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FLEXURAL BEHAVIOUR OF CONCRETE BY USING STEEL FIBER

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CHAPTER NO.1

1.1 INTRODUCTION:

The effect of inclusion of steel fibers on the flexural behavior of high-strength concrete beams is investigated. Eight high-strength concrete beams with different fiber contents and shear span-depth ratios were tested to study the influence of fiber addition on ultimate load crack propagation flexural rigidity and ductility.

In the present world concrete is most used material for Compressive Strength in construction. Tensile load carrying capacity is very low of concrete. This result in brittle failure of concrete components. To increase the performance of concrete under tensile loading different types of the fibre are used in concrete. Mainly Steel fibre reinforcement concrete (SFRC) has the ability of excellent tensile strength, flexural strength, Shock resistance, fatigue resistance, ductility and crack arrest.

The advantages of using fibre as reinforcement have been known since ancient times. In 1960s, research on fibre reinforced concrete was already advancing fast, and at the present time, fibres of various kinds are used to reinforce concrete in structural application. Due its high stiffness, the steel fibre is probably the most commonly used fibre material. However, synthetic fibres are gaining ground, and new materials are under continuous development.

1.2 Research gap :

So much work is done on steel fibre reinforced concrete such as use of steel fibre in pavement block, bricks, road pavement, to prevent cracking by improving flexural strength but not so much work is done on steel fibre reinforced concrete (SFRC) in beam.

1.3 Objectives:

- Increases the first cracking load, Ultimate load, stiffness and ductility of the concrete beams.
- Increases the Compressive strength and the Flexural strength of the concrete.
- Improve impact and abrasion resistance.
- Improving the durability and toughness performance of concrete and mortar.
- Improve freeze-thaw resistance.
- Reduce steel reinforcement requirement.

1.4 Steel Fiber :

Steel fires continue to have a wide range of applications in civil engineering materials. There are some structural applications where they have been used in concrete without any conventional reinforcing bars. These have been short span, elevated slabs, for example a parking garage at Heathrow Airport London, UK with slabs 3 ft 6 in. 1.07 m square by 4 in. 10 cm thick, supported on four sides. In cases like that, load tests should be performed and the fabrication of the elements should employ rigid quality control ACI report, 2002. Steel fiber concrete SFC has also been employed as slabs bridge decks airport pavements parking areas and cavitation erosion environments, as well as worldwide for the production of highway slabs. Steel fiber high-strength concrete (SFHSC) is an option for the design of critical regions in earthquake-resistant structures exposed to impact and fatigue Brandt, 2008. It was reported that ductility and adequate structural seismic response could be achieved without additional seismic reinforcement detailing. Work is required, however, so that building officials accept FRC as a structural material Shah and Ribakov, 2011.

Steel fiber-reinforced refractories have shown excellent performance in a number of refractory application areas including ferrous and nonferrous metal production and processing, petroleum refining applications, and rotary kilns used for producing Portland cement and lime, among numerous other applications (ACI report, 2002)).

Shah and Ribakov (2011) recently presented a good review of steel fiber-reinforced concrete. Some future trends in the development of FRC involve changing the fiber amount during the casting process, so that fibers are employed only in some parts of the structure where they are required using modern non-destructive techniques to monitor the casting and to obtain a feedback for online prediction of hardened properties and controlling the corrosion of fibers with age, by altering their chemical composition.

By tonnage steel-FRC is probably the most successful of all. Steel fibers are rather different from any of those described above. They are generally of larger cross-section with an equivalent diameter of 0.5-1 mm and lengths varying between 20 and 60 mm. They may have a shaped cross-section, often varying along the length to form hooked barbed or crimped fibers intended to increase the anchorage between the fiber and the matrix. Carbon steels are normally used where a greater degree of corrosion resistance is required alloy steels stainless steels or galvanized steels may be substituted. The modulus of steel fibers is 200 GPa and strengths vary between 350 and 1000 MPa. Steel fibers cannot be added in sufficient quantity to provide any primary reinforcement thus they are intended to provide crack control and post- peak toughness. Steel-FRC is often used as a matrix for high-performance steel-bar reinforced concrete (RC) as the steel fibers reduce crack width in cracked sections and thus slow down corrosion of the bars.

1.5 Steel Fiber Reinforced Concrete

SFRC contains concrete mortar and discontinuous and discrete steel fibers. it is not the substitution for the reinforcement. we can use fibers with and without the reinforcement depending upon the nature of use. The use of fibers in the concrete mortar is not for the purpose of gaining tensile strength only. the major use of fibers in concrete is to reduce crack development and to make the concrete a lightweight.

SFRC is composite concrete, which contains disperse fibers. These fibers transfer the stresses, which is very useful to reduce the crack development.

Figure No. 1.1 Steel Fiber Reinforced Concrete

The mixing of fibers with concrete is a very essential part to avoid the unnecessary loss of is not available, can reduce strength in that particular area. and also workability of the concrete can be reduced.

The modulus of elasticity or young's modulus of the steel fiber reinforced concrete is higher than that of traditional concrete.

Affecting factors such as aspect ratio, the volume of fibers, mixing, the orientation of fibers should be strength. For example, if the fibers are not mixed properly then the area, where these steel fibers considered before the mix. with SFRC, the admixture also can be used to achieve the desired quality of the concrete.

1.6 Steel Fibers Properties

Steel fibers are discrete, short in length, round in shape, aspect ratio from 20 to 100, diameter from 0.25 to 0.75mm which are dispersed in the concrete during the mixing process.

Steel fibers are bundled together with the help of water-soluble glue which further separated during the mixing process of the concrete.

The typical properties of the steel fibers are, tensile strength of 280 to 420 Mpa, poison's ratio is 0.30, young's modulus of 200 Gpa, ultimate elongation of 3.6 %, specific gravity of 7.86.

The fibers will transfer the stress as shown in the figure below.

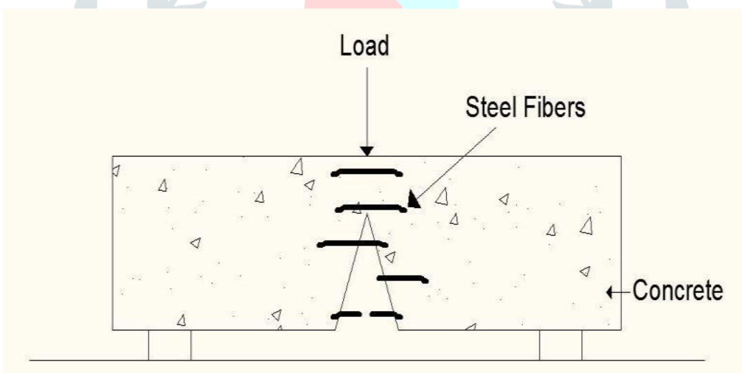


Figure No.1.2 Steel Fiber Reinforced Concrete

The manufacturing technique for the steel fibers is cut wire/ cold drawn. the product should be purchased as per the application. steel fibers are available in the shape of round, rectangular 0.3 to 0.5 mm thick, also available in deformed bundled form.

The shorter length fibers are used to control the cracking while longer length fibers are used to gain high anchorage between fibers and concrete. The mix design can be done according to the purpose of use.

1.7 Types Of Steel Fibers

ASTM A820 classified five different types of steel fibers,

- Cold drawn wire
- Cut sheet steel
- Mill cut
- Melt extract
- Modified cold drawn wire

Due to the shape and composition, the cold drawn wire has the highest tensile strength. hooked steel fiber can make better anchorage between fibers and concrete and also available at low cost. thus, this type of fiber is mostly used.

Depending upon the use, steel fiber has a different shape and size as shown in the figure below. Hooked, non-straight or crimped, button end, indented, straight, puddled, twisted polygonal, etc.

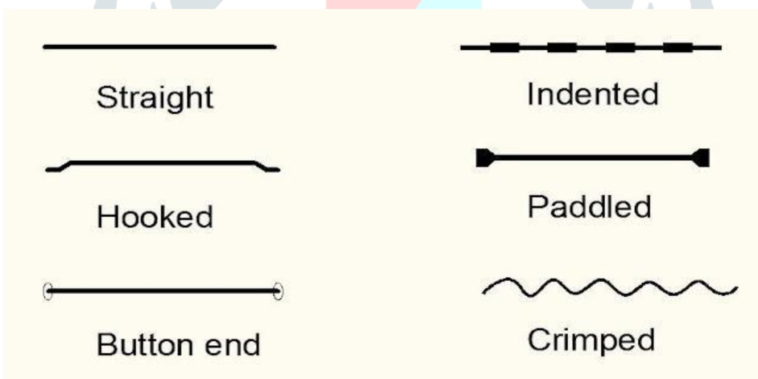


Figure No.1.3 Types Of Steel Fibers

1.8 Mechanical Properties Of SFRC

By adding fibers in concrete, the mechanical properties of SFRC can be enhanced depending upon the previously discussed factors.

According to research, the compressive strength, and shear strength can be increased up to a certain limit Arranged fibers in the concrete results in higher tensile strength as compare to randomly mixed fibers.

Impact loading resistance and increased fatigue strength were observed from the research. Also, a reduction in permeability was observed.

According to the study, flexural strength was increased higher as compare to the direct tensile strength of the concrete. Also, enhancement was found in toughness and the durability of the SFRC with a certain amount and arrangement of the fibers.

1.8.1 Advantages

- The following are the advantages of using steel fibers in concrete.
- Reduction in cost and timing of the project.
- Reduce the absorption of water and the other harmful chemical.
- Reduce the surface permeability and increase the durability of the concrete.
- Reduce curling and eliminates shrinkage stress.
- Increase in fatigue strength, flexural strength, toughness, load-bearing capacity, etc.
- Prevent the development of cracks in concrete.
- Fibers are a distributor of localized stress.

