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CASE STUDY ON FIBRE REINFORCED CONCRETE

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Abstract:

Fibre Reinforced Concrete (FRC) is undeniably useful in a variety of civil engineering applications. Fibre Reinforced Concrete (FRC) is gaining popularity as a viable method of improving the performance of concrete. Fibres are now used in tunnelling, bridge decks, pavements, docks, thin limitless overlays, concrete pads, and concrete slabs. These fibre reinforced concrete solutions are gaining popularity and demonstrating great performance. Fiber-Reinforced Concrete (FRC) is a type of concrete that contains fibrous material that strengthens its structural stability. It is made up of short discrete fibres that are uniformly dispersed and orientated randomly. Steel fibres, glass fibres, synthetic fibres, and natural fibres are all types of fibres. This research looks on the strength of fibre reinforced concrete. Fibre reinforced concrete mechanical characteristics and durability.

Introduction:

Fiber Reinforced Concrete (FRC) is a type of concrete that contains fibrous material to boost structural stability. It is made up of short discrete fibres that are evenly dispersed and orientated randomly. Steel fibres, glass fibres, synthetic fibres, and natural fibres are all types of fibres that provide different qualities to concrete. Furthermore, the nature of fiber-reinforced concrete varies depending on the concrete, fibre materials, geometries, distribution, orientation, and densities used. Concrete is significantly more brittle and has a low tensile strength when compared to other construction materials such as metals and polymers. Steel is at least 65 times more resistant to crack formation than concrete, according to fracture toughness ratings. As a result, concrete in service fractures easily, providing simple entry routes for harmful agents, resulting in early saturation, freeze-thaw damage, scaling, discoloration, and steel corrosion. The downsides of using concrete include low tensile strength, low fracture strain, and the need for formwork. The main disadvantage is that concrete develops tiny fractures when curing. The quick spread of these micro fractures under applied stress is accountable for the material's poor tensile strength. As a result, fibres are added to concrete to compensate for these drawbacks.

Review of Literature:

T. Soetens A. and S.Van Gysel & A. Matthys and L. Taerwe (2013) **s**ays that the remaining post-breaking elasticity of traditional steel fiber built up concrete is straight forwardly connected with both how much filaments crossing a break and the singular take out reactions of every single initiated fiber. Thusly, the information on the single take out conduct is fundamental to comprehend the uni-pivotal or twisting way of behaving of SFRC when it is viewed as an undeniable composite. Since snared end steel strands are viewed as the most appropriate fiber type for underlying purposes, the need to precisely anticipate the take out reaction of these kind of filaments, is of extraordinary functional significance. In this paper, an exploratory examination of the take out reaction of both straight and snared end steel strands is discussed. Based on the gotten trial information, a semi-logical model is created to foresee the fiber pullout behaviour. In along these lines, many blends of both fiber and grid type can be analyzed without labour intensive trial testing.

Ahsan Ali, Shahid Iqbal, Klaus Holschemacher and Thomas A. Bier (2014) **s**ay in current test work, impact on bond execution of lightweight cement is talked about later expansion of steel strands. For the reason, changed Take out examples were tried at 28 days. Snared end steel filaments having length of 35 mm and 0.5 mm in breadth, creating angle proportion of 70 were utilized. Fiber items in 0, 20 and 40 kg/m3 were added to the lightweight substantial blends. Other than bond conduct, aftereffects of new and solidified properties are likewise introduced. Results demonstrate higher rigidities and take out loads for higher fiber contents. The new substantial thickness and compressive strength of blends diminished, while air-content qualities expanded with higher fiber content. Extreme bond strength of lightweight concrete expanded with the expansion of fiber content. It is accepted that filaments will quite often increment extreme bond strength through repression system. An increment up to 28% was seen with 40 kg/m3 fiber content, suggested that the commitment of filaments, in upgrading definitive bond strength be recognized, and component fiber content be viewed as in plan articulations.

