Study of Effects of Different Types of Fibers on Concrete – A Review

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Abstract- **Concrete is the most frequently utilized construction material, and research shows that it will remain so in the long - term ahead. Concrete mix is further differentiated as it mostly produced on-site; as a result, their inherent variability and the necessity for effective quality control become essential factors. It possesses a wide range of engineering qualities, can mould in any shape and is made from low-priced components. Excipients which are trash products from industries are used to make rich-quality concrete in large quantities. In this paper, we planned to examine the impact of fibers on concrete properties. The type of fiber used in concrete is steel fiber, carbon fiber, glass fiber etc. Fibers are discontinuous and are generally distributed randomly throughout the concrete matrix in mat form. Fibers serve as crack arresters, preventing cracks from developing and changing an intrinsically brittle matrix, such as cement concrete, into a strong composite with enhanced crack resistance, improved ductility, and different post-cracking behavior before failure. Fiber Reinforced Concrete (FRC) is a composite material made up of cement, mortar, or concrete and appropriate fibers that are discontinuous, discrete, and uniformly disseminated. Discrete fibers do not include, woven textiles, continuous meshes, rods, or lengthy wires. As a conclusion, the practicality of fibers is investigated in this** work.

***Keywords*:** **Organic fibers, Coirfibers, jute fibers, carbon fibers, Glass Fibers, steel fibers, Polypropylene Fibers.**

I. INTRODUCTION

As we all know the civil engineering industry is growing very rapidly, and the use of new materials for construction is a very important need because it saves our environment and natural resources. Concrete is a versatile material it has very important properties which makes it the best construction material used for making any structure that possesses enough strength. The advantages of using concrete include high water resistance, good fire resistance, low maintenance, high compressive strength, and long service life. Concrete has the disadvantages of low tensile strength, formwork needs, and a reduced fracture strain. In the curing, stage micro-cracks develop in concrete hence to address these disadvantages fibers are added to concrete. The best improvement in concrete is achieved by the utilization of fiber in it. Fibers used in concrete are of several uses and benefits. Mostly fiber is used in concrete for large projects such as the construction of industrial buildings, fly over, bridges, highway pavements, highway overlays, etc. The type of fiber used in concrete is steel fiber, carbon fiber, glass fiber, etc. Fibers are randomly distributed throughout the concrete matrix in mat form and are discontinuous. Fibers are employed alongside traditional reinforcement in structural applications. Fiber-reinforced concrete can be a cost-effective and helpful construction material due to the variety of production methods available. Whatever type of fiber is used in the concrete; the first aspect ratio of the fiber is measured. Aspect ratio is nothing but the ratio of fiber length (L) to fiber diameter (d). Fiber-reinforced concrete (FRC) is made up of water, coarse and fine aggregate, hydraulic cement, and discrete discontinuous fibers. (FRC).For commercial and experimental application, a variety of fiber forms are available. The basic fiber categories are:

Steel Fiber-reinforced concrete- SFRC
Polypropylene Fiber-reinforced concrete- PFRC
Glass Fiber-reinforced concrete - GFRC
Organic Fiber-reinforced concrete - OFRC
Carbon Fiber-reinforced concrete - CFRC

2. LITERATUREREVIEW

2.1 Steel Fiber Reinforced Concrete (SFRC)

Steel fibers are included in concrete to improve structural attributes, especially tensile and flexural strengths. Steel fibers for concrete reinforcement are defined as discrete, short lengths of steel fibers with (length/diameter) ratio of about 20 - 100, of varying cross-sections, and small enough for random dispersion in an unhardened concrete according to normal mixing procedures. A particular amount of steel fiber in concrete can induce a substantial impact on the physical properties of the concrete, considerably enhancing crack resistance, impact, fatigue, bending resistance, tenacity, durability, and other attributes. Steel fibers with rectangular cross-sections are formed by silting 0.25mm thick sheets. Fiber is formed from drawn mild steel wire. Cutting or chopping the wire produces round steel fibers, whereas silting flat sheets produces flat-sheet fibers with a typical cross-section (c/s) ranging from 0.15 - 0.41mm in thickness and 0.25 - 0.90mm in width. Deformed fiber can also be found in the form of a bundle, loosely held together using water-soluble glue. This can be avoided by incorporating fiber bundles that distinguish during the blending process.