1.8.2 Disadvantages

- The following are the disadvantages of steel fiber reinforced concrete.
- The corrosion at the surface of the concrete.
- Proper inspection while mixing is needed.
- Requires precise composition.
- An increase in the number of fibers can reduce the workability and can cause the finishing problem.

1.9 Application

Steel fiber reinforced concrete is used widely nowadays. Some of the common application of the SFRC is as follow.

- Pavement
- Airfields

- Overlays or roads
- Bridge deck
- Flooring
- roads
- Pipes
- Sleepers
- Septic tanks

SFRC is widely used in the construction or repair of roads or highways pavement.

This material has high flexural strength, resistance toward impact, which makes this material more useful to roads and highways pavement.

Also, the thickness of the pavement can be reduced using this material.

Due to its corrosion resisting capacity, this material can be useful where water and corrosion are major concerns like hydraulic structures.

SFRC also used in the making of precast concrete products.

Steel fibers are also used to make fiber shotcrete, which used in tunnel lining, bridge, pipes, stabilization of rocks, dams, steel structure protection, etc.

Steel fibers are also used in the rebar reinforced concrete to improve the mechanical properties and use them in the structural application.

1.10 The Necessity Of Fiber Reinforced Concrete

- It increases the tensile strength of the concrete.
- It increases the durability of concrete.
- It reduces the air voids and water voids the inherent porosity of gel
- Make concrete more durable.
- Gives concrete a tougher surface- More resistant to impact damage.
- Reduce Risk of plastic cracking.

CHAPTER NO. 2 LITERATURE REVIEW

2.1 Literature Survey

C. P. Kumar , M. S. Hameed [2022][1] "Experimental study on the behavior of steel fiber when used as a secondary reinforcement in reinforced concrete beam". The scope of this project is to study experimentally the strength properties of the beam on inclusion of steel fibers. It also aims to investigate the structural behavior of conventional concrete beams and steel fiber reinforced beam when steel fiber is used as a secondary reinforcement in beams. To overcome the deficiency of the conventional concrete, fibers have been added as secondary reinforcement. Steel fibers are added below the neutral axis of the RC beam in order to overcome the development of micro cracks under applied stress in the RC beam. The addition of steel fibers to the concrete has many advantages and the most notable among them is the improvement in the mechanical characteristics of the concrete. In our project steel fibers and modified steel fibers (adding fibers below the neutral axis) are added in the proportion of 1 % to the concrete. The tests for the fresh concrete and hardened concrete are carried out and their results are compared. n this research, the way of inclusion of steel fibers in conventional concrete, the structural parameter like Ductility, Stiffness, Energy absorption capacities are enhanced very much and this is highly desirable for the structure located in seismic prone areas.

P. Sayipriya , Thivya [2021][2] " Study on flexural behavior of steel fibers in tension on RC". Detailed material test, fresh concrete test and hardened concrete test were conducted in the lab and the conclusion were drawn. At the end of this experiment, comparative study was made on the flexural behavior of RCC beam by the use of steel fiber with conventional beam, beam with steel fiber on full depth and beam with steel fiber on the half depth tension zone . Concrete is the most economically used material for construction works. Through it has high strength and durability, it can be increased by adding many admixtures. In that case steel fibers plays an important role in construction works . In this paper we can prove that the concrete mixed with steel fiber possess

high strength. The steel fiber should be added at the ratio of 3% by the weight of concrete . A beam is tested for the flexure strength of concrete and comparing the flexural strength between conventional concrete, beam with steel fiber mixed concrete for the full depth of beam and beam with steel fiber mixed for the half depth of the beam. In order to reduce this effect and increasing the strength of concrete, increasing the durability of the concrete, many fibers are used. As compared to other fibers it is now proved that the steel fiber has the properties of resistance to cracking, and has resistance to deflection. As the beam is strong in compression and weak in tension, it is recommended to use the steel fiber only on the tension zone. When compared to the usage of steel fiber on throughout depth of the beam, the usage of steel fiber on the tension zone will have same flexural strength. Therefore the amount of steel fiber will be reduced and it is cost effective.

S. Shubham , S. Shrivastava [2020][3] "**Review on Steel Fiber Enriched Reinforced Concrete**". It found that the adding of steel fibre in concrete increase the strength and toughness as compare to plain concrete. Steel fibre reinforced concrete gives results for improve abrasion , flexural strength , Impact resistance , high flexural and fatigue flexural with durability. In the construction of any industry or structure there is a common material used as concrete. And concrete is is used in very huge amount in the construction and industries. Many property of the the concrete like brittleness sometimes fails to bear tensile load which is the cause of brittle failure. Since the fibre have the property to increase the toughness of the concrete. In many experiments it is found that, steel fibre reinforced concrete have high resistance to cracking so the reason behind the increasing uses of steel fibre reinforced concrete to increase the hardness or toughness and to reduce the crack deformation characteristics. One more thing that when we added steel fibres in mortar, Portland cement concrete aura factory concrete depending on the the proportion of fibres add and mix design, its flexural strength of the composite is is increase from 26% to 100%. This technology (steel fibre) prawns forms in more ductile material from brittle material. Because the fibre continue supporting the load after cracking occurs therefore catastrophic failure of concrete is virtually eliminated.

S.M. Chiew , I.S. Ibrahim [2018][4] "Behaviour of plain concrete and steel fibre reinforced concrete (SFRC) under biaxial stresses- A Review". This paper provides general overview on the development of biaxial behaviour of plain concrete and steel fibre reinforced concrete SFRC under various types of loading conditions, namely, biaxial compression, biaxial tension- compression and biaxial tension. The biaxial behaviour including failure envelope, ultimate strength, failure mode and stress-strain relationship of plain concrete and SFRC are reported and compared. The effects of fibre volumetric fraction of fibre in SFRC on the biaxial behaviour are also discussed. Overall, previous researchers show that the inclusion of fibre enhance the biaxial behaviour of the concrete, agreed with the biaxial failure envelope developed. However, further experimental works and investigation is required to determine the relationship between the biaxial behaviour of SFRC and its fracture toughness, in addition to prove the analytical prediction of biaxial behaviour of SFRC especially in biaxial tension-compression and biaxial tension. For SFRC, the inclusion of fibre improves the post-cracking behaviour of the concrete and increase the energy absorption of the concrete specimen. The steel fibres hold the concrete matrix and thus induce a passive confinement in the out-of-plane direction for the concrete under loading.

S.P. Nannuta , B R Rashmi [2018][5] "Experimental study on the behaviour of steel fibre Reinforced concrete". Fibre reinforced concrete is a concrete mix that contains short discrete fibres that are uniformly distributed and randomly oriented. As a result of these different formulations, four categories of fibre reinforcing have been created. These include steel fibres, glass fibres, synthetic fibres and natural fibres. Within these different fibres that character of Fibre Reinforced Concrete changes with varying concrete's, fibre materials, geometries, distribution, orientation and densities. The amount of fibres added to a concrete mix is measured as a percentage of the total volume of the composite concrete and fibres termed Volume Fraction. Typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fibre length by its diameter . The addition of steel fibre to high strength concrete in various volumes fractions, can be lengthen concrete in various volume fraction, can lengthen the time elapsed before cracking and can provide a confinement. The experiential results shown that the addition of steel fibre improves the crack arresting capacity of concrete .the addition of steel fibre prove that there is significantly enhancing the energy absorbing capacity of specimens. Addition of steel fibres to concrete increases the

compressive strength of concrete marginally. The addition of steel fibres increases the tensile strength. The tensile strength was found to be maximum with volume fraction of 1%. By the addition of steel fibres the flexure strength was found to decrease marginally.The addition of fibres to concrete significantly increases its toughness and makes the concrete more ductile as observed by the modes of failure of specimens. The stiffness of beams was studied and was found to be maximum for hooked end fibre with 1% volume fraction.

M. G. Pathan, A. Swarup [2017][6] "A review on a Steel Fiber Reinforced Concrete". This paper describes the applications of SFRC and its use in many effective ways improving the strength with developing improved resistance to crack and etal. Concrete is extensively used material in construction industry because of good workability and ability to be moulded to any shape. Ordinary cement concrete possesses very low tensile strength, limited ductility and less resistance to cracking. The concrete shows the brittle behaviour and fails to handle tensile loading hence leads to internal micro cracks which are mainly responsible for brittle failure of concrete. The literature review indicates the the very few publications are available on the fibre reinforcement

concrete with hook stain steel fibre. Mainly Steel fiber reinforced concrete（SFRC） has the ability of excellent tensile strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest. Therefore, it has been applied abroad in various professional fields of construction, irrigation works and architecture. Concretes containing steel fiber have been shown to have substantially improved resistance to impact and greater ductility of failure in compression, flexure and torsion. It has been extensively used in various civil engineering structures.

P. Kawde, A. Warudkar [2017][7] "Steel Reinforced Concrete A Review" In SFRC, thousands of small fibre are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties.