(Simon) Cox (2015) **s**ays that take out conduct of a solitary steel fiber implanted in concrete is concentrated in a trial and mathematical design. Tests are performed on straight and snared end filaments exposed to different lateral pressures. These examinations show enormous variety in results which are somewhat brought about by neighborhood smashing of the concrete grid. Thusly, a mathematical model is introduced, which utilizes a connection point harm model to reenact substantial breaking, and a surface-based contact reproduction to show the bond qualities of the steel fiber. With the mathematical model the impact of the heterogeneous substantial properties on the take out conduct of a snared end fiber is studied. The tests showed a huge variety in take out bends for both the straight and snared end fiber. The most striking contrast in take out bend of the snared end fiber, is the variable five higher pinnacle take out force when contrasted and the straight fiber. Furthermore, a reasonable impact of the fixing system of the snare is seen, which fundamentally builds the take out energy. The impact of the parallel tension was most clear in the post-top way of behaving of both fiber types, and further may cause an essentially expansion in top take out force for the straight fiber.

Rena C. Yu, Héctor Cifuentes, Ignacio Rivero, Gonzalo Ruiz and Xiaoxin Zhang (2015) say that this work is to reenact the powerful crack engendering in fiber-built up cementitious composites, specifically, in Steel Fiber Supported Concrete (SFRC). Radiates stacked in a three-point twist setup through a drop-weight influence gadget are thought of. A solitary durable break is expected to spread at the center segment; the opening of this break is represented by a rate-subordinate durable regulation; the strands around the break plane are expressly addressed through bracket components. The fiber pull-out behaviour is portrayed by an identical constitutive regulation, which is gotten from a scientific load-slip bend. The acquired burden relocation bends and break engendering speeds are contrasted and their trial partners. The great concurrence with experimental information vouches for the achievability of the proposed strategy and makes ready to its application in a multi-scale system.

William Peter Boshoff and Adewumi J Babafemi (2016) say that expansion in the energy retention limit and ductility of a fiber built up cementitious composite after break commencement is subject to the collaboration between the fiber and the cementitious framework. The area of this collaboration between the fiber and the network has been depicted as the interfacial progress zone (ITZ). In fiber built up concrete (FRC), a few variables influence the holding between the fiber and framework at the ITZ; those connected with the fiber properties - fiber type, fiber calculation, fiber surface distortion, fiber strength, fiber width, fiber length, elastic modulus, fiber perspective proportion, and those connected with the properties of the concrete matrix. Single filaments tried under direct pliable tests have demonstrated to be rate delicate with fiber elasticity giving higher worth with expansion in the stacking rate. A mean greatest fiber elasticity of 549 MPa has been gotten for the manufactured full scale fiber at a stacking pace of 1 mm/s.

Rolf Breitenbücher, Günther Meschke, Fanbing Song and Yijian Zhan (2016) say that the pullout conduct of single steel filaments implanted in a substantial framework is investigated for different designs of fiber types and installation lengths and points, respectively, through lab tests and scientific models. Research facility tests on fiber pullout are performed to research the fiber-framework bond components. Boundaries impacting the fiber pullout reaction, for example, fiber shape, fiber elasticity, substantial strength and fiber inclination point are methodically contemplated. From the exploratory outcomes, the impact of these boundaries on the pullout force versus relocation relationship, fiber effectiveness and fiber/network disappointment reaction is broke down. For the insightful displaying of the fiber pullout behavior of straight filaments, a connection point regulation is proposed for the frictional way of behaving between the fiber and network.

Arnaud Rolland, Marc Quiertant, Aghiad Khadour, Sylvain Chataigner, Karim Benzarti and Pierre Argoul (2018) say that study centers around the trial portrayal of the bond conduct between cement and Fiber Built up Polymer (FRP) supporting bars (rebars). Take out tests were performed on glass, carbon, and aramid FRP rebars, as well as on twisted steel rebars. The impact of different boundaries on the bond conduct was examined, like the kind of filaments, the distance across of the FRP bars and their surface calculation. Filtering Electron-Magnifying lens (SEM) perceptions were performed to exactly concentrate on the sand covering qualities of these rebars. A fundamental innovation of the proposed approach depended on the instrumentation of take out examples utilizing Disseminated Optical Fiber Detecting (DOFS) instrumentation. Such a circulated estimation framework gave admittance to the longitudinal strain dispersion along the rebar close the rebar-substantial point of interaction, and afterward made it conceivable to decide the viable advancement length of the different sorts of rebars thought about in this review. As the presentation of DOFS instrumentation might be meddlesome, its effect on the connection point conduct was additionally examined.

