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STEEL FIBER REINFORCED CONCRETE BEAM WITH CONVENTIONAL REBAR UNDER CORROSION DETERIORATION: A REVIEW

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Abstract: One of the most significant deterioration concerns for the Reinforced Concrete or RC structure is the corrosion of reinforcement. The durability and serviceability is also affected genuinely by it. The steel reinforcement corrosion is likely to develop due to passive film and its limited failure on the steel with the help of ions of chloride and also due to the general failure for lacking the concrete neutralization as a result of chemical reaction from air with carbon dioxide. In this article a detailed review about the corrosion deterioration of steel fiber reinforced concrete bars are done. At last a conclusion is drawn highlighting the main points in this area as well as the future directions are also shown.

Keywords: **Reinforced concrete, Corrosion, steel fiber, durability, serviceability etc.**

I INTRODUCTION

A rocklike material is known as concrete which is formed by using crude aggregates, fine aggregates, Portland cement and water. Portland concrete may likewise be fabricated from any number of raw materials, given that the end results have the required strength and properties [1]. Concrete has a few shortcomings, for example, the lesser tensile strength it has, post cracking potential is also low along with a property of being brittle [2]. The shortcoming in tension can be overwhelmed by the utilization of traditional bar (steel bar) reinforcement and to some degree by the consideration of an adequate volume of specific fibres. Addition of fibres in the concrete brings a superior control of its cracking and enhances its mechanical properties. Fibre extension in the substance called concrete allows the better cracking control and also increases some other important mechanical characteristics [3]. More than that it also a post cracking load carrying capacity is also conveyed to the material inciting pseudo ductility, which diminishes its delicate character. As it can be seen the steel plays a very important part in strengthening of concrete it is apparent that the durability of concrete relies heavily on the steel reinforcement corrosion which inside it is implanted [4]. The RC or Reinforced concrete is one of the most commonly used materials for the construction purpose across the globe. There are some issues which have a strong influence on it especially as far as its durability and sustainability is concerned. When we talk about the durability, the basic factors which are supposed to cause the RC deterioration are considered as the important parts for the reinforcement of corrosion as a result of which the there is a deadly reduction of the construction service life, potential of loading as well as seismic resistance. It is therefore that the most vital problems being addressed while designing of the RC structure is the corrosion counteracting [5]. Under ordinary conditions the electrolyte and its pH in the OPC which is ordinary Portland cement is almost basic in nature which is more than 13 PH. Also it helps to create an inactive layer which is able to forestall the process of corrosion. Due to chloride assault and as a result of carbonation, this film can be harmed as well and as a result there is a decline in the pore electrolyte pH and also it undermines the inactive film and its stability [6].

Steel Fibre-Reinforced Concrete (SFRC) is from various perspectives an outstanding construction material, and its utilization had progressively expanded in the course of the most recent decade. The mechanical properties of SFRC are well depicted based on the speculations of fracture mechanics. SFRC has a high cracking resistance and more dynamic post behaviour. It is generally utilized as a part of different kinds of designing construction field with its great crack resistance, flexural toughness and impact resistance [7].

1.2 Cement Concrete

Concrete is a mixture of an inactive binding agent (cement), the activator (water) and aggregates. The paste formed out of Portland cement and water is called mortar and it acts as the binder for the aggregates and other strengthening material used in the mix [8]. This whole mixture of mortar and aggregates is called concrete and when steel bars are also used to reinforce and strengthen the concrete member it is called reinforced concrete. The strength, durability and the ease of handling has made concrete the ideal construction material around the world. Houses, schools and hospitals and also air terminals, bridges, highways and rail systems rely heavily on concrete or the members made of it [9]. The most popular construction material on Earth may be more popular as developing countries turn out to be progressively becoming urban, and also extraordinary climate occasions require more tough building materials and the cost of other framework materials keeps on rising. Sometimes even construction experts mistakenly utilize the terms cement and concrete reciprocally. Cement is actually an element of concrete. cement is a finely ground mix of lime silica and some other materials which when mixed with water in adequate ratio forms a paste that with time set into a rock like solid material [8].

