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Effect of Corrosion in Steel Reinforcement in Reinforced Cement Concrete Beams

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Abstract—*Corrosion of steel reinforcement bar is one a major concern with regards to the service life of reinforced concrete (RC) structures. This increases maintenance and repair cost of the RC structures. In RC structures, corrosion of steel in natural condition is a very slow process. Reinforced concrete structures have not been immune to the destruction of corrosion despite the protection that concrete provides to the embedded steel. Since steel corroded remains unnoticed inside the concrete, it further accelerates and can cause loss of life and property. The main aim is to this study to analyze the strength, deflection and stiffness with an increase in corrosion level. Beams were cast using Ordinary Portland Cement (OPC), aggregate (fine and coarse), and some beams as percentage replacement of cement with fly ash and rice husk ash. Corrosion in beams is induced with the help of impressed current techniques and beams were visually inspected at the end of their respected corrosion period for the extent of damage in Reinforced Concrete (RC) beams, with the increase in age of corrosion.. After the destructive testing, steel reinforcement was retrieved from the beams by dismantling and cleaned to find the mass loss. The studies show that there was an increase in mass loss in the reinforcement with the increase in corrosion level. After the destructive testing of beams, bars are tested using non – destructive technique. The ultrasonic testing is used to detect the damages caused by corrosion at different levels. This paper is the review paper of the past studies related to the corrosion and further what should be experiments to be done in that studies.*

1. INTRODUCTION

Corrosion is the inevitable process that occurs when refined metals return to their more stable combined forms as oxides, carbonates and sulphides. The corrosion process may be defined as the surface wastage that occurs when metals are exposed to reactive environments. Reinforced concrete structures have not been immune to the ravages of corrosion despite the protection that concrete provides to embedded steel. Reasons for the increasing incidence of corrosion damage to reinforced concrete structures include the use of deicing salts and calcium chloride set-accelerators, increased construction in aggressive environments, fast-track construction practices, changing cement composition resulting in finer grinding and lower cement contents, lower cover depths and poor construction practice including inadequate supervision. The use of fly ash in mortar and concrete, as a partial replacement of Portland cement, appears to constitute a very satisfactory outlet for this industrial by-product. The use of fly ash to replace a portion of the cement has resulted in significant savings in the cost of production of concrete. In the same way rice husk ash is also use as apartial replacement of Portland cement and appears to constitute a very satisfactory outlet for this industrial by- product. The use of rice husk ash and fly ash to replace a portion of the cement has resulted in significant improvement in corrosion resistance and strength of concrete.

Corrosion of the embedded steel requires the breakdown of its passivity. However, as the global warming becomes worse along with the increase of CO2 content in air, carbonation may break down the passive layer. Those structures in the tidal zone, or roads and bridge decks suffering from de-icing salt can also have the passive layer broken down due to the chloride attack. Without the passive layer, the steel is subjected to water and air and so initiation and further the propagation of corrosion of steel bar happen. Hsu and Hsu (1994) performed work to find out complete stress-strain behaviour of high-strength concrete under compression [1]. Nayal and Rasheed (2006) proposed tension stiffening model for concrete beams reinforced with steel and FRP bars [2]. Lubliner et al. (1989) worked on constitutive model based on an internal variable-formulation of plasticity theory for the non-linear analysis of concrete. Onset and amount of cracking were studied by a simple post processing of the finite-element plasticity solution [3]. Castel et al. (2000) studied mechanical behavior of corroded reinforced concrete beams [4]. Azher and Syed (2005) carried out work on a prediction model for the residual flexural strength of corroded reinforced concrete beam [5]. Ballim et al. (2003) studied corrosion in reinforcement and found out deflection of RC beams using an experimental critique of current test methods [6]. Broomfield and John (1997) worked on corrosion of steel in concrete with thorough investigation and repair strategies [7]. Cabrera et al. (2001) showed the effect of reinforcement corrosion on the strength of the steel and concrete bond [8]. Li and Zheng (2005) performed work to study propagation of reinforcement corrosion in concrete and its effects on structural deterioration [9]. Coronelli and Gambarova (2004) did structural assessment of corroded reinforced concrete beams [10]. Eyre and Nokhasteh (1992) investigated strength assessment of corrosion damaged reinforced slabs and beams [11]. Fin et al. (2008) showed the effect of under-reinforcement on the flexural strength of corroded beams [12]. Patil (2011) conducted work on residual flexural strength of RC beams subjected to corrosion [13].