Sadoon Abdallah, Mizi Fan and David W.A. Rees (2018) say in this paper presents the impact of raised temperature on the bond instruments related with the take out conduct of steel strands. A progression of take out tests have been performed on 4D and 5D snared end steel strands implanted in four unique kinds of cement, namely, normal strength concrete (NSC), medium strength concrete (MSC), high strength concrete (HSC) and super elite execution mortar (UHPM). At 90 years old days, the examples were warmed to target temperatures of 100, 200, 300, 400, 500, 600, 700 and 800°C individually. The impact of raised temperature on the mechanical and warm properties of cement was examined. The outcomes showed that the take out reaction of the two filaments doesn't shift essentially all through 20-400°C temperature range, however inside the temperature scope of 600 to 800°C, the take out strength diminishes altogether for all cements. The examinations between the two fiber types show that the mechanical mooring commitment given by the 5DH fiber is fundamentally higher than that of the 4DH fiber, particularly for higher strength cements. The decrease in bond strength of the two filaments after raised temperature openness is found to relate intimately with the debasement in compressive strength of the cements.

Farhan, N. A., Sheikh, M. Neaz. & Hadi, M. N. S. (2018) say that this paper researches the impact of erosion on the connection between building up steel bars and fiber supported geopolymer concrete. A sped up consumption strategy was utilized to erode the supporting steel bars implanted in geopolymer concrete. Three kinds of steel strands including straight miniature steel fiber, disfigured large scale steel fiber, and crossover steel fiber were utilized in this review. A sum of ten geopolymer substantial blends was utilized to assess the impact of consumption of steel bar on the connection between steel bar also, fiber built up geopolymer concrete. The take out test examples were made out of substantial 3D squares with a side length of 160mm and supported with a twisted steel bar of 16 mm width situated at the focus of the examples. The experimental outcomes showed that the expansion of steel filaments in geopolymer concrete (fiber supported geopolymer concrete) essentially improved the bond strength of building up steel bar. The bond strength of supporting steel bars implanted in steel fiber built up geopolymer concrete examples diminished because of erosion of reinforcement. The expansion of steel strands to the geopolymer concrete gave beneficial outcomes on the control of the consumption of steel bar and substantial breaking. Steel strands in geopolymer substantial prompted more modest and all the more firmly divided breaks, which diminished the porousness of the geopolymer concrete.

Eunsoo Choi, Behzad Mohammadzadeh, Jin-Ha Hwang and Woo Jin Kim (2018) says that this study examined the impacts of super elastic shape memory compound (SMA) strands end-shape on pullout obstruction through hysteretic pullout testing. Super elastic NiTi SMA wire of 1.0 mm distance across was utilized in assembling short strands. SMAs were created with four end-shapes: 1) kaleidoscopic and straight end, 2) L-molded end, 3) N-formed end, and 4) creased end with an initiate. The installed length of a fiber into the mortar lattice having compressive strength of 50.0 MPa was 18.0 mm, with the exception of for the N-molded end fiber for which the installed length was 21.0 mm. The pullout test was led with relocation control to get hysteretic pullout conduct by four cycling loadings. The outcomes showed that creased end strands significantly amplified the pullout strength, and the distortion was recuperated by their super elastic conduct. As N-molded end strands couldn't show banner influenced conduct, one more test was performed through which strands were tempered to instigate super elasticity, in this way, ideal strain recuperation was gotten.