A. Joshi, P. Reddy, [2016][8] "Experiment work on Steel Fiber Reinforced Concrete". The tensile strength increases significantly as the volume of steel fibre in increase is similar to the grade of concrte. The shear strength of concrete improves as the volume of fibres is increased. The various aspects covered are the materials, mix proportioning for M20, M25, M30, M40 grades of

concrete. As the concrete is weak in tension, a work has been carried out to investigate the improvement in tensile, shear, flexure, and even compressive strength of concrete and also to investigate the cracking strength and reserve strength of concrete & FRC.M20, M25, M30, M40 grades of concrete have been added to investigate the compressive strength, tensile strength & shear strength of concrete. Steel fibres acts as a bridge to retard their cracks propagation, and improve several characteristics and properties of the concrete. Fibers are known to significantly affect the workability of concrete. Steel fibres are short, discrete lengths of steel with an aspect ratio from about 30 to 150, and with any of several cross sections. Some steel fibres have hooked ends to improve resistance to pullout from a cement-based matrix. These are Most commonly used fibre. Their shape will be Round of diameter 0.25 to 0.75mm. they Enhances flexural, impact and fatigue strength of concrete and Used for-overlays of roads, airfield pavements, bridge decks. Steel fibres decrease the workability so, use of superplastic improve the workability. As the volume of steel fibres increases from 0.5% to 1.5% the workability decreases that is slump loss.

Dr. Th. K. Devi, T. B. Singh [2013][9] "Effects Of Steel Fibres In Reinforcement Concrete". In 1960s, research on fibre reinforced concrete was already advancing fast, and at the present time, fibres of various kind are used to reinforce concrete in structural applications. Due to its high stiffness, the steel fibre is probably the most used fibre material. The tension stiffening effect was markedly improved by fibre reinforcement. The cracks spacing was reduced and the characteristics cracks width turned out to be significantly reduced by the fibres. Steel fibre reinforcement concrete (SFRC), a composite material made of hydraulic cements, water, fine and coarse aggregate and dispersion of discontinues small fibres (steel fibre) is well as one of the superior crack resisting building materials. Fibres aligned in the direction of the tensile stress may bring about very large increases in direct tensile strength, as high as 133% for 5% of smooth, straight steel fibres. However, for more or less randomly distributed fibres, the increase in strength is much smaller, ranging from as little as no increase in some instances to perhaps 60%, with many investigations indicating intermediate values, teel fibres are generally found to have aggregate much greater effect on the flexural strength of SFRC than on either the compressive or tensile strength, with increases of more than 100% having been reported.

M. V. Mohod [2012][10] "Performance Of Steel Fibre Reinforcement Concrete". Performance of a steel fibre reinforced Concrete Aspect ratio of steel fibre greater then 100 is not recommended, as it will cause in adequate workability, formations of a mat in the mix and also not uniform distribution of a fibre in the mix. It is observed that the workability of steel fibre reinforced concrete gets reduced as the percentage of steel fibre increase. The flexural strength of concrete goes on increasing with the increase in fibre content up to the optimum value. The optimum value for flexural strength of steel fibre reinforced cement concrete was found to be 0.75%.In this paper effect of fibres on the strength of concrete for M 30 grade have been studied by varying the percentage of fibres in concrete. Fiber content were varied by 0.25%, 0.50%, 0.75%, 1%, 1.5% and 2% by volume of cement. Cubes of size 150mmX150mmX150mm to check the compressive strength and beams of size 500mmX100mmX100mm for checking flexural strength were casted. All the specimens were cured for the period of 3, 7 and 28 days before crushing. The results of fibre reinforced concrete for 3days, 7days and 28days curing with varied percentage of fibre were studied and it has been found that there is significant strength improvement in steel fibre reinforced concrete.

H. Behbahni, B. Nematollahi, [2011][11] "Steel Fiber Reinforced Concrete A Review Steel Fibre" (SF) is the most popular type of fibre used as fibre reinforcement. Initially, SFs are used to prevent/control plastic and drying shrinkage in concrete

T. S. Lok, J. S. Pel[1998][12] "Flexural Behavior Of Steel Fiber Reinforced Concrete" In this paper, a bilinear tensile strain softening model for SFR concrete is proposed. Based on a force- equilibrium relationship at the critical section, an integration process is progressively undertaken to calculate the flexural moment curvature relationship without the need for integration

CHAPTERNO. 3

MATERIAL USED AND TEST CONDUCTED

3.1 Proposed Methodology

a) Material Testing

- Cement
- Sand

- Coarse aggregate

b) Test on Specimen Testing
- Split tensile test
- Flexural test

3.2 Materials:

Materials used for casting concrete specimens consists of Ordinary Portland Cement OPC of grade 43 with 28 days compressive strength of 43 MPa, as a binding material provided by Ultratech Cement complying with IS 8112: 2013 Ordinary Portland Cement 43 Grade - Specifications. Natural washed and uncrushed river sand was used as fine aggregate (FA), and as a coarse aggregate (CA) natural crushed basalt was used in saturated surface dry (SSD) condition.

In this study maximum nominal size of aggregates was restricted to 10 mm and it is smaller than the one-fourth of the minimum thickness of the specimen and satisfying the IS 456: 2000 (Plain and Reinforced Concrete - Code of Practice) requirement. The density of materials used in this experiment like fine aggregate and coarse aggregate in SSD condition was 2500 kg/m3 and 2600 kg/m3 respectively. Most of the civil engineering projects in India are constructed in concrete with 28 days design compressive strength of 30 MPa. Hence, concrete mix design was performed for M20 grade of concrete by considering the water/cement (W/C) ratio 0.45, Cement, fine aggregate and coarse aggregate were mixed in the assistance of distilled water.

3.2.1 Materials Required :
- Cement
- Fine aggregate
- Coarse aggregate
- Steel Fiber
- Water

3.2.1.1 Cement :

Cement is a fine powder made from a combination of limestone, clay, and other minerals. It is a binding material used in construction to bind other materials such as sand, gravel, and water to create concrete, mortar, and other building materials.

Cement is known for its ability to harden and set when mixed with water, creating a solid structure that can support heavy loads and withstand harsh weather conditions. It is a critical component of many construction projects, including buildings, bridges, roads, and dams.

Cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Concrete is the most widely used material in existence and is behind only water as the planet's most-consumed resource.

Cements used in construction are usually inorganic, often lime or calcium silicate based, which can be characterized as hydraulic or the less common non-hydraulic, depending on the ability of the cement to set in the presence of water.

Figure No.3.1 cement bag

A] Application of Cement :

Cement is mostly used as mortar and concrete, in which cement is mixed with aggregates to form a specific grade of concrete.

Mortar is basically a mixture of cement and sand (crushed stone) having a size of less than 5mm i.e 0.2 inches.

On the other hand, Concrete is also a mixture of aggregates and cement, but both coarse and fine aggregates are present in proportions.

Mortars made of cement are used for binding bricks, blocks, and stone in masonry walls or as surface renderings.

Concrete has a wide range of applications in construction. Mixtures of soil with portland cement are used for the construction of the base layer of roads.

Portland cement has applications in the manufacture of bricks, tiles, shingles, pipes, beams, railroad ties, and various extruded construction operations.

B]History of Cement :

As historical research says that people of that time know about the binding property of lime. In the past people has been using lime for making brick bonds and other work.

The Roman Empire used lime concretes and also developed the pozzolanic cement material of lime and certain volcanic earth.

This concrete and lime mortar continued to be used up to the Middle Ages.

An English engineer Joseph Asp din from Leeds city – England 1824, successfully produced a powder made from the claimed mixture of limestone and clay.

After that he patented the material and the name was given Portland Cement because when it hardened it produced a material similar to stones from the quarries near Portland Island in the UK. With time the process of manufacturing cement has changed but the formula and material remain the same.

Later Isaac Charles Johnson in 1845 had an experiment. he burnt a mixture of clay and chalk till the tinkering stage to make better cement and established factories in 1851

In 1877 The German standard specification for Portland cement was drawn. In 1904 The British standard specification was first drawn and moreover The first ASTM specification was issued in 1904.

In India it was first manufactured in 1904 near Madras, by South India Industrial Ltd. But this venture failed.

I. Raw Materials of Portland cement:

Calcareous rocks

rocks material 40-75% $CaCO_3$ such as clayey limestone clayey marl. Portland cement material ($CaCO_3$ > 75% such as limestone marl chalk) Argillaceous rocks material ($CaCO_3$ < 40% such as clay and shale) Argillaceous can be manufactured from any two groups above. This raw material must be used in the proper form and proportions of lime silica and alumina.

II. Manufacture of Cement :

There are four stages in the manufacture of Portland cement

a) Crushing and Grinding
b) Blending the Materials
c) Burning
d) Grinding

a) Crushing and Grinding:

Soft materials are first crushed too in two stages. This Grinding can be done in a wet or dry state that depends on the process which is in use.

However for grinding in the dry state the raw materials are needed to be dried in cylindrical rotary dryers.

Soft materials are needed to be broken down through vigorous stirring with the water in wash mills, producing fine slurry, which is later passed through the screens for removal of oversize particles.

b) Blending:

The next step involved after crushing and grinding is blending the crushed raw materials. Initially an approximation of the chemical composition required for specific cement is obtained through selective quarrying and with control of the raw material fed in the process to the crushing and grinding plant.

In the dry process mixing of the materials in the silos is carried out by agitation and vigorous circulation which include compressed air.

While in the wet process, the slurry tanks are needed to be stirred by the means of mechanical action using compressed air or both used together.

c) Burning:

Bottle kilns ate the traditional types of kilns followed by chamber kilns and then continuous shaft kilns were invented. The shaft kiln is used in many countries modern days but the dominant means of burning is the rotary kiln.

When the raw material is fed to the kiln at the upper end it slowly moves down the kiln at the firing end.

The fuel used for firing is pulverized coal oil or natural gas.

The temperature at the firing end could be as equal as in the range of 1350 to 1550 °C or 2460 to 2820 °F depending on the type of raw material being burned.

The burned product comes out from the kiln in the form of small nodules of clinker. These clinkers are then passed into coolers for cooling.

The cooled clinker depending on its properties can be immediately ground into cement or stored in stockpiles for further use.

d) Grinding:

The clinker and gypsum are ground to form a fine powder in mills similar to those used

Material properly grinned are passed further while the improperly grinned are again taken to grinding. Sometimes it is required to add a small amount of grinding aid to feed material. Finished cement is stored in bags and packages for distribution.