Srikar et al. (2018) [1]attempted to find out strength-tests like split-tensile, flexural & compressive strength using end hooked steel fibers with volume %ages of 0.5% & 1% and for aspect ratio considered for M40 concrete grade. Several cubes were cast, cured and tested. The results of the tests showed that the strength properties are enhanced due to the addition of fibers. The addition of 1.0 % steel fibers (C-3) improves strength by 84.39%, 39.92%, and 26.3% in the flexural, compressive, and split-tensile strength tests, respectively. Steel fibers are particularly useful in heavy structures to reduce secondary reinforcement. Fibers can be used to prevent crack penetration and micro cracks in critical areas.

W. Abbass et al. (2018) [2]used hook-end fibers of lengths (40, 50, & 60 mm) with diameter of (0.62 & 0.75 mm) with water-to-cement ratios of (0.25, 0.35, & 0.45) in this study. Steel fibers were introduced in three different volume fractions: 0.5%, 1.0% & 1.5%. Thirty specimens were cast and tested for results. The findings demonstrate a considerable change in the mechanical properties of concrete, When the fiber content was increased from 0.5 to 1.5%, the flexural strength rose from 3 to 124% for fibers with a smaller aspect ratio of 65, while a 140% rise in flexural strength was seen for fibers with a larger aspect ratio of 80 with a 10 to 25% increase in compressive strength and a 31 to 47% increase in direct tensile strength.

Gao et al. (2017) [3]exhibited the compressive behavior of steel fiber reinforced recycled coarse aggregate concrete using experimental results (SFRCAC). More than 100 specimens were tested for compressive strength, Young's modulus, and stress-strain curves. The emphasis of the study was on the combined influence of steel fibers (SFs) and recycled coarse aggregate (RCA) on the axial compressive behavior of SFRCAC with equivalent compressive strength. With the addition of SFs, the Young's modulus and stress-strain curves of SFRCAC are similar to those of natural coarse aggregate (NCA) concrete; however, the critical strain increases dramatically as the steel fiber content and RCA replacement ratio increase. The SFRCAC constitutive model, Young's modulus, critical strain, and compressive strength regression formula are all proposed. In comparison to NCAC, steel fibers have a stronger strengthening impact on RCAC. The SFRCAC toughness index rises with increasing steel fiber volume content and falls with increasing RCA replacement ratio. With increased RCA, there was a comparable drop in energy dissipation capacity. The Modulus of elasticity of SFRCAC rises as the steel fiber content and concrete density rise. With the combined action of SFs and RCA, the critical strain of SFRCAC increases dramatically, and the maximum increase in ratio hits 40%.

Joshi et al. (2016) [4]investigated the compressive, tensile & shear strength of concrete. Because concrete is weak in tension, experiments have been conducted to determine how to improve the cracking strength and reserve strength of concrete and FRC. Steel fibers serve as a bridge, slowing the spread of cracks and improving a variety of concrete features and attributes. Fibers have been shown to have a considerable impact on the concretes workability. The aspect ratio (50) is taken and variable %age volume fractions (0, 0.5, 1.0, and 1.5) of steel fibers are taken for study. Flexural strength, compressive strength, and splitting tensile strength of the concrete were determined for the hardened properties. Their aim is to improve the energy absorption capacity of material and its toughness. There was a slight improvement in ultimate strength. The inclusion of fiber improves ductility significantly. The workability of concrete decreases as the volume of steel fibers increases from 0.5 to 1.5%, while the compressive strength of concrete increases significantly as the volume of steel fibers increases from 0.5 to 1%, and the increase is almost identical to all the normal concrete grades of M20, M25, M30, and M40. Similarly, as the volume of fibers grows, the tensile, shear, reserve, ultimate strength, and toughness of concrete increase significantly.

2.2 Polypropylene Fiber Reinforced concrete (PFRC)

Polypropylene is one of the most affordable and widely available polymers. Polypropylene fibers are resistant to most chemicals, and it is the cementations matrix that deteriorates first under intense chemical attack. It has a high melting point (about 165°C). As a result, an operating temperature of 100°C can be maintained for short durations without altering the fiber's properties. Polypropylene fibers can be swiftly blended since they are hydrophobic and do not require prolonged contact while mixing. They only need to be uniformly disturbed in the mix. In concrete, short polypropylene fibers in volume fractions ranging from 0.5 to 15 are widely employed.

