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REVIEW

Role of Chemical based Inhibitors in Protecting the Concrete Structures from Corrosion: Present Status and Future Prospects

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Building industry is a rapid growing worldwide because of urbanization. Concrete is a primary requirement in the construction of residential buildings, shopping malls, industry structures, *etc.* The life of a building mainly depends on the ingredients used in the concrete during the construction activity. However, the concrete structures undergo deterioration because of the presence of highly corrosive ions in the admixture after long term. If the corrosion of the steel rods is severe in concrete, the buildings may collapse at any time which will lead to heavy loss for human lives. In this regard, protection of steel embedded in concrete from the corrosive attack is an important issue among civil engineering professionals and chemists. For this purpose, the technologies related to the adoption of suitable composition of steel, suitable combination of ingredients in the concrete, change of processing parameters/methodologies, *etc.* are being worked out. Apart from this, suitable chemical inhibitors are being studied across the globe to overcome this corrosion problem in a greater extent. In this review article, the type of chemical inhibitors used in admixtures and their effective role in protecting the concrete structures are discussed. Based on this, suitable suggestions are also recommended for the benefit of the society.

Keywords: Concrete structures, Corrosion, Failure of buildings, Chemical inhibitors, Protection of steel.

INTRODUCTION

Steel is one of the familiar alloys which are mostly recommended in the construction industry especially for concrete structures as a backbone to hold all other ingredients together [1]. Steel is mainly made up of iron and carbon. Upto 2% of carbon is usually present to improve the strength of steel structures [2]. In olden period, great pyramids in Egypt were constructed using concrete technology [3]. The concrete consists of the following individual components, *viz.* sand, aggregate, a cement binder and water. These components usually mixed in proper ratio during the construction activity [4]. Curing gives adequate strength to the concrete structures [5]. The casting and curing of concrete are usually carried out for 'slabs on ground' like floors, pavements, *etc.* and structural applications like columns, beams, ceiling-tops, *etc.* [6]. Steel rods embedded in concrete may undergo corrosion after prolonged duration because of entry of corrosive ions, atmospheric gases, *etc.* [7]. The pH of concrete paste was reported to be above 12 and in this range steel may not corrode. If the protective coating in the concrete steel reinforcement is removed or broken, steel may undergo corrosion by undergoing reaction with the environment [8,9]. Non-uniform corrosion of reinforcements may be one of the reasons for the removal of protective layer from the concrete structures [10]. The steel rods present in bridges may undergo severe corrosion due to seepage of chloride ions from water reaches the surface of the reinforcing bar [11]. Pitting is one of severe forms of corrosion which can close down the life of bridges easily [12]. Bridges in northern states of USA undergo corrosion because of snow falling with Cl^- ions and the sea shores by presence of humid salt water [13]. In the same way, if steel rods in the concrete admixture undergo corrosion, buildings can be collapsed because of failure in the mechanical strength of steel rebars [14]. Even though corrosion is a universal problem, suitable methodologies need to be adopted to prevent corrosion of steel in concrete. Among the various techniques available, epoxy coating over steel rods is widely suitable one [15]. However, it was reported that epoxy-coated bars may not provide good corrosion prevention to steel in Cl^- environment [16].

By reducing the porosity of concrete, we may protect the steel rebars embedded in the concrete. If the porosity of concrete is reduced, entry of corrosion causing ions may be prevented. For this purpose, pozzolans and hydrophobic products are added in the concrete mixture. Pozzolans are silicate based products that can easily undergo reaction with $Ca(OH)_2$ which will improve the cementious characteristics of concrete to a greater level [17]. It was reported that the hydrophobic agents can improve the contact angle between the surface of concrete and water [18]. The application of pozzolans may reduce the strength of concrete [19]. Also, it was found that hydrophobic agents may not be useful in concrete when the temperature is very low [20]. It was reported that stainless steel reinforcement can also be a suitable method to overcome the corrosion problems exist in concrete structures [21]. However, it is well known that using stainless steel instead of carbon steel in concrete structures is costly [22]. Use of inhibitors in the concrete is an effective method of retarding the corrosion problem of steel rods. Therefore, the presence of chemical inhibitors in the concrete mixture can delay or retard the corrosion activity and extend the life of concrete structures [23]. When the chemical inhibitors are added during concrete mixing, they can form a passivation layer over the steel. This will prevent the corrosive ions to enter the steel surface and prevent it from corrosion completely [24]. Different forms of chemical inhibitors were used to protect the steels rods of concrete. Both inorganic and organic chemical inhibitors were studied by several researchers. In this review article, the role of chemical inhibitors used to protect the steel rebars from concrete corrosion is presented in a detailed manner.