III. Importance of Cement in Construction:

Cement is a crucial ingredient in the construction industry playing a vital role in the creation of infrastructure projects.

Its versatility durability and strength make it an essential material for building structures that can withstand harsh weather conditions and heavy loads.

Cement can be mixed with other materials to create concrete which is one of the most widely used construction materials in the world.

Structures made from cement and concrete are known for their longevity making them a cost- effective choice for long-term projects.

Cement is also a fire-resistant material that can help prevent the spread of fires in buildings. Additionally advances in technology have led to the development of eco-friendly cements that have a lower carbon footprint making them a sustainable choice for construction.

Overall cement is a fundamental building block of the construction industry providing the necessary structural support and stability for buildings bridges roads and other infrastructure projects.

Its importance in the construction industry is likely to remain significant for many years to come.

IV. Why Cement Is Popular Building Material:

Cement is a popular building material for several reasons. Here are some of the main reasons why cement is widely used in the construction industry:

Versatility: Cement is a versatile material that can be used to create a wide range of structures, from buildings and bridges to roads and dams. It can be mixed with other materials such as sand gravel and water to create concrete which is one of the most widely used construction materials in the world.

Durability: Cement is a highly durable material that can withstand harsh weather conditions extreme temperatures and heavy loads. Structures made from cement are known to last for many decades or even centuries making it a cost-effective choice for long-term projects.

Strength: Cement is a strong and sturdy material that can support heavy loads and withstand high levels of stress. This makes it ideal for constructing large buildings and infrastructure projects.

Fire Resistance: Cement is a non-combustible material that does not burn, making it a popular choice for fire-resistant construction.

Availability: Cement is a widely available material that can be sourced locally in many parts of the world. This makes it a convenient and cost-effective choice for builders and construction companies.

Sustainability: Cement can be made from a variety of natural materials such as limestone clay and shale. Additionally advances in technology have allowed for the development of eco- friendly cements that have a lower carbon footprint.

V. Types of Cement :

- Ordinary Portland Cement (OPC)

- Portland Pozzolana Cement (PPC)
- Rapid Hardening Cement
- Extra Rapid Hardening Cement
- Quick Setting Cement
- Low Heat Cement
- Sulphate Resisting Cement
- Portland Slag Cement (PSC)
- High Alumina Cement
- White Cement
- Colored Cement
- Air Entraining Cement
- Hydrophobic Cement
- Masonry Cement

3.2.1.2 Tests carried on Cement :

Various tests are performed on cement to know its properties characteristics and suitability for use. Some of the tests on cement are discussed below

- Fineness
- Setting Time
- Strength

Sr. No.	Description of test	Result
1	Fineness of cement (residue on IS sieve no 9)	6%
2	Standard consistency	33.75
3	Setting time of cement Initial setting time Final setting time	 40 min 500 min

Table No.3.1 Results Of Test Carried On Cement

3.2.1.3 Sieve Analysis Of Cement

The fineness of the cement can be tested using sieve analysis tests however these days more sophisticated methods are now largely used.

A commonly used method to obtain accurate results for both control of the grinding process and testing the finished cement measures the surface area per unit weight of the cement by analyzing the rate of air passage through a bed of cement.

However other methods for finding the fineness of cement depend on the principle of measuring the particle size distribution by the rate of sedimentation of the cement in kerosene or by elutriation in an airstream.

Apparatus Required:

1. 90-micron standard IS sieve with pan,
2. Cement,
3. Weighing machine

Procedure:

- Take some amount of cement and pour it in the sieve size of 90 microns.
- Shake the sieve horizontally so that the cement can pass through that sieve.
- After shaking, note the weight of the cement retain in the sieve

Figure No.3.2 Sieve Analysis

- Repeat the process three time for more accurate result.
- Let, the initial weight of cement before pouring $=W_1$
- Let, the weight of cement retained after sieving$= W_2$
- Now,
- The fineness of cement = % of cement retained$= (W_2/W_1) * 100$

Sample Calculation

1) Fineness of cement W1 =100gm
W2 = W1 Retained cement W2 = 6 gm
Fineness of cement =W2 / W1

= 6 / 100

= 6 %

Result

According to the IS recommendation the standard value of fineness of cement should have a fineness that10%

Figure No.3.3

Figure No.3.4 Sieve Analysis

3.2.1.4 Standard Consistency of Cement

Figure No : 3.5 Vicat Apparatus

Procedure

1. Take empty pan free from dirt and other foreign particles.
2. Weight 400 gm of cement, and put that in the pan.
3. Measure an amount of water using graduates cylinder (This amount of water is nearly 26%- 33% of the amount of cement).
4. Mix the cement and water thoroughly to get a homogenous mixture. Mixing for 4±1/4 minutes.
5. Fill the cement paste in the mould of Vicat apparatus.
6. The plunger is gently lowered on the paste in the mould until it touch the surface of the paste.
7. Release the plunger immediately to penetrate the paste (this must not exceed 30 seconds after completion of mixing).
8. Read the gauge or the penetration depth taking the distance from the base plate to the tip of the plunger.

Calculation

The consistency is measured by the Vicat apparatus, and it is defined as that consistency which will permit a Vicat plunger having 10 mm diameter to penetrate the paste to a point (5-7 mm) from the bottom of the mold.

Therefore:

If the penetration is between 5 mm to 7 mm from the bottom of mold, the water added is correct.

If penetration is not proper, the process is repeated with different percentages of water till the desired penetration is obtained.

Result standard consistency =33.75

3.2.1.5 Setting Time:

The soundness of cement is tested by subjecting the set cement to boiling in water or to high-pressurized steam for a certain period of time.

This test shows the presence of free magnesia or hard-burned free lime in cement. Along with its hardening are continuous processes though two points are differentiated for test purposes.

The initial setting time of cement is the instance between the mixing of the cement with water and when the mix has lost plasticity stiffening to a certain amount.

It roughly states the end of the period when the mix is still wet can be molded into a required shape. The final setting time of the cement can be defined as the point at which the cement has acquired a relatively sufficient firmness to resist a certain degree of pressure.

Figure No : 3.6 Vicat Apparatus

The procedure of the setting time test of cement using the Vicat apparatus method is as follows:

1. Prepare the cement sample: Take a representative sample of the cement and mix it with water to form a paste. The water-cement ratio should be in accordance with the standard specifications.
2. Prepare the Vicat apparatus: Fill the Vicat mould with the prepared cement paste and level the surface. Place the Vicat needle on the surface of the paste, and record the time.
3. Initial setting time: After a few minutes, gently lift the Vicat needle. If the paste is firm enough to resist the movement of the needle, record the time. This is the initial setting time of the cement.

Figure No : 3.7 Initial Setting Time Test Procedure Of Initial Setting Time

1. Take 400 gm of cement and prepare a net cement paste with 0.85 P of water by weight of cement (T1)
2. Placed the test block confined in the mould and resting on the non porous plate under the rod bearing the needle
3. Needle quick release allowing it to penetrate into the test block
4. The needle completely pierces the test block repeated procedure

Note this time (T2) Water add = 0.85P
= 0.85 x 33.75
= 29
= 116 ml
Initial setting time = 40 minutes

4. Final setting time: Repeat the same process after some time, and if the needle penetrates the paste to a depth of 7mm, record the time. This is the final setting time of the cement.
5. Record the results: Record the initial and final setting times of the cement and compare them with the standard specifications for the type of cement being tested.

For example, for Ordinary Portland Cement (OPC), the initial setting time should be between 30 minutes and 60 minutes, and the final setting time should be between 600 minutes and 900 minutes.

Physical Properties	BIS-1489:1991	Test Results
Initial Setting Time	30 Mini	40
Final setting Time	600 Max	500

Table No. 3.2 Results Of Physical Properties Of Cement

3.2.1.6 Aggregates

a) 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.
The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influ- ence the concrete's freshly mixed and hardened proper- ties

mixture proportions and economy. Fine aggregates generally consist of natural sand or crushed stone with most particles smaller than 5 mm (0.2 in.).
Aggregate is a collective term for the mineral materials such as sand gravel and crushed stone that are used with a binding medium (such as water bitumen portland cement lime etc.) to form compound materials (such as asphalt concrete and portland cement concrete). Aggregate is also used for base and subbase courses for both flexible and rigid pavements. Aggregates can either be natural or manufactured. Natural aggregates are

generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often the byproduct of other manufacturing industries.

b) **Natural Aggregate** –

Aggregate from mineral sources which has been subjected to nothing more than mechanical processing

c) **Manufactured Aggregate** –

Aggregate of mineral origin resulting from an industrial process involving thermal or other modification

d) **Recycled Aggregate** –

Aggregate resulting from the processing of inorganic material previously used in construction

e) **Fine Aggregate** –

Designation given to the smaller aggregate sizes with D less than or equal to 4 mm

3.2.1.6 Test Carried On Fine Aggregate

Sr. No.	**Tests**	**Results**
1.	Fineness Modulus	3.7
2.	Silt Content	1.06 ml
3.	Specific Gravity	2.75
4.	Bulk Density	1725kg/m^3
5.	Bulking of sand	30 ml

Table No.3.3 Results Of Test Carried On Fine Aggregate

1. **Fineness Modulus Procedure –**

1. Make the sample air dry and cool it at the room temperature.
2. Weight the dried sample.
3. Arrange the sieve with largest size at the top.
4. Place the sample on set of sieve.
5. Weight the material retained on each sieve and record it.

