *i.e*. 40 mm, 20 mm, 16 mm, 12.5 mm and 10 mm, etc. In this project work, the grading of coarse aggregates is done according to IS 2386 (part 1):1963 and the nominal maximum size of coarse aggregates used for preparation of concrete and cubes is 20mm. Grading analysis for coarse aggregates as per IS 2386 (part 1):1963 is shown in table II.

Table 3.2 – Sieve analysis of coarse aggregates

Sieve Size (mm)	**Retained weight (grams)**	**Cumulative retained weight (grams)**	**Cumulative % age of retained weight**
20	0	0	0
16	1646	1646	32.96
12.5	3082	4728	94.56
10	214	4942	98.84
6.3	47	4989	99.78
4.75	11	5000	100.00
Total weight of sample taken = 5000 grams.			

Water **–** It water is a transparent chemical substance which is nearly colourless and colourless. It is least expensive and most abundantly used material in construction. When water is mixed with cement, sand and aggregates to form concrete, some part of water is used for the hydration of cement to form a binding matrix wherein aggregates are held in suspension until the matrix is hardened. Extra water provides the flow medium to fine and coarse aggregates so that the concrete can be easily mixed and placed. This part of water is responsible for workability of concrete. Water is used in huge amount for curing of concrete. Curing is a necessary and important process as it affects the durability of concrete. In this project work, as per IS 456:2000 recommendations, water used for mixing and preparation of concrete is potable water.

Steel Fiber –Stainless steel fibers of thickness 0.5mm and length of 40mm are used in this experiment for preparation of cubes and beams. Aspect ratio of 80 has been used for this experiment. All the steel fibers used are straight in shape. Stainless steel fibers are corrosion resistant, crease resistant, and recyclable and have high tensile strength.

3.3 Experimental Parameters

The experiments performed for this project work are strictly according to Indian Standards. Following table shows the list of experiments and their corresponding Indian Standard Codes.

Table 3.3 – List of IS codes used.

List of Material/Experiments	**IS Code**
Ordinary Portland Cement 43	IS 8112:1989
Normal Consistency of OPC 43	IS 4031(part 4):1988
Initial/Final setting time of OPC 43	IS 4031(part 5):1988
Fineness of OPC 43	IS 4031(part 1):1996
Soundness of OPC 43	IS 4031(part 3):1988
Compressive strength of OPC 43	IS 4031(part 6):1988
Specific Gravity of OPC 43	IS 4031(part11):1988
Vicat's apparatus	IS 5513:1996
Le-Chatelier apparatus	IS 5514:1996
Slump test apparatus	IS 7320:1974
Compression Testing Machine	IS 14858:2000
Zoning of Sand	IS 383:1970
Specification of aggregates	IS 2386(part 1):1963
Chemical Admixtures	IS 9103:1999
Basic considerations	IS 456:2007

3.4 Testing

As mentioned earlier, the whole research work has been divided into four stages. Each stage includes preparation of samples and different tests are performed to evaluate different properties of concrete.

Stage I:-

1. **Normal Consistency of Cement** – It is one of the most important and basic test of cement. This test is performed to find out the exact amount of water for complete hydration of cement to get maximum strength. Low water content can affect the strength of concrete as the hydration process will not complete and as well as high content of water will increase the water-cement ratio, which will also reduce the strength of concrete. So, optimum quantity of water is required for best results. For calculation of optimum quantity of water, Vicat's apparatus is used. The plunger used in Vicat's apparatus is 50 mm in length and 10mm in diameter. To find out consistency of cement the plunger should penetrate 5 to 7 mm from bottom. Take 400 g of clean, dry and lump free cement. Mix about 25% water by weight of dry cement uniformly to obtain a cement paste. The total time required for gauging should be in between 3 to 5 minutes. Fill the mould and smoothen its top surface and place the assembly of mould, cement and base plate under the plunger of Vicat's apparatus. Lower the plunger and note down the penetration. Prepare more such trial pastes by using different percentage of water and repeat the experimental process until the penetration is 33 to 35 mm.