Sadoon Abdallahand David W. A. Rees (2019) studied that in this paper a flexible plastic reaction has been created to foresee the take out conduct of different snared end fibres implanted in ordinary high strength cements. A flexible plastic second articulation has been proposed to address the to some degree plastic pivot framed during pull-out. The proposed equation has been integrated into a frictional pulley force examination to foresee the applied stacking at each phase of pull-out. This expectation accounts for the variety of mathematical and tractable properties of the fbres as well as substantial strength. The proposed model is approved against test take out after effects of different snared end fbres.

Hu Feng, M. Neaz Sheikh, Muhammad N. S. Hadi, Lu Feng, Danying Gao and Jun Zhao (2019) say that a progression of pullout tests were directed to research the connection point bond properties of seven sorts of steel fbres implanted in the magnesium phosphate cementitious lattice. The micro-morphology of the point of interaction progress zone among MPC and diferent kinds of fbres was analyzed by filtering electron magnifying instrument. Test results showed that more modest breadth steel fbres with metal covering surface accomplished higher normal bond strength, higher pullout energy per unit volume and a higher proportion of material use. The end snare disfigurement gave the mechanical bond locally though the deformity along the length of fbre gave the mechanical bond disseminated along the fbre.

Enrico Wölfel and Harald Brünig (2021) say that the In strain-solidifying concrete based composites (SHCC), polypropylene (PP) strands are frequently used to give pliability through miniature break connecting, specifically when exposed to high stacking rates. For the deliberate material plan of SHCC, key examination is expected to comprehend the disappointment instruments relying upon the mechanical properties of the strands and the fiber-network communication. Thus, PP strands with breadths somewhere in the range of 10 and 30 µm, contrasting tractable strength levels and Youthful's moduli, yet additionally roundabout and trilobal cross-segments were delivered utilizing liquefy turning gear. In view of these discoveries, further improvement of polymer microfibers ought to zero in on characterized organized surfaces to work on mechanical interlocking notwithstanding great mechanical qualities to prompt slip-solidifying and high-energy retention under high stacking rates.

Amir Ebrahim Akbari Baghal, Ahmad Maleki and Ramin Vafaei (2021) say in this review, limited component examination has been utilized, so to advance extensively research the outcomes, more snare points have been examined and the significant boundaries of the take out force-relocation bend are summed up and a few significant take out boundaries of SMA and steel filaments in UHPC as per the fiber. The fiber breadth expands, the take out force increments, while the slip removal or basic partition decreases. Regarding the take out energy retention of the snare molded strands, the tendency filaments will generally retain more energy than the straight strands, and the greatest take out energy happens at the tendency points of around 40 degrees.

Mohammad Hajsadeghi, Chee Seong Chin and Stephen W. Jones (2021) say that Limited Component (FE) recreation contrasted and physical tests and logical strategies, in this paper a conventional nonlinear FE model for steel strands pullout from cementitious network is introduced. In the model, attachment, interfacial debonding, sliding frictional contact, fiber distortion, and material pliancy are integrate. The total bond-slip reaction of the proposed model is approved utilizing exploratory outcomes gotten from the writing. At last, the approved pullout model is utilized as a virtual research facility unit to examine the pullout execution of two new steel strands and advance the strands material. This paper presents a conventional nonlinear limited component model to reproduce the bond-slip conduct of steel fiber in concrete matrix. The traditional fiber improvement approach is a dull cycle including fiber plan, fabricating and exploratory testing which are tedious and not financially savvy. In the future, planning and enhancement of new sorts of steel fiber should be possible with the assistance of the proposed mathematical model which will extensively diminish the quantity of investigations and comparing costs.

Fatiha Teklal, Arezki Djebbar, Samir Allaoui, Gilles Hivet, Yoann Joliff and Bachir Kacimi (2021) Micro mechanical tests are dependable devices to concentrate on the disappointment systems in composites built up with nonstop filaments. This paper presents an outline of different logical models created to concentrate on the pullout (push-back) conduct of a fiber implanted in a framework block to portray the fiber/grid interfacial attachment. Two methodologies can be recognized: one in view of a greatest pressure rule (shear slack) and the other in light of break mechanics. This article gives an outline of the insightful models revealed in the writing to quantify the shear strength and basic break energy at the interface, the boundaries impacting these properties, the calculation of the model, implanted length of the fiber, fiber breadth and stacking conditions (opening width between the blade edges for instance), including parts (fiber, network, interface), fabricating course and the subsequent deformities.

