JIMMA UNIVERSITY

SCHOOL OF POST GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

STRUCTURAL ENGINEERING

Experimental Study on the Effect of Waste Steel Fibers in High Strength Concrete properties

A research thesis Submitted to the School of Post Graduate Studies of Jimma University in Partial Fulfilment of the Requirements for the Degree of Master of Science in Structural Engineering

By

Kumela Mulisa

Feb, 2022

Jimma, Ethiopia

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Approval Sheet

This thesis has been summited for examination with my approval as university .The thesis tittle "**Experimental Study on the Effect of Waste Steel Fibers in High Strength Concrete properties"** Kumela Mulisa is approved for the degree of Master of Science in structural in engineering**.**

Approved by Board of Examiners:

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DECLARATION

This research thesis with title "**Experimental Study on the Effect of Waste Steel Fibers in High Strength Concrete properties "**is my original work and has not been presented by any other person for an award of a degree in this or any other university. I have identified all material in this thesis which is not my own work have been duly acknowledge.

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ABSTRACT

The potential use of fiber reinforcement for enhancing the mechanical properties of fiber reinforced concrete had been clearly established and recognized that fiber reinforcement is an effective way to enhance the fracture toughness of concrete in all modes of failure. However, most of the published work, has focused exclusively on steel fiber-reinforced normal strength concrete (SFRC).

This research have been focused on investigating the effect of steel fibers on workability, compressive strength, splitting tensile strength, and flexural strength of steel fiber reinforced concrete with varying fraction of fibers (0%, 1%, 1.50%, 2.% and 2.5%) by volume of concrete. Three Specimens were prepared for each fibers content with high concrete strength of 40MPa, and 60MPa. The non-fibrous specimen (0% fibers) is used as a controlled concrete and the comparative study between control specimen and steel fiber reinforced concrete were done on the mechanical performance of different high strength concrete depending on the result obtained from the tests. From the research, it was observed that the addition of fibers reduces workability of wet concrete. Concrete compressive strength decreased from 45.75MPa to 44.52MPa for C 40 and also for C 60 concrete strength decreases from 63.1MPa to 61.78MPa up to 1% but the value was greater than the required grade. The greater strength improvement was observed for tensile and flexural strength than compressive strength. The split tensile strength was increased as the percentage of steel fiber increased in the mix by 1%, 1.5%, 02% and 2.5% Steel Fiber addition. The maximum flexural strength was found at 2.5% steel fiber addition. Additional load carrying capacity after peak load is more observed for fiber reinforced concrete than control specimen. The crack bridging mechanism was more observed when fiber was used.

Keywords: *High strength Concrete, Compressive strength, split tensile and flexural strength*

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ABBREVATIONS AND ACCRONYMS

ACI	-	American Concrete Institute
ASTM	-	American Society for Testing and Material
d	-	Diameter
FRC	-	Fiber Reinforced Concrete
h	-	Height
HSC	-	High-strength concrete
HSSFC	-	High strength Steel fiber concrete
l	-	Length
mm	-	Millimeter
MPa	-	Mega Pascal
MOR	-	Modulus of Rupture
SFRC	-	Steel Fiber Reinforced Concrete
w	-	Width

CHAPTER ONE

INTRODUCTION

1.1. Background

Concrete is essentially a mixture of cement, aggregate and water. It is widely used in construction industry because all the raw materials required are widely available and are of low cost. Concrete is very strong in compression; however, it has a very low tensile strength. To improve its tensile strength, reinforcing steel is often used in the concrete. Apart from traditional steel reinforcement, various fibers are also used to improve the properties of concrete, mainly for enhancing the tensile strength. There are mainly four types of fibers which can be used to reinforce concrete: steel fiber, glass fiber, natural fiber and synthetic fiber (Yin *et al.*, 2015).

The engineering characteristics and economic advantages of high-strength concrete (HSC) are distinct from conventional concrete, thereby popularizing the HSC concrete in a large variety of applications in the construction industry. Used for high-rise buildings, HSC avoids the unacceptable oversized columns on the lower floors, allowing large column spacing and usable floor space, or increasing the number of possible stories without detracting from lower floors. (Swamy, 1987). Used for long span bridges, HSC reduces the dead load of bridge girders for fewer and lighter bridge piers and thus enables greater underpass clearance widths. HSC inspires substantial savings in expenditure on bridge maintenance, while prolonging the serviceable life of the bridges (Rabbat, and Russell, 1982).

Further, HSC possesses uniform high density and very low impermeability, endowing itself with excellent resistance to aggressive environments and disintegrating agencies, and benefiting the durability of concrete buildings and structures. (Mbessa and Pera J., 2001)

The comparatively higher compressive strength of HSC is an attractive profit; whereas, the strength behaves against the ductility of the concrete by welcoming brittleness pronouncedly. (Tasdemir, 1996). To foster the compressive strength without sacrificing the ductility, a strategy is to add discrete steel fibers as reinforcement in HSC (Hsu LS&Hsu T, 1994). As the high-strength steel fiber-reinforced concrete (HSSFRC) hardens, shrinks, or bears service loads to develop cracks and to propagate them, the fibers evenly distributed throughout the composite intersect, block, and even arrest the propagating cracks. This way, the addition of fibers contributes strength to the concrete (Chunxiang &Patnaikuni, 1999).

The SFRC is a composite material made of cement, fine and coarse aggregates and discontinuous discrete steel fibers. In tension SFRC fails only after the steel fiber breaks or pulled out of the cement matrix. The composite nature of SFRC is responsible for its properties in freshly mixed and hardened state (Dahake & Charkha, 2016).

The SFRC possess many excellent dynamic performances such as high resistance to explosion and penetration as compared to traditional concrete. When used in structural applications, SFRC should only be used in a supplementary role to inhibit cracking, to improve resistance to impact or dynamic loading and resist material disintegration (Dahake & Charkha, 2016).

The mechanical properties of SFRC are influenced by the type of fiber, aspect ratio, and volume fraction of fibers and the size of the aggregates. One of the most important properties of SFRC is its ability to transfer stresses across a cracked section which increases toughness of concrete in hardened state (Dahake & Charkha, 2016).

However, even after the addition of steel reinforcement, micro cracks in the mortar aggregate interface mostly still appear. Micro cracks are a microscopic crack on the material. On reinforced concrete, micro cracks often appear near the tensile reinforcement and over the time, those fine cracks open the entrance for air and water. Combinations that can occur when air and water enter then trapped in the same space with a metal material (Sisi *et al.*, 2018).

Therefore, the study on the combination of high strength concrete and steel fiber seems promising. Over the last four decades, numerous research articles, international conferences, and research committees demonstrated that the interest in the potential use of steel fibers as a replacement of stirrups in RC structures is increasing in the concrete industry. Until now, however, the use of steel fibers is limited in the construction industry due to a lack of design guidelines in the codes (Md Shahnewaz and M. Shahria, 2014).

This paper further investigated the strength improving potentials of HSSFRC containing 1%, 1.5%, 2%, and 2.5% volume of steel fibers in comparison with the plain concrete of 40 MPa and 60 MPa strength, and predicting the behavior of HSSFRC under compression, splitting tension, and flexural strength.

1.2. Statement of the Problem

The behavior and concrete mechanical properties are commonly known, and also one of the weaknesses of concrete as a material are brittle and its minor ability to restrain tension force. The HSC always possesses a steeper descending stress–strain curve in compression than does the normal strength concrete. The rapid decrease in compressive strength in the post-peak load region brings about a pronouncedly brittle mode of failure. Also to produce HSC it is clear to increase amount of cement content and this causes thermal cracking. Tensile strength of high strength concrete less than normal concrete.This research needed to improve the brittle behavior of HSC without affecting the ductility, the early thermal cracking and shrinkage and tensile strength of HSC. A strategy is to add discrete waste steel fibers as reinforcement in HSC extracted from byproduct of steel factory industry in Ethiopia such as METEC steel industry , by varying the amount of steel fibers (0%,1%,1.5%,2% and 2.5%) and using two different higher strength concretes (40 MPa and 60MPa) .

1.3. Research Questions

The study has been answer the following questions:

1. What is the effect of variation in steel fiber content on improving high strength concrete strength properties?
2. Does the effect of steel fibers on the higher strength concrete is affected by the change in concrete grade?
3. What is the optimum steel fiber content in improving the strength properties of higher strength concrete?

1.4. Objectives of the Study

1.4.1. General Objective

The general objective of the study is to investigate the effect of waste steel fiber on the strength behavior of high strength concrete.

1.4.2. Specific Objectives

- To investigate the effect of variation in waste steel fiber content on high strength concrete on C 40 and C 60.
- To describe the effect of change in concrete grade on the effectiveness of waste steel fibers in improving both, C 40 and C60,the mechanical behavior of high strength concrete.

- To determine the optimum waste fiber content that shows better results in high strength concrete mixture.

1.5. Significance of the Study

The overall aim of the present study was to investigate and improve the understanding of the behavior of high strength concrete with waste steel fiber which is locally available waste. Experimental tests had been performed to investigate the behavior of steel fiber in high strength concrete cubes, cylinders and beams after those would be loaded until failure. It also would be known that the output of this study will be added to the existing academic knowledge and enable to understand the subject matter as it paves the way for further investigation related to this. Moreover, it can benefit other parties of the society through. It allows the researcher to gain knowledge on the effect of waste steel fibers in high strength concrete, thereby build academic knowledge and provide base for further career improvement with this locally available material.

1.6. Scope and limitation of the Study

Since the study of steel fibers effect on reinforced concrete member in recent years includes adverse analysis and experimental investigation. Many researchers studied the compressive strength, tensile strength, flexural Strength and shear strength behavior.

This study have been determine the mechanical properties of high strength concrete with a varying steel fibers volumes (0%,1%,1.5%,2% and 2.5%) by concrete volume for C-40 and C-60 concrete grade after conducting experimental test on fresh concrete (slump test) and on hardened concrete (compressive, tensile strength and flexural strength) tests.

Since casting of the beams with different length in laboratory is time consuming and limited amount of fibers are available, the study were used single beam type. The study was limited to investigate the mechanical behavior of simply supported beam with the formerly mentioned variations of steel fiber content without considering other parameters like; shear span-depth ratios (a/d), flexural reinforcement ratio (ρ), and size of the beam under monotonic center point loading.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1. Concrete

Cement concrete is the most extensively used construction material in the world. The reason for its extensive use is that, the concrete provides good workability and can be molded in any shape (Ajay, 2016) according to the author idea concrete is a composite material composed of aggregate, generally sand and gravel, chemically bound together by hydrated Portland cement. The aggregate generally is graded in size from sand to gravel, with the maximum gravel size in structural concrete commonly being $\frac{3}{4}$-in. or $1\frac{1}{2}$ in. aggregate may be used (James, K. & James,G.,2012).The author discussed that "Plain concrete has two major deficiencies, Aghuy low tensile strength and a low strain at fractures (Mahadik.Et Al.,2014) accordingly the tremendous growth in the infrastructure necessitates the use of quality concrete to serve for long term performance. However, a major setback in the construction industry is the expensive construction materials and early deterioration of conventional concrete due to inappropriate concrete design (Abibasheer and Sivakumar, 2015).

The term high-strength concrete (HSC) is generally used for concrete with compressive strength higher than 40 MPa (Duggal, 2016). The use of HSC has steadily increased over the past years, which leads to the design of smaller sections. This in turn reduces the dead weight, allowing longer spans and more usable area of buildings. Reduction in mass is also important for economical design of earthquake resistant structures (Nilson, 1987), (Swamy, 1987) & (Wafa, 1992). Such advantages outweigh the higher production cost of HSC. HSC is a brittle material, and as the concrete strength increases the post-peak portion of the stress-strain diagram almost vanishes or descends steeply.

The increase in concrete strength reduces its ductility, and this is a serious drawback for the use of HSC. A compromise between these two characteristics of concrete (strength and ductility) can be obtained by adding steel fibers (Swamy, 1987), (Wafa, 1992), (Carrasquillo, 1981) & (Slate, 1986).

2.2. Fiber Reinforced Concrete (FRC)

Fiber Reinforced Concrete (FRC) is a composite material made primarily from hydraulic cements, aggregates and discrete reinforcing fibers. Fiber incorporation in concrete, mortar and cement paste enhances many of the engineering properties of these materials such as fracture toughness, flexural strength, resistance to fatigue, impact, thermal shock etc., and guidelines which fully utilizes the advantages of FRC (Dahake & Charkha, 2016).

Technically, it is possible to produce FRC of very high tensile strength using high fiber content but it is not feasible for structural applications due to practical reasons. For the use of high fiber content leads to severe reduction of the workability of the fresh concrete. FRC is limited to applications where crack distribution and reduction of crack widths is the main purpose.

The fiber reinforced concrete is produced using different types of fibers. The fibers are mainly classified in two groups as metallic and non-metallic fibers (Dahake & Charkha, 2016).

2.2.1 Tensile and Compressive Behavior of FRC

High-strength steel-fiber concretes with and without tie confinement were tested to study stress-strain behavior subjected to uniaxial compression. Typical tensile stress–strain responses for plain and fiber reinforced concrete registered in experimental tensile tests are done and presented as follows in Figure 2.1 by researchers, Lin and Hsu (1994).

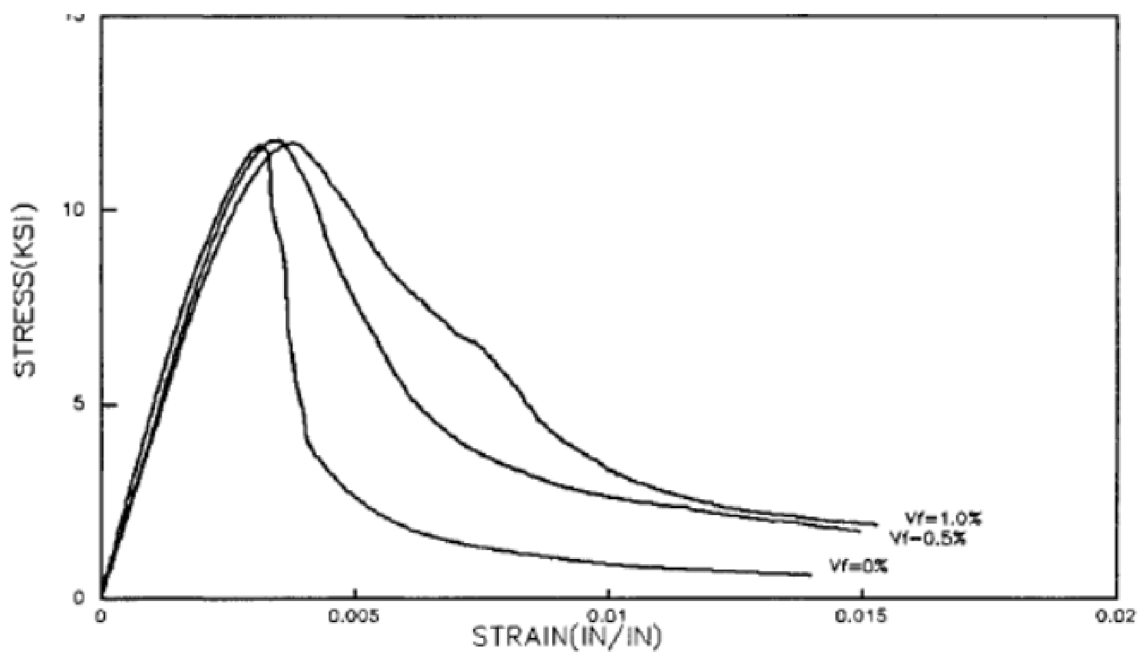

Figure 2. 1 Influence of volume fraction of fiber on compressive stress-strain curves (Lin and Hsu, 1994

2.2.2 Applications of FRC

It is used on account of the advantage of increased static and dynamic tensile strength and better fatigue strength. (Kaur, 2017).FRC is used for:

- Runway, Aircraft parking and Pavements
- Industrial flooring
- Tunnel and canal lining
- Dams and Hydraulic structures
- Composite decks
- Impact resisting structures

2.3. Steel Fiber Reinforced Concrete (SFRC)

According to ACI Committee 544, 2010, Concrete with steel fiber concrete is defined as concrete made from a mixture of cement, fine and coarse aggregates and little steel fibers. Generally, the size of steel fiber used is not more than 76 mm in length, while its diameter is less than equal to 1 mm.

The composite nature of HSSFRC is responsible for its properties in freshly mixed and hardened state. The SFRC possess many excellent dynamic reflected to the tested properties.

The mechanical properties of steel fiber reinforced concrete are influenced by the type of fiber; length-to diameter ratio (aspect ratio); the amount of fiber; the strength of the matrix; the size, shape, and method of preparation of the specimen; and the size of the aggregate. For this reason, mixtures proposed for use in design should be tested, preferably in specimens representing the end use, to verify the property values assumed for design (ACI 544.4R, 1999).

2.4. Compressive and Tensile Behavior of HSSFRC

Concrete is a brittle material with very low tensile strength in comparison with its compressive strength. It is estimated that its tensile strength about 10% of its compressive strength. The tensile failure of plain concrete starts with cracks. Consequently, one of these cracks will extend along the member leading to its structural failure (Al-lami, 2015).

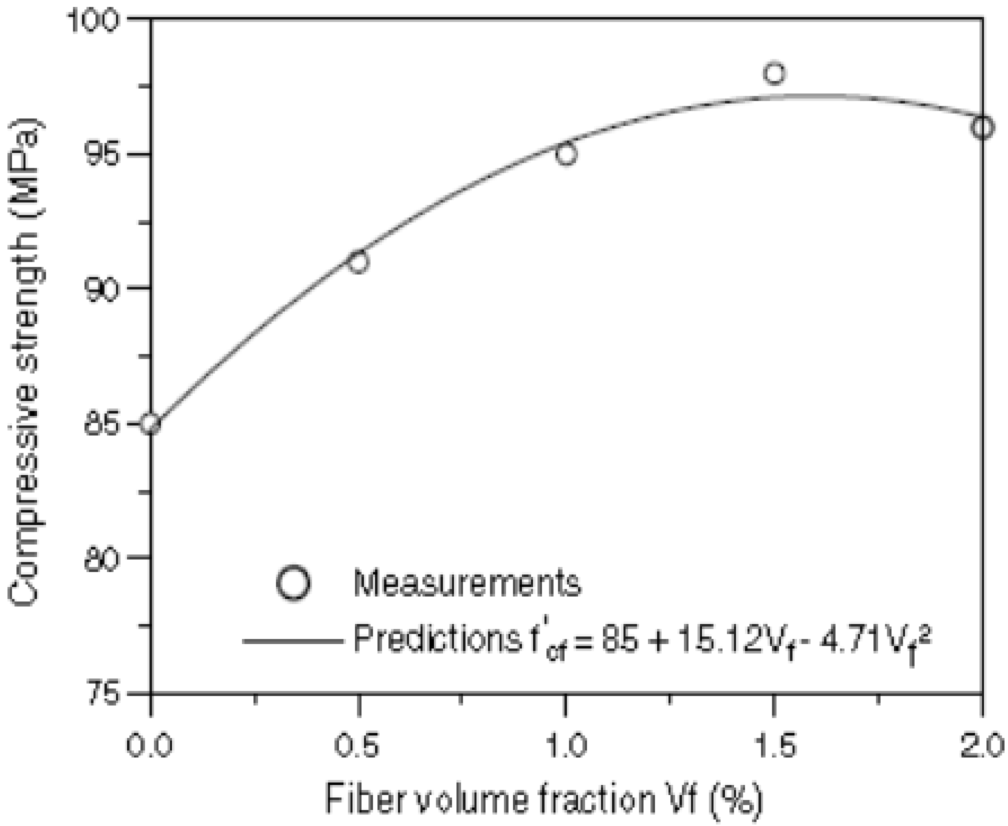

Figure 2. 2 Effect of fiber volume on compressive strength of HSSFRC (Ajah Dahake, 2016)

The compressive strength development of HSSFRC versus HSC appears Figure. 2.2, declaring that the compressive strength of HSC was 85 MPa and of HSSFRC provided an improvement at each volume fraction. The compressive strength improvement of HSSFRC ranged from 7.1% to 15.3% at the volume fractions of 0.5% to 2.0%, comparable to the improvements of 4.3–10.4% for normal-strength concrete at the same fractions. Addition of steel fiber irrespective of type and aspect ratio improves the compressive strength of concrete. Strength comparison between same aspect ratio HK-80 and RD-80 is 54.95 MPa and 50.59 MPa respectively and HK-50, RD-50 and CR-50 is 52.30 MPa, 46.62 MPa and 51.79MPa respectively (Ajah Dahake,2016).

There is gradual increase in the compressive strength with the increase in fiber content for the different types of concrete. The percentage increase in compressive strength due to fiber addition for the different types of concrete. For NSC, the increase of the steel fiber content from 0.0 to 0.5% resulted in an increase in the compressive strength by 11.1 and 6.8 % for concrete containing hooked-end fibers and corrugated steel fibers, respectively. Increasing the fiber content to 1% for the same concrete type resulted in a dramatic increase in the compressive strength by 30 and 20.4%, respectively. A further increase in fiber content to 2% led to a further increase of the compressive strength by 39 and 29.6%, respectively (Hanaa I., 2005).

(Rizkiani et al., 2018) performed tests to determine compressive strength of HSSFRC on a total of 36 cylinders with 10 cm diameter and height 20 cm for each variation of steel fiber content with the amount according to the test result the compressive strength of plain concrete is lower than steel fiber concrete. Average values of compressive strength increased by increasing the fibers volume content. On concrete with 1% steel fiber showed a slight improvement of the peak compressive strength of about 2.5% compared to the plain concrete. On concrete with 2% steel fiber showed better improvement of the peak compressive strength of about 25.7% compared to the plain concrete. On concrete with 3% steel fiber showed improvement of the peak compressive strength of about 11.4% compared to the plain concrete. However, the compressive strength shows a better result on concrete with 2% steel fiber.

