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Experimental Study on the Effects of Corrosion in Reinforced Concrete Incorporating Steel Fiber and Ultra-Fine Slag

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Abstract: In this work, a thorough review of the literature was conducted with a primary focus on accelerated corrosion-induced corrosion. The report that follows compares different reinforced concrete mixtures following corrosion. By adjusting the transparent cover and reinforcement diameter, a simple reinforced concrete specimen, a specimen of reinforced concrete mixed with steel fiber, and a specimen of reinforced concrete mixed with steel fibre and ultra-fine slag were all produced. Using the accelerated corrosion method, the rate of induced corrosion, the flexural strength before and after corrosion, and the depth of corrosion penetration were compared.
Keywords: Corrosion, flexural strength, Faraday's Law, Degree of Induced Corrosion, Ultra-fine Slag, Steel Fiber.
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I. INTRODUCTION

By producing a thin layer of passivity—a protective layer of iron oxide—on the surface, the alkaline property of calcium hydroxide, which has a pH of roughly 13, stops the corrosion of the steel reinforcement. If the concrete is porous, carbonation will spread to the concrete that is in touch with the steel or soluble chlorides will reach the reinforcement; if both water and oxygen are present, the reinforcement will corrode. When the pH drops below approximately 11.0, the passive iron oxide layer disintegrates, and carbonation brings the pH down to approximately 9. Rust increases the volume of steel compared to the original steel, causing swelling pressures to induce cracking and spalling of the concrete. When two different metals are electrically linked in the presence of moisture and oxygen, an electrochemical reaction takes place that causes steel to corrode. Due to changes in the electro-chemical potential on the surface, which generate anodic and cathodic zones and are coupled by an electrolyte in the form of salt solution in hydrated cement, the same process only occurs in steel. While the negatively charged free electrons e- travel along the steel into the cathode where they are absorbed by the elements of the electrolyte and mix with oxygen and water to create hydroxyl ions (OH)-, the positively charged ferrous ions Fe2+ at the anode pass into solution. Iron ions and hydroxyl ions subsequently combine to make ferric hydroxide,

II. LITERATURE REVIEW

A. Rathod and Moharana (2015)

The main cause of degradation of steel reinforcement in concrete is corrosion. Corrosion begins earlier in the reinforcement before the appearance of cracks. Some non-destructive methods to detect corrosion were discussed in this study, as it is not possible to detect corrosion by visual means. In this paper, various non-destructive methods to monitor corrosion using different equipment were defined.

Open circuit potential technique (OCP) worked on the principle of measuring corrosion potential of rebar in comparison with standard reference electrode mostly saturated calomel electrode (SCE). In Surface Potential (SP) technique, an electric current flowed between anodic and cathodic sites in the concrete during corrosion and sensed by measuring the potential drop in concrete. Linear Polarization Resistance (LPR) technique only needed a connection to the steel reinforcement to measure corrosion of reinforced steel in RC structures. Potentiodynamic Anodic Polarization classifies a metal sample by its current-potential connection. These above- mentioned techniques proved useful in only finding the anode and cathode position and failed to provide real time corrosion result. Whereas for measuring real time corrosion methods like AE, Galvanic Monitoring Probe, FO, High Frequency UV overcome the limitation.

B. Shaikh et al. (2016)

This study presents an experimental program to compare corrosion damage using two accelerated corrosion techniques namely, constant voltage and constant current. In this study, six concrete columns were tested. Total of six reinforced deformed bars of diameter 13mm and spiral of 6mm diameter were placed longitudinally. A stainless steel pipe of diameter 20mm placed in the center of the column to act as cathode. To speed up corrosion and to supply oxygen small holes of diameter 2mm and four in number were made along the steel pipe longitudinally. The study consisted of two parts. The first part allowed corrosion around 8 % steel loss using two methods, constant voltage and constant current. The second part was to corroded the columns up to failure by maximum compression load. In the constant current sampled column, longitudinal cracks, crack width and circumferential expansion were more prominent than in constant voltage. Conclusions draws that almost similar steel loss took place but more damage was caused by constant current. As a result great structural damage by constant current as the load carrying capacity also decreased. Therefore, the constant current method gave more desired results to stimulate corrosion in reinforced concrete member.

C. Behera et al. (2016)

In this study, a critical corrosion at the onset of crack formation considered the production of rust at steel concrete junction was observed. The various expansive products of corrosion exerts radial pressure on the cover of concrete that lead to the formation of longitudinal cracks. Further the product of corrosion by accelerated corrosion method were determined using spectroscopic and microscopic method and then compared to natural corrosion of reinforcement in an old building nearly 50 years old. A combination of phase wise mass loss calculations and along with corrosion pressure theory estimated the critical corrosion amount. Various rust phases developed such as goethite, lepidocrocite, akageneite, maghemite, and magnetite. Spectroscopic studies showed some similarity in the rust phases formed under natural corrosion and those formed during accelerated corrosion.