- **Observation table**

Total weight of fine aggregate = 1000gm

Sr.No	**IS Sieve**	**Weight Retained**	**% Retained**	**Cumulative% Retained**
1.	4.75	3	0.3	0.3

2.	2.36	200	20	20.3
3.	1.18	170	17	37.3
4.	600u	110	11	48.3
5.	300u	150	15	63.3
6.	150u	11	1.1	64.4
7.	75u	48	4.8	69.2
8.	pan	50	5.0	74.2

Table No.3.4 Fineness Modulus Of Fine Aggregate

Total = 377.3

Calculation

% Retained

= 3\1000 x 100

= 0.3

Fineness modulus = 377.3/100

= 3.7

Figure No : 3.8 Fineness Modulus Of Fine Aggregate

2. Silt Content Procedure –

1) Prepared 1% solution of common salt by dissolving 10gm of common salt in 1litre water
2) Filled the measuring jar with solution of common salt up to 50ml mark
3) Added sand to be tested in the jar such that the level of common salt solution reaches 100ml mark.
4) Cover the tightly with palm and shake vigorously the mixture and common salt solution by turning upside down repeatedly.
5) Allowed the mixture to settle down in the jar for three hours.
6) Measured the thickness of silt layer , which is settled down on the layer of the sand.

Calculation=

Silt by volume = (V2/V1) x 100

= 1.60/150 x 100

= 1.06 ml

Figure No. 3.9 Silt Content

3. Bulking Of Sand Procedure-

a) Put dry sand up to two third volume of the cylinder.
b) Note the volume of sand (V1)
c) Mixed thoroughly sand by adding water (2 to 4%) volume of dry sand in the tray. Pour gently the wet sand in the jar and level the top of sand
d) Note the volume of wet mixture of sand in the cylinder (V2).
e) Gradually increase the water in regular interval

Calculation =

= (V2-V1)/V1 x 100

= (190 – 100) x 100

= 30 ml

4. **Coarse Aggregate** –

designation given to the larger aggregate sizes with D greater than or equal to 4 mm and d greater than or equal to 2 mm fines - particle size fraction of an aggregate which passes the 0,063 mm sieve

Coarse aggregates are irregular broken stones or naturally occurring round gravels that are used to make concrete, coarse aggregates for structural concrete consist of broken stones of hard rock like granite and limestone (angular aggregates) or river gravels (round aggregates). Aggregates larger than 4.75 mm in size are termed as coarse aggregates.

These aggregates are obtained from stone quarries and stone crushers the size between 4.75 mm to 80mm.

Figure No. 3.10 Coarse Aggregate

5. **Grading** –

Particle size distribution expressed as the percentages by mass passing a specified set of sieves

Good Qualities Of An Ideal Aggregate:

- These aggregate used for the construction of concrete and mortar must meet the following requirements.
- This should include natural stones, gravel, sand, or various mixtures of those materials.
- It should be inflexible strong, and sturdy.
- It should be dense clear and free of any coating.
- Also, free from harmful vegetable issues.
- It shouldn't have flaky (angular) and long items.

- In the case of reinforced concrete no materials should be liable to attack the reinforcement of steel.

5.2.1.7 Types Of Coarse Aggregates:

a) Classification Based On Shape:

Elongated aggregate:

Their size is 1.8 times or nine-fifths of its mean dimension.

Flaky aggregate:

At least the lateral dimension should be lower than 0.6 times or three-fifths of the common dimension in a plane oriented downward with water and air.

Conversely have an effect on the durability and are restricted to a maximum of 15%.

b) Classification Based On Geological Origin:

Natural coarse aggregates:

They are obtained by crushing rocks and weathering motion / natural agencies of rocks.

They are broadly igneous rocks. Artificial aggregate:

They are not used for R.C.C functions.

Artificial aggregates are damaged bricks, blast furnace slag and artificial aggregates.

c) Classification Based On Size:

All-in-aggregate:

Totally different fractions of fine and coarse sizes.

They are not advisable for high-quality concrete.

Graded aggregate:

A mixture that passes through a particular shape of the sieve are often known as hierarchical aggregates.

5.2.1.8 Sizes of Coarse aggregate:

Sr. No	Coarse aggregate	Size
1.	Fine gravel	4mm – 8mm
2.	Medium gravel	8mm – 16mm
3.	Coarse gravel	16mm – 64mm
4.	Cobbles	64mm – 256mm

5.	Boulders	>256mm

- **Uses of Coarse Aggregates:**

Table No.3.5 Sizes Of Coarse Aggregate

- They are also used in the preparation of breaking moisture under slabs and vapor barriers.
- Also they are part of base preparation for driveways and roadways.
- These types of aggregates are used to facilitate drainage to maintain perimeter drains septic leach fields and retaining walls.
- Also used in temporary road surfaces (think of gravel roads) and to create tire knock areas for trucks leaving construction sites.

5.2.1.9 Test Carried on Aggregate

- Aggregate crushing test
- Impact value test
- Abrasion test
- Flakiness index test
- Elongation index test
- Angularity test
- Soundness test
- Specific gravity test
- Water absorption test
- Fineness Modulus

Sr. No	Test	Result
1	Crushing value test	30.62
2	Abrasion Value test	9.98
3	Specific Gravity	2.40
4	Water absorption	2.635
5	Fineness modulus of coarse aggregate	7.47

Table No. 3.6 Results Of Test Carried On Aggregate

1) Aggregate Crushing Value

Aggregate Crushing Value is the relative resistance of aggregates to crushing under gradually applied compressive load.

The aggregate Crushing Value Test is an important test to be performed on aggregate. The strength of aggregate parent rock is determined by preparing cylindrical shape specimens of size 25 mm in diameter and 25 mm in height.

This cylinder is subjected to compressive stress. Depending on the type of parent rock gives the different crushing values of aggregate as a compressive strength varying from a minimum of about 45 MPa to a maximum of 545 MPa.

It is a fact that parent rock compressive strength does not exactly indicate the strength of aggregate in concrete.

For this reason assessment of the strength of the aggregate is made by using a sample of bulk aggregate in a standardized manner.

This testing method is known as an aggregate crushing value test.

The crushing value test of aggregate provides the resistance of an aggregate sample to crushing under a gradually applied compressive load.Generally, the test is conducted on aggregate passing 12.5 mm and retained on a 10 mm sieve. The aggregate sample is filled in a cylindrical mold and a load of 40 tons is applied through a plunger in a compression testing machine.

The crushed aggregate sample which is finer than 2.36 mm is separated and expressed as a percentage of the original weight taken in the mold.

The percentage of weight passed through the 2.36m IS sieve is known as the Aggregate crushing value.

Figure No.3.11 Aggregate Crushing Value Apparatus

a) A 15 cm dia. Steel
b) cylinder with the plunger and base plate.
c) A straight metal tamping rod 16mm in diameter and 45 to 60cm long rounded at one end.
d) A Weigh balance of accuracy up to 1 gam.
e) IS sieves of sizes 12.5mm, 10mm, and 2.36mm
f) A compression testing machine.
g) The cylindrical measure has a diameter of 11.5 cm and 18cm in height.
h) A compression testing machine has a loading capacity of 40 tons and can be operated to give a uniform rate of loading so that the maximum load is reached in 10

- **Procedure**

a) The empty weight of the cylindrical is measured as W1.
b) Fill aggregate sample passing through 12.5 mm and retained on 10 mm IS sieve in measuring cylinder in 3 equal layers such that each layer is subjected to 25 strokes using the tamping rod. Take the weight of the aggregate with the measuring cylinder as W2.
c) Find out the weight of aggregate sample W = W2 – W1
d) Now, fill the aggregate sample in a 15 cm dia. and 13 cm height steel cylinder and level the surface of the aggregate carefully, and insert the plunger so that it rests horizontally on the surface.
e) Place a steel cylinder with a plunger on the loading plate of the compression testing machine.
f) Operate a Compression machine such that 40 tonnes of the load is applied on aggregate in approximately 10 min.
g) Release the load and remove the steel cylinder from the machine.
h) Take out the crushed aggregate sample and sieve on with a 2.36mm IS sieve, care being taken to avoid loss of fines.
i) Take off the weight of the fraction passing through the 2.36 mm IS sieve as (W3).

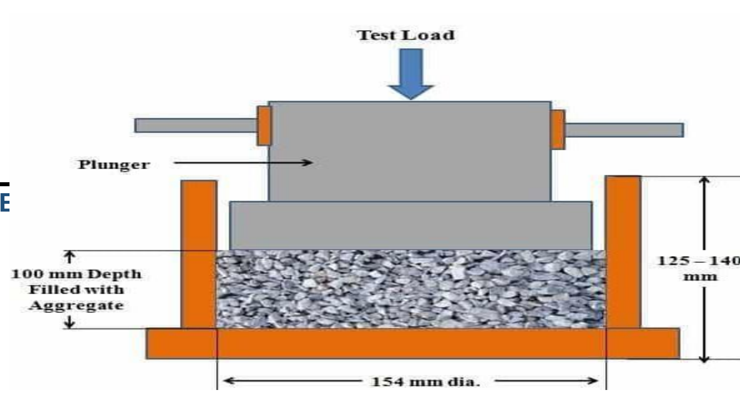


Figure No. 3.12 Aggregate Crushing Value Apparatus

Calculation of Crushing Value Test of Aggregate

The crushing strength of aggregate can be found by the following formula, "Aggregate crushing value is determined by taking a percentage of weight crushed aggregate sample passing through 2.36 mm IS Sieve divided by weight of aggregate sample taken for test" The aggregate crushing value formula is given below,

Aggregate crushing value = (W3 / W) or W3 / (W2 – W1) W1 = Empty weight of cylindrical Measure.