(Song and S. Hwang, 2004) performed tests on the development of splitting tensile strength of HSSFRC at various volume fractions; compared to HSC, the strength of HSSFRC improved with increasing the volume fraction. From the strength effectiveness, the improvement started from 19% at 0.5% fraction and expanded to 98.3% at 2.0% fraction.

2.5. Flexural Strength and Flexural Toughness of HSSFRC

It has been reported that for the flexural strength and modulus of rupture, The modulus of elasticity of HSSFRC mixes with 1.5 %, 3.0 %, 4.5 % and 6.0 % dosage of fibers was obtained 104 %, 106 %, 110 % and 111 % respectively higher than that of plain concrete. Similarly, also noted at 28 days 405 %, 408 %, 522 % and 471 % that was higher than the plain concrete.

The modulus of rupture for HSSFRC at various volume fractions appears in Figure 2.3. And the strength-effectiveness indicates that the MOR values were higher by 28.1%, 57.8%, 92.2%, and 126.6% at the fractions of 0.5%, 1.0%, 1.5%, and 2.0%, respectively, compared to the HSC (Song and Hwang,2004).

Steel fibers can increase the displacement of beams at failure. The central displacement at 80% ultimate load in the descending curve is increased by about 12.2, 35.1 and 12.2%, respectively, by the addition of fibers I, II and III. And after 80% ultimate load I n descending, the load-displacement curve of concrete beams without steel fibers falls much faster with the increase in displacement, which means that the concrete beams with steel fibers possess better ductility (Chunxiang, 1998).

The flexural strength increases proportionally due to the addition of steel fiber. Concrete ductility is indicated by the addition of ≥ 2% steel fiber (Rizkiani et al., 2018).

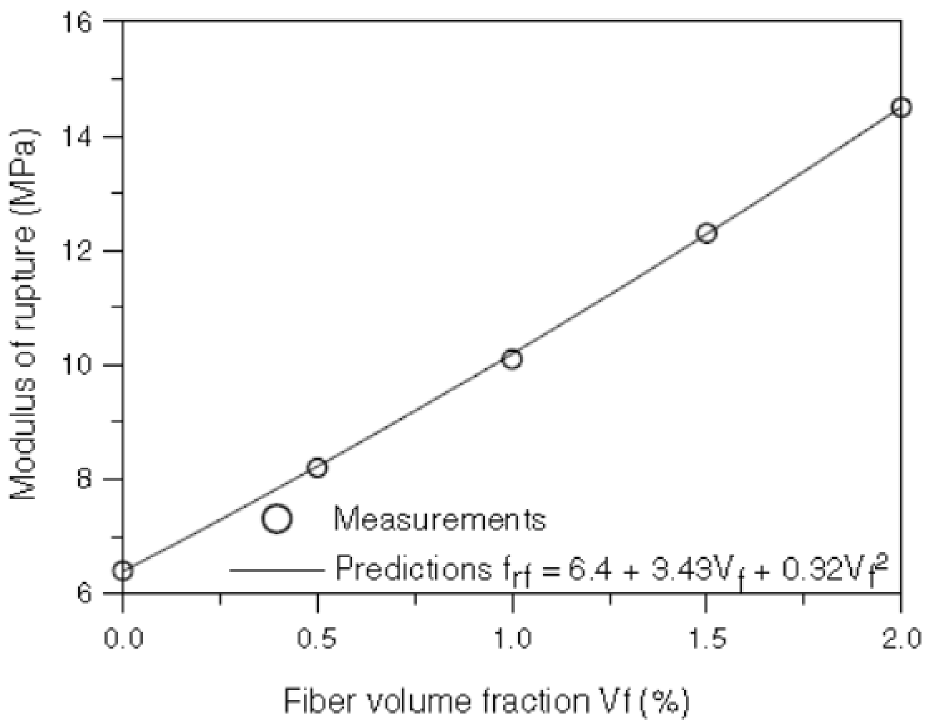

Figure 2. 3 . Effect of fiber volume on modulus of rupture (Rizkiani et al., 2018).

CHAPTER THREE

MATERIALS AND RESEARCH METHODOLOGY

3.1 Material used

Materials that have been used are cement, fine aggregate, coarse aggregate, waste steel fiber, Super plasticizer and water with specification for to the conventional concrete. According to this study, conventional concrete signifies the usual concrete which contains cement, water and virgin (Natural) aggregate as a basic constituent. To prepare sample Ordinary Portland Cement, washed sand, natural coarse aggregate, Steel Fiber, Super plasticizer, mixing and curing water, mixer and curing tanker were required to cast sample beam, cube and cylinder. For the experimental set up automatic compression testing machine was also used in order to test the flexural, compressive and split tensile strength test of high strength steel fiber concrete sample.

3.2 Research Design

In order to achieve the required specific objectives, the experimental investigations were applied on the research. The total number of populations that considered in the study was the numbers of 30 beams, 30 cubes and 30 cylinders used as a control for the experiment per each grade and the number of composite samples of steel fiber concrete per each grade. Based on percentage of addition in the concrete the samples of three were casted for each 7^{th} and 28^{th} day test. The sampling technique used for this research is a non-probability sampling technique which is the purposive method. This sampling technique has been used based on the information that the researcher has and the aim or goal of the researcher to be achieved. An experimental study has been implemented to manipulate the independent variables, and then justified for the steel fiber based on the experimental result. Finally, recommendation was given based on the approaching experimental results.

3.3 Study Variables

3.3.1 Independent variable

Independent variables are the variables which are changed or controlled in a scientific experiment to see the effect on the dependent variables.

a) Percentage of steel fiber added.

b) Concrete strength

3.3.2 Dependent variables

a) Concrete properties

*Workability of fresh concrete

* Hardened concrete strength (i.e Compressive, Split tensile strength And Flexural strength).

3.4 Materials for laboratory experimental works

- **Cement: -** "Dangote" Ordinanary Portland Cement (OPC) whose grade is 42.5R was used throughout the study in the preparation of concrete mixes.
- **Steel Fiber: -** The name steel fiber may include different type of shape with various length and diameter range, which is purposely added to concrete mix to improve tensile strength. Fibers that are required for the study is collected from metallurgical industrial firms in Addis Ababa. Steel fibers (straight and coil spiral) are used to enhance the hardness of the concrete. Adding steel fibers to the composition may alter the crack pattern, slowing down the appearance of the crack and preventing the development of cracks in concrete specimen while inserting short fibers improves concrete strength and reduces the risk of crack formation. One of the most important properties of steel fiber reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. A fiber aspect ratio is defined as its length divided by its diameter. Long, thin fibers often provide superior properties, but are also often more difficult to disperse uniformly in the composite. The typical aspect ratios ranges from 20 to 150.Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Diameter of steel fiber was in the range of 0.25 to 0.76 mm.

  There were two shapes, straight and coil spiral, of waste steel fiber selected for mix purposes as shown in Fig. 3.1. Based on ACI 544.3R-93 specification of steel fibers, and averagely 0.5mm diameter and 50mm length respectively used. The aspect ratio (*l/d*) was fixed to 100 used in the research. For straight steel fiber, the thickness was used as *d* and for coil spiral waste steel fiber coil diameter was used as *d* in calculating aspect ratio. The waste steel fiber inherits the material properties of the main structural steel, the elastic-perfectly plastic model was adopted due to its adequate accuracy and simplicity. Poisson's ratio was set to 0.3, relative density to 7850 $kg/m^{3,}$ and young's modulus to 205,000 MPa. Three volume ratios of waste steel fiber were selected, 1 %, 1.5 %, 2% and 2.5 %, and added to concrete during mix by volume of concrete.

Figure 3. 1 Shows sample steel fiber with different shape

- **Coarse aggregate: -** Locally available crushed stone which is a 20mm, 12.5mm and below maximum nominal size was used.

Figure 3. 2 Shows sample of Coarse Aggregate

- **Sand: -** "Gambella" sand which is commonly available in Jimma City (obtained from Yetababarut).

Figure 3. 3 Sample of washed natural sand

- **Water: -** Drinkable water (potable water) obtained from Jimma institute of technology campus. For both curing and mixing purposes.
- **Super plasticizer**: - In order to achieve concrete with sufficient workability the use of super plasticizers is important. Large quantities, which are up to 5 % of cement mass, are required. However, only the third generation of plasticizer (Polycarboxylate ether, PCE) which allows for sufficient amount of water to make concrete can be implemented. At high doses, the super plasticizer not only has a significant effect on the early cement hydration process but also on later microstructure development.

3.5 Procedure for laboratory experimental works

3.5.1 Sample preparation stage

Natural coarse aggregate, fine aggregate and cement has been bought, and also steel fiber waste is collected from metallurgical industrial firms in Addis Ababa.

3.5.2 Laboratory tests on concrete main ingredients

Tests on aggregate according to ASTM standard procedures

The detailed procedure for finding aggregate properties are illustrated under appendixes.

Tests on cement. Cement properties were conducted as per ASTM standard specification. The detailed procedure for finding cement properties are illustrated under appendix.

3.5.3 Concrete mix design preparation and mixing of concrete

a) C-40 and C 60 Concrete mix-design has been prepared for each concrete grades according to the ACI methods. The detailed procedure for concrete mix design are illustrated under appendices. The following table 3.1 shows the summary of the ratios under each grade.

Table 3. 1 Summary of concrete mix proportion

S. No	Concrete Grade	Cement :Sand :Coarse aggregate	Water to Cement ratio
1	40	1:1.59:2.84	0.48
2	60	1:1.13:2.24	0.41

b) Mixing of concrete

A total of 90 samples, 30 Cubes for compression strength ,30 cylinders was prepared for splitting test and 30 beams was prepared for conducting the flexural test samples has been casted by using 150mm*150mm*150mm cube, Ø100mm*200mm height cylinder and 500mm*100mm*100mm flexural beam dimension per each grade of steel fiber concrete respectively.

Coding (identification) the sample of concrete cubes, cylinders and beam has been done after 24 hrs. And remolding and curing of the concrete cubes, cylinder and beam sample has been proceeded.

3.5.4 Fresh Concrete properties

Among the properties of fresh concrete, workability determines the amount of work required for placement and compacted that determines the resistance to segregation.

a) Slump test

A slump test was conducted to determine the workability of the mixes after the mixing was finished. It is the most widely used method to check the consistency of concrete. The method as devised in the late twenties of America was a simple frustum of a cone. According to ASTM 143(23), the frustum of a cone 305mm high, 203mm and 102mm diameter at the bottom and top respectively. After being moistened, it is placed on a smooth and wide surface plate and filled with concrete sample in three layers each approximately one third of the volume of the cone and also each of layer tamped 25 times. This test is conducted to determine fresh concrete properties and workability. Workability is influenced by different factors, among which are water content, cement content, aggregate characteristics, admixtures, fiber type and content.

In some studies, the test is conducted for collated fibrillated polypropylene fiber reinforced concrete having fiber contents ranging from 0.1 to 2.0 percent by volume. Although fibrillated polypropylene fibers, cement, and aggregates were added to the mixer simultaneously, no balling occurred even at higher quantities of fibers. The fresh concrete with fibrillated polypropylene fibers had no surface bleeding and no segregation.

In this research the test is conducted prior to compressive strength test in both type of fibers for each volume of fiber content to estimate water cement ratio and maintain equal strength.

From the kinds of slump, true slump is associated with workable while the remaining are associated with harsh mixes that lack cohesion.

Figure 3. 4 Shows slump type by figure

3.5.5 Casting and Curing

Proportionally mixed concrete was placed in the moulds of cube, cylinder and flexural beam after workability were checked for different percentage of mixes. During the cast of concrete compaction was executed in three layers with twenty-five tamps for each layer. For each percentage of mix, Six cube mould having a size of (150 mm *150mm* 150mm), Six cylinders of 100mm diameter and 200mm height and Six flexural beam mould having a size (100mm *100mm* 500mm) were casted for compressive, cylinder and flexural strength test of each high strength steel fiber concrete grade. Bonding between concrete and steel mould was prevented by coating with a release agent. Carefully obtained samples of the concrete mix was placed and compacted in steel moulds. The high strength steel fiber concrete mix was casted in the mould for the first 24 hours and then marked with the date of mixing and batch name. After that, the specimens were removed from the mould and cured in the water tanker at a temperature of 23±1°c until the testing age was reached 7 and 28 days.

3.5.6 Hardened Concrete Properties

After 7 and 28 days curing of the concrete sample, the compressive strength, split tensile and flexural test of the concrete has been taken by using automatic compression testing.

3.5.6.1 Compressive strength test

Concrete structures are designed to resist compressive strength. It has great practical and economic significance because the sections and sizes of the concrete structures are determined by it. It is also the most common type of destructive test for concrete.

Using a simple standard cube mould (150x150x150) mm mean and filling by plain concrete considering 0% steel fiber as a control parameter, on the other side for the same dimension filling by concrete which is mixed with steel fiber by volume, the percentage of the mixed have been 1%, 1.5%, 2% and 2.5% by volume then considering all curing requirements up to the time of test, the final test have been done on 28 days.

In the 7th and 28th days of the curing period the concrete cube specimen was removed from the curing tanker and then placed in dry surface until the specimen was surface dried. To determine the density or unit weight, the specimen was weighted before compression test. The specimen was tested by a compression testing machine as per ASTM C 39 specification. The cube is centrally placed inside of a compression testing machines and the load is applied such that the stress increase at the given constant rate until failure. Loading rate for 150 mm cube was 6.79 kilo newton per second until the specimen fails.

a) during crushing

b) crack pattern after crushing

Figure 3. 5 Shows compression strength test set up and after peak load

3.5.6.2 Compressive stress - strain behavior of waste steel fiber concrete

A complete stress strain curve is a basis for concrete structural analysis and design. The mechanical properties of concrete strength like ultimate strain and modulus of elasticity influences the main characteristics of the stress strain curve. The basis of some design codes are descending portion of the curve and ultimate strength. As a result, determining sufficient information to plot stress strain is important for both structural design and analysis. The focus of this study was the effect of steel fiber percentage on the compressive behavior of high strength steel fiber concrete subjected to uniaxial compression load. The behavior of the stress strain curve was studied based on the major parameters like peak strain and peak stress. The strain at peak stress is important in the development of analytical stress and strain curve and specification of failure criteria. The descending shape of the curve and its part of the area represents the plastic deformation ability of concrete; it also indicates the residual strength material after the peak stresses.

$\frac{\sigma c}{fcm} = \frac{K\eta-\eta\verb|^|2}{1+(K-2)\eta}$…………………..equation (1) from ES EN 1992-1-1: 2015.

Where, fcm is peak stress of concrete.

σc is the corresponding stress from sample reading.

$K = \frac{1.05*Ecm*\mathcal{E}c1}{fcm}$ ………………….equation (2)

$\eta = \frac{\mathcal{E}c}{\mathcal{E}c1}$ ………………………….equation (3)

Ecm = 22(fcm/10)$^{0.3}$…………………………………………. equation (4)

Ɛc is the corresponding strain from stresses

Ɛc1 is the peak stress corresponding to the peak stresses of the samples from table 3.1 ES EN 1992-1-1: 2015.

3.5.6.3 Split tensile strength test

This test is an indirect tensile strength test for concrete. It was carried out on a standard cylinder, tested on its side in diameter compression. The load is usually applied on its side in a narrow bearing strip along it height dimension. Failure was in splitting tension at a much lower load than would be required to crush the specimen in compression. The test was conducted as per ASTM C 496 specification for split tensile strength.

A simple cylindrical standard apparatus with a size of 100mm × 200mm (d× h) have been filled by plain concrete (0% steel fiber) to use as a control parameter, on the other side the same dimension has been filled by a mixture of concrete with steel fiber in 1%, 1.5%, 2% and 2.5% by volume of concrete and considering all curing requirements up to the time of test, the final test have been done on 28 days.

Finally, from the result of split tensile strength of the concrete for each case, the average value of tensile strength have been used to make comparison between different fibers content

a) Crack pattern during crushing b) Crushed cylinder after peak

Figure 3. 6 Shows the setup of Split tensile strength and after peak load

3.5.6.4 Flexural strength test

Flexural behavior of steel fiber reinforced concrete beam have been investigated based on American Society for Testing and Material (ASTM) C1609 "Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (using beam with Four-point loading)".

All the flexural beams are 500×150×100 mm (length × width× height) in size and they have been filled with plain concrete (0% steel fiber) as a control parameter and the same size of beam have been filled with a mixture of concrete and four different percentages of steel fiber fractions of 1%, 1.5%, 2% and 2.5% by volume of concrete, have been tested on 28 days.

Based on ASTM C1609, the modulus of rupture is calculated according to the peak flexural load of a beam specimen in the four-point loading test is measured to determine the flexural strength. This material property have been defined for each fiber dosage and the comparison is done between C-40 and C-60 concrete grade and plain concrete to examine the effect of steel on high strength concrete and define the relationship between fiber content and concrete strength.

The strength was determined from the formula of flexural stress.

$\sigma = \frac{MY}{I}$

Where σ is flexural strength in MPa

M – Maximum bending moment at the point of rupture in Nm

Y – The maximum distance from the neutral axis to either to the top or to the bottom extreme edge of the beam cross section.

I – Moment of inertia of the cross section about the neutral axis. Given by;

$I = \frac{bd^3}{12}$

After simplification for two point loading the flexural stress at the mid span of the beam is calculated as follows

Flexural stress = $\frac{PL}{bd^2}$ Where

P -Rupture load in N

L-Length of the beam between the two supports (300mm)

b – Width of the beam cross section (100mm) and

d – Depth of the beam (100mm).

a) Set up for crushing b) Crack after rupture

Figure 3.7 shows the setup of Flexural strength and after peak load

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Physical property of aggregates

Under physical property of materials, the material quality test was conducted. The detailed procedure of material quality is under appendix I. The following table 4.1 shows the summary of the results.

Table 4. 1 Summary of water absorption, specific gravity, unit weight and moisture content of aggregates

Aggregate	Apparent Specific Gravity	Bulk Specific Gravity (SSD)	Bulk Specific Gravity (Oven Dried based)	Absorption Capacity (%)	Unit weight (Kg/m^3)	Moisture Content (%)
Fine	2.59	2.58	2.53	0.88	1697.6	2
Coarse	2.862	2.71	2.786	1.5	1695	0.75

For doing any activity of concrete as much as possible doing some experimental activity is the main concerns for the determined concrete grade. So, the quality of material was conducted as per the standards and test result was with the required specification regarding to the test results.

4.1.2 Gradation of aggregates

Gradation or sieve analysis was conducted to determine particle size distribution of aggregate. The detail procedure was explained under the appendix I F. The graph 4.1 below shows the results.

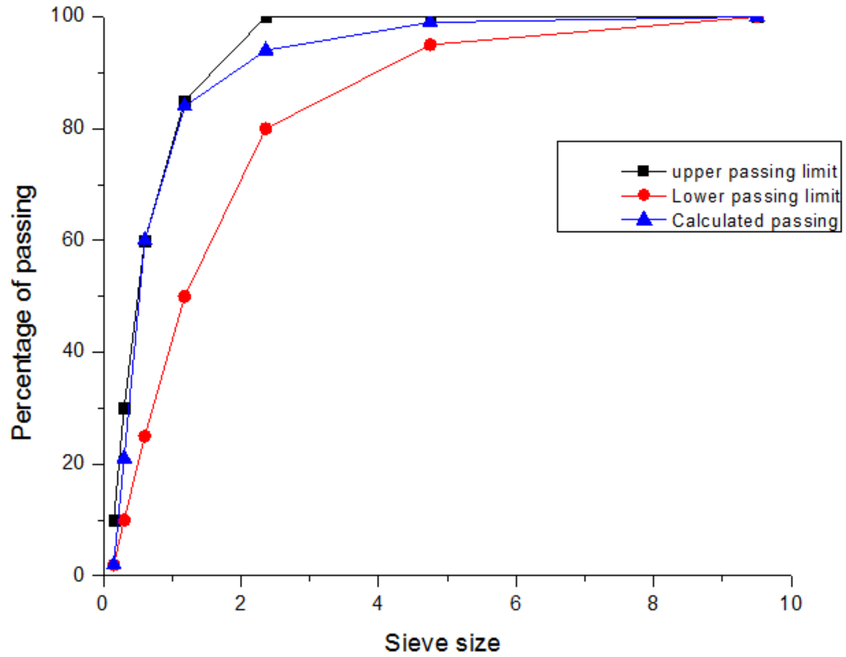

Figure 4. 1 Particle size distribution curve for fine aggregate

Fineness Modulus = 2.6.

As the Fineness Modulus value shows the fine aggregate is medium sand and well graded fine aggregate as per figure 4.1 shows. As the degree of fineness increases the inter lock capacity of sand increases and it consumes less amount of cement and high amount of water required to increases fluidity of concrete.

4.2 Cement physical properties determination

Table 4. 2 The summary of normal consistency of Cement

Trial No	W/C	Cement quantity(g)	Water quantity(g)	Penetration depth(mm)	Remark w/c = [0.26, 0.33] penetration depth=10±1 mm
1	0.3	400	120	6	Not satisfy
2	0.32	400	128	8	Not satisfy
3	0.33	400	132	10	Ok

Table 4. 3 Summary of setting time and fineness of cement

Cement Brand	OPC
Initial setting time of Cement,(Minutes)	180
Final setting time of Cement(minutes)	306
Specific gravity	3.15
Fineness of cement (%)	10

4.3 Workability of high strength concrete with steel fiber

4.3.1 Slump test

From the kinds of slump true slump is associated with workable while the remaining are associated with harsh mixes that lack cohesion. The drawback of this test is not helpful for stiff concrete mixes. For stiff consistency concrete mixes compacting factor test is more suitable.

Table 4. 4 Summary of the slump for C 40 concrete.

Mix code	%addition	Slump height, mm	Remark
C 40-0	0	36	Ok
C 40-1	1	22	Not ok
C 40-1.5	1.5	20	Not Ok
C 40 -2	2	15	Not Ok
C40-2.5	2.5	05	Not Ok

As the researcher was observed from the laboratory results on table 4.4, after mixing of concrete for both waste steel fiber concrete and control of concrete, there was some value variation due to the amount of waste steel fiber added. As the result indicated, as the percentage of waste steel fiber increased the amount of slump height decreases. The amount of slump height decreases as the content of steel fiber increased. This implies that the amount of fluidity of concrete decreases because the consumption of water is more than conventional concrete.

