Nile Higher Institute for Engineering & Technology

Department of Civil Engineering

B.Sc Project
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Effect Of Polypropylene Fiber On Self-Compacted Concrete Containing Fly Ash (15% by weight of cement)

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Abstract

The (brittle) behavior of concrete, although used in many fields, impedes its use in some applications that require (flexible) behavior, wherefore several types of fibers were utilized among them polypropylene fiber, that enhances pre-crack tensile strength, toughness, ductility performance, impact resistance, flexural strength resistance, and failure mode. This project investigates the properties and performance of self-compacted concrete made with different dosages of self-compacted agent (1.8% and 2.1%) and various contents of polypropylene fiber (0- 0.3%, by mass of cement). **Fly ash** was used as a cement replacement material with a content of **(15%)** by mass of cement.

This project complies with Egyptian code ECP: 203 (2020), Egyptian standard specification ES requirements (4756-1/2005) (Appendix A). The results showed that the mechanical properties of concrete improved with the addition of polypropylene fiber. The fresh properties of concrete improved with increasing self-compacted agent dosage. Increasing polypropylene fiber content affects the fresh properties negatively.

Chapter 1: Introduction

1.0 Project definition:

The field of strength of materials, also called mechanics of materials, typically refers to various methods of calculating the stresses and strains in structural members, such as beams, columns, and shafts. Designers and contractors often come across problems that require special concrete solutions. A special concrete made with special ingredients or a special process may ideally suit the need.

The research work is divided into the following activities in order to resolve the given issues:

- Literature review: The aim is knowledge about the current state of the art in concrete technology in general.
- General information: The aim is to understand how special types of concrete are made and the contribution of such materials
- Experimental investigations: The goal is to perform experiments in laboratory-controlled environments to understand SCC properties and failure mechanisms better and develop more efficient concrete material.

1.0.1 The problem:

Explore the properties of Self Compacted Concrete (SCC) as a special type of concrete material

1.0.2 Study objectives:

In this research, the concentration was on:

- Define the SCC and its components and material properties.
- Find the results of fresh and hardened concrete tests.
- Reach a final conclusion on the best properties and components of SCC.

1.1 Cement:

Cement is the soft bonding material that hardens and hardens, thus having cohesive and adhesive properties in the presence of water, which makes it able to bind the components of the concrete to each other. The most important use of cement is mortar and concrete, where it binds synthetic or natural materials to form strong building materials that are resistant to normal environmental influences. Concrete should not be confused with cement, as cement refers to the dry powder used to bind aggregate materials to concrete. There are two types of cement used in construction: hydrated cement and non-aqueous cement.

The cement industry is considered one of the strategic industries. However, it is a simple industry compared to the primary industries, and it depends on the availability of raw materials.

Cement is a soft and sticky material that, if water is added to it, turns into a soft cement paste, and then turns after some time into a hard substance, and with time it acquires resistance, especially if it is placed in water (which is why it is called hydraulic cement.

It consists mainly of calcium oxide (CaO), silicon dioxide (SiO_2), aluminum oxide (Al_2O_3), and iron oxide (Fe_2O_3), to which calcium sulfur is added after burning.

1.2 Cement industry methods:

There are three ways to find the optimal chemical compound for cement.

1.3 Wet method:

The raw materials are selected and mixed with water to give a suspension product.
The clinker is formed at (1480) ° C. This process depends on:

1.4 Raw material crushing and mixing:

The raw materials of limestone and silicate, clay, and surface earth, are broken by crushers, then loosened and transported to be stored in the form of piles in open areas or covered.

The raw materials of limestone, silicate, clay, and surface earth are crushed by crushers, then loosened and transported to be stored in piles in open or covered areas.

1.5 Grinding:

The raw materials are transported to the suspension mills, where they are mixed with water, and the suspension continues to be ground until it reaches the required degree of fineness. Hanging basins, where the mills convert it into a homogeneous mixture.

The raw materials are fed into a rotary dryer (in case the humidity is higher than a certain percentage), where they are dried by hot air or exhaust from the operation of the kiln, then the raw materials are ground in raw material mills and transported to pre-mix storage silos, where they become homogeneous through the process of stacking and drawing, after which the homogeneous raw materials are transported from storage silos or other types of pre-mix storage places to mixing places. The mixing process is 30% clay and 70% limestone.

1.6 Oven and cooler:

The suspension is drawn from the bottom of the pans into the feed slot of the rotary kiln (long cylindrical kiln), lined with refractory bricks, and rotates slowly inclined slightly from the horizontal. This tilt allows the contents of the oven to be pushed forward during rotation. At the front (bottom) end of the furnace, high-temperature combustion gases are generated, which flow to the upper (back) part of the furnace in the opposite current to the movement of the contents of the furnace moving downward, and the clinker is cooled by an air cooler. The length of the ovens in the wet method is longer than in the dry method until the process of drying the mixed paste is completed by means of huge metal chains located inside the oven. As for this process, in the dry method, it is replaced by cyclones whose presence reduces the length of the oven by about 50%.

The homogeneous raw materials are withdrawn from the bottom of the storage silos to the feeding hole of the multi-stage primary heating tower. The height of the tower may reach 120 m. Natural gas or mazut is used as a source of thermal energy, and hot air resulting from cooling clinker is used as an additional source of heat. The furnace tilts slightly on the horizontal plane to allow a slow movement of solids to the bottom, cutting the distance from the feeding hole at the top of the furnace to the lower end (the combustion side), where high-temperature combustion gases are generated in a period of time ranging from (1-3) hours, while the combustion gases move upward in the opposite stream to the movement of solids. The hot combustion gases heat the raw materials at the furnace feed opening and provide calcium carbonate.

1.7 Final grinding and packing:

The clinker is transported to ball mills, where gypsum is added to it and ground, then packed in bags.

1.8 Dry method:

The use of dry processes in the cement industry has spread gradually to replace the wet processes due to the abundance of energy that characterizes the dry processes, the precision in the control processes, and the mixing of raw materials without adding water. The main operations of this method are:

1.9 Semi-dry method:

The semi-dry method is a special case of dry processes, where a kiln (lipol kiln) or a shaft furnace is used. In both cases, the raw materials ground in dry processes is formed in the form of granules ranging in diameter between (10-15) mm, to which 13% is added water.

1.10 Types of cement:

There are 27 types of cement:

- High chimney cement.
- Milky cement (ash) or composite cement (CEMV).
- Different in composition (White cement).
- Ordinary Portland cement.
- Composite Portland cement.
- Antibacterial Portland cement.
- Portland cement is high-temperature hardening and sulfate resistant.
- Fast hardening cement.
- Low-temperature Portland cement.
- Pozzolanic cement.
- Antibacterial Portland cement.

	Classification	Characteristics	Applications
Type I	General purpose	Fairly high C_3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc)
Type II	Moderate sulfate resistance	Low C_3A content (<8%)	Structures exposed to soil or water containing sulfate ions
Type III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C_3S (<50%) and C_3A	Massive structures such as dams. Now rare.
Type V	High sulfate resistance	Very low C_3A content (<5%)	Structures exposed to high levels of sulfate ions
White	White color	No C_4AF, low MgO	Decorative (otherwise has properties similar to Type I)

1.11 Cement properties:-

1.11.1 Chemical properties:

Chemical analyzes and tests are usually carried out to monitor cement manufacturing processes to ensure that the chemical composition of the raw materials matches the production requirements with the final composition of the clinker. The analysis also investigates the final manufactured material, which is cement, to ensure the quality of production and its conformity with specifications.

Portland cement properties	
Physical properties	
Initial Setting Time (minute)	64
Final Setting Time (minute)	121
Specific Surface Area (cm^2/gm)	3907
28 Days Compressive Strength (MPa)	31.5
Chemical properties	
Calcium Oxide (CaO)	62.25%
Silicon Dioxide (SiO_2)	21%
Aluminum Oxide ($Al_2 O_3$)	5.9%
Sulphur Trioxide (SO_3)	2.4%
Ferric Oxide (Fe_2O_3)	3.4%
Magnesium Oxide (MgO)	1.5%
Sodium Oxide (Na_2O)	0.2%
Potassium Oxide (K_2O)	0.45%
Loss of Ignition	1.1%

1.11.2 Physical properties:-

1.11.2.1 Fineness:

The finer the cement, the larger the specific surface area. Softness affects the following elements:

Chemical reaction ratio: the softer the cement, the faster it will react with the mixing water. If the grains are coarse, the chemical reaction process does not take place adequately.

Development of resistance: the hardening process of fine cement is faster than that of coarse cement. The higher smoothness enables greater early resistance

The amount of cement necessary to cover the aggregate granules: the softer the cement granules, the more they can cover the aggregate granules of gravel and sand.

The smoothness is determined by the standard specifications by determining the specific surface area of the cement using a baleen device. Saudi specifications require a minimum fineness of cement of (2250) cm^2/g. The fineness of cement can be divided into three types
Coarse cement: Plain number less than 2800 cm^2/g.
Fine cement: Plain number greater than 4000 cm^2/g.
cement very soft: Plain number from 5000 to 7000 cm^2/g

1.11.2.2 Density:

The specific weight of Portland cement ranges from 3 to 3.2 g/cm^3. It is determined using a pycnometer. The volumetric weight of Portland cement ranges between 0.9 and 1.3 g/cm^3. This property is closely related to the smoothness of cement.

1.11.2.3 Normal Consistency:

It is intended to determine the optimum water ratio (water/cement) to obtain a standard paste using a roller-loaded Vicat device. The m/h for ordinary Portland cement ranges between 0.25 and 0.3

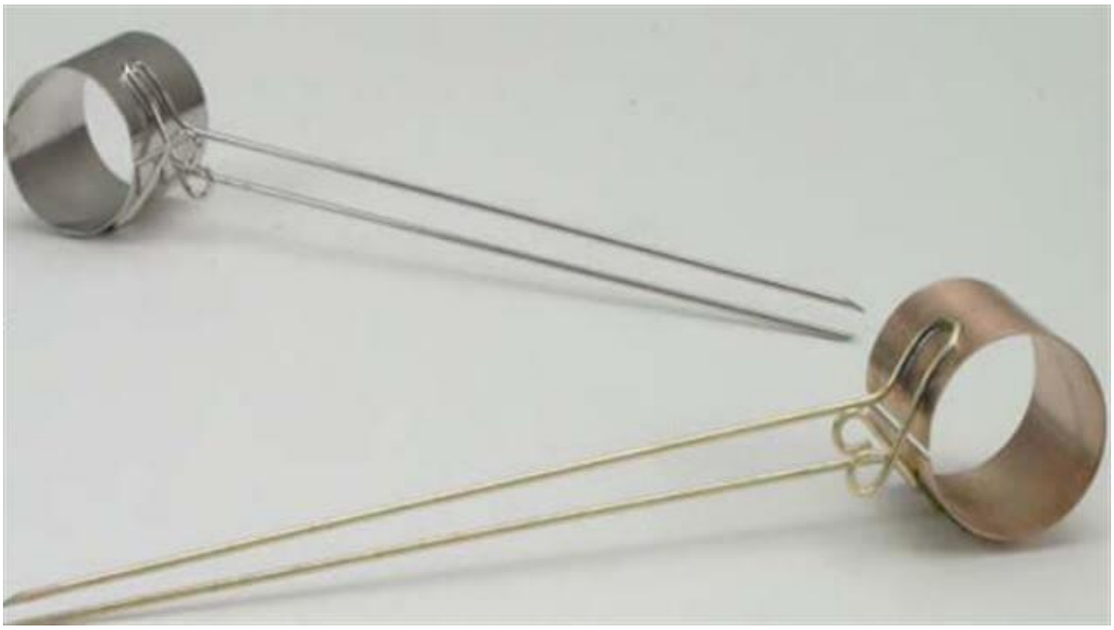
1.11.2.4 Setting Time:

When cement is mixed with water, a paste is obtained that gradually reduces plasticity with time. After a while, a kind of initial cohesion appears in the cement paste. This time is called Initial Setting Time. When the dough begins to harden to bear certain weight, it has reached the Final Setting Time. This time that elapses between the beginning of mixing the cement with water and the initial setting is the so-called setting time, and it is very important for the concrete operation process of mixing, transporting, pouring, shaking, and finishing
There are several factors that affect the setting time, most notably the type of cement (chemical composition), its smoothness, the amount of water, temperature, and the percentage of additives (retarders or accelerators of setting). It is determined on a standard dough at a specified temperature and using a needle-loaded Vicat device. According to the Saudi specifications, the initial doubt should not be less than 45 minutes, and the final doubt should not exceed 10 hours.

1.11.2.5 Soundness:

The volume stability of the cement means that it does not increase in volume after it hardens. Increasing the volume causes cracking and fragmentation of the hardened cement, and it results from the presence of some compounds in the cement, such as free lime CaO (non-consolidated) and an increase in the amount of magnesium, and an increase in the amount of gypsum.

According to the Saudi specifications, the stability test was conducted by the LeChatelier device:



The test is considered simple, as the mold is filled with a standard cement paste and covered with two sheets of glass. Then it is left for 24 hours in water at a temperature of 20°C, then it is raised, and the distance between the two ends of the two indicators of the mold is measured, m1. Then the mold is placed in boiling water for an hour. After that, the distance between the two ends of the template indicators, m^2, is measured again. Then, according to the difference between the two measurements (m^2 - m1), this is an expression of the cement's expansion. The specifications stipulate that this extension shall not exceed 10 mm.

1.11.3 Mechanical properties:

The resistance of cement to pressure is an important characteristic in its uses, while its tensile strength is simple and not of equal importance. And the resistance of pure cement is greater than its resistance if it is mixed with sand. The resistance increases in the first age (about seven days) clearly and significantly, and the rate of increase decreases after that with the passage of time gradually due to the decrease in the degree of reaction. It may take several years for the reactions to complete, and the final resistance is achieved, but the increase in the strength after 28 days is usually limited, and the resistance achieved at this time is considered sufficient to resist the overall concrete on which it is located. That is why international standards chose this time (28 days) as a standard for the quality of concrete.

Although some specifications seek, with the development of the concrete industry, to choose early times such as (3, 7, and 14 days), especially in hot weather, as is the case in the Kingdom.

The average compressive strength of the half-prisms (prism size: 40 x 40 x 160 mm) should not be less than the minimum average required in the Saudi specifications as shown in the following table:

STRENGHT → DAYS ↓	CONCTRETE MIX DESIGN Comp. Strength (N/mm^2)	20 % STEEL FIBRE IN CONCRETE Comp. Strength (N/mm^2)
3 Days	14.44 15.55 14.22	16.89 18.89 18.22
7 Days	16.67 17.78 18.89	23.22 22.22 22.22
28 Days	24.44 24.89 26.67	18.89 22.22 25.55

In addition to the effect of softness on the hardening process, temperature and humidity have a significant role in influencing the development of resistance over time. Therefore, good resistance can only be achieved by treatment under continuous wet conditions. If the concrete is exposed to hot and dry air, it will result in a much lower resistance than that obtained by wet treatment.

1.12 Quality control:-

1.12.1 Acceptance tests:

All shipments coming from a source different from the source of the previously tested shipments are tested before being imported to the site, and they are called acceptance tests. It includes the following tests:

Softness (Blaine device), setting time (Vicat device), volume stability (Le Chatelier device), pressure resistance, lime saturation coefficient, and chemical analysis (insoluble residues, magnesium oxide, total sulfur, and burn losses.(

1.12.2 Periodic tests:

If the source of the shipment does not change, periodic tests are carried out for every 1,000 tons supplied to the site. Periodic tests are also carried out on cement that has been stored for more than three months before using it. Periodic tests include tests for smoothness, setting time, and pressure resistance.

1.13 Cement defects:-

1.13.1 Impact on the environment:

Cement production, especially in old factories, produces large amounts of carbon dioxide, as 5% of the total emissions resulting from human activities are from cement.

1.13.2 Impact on human health:

Diseases resulting from the manufacture of cement and the handling of the amine, which are serious diseases that lead to death, including:

1.13.3 ASBSTOSE Lung Disease:

It is linear fibrosis that affects the respiratory bronchioles and the lung, resulting from inhalation of amine dust, and this varies in size, as medium and large particles larger than (10 microns) are more likely to cause the fibrosis process.

1.13.4 Silicosis:

This disease is caused by inhaling silica or free silica (SiO) dust, and the latter is the only one that causes lung disease, as work that gives dust contains it, which is a particle with a diameter less than (5 microns), and the danger begins when it exceeds the number of molecules is 3000-4000 particles in (cubic centimeter) of air.

1.13.5 The effect on the human sense of hearing:

Noise poses a health problem for factory workers and the neighboring population and can cause them diseases such as high blood pressure.

1.13.6 Impact on animal health:

Cement dust has a significant impact on the health of animals, as their diet is a mixture of grass and cement, thus eliminating the genetic cycle.

1.13.7 The effect on the plant:

One of the most serious drawbacks of the cement industry is the bad impact on the environment and the threat to the surrounding area through the secretions that industrial units put out of gaseous and liquid waste, which have a negative impact on the vegetation cover, such as the accumulation of a thick layer of cement dust on the leaves of trees, which leads to poor production of vegetables and fruits. In addition to the risk of human poisoning when ingested, as well as the animal when eating herbs.

1.14 Production companies:

The global cement industry ranking at the end of 2005 is as follows:

- Lafarge: France ranks first in the world.
- Holcim: Switzerland ranks second in the world.
- Cemex: Mexico ranks third in the world.
- Heidelberg Cement: Germany ranks fourth in the world.
- Italcementi: Italy ranks fifth in the world.

1.15 Concrete mixing water:

Mixing water is the most important and cheapest component of the concrete mix. The role of mixing water in the concrete mix is to interact with the cement to form the connecting medium for the aggregate granules and to facilitate the concrete's workability. Workability is the ease of dealing with fresh concrete in the stage of mixing, transporting, pouring, and successfully compacting so that there is no separation of its components.

The amount of water in concrete controls many fresh and hardened properties in concrete, including workability, compressive strengths, permeability, water tightness, durability and weathering, drying shrinkage, and potential for cracking.

The ratio of the amount of water, minus the amount of water absorbed by the aggregates, to the number of cementitious materials by weight in concrete is called the water-cementitious ratio and is commonly referred to as the w/cm ratio. The w/cm ratio is a modification of the historical water-cement ratio (w/c ratio) that was used to describe the amount of water, excluding what was absorbed by the aggregates, to the amount of the portland cement by weight in concrete.

Because most concretes today contain supplementary cementitious materials such as fly ash, slag cement, silica fume, or natural pozzolans, the W/cm ratio is more appropriate.
To avoid confusion between the w/cm and W/c ratios, use the w/cm ratio for concretes with and without supplementary cementitious materials.
The W/cm ratio equation is: W/cm ratio = (weight of water – weight of water absorbed in the aggregates) divided by the weight of cementitious materials.

Table 1. Strength versus W/CM Ratio (Ref.1)

Compressive Strength (28 days, psi)	W/CM Ratio	
	Non-air-entrained Concrete	Air-entrained Concrete
7,000	0.33	-
6,000	0.41	0.32
5,000	0.48	0.40
4,000	0.57	0.48
3,000	0.68	0.59
2,000	0.82	0.74

Cement needs about 30 percent of its water weight in order to complete the hydration process, but the amount of water in the concrete according to this percentage is considered insufficient, as the mixture is dry and difficult to work with.

Therefore, an additional amount of water is added to improve the operation, provided that this is in the least amount possible due to the negative impact of the increase in water on the mechanical strength of concrete. Upon hardening, the paste or glue consisting of cementitious materials and water binds the aggregates together.

Hardening occurs because of the chemical reaction, called hydration, between the cementitious materials and water.

Obviously, increasing the w/cm ratio or the amount of water in the paste dilutes or weakens the hardened paste and decreases the strength of the concrete. The concrete compressive strength increases as the W/cm ratio decreases for both non-air-entrained and air-entrained concrete.
Decreasing the w/cm ratio also improves other hardened concrete properties by increasing the density of the paste, which lowers the permeability and increases water tightness, improves durability and resistance to freeze-thaw cycles, winter scaling, and chemical attack.

In general, less water produces better concrete. However, concrete needs enough water to lubricate and provide a workable mixture that can be mixed, placed, consolidated, and finished without problems.

The most important factor affecting the amount of drying shrinkage and the subsequent potential for cracking is the water content or the amount of water per cubic yard of concrete.

Fundamentally, concrete shrinkage increases with higher water contents. About half of the water in the concrete is consumed in the chemical reaction of hydration, and the other half provides the concrete's workability. Except for the water lost to bleeding and absorbed by the base material or forms, the remaining water that is not consumed by the hydration process contributes to drying shrinkage.
By keeping the water content as low as possible, drying shrinkage and the potential for cracking can be minimized.

1.16 Reducing Water Will:

- Increase compressive and flexural strengths.
- Lower permeability and increased water tightness.
- Increase durability and resistance to weathering, including chemical attack and freezing-thawing cycles, including surface scaling.
- Reduce concrete drying shrinkage and potential for cracking.

The percentage of water needed for mixing depends on several factors, such as the surface area of the components, the requirements for coating them with water, and the force of friction between the granules, which must be overcome to improve the workability, Factors:

- Cement type and degree of fineness.

- Aggregate gradation.
- Aggregate fineness standard.
- The ratio of small to large aggregate.
- Big aggregate granule shape.
- Surface nature of aggregate granules.
- The natural moisture content of the aggregate used.

1.17 The quality of the mixing water used to mix concrete:

The concrete mixing water must be clean and free from harmful substances such as acid, organic matter, and salts. If these substances are found, they may affect the setting time of concrete and its resistance. It may also cause rusting of the rebar and harm the performance of concrete in the long run. The Egyptian code requires the availability of the following specifications in the mixing water:

- Drinkable water is considered suitable for the concrete mix, with the exception of the biological requirements for drinking water.

- In the event that drinking water is available, other sources can be used, provided that the initial setting time of cement does not exceed the setting time of drinking water by more than 30 minutes, and the setting time is not less than 45 minutes in all cases, and the pressure resistance of the standard mortar cube must not be less than at the age of 7 and 28 days when using this water is less than 90% of its equivalent when using drinking water.
- It is absolutely not allowed to use sea water in the reinforced concrete mix.
- It is permissible to use sea water when necessary in the plain concrete mixture, provided that the required resistance is achieved and that the plain concrete does not touch the reinforced concrete.
- The water suitable for the concrete mix is suitable for its treatment.

- Curing water should not cause stains, sedimentation, flowering, or any other unacceptable phenomena on the concrete surface.

1.18 Maximum limits of salts and harmful substances in the mixing water:

Salts and harmful substances in the mixing water	Maximum limits (gram/liter)
Total dissolved salts	2.00
chloride salts in the form of (Cl^-)	0.50
Sulfate salts in the form of (SO_3)	0.30
Carbonate and bicarbonate salts	1.00
Sodium sulfate salts	0.10
organic matter	0.20
Clay and suspended matter	2.00

1.19 Introduction to aggregates:

Concrete consists of a graded aggregate of small particles and large particles held together. Some with a cementitious substance, which is cement paste. That is, concrete is aggregate, cement, and water. Although the cement is reactive with water, forming a sufficiently hardening and responsible cement paste, however, it is difficult to make and manufacture concrete from cement and water only for two reasons:

- The high cost
- The high volumetric change of cement paste (shrinkage and creep)

1.120 Importance:

The quality and properties of the aggregate have a significant impact on the properties and quality of concrete as it occupies about (70-75%) of the total volume of the concrete block. Aggregate generally consists of rocky grains of gradual size, including small grains such as sand and the other large grains such as gravel or gravel. Freezing and hardening of cement paste or concrete exposure to moisture and dryness. Therefore, aggregates give concrete better durability than if cement paste was used alone. From what was mentioned previously, it is clear that the properties of the aggregate greatly affect the durability and behavior of the concrete structure
When choosing aggregates for use in particular concrete, attention must be paid in general to three requirements: the economy of the mixture, the inherent resistance to the hardening mass, and the potential strength of the concrete structure. Another important characteristic of concrete aggregate is the gradation of its grains, and for the purpose of obtaining a dense concrete structure, the gradation of concrete aggregate must be appropriate by determining the proportion of fine aggregate and coarse aggregate in the mixture.

In addition, the gradation of aggregate particles is an important factor in controlling the workability of soft concrete. When determining the amount of aggregate present in a unit volume of concrete, the workability of the mixture is more when it is gradient.

In general, the greater the amount of aggregate present in a given volume of concrete, the more economical the resulting concrete is because aggregate is cheaper than cement.

For the purpose of obtaining strong concrete, its aggregates must be distinguished from being unaffected by various weather factors such as heat, cold and freezing, which lead to the disintegration of the aggregates, and there must be no harmful interaction between the aggregate minerals and cement compounds, in addition to the necessity that the aggregates be free of clay and impure materials that affect the Resistance and stability of cement paste. The aggregate shall be clean, strong, resistant to crushing and impact, adequate in terms of absorption, of a suitable shape and texture, insoluble, and resistant to abrasion and erosion.

1.21 Requirements:

- Aggregate grains should be semi-spherical and not oblate, and multifaceted types are preferred.
- The absorption rate should not be more than 5%

- The apparent specific weight should not be less than 2.35 d. The weight loss percentage of aggregates when carrying out the stability test should not exceed 10-12% of the weight.
- The aggregate used in concrete mixtures shall be graded within the limits of the mass gradation curves.
- The aggregate must be subjected to washing before using it to ensure that it is free of harmful organic substances and salts.
- It should be solid and not easily breakable.

1.22 Test method or the determination of aggregate impact value:-

1.22.1 Target:

Determination of the impact modulus of a large aggregate.

1.22.2 Tools:

- shock device
- Round metal base
- cylindrical steel bowl
- steel weight
- A way to lift weight and drop it freely
- A means to stabilize the weight when placing or to lift the container containing the test sample
- metal cylindrical meter

- Metal straight rod for blood pressure
- A sensitive scale with a capacity of at least 3 kg and a sensitivity of 1 g
- Standard sieves with holes of 14 mm, 10 mm, and 2.36 mm.
- Ventilated oven at a temperature of 100-110°C

1.22.3 Test steps:

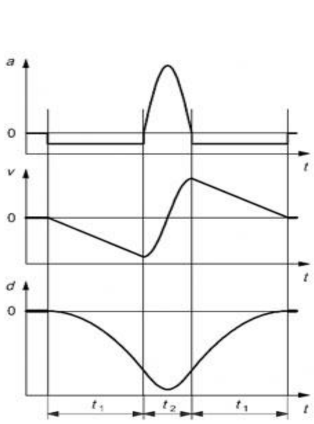
- dry sample test.
- The shock machine is placed on the base, and the device is fixed in its place on the base of the test device. The test sample is placed in it, and it is compacted 25 times with the tamping rod. Then the weight is lifted and left to fall freely under the influence of its weight on the rubble.
- The water is lifted, and the rubble is emptied by roads, then the pot and the rubble are weighed, and it is (m1).
- Sieve the sample on the standard sieve of 2.36 mm. The weight of the aggregates reserved on the sieve and the passing aggregates are determined to the nearest gram. The weights are (M2) and (M3), respectively.
- Wet sample testing.
- The crushed aggregate sample is removed from the container and dried in the oven, then the samples are cooled, weighed, and weighed (m1), and the rest of the steps are completed.

1.22.4 Results:

The aggregate in the dry state = The value of the shock coefficient
Where:

- Impact modulus of the aggregate
- weight of the sample (g)
- The weight of aggregate passing through the sieve is 2.36 mm (g)

The aggregate in the wet state = Weight of soft materials m
Where:
weight of the sample g = Weight of aggregate passing through the sieve is 2.36 mm (g)



1.23 Types of slip:

The gravel consists of gravel deposits of fractures and the fragmentation of rock masses through weathering factors, which transport gravel and gravel over long distances through the water, so we find them on beaches and oceans in abundance.