Methodology:

Procedure and Methodology:

For the 1 cube sample specimen, the concrete mix (M20) used for casting comprised 0.27kg/m3 of cement, 0.41kg/m3 of sand, and 0.81kg/m3.Following the mixing of the concrete, the fibre reinforced concrete was formed into 5 samples of cube 150mm x 150mm x 150mm for testing. For each type of fibre, cubes are cast. After 48 hours, the sample specimens were de-moulded and cured in a curing tank with a temperature of 300°C and a relative humidity of 75-100% over the next 28 days.

- **Mixture Compositions and Placing:** To prevent fibre segregation or balling during mixing, the fibres in the mix should be distributed uniformly. The majority of balling happens during the fibre adding procedure. Increases in aspect ratio, fibre volume percentage, and coarse aggregate size and quantity will exacerbate balling tendencies while decreasing workability. Experience has shown that a water cement ratio of 0.4 to 0.6 and a minimum cement concentration of 400 kg/m3 are necessary to coat the enormous surface area of the fibres with paste. Fibre reinforced concrete mixtures are distinguished from ordinary concrete by the cement factor, fine aggregate content, and coarse aggregate content. A fibre mix often needs additional vibration to correlate the combination. To avoid fibre segregation, external vibration is desirable. Metal to close the surface, trowels and spinning power floats can be utilized. A high aspect ratio was discovered to boost efficacy. It was discovered that crimped end fibres may attain the same properties as straight fibres while utilizing 40% less fibres for the same length and diameter. The same equipment and process used to define the mechanical characteristics of ordinary concrete may also be used to define the mechanical properties of FRC.
- **Compressive Strength:** The inclusion of fibres may modify the failure mode of the cube; however the fibre influence on compressive strength values (0 to 15%) will be modest.
- **Modulus of Elasticity:** The modulus of elasticity of FRC changes minimally as the fibre concentration increases. It was discovered that for every 1% increase in fibre content by volume, the modulus of elasticity increases by 3%.
- **Flexure:** Using 4 percent fibres, flexural power was claimed to be boosted by 2.5 times.
- **Toughness:** The hardness of FRC is approximately 10 to 40 times that of normal concrete.
- **Impact Resistance:** Depending on the amount of fibre, the impact force of fibrous concrete is normally 5 to 10 times that of ordinary concrete.
- **Corrosion of Steel Fibres:** Corrosion was discovered to be limited to fibres that were visible on the surface. Steel fibrous mortar submerged in seawater for ten years exhibited a 15% loss compared to a 40% strength decline in plain mortar.
- **FRC Structural Behaviour:** Fibres bonded to reinforcing bars in structural components will be widely employed in the future. Some examples of structural behaviour are as follows

- **High Strength Concrete:** The use of a fibre improves the ductility of high strength concrete. The use of high-strength concrete and steel results in slender members. Fibre addition will aid in the prevention of cracks and deflections.
- **Cracking and Deflection:** Tests have demonstrated that fibre reinforcing, in addition to strength growth, effectively regulates cracking and deflection. Fibre insertion enhances stiffness and decreases deflection in conventionally reinforced concrete beams. Steel Fibre Reinforced Concrete (3.2) Steel fiber-reinforced concrete is often a less expensive and simpler to use kind of rebar reinforced concrete. Steel bars are put into the liquid cement in rebar reinforced concrete, which involves a lot of labour but results in a significantly stronger concrete. Steel fibre reinforced concrete incorporates tiny steel wires into the cement. This gives the concrete more structural strength, prevents cracking, and helps defend against extreme cold. Steel fibre is frequently aggregated with rebar or another fibre type.