Table 4. 5 Summary of the slump for C 60 concrete.

Mix code	%replacement	Slump height, mm	Remark
C 60-0	0	39	OK
C 60-1	1	26	Ok
C 60-1.5	1.5	23	Not Ok
C 60 -2	2	10	Not Ok
C 60-2.5	2.5	5	Not Ok

As the researcher was observed from the laboratory result on table 4.5, after mixing of concrete for both waste steel fiber concrete and control of concrete, there was some value variation due to the amount of steel fiber added. As the table 4.5 indicated, as the percentage of waste steel fiber increased the amount of slump height decreases. The amount of slump height decreases as the content of steel fiber increased. This implies that the amount of fluidity of concrete decreases because the consumption of water is more than conventional concrete.

4.4 Hardened concrete test result for both grade

4.4.1 Compressive strength test result

Concrete structures are designed to resist compressive strength. In the 7th and 28th days of the curing period the concrete cube specimen was removed from the curing tanker and then placed in dry surface until the specimen was surface dried. And finally, test were conducted. The seven day of curing was conducted as the minimum strength determination while 28 days was the maximum limit as per the standard.

Table 4. 6 Shows the numerical difference from C40 conventional high strength concrete.

Sample	Age	%age	Compressive strength,Mpa	Numerical Difference	Min.Requirement,MPa According to EN ES ,2015
C 40	7th day	0	36.05	0	32.75......Ok
		1	35.08	-2.7	32.75......Ok
		1.5	30.71	-14.8	32.75......Not Ok
		2	27.88	-22.7	32.75......Not Ok
		2.5	23.94	-33.6	32.75......Not Ok
C 40	28th day	0	45.75	0	40....Ok
		1	44.52	-2.7	40....Ok
		1.5	39.78	-13.0	40....Not Ok
		2	35.45	-22.5	40…Not Ok
		2.5	31.36	-31.5	40....Not Ok

As the result on table 4.6, shows the strength development trend was decreased as the percentage of steel fiber increases. This due to lack of inter lock with the ingredients by each other and non-uniformity of steel fiber in size. Based on the result, the researcher want to recommend less amount of waste steel fiber to resist crack propagation of concrete and also to increases the ductility of concrete especially up to 1% steel fiber addition based on EN ES, 2015.

Table 4. 7 Shows the numerical difference C60 from conventional high strength concrete

Sample	Age	%age	Compressive strength,Mpa	Numerical Difference	Min.Requirement,MPa According to EN EBCS,2015
C 60	7th day	0	45.85	0	43.72....Ok
		1	44.62	-2.69	43.72....Ok
		1.5	38.98	-12.44	43.72....Not
		2	35.35	-9.31	43.72....Not
		2.5	30.36	-14.12	43.72....Not
C 60	28th day	0	63.1	0	60...Ok
		1	61.78	-2.09	60...Ok
		1.5	58.34	-7.54	60....Not
		2	50.92	-19.30	60....Not
		2.5	50.34	-20.22	60....Not

As the table 4.7 indicated, compressive strength of concrete decreases as the percentage of steel fiber increases. Because the bondage between ingredients decreases due to consumption of cement paste on fiber surfaces. As the table 4.7, shows the strength development trend was decreased as the percentage of steel fiber increases. This due to lack of inter lock with the ingredients by each other and non-uniformity of steel fiber in size. Based on the result, the researcher want to recommend less amount of steel fiber to resist crack propagation of concrete and also to increases the ductility of concrete especially up to 1% steel fiber addition based on EN EBCS, 2015.

4.4.1.1 Compressive stress - strain behavior of concrete

A complete stress strain curve is a basis for concrete structural analysis and design. The mechanical properties of concrete strength like ultimate strain and modulus of elasticity influences the main characteristics of the stress strain curve. The method of calculation have been stated under methodology. That means equation (1) up to (4) under chapter three. Finally, after the equation became quadratic form, the researcher uses Sci lab software for calculation of strains and figure have been plotted by using origin software

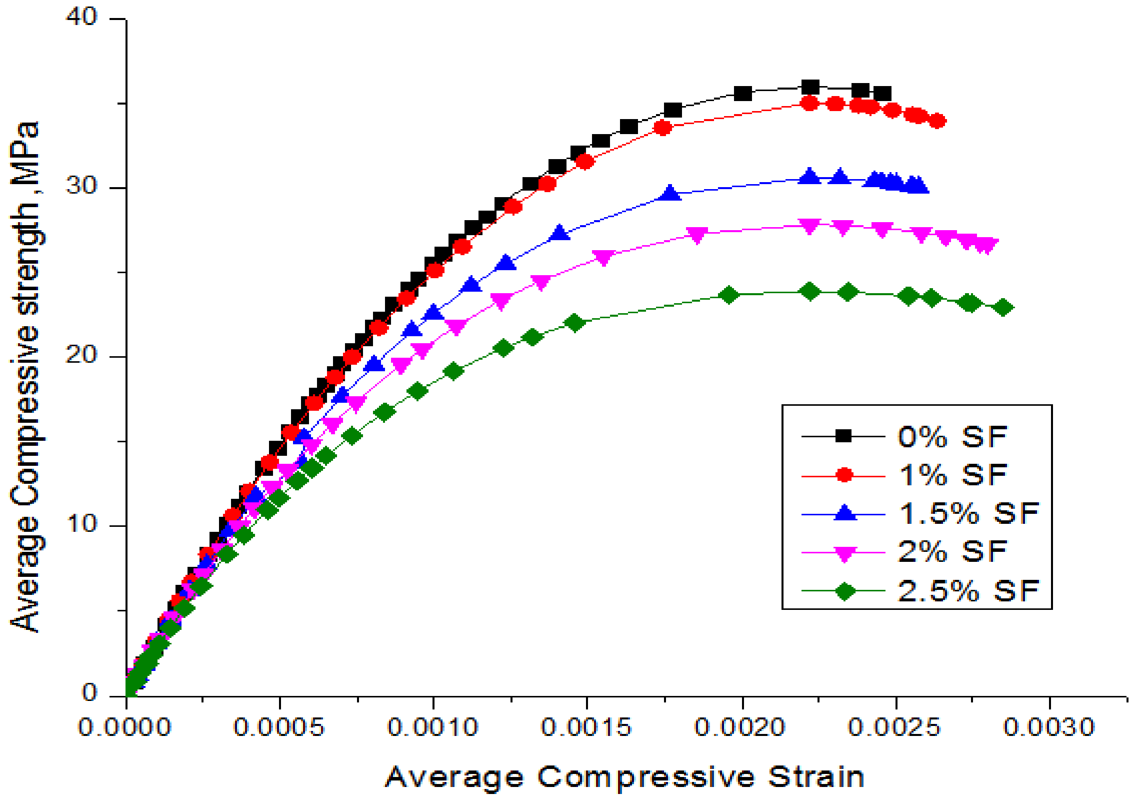

Figure 4. 2 Shows the stress – strain of C 40 concrete at 7 days

As the graph on figure 4.2, shows the compressive stress strain of the high strength of concrete results indicates decrement in strength after 1% percentage of waste steel fiber added. However, up to 1% of steel added high strength of concrete have allowable value according to EBCS EN 1992-1-1: 2015.And also, the increment of ductility as the percentage of steel fiber increases and the tendency to crack propagation was decreases as percentage of steel fiber increases.

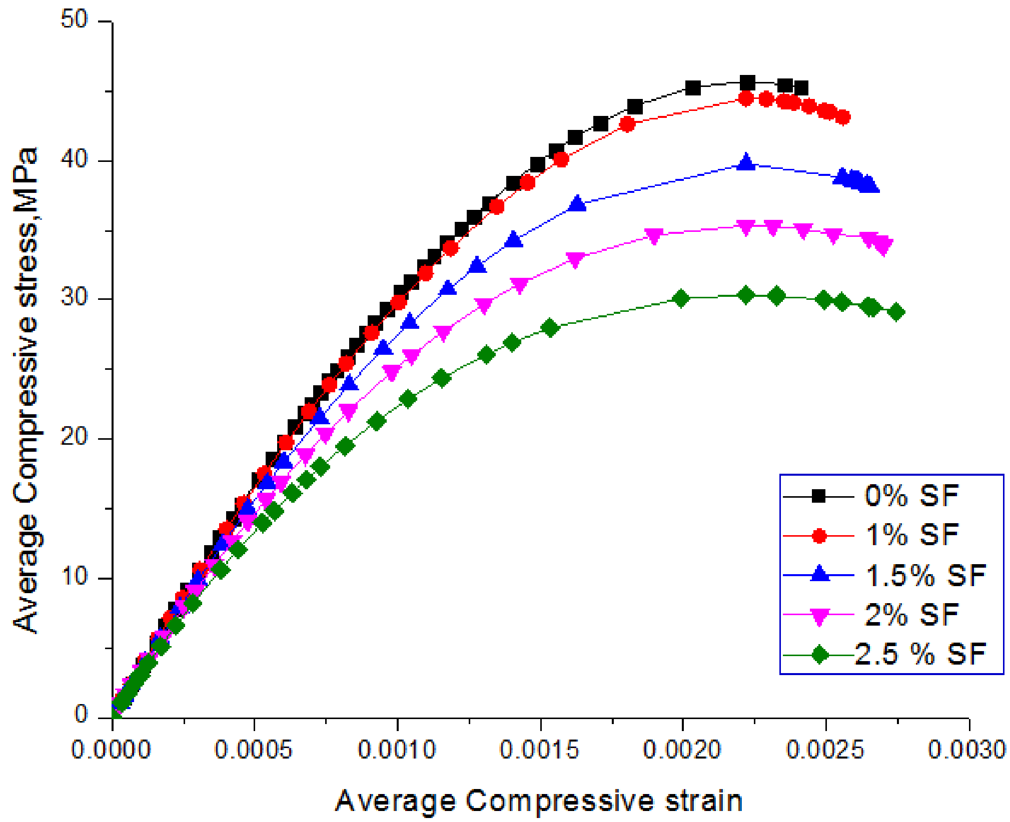

Figure 4. 3 Shows the compressive stress strain of C 40 Concrete at 28 days

As the graph on figure 4.3, shows the compressive stress strain of the high strength of concrete results indicates decrement in strength after 1% percentage of steel fiber added. However, up to 1% of steel added high strength of concrete have allowable value according to EBCS EN 1992-1-1: 2015.And also, shows the increment of ductility as the percentage of steel fiber increases and the tendency to crack propagation was decreases as percentage of steel fiber increases.

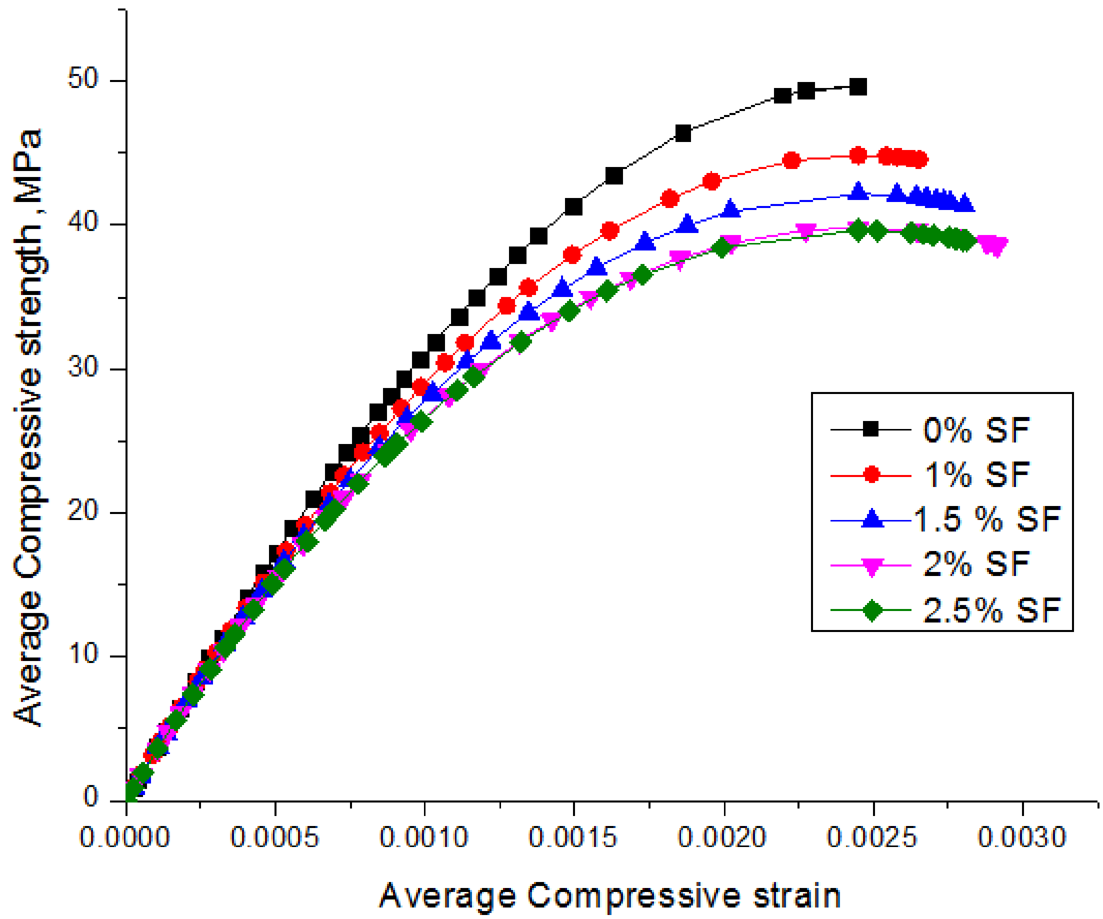

Figure 4. 4 Compressive Stress strain diagram for C 60 at 7 days.

As the graph on figure 4.4, shows the compressive stress strain of the high strength of concrete results indicates decrement in strength after 1% percentage of steel fiber added. However, up to 1% of steel added high strength of concrete have allowable value according to EBCS EN 1992-1-1: 2015.And also, shows the increment of ductility as the percentage of steel fiber increases and the tendency to crack propagation was decreases as percentage of steel fiber increases.

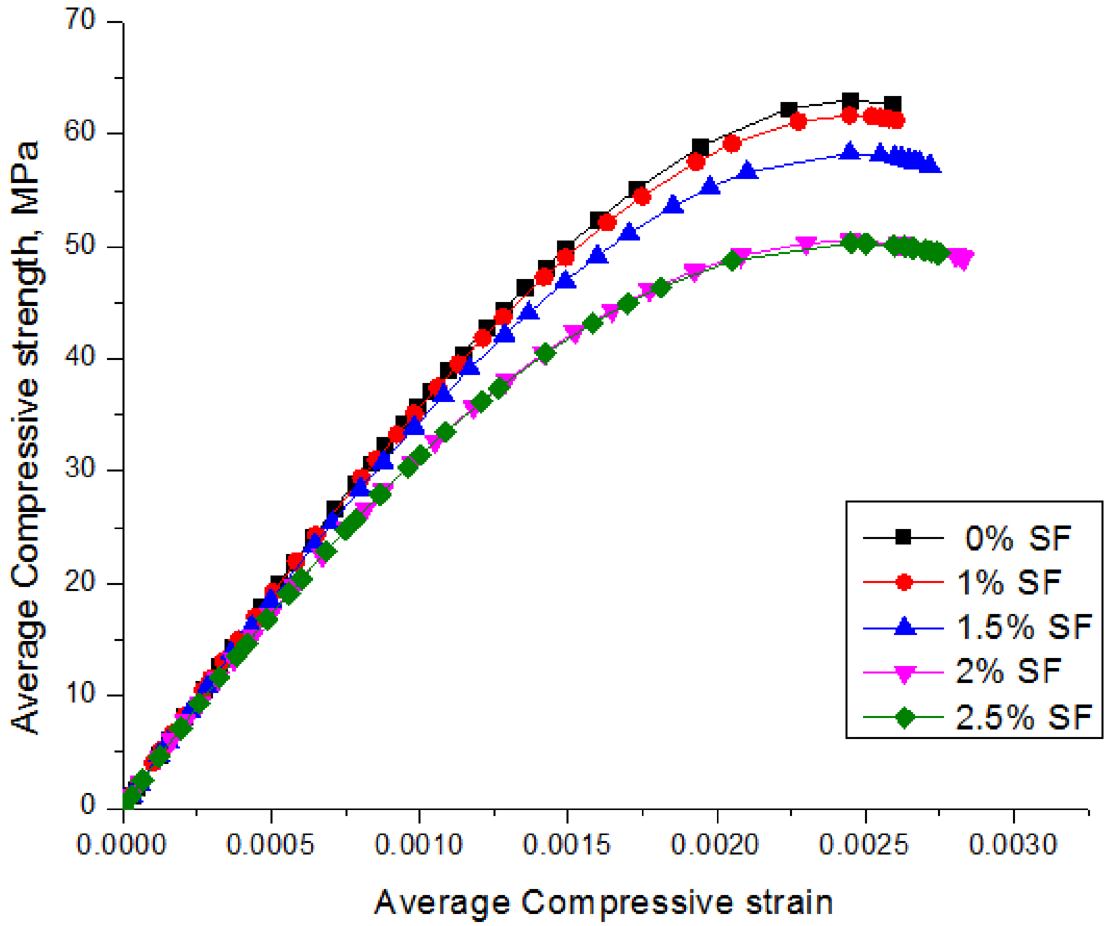

Figure 4. 5 Compressive Stress strain diagram for C 60 at 28 days.

As the graph on figure 4.5, shows the compressive stress strain of the high strength of concrete results indicates decrement in strength after 1% percentage of steel fiber added. However, up to 1% of steel added high strength of concrete have allowable value according to EBCS EN 1992-1-1: 2015.And also, shows the increment of ductility as the percentage of steel fiber increases and the tendency to crack propagation was decreases as percentage of steel fiber increases.

4.4.2 Ductility of high strength concrete with steel fiber wastes.

Ductility is the ability of a material, cross-section, member or structure to sustain large deformation without fracture/failure. For most practical cases, it is defined in terms of the ratio of maximum deformation to the deformation level corresponding to a yield point. This ratio is often referred to as ductility ratio, μ. The deformations can be strains, rotations, curvature, or deflections. Strain-based definition of ductility is used at material level (i.e stress strain relation).

$$\text{Ductility ratio, } \mu = \frac{\varepsilon cu}{\varepsilon cc}$$

Table 4.8.Shows summary of the ductility ratio of high strength concrete.

C 40 at 28 days				
%age	Ɛcc	Ɛcu	Ductility ratio,μ	Numerical Difference
0	0.00221	0.002411	1.0910	0.0000
1	0.00222	0.002559	1.1527	0.0618
1.5	0.002219	0.002567	1.1568	0.0659
2	0.002218	0.002701	1.2178	0.1268
2.5	0.00222	0.002746	1.2369	0.1460

C 60 at 28 days				
%age	Ɛcc	Ɛcu	Ductility ratio,μ	Numerical Difference
0	0.00245	0.002592	1.0580	0.0000
1	0.002447	0.002603	1.0638	0.0058
1.5	0.002448	0.002717	1.1099	0.0519
2	0.002449	0.002749	1.1225	0.0645
2.5	0.00245	0.002832	1.1559	0.0980

As the table 4.8 indicates the ductility ratio of concrete increases as the percentage of steel fiber wastes increases. Since the ductility exhibited by an individual member is derived from cross-sectional response, which is ultimately dependent on its constituent material behavior.

4.4.3 Split tensile strength test

Concrete has low tensile strength and brittle in it nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack The test was conducted as per ASTM C 496 specification for split tensile strength.

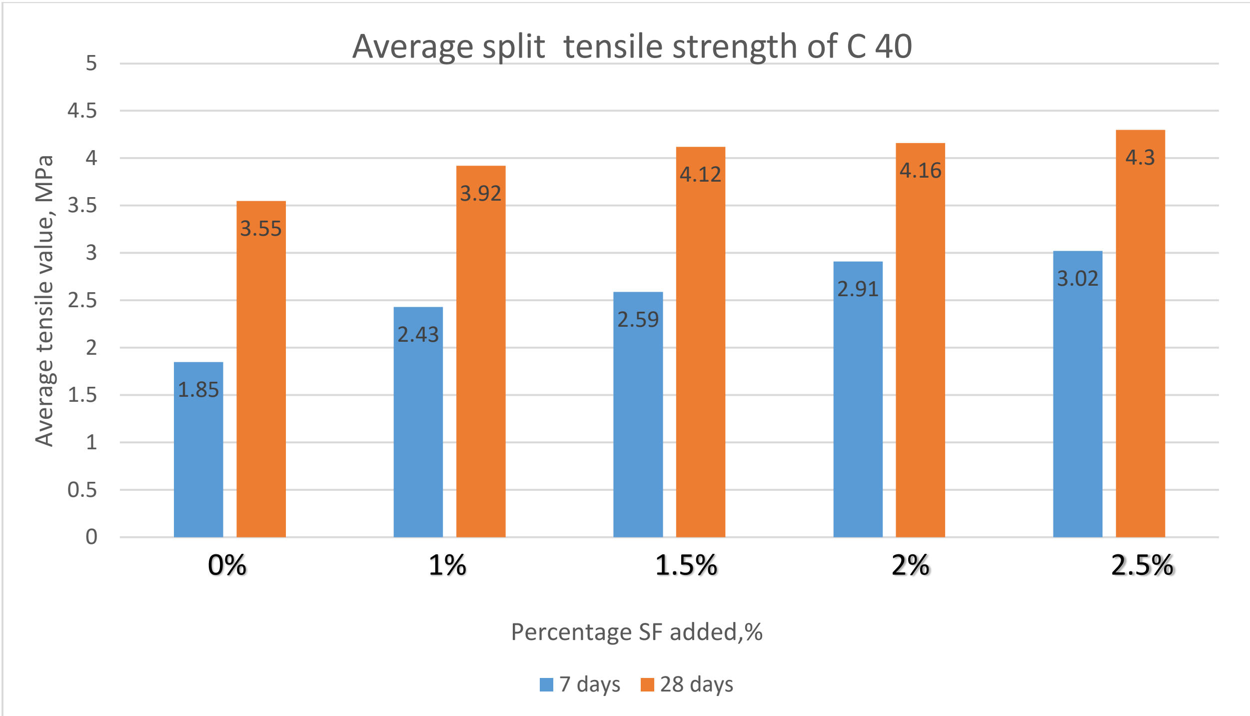

Figure 4. 6 Represents average split tensile strength graphically

As the graph on figure 4.6, shows the split tensile strength of the high strength concrete was increased as the percentage of steel fiber increases from beginning to last percentage added in the concrete mixes. However, the workability of concrete decreases as the percentage of steel fiber increases. But, the problem of workability was solved using super plasticizer admixture.