- ### 1.23.1 Gravel:

Fully gravel is one of the most famous types of gravel used in reinforced concrete to give durability, strength, and rigidity to concrete in construction work. The size of the gravel and its size may range between 0.5-to 5 cm.

- ### 1.23.2 Vino gravel:

Types of gravel used in reinforced concrete poured under-water, as it is also called special gravel with a size of 0.4 cm, and the size of pheno gravel may reach 0.5 cm. It is used in well works that are carried out in mechanical works.

- ### 1.23.3 Gravel habit:

It is one of the types of gravel used in ordinary concrete, and the size of the gravel is usually 0.4-0.5 cm.

- ### 1.23.4 Calculating gravel:

It is also one of the types of gravel used in large-sized replacement concrete in concrete works and architectural structures, with a size starting from 0-7 cm.

1.24 Uses:

It is known that gravel is used in concrete works and architectural buildings, but the role of gravel does not stop in building works; gravel is included in home design and garden decoration to give an aesthetic shape and a wonderful view in a manner befitting the beauty of home decor from those uses:

- ### 1.24.1 Gravel walkers:

-Asphalt walkers are a way to connect garden parts to each other or a way to move from one place to another with an aesthetically pleasing design.

-The gravel walkers also consist of a large group of different raw materials, sizes, and shapes, which makes each type of walker suitable for designated places in order to give full elegance to the place. Among the types of gravel walkers are the walkers made of silica, magnesium, dolomite, and many mineral raw materials.

- ### 1.24.2 Slate flooring decorations:

The cobblestone flooring includes a wonderful assortment that adds aesthetic charm to the place and the floors, which are used in the installation of the decor of the floors of villas, palaces, and gardens. It also suits all tastes, whether it is classic or modern cobblestone flooring.

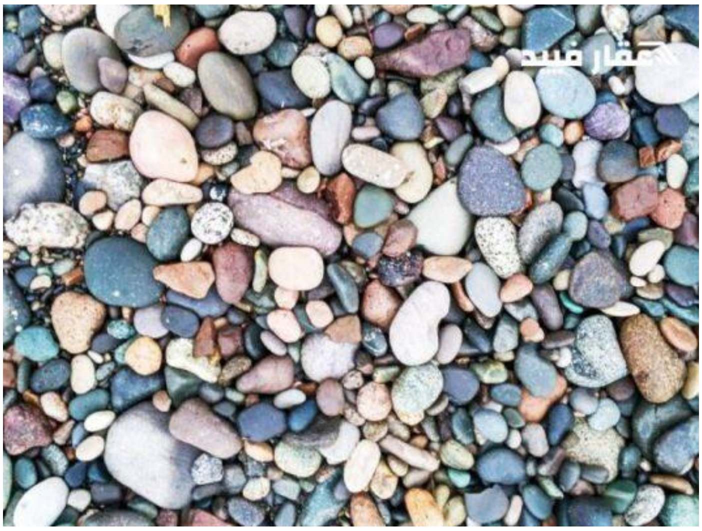
1.25 Slip colors:

White gravel is one of the best types of gravel because it is characterized by the aesthetic shape that is reflected on the floors with its elegant and classic appearance, in addition to the presence of types of fine white gravel used in gardens and landscaping, and coarse white gravel used in the installation of sidewalks, and the prices of gravel vary according to the material and sorting.

1.26 Colored gravel:

Colored gravel is one of the newest and most elegant types of gravel to be used in arts and decorations. Colors of gravel are also available, including red, blue, green, and black used in implementation processes.

Among the places where colored gravel is used are the tourist places that include many places of natural expectation, such as beaches, parks, the edges of the seas, and corridors.



1.27 Shapes:-

1.27.1 Rounded agg:

Like gravel and sand, it is considered the most widely used and preferred for the following reasons:

- Workability High
- High Compressibility
- the cement quantity Low

1.27.2 Angular agg:

All kinds of crushed stone (tooth)

1.27.3 Elongated agg:

like stratified rocks

1.28 The role of aggregates in concrete:

- A cheap filler (60-80% of the concrete mass).
- Helps reduce volume changes in concrete.
- Concrete helps to resist loads, erosion, friction, and heat dryness and wetness.

1.29 Admixtures:

Admixtures are the special ingredients added during concrete mixing to enhance the properties and performance of fresh concrete. Various types of admixtures are available in the market, which are used in construction work. Concrete admixtures are used to enhance the properties of concrete for applications in concrete works with special requirements. Concrete admixtures are used to modify the properties of concrete to achieve the desired workability in case of a low water-cement ratio and to enhance the setting time of concrete for long-distance transportation of concrete.


1.30 Introduction:

Concrete consists of cement, sand, aggregate, and water. Anything other than these, if added in concrete either before or during mixing to alter the properties to our desired requirement, are termed admixtures.

The use of admixtures offers certain beneficial effects to concrete-like improved workability, acceleration or retardation of setting time, reducing the water-cement ratio, and so on.

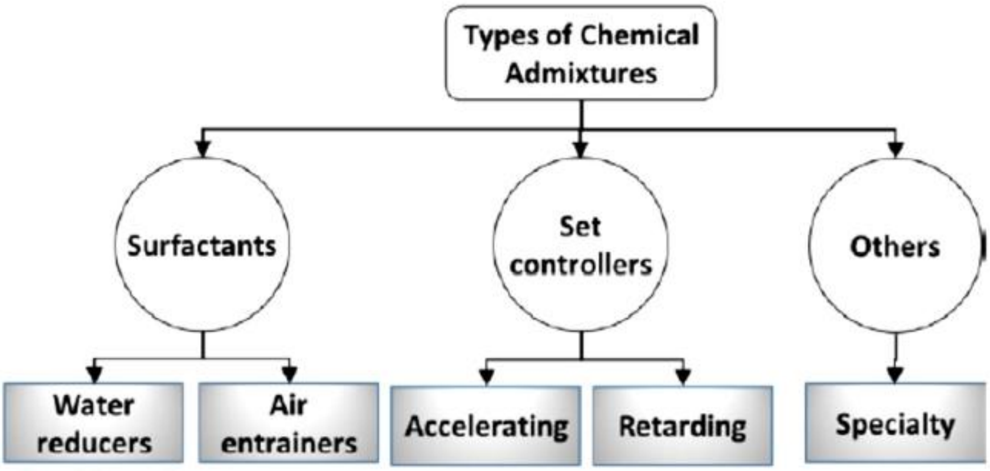
1.31 Function of admixtures:

The major reasons for using admixtures are:

- Increase workability without increasing water content or decreasing the water content at the same workability.
- Retard or accelerate the initial time of setting.
- Reduce or prevent shrinkage or create slight expansion.
- Modify the rate or capacity for bleeding.
- Reduce segregation.
- Improve pumpability.
- Reduce the rate of slump loss.
- Retard or reduce heat evolution during early hardening.
- Accelerate the rate of strength development at early ages.
- Increase strength (compressive, tensile, or flexural).
- Increase durability or resistance to severe conditions of exposure, including the application of deicing salts and other chemicals.
- Decrease permeability of concrete.
- Control expansion is caused by the reaction of alkalis with reactive aggregate constituents.
- Increase bond of concrete to steel reinforcement.
- Increase the bond between existing and new concrete.
- Improve impact and abrasion resistance.

Despite these considerations, it should be borne in mind that no admixture of any type or amount can be considered a substitute for good concreting practice. The effectiveness of an admixture depends upon factors such as type, brand, and amount of cementing materials; water content; aggregate shape, gradation, and proportions; mixing time; slump; and temperature of the concrete.

1.32 Chemical admixture classification is as follows:



- Air entraining admixtures.
- Water reducing admixtures.
- Retarding admixtures.
- Accelerating admixtures.
- Specialty admixtures. (Hydration-control admixtures, corrosion inhibitors, shrinkage reducers, alkali-silica reactivity inhibitors, coloring admixtures, miscellaneous admixtures such as workability, bonding, damp-proofing, permeability reducing, grouting, gas-forming, anti-washout, foaming, and pumping admixtures).

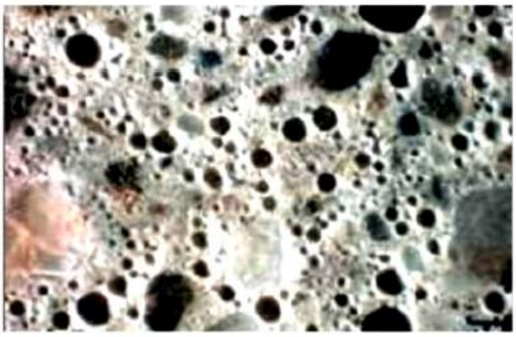
1.33 Air-entraining admixtures:

Air-entraining admixtures are used to purposely introduce and stabilize microscopic air bubbles in concrete (air bubbles predominately between 0.25—1 mm diameter). Air entrainment will dramatically improve the durability of concrete exposed to cycles of freezing and thawing. Furthermore, the workability of fresh concrete is improved significantly, and segregation and bleeding are reduced or eliminated.

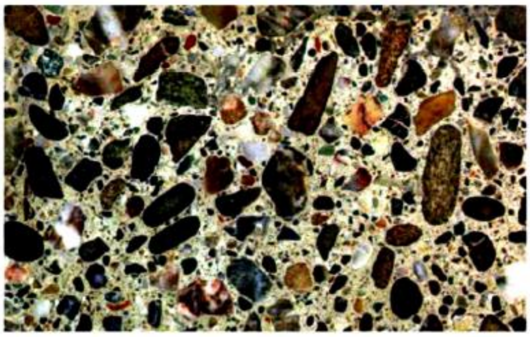
1.34 The air-void system:

As un-reacted water freezes, it expands 9 % by volume on phase change. This internal volume expansion causes internal stresses in the matrix. It can generate cracks in the concrete, which may allow water to infiltrate, and the process can get progressively worse. It can lead to significant degradation of the concrete.

Further, the formation of ice in the pore spaces generates pressure on any remaining unfrozen water. Introducing a large number of air bubbles provides a place for this water to move into, relieving the internal pressure.



Air-Entrained concrete



Non Air-Entrained concrete

1.35 Effect of air on other concrete properties:

Air entrainment will affect the following three properties of concrete directly:

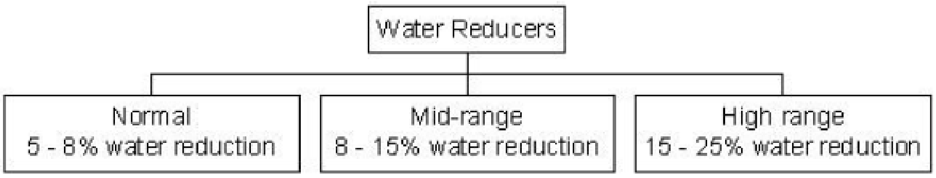
- Increased resistance to freezing and thawing.
- Improvement in workability and cohesiveness of fresh concrete.
- Reduction in strength.

1.36 Water-reducing admixtures:

Water-reducing admixtures are used to:

- Reduce the quantity of mixing water required to produce concrete of a certain slump.
- Reduce water-cement ratio.
- Reduce cement content.
- Improve durability.
- Improve water tightness.
- Increase slump.

Various types of Water Reducers can reduce the water content by approximately 5% to 25%. Adding a water-reducing admixture to concrete without reducing the water content can produce a mixture with a higher slump. The rate of slump loss, however, is not reduced and, in most cases, is increased. Rapid slump loss results in reduced workability and less time to place concrete.



An increase in strength is generally obtained with water-reducing admixtures as the water-cement ratio is reduced.

It can be said that Water Reducers can be used in three ways:

- With given workability, they can reduce the water demand, thus resulting in higher strength and durability.
- For a given w/c and strength, they can increase workability.
- For a given w/c, strength, and workability, the quantity of cement can be reduced.

1.37 Accelerating admixtures:

Accelerating admixtures are water-soluble chemicals that increase the rate of reaction between cement and water and thereby accelerate the setting and early strength development of concrete.

Accelerators materials

Most accelerators are based on one of the following chemicals:

- Soluble inorganic salts (CaCl, carbonates, aluminates, fluorides, and ferric salts).
- Soluble organic compounds (triethanolamine, calcium formate, calcium acetate).

Calcium chloride is the most popular choice due to its low cost and high rate of acceleration for a given dosage.

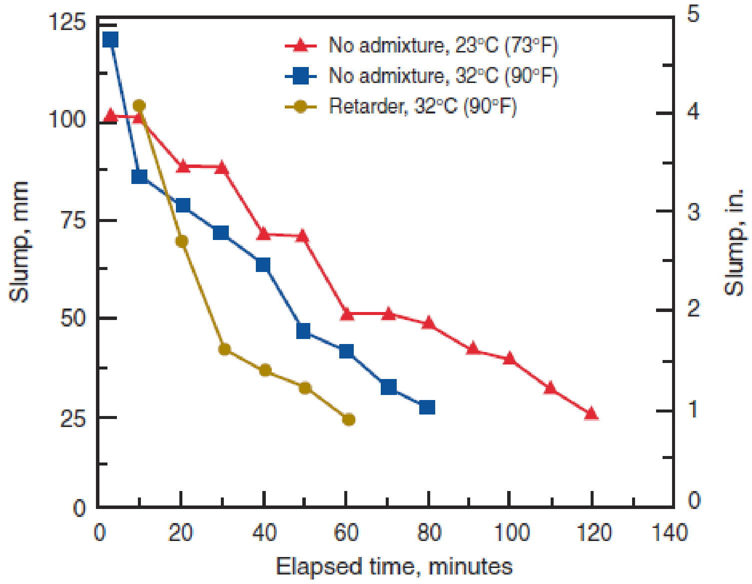
The purposes of using accelerators and the advantages resulting from the use of accelerators are many; among them are:

- Allow an earlier finishing of the concrete surfaces,
- Earlier removal of forms
- Reduction of the required period of curing and protection
- Earlier placement in service of a structure or a repair.
- Partial or complete compensation for the effects of low temperatures on strength development.
- Reduced bleeding and segregation and increased density of concrete.

1.38 Retarding admixtures:

Retarding admixtures are used where the setting time of concrete needs to be delayed. Retarder delays the hydration process but doesn't affect the eventual process. Initial setting time can be delayed by more than 3 hours. The main application of retarding admixtures is in controlling the setting time of concrete.

The retarders slow the rate of early hydration by extending the length of the dormant period.



Slump loss at various temperatures for conventional concretes prepared with and without set-retarding admixture

The main purposes of retarders are:

- To offset the accelerating effect of high ambient temperature (hot weather) and thereby lower the maximum temperature to a level where thermal cracks give fewer problems.
- To keep the concrete workable throughout the entire transport, placing, and finishing periods. Particularly important when transporting concrete over large distances.
- To prevent the setting of the concrete in the truck in case of delay.

1.39 Mineral admixtures:

Mineral admixtures are inorganic materials that also have pozzolanic properties. Mineral admixtures are very fine-grained materials which added to the concrete mix to improve the properties of concrete and make it more economical or as a replacement for Portland cement (blended cement). The designation pozzolana is derived from one of the primary deposits of volcanic ash used by the Romans.

It should be said that most of the mineral admixtures have lesser specific gravity than the other constituents of concrete; therefore, more volume is expected when one of these mineral admixtures replaces OPC by mass.

Mineral admixtures are added to concrete in different amounts in order to:

- Enhance the workability of fresh concrete.
- Improve resistance of concrete to thermal cracking.
- Resist alkali-aggregate expansion and sulfate attack.
- Enable a reduction in cement content.

1.40 Commonly used mineral admixtures are:-

1.40.1 Ground granulated blast furnace slag:

Blast furnace slag is a by-product of the extraction of iron from iron ore. Coal and limestone are added inside the blast furnace. The impurities in iron ore combine with the lime and rise up to the surface of the blast furnace, while the molten iron, which is heavier, stays at the bottom.

The reactivity of slag depends on the rate of cooling. In increasing order of reactivity, the cooling processes may be ranked as Slow cooling (in the air), Rapid cooling (by water spray), and Quenching (dipping in water).

Amongst mineral admixtures, slag possesses the highest specific gravity (2.8 – 3.0). Because it is a processed material, the fineness can be controlled to any desired degree. However, for most typical applications, slag fineness is only slightly higher than cement fineness.

1.40.2 Fly ash:

Fly ash is a by-product obtained during the combustion of coal in thermal power plants. During combustion of coal, 75 – 80% of the ash flies out with the flue gas and is thus called 'fly ash.' The ash that doesn't fly out is called 'bottom ash.'

1.40.3 Silica fume:

Silica fume is a very fine amorphous (non-crystalline) silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon. There are several types of silica fume, including condensed silica fume, micro-silica, silica flour, fumed silica, silica gel, and precipitated silica.

1.40.3.1 Properties:

- Specific gravity: 2.2.
- Typical fineness: 20000 m2/kg (average particle size ~ 0.1 – 0.5 µm).
- Color: light grey to dark grey (lighter implies purer).
- Typically used at 5 – 15% replacement level.

Chapter 2: Literature Review

2.1 Abstract:

Includes introduction and conclusion from 10 research articles.

2.2 Effect of polypropylene fiber in concrete:

2.2.1 Introduction (1):

Concrete is a vast material used worldwide. Concrete is used in the manufacturing of infrastructure such as bridges, roads, buildings, etc., by use of concrete on a vast scale; we are reducing our natural minerals. There is no other substitute by which we can replace concrete. Nowadays, for new constructions, we produce a high volume of concrete. Then it is compulsory that we produce concrete that is more durable and have enhanced mechanical properties of concrete, which will maximize the service life. Concrete has a brittle nature and does not possess any tensile strength. Fiber-reinforced can be an alternative that will modify its brittle nature. Rigid pavement resists all the loading through slab action. In slab action, there is tension force generated at the bottom of rigid pavement. Due to tension at the bottom concrete slab may crack because concrete provides only 10% tensile strength as compared to its compressive strength. To overcome this effect, we can use different available fibers, such as glass fiber, polypropylene fiber, steel fiber, etc., as secondary reinforcement. The present study focuses on the utilization of using Polypropylene Fiber that will act as secondary reinforcement and will improve the brittle nature of concrete. Various fractions were considered for the study, and different tests were carried out in the laboratory. Various properties such as compressive strength, flexural strength, abrasion resistance, and impact resistance were determined. All mechanical properties of concrete increase with varying % of fiber dose. The present study of different fiber content was carried out to check to how much extent the mechanical properties of concrete will vary as compared to its original mechanical property.

Polypropylene fiber was first suggested in 1965 as a blend of concrete for the construction of blast-resistant structures for the US Corps of Engineers. The fiber enhances. Additionally, according to the various studies, now it is used as small, discontinuous fibrillation material for the production of fiber-reinforced concrete. Since the use of polypropylene fiber has expanded tremendously in the construction of various structures because the inclusion of fibers in concrete enhances the toughness, flexural strength, tensile strength, and impact strength, further failure mode of concrete, polypropylene fiber is economical, abundantly available, and like all artificial fibers of consistent quality.

2.2.2 Conclusion (1):

- It is noticeable that growth in polypropylene fiber content in concrete increase compressive strength.
- The polypropylene fiber content in the concrete also increases flexural strength.
- The increase in the above strength is due to the fact that the polypropylene fiber arrests the cracks developed in concrete; this grows the strength of concrete.
- Grow in compressive along with flexural strength up to 0.20% by volume fiber content rapidly, and strength increment decreases after 0.20% fiber content. It shows that fiber content between 0.20%- 0.30 percent is beneficial to use.
- The mechanical properties of polypropylene fiber reinforced concrete are superior to plain reinforced concrete.
- There is a small increment in abrasion resistance of concrete due to polypropylene fiber.

Overall, there is an increment in the mechanical properties and durability properties of concrete.

2.2.3 Introduction (2):

Concrete, due to its numerous advantages and valuable properties like mechanical strength, durability, easy constructability, low cost, and others, is one of the most extensively used construction materials. However, concrete is a brittle material, has low tensile strength and low strain capacity, and does not show resistance to cracking (Reddy and Baswa, 1990). During their service life, concrete structures experience various types of forces and extreme events like dynamic forces caused by an earthquake, accidental blasts, severe chemical exposures, and high-pressure wind caused by cyclones. In addition to these forces, concrete structures may experience a fire or increasingly high temperatures in their design life. During their exposure to fire, RC structures get severely damaged due to spalling, cracking, or others, resulting in a profound impact on the mechanical properties and capacity of the reinforced concrete structures to carry and transfer loads. The pore water present in the concrete and the chemically bound water present in the cement paste get evaporated at elevated temperatures, leading to the generation of internal pore pressure, causing spalling and cracks in cement paste on the deterioration of its bond with the aggregates. In order to counteract such problems arising at high temperatures, various research and studies have been done, and numerous techniques have been developed to overcome them. One of the crucial techniques for reducing the damage induced in concrete due to high elevated temperature is the inclusion of suitable fibers, which develop and perk up the performance of concrete at high temperatures (Weitzeg 2002). Fiber is a reinforcing material having specific characteristics that help in improving the properties of concrete like toughness, impact strength, and flexural strength, which improves post-cracking ductility and cracking strength of concrete (Reddy and Baswa 2018). Thus, creating the application of fiber reinforced concrete (FRC). Polypropylene fibers (PPF) are the ones used in concrete, and their weight is about 1/5th of an equivalent fiber of steel, making their handling easier than steel fibers. It being thermoplastic has a relatively low melting point (~ 170 °C), became famous in the 1970s, and is the fourth-largest volume of artificial fiber after polyester, nylon, and acrylics. These fibers are majorly used in geotextiles, ropes, reinforcing concrete and soils, and sanitary products. (Menyhárd et al., 2020) and are also used in paving due to their excellent properties like increasing cohesiveness, fatigue, abrasion resistance, impact resistance, and reducing plastic shrinkage and permeability (Mohod 2015). PP chain is helical (31-helix) and is a semi-crystalline polymer with many crystal forms like α-form (monoclinic), β-form (pseudohexagonal), γ-form (orthorhombic), and an ε-form recent one (LOTZ, 2014). β form shows high impact resistance (Menyhárd et al. 2020). Substitution of Sf with PPF reduces the durability and permanence of concrete, but it proves beneficial in reducing shrinkage cracks and improving the impact resistance of concrete. Manufacturers recommend that the fiber length should be more than twice the diameter of used aggregates. FRC gained worldwide interest due to its superior mechanical properties like high fracture toughness, excellent energy absorption capacity, high compressive and tensile strength, and high first crack strength. Polypropylene (PP) has a low melting point, so when heated with reinforcement, it melts and provides a pathway for vaporization, thus reducing inner vaporization and inner vapor pressure helping in reducing microcracking (Solhmirzaei and Kodur 2017). Properties like compressive strength and modulus of elasticity are slightly improved with PPF addition at normal temperatures, but at elevated temperatures, it improves these two properties to a great extent. Spalling is reduced by adding fibers made from polymers having a low melting point but with a small quantity (about 0.1% addition). During heating processes, Polypropylene fiber controls explosive spalling (Varona et al., 2018). In a similar manner, steel fibers are added to concrete to enhance the tensile strength and improve the ductility and fracture behavior of concrete (Düğenci et al., 2015). Steel fiber reinforced concrete (SFRC) is an extensively investigated concrete type. Steel fiber addition not only improves tensile, flexure, and other important properties of concrete but also lessens the reinforcement congestion in beam-column junction sections in RC framed structures as per new seismic design codes. Further, the combination of steel fibers with other types of fibers is being extensively investigated by researchers to enhance the properties of concrete with specific importance to boosting the qualities, stability, and sturdiness of concrete at prominent temperatures (Bošnjak et al. 2019).

2.2.4 Conclusion (2):

- Both fibers performed well in improving the compressive strength of the concrete at high temperatures. However, the improvement was more by the addition of steel (32% increase at 900 °C and 49% increase at 1000 °C was observed in SRFC) than polypropylene addition (4–12% increase was observed in PPFRC).
- Between 25 and 700 °C, steel fibers have improved the split tensile strength of concrete than polypropylene, as a 40% increase in STS was shown by SFRC than NC without fibers. Also, for concrete with polypropylene, only an 8–20% increase in STS was observed with the addition of 0.3–0.5% of polypropylene. Moreover, it was observed that the maximum STS occurs in SFRC at 1% of steel fiber.
- In PPFRC, the modulus of elasticity increases with the increase in polypropylene content up to 350 °C, but after that, the modulus of elasticity decreases rapidly. Nevertheless, in SRFC, the modulus of elasticity remains unaffected up to room temperature. Moreover, due to the reduction in crack

formation with the rise in temperature, the modulus of elasticity increases. At 800—900 °C, 1% of steel fiber enhanced the modulus of elasticity. So, again Steel fibers proved better than polypropylene fibers in enhancing the properties of concrete.

- Steel fibers do not influence the spalling resistance of concrete significantly, but it increases the temperature at which spalling occurs. Meanwhile, polypropylene addition has reduced the spalling to a more considerable extent. It enhances the spalling resistance by reducing the pore pressure within the matrix by providing more voids for pore pressure dissipation. Spalling was found to be less in concrete, containing 0.3% to 1.2% polypropylene compared to concrete without any fiber, and spalling did not take place in specimens containing polypropylene greater than 0.05%.
- PPF increases the impact resistance of concrete. An increase of 48%, 62%, 171% and 90% in the impact resistance at failure was found by the addition of 0.05%, 0.1%, 0.2% & 0.3% PPF, respectively, using fiber length of 19 mm. The impact resistance gets enhanced further if pozzolans are used besides PPF. In the case of beams, impact resistance increases by 29% due to the addition of PPF. The optimum energy absorption of concrete was found at 1% PPF by volume.
- Thermal expansion and drying shrinkage initiate cracks in concrete, making concrete weak and prone to failure. SFRC exhibited much better crack resistance than normal concrete, as the initial cracks appeared in normal concrete at a lower temperature of 300 °C; such cracks were observed at a high temperature of 600 °C in SFRC.
- SF also proves efficient in reducing the permeability of concrete due to its property of reducing shrinkage cracks paving the way for aggressive agents like chloride ions, water, sulfates, etc., to enter into the concrete. Further in SFRC, the gradual or slow extension of microcracks occurs along the interfacial zone, and hence permeability decreases. A higher percentage of steel fibers of 1% showed improved results than a lower percentage of 0.5%. However, few studies infer that SF increases the permeability of concrete at all percentages and the reason for this increase is the connecting action of steel fibers between pores. So, further investigation is recommended to establish a relationship between SF addition and permeability.

2.2.5 Introduction (3):

The increase in Carbon Dioxide (CO2) gas emissions during the production of cement have increased the necessity for the development of eco-friendly, sustainable concrete using alternative binders. This research was conducted to study the strength behavior in terms of compressive and flexural strength of concrete incorporating rice husk ash (RHA) as supplementary cementitious material. RHA is a potential alternative binder due to its pozzolanic nature, but it can partially replace cement to a certain amount. Beyond it, the strength decreases, making the concrete less viable. Therefore, to strengthen RHA-based eco-friendly concrete, Polypropylene (PP) fibers were used to reinforce concrete. Based on the results, it was observed that 5% RHA achieved higher strength than the control sample; however, a further increase in RHA content resulted in a significant decrease in strength. Concrete with 10% RHA, which showed reduced strength, was reinforced with PP fibers which resulted in a gain in strength.