Fig No. – 3.2 Vicat's apparatus for Normal consistency of cement

2. **Setting time of cement** – The time at which the cement paste starts losing its plasticity are known as initial setting time of cement. It is the time period between the time of mixing and the time at which needle having 1 mm^2 cross – sectional area fails to penetrate the cement paste up to 5 mm to 7 mm depth from bottom. The cement paste is placed in Vicat's mould. Final setting time is the time elapsed between the moment the water has been added to the cement to the time at which the plasticity of cement paste has been lost completely. At this stage, the cement paste hardens completely and the hardened paste attains the shape of mould. At this time, the needle having cross-sectional of 1 mm^2 makes just an impression on the hardened cement paste placed in the mould while the attachment having diameter of 5 mm fails to do so. This test is performed according to IS 4031(part5):1988. As per Indian Standard 8112:1989, the final setting time should be under 10 hours and initial setting time should not be less than 30 minutes for ordinary Portland cement of grade 43.

Fig. No. – 3.3 Viact's apparatus

A take 400 g of clean, dry and lump free cement and prepare a fine cement paste by using 0.85xP of water by weight of cement, where P denotes the normal consistency of cement. Lubricate the Vicat's mould and the base plate. Use a non-porous base plate. Place the cement paste in Vicat's mould. The mould is then placed under Vicat's apparatus. The rod of the apparatus bears a needle having cross sectional area of 1 mm^2. The needle is then allowed to lower and it was observed that the needle penetrates the cement paste in mould completely. This test is repeated again and again until the needle fails to penetrate the test block for about 5 mm measured from the bottom of the mould. This is how the initial setting time of cement is calculated. For final setting time wait until only the needle puts an impression on the solid cement paste placed in the mould.

3. **Fineness of cement**– Fineness of cement tells about particle size distribution of cement. It is expressed in the terms of summation of the surface areas of all cement grains in 1 g of cement. Fineness of cement is done by sieving cement on the standard sieve of 90 microns. The particles of cement which have their size larger than the specified mesh size are retained on the sieve. The percentage of retained particles tells us about the fineness of cement. Permissible limit for OPC is not more than 10% retained on sieve. Fine cement has more rate of hydration. Finer cement particles provide more surface area which increases the rate of hydration and thus more strength can be achieved at early stages. The test has been performed according to Indian Standard 4031(part 1):1996. Sieve 100 g of cement sample from 90 microns sieve manually (as shown in Figure 3.4) for about 10 to 15 minutes. Cement taken for test should be clean and dry so that it may easily pass through the wire mesh. The retained cement is weighed and fineness modulus of cement is determined.

Fig. No. – 3.4 Sieve (90 microns)

Soundness of cement – Soundness of cement is a very important property. It refers to the ability of cement paste to retain its volume after it gets hardened. Unsoundness of cement leads to crack generation. Unsound cement can cause serious trouble to the durability of structures. More sound cement means more resistance against volume expansion. The expansion may occur due to reaction of free lime, magnesia and calcium sulphate. Free lime is present in the clinker and is inter-crystallized with other compounds. This test has been performed according to IS 4031(part 3):1988. Take 100 g of cement and water of quantity 0.78xP times the weight of cement. P denotes the normal consistency of cement. Prepare a neat cement paste. Fill the Le-Chatelier mould is filled with this paste and level the top surface of the mould with straight-edged implement. Place non-porous glass plates on top and bottom of the mould. Place a small weight on the top of upper glass plate so that expansion in upper direction can be resisted. Le-Chatelier apparatus shown in following figure is then submerged in water bath for 24 hours. After 24 hours, heat the assembly at boiling by keeping it in water at boiling temperature for about 3 hours. Allow the mould to cool at room temperature and measure the distance between the indicator needles after cooling. The difference in the values of measured distance will tell us about soundness of cement. Permissible limit of cement is 10 mm[17].

Fig. No. - 3.5 Le-Chatelier apparatus

5. **Specific Gravity of cement** – It is the ratio of density of cement to that of any known material. Generally water is taken as reference material but here, we take Kerosene oil is used because it does not react with cement while water reacts as soon as it comes in contact with cement. In simple way, it is a value to calculate whether a material is able to float or sink on water. Materials having values greater than 1 will sink and vice-versa. Normally our nominal mix design is based on the value of specific gravity of cement as 3.15. Specific gravity of Kerosene oil is 0.79. This test is performed in accordance with IS 4031(part 11):1988. Le-Chatelier flask having capacity of 250 ml is used in this test. In

this test 64 g cement has been used. The flask used should be clean and dry. Fill the flask with Kerosene oil to upper mark (*i.e.* 1 ml) of graduations below the central bulb. After doing this, pour 64 g of cement into the flask with care. In result, the level of Kerosene oil in the flask is increased. After putting all the cement to the flask, roll the flask in inclined position to expel air until no further air bubble rises to the surface of liquid. The ratio of weight of cement to displaced volume of kerosene gives the specific gravity of cement.