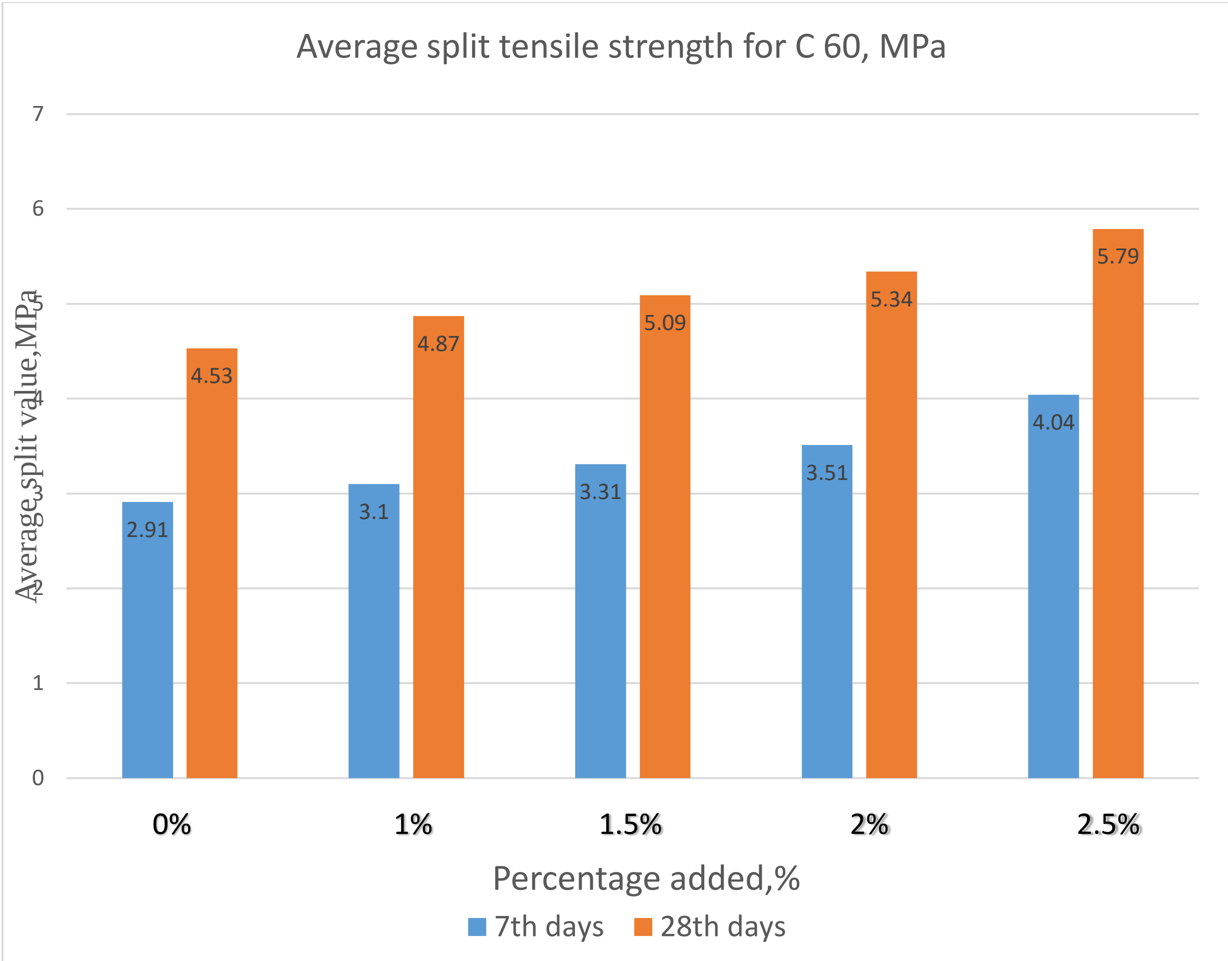

Figure 4. 7 Represents average split tensile strength graphically

As the graph on figure 4.7, above shows the split tensile strength of the high strength concrete was increased as the percentage of steel fiber increases from beginning to last percentage added in the concrete mixes. However, the workability of concrete decreases as the percentage of steel fiber increases. But, the problem of workability was solved using super plasticizer admixture.

4.4.4 Flexural strength test

Flexural strength test was conducted for determination of transversal rupture strength of plain concrete beam. The percentage of steel fiber influences the strength of the concrete as the result on figure 4.8 indicated.

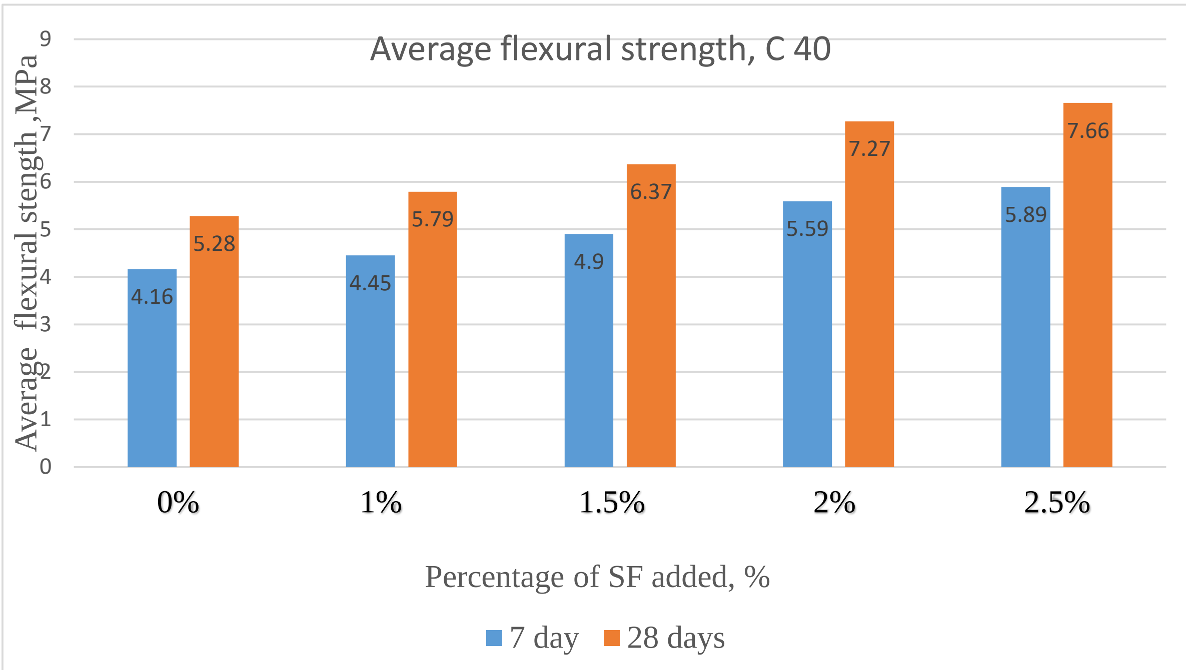

Figure 4. 8 Shows flexural strength results for C 40

As the graph on figure 4.8, above shows the flexural tensile strength of the high strength concrete was increased as the percentage of steel fiber increases from beginning to last percentage added in the concrete mixes. However, the workability of concrete decreases as the percentage of steel fiber increases. But, the problem of workability was solved using super plasticizer admixture.

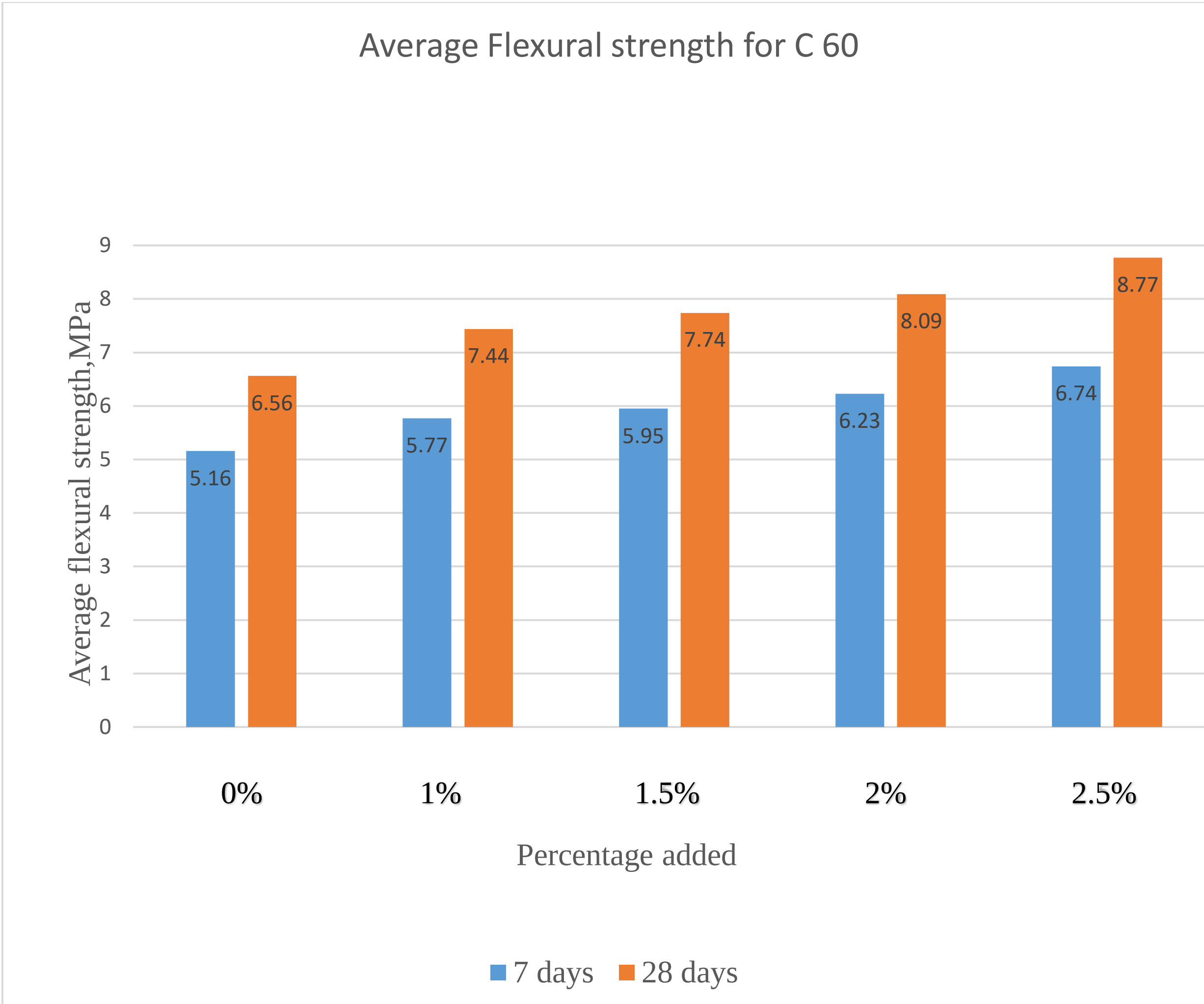

Figure 4. 9 Shows flexural strength results for C 60

As the graph on figure 4.9 above shows the flexural tensile strength of the high strength concrete was increased as the percentage of steel fiber increases from beginning to last percentage added in the concrete mixes. However, the workability of concrete decreases as the percentage of steel fiber increases. But, the problem of workability was solved using super plasticizer admixture.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The main objective of this research was determination of the effect of steel fiber on the high strength of concrete. Accordingly, the main variables taken into account in this study were different percentage of steel fibers in the mix and after attest have been done special attention were given to ultimate (peak) load and Workability under different load stage. A total number of 30 cube, 30 Flexural and 30 Cylinder specimens were casted and tested at 7th and 28th days of concrete age to investigate the effects of steel fibers on high strength concrete properties per each grade by considering steel fibers contents as 1%, 1.5%, 2% and 2.5%.by volume with the random orientation of steel fiber during mix. It is observed that steel fiber (ringed in shape with less than 50mm length) has shown significant change on all high strength concrete strengths compared to that of conventional concrete. Up to 2.5% of fiber percentage demonstrates a higher split tensile strength and flexural strength compared to conventional or control concrete. However, the strength development trend were satisfied in compressive strength up to 1% in the C 40 while 1% for C 60 High strength Concrete and decreases dramatically after 1% percentage of steel added. An addition of steel fiber in concrete mix has not improved on the compressive strength of high strength concrete but it also improved the ductility of and load carrying capacity of high strength of concrete beyond its ultimate capacity. Thus, the result shows steel fiber play great role in the property of high strength concrete after the concrete reaches its peak load and acts as crack arrester at the occurrence of cracked section of and has the ability of transferring stresses at this cracked portion of concrete and increases load carrying capacity of relative to that of conventional concrete. Therefore, from experimental investigation the following results observed and recorded.

1) As the percentage of steel fiber increases in the concrete mix, the workability of the concrete decreased. This was due to interlocking of each steel fiber so no deformation of fresh concrete were observed on slump test.
2) Concrete compressive strength decreased from 45.75MPa to 44.52MPa for C 40 and also for C 60 concrete strength decreases from 63.1MPa to 61.78MPa up to 1% but the value was greater than the required grade.

3) Flexural strength of high strength concrete increased by 33.2% with 2.5% of steel fiber in C 60 Mix and 45.08% in C 40 mix and continues increment was recorded as the percentage of steel fiber increased in the mix. On the other side, existence of steel fiber in concrete minimizes crack opening size and improves concrete ductility (increase load carrying capacity) even after reaching ultimate load carrying capacity of high strength concrete. However, conventional concrete shows complete failure after it attains its peak load.
4) An addition of steel fiber in concrete also improves concrete split tensile strength at both curing days and the experimental result increment of 21.13% in C 40 mix and 27.82% in C 60 Mix of split tensile strength were recorded with 2.5% of steel fiber mixed in concrete. This is due to the existence of strong inter locking force between each steel fiber and concrete.
5) The main problem of steel fiber is the existence of balling during mix. So, in order to overcome this problem researcher was used super plasticizer to increases fluidity and decreases the amount of void occurred due to balling effect of the steel fiber added concrete.
6) As the steel fiber content increases the workability of mixed concrete decreases .Because the ring shaped steel fiber was not easily interlock with other ingredients. Consequently, as the grade of concrete increases the compressive strength of high strength concrete decreases.
7) As the concrete grade was increases the cement paste consumption is increases .However, the tensile strength is not rationally decreased. So, addition of steel fiber improves the tensile strength of high graded concrete than lower grade.

5.2 Recommendation

Under this study the effect of steel fiber on high strength concrete compressive strength, flexural and split tensile strength were done with steel fiber of 1%, 1.5%, 2% and 2.5% by volume in mix and the significant strength change was observed on concrete strength as the percentage of steel fiber increases from 1% to 2.5% except that of compressive strength which is limited to 1% and 1% for C 40 and C 60 respectively. And also, the addition of the steel fiber in high strength concrete enhances strength of the structure by increasing its strength relative to that of conventional concrete. Thus, the researcher recommend that if this experimental work is done by another researcher by considering the effect of steel fiber on high strength concrete beam shear strength, it is possible to use this type of steel wastage from steel production industry at optimum percentage of in concrete mix by recycling this steel wastage as steel fiber. And also, we will keep our environment from different steel production waste.

Further study:-

1) Not only the strength, durability of a structure is also the main concern, investigating the durability of the fibers added need further study.
2) Studying the effect of steel fiber at various length, different percentage combinations and for different concrete grade included in the future research.
3) Further investigation by using software simulation included in the future research.

Limitation

- Strain gauge was not available

Instead of strain gauge the researcher have been used the dial gauge. Which was not exactly, represent the strain of the high strength concrete, which is fibered by waste of steel fiber.

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APPENDIX

APPENDIX – I Physical properties of major ingredients of concrete

A) moisture contents of aggregate

It is well to engineers that water to cement ratio affects the workability and strength of concrete. Design water to cement ratio is usually specified based on the assumption that aggregates are inert. It is determined by using oven dry, which controlled by 110±5°C temperature. The following procedures are the steps in which the physical properties of Coarse and fine aggregates are determined in laboratory as per ASTM standard

1) Weigh a sample of 2 Kg coarse aggregate and 500-gram fine aggregate separately (A).
2) Oven dry the sample for about 24 hours with a controlled temperature.
3) Remove the sample from the oven and place them on the desiccator for about an hour in order to cool without absorbing water from the atmosphere.
4) Weigh the aggregate separately (Oven Dried weight, B)
5) Calculate the moisture content of the aggregate as follows: -

% Moisture content $=\left(\frac{A-B}{B}\right) * 100$

Table I A Moisture content

Result (Virgin coarse Aggregate)

S.No	Description	Sample		
		1	2	3
1	Weight of original sample ,A (Kg)	2.0	2.0	2.0
2	Weight of oven dried sample B ,(Kg)	1.990	1.990	1.985
3	Moisture content(%)=(A-B/A)*100	0.5	0.5	0.75
Average				0.6

Result (Fine Aggregate)				
	Sample	1	2	3
1	Weight of original sample ,A,(Kg)	0.5	0.5	0.5
2	Oven dried mass ,B,(Kg)	0.4975	0.4975	0.4975
3	Moisture content in %=((A-B)/B)*100	0.5	0.5	0.5
Average				0.5

B) Unit Weight of Aggregate

Unit weight can be defined as the weight of a given volume of graded aggregate. It thus, a density measurement and is also bulk density. The unit weight effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them.

The unit weight is simply measured by filling a container of known volume and weighing it. Clearly, however, the degree of compaction will change the amount of voids space, and hence the value of unit weight. Since the weight of the aggregate, a constant moisture content is required. Oven dried aggregate is used this test.

Table I. B Summary of unit weight test result

Volume of cylinder(m^3)=0.010

Sample	mass of cylinder(Kg)	Mass of sample(Kg)	Mass of cylinder and sample(Kg)	Unit weight(Kg/m^3)	Remark
1	1.6770	16.963	18.640	1696.3	Virgin Aggregate
2	1.6770	16.768	18.445	1676.8	
3	1.6770	16.963	18.640	1696.3	
Average(Coarse)				1690	
1	1.051	7.949	9	1590	
2	1.051	7.759	8.81	1552	
3	1.051	7.959	9.01	1592	
Average (Fine)				1578	

Volume of cylinder for fine aggregate = 0.0005 M^3

C) Silt Content of Fine aggregate

Sand used construction should be clean, free from loam, clay and vegetable matter. Silt is unnecessary part of sand with a diameter less than 0.075mm. If there is too much silt, the aggregate will have less adhesive property with cement resulting in weak bond strength with probability of porosity. Moreover, it decreases workability by absorbing water.

If the silt is greater than 6% of the total mass, the sand should not be used for construction unless and otherwise washed. This test can be conducted either in laboratory or in the field.

Table I .C Summarize the silt content values.

Result(Field method)

S.No	Description	Sample		
		1	2	3
1	Volume of sample(silt+sand),V1(ml)	50.0	50.0	50
2	Volume of silt after 3 hrs,V2 (ml)	0.50	1.00	1.00
3	Percentage of silt by Volume,(V2/V1)*100	1.0	2.0	2
		Average		1.67

Laboratory method

S.No	Description	Sample		
		1	2	3
1	Air dried mass(g),M1	1000.0	1000.0	1000
2	Oven dried mass(g),M2	976.0	975.6	976
3	Silt content in %=((M1-M2)/M1)*100	2.4	2.4	2.4
	Average			2.4

D) Specific gravity and water absorption for coarse aggregates

Specific gravity is the ratio between the weights of the substance to that of the same volume of water. It helps for the design of concrete mix and calculating void contents in aggregate.

The water absorption value is the difference in weight between the saturated surface dry aggregate and oven dry sample expressed as percentage of dry weight of aggregate. Knowing the water absorption value of aggregate was helped to calculate the total water to be added to the concrete mix.

Procedure for Coarse aggregate

1) Rejecting material passing 4.75 mm sieve size, and using sample splitter 2 Kg sample of aggregate measured and washed to remove dusts.
2) Using wire basket with sample immersed in pure water for 24 hours at room temperature.
3) Adjust at 50 mm of water above the top of wire basket and the entrapped air is removed by jolting the specific gravity frame 25 times per second, and stay it for 24 hours.
4) After 24hrs, again jolt and weigh the aggregate with wire basket in water.
5) Place the aggregate on the smooth tight cloth and surface dry the sample of aggregate by using this clothes and weigh the mass of wire basket in water after jolting 25 times.
6) Weigh saturated surface dried sample and then placed in an oven for 24 hours.
7) After 24 hours the removed from oven and cooled in desiccator for an hour and finally the dried sample weighted.

