TECHNIQUES FOR ACCELERATED CORROSION TEST OF STEEL CONCRETE FOR DETERMINE DURABILITY

Suresh Bhalgamiya[1], Govind Tivadi[2], Mehul Jethva[3]

[1,2] *PG Student, Structural Engineering (Department of Civil Engineering), Noble Group of Institue (GTU), Junagadh*
[3] *Lecturer, Department of Applied Mechanics, The Maharaja Sayajirao University of Baroda, Vadodara*

Abstract - *Concrete durability is an important design criterion, which must be assessed for every type of structure. Reinforcement corrosion has widely reported in literature over last two Decades. It is one of the major durability problems, mainly when rebar in concrete is exposed to the chloride either contributed from the concrete ingredients or penetrated from surrounding chloride bearing environment. Corrosion of steel in concrete is a slow process. Due to the protective nature of concrete, it takes a reasonably long time for initiation and progress. The assessment of causes and extent of corrosion is carried out using accelerated corrosion techniques. The diffusion of chlorides is recognized as one of major responsible of corrosion phenomenon start. This report presents study on the mechanism of reinforcement corrosion, different Corrosion test utilized to monitor reinforcement corrosion. Methodology that utilized for assessment of Rate of corrosion is discussed. In this report, an attempt has been made to firstly describe commonly used accelerating reinforcement corrosion test and corrosion development of reinforcement bar in concrete by employing accelerated corrosion test, causes of reinforcement corrosion is discussed including carbonation and chloride ingress.*

Key Words: **concrete, reinforcement corrosion, accelerated corrosion techniques**

1. INTRODUCTION

In this paper describe to find rate of corrosion using immersion corrosion techniques and based on this predict estimate service life pf RC structure using accelerated corrosion test Durability is defined as ability to resist weathering action, chemical attack or any other process of deterioration during their service life. The quality of concrete, mainly the permeability nature and intensity of cracks, and the cover thickness, have also a great bearing upon the initiation and sustenance of reinforcement corrosion. Accelerated corrosion testing of metals and coatings was first developed in the late 1890s and early 1900s for testing products to increase their useful performance and service life. This method of testing the corrodibility of ferrous and nonferrous metals and organic and inorganic coatings has since been improved and variations added to better test new materials and help operators understand how they may perform in, and withstand, a wider range of real world environments. Accelerated corrosion testing has also evolved from providing information to help determine durability of products, and their quality assurance during manufacturing, to use In product research and development. Different concretes require different degrees of durability depending on the exposure of environment and the properties desired. Durable concrete will retain its original form, quality and serviceability when exposed to its environment.

The corrosion of reinforcing steel is generally accelerated by means of the impressed current technique. This is done to induce a significant degree of corrosion of reinforcing bars embedded in concrete in limited available time. The impressed current technique has been frequently used to study the effect of reinforcement corrosion on the cracking of concrete cover, bond behaviour, and load-bearing capacity of reinforced concrete structural members. Ahmed et al. used the impressed corrosion technique to evaluate the performance of reinforced concrete members incorporating supplementary cementations materials, such as fly ash, silica fume, and slag, against corrosion-induced damage. Ha et al evaluated the corrosion performance of steel in fly ash cement concrete using the impressed current technique. Due to the flexibility of the impressed current technique, materials such as cladding and coatings on the reinforcing steel and concrete coatings and sealants can be evaluated and compared within a relatively short period of time.

The impressed current technique of corrosion acceleration has many advantages, in addition to the obvious savings in time and money. One advantage over other accelerated techniques is the ability to control the rate of corrosion, which usually varies due to changes in the resistivity, oxygen concentration, and temperature. Any change in one of the variables would be compensated for. For example, a change in the resistivity of the concrete as a result of temperature fluctuations or evaporation of the pore water can be counterbalanced by supplying a greater voltage, thereby maintaining the desired corrosion rate (impressed current level). This removes much of the variation encountered in corrosion measurements with time. An accelerated corrosion test by the impressed current technique is confirmed to be a valid method to study the corrosion process of steel in concrete, and its effects on the damage of concrete cover . The scientific justification for accelerating corrosion using an impressed current is strong, dramatically reducing the initiation period required for depassivation from years to days and fixing the desired rate of corrosion without compromising the reality of the corrosion products formed.

