ROLE OF MAIN FACTORS IN THE REBAR CORROSION AND SERVICE LIFE OF CHLORIDE BEARING R.C. STRUCTURE UNDER NORMAL EXPOSURE

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Dedicated to

My Parents

CERTIFICATE

This is to certify that thesis entitled "**Role of Main Factors in the Rebar Corrosion and Service Life of Chloride Bearing R.C. Structure Under Normal Exposure**" being submitted by **Mr. SHAMSAD AHMAD** to the Indian Institute of Technology, New Delhi, India for award of the **Doctor of Philosophy** in Civil Engineering, is a record of bonafide research work carried out by him under my guidance and supervision.

To the best of my knowledge the thesis has reached the requisite standard. The material presented in this thesis has not been submitted in part or full to any other university or institution for award of degree or diploma.

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ABSTRACT

The numerous cases of early age corrosion distress, recently reported in the R.C. structures, even exposed to normal weather conditions prevailing in Northern India which is far away from the marine or chloride bearing industrial environment, have drawn the attention towards the need of research for identifying the actual cause(s) of reinforcement corrosion under such situations. The relevant literature, although available in a very limited numbers, have revealed that the reinforcement corrosion under normal exposure condition is affected mainly by the three factors, namely; cement content, w/c ratio, and chloride content made available through the ingredients of the concrete itself. The cover thickness over reinforcing bar (rebar) also plays an important role in corrosion cracking of the concrete cover. However, the role of these main factors on the rebar corrosion and the service life against rebar corrosion have not been investigated by considering these functions simultaneously. Further, due to various difficulties encountered during the corrosion measurement in in-situ R.C. structures or large size R.C. specimens, the development of a set-up for in situ corrosion rate measurement has been always a challenging problem.

In the present research work, firstly, the development of a simple electrochemical arrangement together with a calculation procedure has been carried out. The arrangement generates the galvanostatic polarisation data along with the data for determining the ohmic resistance of concrete. Thereafter the ohmic resistance of concrete determined is used to eliminate the error due to ohmic drop, mathematically, and same value of ohmic resistance is used for determining the concrete resistivity approximately. The calculation procedure presented, helps in calculating the true polarisation resistance using transmission line model, which takes into account the error due to non-uniform distribution of the applied electric signal for polarisation through a small disk shaped counter electrode. The calculation procedure also

includes the determination of the accurate values of Tafel slopes using the polarisation data, which in turn gives an accurate estimate of Stern-Geary constant, rather than assuming them arbitrarily. This whole thing has facilitated a simple set up for electrochemical investigation of corrosion on large size R.C. specimen, with a fair degree of accuracy.

For investigating the role of main factors in the rebar corrosion and the service life against the corrosion damage, two different standard statistical experiment designs have been used. The first deals with requirement of test results in order to carry out the analysis of variance which helps in pinpointing the significance of various factors and their possible interactions on a particular corrosion parameter. The second type of experiment design has been used for obtaining an empirical model for the service life prediction. The levels of the factors have been fixed as per the objectives of the present work and the requirements of the experiment designs. The R.C. beams of large size, simulating the in-situ conditions have been used for measuring the electrochemical corrosion parameters, namely; half-cell potential or corrosion potential, concrete resistivity, and corrosion rate. The plain concrete beams of similar size were used for measuring the chemical corrosion parameters, namely, free chloride content and pH of concrete. The core shaped R.C. specimens, simulating the cores cut from R.C. structures, were used for life prediction.

The methodology of the analysis of variance (ANOVA) has been adopted to investigate the effects of main factors on the electrochemical and chemical corrosion parameters. This has been found to be a quite useful and simple way to determine the individual and interactional significance of the factors on each of the corrosion parameters. Through ANOVA, it has also been found possible to separate the overall effects into linear and quadratic forms. After identifying the various individual and interactional source of effect for each of corrosion parameters, the empirical models have been fitted for each of them. These models may be used to evaluate these

parameters, only by determining the free chloride content, w/c ratio, and cement content of the concrete samples obtained from the site. Further, it has been pointed out that the methodology of ANOVA can also be used to diagnose the real cause(s) of corrosion in the affected R.C. structures, which can help in suggesting a suitable protection measure.

At last, an experimental technique and a circuitry for anodic current application have been developed for acceleration of the corrosion process. Based on the cumulative damage theory, a methodology has been devised with the help of the experimental data presented, for predicting the service life of R.C. specimens. Further, an empirical model for service life prediction in terms of the four main factors, namely; cement content, w/c ratio, chloride content, and cover thickness, has been developed. This model can be used to predict the service life of corrosion affected R.C. structures from the knowledge of the values of free chloride content, w/c ratio, and cement content etc. This model can also be used as a basis to obtain the optimal levels of the corrosion factors at the design and construction stages of the R.C. structures in order to ensure a significant life against reinforcement corrosion damage.

The relevant conclusions drawn include conclusions regarding interactions of various factors affecting the electrochemical and chemical corrosion parameters such as; $E_{corr.}$, ρ, I_{corr}, free Cl^- and pH etc.

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