Using the following formula, the specific gravity and absorption capacity calculated for coarse aggregate tabulated on table I .4

Bulk specific gravity (Sat. Surface Dry basis) = $\frac{Mssd}{(Mssd-Mw)}$

Percentage of absorption = $\left(\frac{Mssd-Md}{Md}\right) * 100$

Table I.D Summary of the specific gravity and water absorption Capacity

Coarse aggregate (gravel)

S.NO	Description	Trial1	Trial2	Average
1	M_W=Weight in water of saturated aggregate (Kg)	1.296	1.232	
2	M_{SSD}=Weight in air of saturated surface dry(Kg)	2.006	2.009	
3	M_D=Weight in air of oven dried aggregate(Kg)	1.982	1.983	
4	Specific gravity of gravel	2.825	2.586	2.71
5	Absorption capacity (%)	1.21	1.31	1.26%

E) Specific gravity and water absorption for Fine aggregate

1) A sample of 500 g fine aggregate which is free flowing condition without moisture measured and placed in to the pycnometre then filled up with water 90% capacity of the pycnometre.
2) Using glass rod the air bubbles are eliminated with adjusted temperature and the water levels of pycnometre filled up to its calibrated capacity
3) Then after, the total weight of sample, water and pycnometre is measured (C)
4) Remove the sample from pycnometre and fill with water and weigh it (B)
5) Oven dried the aggregate removed from pycnometre at controlled temperature for 24 hours.
6) Then after, remove dried sample from oven dry and put in the desiccator for an hour.
7) finally, weigh oven drieded sample (A).

Fine aggregate (Gambella Sand)

Description	Sample No			Average
	Trial1	Trial2	Trial3	
Weight of saturated & surface dry sand (gm)	500	500	500	
Weight of pycnometer+sample+water (C) (gm)	1861	1850	1854	
Weight of pycnometer+water (B) (gm)	1553	1550	1549	
Weight of oven dry sand (A) (gm)	498	497	492	
Bulk specific gravity=A/(B+500-C)	2.59	2.485	2.52	2.53
Bulk specific gravity (sat.sur.dry basis)=500/(B+500-C)	2.604	2.500	2.564	2.56
Apparent specific gravity=A/(B+A-C)	2.621	2.523	2.631	2.59
Absorption capacity(%)=((500-A)/A)*100	0.4	0.6	1.6	0.88

F) Grain size analysis of aggregate

Sieve analysis done in order to determine the fineness modulus of aggregate and the relative amount of varies size of particles present in the aggregate using sieve series of square opening starting from the larger. The summation of the cumulative percentage of a sample of aggregate retained on specified series of sieves, excluding intermediate sieves, divided by 100 is called fineness Modulus. It is used as an index to the fineness or coarseness and uniformity of aggregate supplied.

Fine Aggregate sieve analysis result

Sieve Size,mm	mass retained(gm)				% Retained	%cumulative retain	% Passing
	Trial 1	Trial 2	Trial 3	Avg.			
9.5	0	0	0	0	0.00	0.00	100.0
4.75	12	14	16	14	0.69	0.69	99.3
2.36	178	160	170	169	8.46	9.15	90.9
1.18	390	376	383	383	19.15	28.30	71.7
0.60	497	441	476	471	23.56	51.86	48.1
0.30	601	669	662	644	32.18	84.03	16.0
0.15	255	241	208	235	11.73	95.77	4
pan	68	99	85	84	4.18	99.95	0.0
TOTAL	2000	1999	1999	1999		260.0	

Fineness of modulus =2.60

Table I. G Summary of the particle size distribution of coarse aggregate

Natural Coarse Aggregate sieve analysis result							
Sieve Size, mm		mass retained(gm)			% Retained	%cumulative retain	% Passing
	Trial 1	Trial 2	Trial 3	Avg.			
28	0	0	0	0	0	0	100
25	0	0	0	0	0	0	100
19	790	780	804	791	8	8	92
12.50	5315	5210	5250	5258	53	60	40
9.50	2790	2850	2790	2810	28	89	11
4.75	1100	1150	1135	1128	11	100	0
pan	5	9	19	11	0	100	0
TOTAL	10000	9999	9998	9999		356.77	

Fineness Modulus = $\frac{856.77}{100} = 8.5677 \cong 8.6$…. For natural coarse aggregate.

Mix design of concrete C-40

Step 1 collected data for mix design:-

Fineness modulus of selected fine aggregate =2.6

Unit weight of dry rodded coarse aggregate(Normal aggregate) =1695Kg/m^3

specific gravity of coarse and fine aggregate in saturated surface dry condition is 2.72 and 2.61 respectively

Absorption characteristic of both coarse and fine aggregate is 0.9%and 1.5% respectively

Specific gravity of Ordinary portland cement = 3.15

Free surface moisture in sand and coarse Aggregate 2% and 0.75% respectively

Step 2 Determination of water to cement ratio

From the strength point of view the estimated water to cement ratio is 0.57 and

From the Exposure condition the estimated water to cement ratio is 0.48

Therefore ,adopt water to cement ratio of 0.48

Step 3 Maximum size of aggregate and workability

Maximum size of coarse aggregate is 20mm.

slump of concrete is 25- 50mm and air content 2%.

Step 4 cement content

For the slump of 25-50mm and 20mm maximum size of aggregate, the maximum water content is 185 kg/m^3

The maximum cement content = maximum water content divided w/c ratio = 185/0.48 = 385 Kg/m^3

Step 5 weight of coarse aggregate

From ACI table 11.4 for maximum size of 20mm coarse aggregate and fineness modulus of sand 2.6

The dry rodded bulk volume of coarse aggregate is 0.64 per unit volume of concrete.

The weight of coarse aggregate = 0.64*1695Kg/m^3= 1084.8 kg/m^3

Step 6 weight of fine Aggregate

From ACI table 11.9 the first estimate of density of fresh concrete for 20mm maximum size of aggregate

and non-air entrained concrete =2355kg/m^3

Item No	Ingredient	Weight (Kg/m³)	absolute volume (cm³)	
1	Cement	385	122222.222	
2	Water	185	185000	
3	Gravel	1084.8	371506.849	
4	Air		20000	

Therefore ,absolute volume of fine aggregate = 1000000 301270.93

Weight of fine aggregate = 301270.93 *2.61 = 786.317

Step 7

proportions

Ingredients		Cement	sand	gravel	water
quantity					
(kg/m³)		385	786	1085	185
Ratio		1	2.04	2.81818182	0.5
One bag cement,Kg		50	102.0779	140.909091	25

Step 8: Adjustment for field condition

Fine aggregate has surface moisture of 2%.

Weight of fine aggregates = 612.425

Coarse aggregate absorbs 0.9% of water.

Weight of coarse aggregate = 1085

Adjust the amount of water based on moisture content

The required mixing water = 184.49

Step 9: Final design proportion

Ingredients		Cement	sand	gravel	water
quantity					
(kg/m³)		385	612.425	1094.765	184.49
Ratio		1	1.590714	2.84354545	0.4791948
One bag cement,Kg		50	79.53571	142.177273	23.95974

Mix design of concrete C-60

Step 1 collected data for mix design:-

Fineness modulus of selected fine aggregate =2.6

Unit weight of dry rodded coarse aggregate(Normal aggregate) =1695Kg/m^3

specific gravity of coarse and fine aggregate in saturated surface dry condition is 2.72 and 2.61 respectively

Absorption characteristic of both coarse and fine aggregate is 0.9%and 1.5% respectively

Specific gravity of pozzolana portland cement = 3.15

Free surface moisture in sand and coarse Aggregate 2% and 0.75% respectively

Step 2 Determination of water to cement ratio

Adopt water to cement ratio of 0.41

Step 3 Maximum size of aggregate and workability

Maximum size of coarse aggregate is 12.5mm.

slump of concrete is 25- 50mm and air content 2.5%.

Step 4 cement content

For the slump of 25-50mm and 12.5 mm maximum size of aggregate,the maximum water content is kg/m^3

Cement content = maximumum water content divided by w/c ratio = 200/0.41 = 488 Kg/m^3

Step 5 weight of coarse aggregate

From ACI table 11.4 for maximum size of 20mm coarse aggregate and fineness modulus of sand 2.6 the dry rodded bulk volume of coarse aggregate is 0.64 per unit volume of concrete .

The weight of coarse aggregate = 0.64*1695Kg/m^3= 1084.8 kg/m^3

Step 6 weight of fine Aggregate

From ACI table 11.9 the first estimate of densityof fresh conrete for 12.5mm maximum size of aggre and non-air entrained concrete =2315kg/m^3

Item No	Ingredient	Weight (Kg/m^3)	absolute volume (cm^3)	
1	Cement	488	154920.635	
2	Water	185	185000	
3	Gravel	1084.8	371506.849	
4	Air		25000	

Therefore ,absolute volume of fine aggregate = 1000000 263572.52

Weight of Fine aggregate = 263572.52 * 2.61 = 687.92 Kg/m^3

Step 7

proportions

Ingredients	Cement	sand	gravel	water
quantity				
(kg/m^3)	488	688	1085	200
Ratio	1	1.41	2.22336066	0.5
One bag cement,Kg	50	70.48361	111.168033	25

Step 8: Adjustment for field condition

Fine aggregate has surface moisture of 2%.

Weight of fine aggregates = 553.24

Coarse aggregate absorbs 0.9% of water.

Weight of coarse aggregate = 1094.765

Adjust the amount of water based on moisture content

The required mixing water = 200.57

Step 9: Final design

proportion

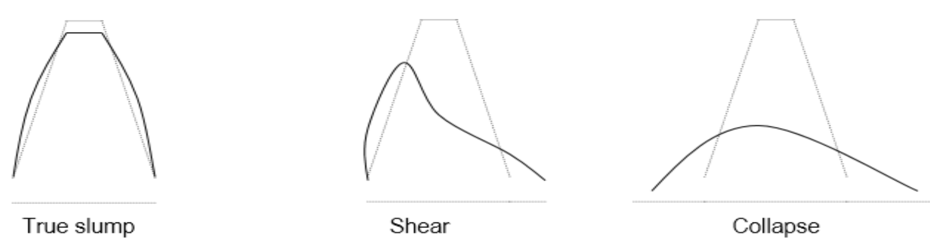
Ingredients	Cement	sand	gravel	water
quantity				
(kg/m^3)	488	553.24	1094.765	200.57
Ratio	1	1.133689	2.2433709	0.4110041
One bag cement,Kg	50	56.68443	112.168545	20.550205

APPENDIX- II Workability of Concrete

Workability describes the ease with which a freshly mixed concrete can be laid, transported and to large extent it is controlled by the amount of water in the concrete. A concrete mix either produced at already mix plant or on site, must be made of the right amount of cement, aggregate and water to make the concrete workable enough for easy compaction, placing and strong enough for good performance in resisting stresses after hardening. Test method have been used to determine workability of concrete are: -Slump test.

Table III. A summary of the slump test result

Mix No	Percent of SF ,%	Slump height for C 60	Slump Height for C 40
1	Convention	39	36
2	1	26	22
3	1.5	23	20
4	2	10	15
5	2.5	5	5



True slump: the slump could slump evenly all round

Shear Slump: Part of the top cones might shear off and slide down an inclined plane

Collapse slump: The cone completely collapses.

APPENDIX – III Hardened Concrete test result

Compressive strength test results for C 40

Age of Cube	Sample	Dimension,mm			Area, mm^2	Mass (Kg)	Peak load (KN)	Compressive strength (Mpa)	%age
		L	W	H					
7th day	1	150	150	150	22500	8.109	840.46	37.35	0
	2	150	150	150	22500	8.29	799.59	35.54	
	3	150	150	150	22500	8.145	793.14	35.25	
	Mean Value							**36.05**	
7th day	1	150	150	150	22500	8.141	783.94	34.84	1
	2	150	150	150	22500	8.52	789.12	35.07	
	3	150	150	150	22500	8.345	794.91	35.33	
	Mean Value							**35.08**	
7th day	1	150	150	150	22500	8.291	692.49	30.78	1.5
	2	150	150	150	22500	8.342	691.42	30.73	
	3	150	150	150	22500	8.249	689.12	30.63	
	Mean Value							**30.71**	
7th day	1	150	150	150	22500	8.001	610.94	27.15	2
	2	150	150	150	22500	7.99	627.52	27.89	
	3	150	150	150	22500	7.89	643.51	28.60	
	Mean Value							**27.88**	
7th day	1	150	150	150	22500	7.915	536.49	23.84	2.5
	2	150	150	150	22500	7.928	540.19	24.01	
	3	150	150	150	22500	7.914	538.94	23.95	
	Mean Value							**23.94**	

Age of cubes	Sample	Dimension,mm			Mass (Kg)	Area , mm^2	Peak load (KN)	Compressive strength (Mpa)	%age
		L	W	H					
28th day	1	150	150	150	8.271	22500	1066.21	47.39	0
	2	150	150	150	8.29	22500	1014.59	45.09	
	3	150	150	150	8.311	22500	1007.49	44.78	
	Mean Value							**45.75**	
28th day	1	150	150	150	8.195	22500	994.41	44.20	1
	2	150	150	150	8.209	22500	1008.92	44.84	
	3	150	150	150	8.301	22500	1001.51	44.51	
	Mean Value							**44.52**	
28th day	1	150	150	150	8.195	22500	878.45	39.04	1.5
	2	150	150	150	8.215	22500	877.41	39.00	
	3	150	150	150	8.31	22500	875.01	38.89	
	Mean Value							**38.98**	

28th day	1	150	150	150	8.101	22500	774.05	34.40	2
	2	150	150	150	8.209	22500	816.49	36.29	
	3	150	150	150	8.311	22500	795.41	35.35	
	Mean Value							**35.35**	
28th day	1	150	150	150	8.109	22500	680.41	30.24	2.5
	2	150	150	150	8.211	22500	685.15	30.45	
	3	150	150	150	8.309	22500	683.49	30.38	
	Mean Value							**30.36**	

Compressive strength test results for C 60

Age of Cubes	Sample	Dimension,mm^2			Area, mm^2	Mass (Kg)	Peak load (KN)	Compressive strength (Mpa)	%age
		L	W	H					
7th day	1	150	150	150	22500	8.091	1123.48	49.93	0
	2	150	150	150	22500	8.101	1114.09	49.52	
	3	150	150	150	22500	8.209	1118.24	49.70	
	Mean Value							**49.72**	
7th day	1	150	150	150	22500	8.304	1012.69	45.01	1
	2	150	150	150	22500	8.001	1010.29	44.90	
	3	150	150	150	22500	8.251	1010.99	44.93	
	Mean Value							**44.95**	
7th day	1	150	150	150	22500	8.01	947.43	42.11	1.5
	2	150	150	150	22500	8.02	951.21	42.28	
	3	150	150	150	22500	7.99	949.95	42.22	
	Mean Value							**42.20**	
7th day	1	150	150	150	22500	8.001	910.92	40.49	2
	2	150	150	150	22500	8.134	901.04	40.05	
	3	150	100	150	22500	8.245	896.49	39.84	
	Mean Value							**40.13**	
7th day	1	150	150	150	22500	8.141	894.28	39.75	2.5
	2	150	150	150	22500	8.045	890.1	39.56	
	3	150	150	150	22500	8.109	892.04	39.65	
	Mean Value							**39.65**	

Age of cube	Sample	Dimension,mm^2			Area, mm^2	Mass (Kg)	Peak load (KN)	Compressive strength (Mpa)	%age
		L	W	H					
28th day	1	150	150	150	22500	8.341	1414.95	62.89	0
	2	150	150	150	22500	8.49	1424.9	63.33	
	3	150	150	150	22500	8.395	1419.09	63.07	
	Mean Value							**63.10**	
28th day	1	150	150	150	22500	8.386	1392.41	61.88	1
	2	150	150	150	22500	8.315	1389.25	61.74	

	3	150	150	150	22500	8.341	1388.49	61.71	
	Mean Value							**61.78**	
28^{th} day	1	150	150	150	22500	8.349	1339.48	59.53	1.5
	2	150	150	150	22500	8.36	1345.09	59.78	
	3	150	150	150	22500	8.375	1253.49	55.71	
	Mean Value							**58.34**	
28^{th} day	1	150	150	150	22500	8.541	1155.4	51.35	2
	2	150	150	150	22500	8.021	1144.91	50.88	
	3	150	150	150	22500	8.015	1137.09	50.54	
	Mean Value							**50.92**	
28^{th} day	1	150	150	150	22500	8.195	1135.04	50.45	2.5
	2	150	150	150	22500	8.285	1130.19	50.23	
	3	150	150	150	22500	8.309	1132.49	50.33	
	Mean Value							**50.34**	

Split tensile strength test results for C 40

Age of cylinder	Sample	Dimension		Mass (Kg)	Area of cylinder mm^2	Peak load (KN)	Split strength (Mpa)	%age
		Diam	H					
7^{th} day	1	100	200	3.787	31415.925	65.38	2.08	0
	2	100	200	3.775	31415.925	54.91	1.75	
	3	100	200	3.746	31415.925	53.73	1.71	
	Mean Value						**1.85**	
7^{th} day	1	100	200	3.816	31415.925	73.71	2.35	1
	2	100	200	3.788	31415.925	78.63	2.50	
	3	100	200	3.743	31415.925	76.54	2.44	
	Mean Value						**2.43**	
7^{th} day	1	100	200	3.792	31415.925	75.66	2.41	1.5
	2	100	200	3.778	31415.925	87.61	2.79	
	3	100	200	3.743	31415.925	81.26	2.59	
	Mean Value						**2.59**	
7^{th} day	1	100	200	3.826	31415.925	93.09	2.96	2
	2	100	200	3.809	31415.925	92.96	2.96	
	3	100	200	3.772	31415.925	88.38	2.81	
	Mean Value						**2.91**	
7^{th} day	1	100	200	3.753	31415.925	94.91	3.02	2.5
	2	100	200	3.816	31415.925	96.45	3.07	
	3	100	200	3.807	31415.925	93.42	2.97	
	Mean Value						**3.02**	

Age of cylinder	Sample	Dimension ,mm		Mass	Area of cylinder	Peak load	Split strength	%age
		Diam	H	(Kg)	mm^2	(KN)	(Mpa)	
28th day	1	100	200	3.728	31415.925	120.36	3.83	0
	2	100	200	3.794	31415.925	115.21	3.67	
	3	100	200	3.801	31415.925	98.65	3.14	
	Mean Value						**3.55**	
28th day	1	100	200	3.868	31415.925	125.68	4.00	1
	2	100	200	3.764	31415.925	124.32	3.96	
	3	100	200	3.755	31415.925	119.16	3.79	
	Mean Value						**3.92**	
28th day	1	100	200	3.768	31415.925	131.05	4.17	1.5
	2	100	200	3.806	31415.925	129.45	4.12	
	3	100	200	3.799	31415.925	128.14	4.08	
	Mean Value						**4.12**	
28th day	1	100	200	3.738	31415.925	132.14	4.21	2
	2	100	200	3.791	31415.925	130.25	4.15	
	3	100	200	3.81	31415.925	129.87	4.13	
	Mean Value						**4.16**	
28th day	1	100	200	3.738	31415.925	135.17	4.30	2.5
	2	100	200	3.836	31415.925	134.61	4.28	
	3	100	200	3.754	31415.925	135.74	4.32	
	Mean Value						**4.30**	

Split tensile strength test results for C 60

Age of cylinder	Sample	Dimension,mm		Mass	Area of cylinder	Peak load	Split strength	%age
		Diam	H	(Kg)	mm^2	(KN)	(Mpa)	
28th day	1	100	200	3.628	31415.925	150.31	4.78	0
	2	100	200	3.894	31415.925	140.2	4.46	
	3	100	200	3.701	31415.925	136.61	4.35	
	Mean Value						**4.53**	
28th day	1	100	200	3.568	31415.925	155.69	4.96	1
	2	100	200	3.664	31415.925	144.3	4.59	
	3	100	200	3.655	31415.925	159.17	5.07	
	Mean Value						**4.87**	
28th day	1	100	200	3.668	31415.925	161.95	5.16	1.5
	2	100	200	3.906	31415.925	169.45	5.39	
	3	100	200	3.899	31415.925	148.14	4.72	
	Mean Value						**5.09**	
28th day	1	100	200	3.638	31415.925	162.84	5.18	2
	2	100	200	3.891	31415.925	160.75	5.12	
	3	100	200	3.79	31415.925	179.87	5.73	
	Mean Value						**5.34**	
28th day	1	100	200	3.758	31415.925	175.19	5.58	2.5
	2	100	200	3.846	31415.925	184.41	5.87	
	3	100	200	3.774	31415.925	185.64	5.91	
	Mean Value						**5.79**	

Age of cylinder	Sample	Dimension		Mass	Area of cylinder	Peak load	Split strength	%age
		Diam	H	(Kg)	mm^2	(KN)	(Mpa)	
7th day	1	100	200	3.787	31415.925	85.61	2.73	0
	2	100	200	3.775	31415.925	94.81	3.02	
	3	100	200	3.746	31415.925	93.71	2.98	
	Mean Value						**2.91**	
7th day	1	100	200	3.816	31415.925	96.72	3.08	1
	2	100	200	3.788	31415.925	98.61	3.14	
	3	100	200	3.743	31415.925	96.75	3.08	
	Mean Value						**3.10**	
7th day	1	100	200	3.792	31415.925	103.28	3.29	1.5
	2	100	200	3.778	31415.925	107.63	3.43	
	3	100	200	3.743	31415.925	101.26	3.22	
	Mean Value						**3.31**	
7th day	1	100	200	3.826	31415.925	113.25	3.60	2
	2	100	200	3.809	31415.925	109.19	3.48	
	3	100	200	3.772	31415.925	108.79	3.46	
	Mean Value						**3.51**	
7th day	1	100	200	3.753	31415.925	124.93	3.98	2.5
	2	100	200	3.816	31415.925	125.54	4.00	
	3	100	200	3.807	31415.925	130.4	4.15	
	Mean Value						**4.04**	

Flexural strength of hardened concrete of high strength 40

Age of Beam	Sample	Dimension,mm			Mass	Peak load	Flexural strength	%age
		L	W	H	(Kg)	(KN)	(Mpa)	
7th day	1	500	100	100	12.942	13.77	4.13	0
	2	500	100	100	12.901	14.50	4.35	
	3	500	100	100	12.897	13.30	3.99	
	Mean Value						**4.16**	
7th day	1	500	100	100	12.921	15.03	4.51	1
	2	500	100	100	12.896	14.13	4.24	
	3	500	100	100	12.928	15.37	4.61	
	Mean Value						**4.45**	
7th day	1	500	100	100	12.935	16.40	4.92	1.5
	2	500	100	100	12.845	16.60	4.98	
	3	500	100	100	12.866	15.97	4.79	
	Mean Value						**4.90**	
7th day	1	500	100	100	11.987	16.80	5.04	2
	2	500	100	100	12.058	19.70	5.91	
	3	500	100	100	12.31	19.40	5.82	
	Mean Value						**5.59**	
7th day	1	500	100	100	11.998	19.77	5.93	2.5
	2	500	100	100	12.01	19.67	5.90	
	3	500	100	100	12.241	19.50	5.85	
	Mean Value						**5.89**	