1.1 TECHNIQUES FOR ASSESSMENT DURABILITY

1. Rapid chloride penetration test (RCPT)
2. Chloride diffusion-migration test
3. Accelerated carbonation test
4. Sulphate immersion test
5. Accelerated corrosion test (ACT)
6. Water sorptivity test
7. Oxygen permeability Index test (OPI)

1.2 VARIOUS ACCELERATED CORROSION TEST

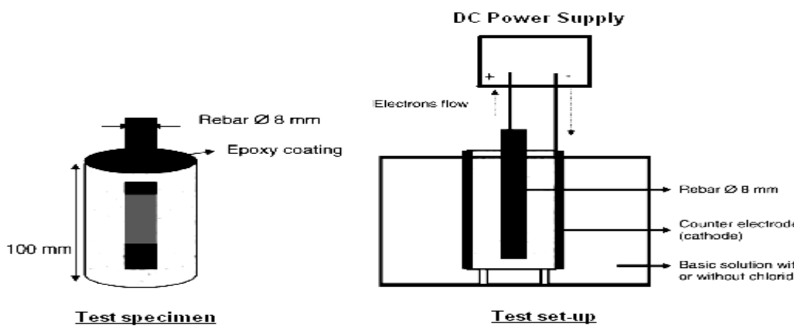
1. ASTM-B117 (SALT SPRAY METHOD)
2. ASTM-B876 (HALF CELL POTENTIAL)
3. ASTM-B368 (COPPER ACCELERATED SALT SPRAY)
4. ASTM-G31 IMMERSION CORROSION TEST
5. ASTM-G50 ATMOSPHERIC CORROSION TEST
6. ASTM-G109-07

2. ASTM-G31 IMMERSION CORROSION TEST

The impressed current technique, also called the galvanostatic method, consists of applying a constant current from a DC source to the steel embedded in concrete to induce significant corrosion in a short period of time. After applying the current for a given duration, the degree of induced corrosion can be determined theoretically using Faraday's law, or the percentage of actual amount of steel lost in corrosion can be calculated with the help of a gravimetric test conducted on the extracted bars after subjecting them to accelerated corrosion. Using the actual amount of steel lost in corrosion, an equivalent corrosion current density can be determined.

3. SET-UPS USED FOR INDUCING REINFORCEMENT CORROSION THROUGH IMPRESSED CURRENT

Set-ups used for inducing reinforcement corrosion through impressed current consist of a DC power source, a counter electrode, and an electrolyte. The positive terminal of the DC power source is connected to the steel bars (anode) and the negative terminal is connected to the counter electrode (cathode). The current is impressed from counter electrode to the rebars through concrete with the help of the electrolyte (normally sodium chloride solution). A typical lollypop reinforced concrete test specimen and set-up used by Care and Raharinaivo for accelerated corrosion study using the impressed current technique. The set-up used by Ahmadet al. for accelerating reinforcement corrosion in several lollypop reinforced concrete specimens connected in series is shown in Figure 3.1



The set-up used by Azad et al. for accelerating reinforcement corrosion in a large-size specimen (150×150×1100 mm reinforced concrete beams) is shown in Figure 3.2

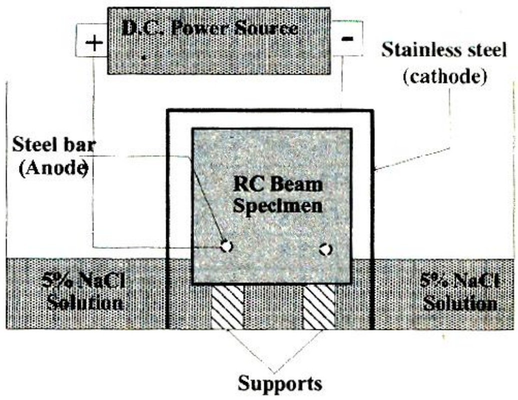


Fig -3.2: The set-up used by Azad et al. for accelerating reinforcement corrosion

4. CALCULATION OF DEGREE OF INDUCED CORROSION AND EQUIVALENT CORROSION CURRENT DENSITY

The mass of rust produced per unit surface area of the bar due to applied current over a given time can be determined theoretically using the following expression based on Faraday's law.

$$M_{th} = \frac{W\, I_{app}\, T}{F}$$

where Mth = theoretical mass of rust per unit surface area of the bar (g/cm2); W = equivalent weight of steel which is taken as the ratio of atomic weight of iron to the valency of iron (27.925 g); Iapp = applied current density (Amp/cm2); T = duration of induced corrosion (sec); and F = Faraday's constant (96487 Amp-sec)

The actual mass of rust per unit surface area may be determined by gravimetric test in accordance with ASTM G1 on rebars extracted from the concrete by breaking the specimens after the accelerated corrosion test is completed.

$$M_{ac} = \frac{(W_i - W_f)F}{\pi DL}$$

where Mac = actual mass of rust per unit surface area of the bar (g/cm2); Wi = initial weight of the bar before corrosion (g); Wf = weight after corrosion (g) for a given duration of induced corrosion (T); D = diameter of the rebar (cm); and L = length of the rebar sample (cm).