1.3 Concrete's durability:

Durability of concrete is its ability to resist exposure to environment, chemicals and abrasion and retain its strength and other physical properties. It is the life span of concrete. Depending on the usage the concrete is designed to have different durability as the method of usage can affect the factors the concrete can be exposed to. We can consider the example of exposed concrete to the seawater tides which is supposed to have various other needs as that of concrete used indoor [10]. For the durable concrete qualification the following properties are supposed to be there in the concrete:

1. For the mix the paste structure is supposed to be denser and offering lesser permeability.
2. It is entrained air to resist the cycle of freeze thaw under extreme conditions.
3. Graded aggregate is supposed to be mixed which is inert as well as strong.
4. The mixture's other ingredients should also have lesser impurities.

1.4 Need of Reinforcement

Concrete is high on compressive strength but low on tensile strength, whereas steel provide high tensile strength which is lacking in concrete. So to balance what concrete lacks, steel is added [11].

1.5 Fibre Reinforced Concrete

In simplest terms Fibre Reinforced Concrete is concrete with fibres. Now the fibres can be of any material like Glass, Aramid, Carbon, Coconut husk, Steel, Basalt etc. Fibres increase the tensile strength and make it more flexible by holding the cracks developed in concrete [12]. The fibres between the two surfaces of concrete can bear the load and can prevent the expansion of cracks in concrete, hence increasing its tensile strength and making it more flexible. FRC increases the tensile strength of the concrete. Water voids and air voids that inherent porosity of gel are reduced by FRC. Durability of the concrete is increased by FRC [13].

1.6 History of Fibre Reinforced

Concrete Reinforcement with fibres has been done since ancient times, for example, the mortar in ancient times was reinforced with horse hair and mud was, and in some areas even now, is reinforced with hay straws. In 20th century asbestos fibres were used for reinforcement and in 50s came the concept of using composite materials to reinforce the concrete. As the time passed new types of fibres, like steel, glass and many other synthetic fibres, were developed to reinforce concrete and that research still continues [14].

1.7 Types of Fibre Reinforced Concrete

Diverse distinctive sorts of fibre reinforced concrete are used are as [15]:

- Natural fibre reinforced concrete
- Concrete reinforced with carbon fibre
- Reinforced concrete with glass fibre
- Concrete reinforced with synthetic fibre.
- Concrete reinforced with steel fibre

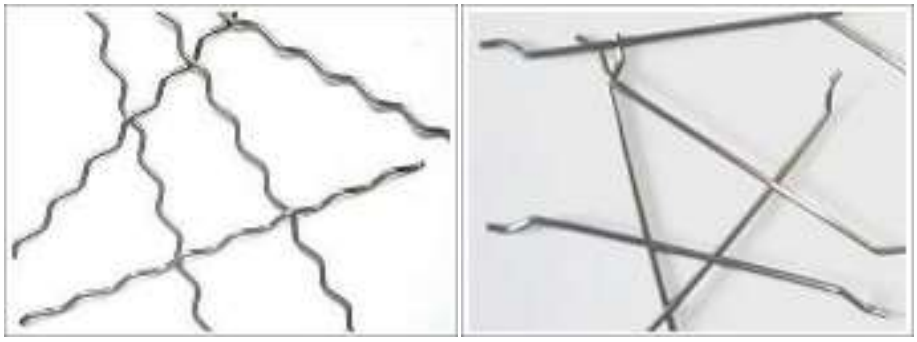
Different-different types of fibre used in a concrete are shown in figure 1.1



Figure 1.1: Types of Fibers (i) Carbon Fiber (ii) Steel Fiber (iii) Glass Fiber (iv) Coir (v) Polypropylene fiber

1.8 Steel Fibres

On the basis of cement type used, the mixture along with the type and amount of fibre which is used along with other fibres can elevate the flexural strength of the components by 25% to 100% [16]. Addition of fibres to concrete can increase its ductility and hence can help eliminate the failure of concrete members to a sizable extent as the fibres in the concrete can continue to support the load even in a cracked member, though the improvement may vary depending on many factors like the type of fibres used or the amount of fibres used in the mix design etc. but no matter what the case may be the members made of fibre reinforced concrete do exhibit more crack resistance, improved fatigue strength, higher post crack flexural strength, higher resistance to spalling and higher first crack strength. The most commonly used fibres to reinforce concrete are steel fibres and they are in varying lengths and aspect ratio between 40 and 60 and they are manufactured either deformed or hooked [17]. Steel fibres in different shapes and different forms are used in the concrete with names such as crippled steel fibre, hooked steel fibre, crippled steel fibre, straight or twisted steel fibres etc. which in figure 1.2 are mentioned



