A Review on corrosion of steel reinforced in cement concrete

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Abstract – *The reinforcing steel corrosion is an important issue of construction industry as corrosion is one of the major cause of structure failure. Furthermore, it has turn out to be financial trouble to many government agencies as lot of public money is wasted due to this corrosion. From the literature present, we know that the iron in the steel has natural affinity to revert sooner or later to its most stable oxide state, so once initiated, it becomes complicated to completely dispose of the corrosion .The adaptation of corrosion defense procedures in new construction such as use of superior design and construction practices, enough concrete cover depth, low permeable concrete and coated reinforcing steel, use of pozzolanic materials such as fly ash in concrete, proper water cement ratio and coated reinforcing steel helps in avoidance of steel reinforcing corrosion to huge extend. In this paper review of various papers is presented, steel corrosion can be tested by various methods it can be physical or chemical different research work used different methods to detect cause and extent of corrosion. When corrosion of steel reinforcement is studied properties and composition of concrete is unavoidable as steel has to remain in contact with concrete ingredients. Early recognition of the corrosion process could facilitate limit the location and extent of required repairs or replacement, as well as reduce the cost related with remedial work.*

Key Words: Corrosion, Reinforced Concrete, Reinforcement Bars, Impermiability, w/c Ratio, Moisture content, Cracks, Damage, Potential

1. INTRODUCTION

Reinforced concrete is extensively used for construction on a large scale due to its advantageous structural properties. Reinforced concrete also called reinforced cement concrete or RCC, that works fine in either tension or compression: the concrete resists squeezing (provides the compressive strength), while the steel resists bending and stretching (provides the tensile strength). In effect, reinforced concrete is using one composite material inside another. Concrete becomes the matrix while steel bars or wires provide the reinforcement. The steel bars (known as rebar, short for reinforcing bar) are usually made from twisted strands with nobbles or ridges on them that anchor them firmly inside the concrete without any risk of slipping around within it. Theoretically, we could use all kinds of materials to reinforce concrete. Generally, we use steel because it expands and contracts in the heat and cold roughly as much as concrete itself, which means it won't crack the concrete that surrounds it as another material might if it stretched more or less.

Fig -1: corroded steel embedded in concrete

The corrosion seems to be an all-pervasive event causing extensive obliteration of all types of structures in all countries across the world and has come to be termed as 'Cancer' for concrete. As in steel reinforced concrete, steel is provided to give tensile strength to reinforced cement concrete hence strength of steel is major point of concern. Steel has great affinity towards corrosion which deteriorates not only the steel but the whole RCC structure rate of corrosion and corrosion amount depends on various parameters. These parameters are studied by many of the researchers so as to control damage of steel by corrosion. Though, over the passage of time, due to carbonation or access of chloride ions, pH value starts moribund slowly and alkaline neighboring of the reinforcement bar is lost, heralding the corrosion process, which in turn causes cracks and spalling of concrete. It would thus be realized that the critical factor giving quality and durability of concrete appears to be its impermeability, which can be ensured by providing adequate cement content, low w/c ratio, complete compaction and curing. To study corrosion in steel various corrosion assessment techniques are used, these techniques are followed as requirement of research work.

Fig -2: Reinforcement Steel Bar (Before Corrosion)

2. Literature review

Stephen et al examined Alkalinity, w/c ratio, concrete fluidity during placement, and steel type all influence the corrosion potential of the reinforcing steel when reinforced concrete is subjected to saltwater. Of the two void sizes evaluated during this study, small voids adjacent to the steel create a greater spread between the 25th and 75th percentile of the half-cell potential measurements when compared to locations without voids; however, these small voids have little influence on the average value measured when compared to the larger voids. The behavior of a mixture during placement can strongly influence the amount of labor required during placement; therefore, a more expensive mixture could provide labor savings during placement.[4]

Zaki et al, examined Acoustic Emission (AE) effectively detects the corrosion of concrete structures at near the beginning stage. The capability of the AE technique to detect corrosion occurring in real-time makes it a strong candidate for serving as an efficient non destructive method, giving it an advantage over other non destructive methods.[20]