This study also concluded that, as the cover-to diameter ratio increased, the critical corrosion amount increased. A radial pressure increased with the loss in weight of the reinforcement at the commencement of corrosion. Further, as the concrete strength increased, critical mass loss and its associated critical corrosion pressure also increased. Huo (2016) This study developed a model that predicted time from corrosion initial to corrosion cracking. No internal force action on steel- concrete interface was considered before the corrosion products filled the concrete pores. A relationship between internal expansion pressure and steel mass loss was established. The model was set as a thick walled cylinder and assumed the wall thickness equal to the concrete cover and the concrete cracking when the internal expansion pressure exceed the strength of concrete. Later the results compared to the computed model accuracy with the experiment result proved to be within the permissible range. Therefore, this forecasting of corrosion induced cracking is feasible.

D. Chakravarthy and Raj (2017)

In this paper presence of Alccofine in the ordinary cement in ideal measurements can be relied upon to enhance the compressive strength and give protection against chloride assault, ocean water assault and quickened erosion assault. The primary target of the work centers on the compressive quality of cement with incomplete replacing of concrete with Alccofine. Replacement of cement in M25 mix with alccofine in varying percentage at 0%, 4%, 8%, 16%, 17%, 20%, 25%, 50%, 75% and 100% for 7 and 28 days the compressive strength was maximum at 16% replacement exhibiting the value of 50.95 % and 60.95%, and on further increase the value decreased . Alccofine when added in concrete mix displays decent permeability parameters that brings about resistance against corrosion. CaO present in alccofine when consolidates with water under mix, gives high resistance against chemical and acid attacks.

Brenna et al. (2017) Corrosion of the reinforcement is caused by AC interference. Due to the dearth of data, tests conducted in alkaline solution and on concrete slabs are used to discuss the impact of AC on the localised corrosion of passive carbon steel in concrete. The AC application ranged from 10 to 500 A/m2. According to the findings, AC interference decreases steel passivity by raising the passive current density and decreasing the [Cl-]/[OH-] molar ratio as well as the passive interval. Findings showed that, depending on the amount of chlorides in concrete, the critical alternative current density ranges between 30 and 100 A/m2.

Angest and Elsener (2017)A long-standing and socially significant difficulty in science and engineering is predicting the lifespan of concrete structures in corrosive conditions. The key factor contributing to the early deterioration of concrete infrastructure around the world is chloride-induced corrosion of the reinforcing steel in concrete. This problem has been approached conceptually since the middle of the last century, relying on a threshold chloride concentration for corrosion onset (Ccrit). This idea serves as the foundation for all current models for predicting chloride-induced steel corrosion in concrete. We propose an experiment that demonstrates how much the exposed steel surface area affects Ccrit. The higher and more varied Ccrit gets, the smaller the

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examined specimen is. This size effect in reinforced concrete's resistance to corrosion can be attributed to the very variable local circumstances present at the steel-concrete contact. The scale effect has significant effects on how the common concept of Ccrit is used going forward. It raises concerns about the reproducibility of normally small-scale laboratory testing as well as the relevance of laboratory findings to engineering structures. Last but not least, we demonstrate that the weakest link theory can be
used to convert Ccrit from small to big dimensions, laying the groundwork for accounting for the size effect in the science and engineering of predicting the longevity of infrastructures.

III.STEEL FIBER

Steel fiber was added to reinforced concrete to affect various parameters. The actual role of the fibers is to reduce the corrosion in the reinforcement. During the progress of impressed current the concrete acted as a medium for transportation of ions so the steel fiber would be affected first. One could suspect that the steel fiber would act as a sacrificing material in order to protect the reinforcement. . An increase in the rate of corrosion will give a rapid break down of thin fibers. Crimped steel fibers were used for this study. The tensile strength and the Young’s modulus of the used steel fibers were 1250 MPa. Other properties of the used steel fibers are summarized in Table 1.

Length	50mm
Diameter	1mm
Appearance	Clear and Bright
Tensile strength	800-2500 MPa