Mechanism of corrosion in concrete structures: The corrosion of steel in concrete may begin with the presence of small cracks or pinholes in its surface. The expansion of corroding steel forms tensile stress in the concrete which may lead to the creation of anodic pinholes or cracks [25]. The remaining portion of steel will become a cathode, while concrete acts as an electrolyte. Thus, an electrochemical cell formation occurs. During the reaction, iron present in steel oxidized to Fe^{2+} ions with the release of electrons. The anodic oxidation can be indicated as per eqn. 1:

$$2Fe_{(s)} \longrightarrow 2Fe^{2+}_{(aq)} + 4e^- \qquad (1)$$

Fe^{2+} ions entered the concrete and the electrons traveled from anodic to cathodic site where they join with water and oxygen in the concrete. It is a reduction reaction, which can be represented as follows (eqn. 2):

$$2H_2O_{(aq)} + O_{2(aq)} + 4e^- \longrightarrow 4OH^-_{(aq)} \qquad (2)$$

Fe^{2+} ions can undergo reaction with hydroxide ions (OH^-) and form green precipitate of ferrous hydroxide (eqn. 3).

$$2Fe^{2+}_{(aq)} + 4OH^-_{(aq)} \longrightarrow 2Fe(OH)_{2\,(s)} \qquad (3)$$

In presence of excess oxygen and water, ferrous hydroxide can be converted into the brown coloured precipitate of ferric hydroxide (eqn. 4).

$$4Fe(OH)_{2\,(s)} + O_{2\,(aq)} + 2H_2O_{\,(aq)} \longrightarrow 4Fe(OH)_{3(s)} \qquad (4)$$

Ferric hydroxide precipitate may further undergo dehydration to form $Fe_2O_3{\cdot}H_2O$, which is called as a rust [26].

Chemical inhibitors and their role in protecting steels from concrete corrosion: Chemical inhibitors are usually added to the concrete admixtures in order to prevent steel structures from corrosion [27]. Usually chemical inhibitors will be mixed in appropriate concentration/quantity when the admixtures are prepared, which may form a protective film over the steel surface. Otherwise, the chemical inhibitors may undergo chemical reaction with concrete to form complexes, which in turn retards the permeability of concrete [28]. Therefore, one must choose chemical inhibitors carefully which should alone hinder the corrosion reaction without degrading the quality of concrete [29]. The chemical inhibitors which are used in concrete may be classified as: (i) inorganic inhibitors; (ii) organic inhibitors; (iii) green inhibitors and (iv) composite inhibitors. A detailed discussion about these inhibitors is indicated below:

Inorganic inhibitors: Inorganic nitrite salts are said to be useful in protecting steel from corrosion caused by chloride and sulphate ions. Calcium nitrite based chemical inhibitor retarded the corrosion rate of steel in Cl^- mixed mortar and enhanced the Cl^- threshold limit from 0.22% to 1.95% by wt. of cement [30]. Potassium nitrite, sodium nitrite, lithium nitrite and bismuth nitrite were added to cement to modify its setting time. Calcium nitrite was found to have excellent rust resisting property in concrete structures [31]. Calcium nitrite based inhibitor was found to be effective for pozzolona portland cement (PPC) mixtures than ordinary portland cement (mixtures) in controlling concrete corrosion [32].

Calcium nitrite based inhibitors: Calcium nitrite is an effective corrosion inhibitor in protecting the concrete structures in a chloride environment. The nitrite ion can react with Fe^{2+} ions to form a passive film over the steel surface which may hinder the corrosive attack of chloride ions [33]. Jinsong *et al.* [34] studied the corrosion characteristics of API X7120 carbon steel of concrete with calcium nitrite as an inhibitor. The results showed that calcium nitrite exhibited excellent inhibition efficiency. Calcium nitrite reduced the stiffening rates of cement by 80% at 50 ºC [35]. It was found that the quarry dust along with calcium nitrite chemical inhibitor in concrete enhanced the corrosion resistance property of steel rebar [36]. When calcium nitride inhibitor is mixed with concrete, it resulted in the reduced compressive strength. Also, it influenced the mechanical characteristics of the concrete and hence it has to be used with utmost care [37]. It was found that calcium nitrite reduced the carbonation depth in the concrete structures [38]. Compressive strength of the concrete slaps enhanced from 26.6 to 38.7 N/mm^2 with the addition of chemical inhibitor calcium nitrite [39]. Addition of calcium nitrite in alkaline environment exhibited with excellent results. NO_2^- ions released by calcium nitrite can undergo reaction with Fe^{2+} ions in alkaline environment and produce γ-FeOOH (Lepidocrocite) film, which is highly stable. The reaction path is indicated in eqn. 5 [40].