Liang Wang et al. (2021) [5] examine the effects of polypropylene fiber on concrete durability, creep, and permeability resistance, including drying shrinkage, chloride-ion penetration, sulphate corrosion, and carbonation resistance, fire resistance, and freeze-thaw cycle resistance, water absorption. The authors looked into how fiber content, diameter, and fiber hybrid ratio affected these durability indices. Blending PPFs with steel fibers can improve the durability of concrete even more. The poor dispersion in concrete and weak connection with the cement matrix are the disadvantages of PPF in concrete. To avoid these limitations, fibers treated with Nano-active powder or chemical treatment can be used. Finally, the authors discuss future research opportunities for PPF-based concrete.

Karimipour et al. (2020) [6] researched the mechanical properties of self-compacting concrete (SCC) containing polypropylene fibers (PPF). 100 specimens of SCC containing polypropylene fibers are prepared and examined. 12-mm white, long PPF was utilized in %age ratios of 0%, 0.1, and 0.3 % by volume. On a fresh SCC specimen, T500 and slump flow are obtained. To examine the performance of SCC in the hardened condition, compression, split-tensile strength, heat resistance, and impact resistance tests are performed. The compressive and split tensile strength of specimens heated in an oven at (250 °C) for 8 hours and on 28th day was examined to determine the influence of heat on SCC with and without PPF. 5 cm, 10 cm, and 30 cm cubic specimens were employed in the impact test. Impact resistance was also coupled to compressive, tensile strength, concrete age, temperature, and PPF content through trial and error. The findings revealed that increasing the number of fibers in SCC reduces dispersion. It also shows that adding 0.1 % PPF to SCC increased its compressive strength substantially. Furthermore, at 0.3 % PPF, the best results were achieved in the split-tensile strength, impact resistance, and heat resistance tests.

AlvesAmancioa et al. (2018) [7]studied the behavior of concrete reinforced with polypropylene fiber exposed to high temperatures. The approach involved preparing 30 MPa concrete specimens with three fiber contents (120 kg/m3, 180 kg/m3, and 240 kg/m3), which were then exposed for 30 minutes at temperatures of 200 °C, 400 °C, 600 °C, and 800 °C. The compressive strength, ultrasonic pulse velocity (UPV), and mass reduction factor were investigated. The analysis of variance revealed that the fiber content has a considerable impact on compressive strength but has no effect on the occurrence of mass loss.

Alsadey& Salem (2016) [8]investigated the optimal amount of polypropylene fibers for attaining maximum compressive strength in M25 concrete. An improvement in polypropylene fiber content in concrete resulted in a remarkable gain in compressive strength, according to a comprehensive and exhaustive experimental study. Even at 2% polypropylene fiber concentration, compressive strength of 28 N/mm2 was measured, compared to 25

N/mm2 at 0%, resulting in a 12 % improvement in compressive strength.

2.3 Glass Fiber Reinforced Concrete (GFRC)

GFRC is similar to chopped fiberglass (type used to build boat hulls and other complex 3-D structures), but far weaker. It is created by blending cement, fine sand, water, polymer (acrylic polymer), various admixtures, and alkali-resistant (AR) glass fibers. Although the relative density of glass fibers is similar to concrete, GFRC panels can be actually thinner than standard CC panels, making them lighter. Glass fibers ranging in length from 10mm to 50mm and diameter from a few microns can be added up to 5 % by weight and premixed with water and cement in a pan or a paddle mixer. Lubricating admixtures such as polyethene oxide or methylcellulose may be added in small amounts to the mix. The finished mixture can be poured into molds. Extrusion or injection molding can also be used to create the items. In some methods, roving's could be chopped in place and sprayed with a proper consistency slurry on a production mold at the same time. This method is particularly successful and practical for casting shell roofing and sheets.