Fig. No. -3.6 Le-Chatelier Flask

6. **Compressive strength of cement mortar** – Compressive strength or compression strength of a material is its ability of withstanding compressive loads. Compressive strength is determined by performing tests of compressive strength on cement mortar cube specimens as shown in figure. The dimensions of the cube mould are 7.06 mm×7.06 mm ×7.06 mm. Tests to determine the compressive strength of cement mortar were performed at 3, 7 and 28 days. This test satisfies the standards given in IS 4031(part 1):1988. Cement mortar is prepared by mixing cement, sand and water. Quantity of water required for mixing is equal to {(P/4) + 3} % by weight of cement. Here P denotes the normal consistency of cement. Lubricate the moulds before placing cement mortar in it. Lubrication makes the process of de-moulding easier and specimen with sharp shape can be obtained. Prepare nine cubes and place them at room temperature for nearly about 1 day. Preventive measures should be taken during preparation of concrete and performing tests. Hand gloves should be used to avoid direct contact of hand and cement paste. After

24 hours remove the moulds and submerge the cubes in water bath for curing with great care. The water bath should be kept undisturbed and the water in it should be potable. Cubes are taken out of water bath tub only at the time of testing. Keep the cubes in sunshine for some time before carrying out the experiment so that the excess water from the surface of cubes may dry out. Three cubes each for 3 days, 7 days & 28 days are tested for compressive strength in Compressive Testing Machine (CTM). The mean value of three cubes is taken as compressive strength for 3 days, 7 days and 28 days.

Fig. No. – 3.7 Casting of Cement Mortar Cubes

7. **Tensile Strength of cement mortar –** The ability of a material ofwithstanding tensile loads is called its tensile strength. Tensile strength is determined in order to gain some idea of the cohesion between the particles. This property is roughly proportional to the crushing strength and easier to determine. For the determination of tensile strength of the cement mortar, cement mortar is prepared and briquette moulds are lubricated so that the

demoulding of specimen and cleaning of moulds may become easier. Water required for the preparation of cement mortar is equal to {(P/5) + 2.5} % by weight of cement, where P denotes the normal consistency of cement. A total of nine briquette specimens were prepared by placing cement mortar in it. Then the specimens were placed at room temperature for next 24 hours. After that, briquette moulds were removed to obtain specimens of briquette. These specimens were then allowed to submerge in potable water in water bath for curing. 3 specimens for each 3, 7, 28 days testing were prepared. Specimens were taken out of the water bath only at the time of testing. The average tensile strength value for each 3 days, 7 days and 28 days is calculated. The test results should satisfy the standards given in IS 8112:1989.

Fig. No. – 3.8 Preparation of briquette specimen.

Stage II:-

Design Mix – The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of required strength, durability and workability as economical as possible, is termed as concrete design mix. The objectives of concrete mix design are to achieve the minimum compressive strength, to maintain adequate workability and to make the concrete more economical. Mixes are of three types namely, nominal mix, standard mix and design mix. Cost of concrete depends primarily on two factors, the first is cost of material and labour cost. Labour cost, by way of formwork, batching at site, mixing of concrete, concrete transportation and curing is normally same as for good concrete. In this research, the design mix is carried out for making concrete of M 40 grade. The process of making M40 concrete follows the guidelines given in IS 10262:2009. Stipulations for proportioning are minimum water content equals to 320 Kg/m^3, the water-cement ratio should not be greater than 0.45 and maximum cement content should be equal to 450 Kg/m^3.

Stage III:-

1. **Preparation of cubes for compressive strength of concrete –** To determine the compressive strength of SFRC and plain concrete, cubes of dimension 150mm are prepared. Varying percentage of steel fiber is added to different cubes. Concrete cubes are prepared by filling concrete in three layers and each layer is compacted by tamping rod. The cube moulds were demoulded after 24 hours and were placed in water tank for curing for 7, 14 and 28 days. After that specimens were tested.