Figure 1: Steel Fibres

Reinforced Glass Concrete:

Glass fiber-reinforced concrete uses fibreglass, similar to fibreglass insulation, to strengthen the concrete. The glass fibre protects the concrete while also strengthening it. Glass fibre also prevents cracking in concrete caused by mechanical or thermal stress over time. Furthermore, unlike steel fibre reinforcement, glass fibre does not interfere with radio transmissions.

Figure 2: Glass Fibers

Reinforced Synthetic Concrete:

Plastic and nylon fibres are used in synthetic fiber-reinforced concrete to increase the strength of the concrete. Furthermore, synthetic fibres provide a variety of advantages over other fibres. While they are not as sturdy as steel, they do aid the cement pump by keeping it from being stuck in the pipes. The artificial fibres do not expand in hot weather or compress in cold weather, which helps to prevent cracking. Finally, synthetic fibres assist in preventing concrete from leaking after accidents or fires.

Figure 3: Nylon Fibres

Natural Fibre:

Reinforced Concrete Natural fibres, such as coconut fibre, have been utilized in fiber-reinforced concrete. While these fibres improve the strength of the concrete, too much of them might make it weaker. Furthermore, if the natural fibres decompose while being mixed in, the rot might continue in the concrete.

Experimental Study:

The following materials and standards were used:

- **Cement:** Ordinary Portland cement with a specific gravity of 3.15* was used. "UltraTech" with 53 grades was the creation utilized.
- **Fine Aggregate**: River sand was employed in the testing. Fine aggregate has a specific gravity of 2.65.The water absorption rate is 0.99%.
- **Coarse Aggregate:** Crushed granite stone aggregates with a maximum size of 20 mm were tested. Coarse aggregate has a specific gravity of 2.73. The water absorption rate is 0.25%.
- **Water:** Potable water was utilized for concrete mixing in accordance with IS 456-2000 standards.

Specimens Casting:

The components were precisely weighed using a computerized mixing machine and properly combined for three minutes. Steel fibres were mechanically scattered throughout the mixing machine following full mixing of the ingredients of concrete. Permanent steel moulds were utilized to prepare the specimen for compressive, tensile, and flexural strength tests.

Cube Casting:

Moulds made of steel to cast the test specimens for panel testing, steel moulds were created. Five steel moulds were made to allow for the simultaneous casting of test panels. For the moulding, two separate layers were used; the panel sizes used were 150 x150 x 150 mm. The moulds were maintained ready before the concrete was integrated. All of the mould's sides and bottom were adequately lubricated for simple remolding. The panel was held at a 45° angle before being sprayed with concrete from a distance of one metre. The top surface was then given an irregular texture.

Specimens Curing:

The test specimens were maintained in a vibration-free environment and at a temperature of 272 C for 24 hours 12 hours after the water were added to the dry components. Following this period, the specimens were labelled, removed from the moulds, and immediately immersed in clean fresh water, where they remained until retrieved for testing. Before testing, the specimens were allowed to dry. The panels were cured using the dry curing procedure, which involved covering them with damp gunny bags.

AVERAGE COMPRESSION STRENGTH IN KN/SQMM			
Specimen Type	**3 Days**	**7 Days**	**28 Days**
PCC	25.27	39.59	59.89
HSFRC 0.5%	24.50	37.29	58.24
CSFRC 0.5%	27.38	39.76	58.43
HSFRC 1%	26.32	38.48	59.01
CSFRC 1%	40.35	32.17	60.00

Figure 4: Bar Compressive Strength

It demonstrates the compressive strength of fibre reinforced concrete. It is obvious that the strength at 28 days for CSFRC 1% is superior to the other instances and so recommended.

Advantages of Fibre Reinforced Concrete Fibres:

Primary function is to bridge cracks in concrete and enhance the ductility of concrete parts. Concrete Post-Cracking Behaviour Improvement Increases impact load resistance; controls drying shrinkage cracking; and reduces the permeability of the concrete matrix, hence reducing water bleeding.