Kasagani & Rao (2018) [9] studied the effect of the addition of Graded Glass fibers of different lengths and volume fractions in Glass Fiber Reinforced Concrete (GFRC). The experiment was conducted under uniaxial tension on Mono Glass Fibers of (0.3 cm, 0.6 cm, 1.2 cm and 2.0 cm fiber lengths) with volumes of 0.1%, 0.2%, 0.3%, 0.4%, and 0.50% for M30 grade concrete. Different fiber volume combinations of Glass fibers in Long Graded form (1.2 cm + 2.0 cm length fiber), Short Graded form (3.0 cm + 6.0 cm length fiber), and combination of long graded fibers + short graded to form combined graded fibers (3.0 cm + 6.0 cm + 1.2 cm + 2.0 cm length fiber) were studied for 0.3 % fiber volume. The results reveal that Graded Glass Fiber Reinforced Concrete has energy absorption capacity, deformation capacity, and higher strength than Mono Glass Fiber Reinforced Concrete. Workability was increased by using graded fibers. The effect of fiber efficiency attributes (orientation, dispersion, and fiber length) on the tensile strength of Glass Fiber Reinforced Concrete (GFRC) was investigated. The failed GFRC specimens are examined using optical microscopic research and an image analysis technique for this purpose.

İskender&Karasu (2018) [10] analyzed scientific publications and testing on GFRC and found that the mechanical and physical properties of the GFRC differ depending on the quality of the materials and the precision of the manufacturing procedures. GFRC can be used anywhere a light, durable, fire-resistant, weather-resistant, attractive, impermeable material is required. In recent years, glass fibers in hybrid mixtures have been researched for high-performance concrete (HPC), a growing technology that has gained appeal in the construction industry. In general, adding glass fiber increases compressive strength, but too much fiber reduces strength due to lower workability. With the addition of low volume % fibers, the concrete's modulus of elasticity does not improve significantly. Because of the control of micro-crack propagation, rusting (specifically AR–glass fiber), and lower permeability, GFRC has greater durability than ordinary concrete. GFRC is a lightweight material that is approximately 50–70% lighter than ordinary concrete. Self–mixing, on the other hand, is tough (requirement of special material). Because of the fiberglass, chemicals, and acrylic copolymer, it costs more than regular concrete, however, advances in technology could significantly alter this comparison. GFRC is widely and consistently utilized in architecture, construction, and engineering.

Shrikant M. Harle (2014) [11] investigated the qualities of the effect of glass fibers as reinforcement in concrete for various amounts based on previous research. While the initial cost is high, the ultimate cost is considerably decreased due to the good features of fiber-reinforced concrete. When compared to 28 days of compressive strength of ordinary concrete, glass fiber reinforced concrete demonstrated a nearly 20% to 25% increase in split tensile, flexural, and compressive strength. The use of AR glass fibers to enhance the durability of concrete from standpoint of acid strikes had showed promising results. As a result, the GFRC is suitable for blast-resistant constructions, dams, and hydraulic structures.

JyothiKumari et al. (2013) [12] investigated how silica-coated GFRP stirrups behaved in the shear test zone. A set of investigations in the shear zone utilized silica-coated GFRP stirrups. Beams reinforced with silica-coated GFRP flats shear reinforcement have been shown to fail at loads greater than the theoretical failure values. Furthermore, GFRP flats used as shear reinforcement are shown to be fairly ductile. Shear reinforcement with silica-coated GFRP bars and Flats has exhibited failure at loads greater than the theoretical failure value loads. This suggests that silica-coated GFRP bars have a stronger connection to concrete. When compared to controlled beams with HYSD bars, beams with GFRP reinforcement, both plain and silica-coated, showed larger deflections, showing enhanced ductility of GFRP-concrete composites. The failure of all the beams was not sudden, but the failure of the GFRP bars and flats was, and it was coupled with a splintering of tension fibers. Furthermore, the ratio of Ultimate shear to shear at first crack suggests that the beams with GFRP shear reinforcement are reasonably ductile, with a %age of variation between the actual ultimate load and the theoretical failure loads ranging from 36 to 60%. The tensile strength of composites, flats, and bars is determined by the fiber orientation and fiber to matrix ratio; the higher the fiber content, the greater the tensile strength. The Pu/Pfcr ratio also reveals that the beams with GFRP shear reinforcement are fairly ductile, with a %age of variation between the actual ultimate load and the predicted failure loads ranging from 34% to 60%.

2.4 Organic Fibers Reinforced Concrete (OFRC)

Organic or natural fibers may be more chemically inert than steel or glass fibers. They're also less expensive, particularly if they're organic. A significant amount of vegetable fiber could be employed to generate a multiple cracking composite. To solve the difficulty of mixing and uniform dispersion, a superplasticizer can be utilised.