2. **Preparation of Beams for flexural strength-** Beams of dimension 150x150x700 mm are prepared by using different percentage of steel fibres. The beams were demoulded after 24 hours and were transferred to water tank for curing. Flexural strength test is conducted at 7, 14 and 28 days intervals. Test is conducted by using two point loading machine.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Normal Consistency of cement

Normal consistency of cement is 31%.

4.2 Setting time of cement

The initial and final setting time of cement (OPC 43) used is given in the following table.

Table 4.1 – Initial and Final setting time of cement

Setting Time	Time (minutes)
Initial setting time	105
Final setting time	290

4.3 Fineness Modulus of cement

Sieve 100 g of cement manually with the help of 90 microns sieve and weigh the mass of cement retained on the sieve. 2.6 grams cement got retained on sieve. Hence, the fineness modulus (FM) of cement is 2.6%.

FM = (weight retained on standard sieve of 90 microns/Total weight) × 100

= (2.6/100) × 100

= 2.6%

4.4 Soundness of cement

Initial measurement, L1 = 10.7 mm

Final measurement, L2 = 13 mm

Therefore, soundness of cement = L2 – L1 =2.3 mm

4.5 Specific gravity of cement

Weight of cement, W = 64 g

Initial reading after kerosene oil is poured, V1 = 1 ml

Final reading after 64 g cement is poured, V2 = 21 ml

Increase in the volume = Final volume – initial volume

= V2 – V1

= 21 ml – 1 ml

= 20 ml

Specific gravity of cement = W/ (V2 – V1)

= 64/ 20

= 3.20

Thus, specific gravity of the cement is found to be 3.21

4.6 Compressive strength of cement mortar

The Table 4.2 shows the results for compressive strength of cement mortar at 3 days, 7 days and 28 days.

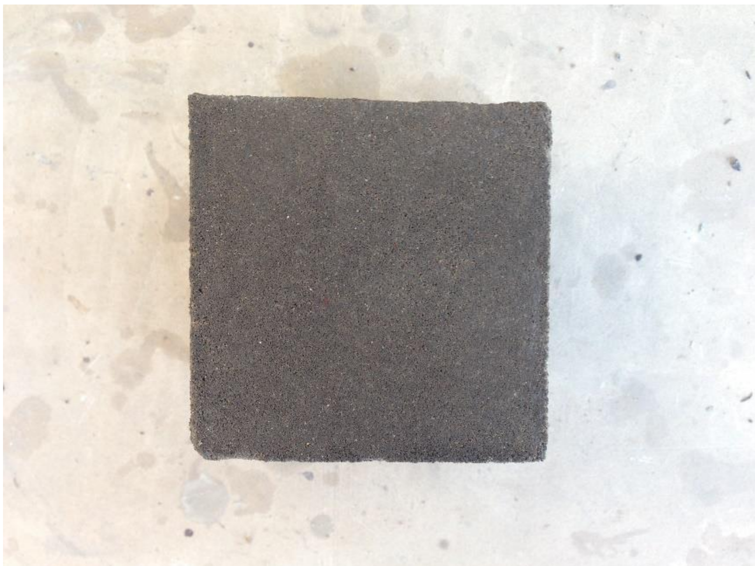

Fig. No. – 4.1 Cement Mortar Cube Specimen

Table 4.2 – Compressive strength of cement mortar cubes

Age	Specimen I	Specimen II	Specimen III	Average strength
3 days	20.46 MPa	20.26 MPa	19.86 MPa	20.19 Mpa
7 days	31.30 MPa	31.70 MPa	31.74 MPa	31.58 MPa
28 days	41.32 MPa	41.52 MPa	41.52 MPa	41.45 MPa

4.7 Tensile strength of cement mortar

Table 4.3 shows the results for tensile strength of cement mortar at age of 3 days, 7 days and 28 days.

Figure 4.2 – 3 days briquette specimen

Table 4.3 – Tensile strength of cement mortar

Age	Briquette I	Briquette II	Briquette III	Average Strength
3 days	2.05 MPa	2.02 MPa	1.96 MPa	2.01 MPa
7 days	2.46 MPa	2.46 MPa	2.49 MPa	2.47 MPa
28 days	3.07 MPa	3.05 MPa	3.00 MPa	3.04 MPa

4.8 Mix proportions for M40 concrete

After carrying out design mix procedure for M40 grade of concrete. The mix proportion for the concrete are as follows:

Cement = 350 kg/m^3

Water = 140kg/m^3

Fine aggregate = 896 kg/m^3

Coarse aggregate = 1140 kg/m^3

Chemical admixture = 7 kg/m^3

Water-cement ratio = 0.4.