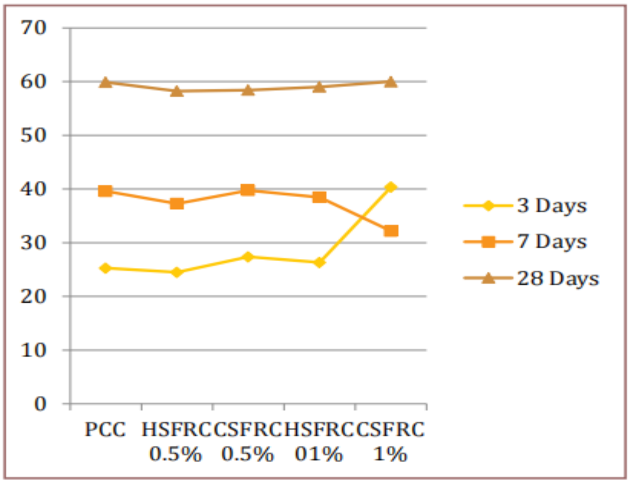

Fig -5: Graphical representation of compressive strength of fiber reinforced concrete

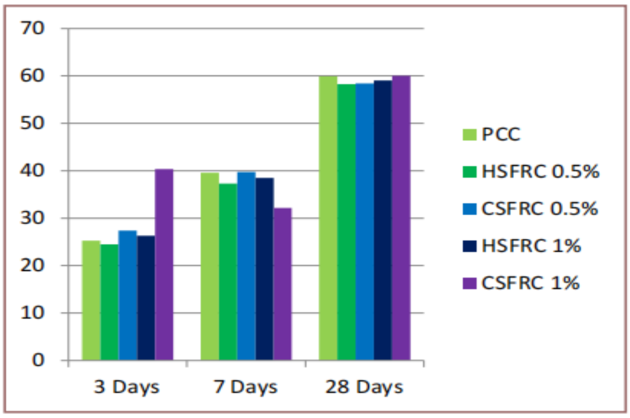

Fig -5: Bar Chart of compressive strength

Final Remarks:

The efficient use of fibrous concrete entails improving static and dynamic qualities such as tensile strength, energy absorption, impact strength, and fatigue strength. Also, give the possibility of completely replacing traditional structural concrete. The addition of glass, coconut, plastic, and synthetic fibre to plain concrete results in a considerable improvement in compressive and tensile strength. The strength qualities of ordinary concrete are uncommon. However, it will be incorrect to assert that fibrous concrete will give a general solution to the problem connected with plain concrete.

References:

1. Adewumi John Babafemi, William peter boshoff tensile creep of macro-synthetic fibre reinforced concrete under uni-axial tensile loading. (Cement and concrete composites 55, 62-69, 2015).
2. AE Naaman, VS Gopalaratnam Impact properties of steel fibre reinforced concrete in bending (Cement and concrete composites 5, 225-233, 2015).
3. Cristina Frazao, Joaquim Barros, Aires Camoes, Alexandra C Alves, Luis Rocha. Corrosion effects on pullout behavior of hooked steel fibers in self compacting concrete(cement and concrete research 79,112-122,2016)
4. DY Yoo JJ Park, SW Kim Fibre pull out behaviour of HPFRCC; Effects of matrix strength and fiber type (Composite Structures 174, 263-276, 2017)
5. Facundo Isla, Gonzalo Ruano, Bibiana Luccioni Analysis of steel fibers pull-out experimental study (construction and building material 100,183-193, 2015).
6. Ferreira, S.R.; Pepe, M.; Martinelli, E.; de Andrade Silva, F.; Toledo Filho, R.D. Influence of natural fibers characteristics on the interface mechanics with cement based matrices. Composites. Part B Eng. 2018, 140,183-196.