Nambiar&Haridharan (2021) [13] evaluated the compressive strength of concrete after 7, 14, and 28 days for various trial mix percentages. The compressive strength of the trial mixes is used to calculate the material proportions. On the basis of this result, samples are cast with a water-cement ratio of 0.28 and maintained for curing. From 30 to 90 days following an acid assault, the compressive strength of the control specimen was lowered by 40.625 percent. Compressive strength was lowered by 35.77 percent and 39.39 percent, respectively, when fiber was introduced at 1% and 2%. Strong interfacial adhesion between fibers and cement matrix improves the mechanical properties of concrete. When fibers were added to concrete, the result was better, in that it resists the concrete and the formation of cracks is reduced when compared to the standard. The mechanical properties improved over the control mix, and the durability study, which included drying shrinkage, acid attack, RCPT and sorptivity also revealed improved results.

M. Asim et al. (2020) [14] investigated the use of natural fibers in concrete and develop an environment-friendly material having better thermal insulation properties. Thermal conductivity tests, scanning electronic microscope tomography (SEM), and microscopic images for interfacial bonding of fibers with concrete were performed on plain concrete and natural fibers lightweight reinforced concrete (RC) samples. The thermal properties of natural fibers reinforced concrete (RC) were tested by thermo-gravimetric analysis (TGA). Increased natural fibers (Sugarcane, Coconut, Basalt, Sisal) in concrete enhanced thermal insulation despite decreased compressive strength, according to thermal conductivity studies. However, at a 2.5 % mixture of jute and coconut, we can improve both thermal insulation and compressive strength, and the results revealed that the Coconut and Basalt fibers RC sample shows the maximum enhancement in thermal insulation, ranging from 6.5% to 17% and 5.8 % to 17.1 %, respectively when fiber contents varied from 2.5 % to 10%. As the percentage of natural fiber increases, the thermal conductivity decreases linearly. The maximum compressive strength of RC samples decreased linearly as the percentage of natural fibers increased. At 2.5 % reinforcement in concrete, Jute, and Coconut fibers improve maximum compressive strength by 6.73 % and 3.77 %, respectively, and thermal insulation by 2.64 % and 6.52 %. Coconut fiber is used as a 2.5 % reinforcement in concrete, which results in a 6.53 % increase in thermal insulation and a 3.72 % increase in ultimate compressive strength when compared to plain concrete.

Kaarthik et al. (2018) [15] choose natural fibers namely sisal & coir and fibers to enhance the attributes of concrete. The effectiveness of this natural fiber reinforced concrete is compared to that of plain concrete (PC). The current study focuses on adding coir and sisal fiber to concrete to increase its load-carrying ability, ductility, and strength. Coir fiber improves the ductility and energy absorption capacity of composite materials by delaying and controlling tensile cracking. They concluded that adding 1.5 % coir to the weight of cement increased the ductility and strength of concrete, which was found to be an ideal amount. When the concrete cylinder was wrapped with sisal fiber with an optimal amount of coir, it improved its load-carrying ability.

Hardjasaputra et al. (2017) [16] conducted experiments on super lightweight concrete (SLC) mixed with coconut fibers. Coconut fibers are one of the strongest natural fibers for strengthening concrete. The (SLC) Super Lightweight Concrete was made by mixing concrete slurry with a foaming agent to achieve a weight reduction of up to 60% while maintaining a compressive strength of up to 60 bar. Super Lightweight Concrete (SLC) is a non-structural wall material that can be used instead of typical building materials like brick. The effect of coconut fiber content on (SLC) Super Lightweight Concrete's flexural tensile strength was investigated. 0 %, 0.1 %, 0.175 %, and 0.25 % by weight of cement content were all investigated. Sixteen SLNFRC micro beams measuring 6 cm x 6 cm x 30 cm were tested to determine their flexural strength. The %age of fibers with the highest tensile strength was determined to be 0.175 %. The findings demonstrate that the mixed design satisfied the criteria of the code. The use of coconut fibers improved the concrete's flexural strength and stiffness. The optimal %age of fibers discovered in this study was 0.175 %. However, due to bonding difficulties between the fibers and the concrete, adding too many fibers reduced the tensile strength.