(i) Crippled steel fiber (ii) Hooked steel fiber



(iii) Straight steel fiber (iv) Twisted steel fiber

Figure 1.2: Different Shapes of Steel Fibre

1.9 SFRC Stands for Steel Fibre Reinforced Concrete:

Concrete inherently is a brittle material with low tensile strength and high compressive strength and strain capacity which can make it hard for concrete to use as a flexural member just as it is, but these shortcomings of concrete can be helped by adding steel fibres to the concrete mix as these irregularly spread fibres in the concrete can fill the cracks in the composite and can manage the shrinkage in the plastic cracking along with shrinkage cracking in drying conditions [18].



Figure 1.3: Steel fibre reinforced concrete.

1.10 Uses of SFRC

For underground tunnel and mines support in the shotcrete linings which are usually in the form of bolts of rocks. In the covering of shotcrete which is to make the ground rock and soil slopes stable, for example at railway cuts and in highways along with other embankments. Structures which are thin shelled such as foam domes of shotcrete [19]. The structures which are resistant to explosion normally in collaboration with the bars of reinforcement. The water based or hydraulic structures such as basins, dams, stilling, slab replacement, sluiceways etc. in order to oppose the cavitation's damage. Overlays along with paving of airports and highways especially where there is a need of thinner as compared to normal slab. Floors of industries so as to impact the resistance to thermal shock. Using high alumina cement in the refractory concrete in both applications of cast-able and shotcrete. The decks of bridge as overlays or sometimes topping whereby the support is given to basic structures by offering concrete reinforcement desk underlying [20].

1.11 Corrosion

The decay or loss of a material along with the basic features is known as corrosion due to the electrochemical, chemical as well as various other responses to surface of the material exposed with the atmosphere. Acidic vapours for example the residue of caustic soda and sulphuric acid is likewise considered to speed up the process of corrosion [21].

Corrosion influences the microstructure, mechanical properties and the physical appearance of the materials. Rusting and different sorts of decay definitely diminish the limit of pipelines, steel reinforcements and equipment, bringing about loss of yield and also loss of equipment, or even life. Hence anti-corrosive coatings are utilized to combat the corrosion harm to basic structures and equipment. The corrosion of steel reinforcements in concrete is one of, if not the biggest problem an RCC member can face as it can drastically reduce the structural integrity and serviceability of the structural member [21-25]. The corrosion of steel is basically the process of oxidation of iron atoms in steel and forming ferrous oxide, i.e. rust, which can deteriorate the steel reinforcement and reduce its load bearing capacity and serviceability. Concrete as itself can act as the protective agent for steel reinforcement inside it by passivation of surface of steel reinforcement. It is done by the high alkalinity of concrete [26-29]. The passivation of steel due to the alkalinity of concrete cannot withstand the chlorides even at high pH, which can happen if the concrete is not dense enough. Oxygen can also play major role in the passivation process. Furthermore the corroded steel has more volume than that of steel hence when corrosion occurs it not only deteriorates the reinforcement but also generates expansive forces inside concrete which affects its integrity and serviceability and also its aesthetics as it not only leads to tensile cracking but also rust staining of concrete. The all-pervasive phenomenon is seen inside the concrete resulting in the destruction of countless and many variable structures in various parts of the world and a term used for it is known as cancer of concrete. Speaking ideally, sufficient security is supposed to be offered to the embedded steel by the good concrete. This is mainly due to the alkaline environment which is opposing as pH is as high as 12.5 in this case which a fresh concrete offers for the defensive coating development on the steel surface which further passivates it from the corrosion and its promotion [30]. On the other hand, with the passage of time, the esteem pH starts to decrease slowly and the surrounding is alkaline which results in the loss of reinforcement in the bar. With the corrosion procedure proclaiming which results in the spilling of concrete as well as cracks inside it the essential factors are supposed to be considered which have quality and only a concrete which is durable is supposed to have lack of permeability which ensures the sufficient content of cement and lower w/c ratio, compaction completion and proper cure. By making use of proper admixtures and offering the increased cover of concrete it can be additionally enhanced [31].