The degree of induced corrosion is also expressed in terms of the percentage weight loss (ρ) calculated as

$$\rho = \frac{(W_i - W_f) * 100}{W_i}$$

The equivalent corrosion current density (Icorr) can be determined by equating Equation 1 and Equation 2, assuming that the theoretical and actual mass of rust are equal (i.e., Iapp = Icorr), as

$$I_{corr} = \frac{(W_i - W_f)F}{\pi DLWT}$$

5. RELATIONSHIP BETWEEN THEORETICAL AND ACTUAL CORROSION MASS LOSS

The current applied for inducing corrosion is not found to be fully efficient in causing loss of mass equal to that theoretically predicted by Faraday's law due to several factors, as described earlier. In other words, Iapp is not found to be equal to Icorr.

$$M_{ac} = \frac{t_c a_c * M_{th}}{t a_c}$$

$$I_{corr} = \frac{t_c a_c * I_{app}}{t A_c}$$

where t = total time of external current applied; tc = duration of the corrosion application; Ac = area of rebar over which the current is applied; and ac = area of the depassivated portion of the rebar. Time of rebar corrosion, tc, is less than the total time of current application, t, because some time is required for depassivation of the rebar. Similarly, the surface area of rebar that is actually depassivated, ac, is less than the whole surface area of the rebar, Ac. Therefore, the coefficient of I_{app} in above Equation, is less than 1 (i.e., Icorr < Iapp).

5.1 Other Alternative Techniques For Inducing Accelerated Reinforcement Corrosion

In view of the fact that the corrosion process is known to be different with the impressed current technique as compared with the natural corrosive environment, Yuan et al have proposed an alternative method of inducing accelerated reinforcement corrosion using artificial climate environment. They accelerated the corrosion process of the reinforced concrete test beams in an artificial climate room controlled by a computer system. The environmental conditions in the artificial climate room were as follows: high temperature of 40 °C; high relative humidity of 80%; and repeated wetting-and-drying cycles. Wetting and drying cycles consisted of salt water (5% NaCl solution) spraying for 1 hour and infrared light shining for 7 hours. They found that the corrosion process and corrosion characteristics of the steel bar under artificial climate environment are similar to that of corrosion under natural environment. They found the artificial climate environment as an accelerated laboratory test method more representative than the impressed current technique. Chunlei et al. have proposed a new method to accelerate reinforcement corrosion by accelerating chloride ion diffusion in concrete so that chloride ion density could reach the threshold value on the steel bar surface in a few days. They have designed a set of Accelerated Chloride Ion Diffusion (ACID) device by using electric field to accelerate the chloride ion diffusion.

The accelerated chloride migration test (ACMT) based on the electrochemical technique, developed by Yang to accelerate chloride ion migration in cement-based material to estimate its permeability, may also be used for accelerating reinforcement corrosion. The set-up for ACMT consists of a two-compartment cell as shown in Figure. The cells are connected to a 24-V DC power source in which the wire mesh in the NaOH compartment becomes the anode and the compartment with NaCl becomes the cathode. A data logger is used to record the current during the experiment. The quantity of chloride ions in anode and cathode cells is measured periodically.

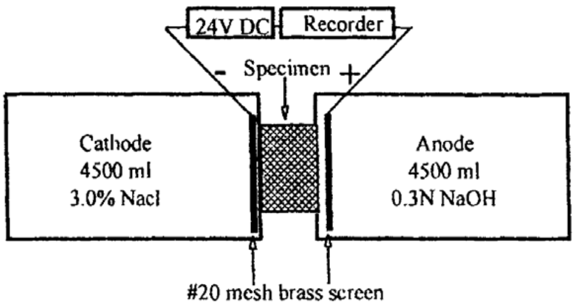


Fig -5.1.1 Schematic diagram of ACMT cell

A rebar centrally cast in a 75 mm × 150 mm concrete cylinder may be used as a test specimen for accelerating rebar corrosion using the accelerated chloride migration technique.

6. PREDICTION OF ESTIMATED SERVICE LIFE OF RC STRUCTURE FROM ACCELERATED TESTING

From the discussion above, it is postulated that a prediction model of an estimated service life of RC structure may be possible by following the test set up described here. In this regard, more data is required for various times of accelerated corrosion testing and from that the estimated normal exposure time can be calculated. A simple empirical formula can be developed to predict the normal exposure time from the accelerated corrosion testing time, based on the logarithmic shifts involved. Note that two more steps

are required for service life prediction. Firstly, limit states must be defined for structural integrity based on chloride-induced corrosion damage, here expressed in terms of mass loss. Secondly, mass loss must be translated to actual loss in resistance for service life estimation, by determination of the mass loss distribution. In this regard, distinction must be made between general, uniformly distributed corrosion-induced steel bar mass loss, as opposed to localized, pitting type deterioration. In the SHCC materials studied here, general corrosion is usual in regions of multiple cracks.

7. CONCLUSIONS

- Set-ups presented in this paper may be used in accelerated corrosion programs involving small- and large-sized specimens.
- The alternative methods of accelerating reinforcement corrosion described in this paper may also be utilized for accelerating reinforcement corrosion.
- The method of prediction service life is based on the assumption of Arrhenius-type equivalent time increase by high potential (voltage), as well as low cover to steel.

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