W2 = Weight of Aggregate with Cylindrical Measure W = W2 –W1 = Weight of Aggregate Sample

W3 = Weight of crushed aggregate sample passed through 2.36 mm IS Sieve.

2) **Abrasion Value test**

Figure No. 3.13 Abrasion Value test

The aggregates sample consists of clean aggregates dried in an oven at 105° – 110°C .

a) Select the size of aggregate to be used in the test such that it conforms to the grading to be used in construction, to the maximum extent possible.
b) Take exactly 5 kg of the sample for grades A, B, C & D, and 10 kg for grading E, F & G.
c) Choose the abrasive charge balls as per Table 2 depending on the grading of aggregates.
d) Place the aggregates and abrasive charge balls on the cylinder and fix the cover.
e) After that Rotate the machine at a speed of 30 to 33 revolutions per minute. The number of revolutions should be 500 for grades A, B, C & D and 1000 for grades E, F & G.
f) The machine is stopped after the specified number of revolutions and the aggregate sample is discharged to a

tray.

g) The entire stone dust made from a machine is sieved on a 1.70 mm IS sieve.

h) The material size of more than 1.7 mm size is weighed correctly to one gram.

3) Flakiness index test

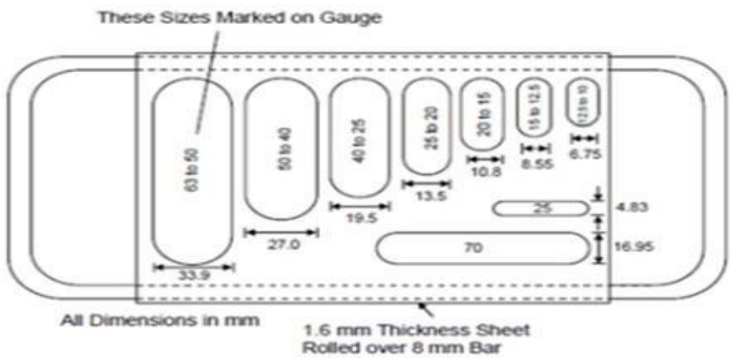


Figure No. 3.14 Flakiness index test

Procedure

1. Given sample of aggregates to be tested is sieved through a set of sieves and separated into specified ranges of size.
2. Minimum 200 pieces of any fraction are taken and weighed properly.
3. In order to separate the flaky materials, the aggregates which pass through appropriate elongated slot of the thickness of gauge are found.
4. The width of appropriate slot would be 0.6 times the average of the range of sizes.
5. The flaky material passing the appropriate slot from each size range of test aggregates are added and then weighed.
6. This weight is then divided by the total weight of sample taken from different range of sizes and the ratio is expressed in percentage which is the desired flakiness index.

- **Calculation**

Total weight of the fraction, W=

Total weight of passing fraction, w= Therefore, Flakiness Index= [w/W] x 100%

4) Elongation index test

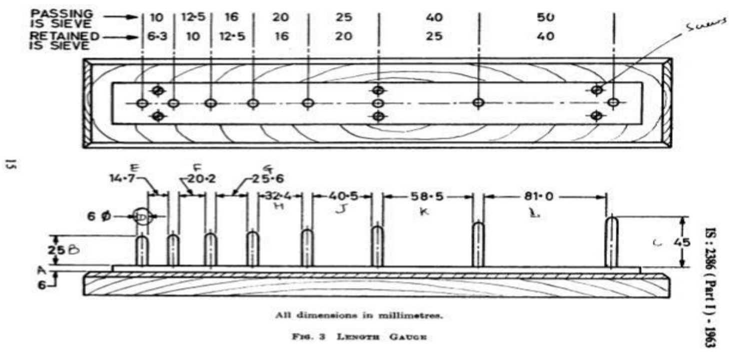


Figure No.3.15 Elongation Index

- **Procedure**

1. The given sample of aggregates which are to be tested are passed through a set of sieves and they are separated into specified range of sizes.
2. A minimum of 200 pieces of any fraction are taken to be tested, and weighed properly by weighing balance.
3. From each of the range of size, the aggregates are then individually passed through the appropriate gauge of the length gauge with the longest side in order to separate the elongated particles.
4. The gauge length will be 1.8 times the mean size of the aggregate.
5. The portion of elongated aggregate which have length greater than the specified gauge from each range is weighed by weighing balance.
6. The weight which is obtained from above is then divided by the total weight of the sample taken from different size ranges and the ratio is expressed as percentage which is the required elongation index.

- **Calculations**

Total weight of the fraction, W=

Total weight retained fractions, w=

Therefore, Elongation Index = [w/W] x 100% =

5.2.1.10 Fineness Modulus For Coarse Aggregate Procedure –

6. Make the sample air dry and cool it at the room temperature.
7. Weight the dried sample.
8. Arrange the sieve with largest size at the top.
9. Place the sample on set of sieve.
10. Weight the material retained on each sieve and record it.

- **Observation table**

Total weight of fine aggregate = gm

Sr. No	IS Sieve	Weight Retained	% Retained	Cumulative% Retained
1	80mm	0	0	0
2	40mm	0	0	0
3	20mm	1482	49.9	4.904
4	20mm	1502	50.06	99.46
5	4.75mm	08	0.26	99.72
6	2.36mm	02	0.06	99.78
7	1.18mm	00	00	99.78
8	600u	02	0.06	99.84

9	300u	02	0.06	99.90
10	150u	02	0.06	99.96
11	75u	00	00	0

Table No.3.7 Fineness Modulus For Coarse Aggregate

Calculation=

Fineness modulus = Total cumulative percentage retained /100 Fm=747.8/100=7.47

3.2.2.1 Test carried out on beam

1 **Flexural test**

- The strength of material against bending is called as flexural strength.
- The Flexural test measures the force required to bend a beam under three point loading conditions. Flexural strength refers to how much stress a material will take before it tears, rupture, breaks, or permanently bends.

Figure No. 3.16 Flexural Test on Concrete (Three Point Loading Test)

- **Flexural test on beam**

The Flexural test is perform on a Universal testing machine (UTM). Capacity of UTM is 2000 KN Dimensions = 700 X 150 X 150 mm

- **Flexural strength**

Flexural strength is the ability of material to resist the bending deflection when energy is applied to the structure. Or

Flexural strength or bending strength is the mechanical parameter of material, which is defined as a the material ability to resist deformation under load

Flexural test on concrete based on the ASTM standards are explained. Differences if present in specification or any other aspects of flexural test on concrete between ASTM standard, Indian standard, and British standard are specified.

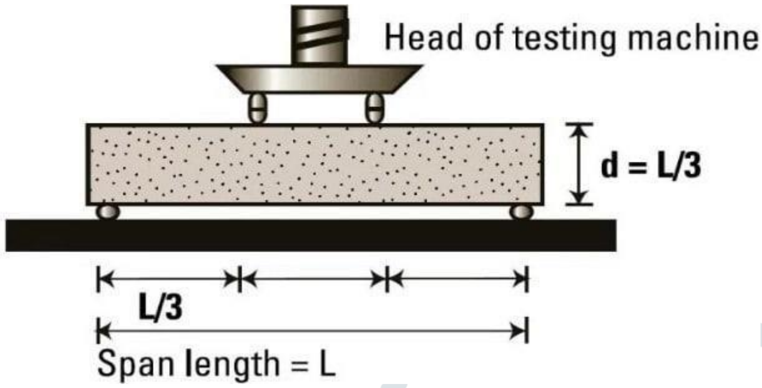


Figure No. 3.17 Flexural Test on Concrete (Three Point Loading Test)

- **Sample Preparation of Concrete**
- Determine proportions of materials including cement, sand, aggregate and water.
- Mix the materials using either by hand or using suitable mixing machine in batches with size of 10 present greater than moulding test specimen.
- Measure the slump of each concrete batch after blending.
- Place moulds on horizontal surface and lubricate inside surface with proper lubricant material and excessive lubrication should be prevented.
- Pour fresh concrete into the moulds in three layers.
- Compact each layer with 16mm rode and apply 25 strokes for each layer or fill the mold completely and compact concrete using vibration table.
- Remove excess concrete from the top of the mold and smoothen it without imposing pressure on it.
- Cover top of specimens in the molds and store them in a temperature room for 24 hours.
- Remove the molds and moist cure specimens at 23+/-2 ^{o} C till the time of testing.
- The age of the test is 14 days and 28 days and three specimens for each test should be prepared (according to Indian Code, the specimen is stored in water at 24-30^{o}C for 48hours and then tested)

Procedure of Flexural Test on Concrete

- The test should be conducted on the specimen immediately after taken out of the curing condition so as to prevent surface drying which decline flexural strength.

- Place the specimen on the loading points. The hand finished surface of the specimen should not be in contact with loading points. This will ensure an acceptable contact between the specimen and loading points.
- Centre the loading system in relation to the applied force.
- Bring the block applying force in contact with the specimen surface at the loading points.
- Applying loads between 2 to 6 percent of the computed ultimate load.
- Employing 0.10 mm and 0.38 mm leaf-type feeler gages, specify whether any space between the specimen and the load-applying or support blocks is greater or less than each of the gages over a length of 25 mm or more.
- Eliminate any gap greater than 0.10mm using leather shims (6.4mm thick and 25 to 50mm long) and it should extend the full width of the specimen.
- Capping or grinding should be considered to remove gaps in excess of 0.38mm.
- Load the specimen continuously without shock till the point of failure at a constant rate (Indian standard specified loading rate of 400 Kg/min for 150mm specimen and 180kg/min for 100mm specimen, stress increase rate 0.06+/-0.04N/mm^2.s according to British standard).
- The loading rate as per ASTM standard can be computed based on the following equation:

$$r = \frac{Sbd^2}{L} \quad \rightarrow \text{Equation-2}$$

Where:
r: loading rate

S: rate of increase of extreme fibre

b: average specimen width **d**: average specimen depth **L**: span length

- Finally, measure the cross section of the tested specimen at each end and at centre to calculate average depth and height.