FIG. 1:- CORROSION IN BEAM

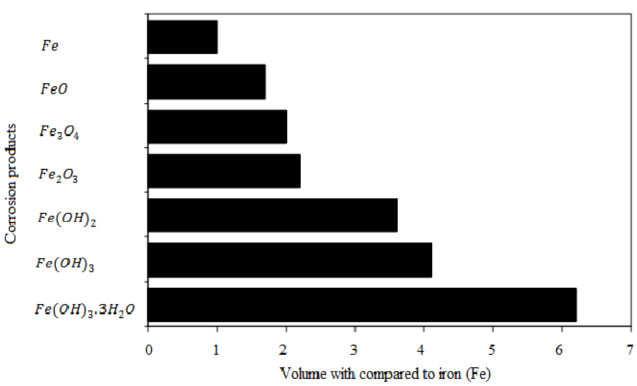

FIG. 2: - VOLUME OF CORROSION PRODUCTS WITH COMPARED TO IRON (ACI 222R, 2001)

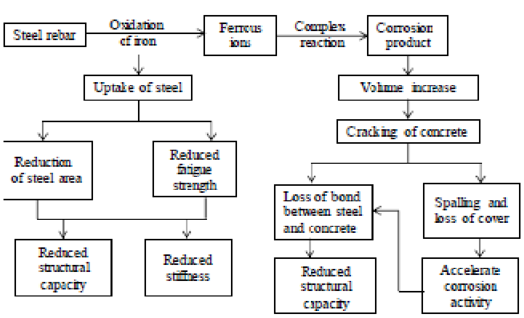

FIG. 3: - EFFECTS OF CORROSION ON REINFORCED CONCRETE

2. METHODOLOGY

Corrosion in steel reinforcement in reinforced concrete beams is studied by various researchers and scholars. Many of them studies on beams to find the strength, durability, deflections and load carrying capacities of beams. Some of them study the flexural strength of corroded beams and bond strength of beams and some studies was based on cracking patterns and their capacities. Some study is based on the finite element modeling of beams with respect to corrosion and analyze the effect of corrosion on beams. There are some studies based on the partial replacement of cement by some industrial by product such as fly ash.

Fly ash is an industrial by product which is used as a percentage replacement of cement content. As we know that from the studies that fly ash has the properties of cement and can improve the strength of concrete and used as a corrosion resistant material. The studies show that up to a critical level of 20% - 30% replacement, fly ash cement improved both the corrosion resistance and strength of concrete.in the same way, rice husk ash is also an industrial by product which can be used as apercentage replacement of cement content. In the previous studies rice husk ash is not used as a percentage replacement of cement. So, the further studies are based on rice husk ash.Beams were cast using Ordinary Portland Cement (OPC), aggregate (fine and coarse), and some beams as percentage replacement of cement with fly ash and rice husk ash.Corrosion in beams is induced with the help of impressed current techniques and beams were visually inspected at the end of their respected corrosion period for the extent of damage in Reinforced Concrete (RC) beams, with the increase in age of corrosion.After the destructive testing, steel reinforcement was retrieved from the beams by dismantling and cleaned to find the mass loss.After the destructive testing of beams, bars are tested using non – destructive technique. The ultrasonic testing is used to detect the damages caused by corrosion at different levels.