$$Fe^{2+} + OH^- + NO_2^- \longrightarrow NO + \gamma\text{-}FeOOH \qquad (5)$$

Sodium nitrite based inhibitors: Sodium nitrite was also used as an inhibitor to overcome concrete corrosion. The strength of self-compacting concrete enhanced with the addition of sodium nitrite based chemical inhibitor [41]. Sodium nitrite was used to control the corrosion rate of steel in geopolymer concrete. It was found that the inhibiting efficiency of sodium nitrite enhanced with an enhancement in dosage [42]. The compressive strength and split tensile strength concrete cubes enhanced by 3% with presence of sodium nitrite chemical inhibitor. The permeability of chloride ions was also retarded in presence of sodium nitrite chemical inhibitor. The water absorption behaviour of concrete was reduced by 40% in presence of sodium nitrite based inhibitor [43]. Sodium nitrite exhibited an inhibition efficiency of 54.84% in steel rebar [44]. A binary system consists of sodium nitrite and Zn^{2+} exhibited 93% of inhibition efficiency in retarding the corrosion of mild steel in simulated concrete pore solution (SCPS) [45]. The compressive strength of concrete specimens with sodium nitrite was enhanced to 38.9% in presence of sodium nitrite [46]. The mixture of $NaNO_2$ with 0.01 M D-sodium gluconate based chemical inhibitor reached an inhibition efficiency of 99.0% against corrosion of steel in simulated polluted concrete pore (SPCP) solution [47].

Lithium nitrite based inhibitors: The role of lithium nitrite based chemical inhibitor in preventing the steel from corrosion was experimented. Further, in presence of lithium nitrite, the durability of concrete was enhanced [48]. Lee & Shin [49] studied the effect of lithium nitrite incorporated in mortar. The dosage of lithium nitrite was 0.6 in terms of NO_2^-/Cl^- to overcome corrosion of rebars in concrete. Kobayashi & Takagi [50] studied the criteria for suppressing the expansion of alkali-silica reaction (ASR) deteriorated concrete by injecting lithium nitrite solution. Lee *et al.* [51] studied the role of lithium nitrite and dimethyl ethanolamine chemical inhibitors in protecting the steel from corrosion in concrete. The results indicated that both of them have exhibited better anti-corrosion properties. The nitrite ion (NO_2^-) from lithium nitrite reacted with Fe^{2+} ions and because of this the movement of Fe^{2+} ions from the anode will be prevented. The reaction yielded ferric oxide (Fe_2O_3), which will deposit over the surface of iron as a passive film to control the corrosion reaction. The reaction path is indicated in eqn. 6:

$$2Fe^{2+} + 2OH^- + 2NO_2^- \longrightarrow 2NO_2\uparrow + Fe_2O_3 + H_2O \quad (6)$$

Sodium monofluoro phosphate based inhibitors: Sodium monofluoro phosphate (Na_2PO_3F) (MFP) has been recommended as a surface inhibitor to protect the steel embedded in concrete mixture [52]. MFP was found to exhibit better inhibitory efficiency at moderate temperatures. It was reported that Na_2PO_3F can be a good inhibitor in protecting the steel from corrosion in carbonated concrete [53]. It was reported that when portlandite is present in the concrete, the interaction between MFP and Ca^{2+} ions can result in the formation of fluoropatite which may inhibit the corrosion [54]. A comparative research work dealt with the protection of steel by adding the inhibitor based on phosphates, *viz.* Na_2PO_3F, Na_2HPO_4 (DHP) and Na_3PO_4 (TSP) in ordinary portland cement (OPC) pastes has been carried out. The results found that the DHP and TSP are excellent alternate chemical inhibitors to the costly MFP [55]. It was found that MFP is effective in protecting the reinforced steel rebars embedded in concrete with not thicker than 1 cm [56]. Douche-Portanguen *et al.* [57] studied the relationship between MFP and concrete and their interaction with the surface of the steel structures by XRD measurements. They have concluded that the interaction is dependent based on the concentration of MFP in the concrete sample.