2.2.6 Conclusion (3):

A positive contribution to the sustainable growth of concrete technology can be achieved using rice husk ash and polypropylene fibers by reducing, rescuing, and recycling the solid agricultural and industrial waste and reduction of CO2 emissions from various cement reactions. Following are the results and observations made by the experiential work conducted:

- Due to its high surface area, the RHA absorbed more water during mixing and thus ultimately adversely impacting the workability of concrete; as higher RHA content was added into the mix, the lower slump value was recorded.
- The optimum replacement was determined to be 5% RHA, where higher strength was recorded. However, for long-term construction, the optimum value of 10% RHA replacement is suggested.
- The inclusion of PP fibers had a negative impact on the workability, but at the same time, it enhanced the compressive and flexural strength of concrete. It was determined that 0.20% PP fibers were optimum when used to reinforce concrete incorporating 10% RHA.

2.2.7 Introduction (4):

Historically, concrete is the most commonly used construction material because of its versatility and availability all over the world. Due to the environmental service conditions and complexity of structures such as high-rise buildings, dams, bridges, hydraulic structures, and offshore structures, any normal grade or ordinary concrete could no longer meet the requirements in generality. It is well known, nevertheless, that the ratio between compressive strength and flexural strength or split tensile strength of ordinary concrete or high-strength concrete will be inevitably brittle in nature. In order to overcome this drawback, research has been focused on various necessary treatments such as adding fibers to concrete, use of supplementary mineral admixtures, and externally strengthening the members with fiber-reinforced polymers. Among these, the addition of fibers like steel, polypropylene, polyvinyl alcohol, and natural and synthetic fibers into concrete has been accepted widely because of its improved mechanical properties such as compressive strength, split tensile strength, flexural strength, and flexural toughness. Besides, in recent few decades, the inclusion of non-metallic polypropylene fiber has also become one of the most extensively used fibers in concrete which in turn enhances the dynamic as well as durability properties of the composite matrix. Generally, the concrete structures will always be subjected to vibration forces such as impact loading on the dynamic shock of moving vehicles. Depending on the type of structure and impact or dynamic load, harmonic excitation exists through the external force of a certain frequency applied to a system for a given amplitude. Resonance can also occur when the external excitation has the same frequency as the natural frequency of the system. In this regard, it is necessary to study the dynamic property of any structure at typical modes, which will be helpful in reducing resonance and attenuating vibration. Therefore, the main aim of the present experimental work is to study the effect of polypropylene fiber on mechanical and dynamic properties and also the effect under the damaged and undamaged condition of polypropylene fiber reinforced concrete (PPFRC).

2.2.8 Conclusion (4):

- The static results emphasize that the addition of PP fibers in concrete significantly improves the flexural strength considerably when compared to compression and splitting tensile strength.
- The addition of PP fibers to concrete resulted in an inherent increase in compressive strength, splitting tensile strength, and flexural strength of PPFRCs. The result showed that 2.5–5% increase in compressive strength, 3.7–22.9% increase in splitting tensile strength, and 5.1–33.5% increase in flexural strength for M2 and M4 mixtures than that of plain concrete.
- The fundamental transverse frequency of concrete specimens tends to change with environmental effects such as wind, humidity, and temperature slightly.
- The damping ratio increased with the addition of PP fiber content and also with an increase in damage.

- The natural frequency of plain and PPFRCs decreases with an increase in fiber content and also decreases with an increase in structural damage.

2.2.9 Introduction (5):

The fiber dispersion into concrete is one of the techniques to improve the building properties of concrete. Polypropylene fibers are synthetic fibers obtained as a by-product from the textile industry. These are available in different aspect ratios and are cheap in cost. Polypropylene fibers are characterized by low specific gravity and low cost. Its use enables reliable and effective utilization of intrinsic tensile and flexural strength of the material along with significant reduction of plastic shrinkage cracking and minimizing of thermal cracking. It provides reinforcement and protects against damage to the concrete structure, and prevents spalling in case of fire. The fibers are manufactured either by the pulling wire procedure with a circular cross-section or by extruding the plastic film with a rectangular cross-section. They appear either as fibrillated bundles or mono-filament. The fibrillated polypropylene fibers are formed by the expansion of a plastic film, which is separated into strips and then slit. The fiber bundles are cut into specified lengths and fibrillated. In monofilament fibers, the addition of buttons at the ends of the fiber increases the pull-out load.

Cracks play an important role as they change concrete structures into permeable elements and consequently with a high risk of corrosion. Cracks not only reduce the quality of concrete and make it aesthetically unacceptable but also make structures out of service. If these cracks do not exceed a certain width, they are neither harmful to a structure nor to its serviceability. Therefore, it is important to reduce the crack width, and this can be achieved by adding polypropylene fibers to concrete. Thus, the addition of fibers in the cement concrete matrix bridges these cracks and restrains them from further opening. In order to achieve more deflection in the beam, additional forces and energies are required to pull out or fracture the fibers. This process, apart from preserving the integrity of concrete, improves the load-carrying capacity of a structural member beyond cracking.

In this project, polypropylene fibers of blended types (24mm, 40mm, 55mm) are used. The project deals with the effects of the addition of various proportions of polypropylene fiber on the properties of concrete in a fresh and hardened state. An experimental program was carried out to explore its effects on workability, compressive, flexural, split tensile strength, and modulus of elasticity of concrete.

2.2.10 Conclusion (5):

The compressive strength of 1.5% of blended length polypropylene fiber reinforced concrete has been found to be a 17% increase in strength when compared to that of conventional concrete. Strength enhancement in split tensile strength is 22%, flexural strength is 24%and modulus of elasticity is 11% compared to that of conventional concrete. The experimental studies proved to be the best method or way to provide strong and durable concrete. It is observed that 1.5% fiber in concrete yields max strength.

2.2.11 Introduction (6):

Fibers are typically added to concrete to improve its properties. Indeed, as compared to unreinforced concrete, fiber-reinforced concrete is characterized by improved resistance to cracking, tensile strength, flexural strength, shear strength, ductility, and toughness. The presence of fibers also results in a more homogeneous, isotropic, and ductile behavior of concrete. In particular, polypropylene fibers (PPF) are widely used in structural concrete to increase its integrity and enhance its strength and durability properties. The most important advantage of fiber-reinforced concrete corresponds to its capacity to sustain larger deformations following the occurrence of the first crack; the fibers will typically stay unbroken after a crack occurs, and those fibers bridging the crack will prevent it from opening further. The main drawback of using increased content of fibers in concrete is the reduction of workability. For example, Bayasi and Zeng stated earlier that PPF additions with a volume fraction exceeding 0.5% led to a decrease in slump values, while PPF has no significant effect on workability when their volume fraction is less than or equal to 0.3%. Furthermore, Mohod and Alsadey, and Salem found that concrete became stiff and posed serious placement and compaction difficulties when the volume fraction of PPF exceeded 1% and 2%, respectively. Concrete workability is affected due to fiber clumping and the subsequent increase in internal friction. However, this problem can be resolved, to a certain extent, by the addition of a suitable admixture capable of ensuring a uniform distribution of fibers in the concrete mixture. Although PPF additions do not significantly change the compressive strength, these induce notably improved splitting tensile and flexural strengths. However, Mohod reported that the enhancement in splitting tensile and flexural strengths was noted for PPF ratios up to 0.5%, after which these strengths decreased. The effect of PPF on the elastic modulus and the Poisson’s ratio of concrete has not yet been sufficiently characterized. This said existing works indicate that PPF inclusions decrease both the elastic modulus and the Poisson’s ratio of concrete.

2.2.12 Conclusion (6):

- Mixes containing PPF present a higher demand in high-range water reducers to achieve the same targeted slump in all mixes. This is associated with the need to reduce fiber clumping and the consequent increase in friction between the fibers and the coarse aggregates.

- No significant effect of PPF on the compressive strength is observed in both NAC and RAC.
- The drops in the splitting tensile strength and the flexural strength due to the inclusion of RCA are, to a large extent, compensated by the addition of PPF. An enhancement of both tensile strengths (i.e., up to 25%) results from the capability of the fibers to bridge the cracks in the cement matrix surrounding the aggregate particles.
- The addition of PPF slightly decreases the modulus of elasticity of all concrete mixes; the maximum drops in Young's modulus observed for RAC are 4.3% and 4.9%, corresponding to PPF ratios of 0.15% and 0.3%, respectively. This said, the addition of RCA is the main factor contributing to the drop in Young's modulus while that of the PPF remains minor.
- The Poisson's ratio of concrete is not significantly affected by the incorporation of PPF. Nevertheless, a small reduction of Poisson's ratio is observed in all mixes; the maximum drops in Poisson's ratio observed for RAC mixes are 4.2% and 6%, corresponding to PPF ratios of 0.15% and 0.3%, respectively.
- The incorporation of PPF does not affect the density of hardened concrete. This is due to the small quantities of PPF retained in this work.
- Water absorption shows a slight tendency to decrease with increased PPF content. The drop in water absorption due to fiber inclusion in RAC mixes does not exceed 3.2%. This drop can be associated with the very low water absorption capacity of the PPF, provided that the latter occupy a certain volume in the concrete mix.
- Voids show a tendency to increase with increased PPF content. The maximum increases of percent voids observed for RAC mixes are 1.4% and 4.8%, corresponding to PPF ratios of 0.15% and 0.3%, respectively.

2.2.13 Introduction (7):

Cement is an essential construction material around the world. This material that is so vital for the construction industry should be endued with the ideal properties (Zhang, Zhang, et al. 2016). The standards on which strengthened basic cement outlines were constructed depend on the solid material utilized along with the quality of steel. Strand in solid enhances the quality of the solid. Concrete, as a typical cement-based composite, is composed of cement as a binder, coarse aggregate as the framework, fine aggregate and fly ash as filler, as well as water and other agents. However, cracks and fissures usually appear on the surface of concrete when it is subjected to tensile or flexural loading due to its poor toughness, thereby resulting in the failure of concrete (Lura and Terrasi 2014). Polypropylene (PP) is a thermoplastic polymer utilized as a part of a wide assortment of uses, including bundling materials (e.g., ropes, warm clothing, and covers), stationery, plastic parts, and reusable compartments of different sorts, research facility gear, amplifiers, car segments, and polymer banknotes. Therefore, in recent years. Among various fibers, macro-polymeric and polypropylene fibers as synthetic fibers have been attracting the increasing attention of researchers due to their lower cost and weight, resistance against corrosion and acids, excellent toughness, and enhanced shrinkage cracking resistance (Alhozaimy, Soroushian, et al. 1996; Banthia and Gupta 2006). Various researchers have discussed the mechanism of fiber-matrix interaction by using various models to compute the bonding between the fibers and cement matrix. The bonding of fiber and the cement matrix plays a major role in the composite behavior. The fibers can interfere and cause finishing problems. Thirumurgan at el. (Thirumurugan and Sivakumar 2013) reported that the workability of concrete decreases with an increase in polypropylene fibers, but it can be overcome by the addition of high array water-reducing admixtures. To improve the workability of concrete, more water is added, but this can lead to a reduction in compressive strength. The decrease in strength can be due to additional water or due to an increase in entrapped (Balaguru and Shah 1992). Kumar et al. carried out experimental investigations on M15, M20, and M25 grade fly ash concrete reinforced with 0%, 0.5%, and 1% polypropylene fibers. It was observed that the compressive strength also increased with the rise up to 1% in fiber content for all the three grades of concrete. Murahari and Rama Mohan Rao (Murahari and Rao 2013) tested 500 x 100 x 100 mm specimens under three-point loading in accordance with ASTM C78. The observations showed that the flexural strength increased with content up to 0.3 percent. The specimen was observed to gain more strength at 28 days as compared to 56 days. The presence of polypropylene fibers inhibits intrinsic cracking in concrete. Fibers in the matrix increase cohesion, and hence the failure is observed to be ductile and gradual for the fiber-reinforced deep beams. Peng Zhang and Li (Peng, Yang et al. 2006) used 0.04%, 0.06%, 0.08%, 0.1%, and 0.12% of polypropylene fibers in concrete containing 15% fly ash and 6% silica fume. They tested beam specimens under three-point loading and reported that the addition of fibers greatly improves the fracture parameters of concrete composite, such as fracture toughness, fracture energy, effective crack length, maximum mid-span deflection, critical crack opening, etc. The fibers embedded in concrete affect the stress and strain, enhance the stress redistribution and reduce strain localization. Fiber-reinforced concrete was successfully used in a variety of engineering applications because of its satisfactory and outstanding performance in the industry and construction field. Most of the research in the last four decades has been done on the mechanical behavior of fiber-reinforced concrete and fiber to study how fibers perform so well in concrete. Balaguru performed the uniaxial compression test on fiber concrete and observed that the fibers could affect the facet of uniaxial compressive behavior that involves shear stress and tensile strain (Balaguru and Shah 1992). This observation was made based on the increased strain capacity and also the increased roughness (area under the curve) in the post-crack portion of the stress-strain curve.

The influence of polypropylene fibers has been studied by using different proportions and lengths of fibers to improve the performance of lightweight cement composites. The fibers used in this study had different lengths (6 mm and 12 mm), while the fiber proportions were 0.15% and 0.35% by cement weight in the mixture design. Compared to unreinforced LWC, polypropylene (PP) reinforced Lightweight Cement Composites (LWC) with fiber proportioning 0.35% and 12mm fiber length caused a 30.1% increase in the flexural strength and 27% increase in the 17-splitting tensile strength. Increased fiber availability in the LWC matrix, in addition to the ability of longer PP fibers to bridge the micro cracks, is suggested as the reason for the enhancement in mechanical properties. All reinforced lightweight concrete specimens displayed improvement in their mechanical strength as a result of fiber's performance in the cement matrix. Among all-fiber proportions and lengths, only the PP fiber with 12 mm length and proportion of 0.35% performed better in all respects compared to the physical and mechanical properties of reinforced lightweight concrete (Bagherzadeh, Pakravan, et al. 2012).

This paper concentrates on the impacts of miniaturized scale manufactured polypropylene fiber in enhancing solid quality. The main concern is the provision of an ideal amount of polypropylene fiber for enhanced compressive and flexural quality. This paper concentrates on the impacts of miniaturized scale manufactured polypropylene fiber in enhancing solid quality. The main concern is the provision of an ideal amount of polypropylene fiber for enhanced compressive and flexural quality.

2.2.14 Conclusion (7):

The use of polypropylene fibers has increased in recent years due to the property of the fibers to eliminate some defects in concrete. The addition of PP fibers to concrete improves its mechanical properties. The high tensile strength as a result of fibers can improve the capacity of the concrete and can control the volume changes with time. From the study, it is concluded that the inclusion of PP fibers increased the compressive strength by 20% and 16 % after 7 days and 28 days, respectively, as compared to controlled samples, whereas 11% and 17% increment was observed in split tensile strength after 7 days and 28 days respectively. The optimum percentage of PP fibers was obtained both in compressive split tensile strength like 1.5% of cement contents. But after 1.5%, the decrease is gradual.

2.2.15 Introduction (8):

Concrete is a brittle material that has low tensile strength and tensile strain capacity. Conventional concrete is typically showing poor performance in terms of fatigue strength, cavitation, abrasion resistance, tensile strength, deformation capacity, shear strength, load carrying strength after cracking, and toughness. Where these properties of concrete are obviously required, the addition of high-tech fibers produced from different materials within the concrete improves the above weaknesses of the concrete. Thus, polypropylene fiber, carbon fiber, plastic-glass-based fibers, and steel fibers have begun to be used in concrete. In terms of advantages in the field of Civil Engineering, the importance of fiber-reinforced concrete is increasing rapidly, and important steps have been taken to improve the properties of composites.

The polypropylene fiber used in this study is a very light polymer that is grouped within the thermoplastics as a material type. From this point of view, it is also possible to say that polypropylene fiber is a cheap plastic to manufacture. The most important effect of polypropylene fiber in concrete or plaster is to control cracks due to plastic shrinkage within the first few hours after pouring concrete into the mold. In the first phase of concrete hardening, the rate of formation of concrete strength is slower than the rate of formation of tensile stresses due to shrinkage. This plastic shrinkage is essentially a natural consequence of evaporation and chemical reaction starting between water and cement. Polypropylene fibers are not very effective in increasing the mechanical strength of concrete compared to steel fibers. Nevertheless, they provide energy-absorbing capability to concrete at minimum levels, and they are very effective in plastic shrinkage. Polypropylene fibers are particularly preferred against non-strong shrinkage. The function of polypropylene fibers is limited by the soft, plastic phase of concrete; the strength-enhancing effect of the steel fibers also persists significantly after the concrete setting and hardening. Steel fibers also have a crack-proof and limiting effect in the plastic phase of concrete. However, it is weaker than the effect of polypropylene fibers dispersed perfectly in concrete. In addition, steel fibers give the material a certain strength and toughness, which significantly increases the strength of the concrete and reduces the cracks that will occur in hardened concrete due to their long-term drying shrinkage.

If we look at the literature studies using polypropylene fiber in concrete, polypropylene fibers were added into concrete at the rate of 1% and 2% by volume, and concrete samples were produced. When the fiber ratio is 1% in concrete, the compressive strength of the concrete is increased, and the compressive strength of concrete is decreased when it is 2%. In addition, as the water/cement ratio decreased, the compressive strength increased, and the flexural strength increased as the fiber ratio increased. Likewise, capillary water absorption and abrasion resistance properties of concrete were also positively affected by polypropylene fibers. As the properties of fresh concrete and concrete mixture proportions were changed, polypropylene fibers had a different influence on strength and durability. Polypropylene fiber and silica fume were added into concrete at the rate of 0.1%, 0.5%, and 1% by volume, and concrete samples were produced. It was observed that as the fiber ratio increased, compressive and flexural strength increased. Likewise, it has been determined that polypropylene fiber has a positive effect on the abrasion resistance and capillary water absorption properties of the concrete, and it would be appropriate to use it in field concrete. Concrete cube samples of 150 mm x 150 mm x 150 mm dimensions were produced by using rates of 1%, 1.5%, and 2% polypropylene fiber in concrete. The compressive strengths of concrete samples were investigated, and the percentage increase of compressive strength of polypropylene fiber concrete mixes compared to the mix without fiber is observed from 4 to 12%. Polymer-based polypropylene fibers were added to mortar mixtures in ratios of 0.6% 0.8% 0.9% and 1.1% by volume. On the mortars, compressive strength, flexural strength, ultrasonic velocity, water absorption, and dynamic modulus of elasticity were defined and compared with control samples. According to experimental results, it was seen that when the compressive strength and dynamic modulus of elasticity were decreased by the addition of fibers to mortar, flexural strength and water absorption were slightly increased. Concrete samples were produced using polypropylene fiber instead of cement at 0.5%, 1.5%, 2.5%, 3.5% and 4.5%. The compressive and tensile strengths of concrete samples were investigated. It was seen that the compressive strengths increased by 11% compared to the control samples, and the tensile strengths increased by 17% compared to the control samples as 1.5% of cement contents; however, after 1.5%, the compressive and tensile strengths decreased.

As known, various fiber-added materials are used to make the concrete more durable and more impermeable. One of them is polypropylene fiber. Also, the tensile strength of concrete is weak. Various fibers are used to increase tensile strength. This study; investigates the effects of polypropylene fiber on the compressive and flexural strength of concrete and the effectiveness of polypropylene fibers in preventing the cracking of concrete due to tensile stresses on the surface in concretes with high surface areas, such as airfield and road concretes.

2.2.16 Conclusion (8):

- Increasing fiber dosage in fluid concrete brings about a decreased slump. This is an important feature in terms of the cohesion of fresh concrete, even if it is seen as having a negative effect on workability.

- For the 7 and 28-day compressive strength test, as the fiber ratio increased, the compressive strength decreased by approximately 5%. However, it is observed that this decrease is within the standards of compressive strength.
- As a result of the 28-day flexural strength results, the increase in fiber ratio caused an increase in bending strength
- As the fiber dosage increased, the water absorption rate and the ultrasonic velocity increased, but the thermal conductivity coefficient decreased. It was thought that the increase in fiber dosage would contribute to thermal insulation by decreasing the thermal conductivity value.
- Generally, the use of polypropylene fiber added concretes does not technically cause a troublesome situation but provides numerous benefits to the concrete.
- It can be said that the use of polypropylene fiber added concretes could be used especially in concretes with high surface areas, such as airfields and road concretes, which can provide improvement in plastic shrinkage cracks.
- Research for new types of concrete is required to satisfy the current needs in the construction industry. Polypropylene fiber added to concrete will be a good substitute to meet these demands.

2.2.17 Introduction (9):

Adding fibers to concrete is not a new concept. Fibers were used during the 1950s of the last century and used as a concrete building material in 1960. The main reason to use fibers such as steel or polypropylene fibers is to control the cracking of concrete members both cracks due to plastic and drying shrinkage of concrete and also to delay the propagation of cracks due to applying loads on concrete members. Using polypropylene fibers in concrete leads to an increase in tension and compressive strength of concrete. In addition, using fibers such as steel fibers improve the flexural strength and ductility of concrete. Different types of fibers can be used to improve the properties of concrete; the main types are steel, glass, and polypropylene fibers.

In this paper, the main objective is to investigate the effects of adding polypropylene fibers using high-performance cement (HP Cement) on concrete quality and mechanical properties. Different percentages of polypropylene fibers and HP Cement were used. The compressive, tensile, and flexural tests were carried out for each concrete mix. The test results of including both polypropylene fibers and HP Cement compared against the test results of a-concrete including HP Cement, b- concrete including polypropylene fibers, and c-concrete without any additional ingredients.

2.2.18 Conclusion (9):

- The flexural and tensile strength of concrete increased considerably due to using HP Cement as partial cement replacement, while the effect was slightly on the concrete compressive strength. In comparison with the concrete reference mix, the flexural, tensile, and compressive strength increased by 99, 56, and 4%, respectively, due to the 10% replacement of HP Cement. Likewise, the relative increases were 149, 83, and 7% for the flexural, tensile, and compressive strength, respectively, due to the 20% replacement of HP Cement.
- The addition of polypropylene fibers could significantly increase the flexural, tensile, and compressive concrete strength. The increases relative to reference concrete mix ranged from 72 to 277% for flexural strength, from 37 to 175% for tensile strength, and from 4 to 24% for compressive strength when the percentages of polypropylene fibers ranged between 0.5 to 3.5%.
- The improvements in flexural, tensile, and compressive concrete strengths were more pronounced and significant when the concrete mix included a combination of both HP Cement and polypropylene fibers. In comparison with the reference concrete mix, the increases ranged from 158 to 432% for flexural strength, from 88 to 261% for tensile strength, and from 7 to 43% for compressive strength when different combinations of both HP Cement and polypropylene fibers were used.
- The concrete specimens, which included a combination of both HP Cement and polypropylene fibers, had adequate strength to counteract further cycles of loading after releasing the failure load.

2.2.19 Introduction (10):

Concrete is very weak to resist the tension stress that develops in the tension zone of the concrete section due to applied foresees. Concrete is a kind of building material with weak tensile strength, which is often crack-ridden connected to plastic and hardened states, drying shrinkage, and the like. The cracks generally develop with time and stress to penetrate the concrete, thereby impairing the waterproofing properties and exposing the interior of the concrete to the destructive substances containing moisture, bromine, acid Sulphate, etc. The exposure acts to deteriorate the concrete, with the reinforcing steel corroding. To counteract the crack, a fighting strategy has come into use, which mixes the concrete with the addition of discrete fibers. Cracks play an important role as they change concrete structures into permeable elements and consequently with a high risk of corrosion. Cracks not only reduce the quality of concrete and make it aesthetically unacceptable but also make structures out of service. If these cracks do not exceed a certain width, they are neither harmful to a structure nor to its serviceability. Therefore, it is important to reduce the crack width, and this can be achieved by adding polypropylene fibers to concrete. Thus, the addition of fibers in the cement concrete matrix bridges these cracks and restrains them from further opening. In order to achieve more deflection in the beam, additional forces and energies are required to pull out or fracture the fibers. This process, apart from preserving the integrity of concrete, improves the load-carrying capacity of a structural member beyond cracking

And explored the bond-slip at the interface between surrounding concrete and steel reinforcement. Plain and deformed steel reinforcement bars were adopted with differences in bar diameter, concrete compressive strength, and the development length on bond-slip relation. Experimental tests showed that the bond strength increases with increasing compressive strength and with decreased bar diameter and development length. Investigated the effects of polypropylene fibers on compressive and flexural strength of concrete material, the main variables are the percentage of polypropylene fiber, type of concrete mix, and presence of steel reinforcement in a prism, and the results showed that the flexural and compressive strength of concrete increased by increasing the percentage of polypropylene fiber, while by further increase up to 0.5% the compressive and flexural strength of concrete started to decrease significantly as compared to the control mix.

Studied the effects of polypropylene fiber content on the strength and workability properties of concrete, the proportions of polypropylene fiber ranged from 0.06% to 2.16%, and the results found that the fiber content of the concrete mix increased compressive, splitting, and flexural strengths of the concrete, The strengths increased and reached their maximum value at about 0.36% of polypropylene fiber, The concrete strengths started to decrease beyond the percentage of 0.36%. It is evident from previous studies that there are no studies on the effect of polypropylene fibers on the bonding behavior between concrete and reinforcing steel. In this study, the effect of polypropylene fibers on the bonding strength between concrete and reinforcing steel will be studied, taking into consideration several variables, namely, percentage of polypropylene fiber, compressive strength of concrete, rebar diameter, concrete cover, and embedded length of rebar.

2.2.20 Conclusion (10):

- In general, adding polypropylene fibers improved the bonding strength between concrete and steel bars as follows:
  - For the specimens with compressive strength of30 MPa, the bonding strength increased by 3.4%, 10.88%, and 16.33% by adding 0.5%, 1% and1.5%, respectively of polypropylene fibers.
  - For the specimens with compressive strength of 60 MPa, the bonding strength increased by3.11%, 9.33%, and 15.54% by adding 0.5%, 1%, and 1.5% respectively of polypropylene fibers.
- When increasing the rebar diameter from 12mm to 16mm, the bonding strength decreased by a percentage of (8.84, 9.87, 13.5, and 14.04) % for percentages of polypropylene fibers of 0%, 0.5%, 1%, and 1.5%, respectively.
- When increasing the concrete cover from 150mm to 200mm, the bonding strength increases by a percentage of (7.84, 7.24, 7.98, and 9.94) % for percentages of polypropylene fibers of 0%, 0.5%, 1%, and 1.5%, respectively.
- When increasing the embedded length from 80mm to 100mm, the bonding strength decreased by a percentage of (0.68, 0.66, 1.23 and 1.17) % for percentages of polypropylene fibers of 0%, 0.5%, 1% and 1.5% respectively.

2.3 Self-Compacted concrete:

2.3.1 Introduction (1):

The development of Self-Compacting Concrete (SCC) has recently been one of the most important developments in the building industry. The purpose of this concrete concept is to decrease the risk due to the human factor, to enable economic efficiency, more freedom for designers and constructors, and more human work. It is a kind of concrete that can flow through and fill gaps of reinforcement and corners of molds without any need for vibrations and compacting during the pouring process. Because of that, SCC must have sufficient paste volume and proper paste rheology. Paste volumes are usually higher than for conventionally placed concrete and typically consist of high powder contents and water-powder ratios. There is no standard method for SCC mix design, and many academic institutions, admixture, ready-mixed, precast, and contracting companies have developed their own mixed proportioning methods. Mix designs often use volume as a key parameter because of the importance of the need to overfill the voids between the aggregate particles. Some methods try to fit available constituents to an optimized grading envelope. Another method is to evaluate and optimize the flow and stability of first the paste and then the mortar fractions before the coarse aggregate is added and the whole SCC mix tested. In any case, the constituent materials are the same as those used in traditional vibrated concrete conforming to EN 206-1: cement, additions (mineral filler, pigments, fly ash, silica fume, ground granulated blast furnace slag, hydraulic lime), aggregate (limited to 20mm), admixture (VMA-viscosity modifying admixture, HRWRA- high range water reducing admixture) and water. This paper analyses the characteristics and properties of mixtures with different additions: fly ash, silica fume, hydraulic lime, and a mixture of fly ash and hydraulic lime.