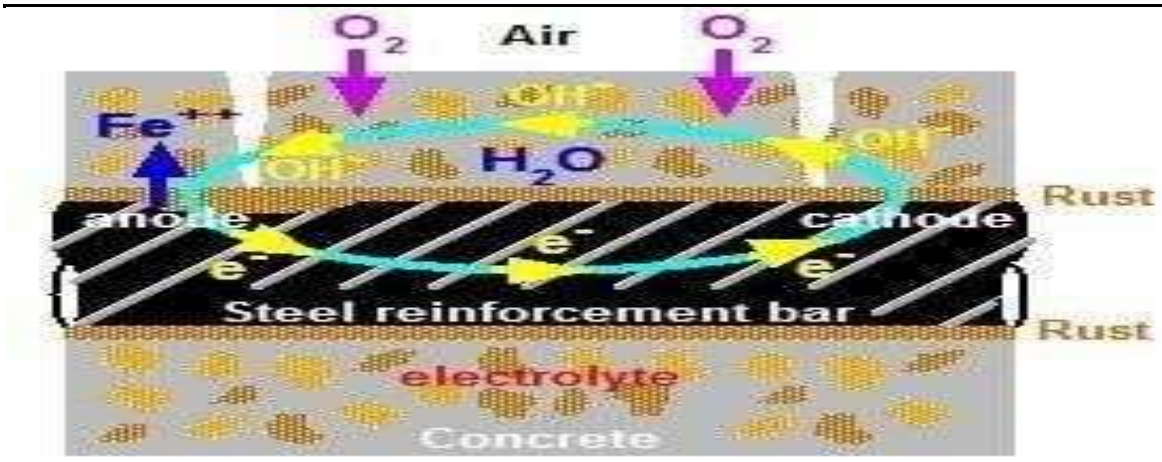


Fig 1.4: Corrosion in Reinforcement (https://theconstructor.org/concrete/corrosion-steelreinforcement-concrete/6179/)

1.12 Corrosion of SFRC

Corrosion of steel fibre in SFRC is considered to be a smaller problem than corrosion of reinforcement bars. Corrosion of steel is an electrochemical process and requires a constant supply of oxygen and water to sustain itself. The concrete inherently has a high pH value of 12.5 and hence can form a protective passive layer around the steel which can provide it protection against corrosion but it can be easily compromised in presence of chloride or if the concrete carbonates to the depth [32]. Since corrosive products of steel have higher volume than the steel itself it can also undermine the integrity and serviceability of steel due to tensile cracking Steel fibres can help with this problem as they themselves can be sacrificed to corrosion without significantly affecting the concrete as they are small and hence cause little to no tensile cracking. Also being randomly spread and discontinuous they are not capable of giving rise to galvanic corrosion. They can also prevent the carbonates of concrete and chlorides from reaching the reinforcement bars and causing any damage by consuming them themselves [29].

1.13 Accelerated Corrosion Method

Corrosion is a slow and gradual process and studying it can be a time consuming task. Hence accelerated corrosion method is used to accelerate the process of corrosion in the member under study so that the results can be acquired quickly. The corrosion in a member can be accelerated by facilitating the elements that carry out the corrosion, like increasing the amount of anions and cations in the medium the member is placed, i.e. placing it in a NaCl solution, and facilitating the corrosive reaction by passing current through the member and the NaCl solution it is placed in [33].

1.14 Non Destructive Testing

Non-destructive testing is a collection of testing methods with which concrete specimens can be tested for their various physical properties without actually destroying or harming the specimen. Nowadays the current methodology has been taken as a standard way to the process of quality control [34]. To investigate the micro cracks this method can be used and also in the determination of depth in crack and concrete deterioration. One of the simplest methods of testing is known as non-destructive concrete testing which at the same time requires the skills and experienced administration which is supposed to have proper knowledge to determine and estimate the outcomes of the test.