Potassium chromate based inhibitors: Potassium chromate is an easily available inorganic salt which can form an ion in the positive polar region. It is found to be a good chemical inhibitor in protecting the steel structures based on A513 mild steel from corrosion in acid/chloride environment. Its inhibiting efficiency is found to be 60% [58]. It was found that 0.145 M potassium chromate can give good inhibitive performance for steel rebars present in concrete when exposed to sulfuric acid medium. Further, the mixture of potassium dichromate (0.032 M) and potassium chromate (0.097 M) can give better inhibiting performance in protecting the steel rebars present in the concrete structures in saline regions [59]. The compressive strength of concrete structure was good in sulfuric acid in presence of 0.145 M K_2CrO_4 medium. However, it was decreased in saline environment in presence of 0.679 M $NaNO_2$ [60]. The inhibition efficiency of potassium chromate–Zn^{2+} in protecting the mild steel embedded in SCPS was found to be 98%. The polarization studies confirmed that K_2CrO_4 is an effective inhibitor in controlling the anodic oxidation reaction of mild steel in the concrete [61]. When K_2CrO_4 (9 to 3 g) was mixed in concrete, a better compressive strength is resulted. However, 7.5 g of K_2CrO_4 was reported to be the better inhibitor concentration in preventing the mild steel from corrosion in sulphuric acid medium [62]. Fayomi *et al.* [63] studied the inhibiting performance of cetylpyridinium chloride (CPC) and K_2CrO_4 against A513 mild steel in HCl and NaCl environment. The inhibitive percentage was found to be 60% for the above combined chemical inhibitors (K_2CrO_4 + CPC). It was reported that a mixture of 0.15 M K_2CrO_4 and 0.07 M $C_6H_5NH_2$ (aniline) chemical inhibitors can give better performance in protecting the mild steel rebars embedded in the concrete against corrosion in NaCl medium [64]. It was reported that 0.03 M K_2CrO_4 can be a very effective chemical inhibitor in controlling the carbon steel and its inhibition efficiency can reach the maximum of 97.63% [65].

Organic inhibitors: It was reported that organic substances may give electrons to the metal surface or may accept electrons from the metal surface, resulting in the formation of covalent bonds thus are considered to be good corrosion inhibitors in preventing the metal against corrosion in concrete structures [66]. Organic inhibitors were tried in preventing the concrete corrosion due to their less cost and ease of availability. They can be used as both admixture chemical inhibitors and migrating chemical inhibitors. They can easily join with iron atoms of the steel surface in concrete and form protective film over the metal surface to control corrosion [67]. Amines and carboxylic acid based organic inhibitors were generally recommended for preventing metals from corrosion in the concrete structures [68]. The description about types of organic inhibitors is discussed below:

Amines based inhibitors: Moreno *et al.* [69] studied the efficiency of amine-ester based chemical inhibitor for preventing corrosion of steel in concrete slabs. They have reported that the specimens containing the 100% dosage (5 kg/m^3) have shown excellent corrosion protection than the control slab. However, this protection withstood only for 400 days. Monoethanolamine (MEA) was found to be active in protecting steel of carbonated concrete structures based on the formation of passive film through physical/chemical adsorption over the steel surface [70]. It was reported that the adsorption of amine based inhibitors can take place in concrete slabs through functional group anchoring process where a non-polar or hydrophobic chain orients perpendicularly to the metal surface. The hydrophobic chains can interact easily with the corrosive ions to form a passive film over the metal surface. Triethylenetetramine (TETA) showed better corrosion inhibition than that of dimethylethanolamine (DMEA) for carbon steel embedded in chloride induced concrete structures [71]. It was found that amine based aliphatic and aromatic compounds adsorb over the metallic surface by co-ordinate bonds which may result as protective film to retard the corrosion rate [72]. Diethanolamine and methyl diethanolamine showed a corrosion prevention efficiency of 35.69% to 39.91% and 66.07% to 69.09%, respectively in presence of $Ca(OH)_2$ mixed with NaCl in concrete [73]. Rai *et al.* [74] studied the effect of ethanolamine and biodiesel in reducing the rate of corrosion in the reinforced structures. The corrosion inhibition efficiency of ethanolamine was found to be 63.41% after 90 days of exposure in presence of 3.5% of NaCl and for biodiesel, it was found to be 68.04%. Nguen & Shi [75] reported that 0.05 M *N,N′*-dimethylethanolamine (DMEA) was a good inhibitor. It was found that DMEA was able to push Cl^- ions from the surface of steel to prevent the surface film. DMEA was considered to be a cathodic inhibitor because it can retard the cathodic reaction of steel in the corrosive environment. It was found that alkanolamine based chemical inhibitors can raise the corrosion resistance property because of carbonation effect in the environment of Cl^- ions. It was also reported that alkanolamine based chemical inhibitor with inorganic coating can result in better corrosion inhibition characteristics in concrete structures [76]. It was notified that aminoalcohol based mixed corrosion inhibitors can be adopted in concrete admixtures [77]. A novel method called bidirectional electromigration rehabilitation (BIEM) was used to add TETA, a chemical inhibitor to steel present in both carbonated and non-carbonated concrete in aqueous medium [78].