Age of Beam	Sample	Dimension			Mass	Peak load	Flexural strength	%age
		L	W	H	(Kg)	(KN)	(Mpa)	
28th day	1	500	100	100	13.125	17.50	5.25	0
	2	500	100	100	13.214	18.43	5.53	
	3	500	100	100	12.987	16.90	5.07	

	Mean Value						**5.28**	
28th day	1	500	100	100	12.958	19.53	5.86	1
	2	500	100	100	12.647	18.37	5.51	
	3	500	100	100	12.964	19.97	5.99	
	Mean Value						**5.79**	
28th day	1	500	100	100	12.865	21.33	6.40	1.5
	2	500	100	100	12.649	21.57	6.47	
	3	500	100	100	12.356	20.77	6.23	
	Mean Value						**6.37**	
28th day	1	500	100	100	12.915	21.83	6.55	2
	2	500	100	100	12.458	25.60	7.68	
	3	500	100	100	12.687	25.23	7.57	
	Mean Value						**7.27**	
28th day	1	500	100	100	12.897	25.70	7.71	2.5
	2	500	100	100	12.879	25.57	7.67	
	3	500	100	100	12.857	25.37	7.61	
	Mean Value						**7.66**	

Flexural strength of hardened concrete of high strength, C 60

Age of beam	Sample	Dimension			Mass (Kg)	Peak load (KN)	Flexural strength (Mpa)	%age
		L	W	H				
7th day	1	500	100	100	12.589	17.07	5.12	0
	2	500	100	100	12.961	16.93	5.08	
	3	500	100	100	12.357	17.63	5.29	
	Mean Value						**5.16**	
7th day	1	500	100	100	12.456	18.63	5.59	1
	2	500	100	100	12.564	19.27	5.78	
	3	500	100	100	12.358	19.80	5.94	
	Mean Value						**5.77**	
7th day	1	500	100	100	12.654	19.83	5.95	1.5
	2	500	100	100	12.756	20.07	6.02	
	3	500	100	100	12.634	19.63	5.89	
	Mean Value						**5.95**	

7th day	1	500	100	100	12.586	20.30	6.09	2
	2	500	100	100	12.595	20.60	6.18	
	3	500	100	100	12.597	21.37	6.41	
	Mean Value						**6.23**	
7th day	1	500	100	100	12.954	21.63	6.49	2.5
	2	500	100	100	12.964	21.50	6.45	
	3	500	100	100	12.879	24.30	7.29	
	Mean Value						**6.74**	

Age of beam	Sample	Dimension			Mass (Kg)	Peak load (KN)	Flexural strength (Mpa)	%age
		L	W	H				
28th day	1	500	100	100	12.956	21.67	6.50	0
	2	500	100	100	12.987	21.50	6.45	
	3	500	100	100	12.985	22.40	6.72	
	Mean Value						**6.56**	
28th day	1	500	100	100	12.964	23.67	7.10	1
	2	500	100	100	12.954	25.03	7.51	
	3	500	100	100	12.689	25.73	7.72	
	Mean Value						**7.44**	
28th day	1	500	100	100	12.876	25.80	7.74	1.5
	2	500	100	100	12.895	26.10	7.83	
	3	500	100	100	12.987	25.53	7.66	
	Mean Value						**7.74**	
28th day	1	500	100	100	12.978	26.40	7.92	2
	2	500	100	100	12.968	26.77	8.03	
	3	500	100	100	12.897	27.77	8.33	
	Mean Value						**8.09**	
28th day	1	500	100	100	12.965	28.13	8.44	2.5
	2	500	100	100	12.956	27.97	8.39	
	3	500	100	100	12.869	31.60	9.48	
	Mean Value						**8.77**	

Table Shows summary of modulus of elasticity of C 40 Concrete grade calculated

Percentage	Age	Max compressive strength,(MPa)	Modulus of elasticity,(GPa)	Difference from control , %
0	7th	36.05	32.32	0
	28th	45.75	34.72	0
1	7th	35.08	32.06	-0.804
	28th	44.52	34.43	-0.835
1.5	7th	30.71	30.80	-4.703
	28th	39.78	33.29	-4.119
2	7th	27.88	29.92	-7.426
	28th	35.45	32.16	-07.373
2.5	7th	23.94	28.59	-11.541
	28th	31.36	31.00	-10.714

As table 4.8, indicated, it has approaches with the value of high strength concrete of C 40 and C 60 requirement with the minimum requirement, according to EBCS EN 1992-1-1:2015specification. However, the percentage of strength development trends decreases as the percentage of steel fiber increases. But, the percentage of decrement is not uniform.

Table Shows Summary of modulus of elasticity of C 60 Concrete grade

Percentage	Age	Max compressive strength (MPa)	Modulus of elasticity (GPa)	Difference from control , %
0	7th	45.85	34.74	0
	28th	63.1	38.23	0
1	7th	44.62	34.46	-0.806
	28th	61.78	38.00	-0.602
1.5	7th	38.98	33.09	-4.750
	28th	58.34	37.34	-2.328
2	7th	35.35	32.13	-7.513
	28th	50.92	35.85	-6.226
2.5	7th	30.36	30.7	-11.629
	28th	50.34	35.73	-6.540

As table 4.9, indicated, it has approaches with the value of high strength concrete of C 40 and C 60 requirement with the minimum requirement, according to EBCS EN 1992-1-1:2013 specification. However, the percentage of strength development trends decreases as the percentage of steel fiber increases. But, the percentage of decrement is not uniform.

APPENDIX-IV Stress strain relationship result

K 40, 0% Compressive strength @7 day									
ΔH	Load(KN)			Area (mm^2)	Stress (Mpa)			Av Stress	Av strain
0	0	0	0	22500	0	0	0	0	0
0.05	21	21	20	22500	0.933	0.933	0.889	0.919	0.0000272
0.1	27	26	24	22500	1.200	1.156	1.067	1.141	0.0000338
0.15	49	44	37	22500	2.178	1.956	1.644	1.926	0.0000574
0.2	77	75	48	22500	3.422	3.333	2.133	2.963	0.0000891
0.25	121	99	67	22500	5.378	4.400	2.978	4.252	0.0001292
0.3	144	125	80	22500	6.400	5.556	3.556	5.170	0.0001583
0.35	171	144	98	22500	7.600	6.400	4.356	6.119	0.0001889
0.4	199	166	125	22500	8.844	7.378	5.556	7.259	0.0002263
0.45	225	199	141	22500	10.000	8.844	6.267	8.370	0.0002636
0.5	247	225	157	22500	10.978	10.000	6.978	9.319	0.0002961
0.55	260	251	178	22500	11.556	11.156	7.911	10.207	0.0003271
0.6	285	278	199	22500	12.667	12.356	8.844	11.289	0.0003656
0.65	299	292	225	22500	13.289	12.978	10.000	12.089	0.0003947
0.7	322	345	246	22500	14.311	15.333	10.933	13.526	0.0004483
0.75	344	382	264	22500	15.289	16.978	11.733	14.667	0.0004922
0.8	356	411	288	22500	15.822	18.267	12.800	15.630	0.0005302
0.85	371	432	311	22500	16.489	19.200	13.822	16.504	0.0005656
0.9	384	455	328	22500	17.067	20.222	14.578	17.289	0.0005981
0.95	398	460	342	22500	17.689	20.444	15.200	17.778	0.0006187
1	424	462	356	22500	18.844	20.533	15.822	18.400	0.0006454
1.05	444	469	377	22500	19.733	20.844	16.756	19.111	0.0006764
1.1	452	478	395	22500	20.089	21.244	17.556	19.630	0.0006996
1.15	483	488	408	22500	21.467	21.689	18.133	20.430	0.000736
1.2	501	495	428	22500	22.267	22.000	19.022	21.096	0.0007671
1.25	524	504	444	22500	23.289	22.400	19.733	21.807	0.0008011
1.3	538	511	461	22500	23.911	22.711	20.489	22.370	0.0008287
1.35	560	520	484	22500	24.889	23.111	21.511	23.170	0.000869
1.4	594	534	498	22500	26.400	23.733	22.133	24.089	0.0009169
1.45	610	545	510	22500	27.111	24.222	22.667	24.667	0.0009481
1.5	629	561	535	22500	27.956	24.933	23.778	25.556	0.0009977
1.55	642	573	547	22500	28.533	25.467	24.311	26.104	0.001029
1.6	662	584	569	22500	29.422	25.956	25.289	26.889	0.001076
1.65	699	590	579	22500	31.067	26.222	25.733	27.674	0.001126
1.7	720	605	588	22500	32.000	26.889	26.133	28.341	0.001169
1.75	736	620	610	22500	32.711	27.556	27.111	29.126	0.001224
1.8	756	654	635	22500	33.600	29.067	28.222	30.296	0.001311
1.85	770	669	678	22500	34.222	29.733	30.133	31.363	0.001399
1.9	781	694	692	22500	34.711	30.844	30.756	32.104	0.001466

1.95	795	713	709	22500	35.333	31.689	31.511	32.844	0.00154
2	806	736	730	22500	35.822	32.711	32.444	33.659	0.001633
2.05	820	759	759	22500	36.444	33.733	33.733	34.637	0.001771
2.1	835	780	793	22500	37.111	34.667	35.244	35.674	0.001999
2.15	840	799	791	22500	37.333	35.511	35.156	**36.000**	0.002219
2.2	839	790	789	22500	37.289	35.111	35.067	35.822	0.002384
2.25	835	783	788	22500	37.111	34.800	35.022	35.644	0.002453

K 40 1% Compressive strength of Cube @7 days									
ΔH	**Load (KN)**			**Area(mm^2)**	**Stress (Mpa)**			**Av Stress**	**Av strain**
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	17	17	17	22500	0.756	0.756	0.756	0.756	0.0000226
0.1	18	28	23	22500	0.800	1.244	1.022	1.022	0.0000306
0.15	35	49	42	22500	1.556	2.178	1.867	1.867	0.0000563
0.2	60	86	73	22500	2.667	3.822	3.244	3.244	0.000099
0.25	83	119	101	22500	3.689	5.289	4.489	4.489	0.0001385
0.3	115	138	127	22500	5.111	6.133	5.622	5.622	0.0001753
0.35	150	154	152	22500	6.667	6.844	6.756	6.756	0.0002129
0.4	194	182	188	22500	8.622	8.089	8.356	8.356	0.0002673
0.45	246	234	240	22500	10.933	10.400	10.667	10.667	0.0003493
0.5	270	275	273	22500	12.000	12.222	12.111	12.111	0.0004027
0.55	315	306	311	22500	14.000	13.600	13.800	13.800	0.0004677
0.6	349	351	350	22500	15.511	15.600	15.556	15.556	0.0005382
0.65	385	394	390	22500	17.111	17.511	17.311	17.311	0.0006123
0.7	421	426	424	22500	18.711	18.933	18.822	18.822	0.0006794
0.75	456	445	451	22500	20.267	19.778	20.022	20.022	0.0007351
0.8	493	486	490	22500	21.911	21.600	21.756	21.756	0.00082
0.85	543	514	529	22500	24.133	22.844	23.489	23.489	0.0009112
0.9	589	542	566	22500	26.178	24.089	25.133	25.133	0.001005
0.95	612	583	598	22500	27.200	25.911	26.556	26.556	0.001093
1	675	626	651	22500	30.000	27.822	28.911	28.911	0.001257
1.05	698	664	681	22500	31.022	29.511	30.267	30.267	0.001368
1.1	716	705	711	22500	31.822	31.333	31.578	31.578	0.001492
1.15	749	762	756	22500	33.289	33.867	33.578	33.578	0.001743
1.2	783	794	789	22500	34.800	35.289	35.044	**35.044**	0.00222
1.25	782	793	788	22500	34.756	35.244	35.000	35.000	0.002304
1.3	780	790	785	22500	34.667	35.111	34.889	34.889	0.002378
1.35	778	788	783	22500	34.578	35.022	34.800	34.800	0.002418
1.4	775	782	779	22500	34.444	34.756	34.600	34.600	0.002488
1.45	770	776	773	22500	34.222	34.489	34.356	34.356	0.002554
1.5	766	775	772	22500	34.044	34.444	34.311	34.267	0.002575
1.55	751	774	769	22500	33.378	34.400	34.178	33.985	0.002635
1.6			765	22500	0.000	0.000	34.000	11.333	0.002659

K 40 1.5% Compressive Strength @ 7 Days									
ΔH	**Load ,KN**			**Area,mm^2**	**Stress, MPa**			**Av Stress**	**Av Strain**
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	18	19	19	22500	0.800	0.844	0.822	0.822	0.0000257
0.1	26	28	27	22500	1.156	1.244	1.200	1.200	0.0000376
0.15	35	49	42	22500	1.556	2.178	1.867	1.867	0.000059
0.2	59	82	71	22500	2.622	3.644	3.133	3.133	0.0001004
0.25	99	103	101	22500	4.400	4.578	4.489	4.489	0.0001461
0.3	145	136	141	22500	6.444	6.044	6.244	6.244	0.0002077
0.35	190	159	175	22500	8.444	7.067	7.756	7.756	0.000263
0.4	246	195	221	22500	10.933	8.667	9.800	9.800	0.0003417
0.45	287	243	265	22500	12.756	10.800	11.778	11.778	0.0004226
0.5	342	276	309	22500	15.200	12.267	13.733	13.733	0.0005708
0.55	386	301	344	22500	17.156	13.378	15.267	15.267	0.0005791
0.6	438	359	399	22500	19.467	15.956	17.711	17.711	0.0007023
0.65	486	394	440	22500	21.600	17.511	19.556	19.556	0.0008049
0.7	517	453	485	22500	22.978	20.133	21.556	21.556	0.0009283
0.75	548	468	508	22500	24.356	20.800	22.578	22.578	0.0009976
0.8	598	492	545	22500	26.578	21.867	24.222	24.222	0.001121
0.85	612	537	575	22500	27.200	23.867	25.533	25.533	0.001233
0.9	640	586	613	22500	28.444	26.044	27.244	27.244	0.001407
0.95	692	641	667	22500	30.756	28.489	29.622	29.622	0.001767
1	688	690	689	22500	30.578	30.667	30.622	**30.622**	0.00222
1.05	685	691	688	22500	30.444	30.711	30.578	30.578	0.002318
1.1	684	685	685	22500	30.400	30.444	30.422	30.422	0.00243
1.15	683	684	684	22500	30.356	30.400	30.378	30.378	0.002453
1.2	681	683	682	22500	30.267	30.356	30.311	30.311	0.002483
1.25	680	682	681	22500	30.222	30.311	30.267	30.267	0.002501
1.3	675	681	678	22500	30.000	30.267	30.133	30.133	0.002551
1.35	673	680	677	22500	29.911	30.222	30.067	30.067	0.002573

K 40 2% Compressive strength @7 days									
ΔH	**Load (KN)**			**Area(mm^2)**	**Stress (Mpa)**			**Av Stress**	**Av strain**
0	0	0	0	22500	0	0	0	0	0
0.05	20	17	19	22500	0.889	0.756	0.822	0.822	0.0000265
0.1	29	28	29	22500	1.289	1.244	1.267	1.267	0.000041
0.15	38	44	41	22500	1.689	1.956	1.822	1.822	0.0000594
0.2	53	67	60	22500	2.356	2.978	2.667	2.667	0.000088
0.25	67	84	76	22500	2.978	3.733	3.356	3.356	0.0001118
0.3	94	113	104	22500	4.178	5.022	4.600	4.600	0.000156
0.35	128	154	141	22500	5.689	6.844	6.267	6.267	0.000218
0.4	152	170	161	22500	6.756	7.556	7.156	7.156	0.0002524
0.45	183	205	194	22500	8.133	9.111	8.622	8.622	0.0003114
0.5	211	238	225	22500	9.378	10.578	9.978	9.978	0.0003688
0.55	234	265	250	22500	10.400	11.778	11.089	11.089	0.000418
0.6	264	291	278	22500	11.733	12.933	12.333	12.333	0.0004759
0.65	276	324	300	22500	12.267	14.400	13.333	13.333	0.0005246
0.7	301	368	335	22500	13.378	16.356	14.867	14.867	0.0006039
0.75	329	394	362	22500	14.622	17.511	16.067	16.067	0.0006702
0.8	340	441	391	22500	15.111	19.600	17.356	17.356	0.0007466
0.85	386	495	441	22500	17.156	22.000	19.578	19.578	0.0008934
0.9	403	520	462	22500	17.911	23.111	20.511	20.511	0.0009624
0.95	420	564	492	22500	18.667	25.067	21.867	21.867	0.001073
1	463	590	527	22500	20.578	26.222	23.400	23.400	0.001218
1.05	490	615	553	22500	21.778	27.333	24.556	24.556	0.001348
1.1	541	628	585	22500	24.044	27.911	25.978	25.978	0.001552
1.15	589	640	615	22500	26.178	28.444	27.311	27.311	0.001854
1.2	610	643	627	22500	27.111	28.578	27.844	**27.844**	0.00222
1.25	609	642	626	22500	27.067	28.533	27.800	27.800	0.002329
1.3	603	641	622	22500	26.800	28.489	27.644	27.644	0.002455
1.35	594	638	616	22500	26.400	28.356	27.378	27.378	0.002582
1.4	591	631	611	22500	26.267	28.044	27.156	27.156	0.002662
1.45	588	624	606	22500	26.133	27.733	26.933	26.933	0.002731
1.5	584	621	603	22500	25.956	27.600	26.778	26.778	0.002775
1.55	581	620	601	22500	25.822	27.556	26.689	26.689	0.002798

K40 2.5% Compressive Strength at 7 days									
ΔH	**Load, KN**			**Area,mm²**	**Stress, Mpa**			**Av Stress**	**Av strain**
0	0	0	0	22500	0.000	0.000	0.000	0.000	0.0000000
0.05	18	20	19	22500	0.800	0.889	0.844	0.844	0.0000285
0.1	29	31	30	22500	1.289	1.378	1.333	1.333	0.0000455
0.15	40	46	43	22500	1.778	2.044	1.911	1.911	0.0000659
0.2	47	59	53	22500	2.089	2.622	2.356	2.356	0.0000819
0.25	64	74	69	22500	2.844	3.289	3.067	3.067	0.0001080
0.3	89	92	91	22500	3.956	4.089	4.022	4.022	0.0001443
0.35	120	114	117	22500	5.333	5.067	5.200	5.200	0.0001909
0.4	153	138	146	22500	6.800	6.133	6.467	6.467	0.0002437
0.45	190	186	188	22500	8.444	8.267	8.356	8.356	0.0003283
0.5	210	218	214	22500	9.333	9.689	9.511	9.511	0.0003839
0.55	231	264	248	22500	10.267	11.733	11.000	11.000	0.0004607
0.6	245	281	263	22500	10.889	12.489	11.689	11.689	0.0004985
0.65	256	316	286	22500	11.378	14.044	12.711	12.711	0.0005575
0.7	264	342	303	22500	11.733	15.200	13.467	13.467	0.0006037
0.75	278	361	320	22500	12.356	16.044	14.200	14.200	0.0006508
0.8	301	391	346	22500	13.378	17.378	15.378	15.378	0.0007320
0.85	345	410	378	22500	15.333	18.222	16.778	16.778	0.0008392
0.9	381	430	406	22500	16.933	19.111	18.022	18.022	0.0009471
0.95	411	453	432	22500	18.267	20.133	19.200	19.200	0.0010640
1	450	475	463	22500	20.000	21.111	20.556	20.556	0.0012250
1.05	462	493	478	22500	20.533	21.911	21.222	21.222	0.0013190
1.1	491	501	496	22500	21.822	22.267	22.044	22.044	0.0014570
1.15	532	535	534	22500	23.644	23.778	23.711	23.711	0.0019580
1.2	536	540	538	22500	23.822	24.000	23.911	23.911	0.0022200
1.25	535	539	537	22500	23.778	23.956	23.867	23.867	0.0023440
13	531	533	532	22500	23.600	23.689	23.644	23.644	0.0025410
1.35	527	531	529	22500	23.422	23.600	23.511	23.511	0.0026170
1.4	520	527	524	22500	23.111	23.422	23.267	23.267	0.0027300
1.45	519	526	523	22500	23.067	23.378	23.222	23.222	0.0027480
1.5	512	521	517	22500	22.756	23.156	22.956	22.956	0.0028480