2.3.2 Conclusion (1):

Due to test results, the addition of fly ash to the mixture containing hydraulic lime is quite beneficial, bringing a substantial improvement in the behavior of SCCFAHL concrete. Also, this mixture has a smaller filling capacity and fluidity than other mixtures.

The silica fume, a more expensive additive, imparts in the SCC a similar behavior to the one of normal concrete compacted by vibrations. It is caused by an incompatibility between silica fume and superplasticizer, requiring an increase in water/cement ratio for the same concrete workability.

2.3.3 Introduction (2):

In Brazil, the gross production of coal in 2015 was 13 million tons. Of these, 6.7 million tons were destined for energy production. The southern Brazilian states were responsible for 100% of the coal consumption (58.5% in the Rio Grande do Sul, 40.0% in Santa Catarina, and 1.5% in Paraná). The Jorge Lacerda thermoelectric complex, located in the Santa Catarina state, produced, in the months of 2018, on average, 344.5 MWh. In this process, 89031.07 tons of ash were generated, of which 54191.86 were commercialized, and 34839.22 were sent to sedimentation basins (Department of Thermal Generation - Jorge Lacerda Thermoelectric Complex, 2019).

Waste from thermoelectric plants is formed by non-combustible components and not-burned particles of coal due to incomplete combustion. These residues are classified in light of fly ashes and heavy or bottom ashes (Kreuz et al., 2002). The high cost of storage and the concern with the proper disposal of this residue have been encouraging alternatives in waste management for several applications such as pozzolanic cement production, concrete, and mortar mixtures (Rohde and Machado, 2016).

The self-compacting concrete (SCC) is a high-performance concrete with excellent rheological properties and high resistance to segregation. The SCC can be spread over long distances by only its own weight and can fill out complex shapes with congested steel in areas of difficult access without the need for vibration (Metha and Monteiro, 2014). It has sufficient stability to be handled and released without segregation or exudation. As a result, the use of SCC can reduce the work time and the labor cost, in addition to improving the working environment by eliminating the vibration and noise during its production. For these reasons, SCC has been widely used in various types of works (Barbhuiya, 2011; Das and Chatterjee, 2012; Ashtiani et al., 2013; Zhao et al., 2015). In order to provide high fluidity and to avoid segregation and exudation during transport and application of the SCC, its production demands a large amount of Portland cement (450-600 kg/m³), so its production cost is remarkably greater than a conventional vibrated concrete. In addition to the economic issue, excessive use of Portland cement also has a negative effect on the environmental aspect (Barbhuiya, 2011; Zhao et al., 2015). Cement production releases significant amounts of CO2 into the atmosphere; it is estimated that the industry already emits 5% of the CO2 generated in the world (Escola Politécnica da USP, 2015). The emission of CO2 varies from country to country and depends on the technology and raw materials used in the production. Brazil currently has an emission factor of about 610 kg CO2/t cement, one of the lowest in the world. Almost 30% less than China, with an emission factor of 848 kg CO2/ton of cement, one of the highest in the world (Escola Politécnica da USP, 2015).

An alternative to solve this problem is to replace part of the SCC cement with mineral additions. Fly ash is a mineral admixture type often used in the production of SCC (Dehwah, 2011; Dinakar, 2012; Ponikiewski and Gołaszewski, 2014; Faseyemi, 2015). It is a very fine residue derived from the burning of mineral coal in thermoelectric plants.

The use of mineral addition in the production of SCC, besides reducing the production cost of the SCC, can also generate environmental benefits (Pathak and Siddique, 2012).

In this study, the percentages of mineral additions to replace Portland cement were 20% and 40% (by weight). The following properties in fresh SCC were tested: spreading and workability (through spreading - slump flow test), passing ability (J-Ring), setting, and viscosity times (V-Funnel). The compressive strength was measured in the hardened state

2.3.4 Conclusion (2):

Analyzing the results, it is observed that the replacement of cement CP II-Z by both fly ashes in the percentages of 20% for self-compacting concrete is a viable alternative. The addition of fly ash significantly reduced the specific spreading ability.

For fly ash 1, the more fly ash, the better the maintenance of workability over time. Regarding the maintenance of the workability of the concrete self-compacting concrete with fly ash 2, which measured the spread after 30 minutes, the control mixture obtained a 14% reduction in workability, the mixture with 20% substitution achieved a reduction of 5.70%, and the mixture with 40% replacement achieved a reduction of 3.2%. Thus, it was concluded that the action of pozzolan, with its ability to decrease the hydration heat, thus reducing the water loss, minimized spreading reduction over time. In passing ability, mixing with the replacement of 20% fly ash 1 was the most effective. The smaller the variation between the amount of spreading (slump flow test) and the value of the J-Ring Test, the better the passing ability of the self-compacting concrete. The substitution of fly ash 1 for cement significantly improved the passing ability of the concrete. This improvement is proportional to the amount of fly ash 1 used.

As to fly ash 2, the self-compacting concrete with 20% replacement obtained the best result for passing ability. In general, the replacement of cement with ash improved the passing capacity. For viscosity, the control concrete had a lower flow time in the V-funnel, consequently, lower plastic viscosity. The mixture with 20% ash fly ash 1 obtained a reduction of 83% compared to the control and mixing with 40% replacement, 29.73%, which implies the fly ash one efficiency as its proportion increases. This is another factor that can be explained due to a decrease in water loss by reducing the hydration heat. As to the cement replacement for fly ash 2, in the ratio of 20%, it reduced the flow capacity of the concrete through the funnel, increasing its apparent plastic viscosity more significantly than that for concrete with 40% fly ash 2.

In general, the addition of fly ash increases the apparent plastic viscosity of the self-compacting concrete, reducing its flow capacity, but not to the point of changing its classification according to the use.

For the compressive strength, concrete with fly ash 1 had the best performance, which was significantly superior to the performance of concrete with fly ash 2. The control concrete reached 34.71 MPa compressive strength at 28 days, while concrete with 20% FA1 reached 31.69 and concrete with 40% FA1, 19.61 MPa. As to concretes with 20% and 40% FA2, they reached 20.80 MPa and 14.22 MPa respectively after 28 days.

In general, the replacement of up to 20% of the amount of self-compacting concrete cement for fly ash FA1 or FA2 is feasible because it meets the standard requirements, classifying these concretes as structural C30 and C20 respectively, as both exceeded 20 MPa after 28 days. The cement used in this study, CP II-Z32, has up to 14% pozzolan in its composition. That is, the actual ash/binder ratio is probably greater than 20% and 40% and depends on the amount of ash that was added by the cement manufacturer, which probably impacted, even more the compressive strength. It is important to remember that despite the replacement of fly ash for cement as a great alternative, fly ash is a residue derived from an industrial process, so it does not undergo quality control during or after its production. Thus, it is possible that different batches of the same product may show different characteristics. And this should be taken into account before the use of the cement replacement material.

2.3.5 Introduction (3):

Cement-based materials are the most widely used of all manufactured materials considering their various applications in the construction industry. Traditional construction and engineering materials are needed to meet new and challenging demands. One of the recent advances in concrete technology was the evolution of Self-Compacted Concrete (SCC). Self-compacting concrete is a new category of concrete that does not require vibration for placing and compaction. It can flow under its own weight to fill the formwork and achieve full compaction even in the presence of congested reinforcement. Hardened SCC is dense and homogeneous with mechanical and durability properties comparable to that of conventional concrete. Self-compacting concrete offers higher rates of concrete placement, with faster construction time and ease of flow around congested reinforcement. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids, and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. SCC is often produced with a low water-cement ratio providing the potential for high early strength, high durability, and fast use of elements and structures.

The consistency of hydraulic cement concrete is significantly influenced by the ambient temperature. Special measures during mixing, placing, and curing of concrete should be applied in hot weather. Manufacturing of concrete in hot weather is described in practicing codes and specifications. For this reason, an upper-temperature limit for the acceptance of ready-mix concrete is specified. The ACI-305 report states that concrete temperature should not exceed 35℃, while ASTM - C94 specifies a limit of 32℃. Other standards allow concrete casting only when the temperature is between 29℃ and 32℃.

During concrete manufacturing, high ambient temperature induces problems that refer to increased cement hydration and mixing water evaporation rates. The rate of cement hydration is dependent on its temperature, cement composition, and its fineness, and the use of admixtures. Increased cement hydration and water evaporation rates not only impede the fresh concrete state but also affect the strength and durability of hardened concrete. The research work conducted by Park et al.; showed that water contents, hydration products, and pore structure are the main factors affecting strength. Their work was carried out under typical summer weather conditions. The results showed that the elevated summer temperature did not influence the early-age concrete strength.

On the other hand, a significant loss of strength was recorded at later ages due to the restriction of hydration product development and increased porosity.

Fresh concrete properties are influenced by high ambient temperature and exposure to direct solar radiation, and concerting circumstances get worse with the speedy wind. Plastic shrinkage occurs before concrete setting due to water evaporation from the concrete surface. Plastic shrinkage, cracking, and strength reductions occur due to exposure to the aforementioned factors. Kar and Sanjay reported the benefits of using different admixtures to control SCC shrinkage. Kamal et al. studied the retempering of SCC concrete to maintain the flow characteristics. Over the past 50 years, the average global temperature has increased at the fastest rate in recorded history, and this trend is accelerating. These statistics motivated the current work to explore SCC production in hot weather.

2.3.6 Conclusion (3):

- The flow and filling ability were restricted as the temperatures increased. The flow rate was more adversely influenced by increased temperature and delayed casting compared to the slump flow diameter. In the same context, the initial flow diameter rather than the flow rate was satisfactorily restored by retempering after 20 minutes of mixing.
- The J-ring flow diameter and the slump flow diameter after 20-min. were below typical limits specified for satisfactory SCC performance. On the other hand, the blocking step and V-funnel times (T and T5) were exceptionally higher than the upper limit. Cooling the concrete constituents was sufficient to retrieve these properties to the desired limits.
- While the use of a retarder maintained the slump flow performance, increased shrinkage in terms of height change was considerably increased due to delayed setting allowing more plastic shrinkage before concrete sets.
- The use of a retarder had an adverse effect on the compressive strength between 7 and 90 days in simulated hot weather conditions.
- The J-ring outputs were the most improved due to cooling SCC materials. On the other hand, V-funnel time T5 and the 28-day compressive and tensile strength were the least improved. The use of a retarder further reduced the compressive and tensile strength improvement percentage and increased the percentage enhancement of V-funnel T5 time.

2.3.7 Introduction (4):

The current study experimentally probes into the possibilities of using M-sand with ground granulated blast furnace slag in Self-Compacting Concrete (SCC). The ground granulated blast furnace slag is a by-product material obtained through the blast furnaces used to make iron. Dumping of this waste material near the industries creates land pollution. The research analyses the potential of GGBS when it is added at 10, 20, 30, 40, and 50% by weight instead of cement in the preparation of SCC. M-sand was also used instead of fine natural aggregate at 20, 40, 60, and 80% by weight. An evaluation of the Fresh and hardened properties of the samples was also done. Efforts were made to study in detail the microstructure of the SCC specimens by subjecting them to Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Analyzer (EDAX) analysis. In order to achieve the required flow parameters, a superplasticizer was added. Likewise, fly ash (FA) was employed as an additional mineral admixture to the components. The results revealed that the inclusion of M-sand with the GGBS increases the compressive strength of SCC to about 55.55 MPa with 20% replacement of GGBS, which helps to reduce the CO2 emission due to cement industries.

Social and economic developments are the key to human growth. Industrial growth benefits society and degrades the environment by producing waste. Disposal of the waste directly pollutes land and indirectly pollutes water, and it turns toxic. Most industrial processes release useful products along with harmful pollutants and waste products. The construction industry is also one of the major sources of pollution, which contributes 4% of particulate emissions, and increases water and noise pollution. Particularly in the cement industries, when the calcium carbonate is heated to a very high temperature to produce lime, the carbon dioxide is also released, which contributes directly to greenhouse gases. The industry also uses nonrenewable energy sources like fossil fuels. The researchers suggest that policymakers should arrive at a suitable level of the carbon tax to promote the smooth progress of construction projects and to improve the emission reduction effect. Concrete is said to be sustainable material when it is produced with less energy consumption. It must produce durable structures using only little energy. It must use recyclable and green materials. This goal can be achieved by using industrial by-products in concrete. In order to achieve the goal of sustainable development in concrete production, this study examines the possibility of using ground granulated blast furnace slag (GGBS) in concrete as a partial replacement for cement. The cement consumption can be reduced by using these industrial by-products like GGBS, which contributes directly to reduced carbon emissions. Also, the use of M-Sand (Manufactured Sand) as a partial and full replacement instead of natural sand helps in producing green concrete. When we use these kinds of unconventional materials in concrete, it is necessary to study the strength and durability of such concrete. This research paper investigates the fresh and hardened properties of Industrial waste GGBS, fly ash, and M-Sand admixed self-compacting green concrete.

GGBS is a by-product material obtained through the blast furnaces used to make iron. GGBS is being used as a successful alternative replacement material for cement in construction industries all over the world. GGBS has been successfully used in self-compacting concrete. The addition of GGBS in self-compacting concrete provides many benefits related to increasing its compact ability and consistency and retaining it for a longer time. Many research articles have been done using GGBS, and the results show that self-compacting concretes with GGBS at various replacement levels achieved higher strengths ranging from 30 to 100 MPa. GGBFS enhances the service life of concrete structures and improves the durability of concrete.

The consumption of natural sand is high to accomplish rapid infrastructural growth. This situation leads developing countries like India to face the scarcity of good quality natural sand in the near future. In India, natural sand deposits are being depleted and creating many environmental degradations. In order to overcome the scarcity of natural resources and to protect the environment, research is done to suggest reasonably priced and easily available alternative materials. Many alternative materials have already been used instead of natural sand, e.g., Manufactured sand, copper slag, fly ash, slag, limestone, and siliceous stone powder, and they are used in concrete mixtures as a partial replacement. Among these materials, manufactured sand proved as a suitable substitute for natural river sand for many researchers. The M-sand is produced by crushing rock deposits. This alternative material can be produced abundantly, and it satisfies the requirements of fresh and hardened concrete properties similar to fine aggregate. From the literature, the researchers conducted a study on SCC using M-sand and proved that Manufactured sand is a suitable replacement material for river sand and it is suitable for the development of SCC due to an increase in paste volume.

2.3.8 Conclusion (4):

GGBS, which is both cementitious and pozzolanic over conventional cement concrete material, may be added to enhance the rheological characteristics of concrete. It allows for a very high replacement of cement and provides many benefits over conventional cement concrete. In the adopted concrete mixes, the cement replaced with 20% GGBS content is the optimum content than other Proportions. Among the various mixes, G20 MS40 has high compressive strength than the other mixes. The achieved compressive strength at 28 days was 55.55 MPa. From the SEM results, it is found that the GGBS consists of rough and dense micro-sized angular particles. The inclusion of mineral admixtures like GGBS and fly ash increases the paste volume. This increase in paste volume reduces the friction between the aggregate and paste particles, and hence the fluidity of the mix is good when the GGBS content increases. The addition of M-sand beyond 80% will affect the flowability characteristics of SCC. All proportions of GGBS enhance the splitting tensile strength. The splitting tensile strength results show that there is an increase in tensile strength with the inclusion of GGBS and M-sand in SCC compared to the control mix. But there is a reduction in tensile strength beyond 60% of M-sand in the 20% GGBS replaced specimens. Thus, it is proposed that GGBS can be used in SCC as a pozzolanic material. Hence it enhances environmental safety. And M-sand can also be a good substitute for natural sand in the production of SCC. The sustainability of the natural resources is ensured by using M-sand. The goal of a sustainable environment and reduced carbon emissions can be achieved by replacing the cement content in self-compacting concrete with industrial waste GGBS and natural sand with M-sand.

2.3.9 Introduction (5):

The introduction of the "modern" self-compacting concrete (SCC) is associated with the drive towards a better quality concrete pursued in Japan in the late 1980‟s, where the lack of uniform and complete compaction had been identified as the primary factor responsible for the poor performance of concrete structures. There were no practical means by which full compaction of concrete on a site was ever to be fully guaranteed. Instead, the focus, therefore, turned onto the elimination of the need to compact by vibration or any other means. This led to the development of the first practicable SCC by researchers Okamura & Ouchi at the University of Tokyo.

The SCC, as the name suggests, does not require to be vibrated to achieve full compaction. These include improved quality of concrete and reduction of on-site repairs, faster construction times, lower overall costs, and facilitation of the introduction of automation into concrete construction. The composition of SCC mixes includes substantial proportions of fine-grained inorganic materials; this offers possibilities for utilization of "dust," which are currently waste products demanding with no practical applications and which are costly to dispose of.

The current Indian scenario in construction shows increased construction of large and complex structures, which often leads to difficult concreting conditions. Vibrating concrete in congested locations may cause some risk to labor in addition to noise stress. There are always doubts about the strength and durability placed in such locations. So, it is worthwhile to eliminate vibration in practice, if possible. In countries like Japan, Sweden, Thailand, the UK, etc., the knowledge of SCC has moved from the domain of research to application. But in India, this knowledge is to be widespread.

2.3.10 Conclusion (5):

Particularly in India, the use of Self-compacting concrete for routine construction is not much because of the lack of awareness, while in countries like Canada, Denmark, Sweden, Thailand, the UK, etc., apart from Japan, SCC is used for the routine construction and with research data available, awareness can be spread in order to utilize the various benefits of this material. It is not fully clear whether existing design codes for structural concrete can be practical in the case of self-compacting concrete. The use of viscosity modifying agents along with high-range water-reducing agents is essential for flowability and segregation control. A better understanding of the rheology of SCC has made it easier to know the functions of fines, superplasticizers, and VMA in SCC, and the compatibility between these gives the designers a clear understanding of the mechanical properties, including stress-strain characteristics of SCC in its hardened state. No standard codes are available for the mixed design of self-compacting concrete apart from a few methods developed by the researchers and many institutions, RMC; companies are using their own methods with one or other limitations. Thus, some generalized methods can be developed, taking into consideration all the aspects.

Self-Compacting Concrete (SCC) can save time and cost and enhance quality and durability; moreover, it is a green concept.

- Due to its ability to guide itself into every nook and cranny in the form, SCC can produce nearly nil defects in concrete. The number of pouring points can be reduced, thus eliminating the cumbersome activity of pipe laying over the pour.
- About 40 to 50% of cement content can be replaced by materials like fibers; the cost of the concrete is greatly reduced. The number of skilled supervisors, engineers, vibrator operators, and pipe fitters can drastically be reduced. Formwork can be used a greater number of times. The cost of repairing the structure is reduced as the number of defects is reduced to a great extent.
- Since the concrete is capable of self-consolidating and reaching the difficult areas in molds, manual variables in terms of placing and compacting concrete are nil. This factor ultimately yields defect-less, better-quality concrete structures.

2.3.11 Introduction (6):

Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous, and has the same engineering properties and durability as traditional vibrated concrete.

Concrete that requires little vibration or compaction has been used in Europe since the early 1970s, but self-compacting concrete was not developed until the late 1980s in Japan. In Europe, it was probably first used in civil works for transportation networks in Sweden in the mid1990's. The EC funded a multi-national industry lead project, "SCC" 1997-2000, and since then, SCC has found increasing use in all European countries. Self-compacting concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids, and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure. SCC is often produced with a low water-cement ratio providing the potential for high early strength, earlier demolding, and faster use of elements and structures.

The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration.

The improved construction practice and performance, combined with the health and safety benefits, make. SCC is a very attractive solution for both precast concrete and civil engineering construction.

In 2002 EFNARC published their "Specification & Guidelines for Self-Compacting concrete," which, at that time, provided state-of-the-art information for producers and users. Since then, much additional technical information on SCC has been published, but European design, product, and construction standards do not yet specifically refer to SCC, and for site applications, this has limited its wider acceptance, especially by specifiers and purchasers. In 1994 five European organizations, BIBM, CEMBUREAU, ERMCO, EFCA, and EFNARC, all dedicated to the promotion of advanced materials and systems for the supply and use of concrete, created a "European Project Group" to review current best practices and produce a new document covering all aspects of SCC.

2.3.12 Conclusion (6):

The following conclusions can be drawn on the basis of the SCC mix design tool Self-Compacting Concrete is considered to be the most promising building material for the expected revolutionary changes on the job site as well as on the desk of designers and civil engineers. The self-compacting concrete mix design tool is developed based on the key proportions of the constituents. This tool is very simple and user-friendly for the self-compacting concrete mix design. It can be used for the SCC mix with or without blended cement and coarse aggregate with or without coarse aggregate blending. This tool can also be enhanced for multi-blended cement with more additives and is also useful for Self-compacting mortar design. It displays all necessary data for SCC mix design and also displays constituent materials for SCC or SCM for the required volume.

2.3.13 Introduction (7):

This study concerns the durability of self-compacting concrete (SCC). Since its first use in Japan at the end of the century, SCC has been increasingly used in ready-mixed concrete and in the precast industry to improve several aspects of construction. SCC is expected to replace vibrated concrete (VC) in many applications in the long term because of its various advantages: reduction of the harmful effects of sound in urban environments, the possibility of pouring in strongly reinforced places, or with complex geometry, and reduction in the industrial process costs. But some questions remain unanswered; for example: is SCC as durable as VC, especially in terms of physicochemical durability, at the same level of compressive strength. The few results available partly answer this question, but they usually concern high-performance concrete (HPC). Few studies provide results on SCC with low or average compressive strength.

This research program was therefore set up to study concrete with a compressive strength of about 20– 70 MPa. The main goal of the project was to compare the durability properties of SCC and VC with equivalent compressive strength. The properties studied were those recommended by the French Association of Civil Engineering for evaluation and prediction of reinforced concrete durability by means of durability indicators. The behavior of self-compacting concretes, in relation to the water absorption by capillarity, represented by the sorptivity coefficient (one of the parameters used to foresee durability), is equal to or better than the one of a normal concrete compacted by vibration.

The addition of fly ash, used in this work, resulted in a better performance of the self-compacting concrete appraised through the water absorption by capillarity. The same additive mixed with hydraulic lime also improved the concrete performance at the age of 28 days. The silica fume, a more expensive additive, imparts in the self-compacting concrete a similar behavior to the one of normal concrete compacted by vibration. Apparently, this behavior is caused by an incompatibility between the silica fume and superplasticizer, requiring an increase in water/cement ratio for the same concrete workability.

2.3.14 Conclusion (7):

The results of the experimental work on different SCC and VC mixes and associated compressive strength and results have been considered in this research. On the sound of results obtained in this paper, the following conclusions can be drawn as follows:

- Utilizing self-compacting concrete SCC with all mixes used in this research is reliable in achieving sulfate resistance and durable concrete.
- Incorporating silica fume SF and blinded binders SF with limestone powder LSP to produce durable concrete from SCC is considered vital and produces better results than utilizing LSP only as a binder.
- Utilizing basalt type and size 10 mm with ratios C/F 35:65 achieved high resistance against sulfate attack, whereas utilizing dolomite gave a vulnerable result compared with basalt or gravel but still more resistance compared to VC.
- Cement content and type have a vital effect on the resistance of SCC mixes, as rich mixes with SRC type provided good results for resisting sulfate attack.

2.3.15 Introduction (8):

Despite its widespread use now in developed countries, it has been difficult to define high-performance concrete (HPC) in a unified way, and no simple and consensus definition exists to date. American Concrete Institute (ACI) defines HPC as the concrete that meets special performance and uniformity requirements that may not always be obtained using conventional ingredients, normal mixing procedures, and typical curing practices. And these requirements may include enhancement of ease of placement without segregation, long-term mechanical properties, early age strength, toughness, volume stability, and life in severe environments. Several researchers have defined HPC in their own way. In this study, like many others, the term HP is used in terms of ease of placement without segregation and is therefore applicable to SCC as well.

The vibrated concrete produces differential compaction and hence differential durability. This aspect, coupled with a shortage of skilled workmen and the noisy nature of vibrated concrete, were the factors that forced the Japanese to think about concrete that flows by itself without segregation, does not need vibration for full compaction, and is environmentally friendly due to the absence of noise. It was Prof. Okamura and his team from Tokyo university Japan who was able to conceive and produce a powder type of flowing concrete in the early nineties of the previous century. This was called self-compacting concrete (SCC). With the continued research, special flow tests and equipment were designed, and specifications were written after detailed testing of this innovative building material which has also been very much liked by the architects due to its excellent surface finish. The main requirements of SCC are very high flow or slump spreads and very high segregation resistance, the two properties which are often contradictory in nature. In the literature, SCC has been classified as powder type, viscosity agent type, and the combination type, each differing in the way segregation resistance is achieved. The combination type of SCC uses a moderate powder content and a reasonable quantity of viscosity agent and is considered more robust for structural applications and was chosen for local placements in the tunnel.

In addition to SP, secondary raw materials (SRM) or secondary cementitious materials including limestone powder (LSP), fly-ash (FA), rice-husk ash (RHA), ground granulated blast furnace slag (GGBFS), or silica fume (SF) are also used. The selection of a typical powder is largely based on the required qualities of concrete in both fresh and hardened states. The role of SRMs is to improve packing and hence reduce the water demand of the system. They also replace a part of cement in mortars and concretes, resulting in the economy, less heat of hydration, and hence lower shrinkage. In ready mixed concrete constituents, cement is the most expensive, energy-intensive, and environmentally unfriendly material. The less energy-intensive SRMs being sought are the easily available industrial by-products requiring little or no pyro-processing and having inherent or latent cementitious properties. Low calcium fly ash and blast furnace slag have been in the market for a long time, whereas high-calcium fly ash, condensed silica fume, and rice husk ash are relatively new. The use of Fly Ash in concrete is increasing. The high cost of cement and pressure from environmental lobbyists are encouraging the use of SRMs to replace cement in concrete.

2.3.16 Conclusion (8):

- A simple procedure for calculating of water demand of SCC mixes has been developed and used. All HP/SCC mixes must be at a mixing water content equaling that corresponding to the demand of the system for economy and durability.
- The shape of coarse aggregate is very important for the flow response of SCC. Elongated coarse aggregates create larger voids in the mix and therefore require higher paste contents for meeting flow targets. Such aggregates can produce pipe-blocking during pumping if the mix is inadequately designed.
- The mixing regime is very important for making HPC/SCC. The time and sequence of addition of chemical admixtures were also very important.
- The use of FA reduces cement and hence early shrinkage, which is a very big consideration in HPC/SCC. Its spherical particle shape is useful for flow through congested sections.

- In the laboratory, the flow measurements should be taken only after the activation of the superplasticizer.
- Increasing SP/VEA ratio increases flow. The flow starts at a typical SP/VEA ratio for a given SCC formulation, and further increases do not improve the flow very significantly.
- The reasons for the response differences of a similar formulation when tested in the laboratory, at the plant, and then at the site are attributed to batch size differences, inadequate estimation of aggregate surface moisture, transportation time, and waiting at the site. Pumping also changes flow response.

2.3.17 Introduction (9):

The concept of Self Compacting Concrete (SCC) was first developed in Japan in the mid to late 1980s, and by the mid-1990s, it spread around the world because of the major concerns poor compaction was having on the quality and durability performance of concrete structures. The reasons for compacting conventional concrete are to ensure that maximum density is achieved by fully expelling entrapped air entrained during mixing and placing and to further ensure that the concrete is in full contact with both the steel reinforcement and the formwork.