Figure No. 3.18 Flexural Strength On Beam

2 Split Tensile Test

- The split cylinder test is a common method used to determine the tensile strength of concrete.
- Dimensions = Height : 300mm

  Diameter : 150mm

- This test will be taken on UTM

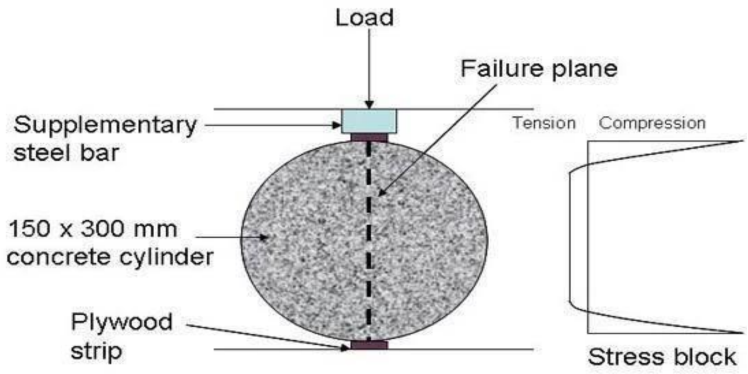


Figure No.3.19 Split Tensile Strength

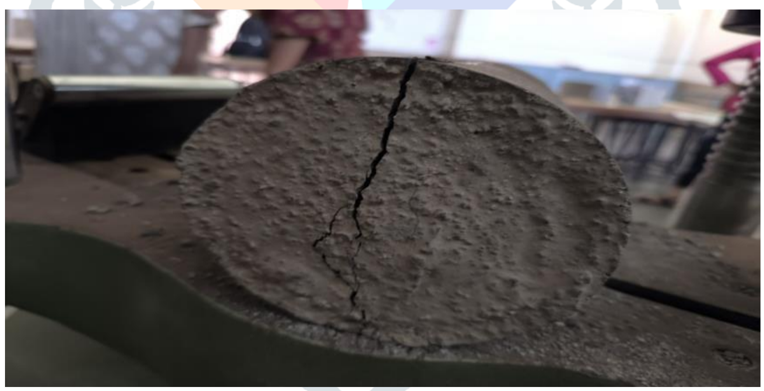


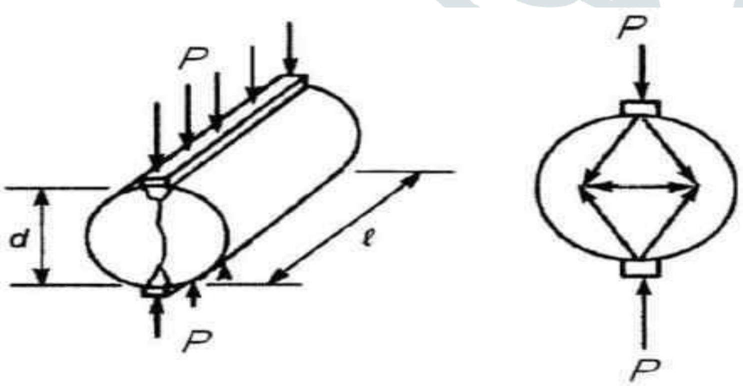
Figure No.3.20 Spilt Tensile Strength

Procedure of Splitting Tensile Test

- Initially, take the wet specimen from water after 7, 28 of curing; or any desired age at which tensile strength to be estimated.
- Then, wipe out water from the surface of specimen
- After that, draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place.
- Next, record the weight and dimension of the specimen.
- Set the compression testing machine for the required range.
- Place plywood strip on the lower plate and place the specimen.
- Align the specimen so that the lines marked on the ends are vertical and centered over the bottom plate.
- Place the other plywood strip above the specimen.
- Bring down the upper plate so that it just touch the plywood strip.
- Apply the load continuously without shock at a rate within the range 0.7 to 1.4 MPa/min (1.2 to 2.4 MPa/min based on IS 5816 1999)
- Finally, note down the breaking load(P)

Calculations

Calculate the splitting tensile strength of the specimen as follows: T= 2P/ pi LD Where: T = splitting tensile strength, MPa P: maximum applied load indicated by the testing machine,N D: diameter of the specimen, mm L: length of the specimen,mm

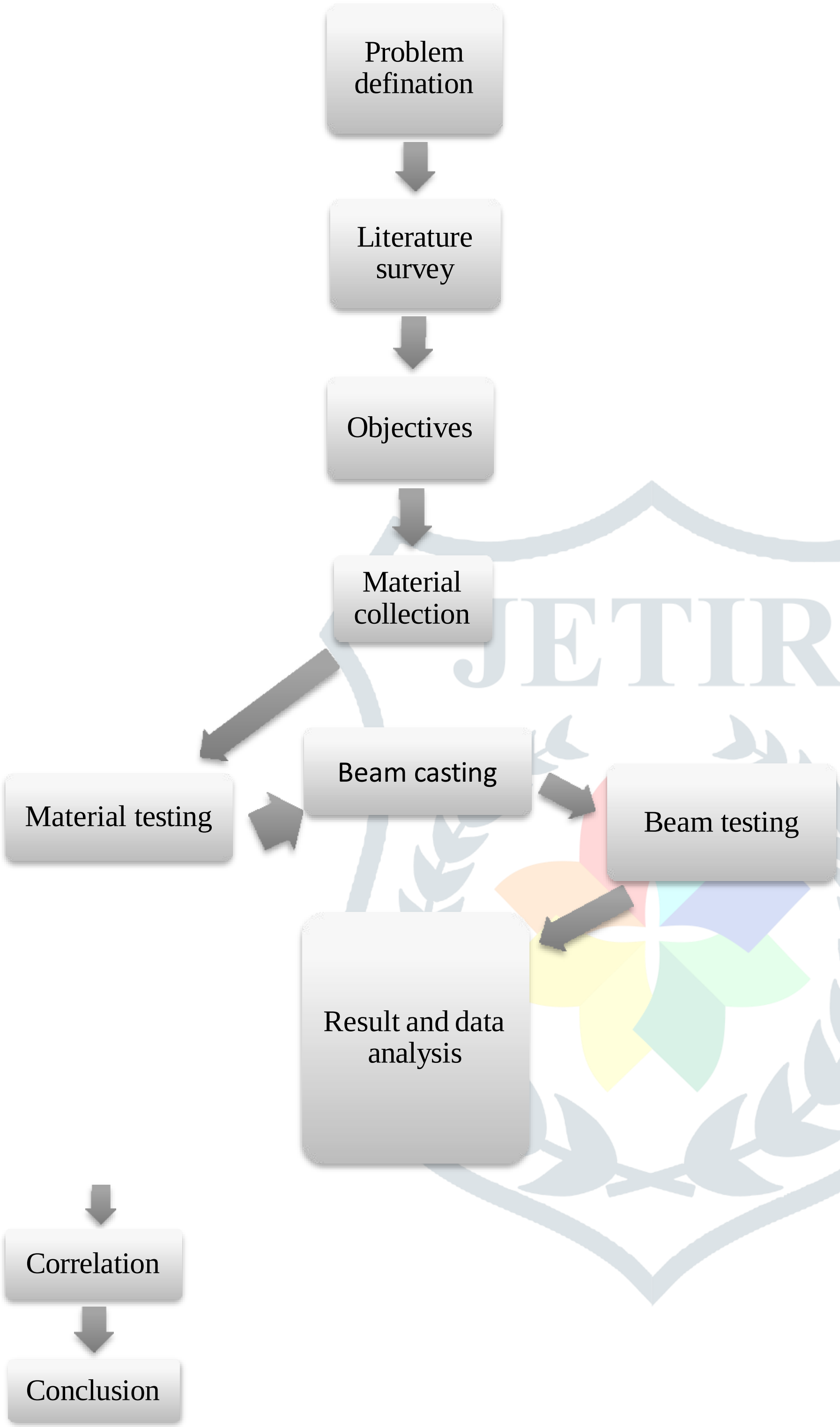


- **Material Test results**

Sr. No.	Test Description	Results
1.	Sieve analysis of cement	6 %
2.	Standard Consistency	33.75
3.	Initial setting time	40 mins
4.	Final setting time	500mins
5.	Fineness Modulus of fine aggregate	3.7
6.	Silt Content	1.06ml
7.	Abrasion Value test	5%
8.	Water Absorption	2.635%
9.	Fineness Modulus of Coarse aggregate	7.47
10.	Crushing value test	30.62
11.	Specific gravity of fine aggregate	2.75
12.	Specific gravity of coarse aggregate	2.78
13.	Bulk density of fine aggregate	1725kg/m^3

Table No. 3.8 Results Of Tests

- **Casting And Testing Schedule Of Specimens**


Problem defination
Literature survey
Objectives
Material collection
Material testing
Beam casting
Beam testing
Result and data analysis
Correlation
Conclusion

CHAPTER NO 4 RESULT AND DISCUSSION

4.1 General:

The result of the experimental investigation on sugar cane bagasse ash concrete where marble chips aggregates has been used as partial replacement of fine aggregate in concrete mix. On replacing cement with 15% percentage of fine aggregate the compressive strength are studied after cubes exposed to different elevated temperatures for 1 hour and then gradually cooled in air and provided a 3 days post fire water curing.

4.2 Test On Hard Concrete:

Keeping in mind the gap in the research area, the To study the behavior of replacement of marble chips in concrete at elevated temperature the result which are increasing durability and good performance under elevated temperature.