1.14.1 Ultrasonic Pulse Velocity Test

In this testing method a pulse of ultrasonic wave is first passed through a standard bulk and then the wave is passed through the specimen to be tested and the time taken by the wave to pass through them are compare. Since the sound waves travel faster in solids than in air if there are cracks or voids in the test specimen, the waves would take more time than normal to pass through it and if they pass faster the specimen is assumed to be of satisfactory quality [35-36].

1.14.2 Half-cell potential

The corrosion of concrete is an electrochemical process and hence in this the area of steel getting corroded behaves as a part of a battery and by connect another standard half to it the potential energy of the steel can be calculated and by repeating the procedure at many spots on the specimen the area most prone to corrosion can be found out be taken care of beforehand. Most commonly the half-cell used has a copper sulphate electrode as standard and a voltmeter is used to measure the potential [37-40].

II Literature Review

R. Rider et al. (1980) determined the condition of marine environment on the metallic fibre integrity for the concrete reinforcement. Cement which is reinforced by the metal fibre has a capacity to be used as a structure of marine whereby the rigidity, resistance to abrasion and metal fibres are discussed along with the weakness features which can result in legitimize the more cost when conventional concrete is contrasted to it. In the flowing sea water and fresh water exposures of the lab the mental fibre reinforcement of specimens of concretes were tested. Of the specimens used the comparison was made which uncover the tidal quarter of the Narragansett Bay. The experiments on the basis of freeze thaw are furthermore executed. By making use of standard as well as modified ASTM testing the results were obtained. The rate of corrosion in the electrochemical series is checked via strategies. It was indicated in the outcomes that the marine applications require the stainless steel fibres [41].

I. Janotka et al. (1989) performed a study based on experiment to determine the resistance to corrosion for the steel fibre and the reinforcement of mortar of concrete in the steel bar. Different measures were incorporated in the mortar matrix for calcium chloride from two to ten percent of the consumption rate and it was seen by the policy of anode potential. The mortar and its main structure along with the surface of steel is estimated with the help of microscopy of filtering electron. It was proven by the outcomes that the calcium chloride enlargement altered the mortar mix and its microstructure. Its potential to absorb water along with the porosity it has was expanded when it was estimated with the help of calcium chloride. It was demonstrated by the electric potential measurement that as the 2 percent consumption of calcium chloride is shown by the bar reinforcement, the unsafe corrosion of any type was not shown by the fibres unless the point comes when the content of chloride reaches as much as 6 percent. The admixtures of chloride when added into the cement are in this way likely to be less threatening as that of steel which is used inside the steel fibre concrete when used inside the concrete reinforcement [42].

Jean-Louis Granju et al. (2004) draw a conclusion that for most of the parts, in the reinforcement of steel fibre occurrence in the corrosion of the steel which is not as powerful as compared with the bars of steel concrete reinforced. In the segmented split the material and its solidness also relies mainly on the execution of the potential bridging for the concrete and embedded fibres inside it. The fibres and their corrosion are also likely to deliver the concrete spalling along with the zones of fibre diminishing altogether which further reduces the structure's integrity. The main examination of it keeps a focus on the fibre corrosion and its two parts. On the cracked samples with 0.5mm mouth openings the tests were performed with the exposed CMOs to the marine environment for the period of as much as one year. It was confirmed from the outcomes that to SFRC the smaller sensitivity to the use are depressingly lower; they also demonstrated that there is an increase in the flexural strength of a material after corrosion [43].

