

APPENDIX - A

A.1 CORROSION ASSESSMENT TECHNIQUES

Due to numerous reasons the rebars embedded in concrete subjected to different types of corrosion damage due to which the concrete is subjected to spots, cracks, spalling, etc. Before these states become apparent the steel corrodes without any external sign of deterioration. Owing to these facts the corrosion of reinforcements has been very difficult to observe and study; moreover, the techniques of measurements need to be applied through the concrete without disturbing or deteriorating it. Most of the corrosion assessment techniques are based on electrochemical principles. Various states of rebars due to corrosion can be assessed both in qualitative and quantitative manner. In this section corrosion rate determination has been explained.

A.2 CORROSION RATE DETERMINATION-ELECTROCHEMICAL TECHNIQUE

A.2.1 Polarisation Method

In general, the corrosion process involves transfer of charge (electrons) from one species to another. For an electrochemical reaction to occur (in the absence of an external electrical source) there must be two half cell reactions: one capable of producing electrons (the anodic reaction) and another capable of consuming

electrons (the cathodic reaction). Moreover, the rates of the production and consumption must be equal in order to satisfy a charge balance. Therefore, there is no net current and it is not possible to measure the current due to corrosion directly, but it can be determined indirectly as explained subsequently.

The possibility of corrosion reaction occurring can be predicted theoretically but the kinetics of the reaction, i.e. the rate at which it proceeds, can only be determined empirically. Yet it is the rate at which the steel corrodes which is of interest to the engineer and is, thus, of great importance.

Electrochemical kinetic measurements are standardised and involve very common procedures in the study of the corrosion of metals in aqueous solutions. However, they have not been widely used for steel embedded in concrete because of the experimental difficulties involved with, such as, (i) the very low current densities, (ii) the high electrical resistance of concrete, and (iii) the long experimental times involved. However, such measurements can be used to give both an estimate of the corrosion rate occurring at the time of the investigation, and an idea of how the corrosion rate will change due to environmental changes and so on.

The experimental setup is shown in Fig.A.1, which describes the basic disposition for the measurement of corrosion current. A steel rod is embedded in concrete. The corrosion potential, E_{corr}^* of the steel is measured relative to a reference electrode,

and then, by means of a potentiostat, the potential of the embedded steel is shifted away from E_{corr} . That is, by polarising the specimen about 250 mV anodically (positive going potential) and cathodically (negative going potential) from the corrosion potential. The potential does not have to be scanned, but can be "stepped" in staircase waveform.

The resulting current flowing between the embedded steel (the working electrode) and an external steel plate (the counter electrode) is then measured and plotted on a logarithmic scale as shown in Fig.A.2.

The corrosion current, i_{corr} is obtained from a Tafel plot by extrapolating the linear portion of the curve to E_{corr} , as indicated in Fig.A.2. The anodic or cathodic Tafel plots are described by the Tafel equation.

$$\eta = \beta \times \log(i / i_{\text{corr}}) \quad \text{--- (a.1)}$$

Where,

η = Over voltage, the difference between the potential of the specimen and the corrosion potential.

β = Tafel constant

i = Current at over voltage, μA

* When a metal or alloy is placed in contact with a solution, the metal will assume a potential that is dependent upon the metal and the nature of the solution. This 'open circuit' potential, i.e. no external potential is applied to the cell, is referred to as the corrosion potential, E_{corr} and this can be measured using a potentiometer which does not draw any current while making a voltage measurement.

Rearranging Eq.(a.1):

$$\eta = \beta \times (\log i - \log i_{\text{corr}}) \quad \text{---(a.2)}$$

This equation has the form $y = mx + c$, so a plot of η Vs $\log i$ is a straight line with slope β . It is to be noticed from Eq.(a.1) that when $\eta = 0$ (at E_{corr}), $\log(i / i_{\text{corr}}) = 0$, or $i = i_{\text{corr}}$. The following are the steps involved in the calculation of corrosion rate from the corrosion current:

According to Faraday's Law

$$Q = (n \times F \times W) / M \quad \text{---(a.3)}$$

Where,

Q = Coulombs

n = number of electrons involved in the electrochemical reaction.

F = the Faraday, 96 487 Coulombs.