The purpose of good compaction is to ensure satisfactory strength, sound impermeable concrete with satisfactory detail at corners, good bond with the steel reinforcement, good finish and appearance, and impermeable protective cover to the steel reinforcement. SCC, on the other hand, does not require any mechanical effort, such as the use of immersion vibrators or external formwork vibrators, to achieve full compaction.

A well-designed and produced SCC has the capability to flow under its own weight through and around congested steel reinforcement, fully encapsulating it, completely filling the space within the formwork without any loss of strength, stability, or homogeneity while still achieving the same outcomes of good compaction. It is now well accepted that the fundamental research into producing SCC has now been completed, and it is being used successfully in practice in many countries around the world for both precast concrete and in-situ applications.

2.3.18 Conclusion (9):

SCC offers improved quality and durability compared to conventional vibrated concrete, provided it is considered as part of the whole construction process, including the detailed design stage of a project. This technical note has identified a number of benefits that can be realized both in the fresh and hardened state. However, these benefits can only be achieved through the adoption of a stricter quality control regime, production control, construction control, and training regime for personnel involved with SCC. In this regard, more knowledge and control are required by the concrete suppliers and users. In terms of VicRoads works, this means strict compliance with specification requirements, including those of "Structural Concrete."

2.3.19 Introduction (10):

With the tremendous development of the construction of mega structures the world over, the demand for self-compacting concrete (SCC) applications is increasing. Many sites have the problems of congestion of reinforcement in principle structural members. The design issues are compounded due to the high risk of the seismic zone, vulnerability to cyclonic storms, and huge capacity addition of the plants to a very large scale. SCC has become the only choice in such difficult site environments. Ideally, the development of a concrete mix where placing and compaction have minimal dependence on the Standard of workmanship available on a particular site should improve the true quality of the concrete in the final structure and hence its durability. This was an important driving force behind the development of self-compacting concrete (SCC).

Self-compacting concrete (SCC), also called as Self-Consolidating Concrete or Rotodynamic concrete, is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous, and has at least engineering properties at par with and durability of traditional vibrated concrete. The principle behind Self Compacting Concrete (SCC) is that the settlement of aggregates is related to the viscosity of the fresh concrete.

This equilibrium has to be maintained for a sufficient time period to allow for its transportation, placing, and finishing. Combinations of tests are required to characterize the workability properties.

2.3.20 Conclusion (10):

Self-Compacting Concrete (SCC) to be made using various Mineral Admixtures and Fibers. In the current scenario of construction industries, demand in the construction of large and complex structures often leads to difficult concreting conditions. When a large quantity of heavy reinforcement is to be placed in a reinforced concrete (RC) member, it is difficult to ensure fully compacted without voids or honeycombs. Compaction by manual or by mechanical vibratos is very difficult in this situation. That led to the invention of a new type of concrete named self-compacting concrete (SCC). This type of concrete flows easily around the reinforcement and into all corners of the formwork. Self-compacting concrete describes concrete with the ability to compact itself only by means of its own weight without the requirement of vibration. Self–compacting concrete is also known as Self-consolidating Concrete or Self-Compacting High-Performance Concrete. It is very fluid and can pass around abstractions and fill all the nooks and corners without the risk of either mortar or other ingredients of concrete separating out. At the same time, there are no entrapped air or rock pockets. This type of concrete mixture does not require any compaction and saves time, labor, and energy. This review paper explains the utilization of fibers and various mineral admixtures in the properties of Self Compacting Concrete.

2.4 Steel fiber concrete:

2.4.1 Introduction (1):

Concrete is widely used all over the world. It gives a compression strength, and when it has collaborated with the steel, the tension strength is increased. Traditional reinforcement will take time. So, using the steel fibers in the concrete will provides high strength and durability. The fiber will lead to compensate for the weakness in the concrete. Steel fiber reinforced concrete (SFRC) is successfully used in the slabs, flooring, and even beams. The formation had proved the high tensile strength when added to the concrete. The Mix proportion followed in these is M20 and M30 mixes. By using steel fibers, concrete is cast at a rate of 0 percent, 0.25 percent, 0.50 percent, 0.75 percent, and 1 percent of the steel fibers applied. The important purpose is to provide high tensile strength and flexural strength.

Concrete is a construction substance composed of cement, gravel, or crushed stone (coarse aggregate) and sand (fine aggregate). Concrete is strong in compression and poor in strain. Commonly said, concrete is breakable in nature. Durability is, for the most part, influenced because of cracks created by creep and shrinkage. So, to compensate for the formation of the weakness, the steel fiber is added inside the concrete, which offers high tensile strength. Steel fiber reinforcement has the capacity to resist tensile strength, fatigue resistance, ductility, crack arrest, and shock resistance. Its advantages are the addition of higher compressive strength in concrete. The volume fraction is calculated at 1% to 2% typically by the volume of concrete.

2.4.2 Conclusion (1):

Steel fiber concrete has many excellent properties, such as crack resistance, toughness, resistance to bending forces, impact resistance, etc., but also drawbacks; steel fibers are too costly, steel fiber reinforced concrete costs Increase, and economy. Using steel fiber gives durability, workability, crack resistance, and good flexural strength. Steel fibers are the most part utilized fiber for fiber-reinforced concrete out of accessible fibers in the market. The compressive strength of concrete increases considerably as the number of steel fibers increases from 0.5 percent to 1 percent. When we increase the volume of fibers, the shear strength gets improves. Due to the excellent properties of fiber, it can be used for important construction materials since the steel fiber is economical and has good tensile strength.

2.4.3 Introduction (2):

The use of concrete reinforced with steel fibers has emerged as an effective material that has the advantage of being used in the most unconventional situations in reinforced concrete structures. These advantages involve reinforcements in structures that intend to resist loads in extreme conditions or change in the type of use, design and or construction errors, degradation of materials (carbonation or corrosion of reinforcement), and also the possible occurrence of accidents such as fires, floods, gusts of wind and earthquakes. In addition, the increasing use of this reinforcement system requires the development of more conclusive studies regarding the characteristics and behavior of the steel fibers, as well as a critical evaluation of this material and its techniques. This manuscript presents a review of the interaction between steel fiber and the concrete substrate. Initially, a brief description of some fiber's materials is made, followed by a summary of some works on adhesion between steel fibers and concrete under static loads. Finally, a summary of the few works on the main contribution of the steel fibers application to increase the strength after the cracking of concrete matrix during loading.

The need to guarantee the quality of a structure obligates the designers to consider new loading situations more and more. When a given structure needs to be designed to withstand impact loads, it is essential to understand the behavior of the concrete subjected to this type of loading as well as the characteristics of a suitable material capable of withstanding short-term dynamic stresses. The use of fibrous materials to improve the mechanical properties of cementitious materials was not exclusively created by man but rather adapted since some birds utilize small sticks and grasses (fibrous filaments) to mix them with clay and build their nests. Similar to birds, there are records that the Egyptians mixed straw and clay to build their shelters. About 5000 years ago, man mixed clay and asbestos (natural silicate whose purest form fibrous minerals), thus making a kind of asbestos cement. In 1971, the first building was built in London using concrete reinforced with steel fibers by 3% of volume. Currently, the use of fibers in civil construction goes far beyond wood, straw, and shrubs. In addition to fibers obtained directly from nature, artificial fibers are being widely used, for example, steel, glass, and carbon fibers. In addition, vegetable fibers are still used widely in civil construction, either in natural form or after undergoing industrial processes that make it possible to obtain the fibrous filaments themselves, such as sisal, curaua, piassava, and coconut fibers.

Staple fibers are used to reinforce concrete material, giving rise to fiber-reinforced concrete. Concretes, or mortars with fibers, are generally defined as materials made up of at least two main distinct phases. If we interpret this definition to the letter, we conclude that the fibreless concrete itself is already a composite since it is formed by cement paste and fine and coarse aggregates. In order not to escape the already established definition of concrete with fibers, the main phases of this material are considered to be the matrix (which is the concrete itself) and the fibers (whether natural or artificial). Parra-Montesinos et al. presented the mechanism of fiber action on the concrete strength, and the main factors that affect the performance of the composite are presented in detail. There are several types of fibers that are added to the concrete, and each type of fiber causes different changes in the mechanical properties of the concrete. The steel fibers and their influence on the mechanical properties of concrete with other types of fibers are presented in this review paper.

2.4.4 Conclusion (2):

Researchers have studied reinforced concrete with different kinds of fibers, including steel fibers, polyvinyl alcohol fibers, polypropylene, glass fibers, nylon bundles, and carbon fibers. The use of steel fibers in reinforced concrete is widely applied around the world because it improves the post-peak ductility and the energy absorption capacity of the concrete. The steel fiber reinforced concrete has shown a densified matrix with better bonding between steel and concrete. Therefore, taking advantage of fresh concrete properties (the ability of the fresh concrete mixture to maintain uniform distribution of mortar paste and aggregates during the construction process) by including steel fibers should provide a positive new feature and a new dimension in concrete technology, which could lead to better behavior in its mechanical performance in the hardening state. The incorporation of steel fibers (both long and short) successfully enhances the toughness of fibrous concrete mixtures. The post crack strength and flexural strength values can be directly used for design purposes because they provide numerical values regarding the allowable stresses at a given deflection based on the load-deflection curve. The hardness and toughness performance of concrete with steel fibers is excellent in the presence of abrasive forces. Overall, the short steel fiber-concrete mixtures perform better than the long steel fiber mixtures with the same fiber dosages. The recommendation for future work is to assess whether this performance is achieved when the models used are larger and increasing the range and weight of the fiber fabrics used

2.4.5 Introduction (3):

Ultra-High-Performance Concrete (UHPC) is an advanced cement-based composite material with improved mechanical and durability properties compared to conventional concrete. There is an increasing interest in research and commercial use of UHPC. Although applications of UHPC have been successfully demonstrated in several countries, widespread use is still limited. Several obstacles are known, including a lack of understanding of the structural behavior, procedures for material characterization, and generally accepted design codes. One driving force for increased use is the potential to design low-weight and slender structures. Others are reduced cost and environmental footprint, and low maintenance requirements. The existing codes for the production and structural use of conventional concrete are not fully applicable to UHPC. Design guidelines or recommendations for UHPC are currently emerging in several countries, including Germany, Switzerland, Australia, Canada, Spain, and Japan. Each of these nationally emerging design guidelines has different requirements for material characterization, and each approaches the design process differently. The Association Française de Génie Civil (AFGC) published design recommendations for UHPC already in 2002 [9]. In 2016, a development of this was adopted in France as a national appendix to the design code for conventional concrete (Eurocode 2). An essential constituent in UHPC is discontinuous fiber reinforcement. The inclusion of fibers is necessary to impose the ductility in compression required for structural safety. Fibers prevent a brittle behavior and might also improve several other material properties, e.g., providing exploitable tensile strength and increasing the energy absorption capacity. Multiple types of fibers are used, varying in size, shape, and material. Numerous factors cause variations in the distribution and orientation of the fibers, including the rheological properties of the fresh UHPC, the placement methods, and the geometrical conditions shaped by the formwork. Variations in fiber content, geometry, combination, distribution, and orientation are all central contributors to making the structural design of UHPC complex. Fibers are also one of the main reasons for the high unit cost and carbon footprint of UHPC. Consequently, increasing the knowledge of the effects of fiber reinforcement is an essential step towards the development of commonly accepted design codes and the widespread use of UHPC. Some review papers cover the mechanical properties of UHPC, but none focus specifically on the effects of steel fiber reinforcement on compressive and tensile strength. This study aims at contributing by presenting state of the art in research based on a literature review. A preliminary version of this paper was presented and discussed at the 5th International Federation of Structural Concrete (fib) Congress in Melbourne, 2018. The preliminary paper demonstrated that the research conclusions diverge considering the effects of fibers on the mechanical properties of UHPC. Enriched by the discussion at the fib Congress, this paper presents the results from a comprehensive literature review on the impact of steel fiber reinforcement on the compressive and tensile strength of UHPC.

2.4.6 Conclusion (3):

- ASTM C1609 is the most frequently applied standard for testing the effects of fibers on the flexural tensile strength of UHPC. This is a standard for fiber-reinforced concrete. Standardized procedures for conventional or fiber reinforced concrete are often applied, in spite of the emergence of dedicated UHPC standards. For some tests, e.g., compressive strength, even the dedicated UHPC standards refer to standards for conventional concrete.
- Different test specimen geometries have been used to measure the effects of fiber reinforcement on the compressive and tensile strength of UHPC. This is often a consequence of applying different standards. Differences in geometry are often claimed to influence the test results. From the analysis of the accumulated results from all the included papers in this review, it seems clear that geometry plays a role in both compressive and tensile strength. However, few of the papers have investigated this, and the effects of variations in other factors like constituting materials, mix proportion, and curing regime seems not to be focused.
- Variations in fiber types have been investigated, spanning from micro to macro fibers, straight or deformed (hooked-end, twisted or corrugated). For all fiber geometries, high-strength steel fibers (tensile strength > 2000 MPa) were mostly used. For compressive strength, the accumulated results show little effect of using deformed fibers rather than straight. It seems that deformed fibers can improve the flexural tensile strength for low fiber volumes. In contrast, at higher fiber volumes, straight fibers perform better. Hence, the optimum fiber type seems to be dependent on the fiber volume fraction.
- Fiber reinforcement is necessary for UHPC to avoid explosive behavior at failure. Several investigations reported that the compressive strength was affected by the inclusion of fiber reinforcement, giving UHPC higher strength. However, the influence of variations in test specimen geometry and other variable factors were hardly discussed. When the accumulated results are differentiated, it seems that the inclusion of fibers has little effect on compressive strength when tested on cylinders, though some higher effects on large cubes (100 mm). For small cubes (40–50 mm), there seems to be an increase in compressive strength as a function of fiber content up to 3 vol-%.
- The inclusion of fiber reinforcement profoundly influences the flexural tensile strength of UHPC. In most cases, the flexural tensile strength is improved as a function of increased fiber content. This seems to be valid for both small (l =

160 mm) and large (l > 280 mm) test specimens. At high content, fibers may have the opposite effect by reducing the tensile strength. This might partly be explained by fiber agglomeration and entrapped air.

- Combining different types of fibers might benefit from exploiting the synergetic effect of each type. This is often denoted as hybrid fiber combinations. The use of hybrid fiber combinations has the potential to increase the tensile strength of UHPC. Some hybrid combinations seem to improve, especially the flexural tensile strength, while others have little effect.

2.4.7 Introduction (4):

One of the undesirable characteristics of the concrete as a brittle material is its low tensile strength and strain capacity. Therefore, it requires reinforcement in order to be used as the widest construction material. Conventionally, this reinforcement is in the form of continuous steel bars placed in the concrete structure in the appropriate positions to withstand the imposed tensile and shear stresses. Fibers, on the other hand, are generally short, discontinuous, and randomly distributed throughout the concrete member to produce a composite construction material known as fiber reinforced concrete (FRC). Fibers used in cement-based composites are primarily made of steel, glass, and polymer or derived from natural materials. Fibers can control cracking more effectively due to their tendency to be more closely spaced than conventional reinforcing steel bars. It should be highlighted that fiber used as the concrete reinforcement is not a substitute for conventional steel bars. Fibers and steel bars have different roles to play in advanced concrete technology, and there are many applications in which both fibers and continuous reinforcing steel bars should be used. Steel fiber (SF) is the most popular type of fiber used as concrete reinforcement. Initially, SFs are used to prevent/control plastic and drying shrinkage in concrete. Further research and development revealed that the addition of SFs in concrete significantly increases its flexural toughness, energy absorption capacity, ductile behavior prior to the ultimate failure, reduced cracking, and improved durability (Altun et al., 2006). This paper reviews the effects of the addition of SFs in concrete and investigates the mechanical properties and applications of SF reinforced concrete (SFRC).

2.4.8 Conclusion (4):

Steel Fiber Reinforced Concrete (SFRC), its advantages, and its applications. During the last decades, incredible development has been made in concrete technology. One of the major progress is Fiber Reinforced Concrete (FRC) which can be defined as a composite material consisting of conventional concrete reinforced by the random dispersal of short, discontinuous, and discrete fine fibers of specific geometry. Unlike conventional reinforcing steel bars, which are specifically designed and placed in the tensile zone of the concrete member, fibers are thin, short, and distributed randomly throughout the concrete member. Among all kinds of fibers which can be used as concrete reinforcement, Steel Fibers are the most popular ones. The performance of the Steel Fiber Reinforced Concrete (SFRC) has shown a significant improvement in flexural strength and overall toughness compared to Conventional Reinforced Concrete.

2.4.9 Introduction (5):

Fiber-reinforced concrete (FRC) may be defined as a composite material made with Portland cement, aggregate, and incorporating discrete, discontinuous fibers.

Now, why would we wish to add such fibers to concrete? Plain, unreinforced concrete is a brittle material with low tensile strength and a low strain capacity. The role of randomly distributing discontinuous fibers is to bridge across the cracks that develop and provides some post-cracking "ductility." If the fibers are sufficiently strong, sufficiently bonded to material, and allow the FRC to carry significant stresses over a relatively large strain capacity in the post-cracking stage.

There are, of course, other (and probably cheaper) ways of increasing the strength of concrete. The real contribution of the fibers is to increase the toughness of the concrete (defined as some function of the area under the load vs. deflection curve) under any type of loading. That is, the fibers tend to increase the strain at peak load and provide a great deal of energy absorption in a post-peak portion of the load vs. deflection curve.

When the fiber reinforcement is in the form of short discrete fibers, they act effectively as rigid inclusions in the concrete matrix. Physically, they have thus the same order of magnitude as aggregate inclusions; steel fiber reinforcement cannot, therefore, be regarded as a direct replacement of longitudinal reinforcement in reinforced and prestressed structural members. However, because of the inherent material properties of fiber concrete, the presence of fibers in the body of the concrete or the provision of a tensile skin of fiber concrete can be expected to improve the resistance of conventionally reinforced structural members to cracking deflection and other serviceability conditions.

The fiber reinforcement may be used in the form of three-dimensionally randomly distributed fibers throughout the structural member when the added advantages of the fiber to shear resistance and crack control can be further utilized. On the other hand, the fiber concrete may also be used as a tensile skin to cover the steel reinforcement when a more efficient two – dimensional orientation of the fibers could be obtained.

2.4.10 Conclusion (5):

A comprehensive review of the literature covering papers from Journals and conferences was carried out; the papers reviewed were predominantly based on fiber-reinforced concrete. The literature review indicates that very few publications are available on fiber-reinforced concrete with hook tain steel fibers. Variables such as aspect ratio, different grades of concretes, and different percentages of steel fibers are simultaneously not covered in the papers reviewed. No work is reported in the development of mathematical models and their validation using own experimental values and values from other researchers, considering parameters like compressive strength, Split tensile strength, and Flexural Strength for Steel fiber reinforced concrete.

2.4.11 Introduction (6):

Different types of steel fibers can be used to reinforce concrete. Steel fibers are generally classified depending on their manufacturing method. Hooked-end stainless steel has proven to give the best performance. The addition of steel fibers to concrete necessitates an alteration to the mix design to compensate for the loss of workability due to the extra paste required for coating the surface of the added steel fibers. While many technical and economic advantages are benefited from using SFRC, drawbacks can also be found. They are, however, not likely to cause major problems. It was thought that steel fibers would have negative implications in concrete practice (i.e., transporting, surfacing, finishing, etc.), but experience has shown that the influence of steel fibers on these practical aspects is negligible.

Dispersion of steel fibers in concrete alters its engineering characteristics. The after-crack mechanism associated with the SFRC positively influences its mechanical and physical properties. The improvement differs depending upon the dosage and the steel fiber parameters considering the other strength-determining factors to be constant.

2.4.12 Conclusion (6):

- Although different types of steel fibers have been used, hook-ended steel fibers were found to perform better than the other types because of their hooked ends and! or high tensile strength, which requires additional loads for pulling out and for breaking.
- The mechanistic mix proportioning design approach for SFRC strives to adjust the additional paste required to coat the added steel fibers; therefore, some sort of coupling concept can be used. In other words, any of the plain concrete proportioning mix criteria can be used to design the mix, and thereafter the mix can be adjusted for the added fibers.

- The normal transporting, placing, and finishing methods used for plain concrete can also use for SFRC.
- Steel fiber has an effect ranging between little and significant on the mechanical properties. Endurance limit, impact strength, and shear strength are significantly improved while compressive strength, modulus of elasticity, and Poisson's ratio improve slightly when the steel fiber is added. The flexural strength at first crack and maximum load are slightly improved, but on the other hand, the imparted toughness improves the equivalent strength (after crack) significantly (as high as 100%).
- The physical properties are also altered by the use of steel fibers. The steel fibers have a significant effect on the plastic shrinkage, while a little effect is found for the drying shrinkage. Methods used to measure the shrinkage are found not to simulate pavements. Creep is significantly influenced when using a high dosage of steel fiber, while the little effect is found with low steel fiber dosages. The abrasion and skid resistance is also improved significantly. A negligible effect is found on the electrical conductivity. The thermal properties of the SFRC are not properly established, and problems could be encountered as a result of the wide difference between the thermal expansion factor for the steel fiber and the other mixture constituents. Durability is not influenced by the use of steel fibers.

2.4.13 Introduction (7):

Fiber-reinforced concrete, with the supplement of steel fibers, is commonly applied to make industrial floors as well as road and airport runways. Fiber-reinforced concrete is also used to make machine foundations and other elements exposed to dynamic loads. In addition, concrete with the supplement of fibers is used as the shotcrete technology, for example, as casing of the underground structures or for renovation-repair activities. At the same time, it should be noted that fiber-reinforced concrete is used more and more often as the material for structural elements. An example may be the latest structural solution, the steel-fiber composite floor, or RC elements absorbing the energy of destruction in the case of structures exposed to seismic action. An interesting example of fiber-reinforced concrete application in water construction is the surface slab of the dam in Longshua (China), located in the area of seismic impacts. This structure is located in an alternately wet and dry environment, and it is periodically influenced by large differences in temperatures (during the day and at night). Some of the dam panels were made of traditionally reinforced concrete and some of the same concrete with the supplement of steel fibers. The longest panel with fibers has 75 meters, and it does not show clear cracks even after the recent earthquake.

Another example of steel fibers application in the structural elements is a thin shell structure covered buildings located in the European Oceanographic Park in Valencia. Structures are a combination of traditionally reinforced concrete and fiber-reinforced concrete.

Other structures constructed using concrete with the supplement of fiber are railway stations made in the Ductal technology, e.g., Shawnessy Light Rail Transit Station Calgary in Canada or Papatoetoe Railway Station in New Zealand, tunnels, reservoirs, pools, structures resistant to explosions, and other impact loads, elements for reinforcement of hills and slopes, pipes and walls, as well as a number of footbridges for pedestrians and bridges (Ductal), among others in Sherbrooke (Canada), in Seoul (Korea), Sakata-Mirai footbridge in Japan, “Point du Diable” Ductal footbridge in France or the bridge over Shepherds Creek, 150km north of Sydney in Australia.

The essence of adding steel fibers to the concrete matrix is their anchorage force. Therefore fibers with deformed tips are used. The geometric parameters of the applied fibers are also important. When comparing the graph of σ-ε relation for concrete with and without fibers, it can be noticed that the area under the curve, that is, the energy needed to destroy the element, is greater for a material with the supplement of dispersed reinforcement. At the same time, the limit deformation accompanying the total destruction of an element is greater for the one made of fiber-reinforced concrete.

2.4.14 Conclusion (7):

he conducted tests that indicated that the course of destruction process of concretes containing dispersed reinforcement in the quantity of 1 and 3% loses its three-stage character. It is not possible to determine in these concretes the levels of stresses initiating cracking Vi. For these concretes, we may rather refer to "temporary" stable propagation of micro-cracks, developing, in turn, into "temporary" sudden propagation of micro-cracks. It should be assumed that during destruction, the presence of dispersed reinforcement in concrete hinders the propagation of cracks and contributes to a reduced concentration of stresses at the places of defects and discontinuities in the structure.

Added fibers make cement matrix somehow "sown together." Under the impact of load, energy cumulates to be finally released at a level of critical stresses that is higher than for "witness" concrete. So that an element with the addition of steel fibers would be destroyed, adhesion between cement matrix and aggregate must be lost, fibers must detach from the matrix, the matrix must be cut along fibers, or fibers should rupture. The addition of fibers gives concrete elements greater ductility.

At this point, it is worth noting some analogies between the fiber-reinforced concrete destruction process and the process of destruction of concrete saturated with polymer: methyl-methacrylate. The test proved that in polymer-impregnated concrete being compressed, it is not possible to determine unambiguously the level of stresses initiating cracking Vi. As a result of reinforcement of the concrete structure with polymer inclusions, the three-stage character of destruction is lost. In addition, the level of critical stresses for concrete saturated with methyl-methacrylate is higher than for witness concrete.

2.4.15 Introduction (8):

High-strength concrete is used in the construction of long-span bridges, walkways, piles, and high-rise structures, and the use of high-strength concrete in the construction industry is increasing rapidly. Furthermore, the development of steel fiber reinforced concrete in 1874 Bernard improved the mechanical performance of concrete. High-strength concrete contains more cement and tends to shrink more. The use of Portland cement and a reduction in the water content (w/c) will increase the strength of concrete. Once there is an increase in the strength, the elastic modulus of the concrete will also increase, thereby reducing the creep coefficient. This is why high-strength concrete tends to be more prone to resisting pressure than low-strength concrete. Besides that, various types of steel fibers have been produced in different geometrical shapes, such as the hooked end, crimped, deformed end, and deformed wire, with the most popular type of steel fiber used in the market being the hooked end. Steel fiber has been proven to be the best combination for high-strength concrete to produce the highest mechanical strength and durability with regard to the curing time, curing type and the steel fiber geometry. The addition of steel fiber will increase the compressive strength by a certain percentage and will also increase the tensile strength of high-strength concrete to potentially produce improvements in the workability of high-strength concrete. The compressive strength of steel fiber reinforced concrete usually ranges between 60MPa-100MPa. Song and Hwang stated that the compressive strength increases at the volume fraction of 1.5% steel fiber used, which means that the highest compressive strength is produced at a volume of 1.5%. As the volume of steel fiber increases to 2%, the compressive strength decreases slightly. Further, the splitting tensile strength of the high-strength fiber reinforced concrete increases when there is an increase in the steel fiber volume fraction. It has been found that the relationship between the duration of mixing, the mixing sequence, the volume of steel fiber, and the steel fiber geometry has an influence on the segregation of the fiber during mixing.

The addition of steel fiber into a wet concrete matrix can prevent fiber agglomeration because if the mix is too dry or wet, it can cause bundling of the steel fibers. For concrete that contains steel fibers, the amount or the volume of the superplasticizer

(SP) is used to maintain the flow rate of the fresh mortar mix at around 150mm-160mm to ensure good workability. The main purpose of a superplasticizer is to control the water binder ratio and thus reduce the water content during mixing. According to Yao, steel fibers give the highest compressive strength, while polypropylene fibers give the lowest compressive strength among the three types of fibers. The superplasticizer is added until a flow rate of 160mm is reached. In this research, the addition of steel fiber increased the modulus of rupture, while the polypropylene fiber gave the lowest modulus of rupture. The ductility improved with the addition of steel fiber and resulted in an increase in the flexural strength, which was higher than that of the other types of fibers used. The use of short fibers can provide a good bridging effect to resist cracking propagation. When cracking occurs as the concrete hardens, the steel fibers are distributed evenly to block the crack. Thus, the inclusion of steel fibers contributes good mechanical strength to the concrete. The incorporation of uniformly distributed short steel fibers increases the void content and decreases the workability of cement-based materials. Besides that, the increase in the pores volume of steel fiber reinforced concrete will raise the value of the corresponding ultrasonic pulse velocity. In other words, when there is a decrease in the unit weight, there will be an increase in the ultra-pulse velocity of the concrete. When the specimen was tested at 28 days, the average ultra-pulse velocity that was obtained was around 4543m/s for the control mixture or what is known as normal concrete. A relationship exists between the ultrasonic pulse velocity and the unit weight in conventional concrete. The volume and the length of the steel fibers used clearly influence the porosity and the permeability of the concrete.