Table 1: Summary of Research Work Done the Mechanical behavior of Corroded Beams

AUTHORS	TIME	SPRCIMEN	ENVIRONMENT	CORROSION CONDITIONS	LOADING CONDITIONS
TACHIBANA ET AL	1990	RC BEAMS	CHLORIDE ENVIRONMENT	GALVANOSTAIC CORROSION	CORROSION PRIOR TO LOADING
TING ET AL	1991	RC BEAMS	CHLORIDE ENVIRONMENT	NUMERICAL SIMULATION	CORROSION PRIOR TO LOADING
CAIRNS ET AL	1993	RC BEAMS	CHLORIDE ENVIRONMENT	SIMULATION OF CORROSION THROUGH REINFORCEMENT EXPOSED	CORROSION PRIOR TO LOADING
ALMUSALLAMET AL	1996	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	CORROSION PRIOR TO LOADING
RODRIGUEZ ET AL	1997	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	SIMULTANEOUS CORROSION AND LOAD
MANGAT ET AL	1999	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	SIMULTANEOUS CORROSION AND LOAD
CASTEL ET AL	2000	RC BEAMS	CHLORIDE ENVIRONMENT	NATURAL CORROSION	CORROSION PRIOR TO LOADING
YOON ET AL	2000	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	SIMULTANEOUS CORROSION AND LOAD
CAPOZUCCA ET AL	2003	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	SIMULTANEOUS CORROSION AND LOAD
TORRES- ACOSTA ET AL	2004	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	CORROSION PRIOR TO LOADING
EL MAADDAWY ET AL	2005	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	CORROSION PRIOR TO LOADING
DU ET AL	2007	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	CORROSION PRIOR TO LOADING
AZAD ET AL	2007	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	CORROSION PRIOR TO LOADING
TORRES-ACOSTA ET AL	2007	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	SIMULTANEOUS CORROSION AND LOAD
VIE D ET AL, PETRE-LAZER ET AL	2007	RC AND PRESTRESSED BEAMS	CHLORIDE ENVIRONMENT	NATURAL CORROSION	SIMULTANEOUS CORROSION AND LOAD
VIDAL ET AL	2007	RC BEAMS	CHLORIDE ENVIRONMENT	NATURAL CORROSION	SIMULTANEOUS CORROSION AND LOAD
ZHANG ET AL	2009	RC BEAMS	CHLORIDE ENVIRONMENT	NATURAL CORROSION	SIMULTANEOUS CORROSION AND LOAD
MALUMBELA ET AL	2009	RC BEAMS	CHLORIDE ENVIRONMENT	IMPRESSED CURRENT	LOADING PRIOR CORROSION
ABABNEH ET AL	2011	RC BEAMS	CHLORIDE ENVIRONMENT		SIMULTANEOUS CORROSION AND LOAD
KHAN ET AL	2011	RC BEAMS	CHLORIDE ENVIRONMENT	NATURAL CORROSION	SIMULTANEOUS CORROSION AND LOAD
DANG AND FRANCOIS	2013	RC BEAMS	CHLORIDE ENVIRONMENT	NATURAL CORROSION	SIMULTANEOUS CORROSION AND LOAD

3. Conclusion

The different studies based on the beams with the Ordinary Portland Cement shows that there is a decrease in load carrying capacity, deflection capacity and stiffness with the increase in age of corrosion. Weight loss measurements, visual observations and anodic polarization tests confirmed that upto a critical level of 20–30% replacement, activated fly ash improved the corrosion-resistance of concrete. Compressive strength data showed that, upto 30% replacement level, the activated fly ash systems improved the strength of concrete. Among the activated systems, fly ash improved both the corrosion-resistance and strength of concrete to a greater extent. The chemical and thermal activated fly ash concretes performed well when compared to OPC. In the same way, rice husk ash can also be used to improve both the corrosion resistance and the strength of concrete. The use of fly ash and rice husk ash simultaneously reduces the cost of construction and improve the strength of concrete.

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