W = weight of electroactive species

M = molecular weight

From Eq.(a.3)

$$W = (Q \times M) / (n \times F)$$

Since equivalent weight, $EW = M/n$

$$W = (Q \times EW) / F$$

and since $Q = i \times t$ from Faraday's Law

$$W = i \times t \times EW / F \quad \text{---(a.4)}$$

Where,

t = time in seconds

(W/t) is the corrosion rate (CR) in grammes /second. It is convenient and traditional to express corrosion rate as millimeters per year (mmpy). These units provide an indication of penetration.

Dividing the Eq.(a.4) by t, area of exposure of corroding species in cm^2 (A), and density (d) of the corroding species in g/cm^3 , we get

$$\text{CR (cm/s)} = (i \times \text{EW}) / (d \times F \times A) \quad \text{---(a.5)}$$

Converting the seconds to years and centimeters to millimeters and the Faraday (amp.sec/eq) to milliamps, we get

$$\text{CR (mmps)} = (31.6 \times 10^7 \times i \times \text{EW}) / (d \times F \times A \times 10^3) \quad \text{---(a.6)}$$

Expressing the terms i/A as current density and substituting in Coulombs,

$$\text{CR (mmps)} = (3.27 \times I_{\text{corr}} \times \text{EW})/d \quad \text{---(a.7)}$$

(I_{corr} , the current density is expressed in mA/cm^2 , EW in grammes and density in g/cm^3)

In this investigation, steel corrosion is the prime object of interest and hence substituting for EW and d in Eq.(a.7),

$$\text{CR of steel (expressed in mmpy)} = 23.26 \times I_{\text{corr}} \quad \text{---(a.8)}$$

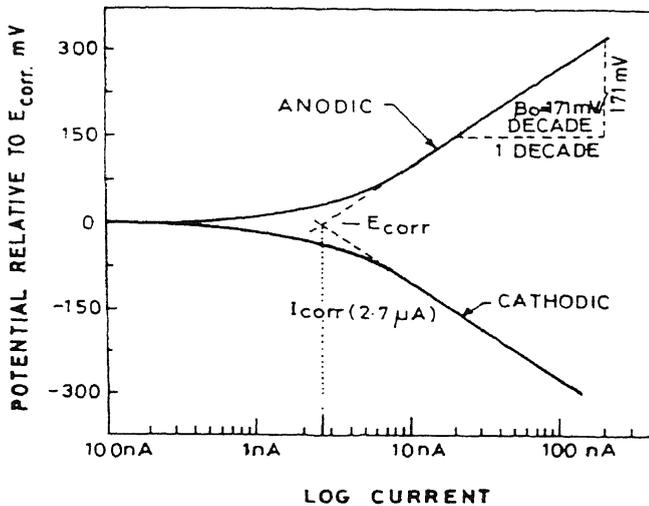


FIG. A2 Experimentally Measured Tafel Plot

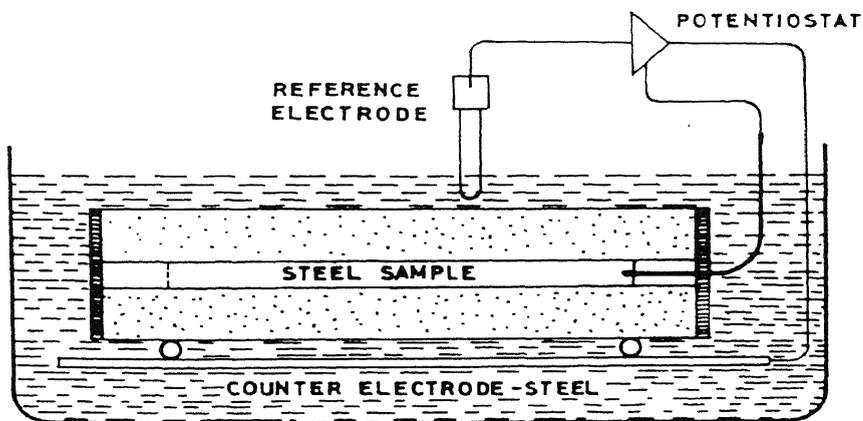


FIG. A1 Disposition of Potentiostatic Measurements