2.4.16 Conclusion (8):

- The incorporation of steel fiber into high-strength concrete increases the compressive strength and the flexural strength of the concrete.
- The maximum compressive strength and flexural strength of 70.7 MPa and 11.45 MPa, respectively, are attained at a steel fiber volume fraction of 3.0%.
- Steel fiber high strength concrete (SFHSC) shows good mechanical behavior and compressive strength in normal water curing compared to hygrothermal curing.
- Normal strength concrete shows an increase in compressive and flexural strength with hygrothermal curing.
- It has been found that steel fiber high strength concrete (SFHSC) is not suitable for hygrothermal curing compared to normal strength concrete.
- Steel fiber high-strength concrete shows improved durability compared to normal concrete.

- The mechanical properties and durability of steel fiber high-strength concrete are expected to increase if it is sustained in normal water curing for the testing period of 28 days.

2.4.17 Introduction (9):

Durability is one of the most important aspects of concrete due to its fundamental incidence in the serviceability life of structures. The structures must be able to resist the mechanical actions and the physical and chemical aggressions they are submitted to during their expected service life. In this respect, cracking plays a key role in the durability of concrete structures. Due to this fact, it is necessary to establish measures in order to maintain the cracks under the limit that imply a non-significant risk to the durability of structural elements. In this context, steel fibers are presented as a solution for this problem since, due to fiber reinforcement mechanisms, the concrete ductility and post-cracking resistance can be significantly improved. Though much research has been performed to identify, investigate, and understand the mechanical traits of steel fiber reinforced concrete (SFRC), little research has concentrated on the transport properties of this material. Material transport properties, especially permeability, may affect the durability and integrity of a structure. The increase in concrete permeability, due to the initiation and propagation of cracks, provides ingress of water, chlorides, and other corrosive agents, facilitating deterioration. Rapoport et al. examined the effects of different steel fiber volumes (0%, 0.5%, 1%) in fiber-reinforced cracked concrete. Specimens were cracked to specified crack mouth opening displacement (0, 100, 200, 300, 400, and 500 μm). After the cracks were induced, the specimens were unloaded, and the cracks relaxed. Later the cracked specimens were tested for low-pressure water permeability. There are two major conclusions from this research: at larger crack widths, steel fibers might stitch the cracks, shortening the length of the crack and reducing the crack area for permeability. The higher steel volume of 1% has reduced the permeability more than the low steel volume of 0.5%, which allowed us to conclude that the SFRC permeability decreases with the fiber content. This is probably due to the crack stitching and multiple cracking effects of steel fiber reinforcement. For crack width lower than 100 μm, steel fibers do not seem to affect the permeability.

2.4.18 Conclusion (9):

- The addition of steel fibers resulted in a very slight increase in open porosity.
- Adding steel fibers did not change the water absorption significantly by capillarity, indicating that the capillarity pore size was not substantially changed.
- The air penetrability was not substantially affected by the steel fibers, although a slight reduction in SFRSCC was observed.
- The presence of steel fibers reduces the electrical resistivity of concrete.

- Determining the diffusion coefficient from the chloride migration test under a non-steady-state may not be feasible for an SFRSCC since the methodology can cause significant corrosion of steel fibers, and chlorides may tend to settle in steel fibers. However, the results obtained in both concretes were similar.
- Due to the relatively high compactness of SCC mixes, they presented good resistance to carbonation.

The study also concluded that, in extremely aggressive conditions, corrosion of steel fibers could induce cracking in concrete and decrease the tensile strength of concrete.

2.4.19 Introduction (10):

Highlight Plain concrete possesses a very low tensile strength, limited ductility, and little resistance to cracking (Naaman, 2003; Dasari et al., 2012). Internal micro-cracks are inherently present in the concrete, and their poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete (Dasari et al., 2012). It has been recognized that when reinforced with small, closely spaced, and uniformly distributed fibers, it gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete (Naaman, 2003; Pawade et al., 2011a; Pant and Parekar, 2009).

The addition of fibers to the concrete would provide better control of the crack initiation and its subsequent growth and propagation to improve the structural durability and would substantially increase elastic modulus and decrease brittleness (Naaman, 2003; Pawade et al., 2011b; Pant and Parekar, 2009). Moreover, fiber reinforcement enhances the impact and fatigue resistance of concrete structures (Luca et al., 2006).

Because of the vast improvements achieved by the addition of fibers to concrete, there are several applications where Fiber Reinforced Concrete (FRC) can be intelligently and beneficially used (Oslejs, 2008). Steel fibers are particularly suitable for structures when they are subjected to loads over the serviceability limit state in bending and shear and when exposed to impact or dynamic forces as they occur under seismic or cyclic action (Pawade et al., 2011a; Neves and Fernandes, 2005). These fibers have already been used in many large projects involving the construction of industrial floors, pavements, highway- overlays, parking areas, airport runways, floors resting on soil, floor slabs, walls, and foundations (Luca et al., 2006; Pant and Parekar, 2009). To help obtain uniform fiber dispersion in the matrix and improve strength and the bonding between fiber and matrix, Silica fume can be introduced (Pawade et al., 2011b).

The toughness of steel fiber reinforced silica fume concrete under compression and dynamic action was done by Ramadoss et al. (2009). They quantify the effect of fiber on the compressive strength of concrete in terms of fiber reinforcing parameters.

2.4.20 Conclusion (10):

A model that incorporates the steel fiber curvature into micromechanical schemes via a multiphase composite approach is developed. Compared to the true Young's modulus, finite element results of embedded fibers and the Voigt model show that the EERM of the fiber is too close to its true modulus. Using the effective fiber properties, it has been shown that the fiber curvature effect on the steel fiber concrete composite can be neglected.

After highlighting the influence of the steel fiber curvature, the Weng and Huang models were used to predict the elastic properties of 3D random orientated crimped steel fiber/concrete composites. The data delivered by the micromechanical models are compared against experiments. On examining the validity of the two models, there exists a good correlation between the predicted values and the experimental results.

Chapter 3: Experimental Program

3.1 Tests:-

3.1.1 L- Box Test method:

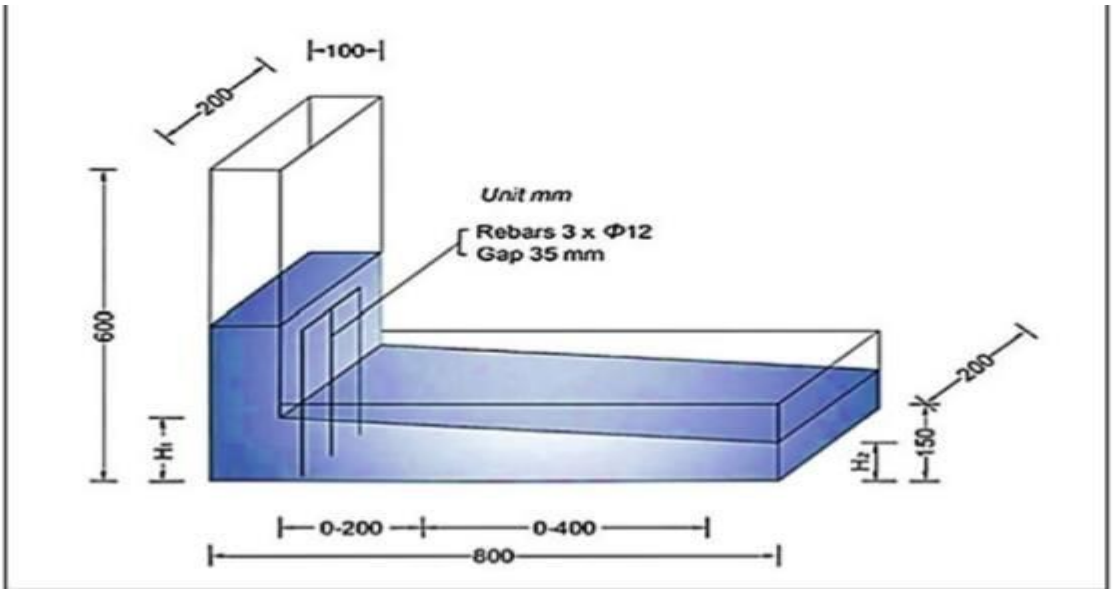
L-box consists of a rectangular-section box in the shape of an "L" with a vertical and horizontal section separated by a moveable gate in front of which vertical lengths of reinforcement bar are fitted. The test procedures are as follows:

- Fill the vertical section with concrete;
- Lift the gate to let the concrete flow into the horizontal section;
- Record the height (H1 and H2) of the concrete at the end of the horizontal section when the flow stops.

3.1.1.1 Equipment:

- L box of a stiff non-absorbing material
- Trowel
- Scoop
- Stopwatch

L-box Dimensions



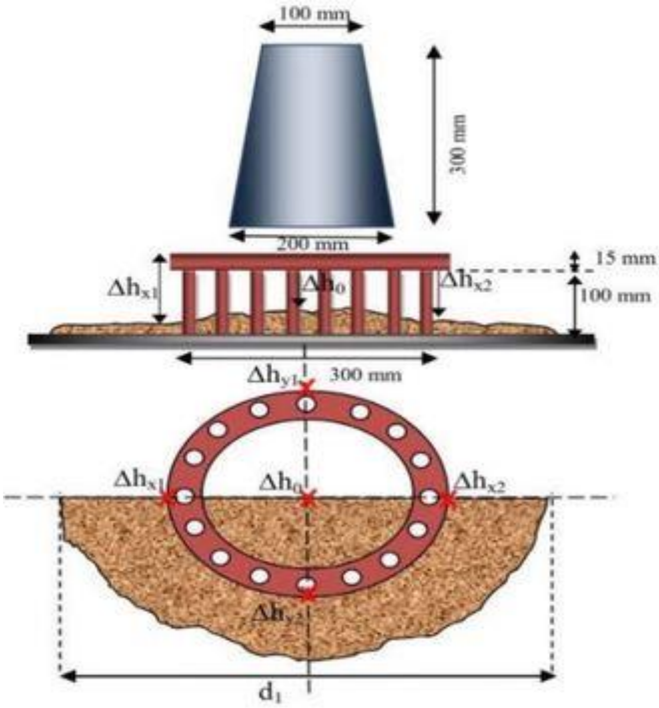
L- box Test

The proportion of H2/H1 is an indication of the passing ability or the degree to which the passage of concrete through the bars is restricted.

3.1.2 J-ring test method:

The J-ring test was used to assess a strong index for the evaluation of the passing ability of the SCC mixture; it is possible to be used in conjunction with the slump flow test. These combined tests examined the flowing ability and the passing ability of the concrete through gaps in the obstacles, e.g., reinforcement.

- For this test, the slump test apparatus is used with an open steel rectangular section ring with 16 steel rods (ϕ16 mm) and 100 mm in height.
- The gap between the bars is 42 mm.
- Wider gaps can be used when fibers are introduced to the mix, which should be 1-3 times the maximum length of fibers used.



J-Ring test instruments and procedure

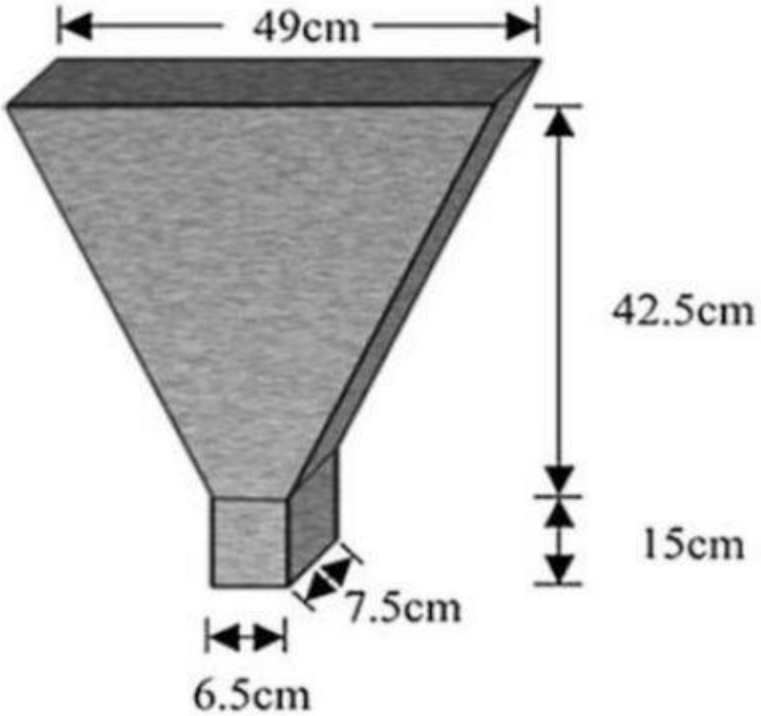
3.1.3 V-funnel test method:

The v-funnel test method was developed in Japan. The V-funnel flow test gives an indication of the filling ability of SCC, provided that blocking and/or segregation do not take place.

The flow time of the V-funnel test is related to the plastic viscosity of SCC

The required amount of concrete that is needed to carry out the test is about 0.012 m^3. The procedures of this test are:

- Placing the V-funnel on firm ground. Moisten the inside surfaces of the funnel. Then keep the trap door open to allow any surplus water to drain.
- Close the trap door and place a bucket underneath
- Fill the apparatus completely with concrete without compacting; simply strike off the concrete level with the top with the trowel
- After the funnel is fully filled within 10 sec, the trap door is opened and allows the concrete to flow out under gravity.
- The time for the discharge to complete is recorded (flow time) by stopwatch. The V-funnel flow time tV is the period from releasing the gate until the first light enters the opening, expressed to the nearest 0.1 seconds.



V-funnel apparatus

(A) V-funnel test (B)

3.2 Compressive and flexure strength of hardened concrete:

The compressive strength of concrete is given in terms of the characteristic compressive strength of 150 mm size cubes tested after 28 days. In the field, compressive strength tests are also conducted at interim duration, i.e., after seven days, to verify the anticipated compressive strength expected after 28 days. The same is done to be forewarned of an event of failure and take necessary precautions. The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall.

For design purposes, this compressive strength value is restricted by dividing by a factor of safety, whose value depends on the design philosophy used.

The construction industry is often involved in a wide array of testing. In addition to simple compression testing, testing standards such as ASTM C39, ASTM C109, ASTM C469, and ASTM C1609 are among the test methods that can be followed to measure the mechanical properties of concrete. When measuring the compressive strength and other material properties of concrete, testing equipment that can be manually controlled or servo-controlled may be selected depending on the procedure followed. Certain test methods specify or limit the loading rate to a certain value or a range, whereas other methods request data based on test procedures run at very low rates . Concrete and ceramics typically have much higher compressive strengths than tensile strengths. Composite materials, such as glass fiber epoxy matrix composite, tend to have higher tensile strengths than compressive strengths. Metals are difficult to test to failure in tension vs. compression. In compression, metals fail from buckling/crumbling/45deg shear, which is much different (though higher stresses) than tension which fails from defects or necking down.

(a) (b)

(A) (b)

Cube compression test at failure

(a) (b)

. cylinder compression test at failure

(A)

(B)

3.3 Experimental work:-

3.3.1 Introduction:

This chapter presents an elaborated characterization of the utilized specimens 'material properties, the testing setup, instrumentation, and testing procedure. The test was conducted on four different patches with the only variable was using different quantities of superplasticizers as follows (patch I as a control patch with no superplasticizers 1% of cement weight, patch III with superplasticizers 1.5% of cement wright, and patch IV with superplasticizers 2% of cement weight. All experiments were carried out in the Faculty of Engineering at Nile Higher Institute.

3.4 SCC materials:

Materials of the SCC concrete used in this experimental work were procured from the available local materials. they include ordinary Portland cement crushed dolomite, sand, water, silica fume, and superplasticizers.

3.5 Coarse aggregate:

Coarse aggregate is stone that is broken into small sizes and irregular in shape. In construction work, the aggregate is used, such as limestone and granite or river aggregate.

The first category of the nominal maximum size is not more than 15mm and not smaller than 10mm, while the second category of nominal maximum size does not exceed 20mm.

crushed Dolomite

3.6 Fine aggregate:

Fine aggregates are essentially any natural sand particles won from the land through the mining process. Fine aggregates consist of natural sand or any crushed stone particles that are ¼” or smaller. This product is often referred to as 1/4'” minus as it refers to the size, or grading, of this particular aggregate.

3.7 Mixing water:

Portable water free from compounds or impurities was utilized in the mixture. A high-water range reducer (Superplasticizer) was used with a water-cement ratio (w/c) equal to 0.4 by weight: to ensure adequate workability of casting.

3.8 Cement:

The cement used in the SCC mix was CEM I N 42.5 Ordinary Portland cement which complies with the Egyptian standard specification. Silica fume produced by Sika company was also used with 5% of cement by weight.

3.9 Sika silica fume:

Also known as micro silica (CAS number 69012-64-2, EINECS number 273-761-1) is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high-performance concrete.

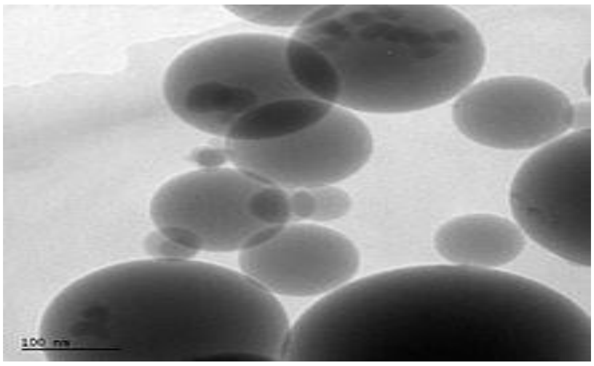


Table (8.5) Silica fume specifications

Property	Additive
Packaging	5 Kg bag
Composition	A latently hydraulic blend of active ingredients
Appearance / Color	Grey- fine powder / odorless
Bulk Density	300 kg/m^3

3.10 Sika viscocrete -3425:

Sika viscocrete 3425 was used as a viscosity-enhancing agent (VEA). It contains a polycarboxylic –based. Copolymer-based mixture and modified cellulose product to achieve the dual-action effect of high-range water reducer and viscosity-modifying admixture, respectively. It meets the requirements for superplasticizers according to swiss specification [SIA 162(2989)], EUROPE specification [EN934-2], and American specification (ASTM- C-494 type G and F). Mechanical and physical properties are given in Table

Property	Saturant
Packaging	5 Kg container
Appearance / Color	Clear liquid
Solid content	40% by weight
Density	1.08 kg/liter (ASTM C494)

3.11 Concrete mix:

The figure shows the SCC mixture produced at the concrete laboratory by casting trial batches. This SCC mixing was designed to develop (35Mpa) for cube strength. The SCC mixing was done mechanically by mixing plus additives and continuing the mixing for another two minutes. Table (1) gives the mass of the ingredients for a cubic meter of SCC concrete.

OPC	Fly ash (15%)	W/C	water	C.A	F.A	Viscocrete 3425		Polyropylene Fiber	
						%	kg	%	kg
10.328	1.823	0.48	5.832	16.2	32.4	0	0	0	0
10.328	1.823	0.48	5.832	16.2	32.4	1.8	0.2187	0	0
10.328	1.823	0.48	5.832	16.2	32.4	1.8	0.2187	0.1	0.0122
10.328	1.823	0.48	5.832	16.2	32.4	1.8	0.2187	0.2	0.0243
10.328	1.823	0.48	5.832	16.2	32.4	1.8	0.2187	0.3	0.0365
10.328	1.823	0.48	5.832	16.2	32.4	2.1	0.2552	0	0
10.328	1.823	0.48	5.832	16.2	32.4	2.1	0.2552	0.1	0.0122
10.328	1.823	0.48	5.832	16.2	32.4	2.1	0.2552	0.2	0.0243
10.328	1.823	0.48	5.832	16.2	32.4	2.1	0.2552	0.3	0.0365

Concrete mixing in a batch drum mixer

3.11 Casting and compaction:

After the concrete mixing had finished, it was cast in the molds and Shaked by a shake table for 0.5 minutes to compact the concrete. The top surface of the concrete was finished manually with a trowel.

Casting and compaction

3.12 Curing:

After 24 hours from the time the concrete was cast, they were left to cure for 28 days after submerging them in containers. Then they were taken from the molds and placed for the testing**.**

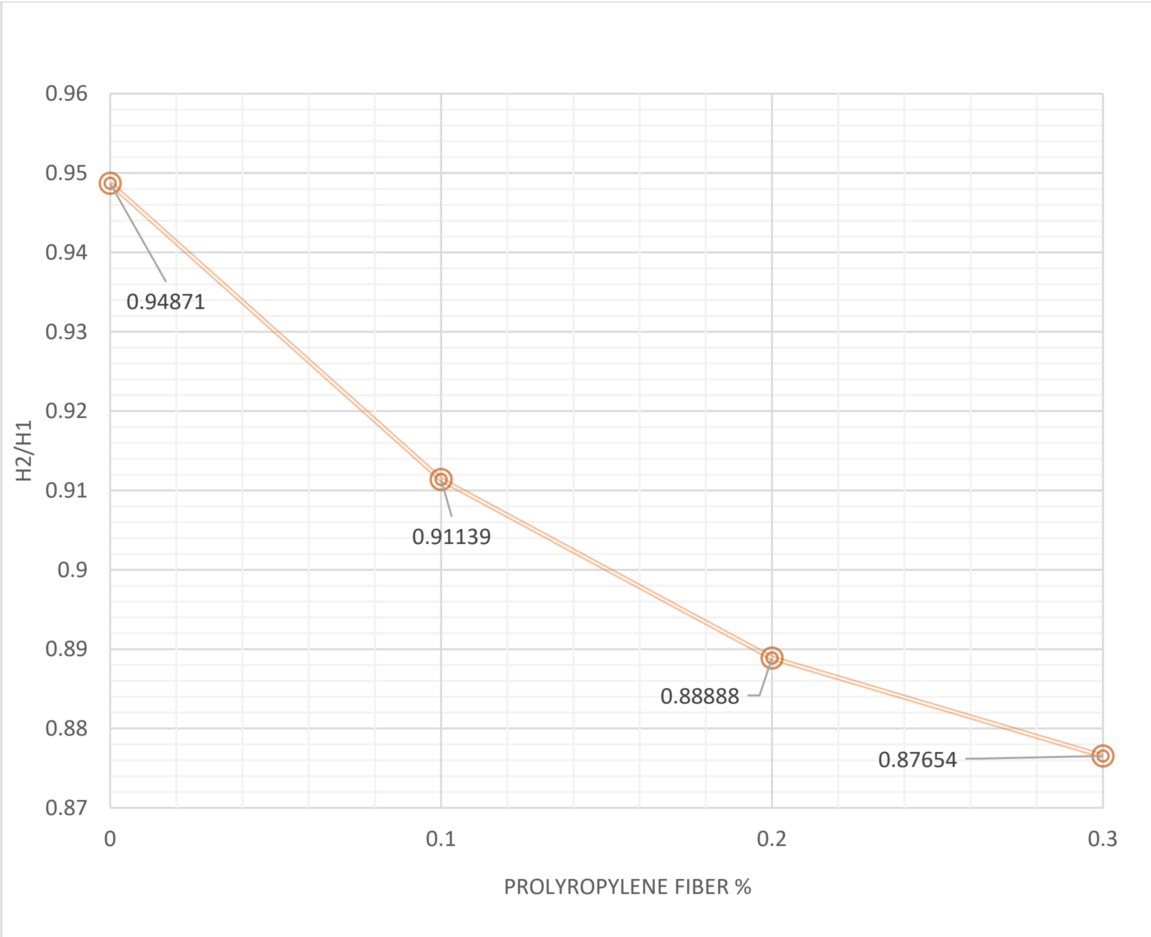
Curing of samples

Chapter 4: Results and discussion

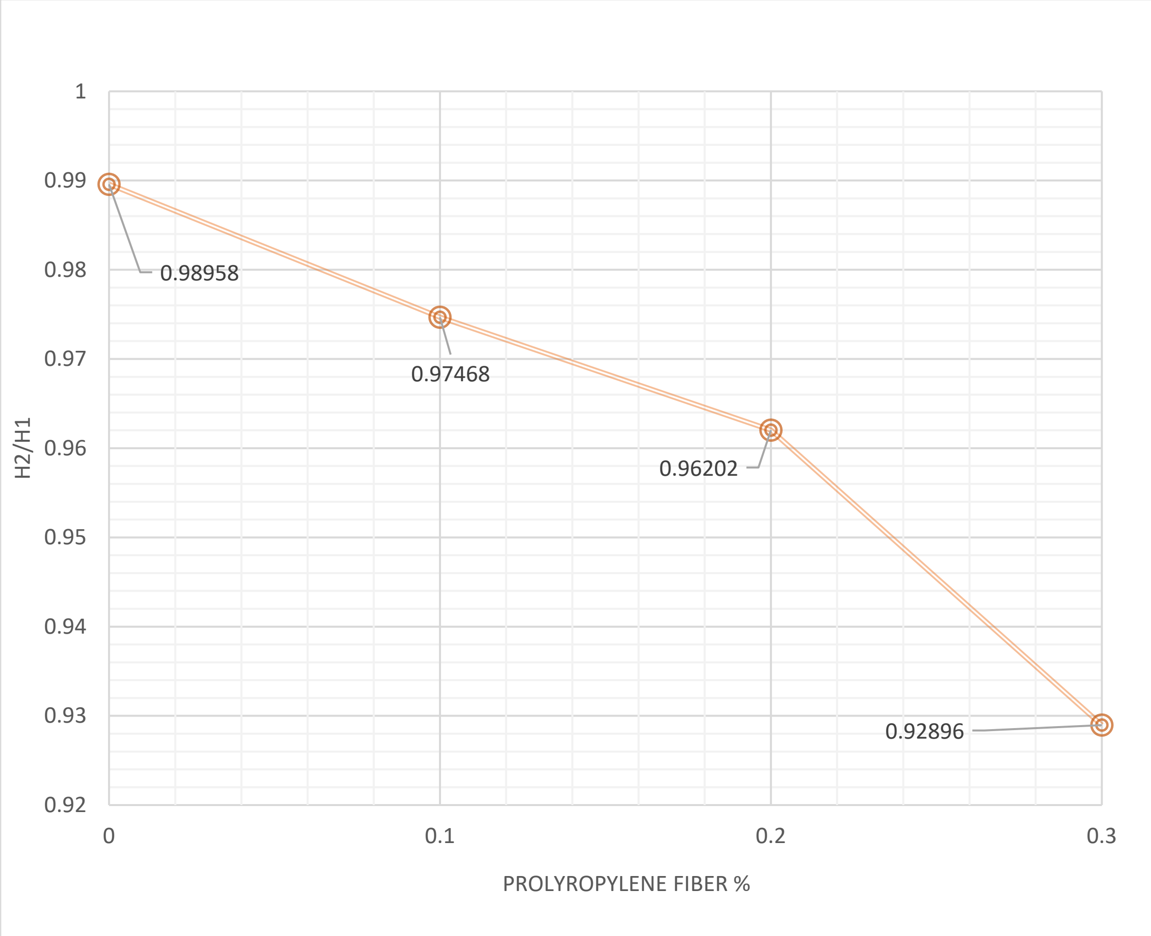
4.1 Practical results table (L-Box):