K 40, 0% Compressive strength @28 day									
ΔH	Load(KN)			Area (mm^2)	Stress (Mpa)			Av stress	Av strain
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	27	27	25	22500	1.185	1.185	1.128	1.166	0.0000322
0.1	34	33	30	22500	1.523	1.467	1.354	1.448	0.00004
0.15	62	56	47	22500	2.764	2.482	2.087	2.444	0.0000678
0.2	98	95	61	22500	4.344	4.231	2.708	3.761	0.0001049
0.25	154	126	85	22500	6.826	5.585	3.779	5.397	0.0001517
0.3	183	159	102	22500	8.123	7.051	4.513	6.562	0.0001854
0.35	217	183	124	22500	9.646	8.123	5.528	7.766	0.0002207
0.4	253	211	159	22500	11.226	9.364	7.051	9.214	0.0002637
0.45	286	253	179	22500	12.692	11.226	7.954	10.624	0.0003062
0.5	314	286	199	22500	13.933	12.692	8.856	11.827	0.0003431
0.55	330	319	226	22500	14.667	14.159	10.041	12.956	0.0003781
0.6	362	353	253	22500	16.077	15.682	11.226	14.328	0.0004213
0.65	380	371	286	22500	16.867	16.472	12.692	15.344	0.0004538
0.7	409	438	312	22500	18.164	19.462	13.877	17.168	0.0005132
0.75	437	485	335	22500	19.405	21.549	14.892	18.615	0.0005615
0.8	452	522	366	22500	20.082	23.185	16.246	19.838	0.0006031
0.85	471	548	395	22500	20.928	24.369	17.544	20.947	0.0006415
0.9	487	578	416	22500	21.662	25.667	18.503	21.944	0.0006767
0.95	505	584	434	22500	22.451	25.949	19.292	22.564	0.0006988
1	538	586	452	22500	23.918	26.062	20.082	23.354	0.0007274
1.05	564	595	479	22500	25.046	26.456	21.267	24.256	0.0007606
1.1	574	607	501	22500	25.497	26.964	22.282	24.915	0.0007852
1.15	613	619	518	22500	27.246	27.528	23.015	25.930	0.0008237
1.2	636	628	543	22500	28.262	27.923	24.144	26.776	0.0008565
1.25	665	640	564	22500	29.559	28.431	25.046	27.679	0.0008921
1.3	683	649	585	22500	30.349	28.826	26.005	28.393	0.0009208
1.35	711	660	614	22500	31.590	29.333	27.303	29.409	0.0009626
1.4	754	678	632	22500	33.508	30.123	28.092	30.574	0.001012
1.45	774	692	647	22500	34.410	30.744	28.769	31.308	0.001044
1.5	798	712	679	22500	35.482	31.646	30.179	32.436	0.001094
1.55	815	727	694	22500	36.215	32.323	30.856	33.132	0.001126
1.6	840	741	722	22500	37.344	32.944	32.097	34.128	0.001173
1.65	887	749	735	22500	39.431	33.282	32.662	35.125	0.001222
1.7	914	768	746	22500	40.615	34.128	33.169	35.971	0.001266
1.75	934	787	774	22500	41.518	34.974	34.410	36.968	0.001319
1.8	960	830	806	22500	42.646	36.892	35.821	38.453	0.001403
1.85	977	849	861	22500	43.436	37.738	38.246	39.807	0.001487
1.9	991	881	878	22500	44.056	39.149	39.036	40.747	0.001551
1.95	1009	905	900	22500	44.846	40.221	39.995	41.687	0.00162
2	1023	934	927	22500	45.467	41.518	41.179	42.721	0.001706
2.05	1041	963	963	22500	46.256	42.815	42.815	43.962	0.001831
2.1	1060	990	1007	22500	47.103	44.000	44.733	45.279	0.002033
2.15	1066	1014	1004	22500	47.385	45.072	44.621	**45.692**	0.00222
2.2	1065	1003	1001	22500	47.328	44.564	44.508	45.467	0.002356
2.25	1060	994	1000	22500	47.103	44.169	44.451	45.241	0.002411

K 40 1% Compressive strength of Cube @28days									
ΔH	**Load (KN)**			**Area ,mm^2**	**Stress, Mpa**			**Av stress**	**Av strain**
0	0	0	0	22500.000	0.000	0.000	0.000	0.000	0
0.05	22	22	22	22500.000	0.959	0.959	0.959	0.959	0.000026
0.1	23	36	29	22500.000	1.015	1.579	1.297	1.297	0.000036
0.15	44	62	53	22500.000	1.974	2.764	2.369	2.369	0.000066
0.2	76	109	93	22500.000	3.385	4.851	4.118	4.118	0.000116
0.25	105	151	128	22500.000	4.682	6.713	5.697	5.697	0.000161
0.3	146	175	161	22500.000	6.487	7.785	7.136	7.136	0.000204
0.35	190	195	193	22500.000	8.462	8.687	8.574	8.574	0.000247
0.4	246	231	239	22500.000	10.944	10.267	10.605	10.605	0.000309
0.45	312	297	305	22500.000	13.877	13.200	13.538	13.538	0.000401
0.5	343	349	346	22500.000	15.231	15.513	15.372	15.372	0.000461
0.55	400	388	394	22500.000	17.769	17.262	17.515	17.515	0.000532
0.6	443	446	444	22500.000	19.687	19.800	19.744	19.744	0.000609
0.65	489	500	494	22500.000	21.718	22.226	21.972	21.972	0.000689
0.7	534	541	538	22500.000	23.749	24.031	23.890	23.890	0.000761
0.75	579	565	572	22500.000	25.723	25.103	25.413	25.413	0.000820
0.8	626	617	621	22500.000	27.810	27.415	27.613	27.613	0.000909
0.85	689	652	671	22500.000	30.631	28.995	29.813	29.813	0.001003
0.9	748	688	718	22500.000	33.226	30.574	31.900	31.900	0.001098
0.95	777	740	758	22500.000	34.523	32.887	33.705	33.705	0.001186
1	857	795	826	22500.000	38.077	35.313	36.695	36.695	0.001348
1.05	886	843	864	22500.000	39.374	37.456	38.415	38.415	0.001455
1.1	909	895	902	22500.000	40.390	39.769	40.079	40.079	0.001572
1.15	951	967	959	22500.000	42.251	42.985	42.618	42.618	0.001804
1.2	994	1008	1001	22500.000	44.169	44.790	44.479	**44.479**	0.00222
1.25	993	1007	1000	22500.000	44.113	44.733	44.423	44.423	0.00229
1.3	990	1003	996	22500.000	44.000	44.564	44.282	44.282	0.002352
1.35	987	1000	994	22500.000	43.887	44.451	44.169	44.169	0.002385
1.4	984	993	988	22500.000	43.718	44.113	43.915	43.915	0.002441
1.45	977	985	981	22500.000	43.436	43.774	43.605	43.605	0.002495
1.5	972	984	980	22500.000	43.210	43.718	43.549	43.492	0.002512
1.55	953	982	976	22500.000	42.364	43.662	43.379	43.135	0.002559
1.6			971	22500.000	0.000		43.154	14.385	

K 40 1.5% Compressive Strength @ 28 Days									
ΔH	**Load ,KN**			**Area,mm²**	**Stress,Mpa**			**Av stress**	**Av strain**
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	23	24	23	22500	1.015	1.072	1.044	1.044	0.00003
0.1	33	36	34	22500	1.467	1.579	1.523	1.523	0.00004
0.15	44	62	53	22500	1.974	2.764	2.369	2.369	0.00006
0.2	75	104	89	22500	3.328	4.626	3.977	3.977	0.00011
0.25	126	131	128	22500	5.585	5.810	5.697	5.697	0.00017
0.3	184	173	178	22500	8.179	7.672	7.926	7.926	0.00024
0.35	241	202	221	22500	10.718	8.969	9.844	9.844	0.00030
0.4	312	248	280	22500	13.877	11.000	12.438	12.438	0.00039
0.45	364	308	336	22500	16.190	13.708	14.949	14.949	0.00048
0.5	434	350	392	22500	19.292	15.569	17.431	17.431	0.00057
0.55	490	382	436	22500	21.774	16.979	19.377	19.377	0.00078
0.6	556	456	506	22500	24.708	20.251	22.479	22.479	0.00089
0.65	617	500	558	22500	27.415	22.226	24.821	24.821	0.00101
0.7	656	575	616	22500	29.164	25.554	27.359	27.359	0.00108
0.75	696	594	645	22500	30.913	26.400	28.656	28.656	0.00121
0.8	759	624	692	22500	33.733	27.754	30.744	30.744	0.00132
0.85	777	682	729	22500	34.523	30.292	32.408	32.408	0.00148
0.9	812	744	778	22500	36.103	33.056	34.579	34.579	0.00182
0.95	878	814	846	22500	39.036	36.159	37.597	37.597	0.00202
1	873	876	875	22500	38.810	38.923	38.867	**38.867**	0.00222
1.05	869	877	873	22500	38.641	38.979	38.810	38.810	0.00230
1.1	868	869	869	22500	38.585	38.641	38.613	38.613	0.00239
1.15	867	868	868	22500	38.528	38.585	38.556	38.556	0.00241
1.2	864	867	866	22500	38.415	38.528	38.472	38.472	0.00244
1.25	863	866	864	22500	38.359	38.472	38.415	38.415	0.00245
1.3	857	864	861	22500	38.077	38.415	38.246	38.246	0.00249
1.35	854	863	859	22500	37.964	38.359	38.162	38.162	0.00251

K 40 2% Compressive strength @28 days									
ΔH	**Peak load ,KN**			**Area,mm^2**	**Stress,MPa**			**Av stress**	**Av strain**
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	25	22	23	22500	1.128	0.959	1.044	1.044	0.0000312
0.1	37	36	36	22500	1.636	1.579	1.608	1.608	0.0000483
0.15	48	56	52	22500	2.144	2.482	2.313	2.313	0.0000699
0.2	67	85	76	22500	2.990	3.779	3.385	3.385	0.0001032
0.25	85	107	96	22500	3.779	4.738	4.259	4.259	0.0001308
0.3	119	143	131	22500	5.303	6.374	5.838	5.838	0.0001818
0.35	162	195	179	22500	7.221	8.687	7.954	7.954	0.0002525
0.4	193	216	204	22500	8.574	9.590	9.082	9.082	0.0002915
0.45	232	260	246	22500	10.323	11.564	10.944	10.944	0.0003579
0.5	268	302	285	22500	11.903	13.426	12.664	12.664	0.0004217
0.55	297	336	317	22500	13.200	14.949	14.074	14.074	0.000476
0.6	335	369	352	22500	14.892	16.415	15.654	15.654	0.0005393
0.65	350	411	381	22500	15.569	18.277	16.923	16.923	0.0005921
0.7	382	467	425	22500	16.979	20.759	18.869	18.869	0.0006771
0.75	418	500	459	22500	18.559	22.226	20.392	20.392	0.0007475
0.8	432	560	496	22500	19.179	24.877	22.028	22.028	0.0008276
0.85	490	628	559	22500	21.774	27.923	24.849	24.849	0.0009791
0.9	512	660	586	22500	22.733	29.333	26.033	26.033	0.001049
0.95	533	716	624	22500	23.692	31.815	27.754	27.754	0.00116
1	588	749	668	22500	26.118	33.282	29.700	29.700	0.001303
1.05	622	781	701	22500	27.641	34.692	31.167	31.167	0.001428
1.1	687	797	742	22500	30.518	35.426	32.972	32.972	0.001621
1.15	748	812	780	22500	33.226	36.103	34.664	34.664	0.001898
1.2	774	816	795	22500	34.410	36.272	35.341	**35.341**	0.00222
1.25	773	815	794	22500	34.354	36.215	35.285	35.285	0.002314
1.3	765	814	789	22500	34.015	36.159	35.087	35.087	0.00242
1.35	754	810	782	22500	33.508	35.990	34.749	34.749	0.002526
1.4	750	801	776	22500	33.338	35.595	34.467	34.467	0.002649
1.45	746	792	769	22500	33.169	35.200	34.185	34.185	0.002685
1.5	741	788	765	22500	32.944	35.031	33.987	33.987	0.002704
1.55	737	787	762	22500	32.774	34.974	33.874	33.874	0.002701

K40 2.5% Compressive Strength at 28 days									
ΔH	Load, KN			Area,mm^2	Stress,Mpa			Av Stress	Av strain
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	23	25	24	22500	1.015	1.128	1.072	1.072	0.000034
0.1	37	39	38	22500	1.636	1.749	1.692	1.692	0.0000541
0.15	51	58	55	22500	2.256	2.595	2.426	2.426	0.0000782
0.2	60	75	67	22500	2.651	3.328	2.990	2.990	0.000097
0.25	81	94	88	22500	3.610	4.174	3.892	3.892	0.0001276
0.3	113	117	115	22500	5.021	5.190	5.105	5.105	0.0001699
0.35	152	145	149	22500	6.769	6.431	6.600	6.600	0.0002238
0.4	194	175	185	22500	8.631	7.785	8.208	8.208	0.0002842
0.45	241	236	239	22500	10.718	10.492	10.605	10.605	0.0003796
0.5	267	277	272	22500	11.846	12.297	12.072	12.072	0.0004415
0.55	293	335	314	22500	13.031	14.892	13.962	13.962	0.0005261
0.6	311	357	334	22500	13.821	15.851	14.836	14.836	0.0005672
0.65	325	401	363	22500	14.441	17.826	16.133	16.133	0.000631
0.7	335	434	385	22500	14.892	19.292	17.092	17.092	0.0006804
0.75	353	458	406	22500	15.682	20.364	18.023	18.023	0.0007304
0.8	382	496	439	22500	16.979	22.056	19.518	19.518	0.0008157
0.85	438	520	479	22500	19.462	23.128	21.295	21.295	0.0009267
0.9	484	546	515	22500	21.492	24.256	22.874	22.874	0.001037
0.95	522	575	548	22500	23.185	25.554	24.369	24.369	0.001154
1	571	603	587	22500	25.385	26.795	26.090	26.090	0.001311
1.05	586	626	606	22500	26.062	27.810	26.936	26.936	0.001402
1.1	623	636	630	22500	27.697	28.262	27.979	27.979	0.001533
1.15	675	679	677	22500	30.010	30.179	30.095	30.095	0.001992
1.2	680	685	683	22500	30.236	30.462	30.349	**30.349**	0.00222
1.25	679	684	682	22500	30.179	30.405	30.292	30.292	0.002326
13	674	677	675	22500	29.954	30.067	30.010	30.010	0.002492
1.35	669	674	671	22500	29.728	29.954	29.841	29.841	0.002556
1.4	660	669	664	22500	29.333	29.728	29.531	29.531	0.002649
1.45	659	668	663	22500	29.277	29.672	29.474	29.474	0.002664
1.5	650	661	656	22500	28.882	29.390	29.136	29.136	0.002746

K 60 0% Compressive strength at 7 days									
∆H	Load ,KN			Area, mm^2	Stress,Mpa			Av stress	Av Strain
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	18	23	20.5	22500	0.800	1.022	0.911	0.911	0.0000245
0.1	30	33	31.5	22500	1.333	1.467	1.400	1.400	0.0000377
0.15	79	91	85	22500	3.511	4.044	3.778	3.778	0.0001028
0.2	102	115	108.5	22500	4.533	5.111	4.822	4.822	0.0001318
0.25	150	140	145	22500	6.667	6.222	6.444	6.444	0.0001775
0.3	198	178	188	22500	8.800	7.911	8.356	8.356	0.0002323
0.35	248	199	223.5	22500	11.022	8.844	9.933	9.933	0.0002783
0.4	291	220	255.5	22500	12.933	9.778	11.356	11.356	0.0003204
0.45	345	290	317.5	22500	15.333	12.889	14.111	14.111	0.0004041
0.5	365	348	356.5	22500	16.222	15.467	15.844	15.844	0.0004581
0.55	389	387	388	22500	17.289	17.200	17.244	17.244	0.0005026
0.6	412	442	427	22500	18.311	19.644	18.978	18.978	0.0005589
0.65	451	495	473	22500	20.044	22.000	21.022	21.022	0.0006271
0.7	486	542	514	22500	21.600	24.089	22.844	22.844	0.0006897
0.75	501	589	545	22500	22.267	26.178	24.222	24.222	0.0007383
0.8	535	612	573.5	22500	23.778	27.200	25.489	25.489	0.000784
0.85	586	630	608	22500	26.044	28.000	27.022	27.022	0.0008407
0.9	610	658	634	22500	27.111	29.244	28.178	28.178	0.0008847
0.95	642	677	659.5	22500	28.533	30.089	29.311	29.311	0.0009287
1	678	704	691	22500	30.133	31.289	30.711	30.711	0.0009847
1.05	715	721	718	22500	31.778	32.044	31.911	31.911	0.001034
1.1	761	756	758.5	22500	33.822	33.600	33.711	33.711	0.001111
1.15	796	780	788	22500	35.378	34.667	35.022	35.022	0.00117
1.2	846	798	822	22500	37.600	35.467	36.533	36.533	0.001241
1.25	893	814	853.5	22500	39.689	36.178	37.933	37.933	0.00131
1.3	918	850	884	22500	40.800	37.778	39.289	39.289	0.00138
1.35	964	895	929.5	22500	42.844	39.778	41.311	41.311	0.001494
1.4	1010	945	977.5	22500	44.889	42.000	43.444	43.444	0.001628
1.45	1095	994	1044.5	22500	48.667	44.178	46.422	46.422	0.001861
1.5	1123	1085	1104	22500	49.911	48.222	49.067	49.067	0.002196
1.55	1122	1114	1118	22500	49.867	49.511	49.689	**49.689**	0.002447
1.6	1109	1113	1111	22500	49.289	49.467	49.378	49.378	0.002271
1.65	1101			22500	48.933	0.000	0.000	16.311	

K 60 1% Compressive strength at 7 days									
ΔH	**Load ,KN**			**Area, mm^2**	**Stress,Mpa**			**Av stress**	**Av Strain**
0	0	0	0	22500	0	0	0	0	0
0.05	18	23	21	22500	0.800	1.022	0.911	0.911	0.0000253
0.1	40	42	41	22500	1.778	1.867	1.822	1.822	0.0000508
0.15	65	78	72	22500	2.889	3.467	3.178	3.178	0.0000893
0.2	94	91	93	22500	4.178	4.044	4.111	4.111	0.0001161
0.25	112	123	118	22500	4.978	5.467	5.222	5.222	0.0001485
0.3	145	148	147	22500	6.444	6.578	6.511	6.511	0.0001865
0.35	186	187	187	22500	8.267	8.311	8.289	8.289	0.0002401
0.4	201	208	205	22500	8.933	9.244	9.089	9.089	0.0002647
0.45	220	245	233	22500	9.778	10.889	10.333	10.333	0.0003034
0.5	268	264	266	22500	11.911	11.733	11.822	11.822	0.0003506
0.55	299	304	302	22500	13.289	13.511	13.400	13.400	0.0004018
0.6	335	347	341	22500	14.889	15.422	15.156	15.156	0.0004602
0.65	389	391	390	22500	17.289	17.378	17.333	17.333	0.0005351
0.7	410	452	431	22500	18.222	20.089	19.156	19.156	0.0006001
0.75	465	498	482	22500	20.667	22.133	21.400	21.400	0.0006833
0.8	491	526	509	22500	21.822	23.378	22.600	22.600	0.0007294
0.85	513	576	545	22500	22.800	25.600	24.200	24.200	0.0007929
0.9	546	604	575	22500	24.267	26.844	25.556	25.556	0.0008485
0.95	584	643	614	22500	25.956	28.578	27.267	27.267	0.0009216
1	615	679	647	22500	27.333	30.178	28.756	28.756	0.0009881
1.05	665	705	685	22500	29.556	31.333	30.444	30.444	0.001067
1.1	690	742	716	22500	30.667	32.978	31.822	31.822	0.001135
1.15	754	794	774	22500	33.511	35.289	34.400	34.400	0.001273
1.2	791	814	803	22500	35.156	36.178	35.667	35.667	0.001347
1.25	842	865	854	22500	37.422	38.444	37.933	37.933	0.001493
1.3	893	890	892	22500	39.689	39.556	39.622	39.622	0.001618
1.35	942	941	942	22500	41.867	41.822	41.844	41.844	0.001819
1.4	981	956	969	22500	43.600	42.489	43.044	43.044	0.00196
1.45	1012	990	1001	22500	44.978	44.000	44.489	44.489	0.002227
1.5	1009	1010	1010	22500	44.844	44.889	44.867	**44.867**	0.00245
1.55	1007	1009	1008	22500	44.756	44.844	44.800	44.800	0.002544
1.6	1006	1007	1007	22500	44.711	44.756	44.733	44.733	0.002582
1.65	1005	1004	1005	22500	44.667	44.622	44.644	44.644	0.002621
1.7	1003	1002	1003	22500	44.578	44.533	44.556	44.556	0.002652

K 60 1.5% Compressive strength at 7 days									
ΔH	**Load ,KN**			**Area, mm^2**	**Stress,Mpa**			**Av stress**	**Av Strain**
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	18	23	21	22500	0.800	1.022	0.911	0.911	0.0000258
0.1	39	39	39	22500	1.733	1.733	1.733	1.733	0.0000493
0.15	78	89	84	22500	3.467	3.956	3.711	3.711	0.0001069
0.2	97	112	105	22500	4.311	4.978	4.644	4.644	0.0001346
0.25	145	165	155	22500	6.444	7.333	6.889	6.889	0.0002029
0.3	189	197	193	22500	8.400	8.756	8.578	8.578	0.0002558
0.35	245	242	244	22500	10.889	10.756	10.822	10.822	0.0003282
0.4	286	287	287	22500	12.711	12.756	12.733	12.733	0.0003922
0.45	342	313	328	22500	15.200	13.911	14.556	14.556	0.0004552
0.5	398	349	374	22500	17.689	15.511	16.600	16.600	0.0005286
0.55	429	398	414	22500	19.067	17.689	18.378	18.378	0.0005949
0.6	496	429	463	22500	22.044	19.067	20.556	20.556	0.0006798
0.65	514	489	502	22500	22.844	21.733	22.289	22.289	0.0007507
0.7	579	525	552	22500	25.733	23.333	24.533	24.533	0.0008474
0.75	610	585	598	22500	27.111	26.000	26.556	26.556	0.0009402
0.8	658	615	637	22500	29.244	27.333	28.289	28.289	0.001025
0.85	696	676	686	22500	30.933	30.044	30.489	30.489	0.001141
0.9	715	720	718	22500	31.778	32.000	31.889	31.889	0.00122
0.95	765	762	764	22500	34.000	33.867	33.933	33.933	0.001347
1	799	800	800	22500	35.511	35.556	35.533	35.533	0.001459
1.05	826	839	833	22500	36.711	37.289	37.000	37.000	0.001574
1.1	864	880	872	22500	38.400	39.111	38.756	38.756	0.001736
1.15	898	901	900	22500	39.911	40.044	39.978	39.978	0.001877
1.2	914	929	922	22500	40.622	41.289	40.956	40.956	0.002022
1.25	947	951	949	22500	42.089	42.267	42.178	**42.178**	0.00245
1.3	945	948	947	22500	42.000	42.133	42.067	42.067	0.00258
1.35	944	943	944	22500	41.956	41.911	41.933	41.933	0.002643
1.4	942	941	942	22500	41.867	41.822	41.844	41.844	0.002678
1.45	938	940	939	22500	41.689	41.778	41.733	41.733	0.002711
1.5	937	937	937	22500	41.644	41.644	41.644	41.644	0.002736
1.55	936	934	935	22500	41.600	41.511	41.556	41.556	0.002758
1.6	930	931	931	22500	41.333	41.378	41.356	41.356	0.002805