4.9 Flexural Strength Results -

Table 4.4 – Flexural strength at 7 days

S. No.	%age of Steel Fiber	Specimen 1 (MPa)	Specimen 2 (MPa)	Specimen 3 (MPa)	Avg. Strength (MPa)
1	0	3.4	4.1	3.7	3.73
2	0.6	4.2	4.8	4.4	4.46
3	1.2	5.1	5.7	5.3	5.36
4	1.8	4.9	5.1	5.2	5.06
5	2.4	4.4	4.9	4.5	4.6

Table 4.4 – Flexural strength at 14 days

S. No.	%age of Steel Fiber	Specimen 1(MPa)	Specimen 2(MPa)	Specimen 3(MPa)	Avg. Strength(MPa)
1	0	3.9	4.2	4.3	4.13
2	0.6	5.0	5.3	5.4	5.26
3	1.2	5.9	6.2	6.3	6.13
4	1.8	5.8	6.1	5.7	5.86
5	2.4	5.3	5.5	5.2	5.33

Table 4.4 – Flexural strength at 28 days

S. No.	%age of Steel Fiber	Specimen 1(MPa)	Specimen 2(MPa)	Specimen 3(MPa)	Avg. Strength(MPa)
1	0	5.3	4.8	5.1	5.06
2	0.6	6.1	6.4	5.9	6.26
3	1.2	7.5	7.9	7.7	7.7
4	1.8	6.3	6.5	6.6	6.45
5	2.4	6.5	6.6	6.8	6.63

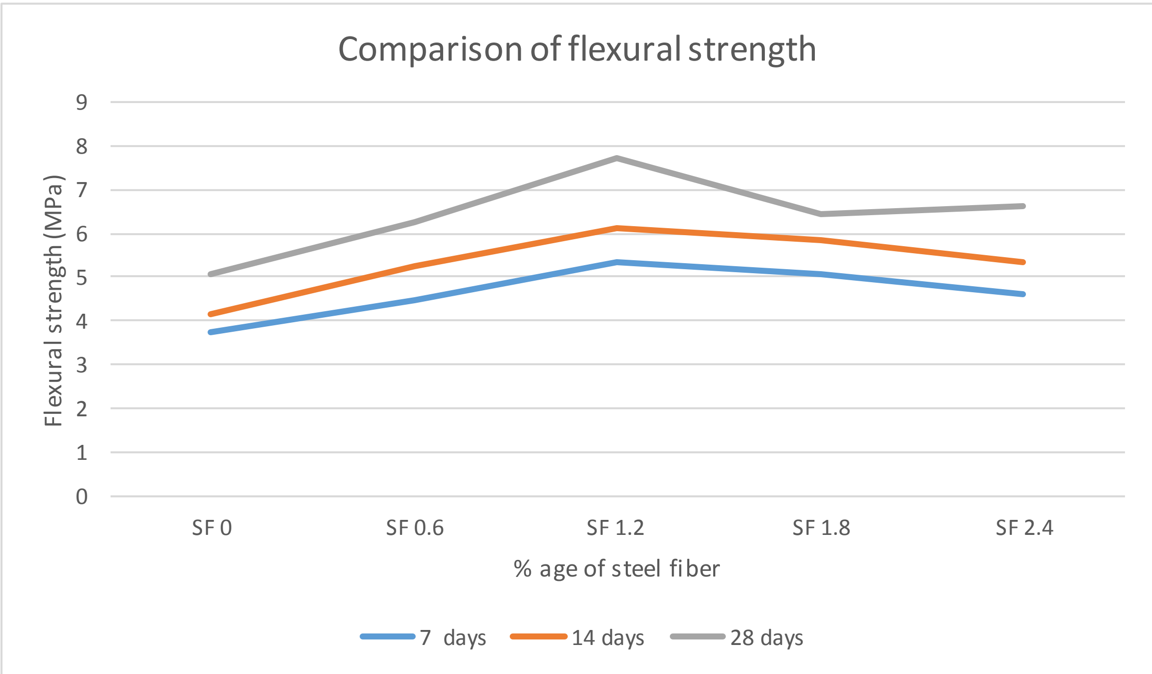

Fig. No. – 4.3 Comparison of flexural strength of concrete at ages with different %age of steel fiber.