2.5 Carbon Fibers Reinforced Concrete (CFRC)

Carbon fibers are the newest and most spectacular addition to the range of commercially available fibers. Carbon fiber has a high modulus of elasticity and flexural strength. These are fairly substantial. Steel's strength and rigidity have also been demonstrated to be superior. They are frequently covered with resin since they are more prone to damage than even glass fiber.

Kuzina &Rimshin (2019) [17] investigated the use of carbon fiber to strengthen concrete beams, proposing a method for additional reinforcement to concrete bent beams with carbon fiber, and trying to present experimental results of destruction models of RC beams. The effect of this sort of fiber composite material reinforcement on flexural beam carrying capacity is evaluated. The destruction ability of concrete beams reinforced with carbon fiber was acquired and examined utilizing scientific results on the mechanical features of bending reinforced concrete beams reinforced with carbon-based material.

Thakur & Singh (2018) [18] aims at the properties related to the strength of concrete by the inclusion of carbon fiber with varied dosages. The optimization and influence of fibers on concrete attributes are investigated, and concrete nature is experimentally validated using flexural member (beam), cylinders, and cube specimens. Carbon Fibers (CF) have a higher tensile strength than any other fibers, which benefits the strength of concrete. To test the strength of concrete, varying percentages of fibers were added by the weight of cement in an experimental investigation. Tests were carried out for different percentage ratios (0.10 %, 0.20 %, 0.25 %, 0.30 %, 0.40 %, 0.50 %, 0.60 %, 0.75 %, 1.00 %) of carbon fiber in M30, M40, and M60 concrete grade at varying curing periods of 3-days, 7-days, 14-days, and 28- days, and it was concluded that toughness impact, tensile strength, flexural strength, compressive strength, and others are majorly influenced by the inclusion of carbon fibers.

A. Manikanta et al. (2018) [19] studied the effects of carbon fiber on reinforced concrete. They conducted various tests like modulus of rupture, toughness test, and compression test, which gave a better result than the normal concrete. After their research, they concluded that this type of concrete is better in giving higher strength. The toughness test gives promising results in the range of 2.474 N-m to 3.500N-m which is higher than conventional concrete. Similarly, the flexural strength test done on the carbon fiber reinforced concrete gives the result in the range of 77 to 85 bar, and these tests give better results on the properties of the carbon fiber reinforced concrete.

Bandyopadhyay et al. (2015) [20] explored the use of carbon fiber in the civil engineering field. The plates made from carbon fibers are flexible, strong, and thin, allowing for a cost-effective option that does not distract from the structure's original design. It is one of the most used materials in civil engineering because of its less weight, high-temperature tolerance, high tensile strength, high chemical resistance, and high stiffness. It has five times the strength of steel while being one-third the weight. Carbon fiber in construction is always effective and provides great strength to the structure since it has more uses in civil engineering, medical, military, automobile industries, sporting goods, and others.

CONCLUSION

The goal of the investigation was to offer an analysis of recyclable material utilized as fiber additives in concrete and the following conclusions were drawn:

- The inclusion of fiberin concrete mixes alters fresh and hardened properties of the concrete. The impacts vary according to the type of fiber and its shape used.Fiber enhances the durability, fatigue resistance, erosion resistance, shrinkage resistance and strength of concrete.
- Steel fibers, with their pull-out hook mechanism, provide post-cracking bending behaviour. It also improves load-bearing capacity and cracking response while lowering ductility. When both carbon and steel fibers were used together, the best bending results were obtained.The amount of hooked-end fiber in concrete increases the splitting tensile strength.
- Natural/Organic fibers showed promising results in mix design, but they did not outperform other fiber types in terms of strength.
- Most fibers have poor creep resistance, whereas graphite and glass have excellent creep resistance. As a result, the orientation and volume of fibers have a significant impact on rebar/tendon creep performance.
- The mechanical qualities of high-performance concrete using silica fume as a mineral additive are affected by the inclusion of polypropylene fibers. It improves qualities including split tensile strength, flexural strength, and compressive strength while not affecting workability.
- The optimum dose for glass fiber reinforced high-performance concrete is 1.0 % glass fiber volume, which can be utilised to achieve maximum compressive strength at any age.
- Overall research shows that steel fibers give the most promising result as it enhances strength to a new level. Other than steel fibers polypropylene and carbon fiber also give good results as compared to other fibers classes.

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