For this purpose different test on harden concrete were conducted at the age of 56 days like compressive strength on 150 x 150 x 150 mm size cube, splitting tensile strength on 51 mm X 102 mm cylinder, As per codal provision total 60 number of specimen were tested and results are tabulated as below.

4.2.1 Flexural Strength Test:

The test was carried out as per IS 516: 1959 code. Compressive strength tests were performed on cube samples using compression testing machine. Three samples per batch were tested with the average strength values reported in Table No.4.1. The test was carried out for 28 days water curing at 27°C. The average strength for 28 days was calculated from breaking load obtained from compression testing machine for marble chip with percentage of 15%.

Test Carried Out On Plain Concrete

Sr. No.	Beam No.	Average breaking load	Ultimate flexural strength after 28 days (N/mm^2) ($3FL/2bd^2$)	rage flexural strength (N/mm^2)
1	01	7500	2.00	2.53
2	02	9000	2.4	
3	03	12000	3.2	

Table No.4.1 Results Of Steel Fiber Is Added 0% Of Weight

Steel Fiber Is Added 3% Of Weight

Sr. No.	Beam No.	Average breaking load	Ultimate flexural strength after 28 days (N/mm^2) (3FL/2bd^2)	rage flexural strength (N/mm^2)
1	01	7500	2.00	2.53
2	02	9000	2.4	
3	03	12000	3.2	

Table No.4.2 Results Of Steel Fiber Is Added 3% Of Weight

Steel Fiber Is Added 5% Of Weight

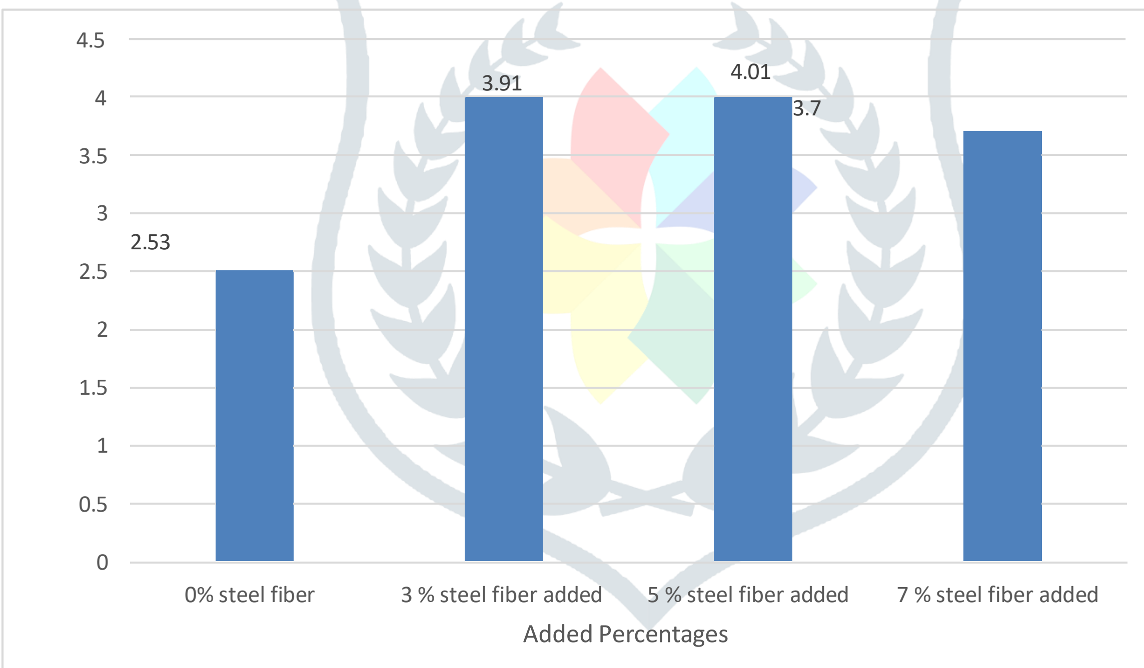
M20				
Flexural strength test result at 28 days				
Sr. No.	Beam No.	Average breaking load	Ultimate flexural strength after 28 days (N/mm^2) (3FL/2bd^2)	Average flexural strength (N/mm^2)
1	01	13.5	3.94	4.01
2	02	15.8	4.65	
3	03	13.85	3.7	

Table No.4.3 Results of Steel Fiber Is Added 5% Of Weight Steel fiber is added 7% of weight

M20
Flexural strength test result at 28 days

Sr. No.	Beam No.	Average breaking load	Ultimate flexural strength after 28 days (N/mm^2) (3FL/2bd^2)	rage flexural strength (N/mm^2)
1	01	14.18	3.94	3.7
2	02	15.12	4.03	
3	03	12.25	3.26	

Table No.4.4 Results Of Steel Fiber Is Added 7% Of Weight



Graph-Comparative Graph Of Flexural Strength Of SFRC With Various Percentage Added And Plane Concrete

Results Of Spilt Tensile Test

Steel Fiber Is Added 0% Of Weight

Sr. No.	linder No.	Average breaking load (P)	Ultimate Split tensile strength after 28 days (2P/nld)	Average Split tensile strength (N/mm^2)
1	01	168	2.37	2.29
2	02	158	2.23	
3	03	162	2.29	

Table No.4.5 Results Of Steel Fiber Is Added 0% Of Weight

Steel Fiber Is Added 3% Of Weight

Sr. No.	linder No.	Average breaking load	Ultimate Split tensile strength after 28 days (2P/nld)	Average Split tensile strength (N/mm^2)
1	01	165	2.33	2.4
2	02	178	2.51	
3	03	167	2.36	

Table No.4.6 Results of Steel Fiber Is Added 3% Of Weight

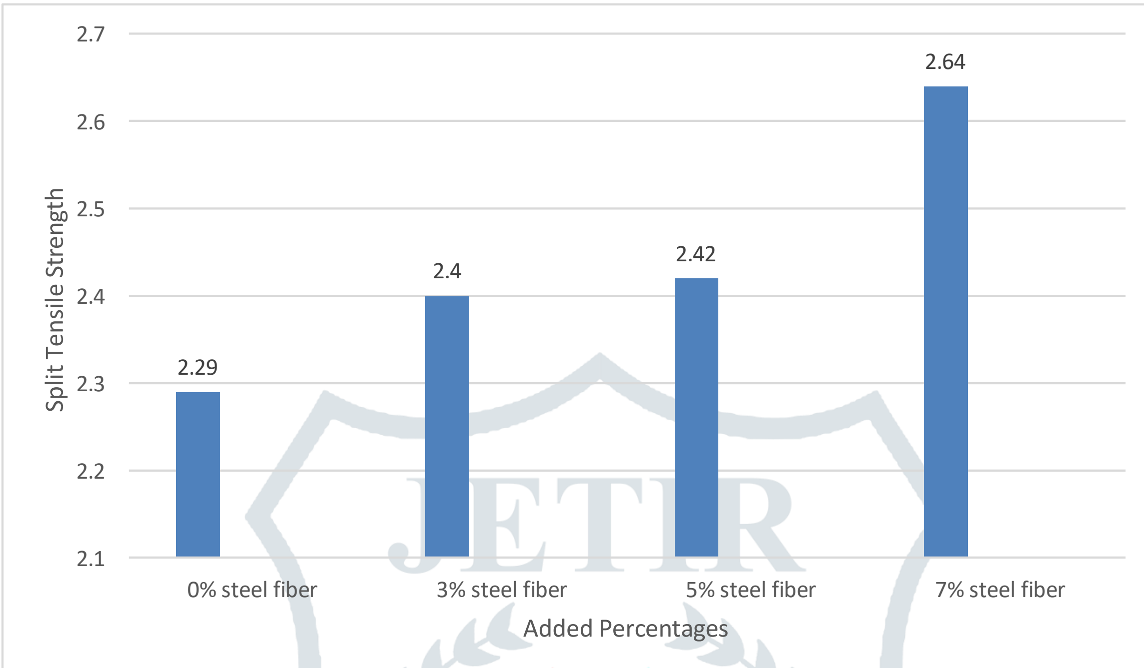
Steel fiber is added 5% of weight

Sr. No.	linder No.	Average breaking load	Ultimate Split tensile strength after 28 days (2P/nld)	Average Split tensile strength (N/mm²)
1	01	158	2.23	2.42
2	02	180	2.54	
3	03	176	2.49	

Table No.4.7 Results Of Steel Fiber Is Added 5% Of Weight **Steel fiber is added 7% of weight**

Sr. No.	Cylinder No.	Average breaking load	Ultimate Split tensile strength after 28 days (2P/nld)	Average Split tensile strength (N/mm²)
1	01	189	2.67	2.64
2	02	193	2.73	
3	03	180	2.54	

Table No.4.8 Results Of Steel Fiber Is Added 7% Of Weight



Graph-Comparative Graph Of Split Tensile Strength Of SFRC With Various Percentage Added And Plane Concrete

CHAPTER NO. 5

Conclusion

1. It is found that the addition of steel fiber in concrete improves the flexural strength and toughness as compared plain concrete.
2. Addition 5% of steel fiber in plain concrete it gives better result for improve flexural strength as compare to other percentages added.
3. Steel fiber reinforcement concrete gives better result for improve flexural strength.
4. Addition of steel fiber in concrete increase the ductility and avoid sudden breaking of concrete .
5. Addition 7% of steel fiber in plain concrete it gives better result for improve tensile strength of concrete as compare to other percentages added

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APPENDIX


200
150
100
50


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Civil Engg. Dept.


Polytechnic,Yeola
Civil Engg.Dept.
SILENCE
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Submitted by:-

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