L-Box					
Mixture No.	Polyropylene Fiber %	H2(cm)	H1(cm)	H0(cm)	(H2/H1)
1	0	7.4	7.8	15	0.94871
2	0.1	7.2	8	15	0.91139
3	0.2	7.2	8.1	15	0.88888
4	0.3	7.1	8	15	0.87654
5	0	9.5	9.6	15	0.98958
6	0.1	7.7	7.9	15	0.97468
7	0.2	7.6	7.9	15	0.96202
8	0.3	8.5	9.15	15	0.92896

4.1.1 L-Box chart for mixture 1,2,3,4 (Viscocrete 3425 (1.8%)):



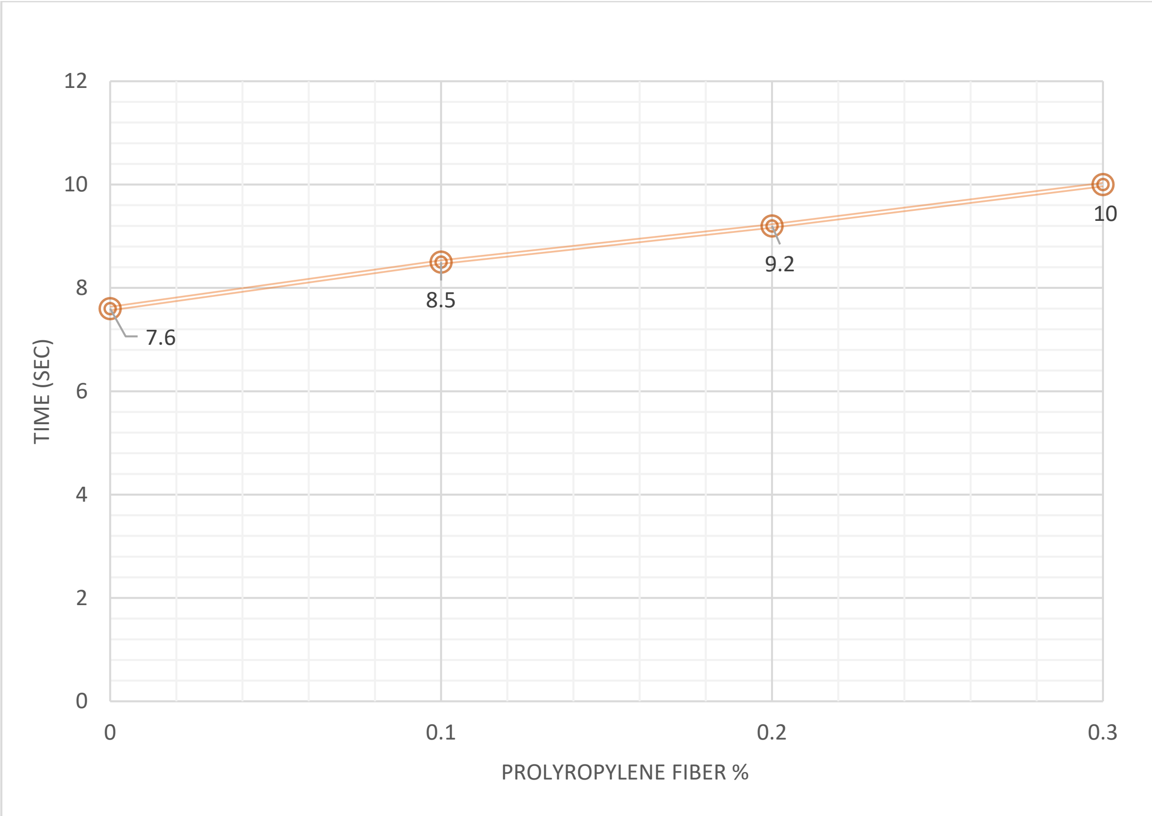
4.1.2 L-Box chart for mixture 5,6,7,8 (Viscocrete 3425 (2.1%)):



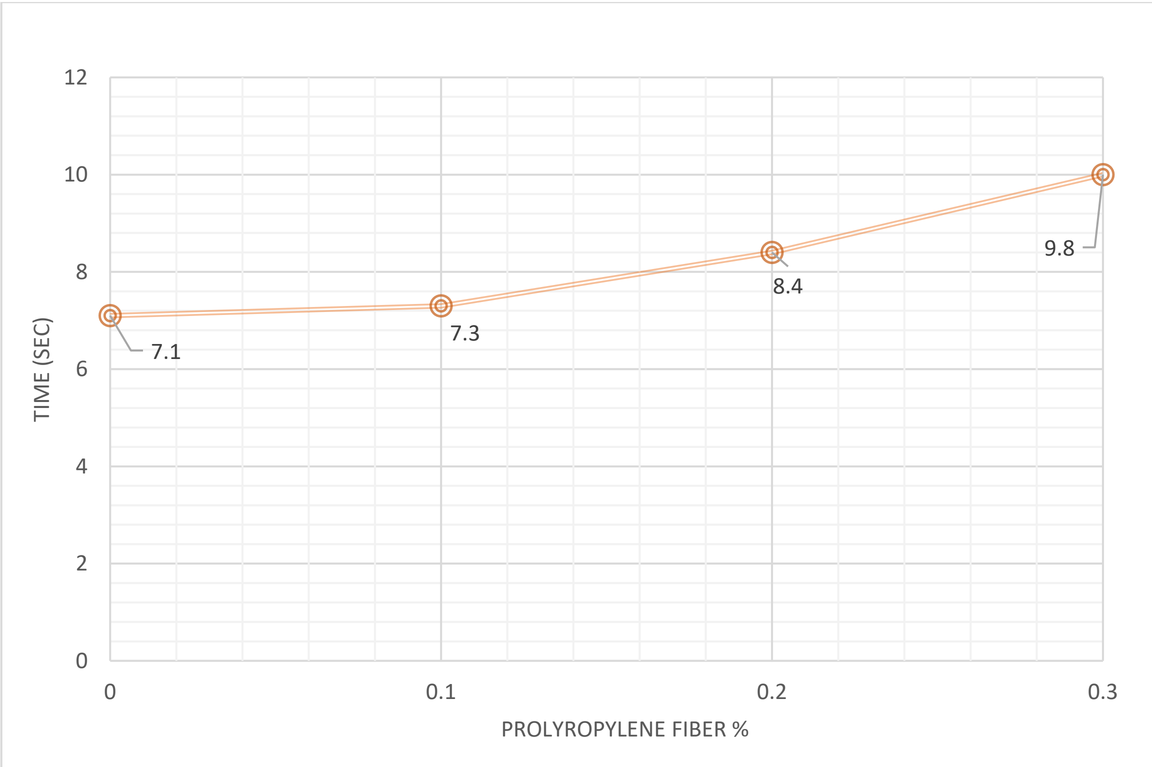
4.2 Practical results table (V-Funnel):

V-Funnel		
Mixture No.	Polyropylene Fiber %	Time(second)
1	0	7.6
2	0.1	8.5
3	0.2	9.2
4	0.3	10
5	0	7.1
6	0.1	7.3
7	0.2	8.4
8	0.3	9.8

4.2.1 V-Funnel chart for mixture no. 1,2,3,4 (Viscocrete 3425 (1.8%)):



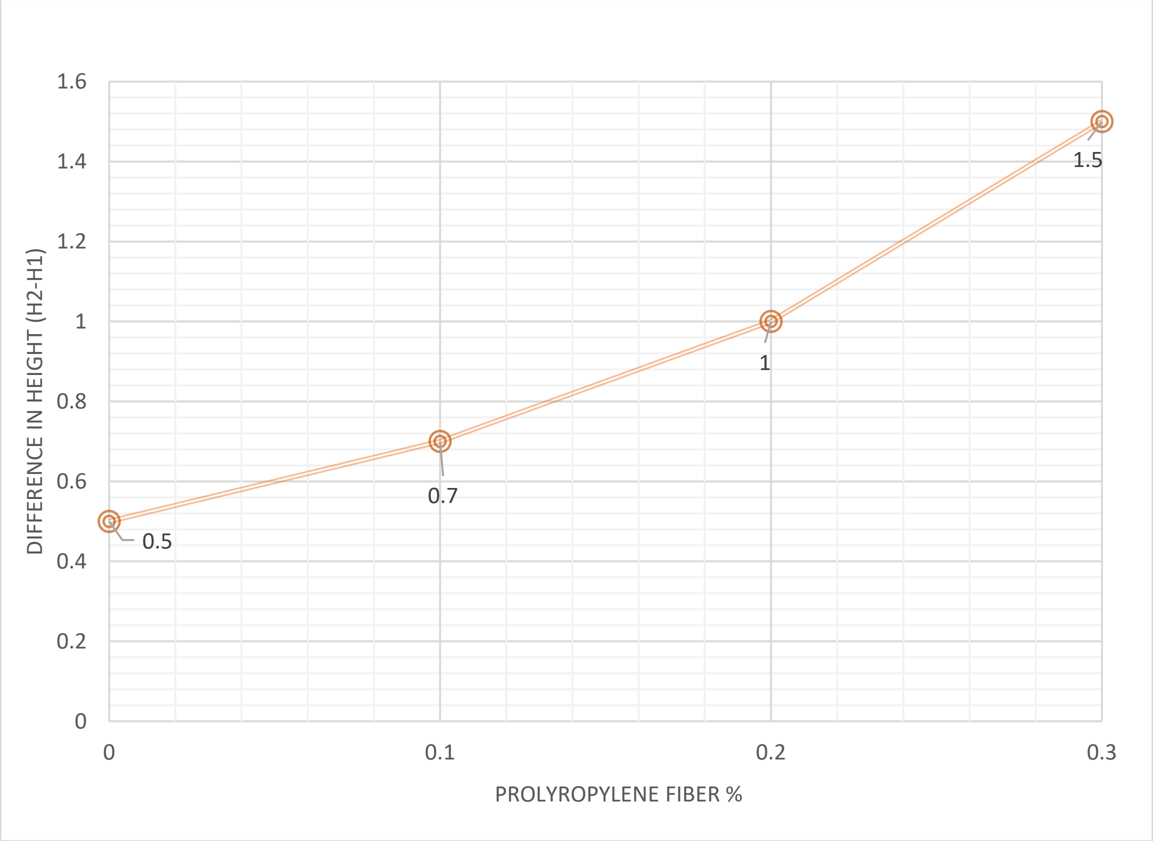
4.2.2 V-Funnel chart for mixture no. 5,6,7,8 (Viscocrete 3425 (2.1%)):



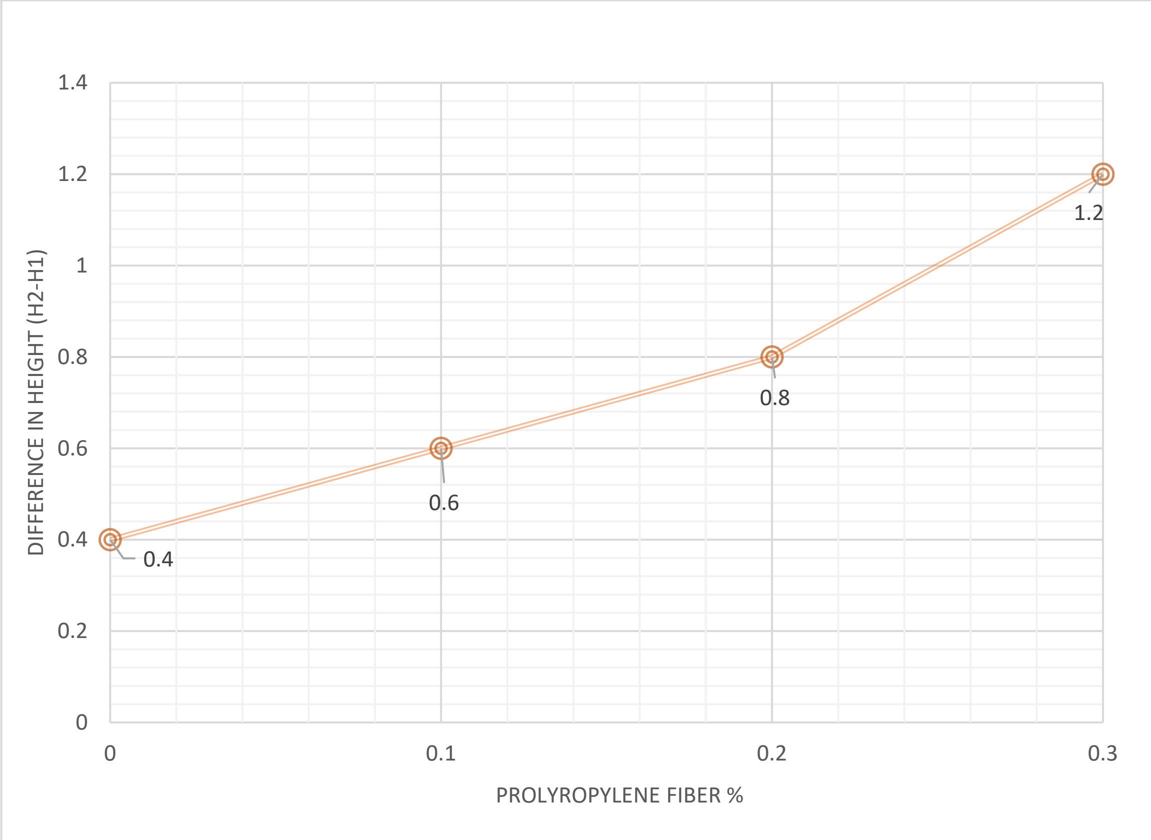
4.3 Practical results table (J-Ring):

J-Ring					
Mixture No.	Polyropylene Fiber %	R (cm)	Conc. Height Inside (H1)	Conc. Height Outside (H2)	Difference In Height (H2-H1)
1	0	74	10.4	10.9	0.5
2	0.1	62	11.5	12.2	0.7
3	0.2	55	12	13	1
4	0.3	52	11.5	12.7	1.5
5	0	77	13.6	14	0.4
6	0.1	58	12.5	13.3	0.6
7	0.2	46	10.5	11.5	0.8
8	0.3	41	10	11.7	1.2

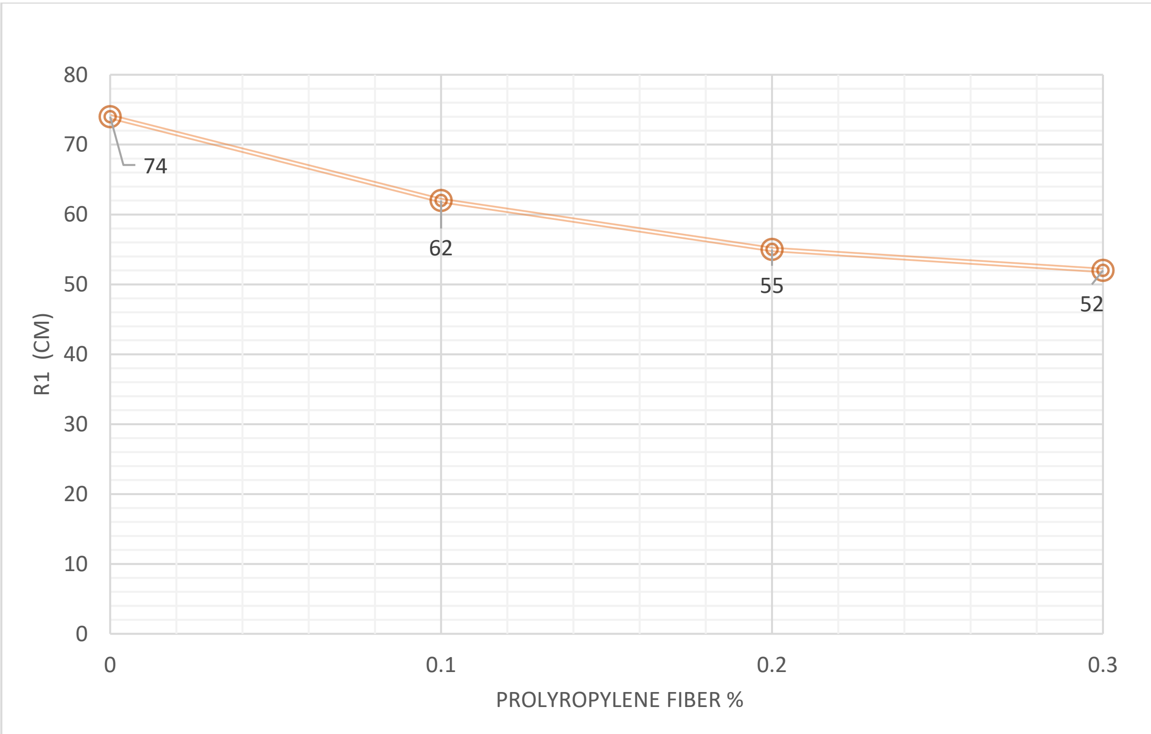
4.3.1 J-Ring chart for mixture no. 1,2,3,4 (Viscocrete 3425 (1.8%)):



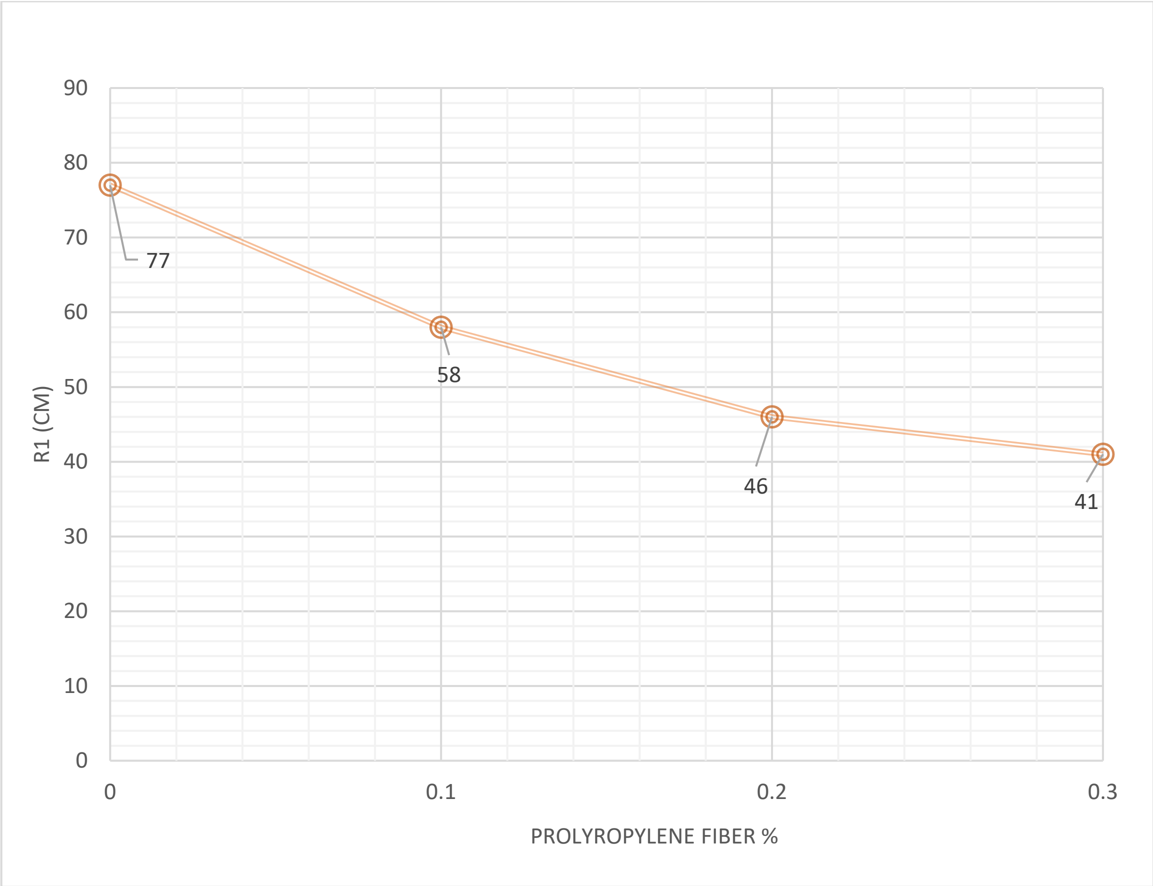
4.3.1 J-Ring chart for mixture no. 5,6,7,8 (Viscocrete 3425 (2.1%)):



4.3.1 J-Ring chart for mixture no. 1,2,3,4 (Viscocrete 3425 (1.8%)):



4.3.2 J-Ring chart for mixture no. 5,6,7,8 (Viscocrete 3425 (2.1%)):



4.4 The proportion of concrete mix:

4.4.1 Mixture no. 1:

OPC	Fly Ash (15%)	W/C	Water	C.A	F.A	Viscocrete 3425		Polypropylene Fiber	
						%	kg	%	kg
10.328	1.823	0.48	5.832	16.2	32.4	1.8	0.2187	0	0

4.4.1.1 Test results for cubes after 7 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.305	160.230
2	2.310	190
3	2.330	188.15

4.4.1.2 Test results for cubes after 28 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.305	199.3
2	2.305	230.3
3	2.325	270.9

4.4.1.3 Cubes test examples:





4.4.1.4 Test results for cylinder after 28 days:

Mixture No.	Weight (kg)	Tensile Strength	
		KN	MPa
1	3.845	91.7	17.1
2	3.525	86.4	16.11

4.4.1.5 Cylinder test examples:




4.4.1.6 Test results for beam after 28 days:

Mixture No.	Weight (kg)	Flexural Strength	
		KN	MPa
1	11.385	7.889	3.550
2	11.225	8.606	3.873
3	11.365	8.290	3.731

4.4.1.7 Beam test examples:







4.4.2 Mixture no. 2:

OPC	Fly Ash (15%)	W/C	Water	C.A	F.A	Viscocrete 3425		Polypropylene Fiber	
						%	kg	%	kg
10.328	1.823	0.48	5.832	16.2	32.4	1.8	0.2187	0.1	0.0122

4.4.2.1 Test results for cubes after 7 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.425	170.76
2	2.390	185.5
3	2.405	198.45

4.4.2.2 Test results for cubes after 28 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.410	216.2
2	2.365	230.4
3	2.350	289.3

4.4.2.3 Test results for cylinder after 28 days:

Mixture No.	Weight (kg)	Tensile Strength	
		KN	MPa
1	3.800	95	17.72
2	3.835	95.9	17.89

4.4.2.4 Test results for beam after 28 days:

Mixture No.	Weight (kg)	Flexural Strength	
		KN	MPa
1	11.670	8.378	1.06
2	12.265	8.665	1.1
3	11.550	8.641	1.09

4.4.3 Mixture no. 3:

OPC	Fly Ash (15%)	W/C	Water	C.A	F.A	Viscocrete 3425		Polypropylene Fiber	
						%	kg	%	kg
10.328	1.823	0.48	5.832	16.2	32.4	1.8	0.2187	0.2	0.0243

4.4.3.1 Test results for cubes after 7 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.325	269.18
2	2.340	285.1
3	2.335	258.29

4.4.3.2 Test results for cubes after 28 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.325	318.3
2	2.370	329.3
3	2.335	291.241

4.4.3.3 Test results for cylinder after 28 days:

Mixture No.	Weight (kg)	Tensile Strength	
		KN	MPa
1	3.950	100.3	18.71
2	3.860	107.2	20

4.4.3.4 Test results for beam after 28 days:

Mixture No.	Weight (kg)	Flexural Strength	
		kg/cm^2	MPa
1	11.365	9.737	4.382
2	12.285	9.855	4.435
3	12.660	9.160	4.122

4.4.4 Mixture no. 4:

OPC	Fly Ash (15%)	W/C	Water	C.A	F.A	Viscocrete 3425		Polypropylene Fiber	
						%	kg	%	kg
10.328	1.823	0.48	5.832	16.2	32.4	1.8	0.2187	0.3	0.0365

4.4.4.1 Test results for cubes after 7 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.365	282.57
2	2.370	290.22
3	2.355	277.54

4.4.4.2 Test results for cubes after 28 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.370	343.5
2	2.340	331.3
3	2.375	342.2

4.4.4.3 Test results for cylinder after 28 days:

Mixture No.	Weight (kg)	Tensile Strength	
		KN	MPa
1	3.840	101.2	18.8
2	3.800	115.8	21.6

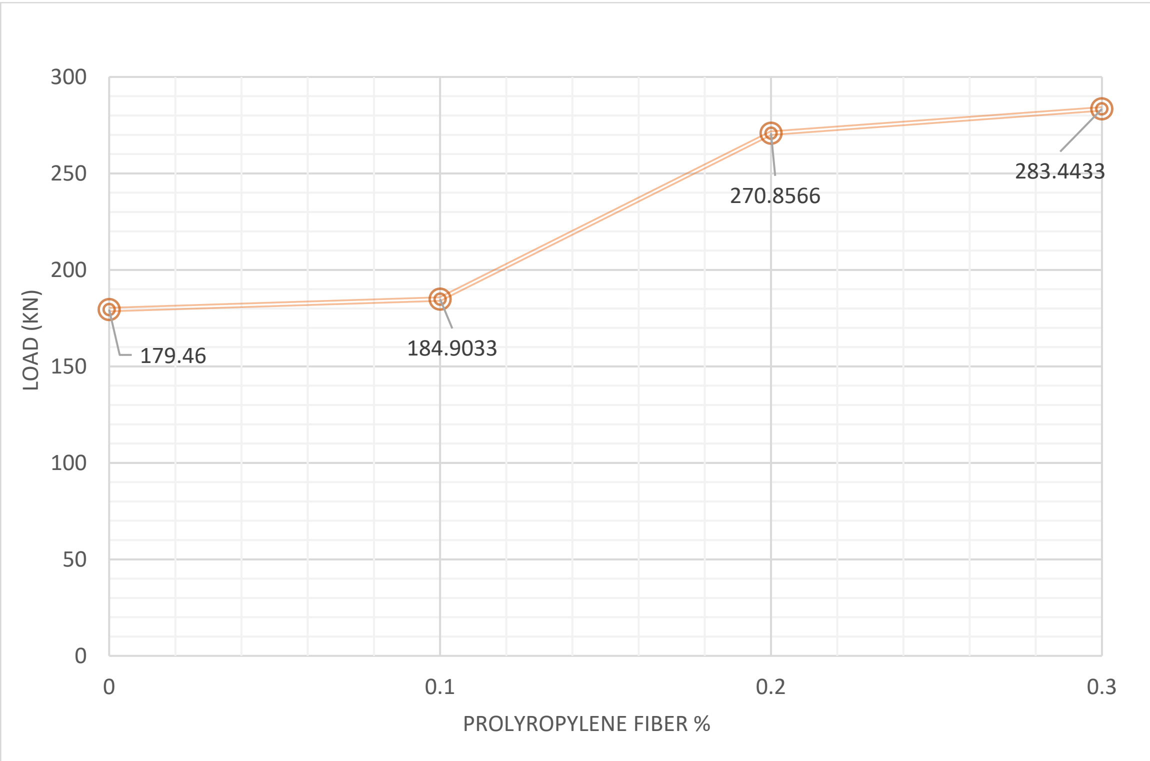
4.4.4.4 Test results for beam after 28 days:

Mixture No.	Weight (kg)	Flexural Strength	
		KN	MPa
1	11.530	9.843	4.449
2	11.470	9.891	4.471
3	11.550	10.391	4.626