4.10 Compressive strength results-

Table 4.5 – Compressive strength at 7 days

S. No.	%age of Steel Fiber	Specimen 1 (MPa)	Specimen 2 (MPa)	Specimen 3 (MPa)	Avg. Strength (MPa)
1	0	22.4	24.7	23.6	23.58
2	0.6	29.3	28.7	29.6	29.21
3	1.2	33.7	32.6	34.1	33.46
4	1.8	28.6	27.9	28.4	28.3
5	2.4	28.2	29.8	28.8	28.93

Table 4.6 – Compressive strength at 14 days

S. No.	%age of Steel Fiber	Specimen 1 (MPa)	Specimen 2 (MPa)	Specimen 3 (MPa)	Avg. Strength (MPa)
1	0	34.2	34.8	33.7	34.2
2	0.6	36.8	38.4	37.5	37.56
3	1.2	42.8	40.6	39.4	40.93
4	1.8	38.8	37.5	36.9	37.73
5	2.4	40.8	41.9	39.7	40.8

Table 4.7 – Compressive strength at 28 days

S. No.	%age of Steel Fiber	Specimen 1(MPa)	Specimen 2(MPa)	Specimen 3(MPa)	Avg. Strength(MPa)
1	0	38.7	41.2	39.6	39.83
2	0.6	41.7	42.6	40.9	41.73
3	1.2	43.8	44.1	42.7	43.5
4	1.8	39.7	41.6	44.8	40.7
5	2.4	39.9	41.2	40.8	40.6

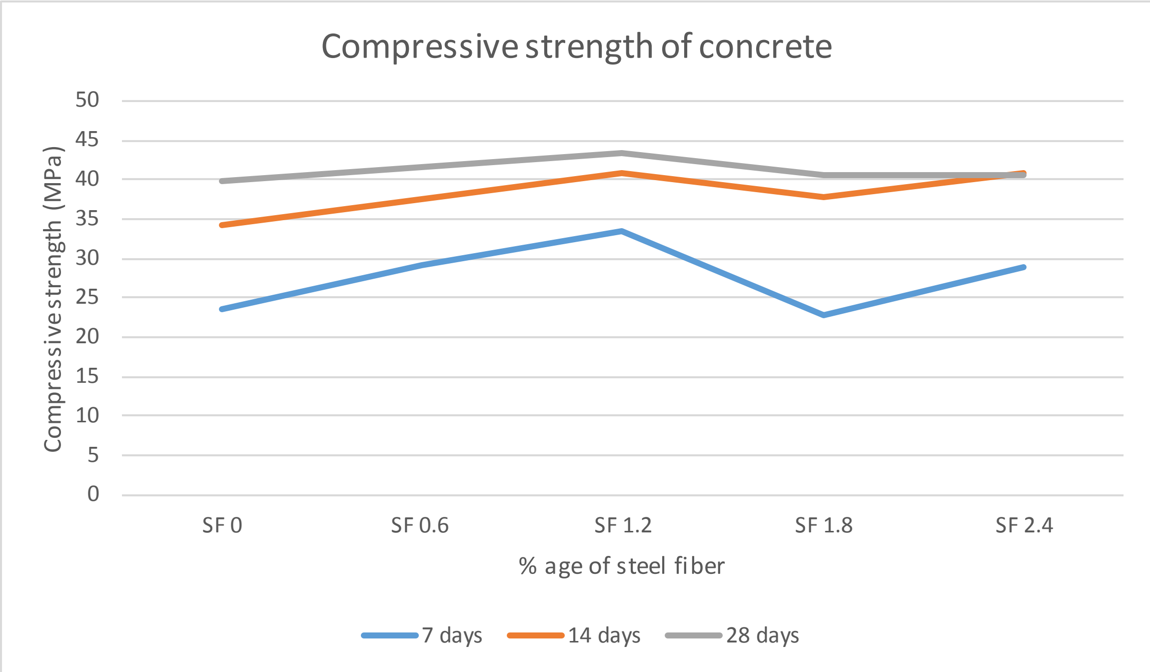

Fig. No. – 4.3 Comparison of compressive strength of concrete at ages with different %age of steel fiber.