Carboxylic acid/carboxylate based inhibitors: Water soluble carboxylic acids were tried as chemical inhibitors to protect corrosion of steel in concrete admixtures. It was found that malonic acid can be an effective chemical inhibitor even in the Cl^- (2.5 wt.%) environment [79]. It was found that carboxylic acid based inhibitors can improve the corrosion resistance of steel along with that they can enhance the environmental and economic aspects to a greater level [80]. The adsorption of carboxylate based inhibitors on a steel surface was mainly due to the formation of $Fe\text{-}OOC\text{-}C_x$ based compounds [81]. Amino carboxylate based inhibitors can be able to provide perfect corrosion prevention to the steel rebars present in the concrete thus they can enhance their life to a greater level [82].

The corrosion of steel was prevented mainly because of the adsorption of carboxylic based groups over the steel surface [83]. Xu *et al.* [84] reported the synthesis of polycarboxylate super-plasticizer based chemical inhibitor for protecting the steel of concrete structures. Cabrini *et al.* [85] studied the effect of aspartic and lactic acid salts based chemical inhibitors on Cl^- corrosion of steel rebars embedded in concrete structures in alkaline pore solution. Further, it was observed that the aspartate ions could adsorb over Fe^{2+} surface easily because of their chelating behaviour resulting in better corrosion inhibition property. Polycarboxylates based chemical inhibitors were found to be effective in providing corrosion protecting behaviour to steel specimens present in concrete. Polymethacrylate acid-*co*-acrylamide exhibited a corrosion inhibition efficiency of 92.35% [86]. Peng *et al.* [87] reported the leaching behaviour and corrosion inhibition of rare earth carboxylate incorporated epoxy coating system.

Green inhibitors: To protect the steel present in concrete, generally organic and inorganic inhibitors were used. In order to enhance the corrosion resistant property of steel, green inhibitors based on plant extracts were effectively used. These green inhibitors were selected based on their physico-chemical and biological characteristics [88]. The green inhibitors are safe, biodegradable and environmental friendly. As studied, these inhibitors can also form a protective film over the metallic surface of the concrete, which generally prevent the corrosive gases/chemicals/ions, *viz.* O_2, CO_2, SO_4^{2-}, Cl^- and moisture from attacking the metallic surface. A brief discussion on various green compounds used for preventing the concrete corrosion is as follows:

Azadirachta indica (Neem) based inhibitor which is generally available in two forms (powder and solution). Compressive strength of concrete got reduced with the addition of neem powder, whereas the neem solution delivered good results [89]. *A. indica* leaf extract (neem) was used as a green inhibittor for carbon steel in reinforced concrete in saline simulated media. It resulted in the long-term corrosion protection of 95% after 182 days of examination [90]. Harb *et al.* [91] used olive leaf extracts made in different common organic solvents and found the best inhibition efficiency (91.9%) with methanol extract. It was also reported that *Vernonia amygdalina* (bitter leaf) extract can exhibit better corrosion inhibition efficiency of 75% for the carbon steel embedded in concrete in simulated seawater [92]. Subbiah *et al.* [93] reported that conifer cone (*Pinus resinosa*) can be used as a green corrosion inhibitor. Extracted conifer cone extract possessed a corrosion inhibition efficiency of 81.2% in Cl^- contaminated simulated concrete pore solution (SCPS). Extract made from the endosperms of some leguminosae plants was used as an effective green inhibitor for concrete armor protection against H_2SO_4 corrosion. It resulted with a corrosion protection efficiency 94.1% [94]. The extracts made from *A. indica* (Neem) and aloe-vera leaves were also used to study the corrosion resistance properties of steel reinforcement in concrete. *Azadirachta indica* (neem) inhibitor has shown good corrosion inhibition than that of aloe-vera inhibitor [95]. Ascorbic acid was tried as a green corrosion inhibitor and found that 0.1 g/L of ascorbic acid resulted with an inhibition efficiency of 88.96% [96]. Coconut coir dust extract was tried as a green corrosion inhibitor for steel rebar in the concrete and it exhibited an inhibition efficiency of 95% in SCPS with 3.5% NaCl solution [97]. Green tea extract was reported as a mixed-type corrosion inhibitor which can produce a protective layer over the surface of steel rebar and exhibit the inhibition efficiency of 75-80% [98]. Calcium palmitate can be used as a green corrosion inhibitor for steel in concrete environment. It resulted with 91-92% inhibition efficiency after 90 days of observation in 3.5% NaCl solution [99]. *Bambusa arundinacea* leaves extract was also used as a sustainable corrosion inhibitor [100]. This was considered as an alternate for commercially available nitrite and amine based corrosion inhibitors because of its viability, versatility and environment friendly. Similarly, *Mangifera indica* resins paste extracts were used as corrosion inhibitors to protect steel rebars from corrosion in concrete environment. The inhibited specimens resulted with enhanced tensile strength values [101].

Composite inhibitors: A composite inhibitor of layered double hydroxides (LDHs) intercalated with organic phthalates (PTL) and hydroxide ion (MgAl-LDHs-OH-PTL) was tried and its inhibition efficiency was found to be 90% against carbon steel present in SSCP solutions [102]. A composite corrosion-inhibiting system containing both mineral and chemical [ordinary portland cement + fly ash + sodium hydroxide (1%) + sodium citrate (1%) + sodium stannate (1%) + calcium oxide (0.5%)] admixtures was designed to examine its performance in concrete. The above composite inhibiting system resulted in 10-fold decrease in the corrosion rate [103]. Composite inhibitor containing $NaNO_2$ and NaH_2PO_4 was applied over the surface of rebar for studying the corrosion behaviour in concrete environment. The results confirmed that nitrite has better inhibitory effect than phosphate [104]. The corrosion inhibition effect of DMEA with caprylic acid was examined for preventing carbon steel corrosion in the chloride solution. The synergic effect of both compounds resulted in better inhibition efficiency. It was confirmed that DMEA makes a quaternary ammonium salt with the proton in carboxylic acid and a cyclic complex resulted between the salt and iron. This was the reason for the better inhibiting efficiency by DMEA and carboxylic acid [105].

Calvo *et al.* [106] studied the corrosion inhibition properties of a composite containing calcium nitrite and disodium tetrapropenyl succinate in combination with fly ash and silica fume portlant cement. They found to exhibit excellent performance in enhancing the strength and durability characteristics of the concrete. Composite containing organic amino-alcohol compound and DMEA was prepared and used as the corrosion inhibitors for reinforced steel in SCPS. It resulted with a good corrosion inhibition of 98.63% in dry-wet cycle experiments [107].

Conclusion

Concrete structures tend to undergo deterioration because of corrosion in steel rebars. Excess corrosion in steel structures may lead to damaging of buildings, bridges, dams, concrete structures, *etc.* Suitable user friendly techniques are needed to overcome this global problem. Adding chemical inhibitors in appropriate concentration/quantity to the admixtures is one of the growing interest to avoid this problem. Generally four types of inhibitors, *viz.* inorganic, organic, green and composite were used for this purpose. The inorganic mixture of $NaNO_2$ with 0.01 M D-sodium gluconate based chemical inhibitor reached an inhibition efficiency of 99.0% in concrete. Organic inhibitor based on *N*,*N′*-dimethylethanolamine (DMEA) was found to be effective in preventing the corrosion of steel in concrete. Green inhibitors were found to be safe, biodegradable and environment friendly. Among different green inhibitors studied in concrete admixtures, *Azadirachta indica* leaf extract (neem) was good in giving long-term corrosion protection of 95% after 182 days. Based on the studies made by several researchers, it has been concluded that addition of chemical inhibitors can be adopted in suitable proportions to overcome the corrosion issues in concrete structures.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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