Kumar et al studied Reinforcement corrosion to concrete structures, its mechanism and factors affecting corrosion of steel in concrete are offered. Extensive research work has been devoted to develop models that predicts the time for corrosion beginning. The study reveals that though Calcium palmitate and its combination with calcium nitrite reduces the concrete strength but inhibition to the corrosion of the rebar increases the service life of the Reinforced concrete by eight to ten times.[2]

Cao et al The water-cement ratios had a significant influence on the magnitude of macro cell current. The lower water cement ratio could effectively inhibit the macrocell current by weakening the kinetics of cathodic and anodic reactions and decreasing macro cell potential difference between cathode and anode.

The water-cement ratios had little effect on the macrocell polarization ratios of cathode and anode but impacted the macrocell polarization slopes of cathodic and anodic steels. The lower water-cement ratio could decrease the macrocell polarization slope of cathode and increase the macrocell polarization slope of anode. Thus, the lower water-cement ratio could not only increase the macrocell polarization resistance of cathode but also increase the macrocell polarization resistance of anode.[1]

Ahmad et al examined that Controlling water cement ratio for corrosion resistance is the easiest and cost effective method. Therefore it should be given prime consideration both at the design and construction stage. A water cement ratio of less than 0.6 compressive strength; therefore it should be kept to the increase in the water cement ratio (as is used in a number of construction projects in Pakistan) may be investigated further for environmental its effect in reducing corrosion rates considering shall give improved corrosion resistance as well as good different conditions. Lowest probable value depending upon the type of construction. A water-cement ratio of more than 0.6 may also be helpful in reducing corrosion rates but with its increase, compressive strength decreases.[12]

Chung et al observed after detailed studies that in a non destructive technique to determine the water content of early-age concrete. The proposed model describes that the dielectric constant increases linearly with increasing water-cement ratio. The corroboration shows that the achieved model has good adaptability and high accuracy, which can be used to develop new diagnosis method based on the measured dielectric constant. This can acquiesce interesting information regarding the concrete curing-sate and structural health monitoring.[3]

Johan et al examined Exposures in constant RHs from 75% to 100% show that the corrosion rate is moisture dependent with a maximum in the interval 91% to 97% depending on the chloride concentration. At higher chloride concentration (2%) the maximum is at the lower end of this RH interval while at lower chloride concentrations (0.1% to 1.0%) the maximum is at the top end of this interval. The interpretation of the maximum corrosion rate is that under the respective relative humidity there is a resistive control while more than the maximum the high water content results in a limitation of oxygen transport. This suggests that chloride brink levels should be evaluated at rather humid conditions (97%) despite the fact that the maximum corrosion rate at higher chloride levels is observed in the interval 91% to 94%.

For cyclic moisture conditions between 75% and 100% RH the corrosion rate at 0.6% chloride was higher than the maximum value obtained at 97% RH static conditions, the most corrosive RH value. This suggests that there is an over estimation of chloride threshold levels evaluated from exposures performed at a standstill conditions.[8]

Falah M. Wegian Experimented out Concretes mixed and cured in seawater have higher compressive, tensile, flexural and bond strengths than concretes mixed and cured in fresh water in the early ages at 7 and 14 days. The strengths after 28 and 90 days for concrete mixes mixed and cured in fresh water increase in a steady manner.[9]

Prakash R. et al showed in their study, it is concluded that the corrosion rate of rebar surrounded in M30, M100 and polymer cement concrete was found to fluctuate with respect to age of concrete and grade of concrete. The result shows that the M100 grade concrete shows lower corrosion rate than normal strength concrete. This may be due to lower permeability and hence the exchange of ions is less and this lead to the lower rate of corrosion. On the other hand the concrete with water soluble polymer exhibits very high rate of corrosion. This may be due to the fact that the effect of polymer in polymer cement concrete was quiescent and hence higher rate of corrosion exhibits.[13]

Altoubat et al examined that With respect to corrosion damage, it was observed that during the corrosion process, there were more longitudinal cracks in the constant current specimens than in the constant voltage specimens. Also, the maximum crack widths for the constant current specimens were greater than those of constant voltage specimens.