CHAPTER 5

CONCLUSIONS

1. It can be concluded that optimum dosage of steel fiber for M40 concrete is 1.2 % by weight of concrete.
2. It can be concluded that compressive strength of SFRC get increased upto 42% with 1.2% steel fibres as compared to plain concrete.
3. It can be concluded that flexural strength of SFRC get increased upto 30% with 1.2% steel fibres as compared to plain concrete.
4. Incorporation of steel fiber has increased the ductile behaviour of SFRC.

REFERENCES

1. Biolzi L. et al. (2016), "Response of steel fiber reinforced high strength concrete beams: Experiments and code predictions," *Cement and Concrete Composites*, Vol. 77, 1-13, Elsevier.
2. Eid R. et al. (2016), "Compressive behaviour of FRP confined reinforced concrete columns,"*Engineering Structures*, 132, 518-530.
3. Li J. J. et al (2016), "Investigation on flexural toughness evaluation method of steel fiberreinforced lightweight aggregate concrete,"*Construction and Building Materials*, 131, 449-458.
4. Caratelli A. et al (2016), "Punching shear behavior of lightweight fiber reinforced concrete slabs,"*Composites Part B*, 99 , 257-265.
5. Pogorelov S. N. et al (2016), "Frost Resistance of the Steel Fiber Reinforced Concrete Containing Active Mineral Additives,"*International Conference on Industrial Engineering*, Procedia Engineering, 150, 1491-1495.
6. Grabois T. M. et al (2016), "Fresh and hardened-state properties of self-compacting lightweight concrete reinforced with steel fibers,"*Construction and Building Materials*, 104, 284-292.
7. Dunar C. et al (2015), "Studies on carbon fiber polymer confined slender plain and steel fiber reinforced concrete Columns," *Engineering Structures*, 102, 31-39.
8. Kim J. et al (2015), "Evaluation of mechanical properties of steel fibre reinforced concrete exposed to high temperatures by double punch test,"*Construction and Building Materials*, 79, 182-192.
9. Karadelis J. N. et al (2015), "Flexural strengths and fibre efficiency of steel fibre reinforced, roller compacted, Polymer modified concrete," *Construction and Building Materials*, 93, 498-505.
10. Xie T. et al (2015), "Behavior of steel fiber reinforced high strength concrete filled FRP tube columns under axial compression," *Engineering Structures*, 90, 158-171.
11. Patil S. et al (2014), "Study of Flexural Strength in Steel Fibre Reinforced Concrete,"*International Journal of Recent Development and Engineering and Technology*, Vol. 2, Issue 5, 13-16.
12. Harle S. et al (2014), "Steel Fiber Reinforced Concrete & Its Properties,"*International Journal of Engineering Sciences and Research Technology*, 30-32
13. Gadge N. A. et al (2013), "Mix Design of Fiber Reinforced Concrete (FRC) Using

Slag & Steel Fiber,"*International Journal of Modern Engineering Research*, Vol. 3, Issue 6, 3863-3871.

14. Vishnuram B. G. et al (2013), "Studies on Steel Fibre Reinforced Concrete – A Sustainable Approach,"*International Journal of Scientific and Engineering Research*, Vol.4 , Issue 5 May 2013, 1941-1944.
15. Choi S. Y. et al (2011), "A Study on the Shrinkage Control of Fiber Reinforced Concrete Pavement,"*12 East Asia – Pacific Conference on Structural Engineering and Construction*, Procedia Engineering 14 , 2815-2822.
16. Bureau of Indian Standards (1996), " Method of Physical Test for Hydraulic Cement, Part 1, Determination of Fineness by Dry Sieving," *Indian Standards 4031 (Part 1):1996*, Second Revision.
17. Bureau of Indian Standards (1988), " Method of Physical Test for Hydraulic Cement, Part 1, Determination of Soundness," *Indian Standards 4031 (Part 3)* : *1988* , First Revision
18. Bureau of Indian Standards (1970), " Specification for Coarse and Fine Aggregates from Natural Resources for Concrete," *Indian Standards 383* : *1970* , Second Revision, Table 4.
19. Bureau of Indian Standards (1970), " Method of Physical Test for Hydraulic Cement," *Indian Standards 4031 (Part 6)* : *1988*, First Revision, Clause 6.1.2.