Figure 1: Steel fibers

Comparison of Actual mass loss and Theoretical mass loss

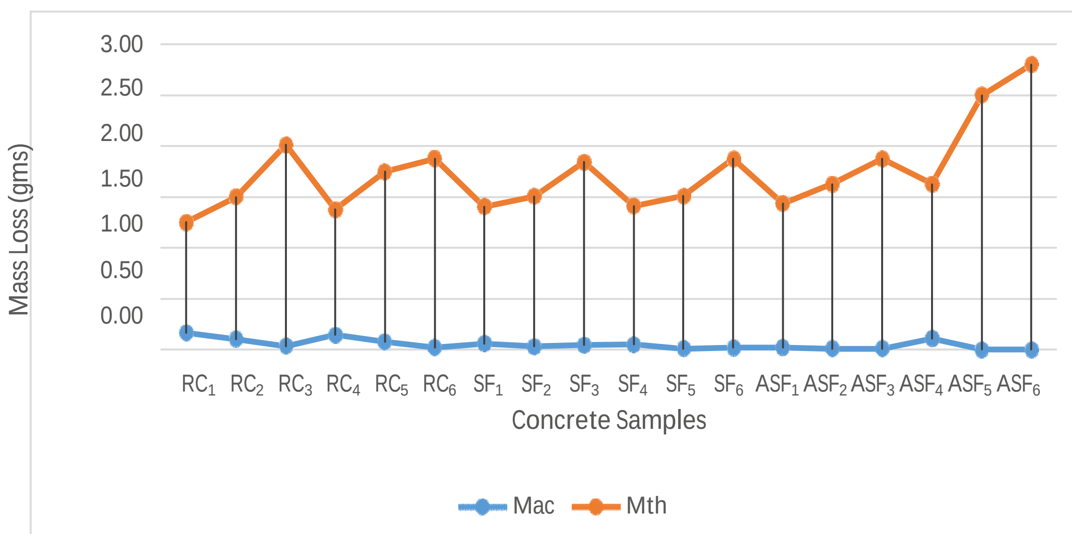

Figure 2: Comparison of Actual mass loss and Theoretical mass loss

IV. CONCLUSION

Based on the above study following conclusions can be made

1) According to the accelerated corrosion method adopted in this research, large steel bars need longer duration, compared for producing a similar corrosion level, but tend to exhibits high corrosion depth.
2) The variation in clear cover on the sample produced a little effect on corrosion, as it took almost similar time to induce corrosion in the samples.

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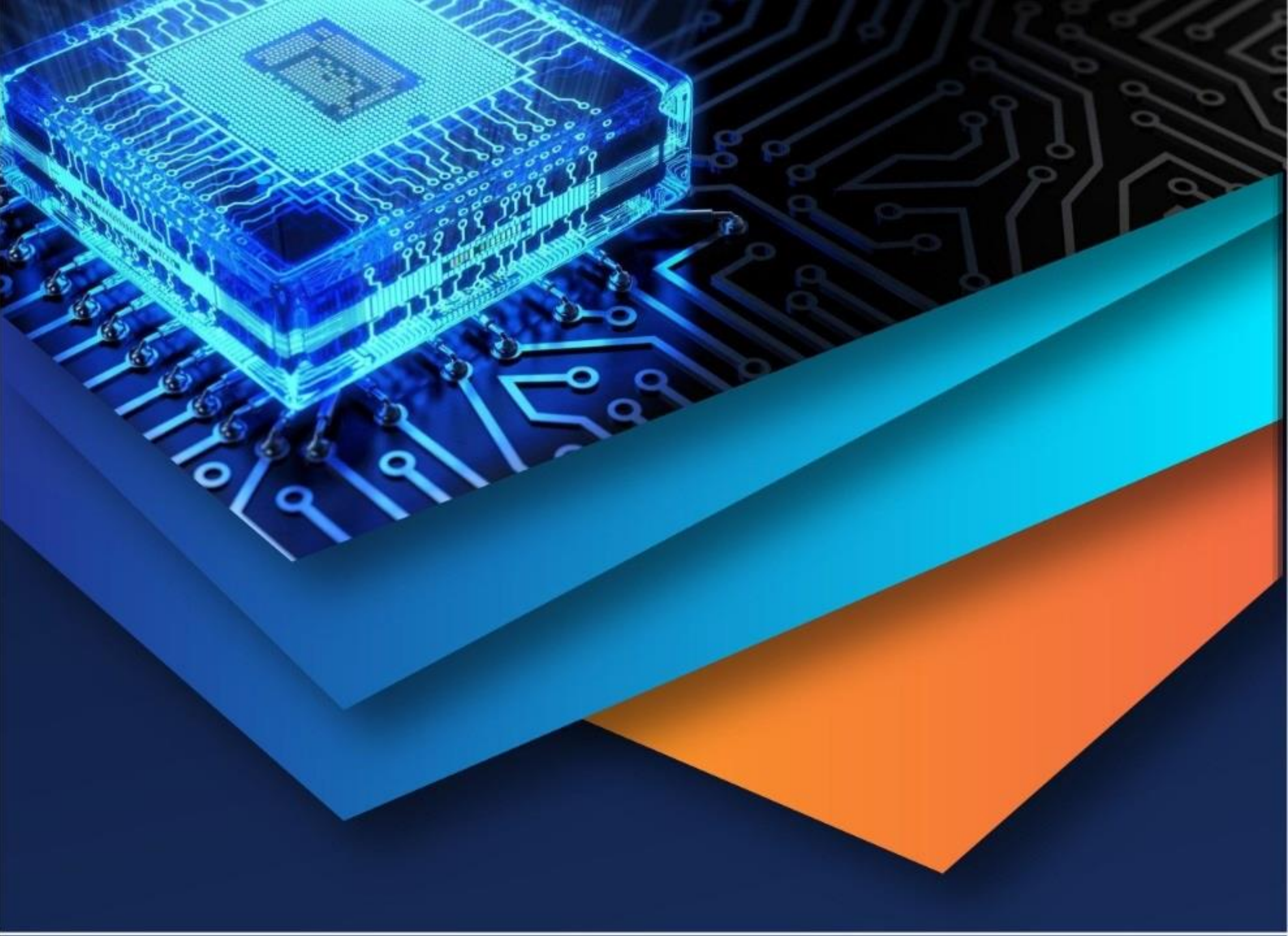

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