M. B. Otieno et al. (2010) investigated on the crack impact with the width of (0.7 mm, 0. 4 mm and incipient cracks), binder type (100% CEM I (common Portland bond – OPC) and 50/50 OPC/Corex slag mix), water-to-binder (w/b) ratio (0.40 and 0.55) and crack reopening on chloride-induced corrosion in RC specimens with constant cover of 40 mm. Over the study period (31 weeks), corrosion rates fluctuated from passive values of 0.01 A/cm2 to active values of 1.50 A/cm2. It was demonstrated in the outcomes that the rate of corrosion is touchy to the width of crack, the quality of concrete along with the write cover and proportion of w/b and the reopening of cracking. For a binder type which is given, the ratio of w/b and the rate of corrosion which is expanded along with the width of a crack was on the other hand shown along with the smaller cortex slag expansion in the specimens whereby there is an increase in the OPC specimens for more than 40 percent of increments. There is a need of at least 21 percent increase as well. Specimens of corex slag bring down the rates of usage as compared to the specimens of OPC which are used. For the specimens of both OPC and corex the rate of corrosion is seen to reduce considerably with the w/b proportional decline. The rate of corrosion is expanded due to the crack reopening in the specimens of crack. In the rate of corrosion the expansion was higher especially if the specimen was higher with the corrosive rate. If the specimen was currently corroding before the crack reopening this expansion in corrosion rate was higher [44].

B. Kim et al. (2011) discussed polypropylene (PP; 0.5%) along with the polyvinyl alcohol (PVA; 0.75%), and also the steel hooked ends with 1 percent of fibres which were estimated inside this investigation by the concrete fibre reinforcement and their execution especially when exposed to the severe or critical environment. The width of 100x100x360mm for the conventional beam specimens was made and for the three sort of conditioning system they were uncovered for the period of 27 months. This was done in both the

situations of un-cracked and pre-cracked structures. For the FRC the degradation turned into the estimation while making use of research with visible and photographic tools. The porous pore area exposure along with the trying out of the destructive beam the analysis was made for the electron microscopy scanning and the measurement in the carbonation depth. For the fibre types of all the shapes and kinds which were assessed and blended, the degradation of important surface and carbonation also demonstrated that the specimens remain uncovered to the lower pH drenching which is intended to stimulate the water swamp. The further noteworthy degradation in each of the net residual strength is shown by these specimens along with toughness. Here in the case, the troubles again in the comparison between the samples which were un-cracked or pre cracked were found as a result of re following of the mended and pre cracked specimens for the solutions such as lime or salt with the materials disintegrated. An unobtrusively not all that terrible opposition from salt water splashing and w/d moulding was looked for all fibres, among fibres types, steel filaments exhibited the most dumbfounding solidarity to moulding contrasted and PP and PVA strands [45].

BERROCAL Carlos G et al. (2013) showed distinctive strength in parts of steel-fibre reinforced cement (SFRC). They investigated that on account of the fibres' ability to capture crack width propagation, porosity was unequivocally affected for broken cement contrasted and plain concrete. This paper goes for deciding the common sense of using steel fibre reinforced concrete in blend with customary steel support in chloride condition as a way to deal with improve the durability of reinforced concrete structures [46].

Mandeep Singh Saroe et al. (2014) investigated the effect of including steel fibres with perspective proportion 80 and length 60mm on solid properties in newly blended and solidified states. The concrete are created by fibres with changing volume rates i.e., 0.5%, 1.0% and 1.5% by volume. Around the complete of the examination, the effects of the mixes with the plain concrete and the relationship bend are gotten for compressive strength, flexural strength, bounce back number and ultrasonic pulse velocity. The outcomes have exhibited that the adding concrete to the solid addition the compressive strength, flexural strength and rebound number of course including fibres tumbling off the workability and ultrasonic pulse velocity of cement [47].

Abdul Ghaffar et al. (2014) analysed the utilization of steel fibres in basic cement to upgrade the mechanical properties of cement. The objective of the examination was to decide and take a gander at the refinements in the properties of cement containing without fibres and cement with fibres. This examination was finished using a couple of tests, compressive test and flexural test. An aggregate of eleven blend clumps of cement containing 0% to 5% with a break of 0.5% by wt. of cement. 'Hooked' steel fibres were endeavoured to decide the difference in the mechanical properties of cement. The functionality of cement, in a general sense, is tumbling off as the fibre portion rate increases [48].

Alizade et al. (2015) investigated the impact of steel fibre corrosion on the mechanical properties of steel fibre strengthened cement. He performed 3 tests 1) acceleration corrosion tests of steel fibre reinforced concrete, and 2) pre-corroded steel fibre-reinforced concrete test. 3) Single fibre pull out test to survey the effect of corrosion on the behaviour and the failure modes. He broke down that the shade of the example surface stretched out from light orange to dull darker. A Little changed in introductory modulus of flexibility was also distinguished after presentation. Despite the preliminary and the presentation condition, no cracking in perspective of corrosion, was perceived on the surface of steel fibre reinforced concrete [49].