Furthermore, the constant current specimens also experienced greater circumferential expansion than the constant voltage specimens. Hence, it can be accomplished that accelerated corrosion using constant current is recommended over the constant voltage in studying the effectiveness of various materials, repair strategies and admixtures to resist corrosion harm.[14]

Sadowski et al explained that In the best ANN optimized by ICA in predicting steel corrosion rate in concrete in the training and test stage, the coefficient is 0.8019 and 0.9045, in that order, and also the line slope of this parameter is equal to 0.7337 and 0.8877, indicating the higher accuracy of model to the peers, also in this model, the statistical factor values of MAE, RMSE and RMSD are less than all models, which presented lower error in this model.[5]

Yujie Zhang concluded that Specimens under tensile stress corrode faster that those under compressive stresses and no stress. On the other hand, specimens under compressive stress show better performance than those under no loading condition, when exposed to chlorides. Inspite of having more protective submissive later under tensile stresses, this layer cannot guard the steel effectively when it is exposed to chlorides. The impact of stress is far more important than the effect of passive layer in protecting the steel against corrosion. One cause could be different nanostructure of the passive layer, formed under tensile compare to that formed under compressive stresses. More porous passive layer with nano cracks on the steel under tensile could cause quick dissolution of this layer against chlorides. While there is no distinguished trend among compressive stresses, usually, higher tensile stress leads to more active corrosion.[16]

Suryavanshi et al studied out that the steel electrodes in-chloride-free OPC and SRPC mortar mixes of 0.70 w/c ratio attained passivity from the beginning of the curing time. in spite of the higher w/c ratio (0.70) of the mix, the steel electrodes in OPC (11.2% C3A) mortars with chloride levels as high as 1% by weight of cement, also attained submissiveness. However, steel electrodes in OPC mortar with 1.75% and 3.5% chloride by weight of cement underwent corrosion attack.[17]

Watson et al examined a methodology which has been developed to measure the wear corrosion synergism in aqueous tribosystems. It is valid for both erossive/abrasive wear-corrosion and for sliding wear corrosion. Penetration rates are defined that measure the material losses due to wear, corrosion and the wear corrosion synergism. Penetration rate equations are applied to slurry wear and aqueous sliding wear.[18]

Verma et al stated An effectual method to measure corrosion is a essential requirement for planning maintenance, repairing, and taking away for reinforced concrete structures. Information regarding corrosion state required three parameters: half-cell potential, concrete resistivity, and corrosion current density. Corrosion rate in a concrete structure is governed by several parameters such as moisture content, availability of oxygen, and temperature. So, for better results it is necessary to repeat corrosion rate measurement in regular time interval.[19]

Hamada et al examined the corrosion behavior of A106 carbon steel absorber for CO2 removal in amine promoted hot potassium carbonate solution (Benfield solution). The corrosion rate was measured by weight loss technique.

3. METHODS FOR EVALUATING CORROSION

Corrosion is a chemical process and not too easy to evaluate its correct magnitude and damage given to the steel of reinforced concrete. Several techniques have been reported in previous literatures that can be used for monitoring and evaluating the corrosion of rebars in concrete structures for diagnosing the cause and effect of corrosion. Some methods followed by various researchers to evaluate corrosion, these methods are

- Coulostatic technique.
- Galvanostatic pulse Method
- Half-cellpotential
- Linear polarization resistance (LPR)
- Time domain reflectometry (TDR)
- Ultrasonic guided Waves
- X-ray diffraction and atomic absorption

4. CONCLUSION

This paper provides the overview on corrosion of steel reinforced structures. In result of study of various papers it is observed that steel has high affinity towards corrosion if steel comes in contact with moisture various chemically active substances present in concrete also play great role in corrosion of steel embedded in concrete and extent of it these substances can be oxides of different metals. Chloride content of concrete also plays significant role in rebars corrosion. Various properties of concrete like porosity, w/c ratio, pH value, compaction, curing, cement content etc. also affects corrosion in reinforced concrete hence these parameters can be studied in detail so that their relation with reinforcement bars corrosion can be examined in detail which can help in controlling the corrosion damage of RCC structures.

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