7. Jianan Qi, Zemei Wu, Zhongguo John Ma, Jingquan Wang Pull out behaviour of straight hooked end steel finers in UHPC matrix with various embedded angles (construction and building material 191, 764-774, 2018).
8. JP. Robins, S. Austin, P. Jones Pull-out behaviour of hooked steel fibres (materials and structures 35(7), 434-442, 2012)
9. Kang, S.T.; Kim, J.; Lee, B. Effects of Water Reducing Admixture on Rheological Properties, Fiber Distribution and Mechanical Behavior of UHPFRC. Applied. Science 2019, 9, 29.
10. L. Chen, W Sun, B Chen, Z Shi Multiscale study of fibre orientation effect on pullout and tensile behaviour of steel fibre reinforced concrete (construction and building material 283, 122-506, 2021).
11. Majid Ali, Nawawi Chouw Experimental investigations on coconut fibre rope tensile strength and pullout from coconut fibre reinforced concrete. (construction and building material 41, 681-690, 2013).
12. Kay Wille, Antoine E Naaman Pullout behaviour of high strength steel fibers embedded in ultra high performance concrete. (ACI Materials 109 (4), 2012).
13. Mehran khan, Cao, Majid Ali Cracking behaviour and constitutive modelling of hybrid reinforced concrete. (Journal Building Engineering 30, 101272, 2020)
14. Pieter Daniel Nieuwoudt, William Peter Boshoff Time -dependent pull out behaviour of hooked end steel fibres in concrete. (Cement and concrete composites 79, 133-147, 2017)
15. Qu, D.; Cai, X.; Chang, W. Evaluating the Effects of Steel Fibers on Mechanical Properties of Ultra-High Performance Concrete Using Artificial Neural Networks. Applied. Science. 2018, 8, 1120.
16. Sadoon Abdallah, David WA Rees Comparisons between pull out behaviour of various hooked end fibres in normal high strength concretes. (Concrete structure and material 13(1), 1-15, 2019.
17. VMCF Cunha, JAO Barros, J Sena Cruz .Pull out behavior of steel fibres in self compacting concrete (American Society of Civil Engineers 2010).
18. Venkateshwaran, A.; Tan, K.H.; Li, Y. Residual flexural strengths of steel fiber reinforced concrete with multiple hooked-end fibers. Structural. Concrete. 2018, 19, 352-365.
19. Wille, K.; Naaman, A.E.; El-Tawil, S.; Parra-Montesinos, G.J. Ultra-high performance concrete and fiberre inforced concrete: Achieving strength and ductility without heat curing. Mater. Struct. 2012, 45, 309-324.
20. Wille, K.; El-Tawil, S.; Naaman, A.E. Properties of strain hardening ultra high performance fiber reinforced concrete (UHP-FRC) under direct tensile loading. Cement Concrete. Compos. 2014, 48, 53-66.
21. W Wei,F Liu,Z Lu,L Li Bond performance between fibre reinforced polymar bars and concrete under pull-out tests (construction and building material 227,116-803,2013).
22. Ultra-High Performance, Fiber-Reinforced Concrete (UHPFRC) Beam-Column Joints. Applied. Science 2018, 8, 810.
23. Yu, R.; Spiesz, P.; Brouwers, H.J. Energy absorption capacity of a sustainable Ultra-High Performance Fibre Reinforced Concrete (UHPFRC) in quasi-static mode and under high velocity projectile impact. Cement Concrete. Composites. 2016, 68, 109-122.
24. Y.Hao,H Hao Pull out behaviour of spiral shaped steel fibres from normal strength concrete matrix (construction and building material 139, 34-44, 2017).
25. Zhao, M.; Zhao, M.; Chen, M.; Li, J.; Law, D. An experimental study on strength and toughness of steel fiber reinforced expanded-shale lightweight concrete. Construction. Building Material. 2018, 183, 493-501. 26.IRC Code Book 5 :Standard Specifications of Road Bridges: General Features of Design
26. IRC Code Book 6: Loads and Stresses.
27. IRC Code Book: SP 13- 2012 Guidelines for Designs for Small Culverts and Bridges.
28. IS 456 (2000): Plain and Reinforced Concrete - Code of Practice.