K 60 2% Compressive strength at 7 days									
∆H	Load ,KN			Area, mm^2	Stress,Mpa			Av stress	Av Strain
0	0	0	0	22500	0	0	0	0	0
0.05	18	23	20.5	22500	0.800	1.022	0.911	0.911	0.0000262
0.1	34	45	39.5	22500	1.511	2.000	1.756	1.756	0.0000509
0.15	68	94	81	22500	3.022	4.178	3.600	3.600	0.0001058
0.2	99	115	107	22500	4.400	5.111	4.756	4.756	0.000141
0.25	114	159	136.5	22500	5.067	7.067	6.067	6.067	0.0001818
0.3	145	188	166.5	22500	6.444	8.356	7.400	7.400	0.0002242
0.35	194	214	204	22500	8.622	9.511	9.067	9.067	0.0002786
0.4	224	246	235	22500	9.956	10.933	10.444	10.444	0.0003248
0.45	256	289	272.5	22500	11.378	12.844	12.111	12.111	0.0003824
0.5	298	314	306	22500	13.244	13.956	13.600	13.600	0.0004356
0.55	345	356	350.5	22500	15.333	15.822	15.578	15.578	0.0005088
0.6	398	401	399.5	22500	17.689	17.822	17.756	17.756	0.0005934
0.65	435	449	442	22500	19.333	19.956	19.644	19.644	0.0006706
0.7	449	497	473	22500	19.956	22.089	21.022	21.022	0.0007294
0.75	488	515	501.5	22500	21.689	22.889	22.289	22.289	0.0007857
0.8	523	568	545.5	22500	23.244	25.244	24.244	24.244	0.000877
0.85	549	610	579.5	22500	24.400	27.111	25.756	25.756	0.0009521
0.9	591	675	633	22500	26.267	30.000	28.133	28.133	0.00108
0.95	634	715	674.5	22500	28.178	31.778	29.978	29.978	0.001188
1	691	746	718.5	22500	30.711	33.156	31.933	31.933	0.001316
1.05	713	790	751.5	22500	31.689	35.111	33.400	33.400	0.001424
1.1	754	819	786.5	22500	33.511	36.400	34.956	34.956	0.001554
1.15	789	846	817.5	22500	35.067	37.600	36.333	36.333	0.001688
1.2	804	892	848	22500	35.733	39.644	37.689	37.689	0.001852
1.25	843	901	872	22500	37.467	40.044	38.756	38.756	0.002025
1.3	890	894	892	22500	39.556	39.733	39.644	39.644	0.002275
1.35	910	882	896	22500	40.444	39.200	39.822	**39.822**	0.00245
1.4	909	873	891	22500	40.400	38.800	39.600	39.600	0.002647
1.45	904	861	882.5	22500	40.178	38.267	39.222	39.222	0.002775
1.5	899	846	872.5	22500	39.956	37.600	38.778	38.778	0.00288
1.55	893	846	869.5	22500	39.689	37.600	38.644	38.644	0.002907
1.6	892	845	868.5	22500	39.644	37.556	38.600	38.600	0.002916

K 60 2.5% Compressive strength at 7 days									
ΔH	Load ,KN			Area, mm^2	Stress,Mpa			Av stress	Av Strain
0	0	0	0	22500	0	0	0	0	0
0.05	17	23	20	22500	0.756	1.022	0.889	0.889	0.0000256
0.1	43	45	44	22500	1.911	2.000	1.956	1.956	0.0000568
0.15	94	68	81	22500	4.178	3.022	3.600	3.600	0.0001059
0.2	150	102	126	22500	6.667	4.533	5.600	5.600	0.0001674
0.25	197	134	166	22500	8.756	5.956	7.356	7.356	0.0002231
0.3	234	178	206	22500	10.400	7.911	9.156	9.156	0.000282
0.35	278	201	240	22500	12.356	8.933	10.644	10.644	0.0003322
0.4	299	221	260	22500	13.289	9.822	11.556	11.556	0.0003637
0.45	351	246	299	22500	15.600	10.933	13.267	13.267	0.0004244
0.5	390	287	339	22500	17.333	12.756	15.044	15.044	0.0004898
0.55	412	312	362	22500	18.311	13.867	16.089	16.089	0.0005295
0.6	465	345	405	22500	20.667	15.333	18.000	18.000	0.0006048
0.65	498	379	439	22500	22.133	16.844	19.489	19.489	0.000666
0.7	512	398	455	22500	22.756	17.689	20.222	20.222	0.000697
0.75	564	426	495	22500	25.067	18.933	22.000	22.000	0.0007752
0.8	597	479	538	22500	26.533	21.289	23.911	23.911	0.0008642
0.85	613	501	557	22500	27.244	22.267	24.756	24.756	0.0009054
0.9	648	538	593	22500	28.800	23.911	26.356	26.356	0.0009871
0.95	694	589	642	22500	30.844	26.178	28.511	28.511	0.001106
1	716	610	663	22500	31.822	27.111	29.467	29.467	0.001163
1.05	751	684	718	22500	33.378	30.400	31.889	31.889	0.001321
1.1	789	742	766	22500	35.067	32.978	34.022	34.022	0.001484
1.15	799	795	797	22500	35.511	35.333	35.422	35.422	0.00161
1.2	820	825	823	22500	36.444	36.667	36.556	36.556	0.001729
1.25	865	864	865	22500	38.444	38.400	38.422	38.422	0.001993
1.3	894	890	892	22500	39.733	39.556	39.644	**39.644**	0.00245
1.35	893	890	892	22500	39.689	39.556	39.622	39.622	0.002512
1.4	890	886	888	22500	39.556	39.378	39.467	39.467	0.002627
1.45	888	884	886	22500	39.467	39.289	39.378	39.378	0.002667
1.5	886	882	884	22500	39.378	39.200	39.289	39.289	0.002701
1.55	881	880	881	22500	39.156	39.111	39.133	39.133	0.002752
1.6	879	878	879	22500	39.067	39.022	39.044	39.044	0.002777
1.65	877	876	877	22500	38.978	38.933	38.956	38.956	0.002801
1.7	876	875	876	22500	38.933	38.889	38.911	38.911	0.002812

K 60 0% Compressive strength at 28 days									
ΔH	Load ,KN			Area ,mm^2	Stress, Mpa			Av stress	Av strain
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	23	29	26	22500	1.015	1.297	1.156	1.156	0.0000289
0.1	38	42	40	22500	1.692	1.862	1.777	1.777	0.0000444
0.15	100	116	108	22500	4.456	5.133	4.795	4.795	0.0001207
0.2	129	146	138	22500	5.754	6.487	6.121	6.121	0.0001545
0.25	190	178	184	22500	8.462	7.897	8.179	8.179	0.0002075
0.3	251	226	239	22500	11.169	10.041	10.605	10.605	0.0002706
0.35	315	253	284	22500	13.990	11.226	12.608	12.608	0.0003232
0.4	369	279	324	22500	16.415	12.410	14.413	14.413	0.0003712
0.45	438	368	403	22500	19.462	16.359	17.910	17.910	0.0004656
0.5	463	442	452	22500	20.590	19.631	20.110	20.110	0.0005261
0.55	494	491	492	22500	21.944	21.831	21.887	21.887	0.0005756
0.6	523	561	542	22500	23.241	24.933	24.087	24.087	0.0006378
0.65	572	628	600	22500	25.441	27.923	26.682	26.682	0.0007125
0.7	617	688	652	22500	27.415	30.574	28.995	28.995	0.0007805
0.75	636	748	692	22500	28.262	33.226	30.744	30.744	0.0008328
0.8	679	777	728	22500	30.179	34.523	32.351	32.351	0.0008817
0.85	744	800	772	22500	33.056	35.538	34.297	34.297	0.000942
0.9	774	835	805	22500	34.410	37.118	35.764	35.764	0.0009884
0.95	815	859	837	22500	36.215	38.190	37.203	37.203	0.001035
1	861	894	877	22500	38.246	39.713	38.979	38.979	0.001093
1.05	908	915	911	22500	40.333	40.672	40.503	40.503	0.001144
1.1	966	960	963	22500	42.928	42.646	42.787	42.787	0.001223
1.15	1010	990	1000	22500	44.903	44.000	44.451	44.451	0.001283
1.2	1074	1013	1043	22500	47.723	45.015	46.369	46.369	0.001354
1.25	1133	1033	1083	22500	50.374	45.918	48.146	48.146	0.001422
1.3	1165	1079	1122	22500	51.785	47.949	49.867	49.867	0.001491
1.35	1224	1136	1180	22500	54.379	50.487	52.433	52.433	0.001601
1.4	1282	1199	1241	22500	56.974	53.308	55.141	55.141	0.001729
1.45	1390	1262	1326	22500	61.769	56.072	58.921	58.921	0.001944
1.5	1425	1377	1401	22500	63.349	61.205	62.277	62.277	0.002238
1.55	1424	1414	1419	22500	63.292	62.841	63.067	**63.067**	0.002447
1.6	1408	1413	1410	22500	62.559	62.785	62.672	62.672	0.002592
1.65	1397	0	0	22500	62.108	0.000	0.000	20.703	0.002609

K 60 1% Compressive strength at 28 days									
ΔH	Load ,KN			Area ,mm^2	Stress ,Mpa			Av stress	Av strain
0	0	0	0	22500	0	0	0	0	0
0.05	23	29	26	22500	1.015	1.297	1.156	1.156	0.0000291
0.1	51	53	52	22500	2.256	2.369	2.313	2.313	0.0000583
0.15	83	99	91	22500	3.667	4.400	4.033	4.033	0.000102
0.2	119	116	117	22500	5.303	5.133	5.218	5.218	0.0001324
0.25	142	156	149	22500	6.318	6.938	6.628	6.628	0.0001688
0.3	184	188	186	22500	8.179	8.349	8.264	8.264	0.0002113
0.35	236	237	237	22500	10.492	10.549	10.521	10.521	0.0002705
0.4	255	264	260	22500	11.338	11.733	11.536	11.536	0.0002974
0.45	279	311	295	22500	12.410	13.821	13.115	13.115	0.0003396
0.5	340	335	338	22500	15.118	14.892	15.005	15.005	0.0003906
0.55	380	386	383	22500	16.867	17.149	17.008	17.008	0.0004453
0.6	425	440	433	22500	18.897	19.574	19.236	19.236	0.000507
0.65	494	496	495	22500	21.944	22.056	22.000	22.000	0.000585
0.7	520	574	547	22500	23.128	25.497	24.313	24.313	0.0006515
0.75	639	685	662	22500	28.417	30.433	29.425	29.425	0.0008034
0.8	675	723	699	22500	30.006	32.144	31.075	31.075	0.0008541
0.85	705	792	749	22500	31.350	35.200	33.275	33.275	0.0009231
0.9	751	831	791	22500	33.367	36.911	35.139	35.139	0.0009829
0.95	803	884	844	22500	35.689	39.294	37.492	37.492	0.001061
1	846	934	890	22500	37.583	41.494	39.539	39.539	0.00113
1.05	914	969	942	22500	40.639	43.083	41.861	41.861	0.001212
1.1	949	1020	985	22500	42.167	45.344	43.756	43.756	0.001282
1.15	1037	1092	1064	22500	46.078	48.522	47.300	47.300	0.001419
1.2	1088	1119	1103	22500	48.339	49.744	49.042	49.042	0.001491
1.25	1158	1189	1174	22500	51.456	52.861	52.158	52.158	0.001631
1.3	1228	1224	1226	22500	54.572	54.389	54.481	54.481	0.001748
1.35	1295	1294	1295	22500	57.567	57.506	57.536	57.536	0.001929
1.4	1349	1315	1332	22500	59.950	58.422	59.186	59.186	0.002051
1.45	1392	1361	1376	22500	61.844	60.500	61.172	61.172	0.002274
1.5	1387	1389	1388	22500	61.661	61.722	61.692	**61.692**	0.002447
1.55	1385	1387	1386	22500	61.539	61.661	61.600	61.600	0.002522
1.6	1383	1385	1384	22500	61.478	61.539	61.508	61.508	0.002551
1.65	1382	1381	1381	22500	61.417	61.356	61.386	61.386	0.002579
1.7	1379	1378	1378	22500	61.294	61.233	61.264	61.264	0.002603

K 60 1.5% Compressive strength at 28 days									
ΔH	**Load ,KN**			**Area ,mm^2**	**Stress ,Mpa**			**Av stress**	**Av strain**
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	23	29	26	22500	1.015	1.297	1.156	1.156	0.0000296
0.1	50	50	50	22500	2.200	2.200	2.200	2.200	0.0000564
0.15	99	113	106	22500	4.400	5.021	4.710	4.710	0.0001217
0.2	123	142	133	22500	5.472	6.318	5.895	5.895	0.0001528
0.25	184	209	197	22500	8.179	9.308	8.744	8.744	0.0002286
0.3	240	250	245	22500	10.662	11.113	10.887	10.887	0.0002865
0.35	311	307	309	22500	13.821	13.651	13.736	13.736	0.0003649
0.4	363	364	364	22500	16.133	16.190	16.162	16.162	0.0004329
0.45	434	397	416	22500	19.292	17.656	18.474	18.474	0.000499
0.5	563	494	528	22500	25.017	21.937	23.477	23.477	0.0006466
0.55	607	563	546	22500	26.966	25.017	24.259	25.414	0.0007057
0.6	701	607	611	22500	31.177	26.966	27.133	28.425	0.0008
0.65	727	692	662	22500	32.309	30.737	29.421	30.822	0.0008775
0.7	819	743	729	22500	36.394	33.000	32.384	33.926	0.0009817
0.75	863	827	789	22500	38.343	36.771	35.053	36.723	0.00108
0.8	931	870	840	22500	41.360	38.657	37.341	39.119	0.001168
0.85	984	956	906	22500	43.749	42.491	40.245	42.162	0.001286
0.9	1011	1018	947	22500	44.943	45.257	42.093	44.098	0.001366
0.95	1082	1078	1008	22500	48.086	47.897	44.792	46.925	0.00149
1	1130	1131	1055	22500	50.223	50.286	46.904	49.138	0.001597
1.05	1168	1187	1099	22500	51.920	52.737	48.840	51.166	0.001704
1.1	1222	1245	1151	22500	54.309	55.314	51.157	53.593	0.001852
1.15	1270	1274	1187	22500	56.446	56.634	52.771	55.284	0.001977
1.2	1293	1314	1216	22500	57.451	58.394	54.061	56.636	0.002102
1.25	1339	1345	1253	22500	59.526	59.777	55.675	**58.326**	0.002447
1.3	1337	1341	1249	22500	59.400	59.589	55.528	58.172	0.00255
1.35	1335	1334	1245	22500	59.337	59.274	55.352	57.988	0.002598
1.4	1332	1331	1243	22500	59.211	59.149	55.235	57.865	0.002622
1.45	1327	1329	1239	22500	58.960	59.086	55.088	57.711	0.002648
1.5	1325	1325	1237	22500	58.897	58.897	54.971	57.588	0.002666
1.55	1324	1321	1234	22500	58.834	58.709	54.853	57.465	0.002683
1.6	1315	1317	1228	22500	58.457	58.520	54.589	57.189	0.002717

K 60 2% Compressive strength at 28 days									
ΔH	Load ,KN			Area ,mm^2	Stress , MPa			Av stress	Av strain
0	0	0	0	22500	0	0	0	0	0
0.05	23	29	26	22500	1.015	1.297	1.156	1.156	0.0000309
0.1	43	57	50	22500	1.918	2.538	2.228	2.228	0.0000598
0.15	86	119	103	22500	3.836	5.303	4.569	4.569	0.000124
0.2	126	146	136	22500	5.585	6.487	6.036	6.036	0.0001648
0.25	145	202	173	22500	6.431	8.969	7.700	7.700	0.0002119
0.3	184	239	211	22500	8.179	10.605	9.392	9.392	0.0002605
0.35	246	272	259	22500	10.944	12.072	11.508	11.508	0.0003224
0.4	284	312	298	22500	12.636	13.877	13.256	13.256	0.0003747
0.45	325	367	346	22500	14.441	16.303	15.372	15.372	0.0004393
0.5	378	399	388	22500	16.810	17.713	17.262	17.262	0.0004984
0.55	438	452	445	22500	19.462	20.082	19.772	19.772	0.0005792
0.6	505	509	507	22500	22.451	22.621	22.536	22.536	0.0006715
0.65	552	570	561	22500	24.538	25.328	24.933	24.933	0.0007548
0.7	570	631	600	22500	25.328	28.036	26.682	26.682	0.0008177
0.75	619	654	637	22500	27.528	29.051	28.290	28.290	0.0008773
0.8	664	721	692	22500	29.503	32.041	30.772	30.772	0.0009731
0.85	697	774	736	22500	30.969	34.410	32.690	32.690	0.001051
0.9	750	857	803	22500	33.338	38.077	35.708	35.708	0.001181
0.95	805	908	856	22500	35.764	40.333	38.049	38.049	0.001291
1	877	947	912	22500	38.979	42.082	40.531	40.531	0.001418
1.05	905	1003	954	22500	40.221	44.564	42.392	42.392	0.001522
1.1	957	1040	998	22500	42.533	46.200	44.367	44.367	0.001647
1.15	1001	1074	1038	22500	44.508	47.723	46.115	46.115	0.001773
1.2	1020	1132	1076	22500	45.354	50.318	47.836	47.836	0.001924
1.25	1070	1144	1107	22500	47.554	50.826	49.190	49.190	0.002081
1.3	1130	1135	1132	22500	50.205	50.431	50.318	50.318	0.002301
1.35	1155	1119	1137	22500	51.333	49.754	50.544	**50.544**	0.00245
1.4	1154	1108	1131	22500	51.277	49.246	50.262	50.262	0.002615
1.45	1147	1093	1120	22500	50.995	48.569	49.782	49.782	0.002719
1.5	1141	1074	1107	22500	50.713	47.723	49.218	49.218	0.002804
1.55	1133	1074	1104	22500	50.374	47.723	49.049	49.049	0.002825
1.6	1132	1073	1102	22500	50.318	47.667	48.992	48.992	0.002832

K 60 2.5% Compressive strength at 28 days									
ΔH	Load ,KN			Area,mm^2	Stress, MPa			Av stress	Av. Strain
0	0	0	0	22500	0.000	0.000	0.000	0.000	0
0.05	22	29	25	22500	0.959	1.297	1.128	1.128	0.0000302
0.1	55	57	56	22500	2.426	2.538	2.482	2.482	0.0000669
0.15	119	86	103	22500	5.303	3.836	4.569	4.569	0.0001242
0.2	190	129	160	22500	8.462	5.754	7.108	7.108	0.0001954
0.25	250	170	210	22500	11.113	7.559	9.336	9.336	0.0002594
0.3	297	226	261	22500	13.200	10.041	11.621	11.621	0.0003265
0.35	353	255	304	22500	15.682	11.338	13.510	13.510	0.0003833
0.4	380	281	330	22500	16.867	12.467	14.667	14.667	0.0004186
0.45	446	312	379	22500	19.800	13.877	16.838	16.838	0.0004864
0.5	495	364	430	22500	22.000	16.190	19.095	19.095	0.0005587
0.55	523	396	459	22500	23.241	17.600	20.421	20.421	0.0006023
0.6	590	438	514	22500	26.231	19.462	22.846	22.846	0.0006842
0.65	632	481	557	22500	28.092	21.379	24.736	24.736	0.0007503
0.7	650	505	578	22500	28.882	22.451	25.667	25.667	0.0007836
0.75	716	541	628	22500	31.815	24.031	27.923	27.923	0.0008666
0.8	758	608	683	22500	33.677	27.021	30.349	30.349	0.0009601
0.85	778	636	707	22500	34.579	28.262	31.421	31.421	0.0010030
0.9	822	683	753	22500	36.554	30.349	33.451	33.451	0.0010870
0.95	881	748	814	22500	39.149	33.226	36.187	36.187	0.0012090
1	909	774	842	22500	40.390	34.410	37.400	37.400	0.0012660
1.05	953	868	911	22500	42.364	38.585	40.474	40.474	0.0014230
1.1	1001	942	972	22500	44.508	41.856	43.182	43.182	0.0015810
1.15	1014	1009	1012	22500	45.072	44.846	44.959	44.959	0.0017000
1.2	1041	1047	1044	22500	46.256	46.538	46.397	46.397	0.0018120
1.25	1098	1097	1097	22500	48.795	48.738	48.767	48.767	0.0020530
1.3	1135	1130	1132	22500	50.431	50.205	50.318	**50.318**	0.0024500
1.35	1133	1130	1132	22500	50.374	50.205	50.290	50.290	0.0025020
1.4	1130	1125	1127	22500	50.205	49.979	50.092	50.092	0.0025980
1.45	1127	1122	1125	22500	50.092	49.867	49.979	49.979	0.0026310
1.5	1125	1119	1122	22500	49.979	49.754	49.867	49.867	0.0026590
1.55	1118	1117	1118	22500	49.697	49.641	49.669	49.669	0.0027000
1.6	1116	1114	1115	22500	49.585	49.528	49.556	49.556	0.0027210
1.65	1113	1112	1112	22500	49.472	49.415	49.444	49.444	0.0027400
1.7	1112	1111	1111	22500	49.415	49.359	49.387	49.387	0.0027490

APPENDIX V. PHOTO GALLARY

Figure a during flexural test

Figure C during Sieve analysis of fine aggregate

Figure b flexural testing set up

Figure d Sample taken during split tensile strength

Figure E photo during split test conducted

Figure F Photo during specific gravity

Figure G Photo during specific gravity and water absorption sand determination

Figure H Photo during specific gravity and water absorption of coarse aggregate determination

Figure I Photo during length determination for steel fiber