Carlos G.Berrocal et al. (2017) researched, probably and numerically, the impact of fibre reinforcement on the beginning of corrosion induced cracks in cement and the bond behaviour of corroded reinforcement bars in fibre reinforced concrete. He inspected that after cracking, fibre reinforced specimens dependably shown diminished crack widths contrasted with plain concrete specimens, cracks being around half as wide at corrosion levels drawing nearer toward 8% [50].

Jun-hua Wang et al. (2017) analysed the fundamental mechanical behaviour of reinforced concrete (RC) beams using chloride corrosion harmed steel reinforcement and exposed to sulphate ions condition. To this end, ten RC beams were viewed as which contained 5% sodium chloride and executed by a progression of drying inundation cycling (15% sodium sulphate immersion solution). The failure mode of test shaft changed from shear to flexural failure mode when the corrosion level of steel reinforcement and cement accomplishes a critical level, despite for test beams with little shear span ratio which fails in shear mode [51].

Mohammad Ali Barkhordari Bafghi et al. (2017) studied that the deterioration in the marine concrete structures and their reinforcement or RC structures with the well-defined structure inside the bars of steel is the corrosion due to the concrete surface

cracks and they are likely to prompt the load carrying capacity reduction along with ductility and safeness of structure. It also is seen that the fibres of steel can be declined and cracking can be postponed and the flexural strength can be increased along with the added ductility in the structures of RC. In order to carry it out, the atmosphere of marine as well as Oman sea tidal zones and the fresh water are seen for the beams and their flexural behaviour, the PC which stands for the plain concrete, along with SRFC which stands for the steel fibre reinforcement of RC, the steel fibre containing concrete etc. along with the reinforcement bars with ((R+S).C) at 28, 90 and 180 days were resolved. The beams comprised of bars which were 99 percent un-cracked and precracked with the width estimation of as much as 200x200x750 mm. As seen in the outcomes for the period of 180 days the toughness of the pre cracked material along with the flexural strength of the beams were more than 22 to 44 percent higher as compared to the bars of RC pre-cracked. The steel fibre impact on the load potential addition along with the RC toughness of the pre-cracked surface was used at the same time for the beams. When the steel fibre was added inside the RC beams un-cracked, the capacity to carry load and their toughness was seen to increase by 20 percent. Toughness inside the marine atmosphere along with the load carrying potential and the tidal zones were seen to be lower by 15% as compared to the conditions where freshwater was used [52].

In 2018, Lijun Hou et al. present paper on the central pull-out tests were carried out to investigate the bond behaviour of SFRC and pre-corroded steel bar obtained in concrete specimens. The varied parameters included corrosion ratio and cover thickness to rebar diameter ratio (*C/D*). The experimental results revealed that the confinement and bridging action of fibre can improve the bond strength and transform the failure mode from splitting to pull-out or combined splitting and pull-out. Bond strength decreased with increasing corrosion ratio and decreasing *C/D*, whereas the residual bond strength remained no less than that of non-corroded rebar especially for specimens with a small *c/d*. Bond strength degradation, bond toughness variation and bond-slip descending behaviours with corrosion ratio were correlated to *C/D* and failing mode. A modified bond strength model considering the coupling effect of corrosion and *C/D* was proposed, and the calculated strength agreed well with the tested [53].

In 2019, Liang Fan et al. proposes a smart reinforced concrete instrumented with a distributed fibre optic sensor for in-situ monitoring, presents an innovative method to quantify mass loss of steel bar using unique distributed sensor data, and studies corrosion-induced expansion of steel bar in steel fibre reinforced concrete. Electrochemical test and the distributed sensor data were used to understand the corrosion deterioration process of the steel-concrete composite. Effect of the steel fibre on the deterioration process is evaluated under different concrete surface conditions, and the underlying mechanisms are investigated. The results indicate that steel fibres reduced the corrosion rate of steel bars by mitigating electron transfer from the steel bar, delaying concrete cracking, and limiting the crack width. The effect of concrete surface defects shows a transition phenomenon. This research gains insights into the corrosion deterioration mechanism and strategies for improving the long-term durability of steel-concrete composite [54].