4.5 Charts for mixtures (By using the average value of every mixture):

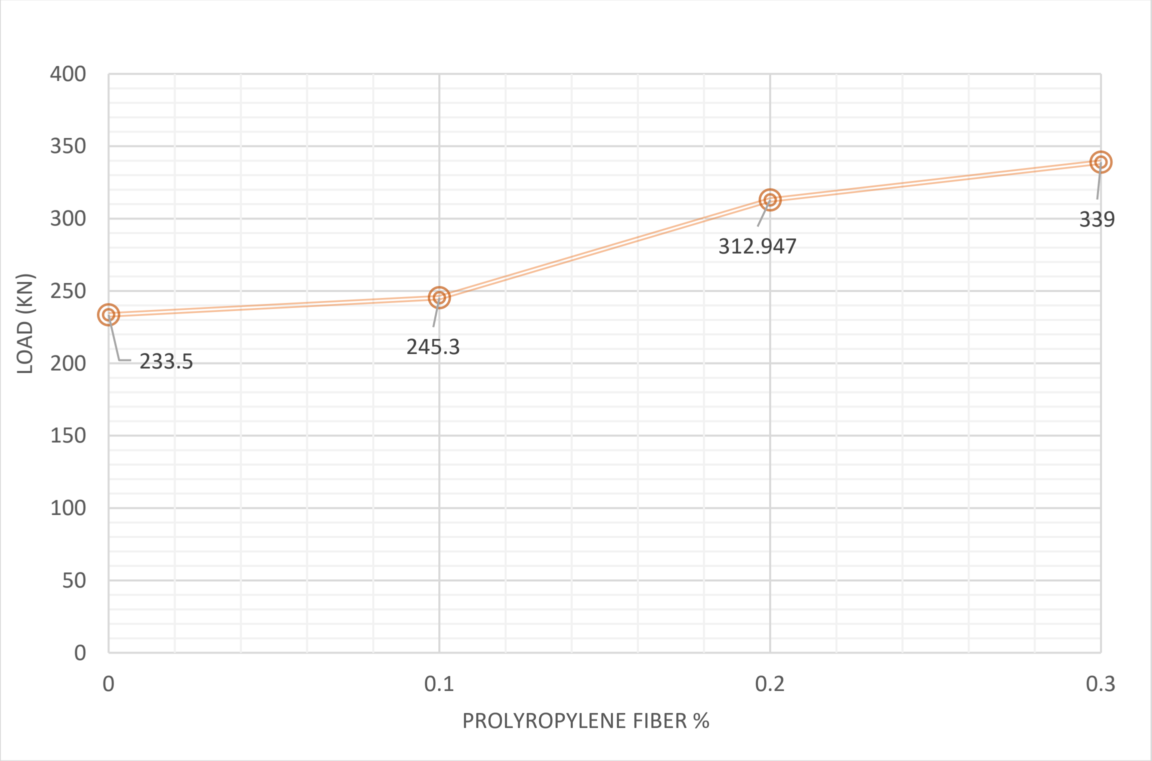
4.5.1 Chart for cubes after 7 days for mixture no. 1,2,3,4 (Viscocrete 3425 (1.8%)):

Mixture No.	Polypropylene Fiber (%)	Load (KN)	Compressive Strength (N/mm^2)
1	0	179.4600	17.94600
2	0.1	184.9033	18.49033
3	0.2	270.8566	27.08566
4	0.3	283.4433	28.34433



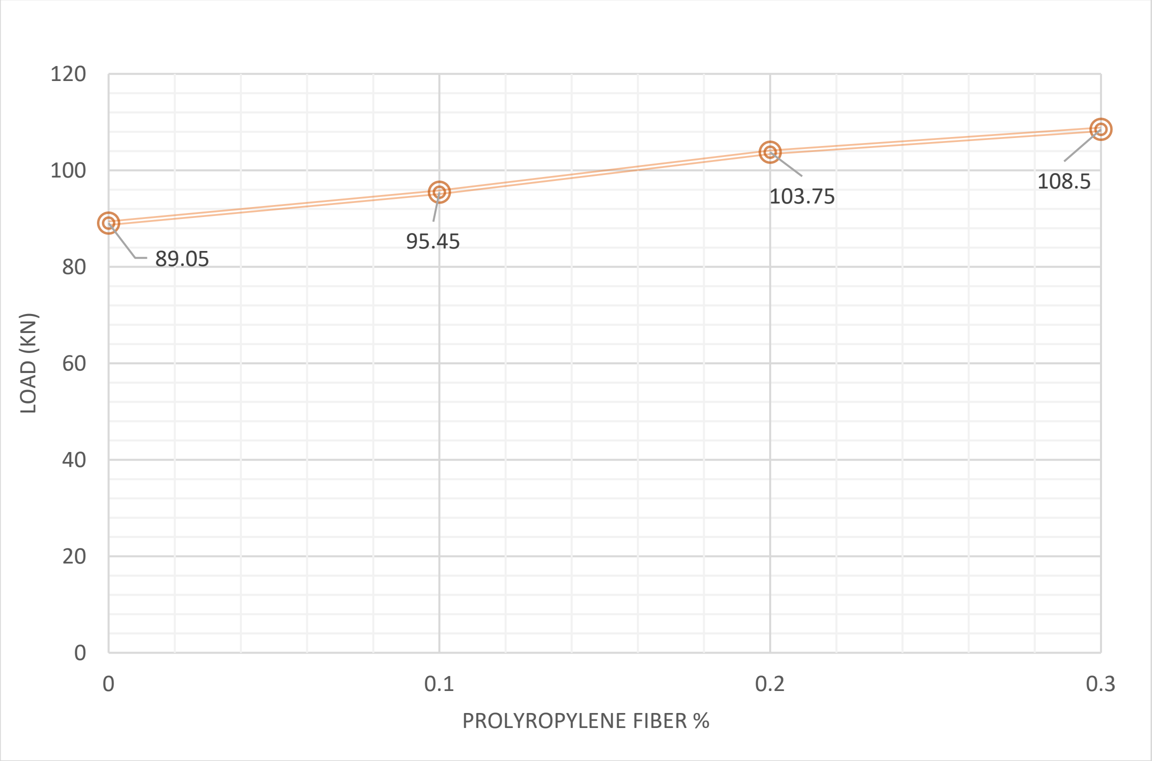
4.5.2 Chart for cubes after 28 days for mixture no. 1,2,3,4 (Viscocrete 3425 (1.8%)):

Mixture No.	Polypropylene Fiber (%)	Load (KN)	Compressive Strength (N/mm^2)
1	0	233.5000	23.35000
2	0.1	245.3000	24.53000
3	0.2	312.9470	31.29470
4	0.3	339.0000	33.90000



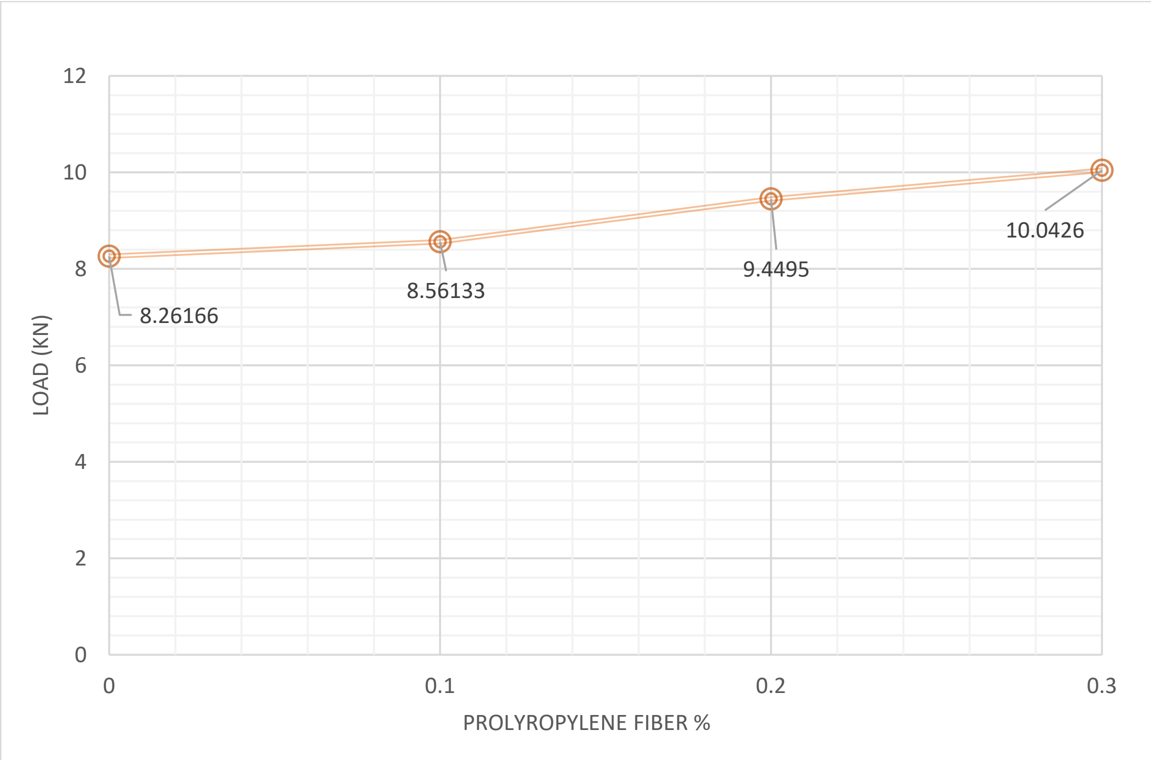
4.5.3 Chart for cylinders after 28 days for mixture no. 1,2,3,4 (Viscocrete 3425 (1.8%)):

Mixture No.	Polypropylene Fiber (%)	Load (KN)
1	0	89.050
2	0.1	95.450
3	0.2	103.75
4	0.3	108.50



4.5.4 Chart for beams after 28 days for mixture no. 1,2,3,4 (Viscocrete 3425 (1.8%)):

Mixture No.	Polypropylene Fiber (%)	Load (KN)
1	0	8.261660
2	0.1	8.561330
3	0.2	9.449500
4	0.3	10.04260



4.4.5 Mixture no. 5:

OPC	Fly Ash (15%)	W/C	Water	C.A	F.A	Viscocrete 3425		Polypropylene Fiber	
						%	kg	%	kg
10.328	1.823	0.48	5.832	16.2	32.4	2.1	0.2552	0	0

4.4.5.1 Test results for cubes after 7 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.370	195.56
2	2.330	205.44
3	2.425	210.28

4.4.5.2 Test results for cubes after 28 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.370	267.6
2	2.330	269.3
3	2.425	292.3

4.4.5.3 Test results for cylinder after 28 days:

Mixture No.	Weight (kg)	Tensile Strength	
		KN	MPa
1	3.805	86.5	16.13
2	3.760	98.6	18.39

4.4.5.4 Test results for beam after 28 days:

Mixture No.	Weight (kg)	Flexural Strength	
		KN	MPa
1	11.165	9.292	4.181
2	11.670	9.616	4.327
3	12	9.598	4.319

4.4.6 Mixture no. 6:

OPC	Fly Ash (15%)	W/C	Water	C.A	F.A	Viscocrete 3425		Polypropylene Fiber	
						%	kg	%	kg
10.328	1.823	0.48	5.832	16.2	32.4	2.1	0.2552	0.1	0.0122

4.4.6.1 Test results for cubes after 7 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.295	210.55
2	2.305	234.12
3	2.310	230.22

4.4.6.2 Test results for cubes after 28 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.290	310
2	2.300	292.1
3	2.335	301.7

4.4.6.3 Test results for cylinder after 28 days:

Mixture No.	Weight (kg)	Tensile Strength	
		KN	MPa
1	3.840	104.1	19.42
2	3.980	100.6	18.76

4.4.6.4 Test results for beam after 28 days:

Mixture No.	Weight (kg)	Flexural Strength	
		KN	MPa
1	11.220	10.142	4.564
2	11.445	10.118	4.553
3	11.330	10.532	4.739

4.4.7 Mixture no. 7:

OPC	Fly Ash (15%)	W/C	Water	C.A	F.A	Viscocrete 3425		Polypropylene Fiber	
						%	kg	%	kg
10.328	1.823	0.48	5.832	16.2	32.4	2.1	0.2552	0.2	0.0243

4.4.7.1 Test results for cubes after 7 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.345	251.42
2	2.320	254.18
3	2.335	220.89

4.4.7.2 Test results for cubes after 28 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.350	316.3
2	2.330	324.5
3	2.320	276.4

4.4.7.3 Test results for cylinder after 28 days:

Mixture No.	Weight (kg)	Tensile Strength	
		KN	MPa
1	3.825	116.2	21.68
2	3.725	107.9	20.13

4.4.7.4 Test results for beam after 28 days:

Mixture No.	Weight (kg)	Flexural Strength	
		KN	MPa
1	11.225	10.001	4.500
2	11.210	10.519	4.734
3	11.260	10.852	4.883

4.4.8 Mixture no. 8:

OPC	Fly Ash (15%)	W/C	Water	C.A	F.A	Viscocrete 3425		Polypropylene Fiber	
						%	kg	%	kg
10.328	1.823	0.48	5.832	16.2	32.4	2.1	0.2552	0.3	0.0365

4.4.8.1 Test results for cubes after 7 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.315	352.44
2	2.320	338.32
3	2.345	366.58

4.4.8.2 Test results for cubes after 28 days:

Mixture No.	Weight (kg)	Load (KN)
1	2.340	224.8
2	2.295	196.5
3	2.345	231.7

4.4.8.3 Test results for cylinder after 28 days:

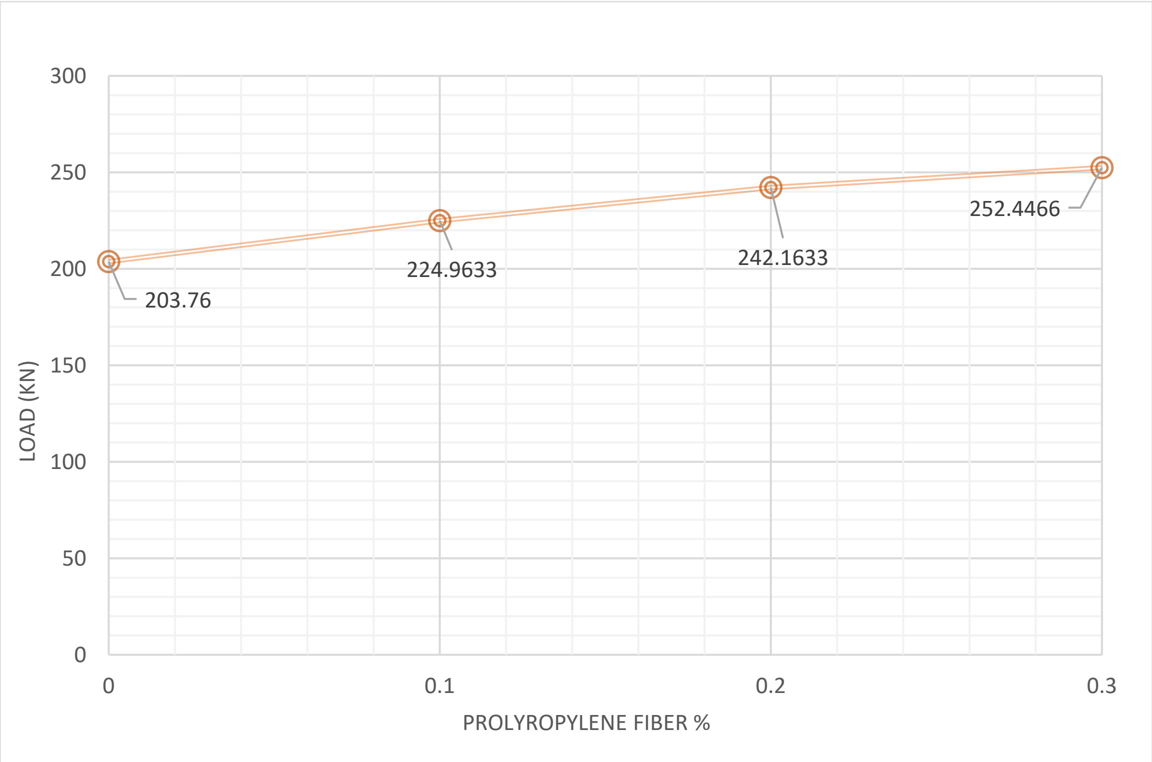
Mixture No.	Weight (kg)	Tensile Strength	
		KN	MPa
1	3.925	128	23.88
2	4.005	115.1	21.47

4.4.8.4 Test results for beam after 28 days:

Mixture No.	Weight (kg)	Flexural Strength	
		KN	MPa
1	11.210	11.149	5.017
2	11.260	11.387	5.124
3	11.015	11.937	5.372

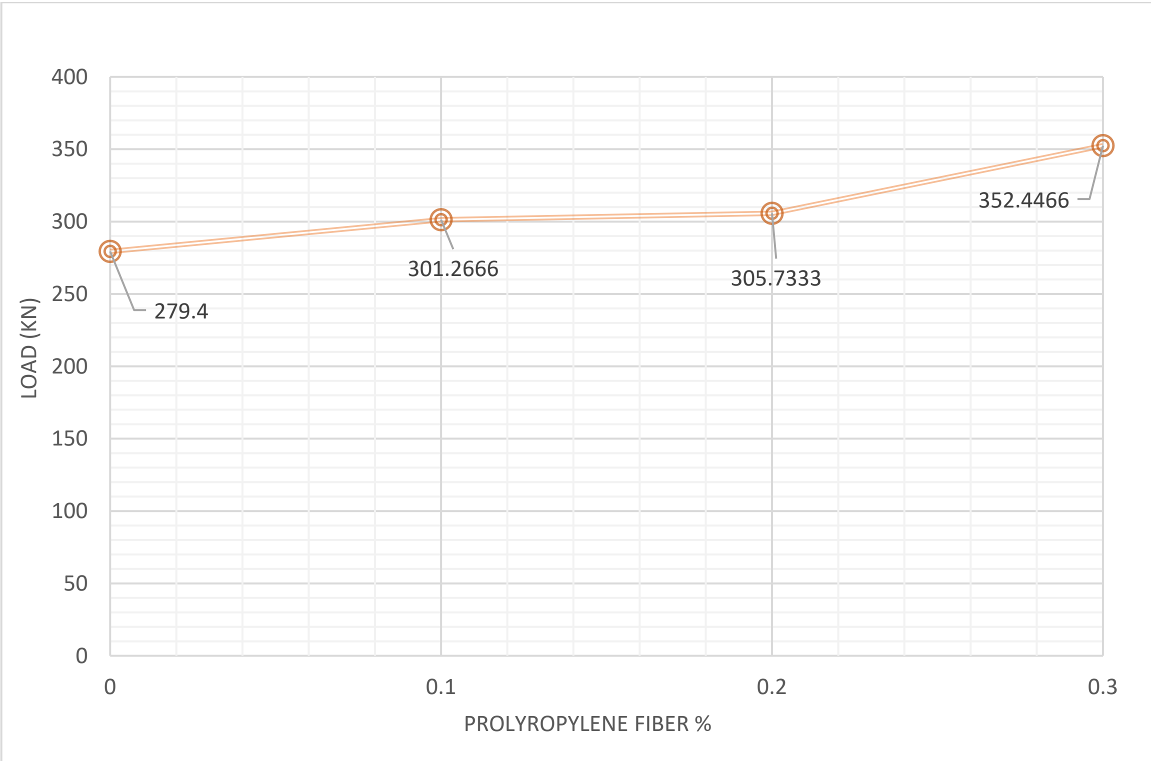
4.5.5 Chart for cubes after 7 days for mixture no. 5,6,7,8 (Viscocrete 3425 (2.1%)):

Mixture No.	Polypropylene Fiber (%)	Load (KN)	Compressive Strength (N/mm^2)
5	0	203.7600	20.37600
6	0.1	224.9633	22.49633
7	0.2	242.1633	24.21633
8	0.3	252.4466	25.24466



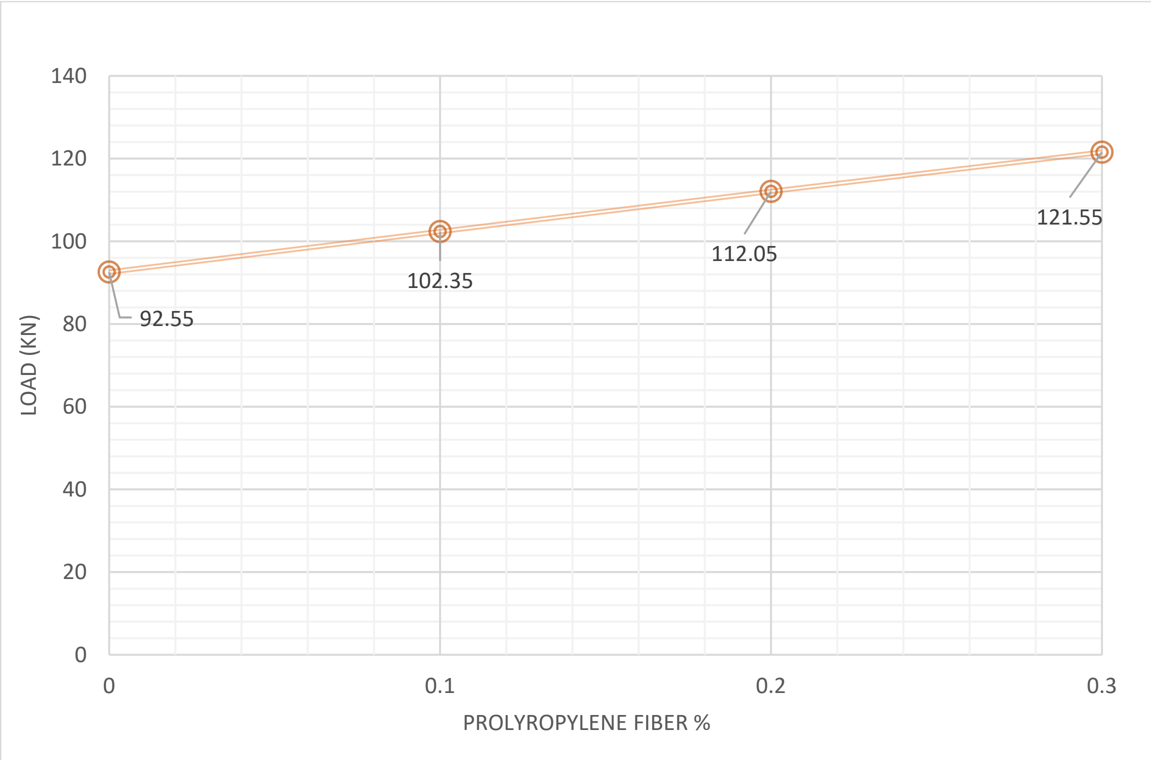
4.5.6 Chart for cubes after 28 days for mixture no. 5,6,7,8 (Viscocrete 3425 (2.1%)):

Mixture No.	Polypropylene Fiber (%)	Load (KN)	Compressive Strength (N/mm^2)
5	0	279.4000	27.94000
6	0.1	301.2666	30.12666
7	0.2	306.7333	30.67333
8	0.3	352.4456	35.24456



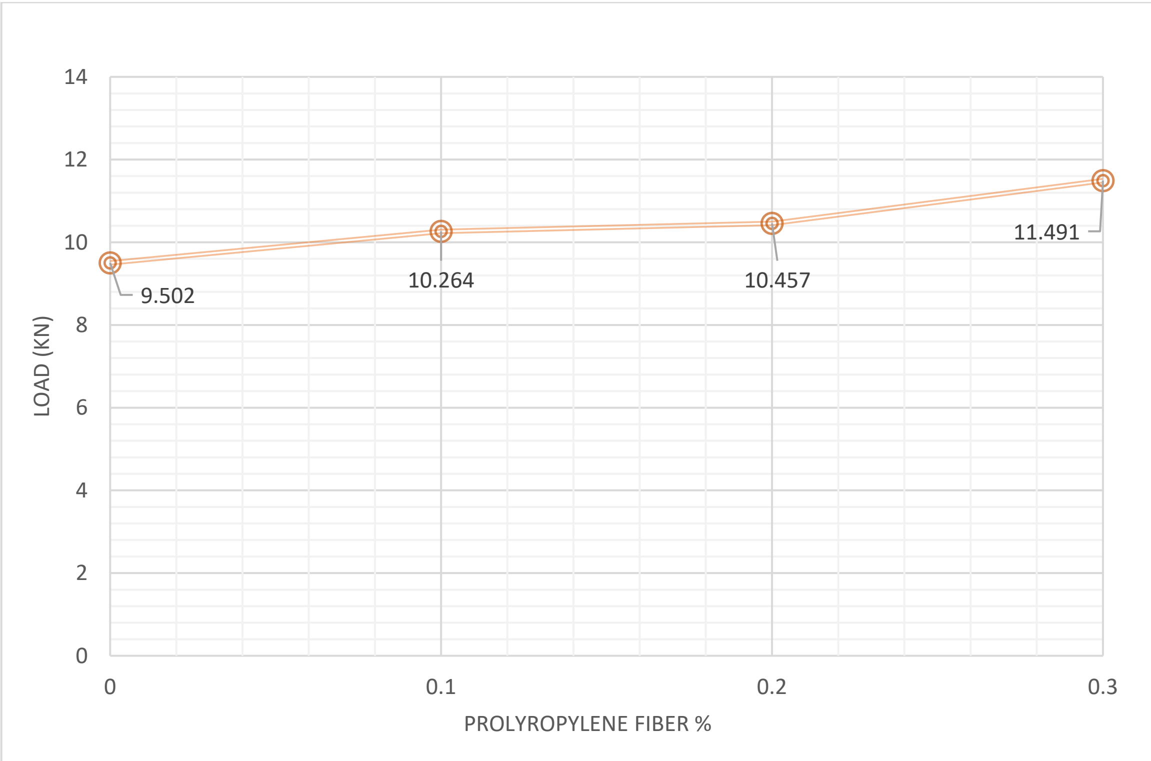
4.5.7 Chart for cylinders after 28 days for mixture no. 5,6,7,8 (Viscocrete 3425 (2.1%)):

Mixture No.	Polypropylene Fiber (%)	Load (KN)
5	0	92.550
6	0.1	102.35
7	0.2	112.05
8	0.3	121.55



4.5.8 Chart for beams after 28 days for mixture no. 5,6,7,8 (Viscocrete 3425 (2.1%)):

Mixture No.	Polypropylene Fiber (%)	Load (KN)
5	0	9.5020
6	0.1	10.264
7	0.2	10.457
8	0.3	11.491



4.6 Conclusion:

SCC is a new type of cementitious material, and at the same time a new type of production method for casting concrete structures. However, SCC mainly remains a cement-based material, which means that most of our knowledge and understanding based on VC is not obsolete. SCC pushes the limits of classical concrete technology. However, the main driving forces and the fundamental chemical, physical, and mechanical laws remain unchanged. Nevertheless, due to its specific mix design, SCC can sometimes behave differently in comparison with VC.
After testing the SCC, we reach the following:

- SCC can’t be produced without a sufficient amount of S.P.
- In V-funnel test, When the S.P. Increased in patches, the time for SCC to exit the funnel decreased. The flow of Concrete was very slow in the first two patches which means that wasn’t a SCC.
- In L-box test, When the S.P. Increased in patches, the height of SCC at the lower end increased. The Concrete didn’t reach the end of Hz compartment in the first two patches, which means that wasn’t a SCC.
- In J-ring test, When the S.P. Increased in patches, the time for SCC to exit the funnel decreased. The diameter of flowing Concrete increased, and the time for SCC to reach 500 mm in diameter decreased. Also, the difference between the inner and outer heights were decreased.
- The compressive and flexure strength were adequate in all patches for the tested samples.

4.7 Resources:

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(Appendix A)

4.8 Project Standards

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