In 2020, Haitang Zhu et al. investigates the flexural performance of steel fibre reinforced concrete (SFRC) beams with fibre-reinforced polymer (FRP) bars under repeated loading. Fourteen beams with dimensions of 150 mm × 300 mm × 2100 mm were cast and tested via a four-point bending test. The effects of the FRP reinforcement ratio, type of reinforcement, concrete strength, steel fibre shape, and steel fibre volume fraction on the failure mode, cracking moment, skeleton curve, deflection, strength degradation, and flexural strength of the beams were investigated. The test results revealed two different failure modes for the SFRC beams reinforced with FRP bars, including compression failure and tensile failure. The flexural strength of the beams decreased as the number of load cycles increased under the same deflection. A higher FRP reinforcement ratio, concrete strength, and steel fibre volume fraction enhanced the flexural strength of the beams and decreased the deflection. Finally, the flexural strength test results were compared with several different prediction models. The ACI 440.1R-15, CSA S806-12, and GB 50608–2010 models underestimated the flexural strength of the beams, while the proposed prediction model, which based on the equivalent force block, provided more accurate prediction results[55].

In 2021, Doo-Yeol Yoo et al. studied the corrosion behaviours of partially and fully deboned steel fibres embedded in ultra-high-performance concrete (UHPC) and their impact on the pull-out behaviour were investigated. For this purpose, pre-loaded dog-bone samples were immersed in a 3.5% standard sodium chloride (NaCl) solution for 4, 10, and 20 weeks and then pull-out tested. The degree of corrosion on the fibre surface was determined by energy-dispersive X-ray spectroscopy. The test results indicated that the

bond strength and pull-out energy are improved by 54% and 90% maximally due to surface corrosion up to an immersion duration of 20 weeks. The effect of surface corrosion on the pull-out properties was insignificantly influenced by the fibre pull-out state (partially or fully deboned) up to 10 weeks, but the fully deboned fibre was prematurely ruptured at the longest duration of 20 weeks. The corrosion resistance of steel fibre in UHPC was earlier deteriorated, given the full deboning state (or the larger slip). The chemically deboned region was evidently corroded due to ferric oxide formation even after the shortest immersion duration of 4 weeks, whereas the bonded region with highly densified microstructures was insignificantly corroded. By surface corrosion, the pull-out energy of the steel fibre in UHPC increased more significantly as compared with the average bond strength, owing to the twice or more frictional shear stress acting at the fibre–matrix interface [56].

In 2022, Francesco Bencardino et al. tries to reduce times and costs of intervention, number of used materials, as well as the amount of chemical compounds, a novel Inhibiting-Repairing-Strengthening (IRS) technique is proposed and experimentally tested. Using a suitable matrix (thixotropic mortar with passivation properties) the main three operations of steel bars corrosion inhibition/protection, restoring of deteriorated concrete, and installation of the external strengthening can be carried out in one-step. For evaluating the effectiveness of both new strengthening system and installation technique an extensive experimental investigation was planned and developed. A part of the experimental research includes two groups of three RC beams (3.00 m and 4.80 m long): one strengthened with IRS technique, one strengthened with EB technique and one control beam. These beams were tested under monotonic loading. Further two beams, one beam for each group, strengthened according to IRS technique, were also tested under cyclic loading. The experimental results show the validity of the proposed solution in terms of structural performance and environmental sustainability [57].

III CONCLUSION

It is known quite commonly from various aspects of literature that steel fibre addition in the reinforcement cement concrete enhances the mechanical features of it by many folds. In many applications it has been used but as far as structural elements are concerned its applications are limited such as beam and slabs due to the confidence lacking in the designers structure on its toughness and durability and when adverse environments are exposed its long term behaviour. On the other hand, some evidence is there in the literature which discovers the long term steel fibre behaviour for the reinforced concrete but no proper or adequate research is there on the behaviour it shows under the adverse atmosphere for a long time. So the current demand is to determine the corrosive environment and its impacts on the rebar which in the steel fibre are embedded for the concrete reinforcement.

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