IMPACT OF ACCELERATED CORROSION TEST IN FLEXURAL BEHAVIOUR OF RC BEAMS

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Abstract – *Corrosion is one of the major problems found in RCC structures especially in marine environment. Even good quality RCC beams found deteriorating as time proceeds. Here in this paper we examine the flexural behaviour of RCC beams under 5%, 10% and 15% of corrosion. Accelerated corrosion test was used to induce corrosion in beams. Validation of accelerated corrosion test was done before inducing corrosion. Beams of size 100 mm × 150 mm × 700 mm and M30 grade concrete were used. The ultimate load carrying capacity of corroded beams and control beams were tested and found decreasing as percentage of corrosion increases. Corroded beams also had more deflection than control specimens*

Key Words: RCC beams, corrosion, flexural behaviour, ultimate load carrying capacity

1. INTRODUCTION

Concrete has low tensile strength, which is often used in combination with reinforcing bars. Reinforced concrete uses steel to provide the tensile properties that are needed in structural concrete. Reinforced concrete structures show a very good durability as it is capable of withstanding the different kind of environmental exposure. However, the main limitation of concrete, even of good quality, is that the penetration of chlorides, carbon dioxide, moisture, etc., which can cause corrosion of reinforcement bars. Corrosion of steel reinforcements is considered to be the reason behind the reduced service life and failure of RC structures. The use of pre-rusted steel, exposure to corrosive environment, loading conditions etc can impart corrosion in RCC structures. The effect of corrosion on RCC structures include cracking of concrete cover, reduction and eventual loss of bond between concrete and reduction of cross sectional area of reinforcing steel. Reduction in the cross sectional area of steel reduces its strength capacity. 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. It works on Faraday's law. The rebar of beam is connected to anode which is positive and stainless steel metal plate is taken as cathode which is negative. 5% NaCl solution is used as electrolyte and a constant DC power is provided.

2. EXPERIMENTAL PROGRAM

It includes collection of materials, testing of materials, mix design, preparation of specimens, inducing corrosion to specimens, testing of specimens, comparison of results.

2.1 Materials Used

Cement

Portland pozzolana cement was used for the present study. The physical properties of cement are found within the codal limits and can be used for casting.

Coarse aggregates

The maximum size of coarse aggregate used in the present study was 20 mm. The physical properties of coarse aggregate found satisfactory and well graded.

Fine aggregates

Fine aggregate used for the present study is manufactured sand. Fine aggregate under saturated surface dry condition was used for casting. The physical properties of fine aggregate were also within the codal provisions and also well graded.

Water

Potable water which is available at the laboratory premises was used for mixing of concrete ingredients

Reinforcement bars

Reinforcing bars of 8mm, 10mm and 12mm diameters of plain and deformed bars (Fe415) were used.

2.2. Mix Design

IS code method is used for the design of M 30 grade concrete. The quantity of materials is tabulated in Table-1.

Table -1: Mix Design for 1 m^3 of M30 concrete

Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (liter)
443.26	697.69	1152.47	206.55

Hence, the mix proportion obtained is 1: 1.54: 2.6 with water-cement ratio 0.46

2.3. Tests on Fresh Concrete

The following are the tests conducted on fresh concrete and values are showed in Table-2

Table- 2: Fresh Properties of Concrete

Properties	Value
Slump Flow	80 mm
Compaction Factor	0.94

2.4. Tests on Hardened Concrete

The tests conducted were cube compressive strength test and flexural test.

2.4.1 Cube Compressive Strength Test

Concrete cubes of 150 ×150 × 150 mm dimension are casted for compressive strength. The compressive strength at 28 day was found out using compression testing machine as recommended by the Indian Standard. The compressive strength of 28 day cured specimen was obtained as 39.1MPa which satisfies the design criteria.

2.4.2 Flexural Behaviour

Preparation of specimen

The ingredients of concrete were mixed in a pan mixer. Firstly, coarse aggregate and fine aggregate were mixed thoroughly in a dry condition, and then required quantity of cement is added and mixed thoroughly. The prepared concrete is poured in the required moulds. The mould is striped after 24 hours. The test specimens were cured for 28 days in a curing tank.. For flexural beam specimens of size 100 × 150 × 700 mm are used. Sample description is showed in Table-3.

Table-3: Sample Description

Designation	Percentage of Corrosion
B0	0
B5	5
B10	10
B15	15
RB5	5
RB10	10
RB15	15

Beam is designed as under reinforcement. 2 numbers of 10 mm dia bars are used in tension, 8 mm dia bars are used in top and 6 mm dia bars are used for stirrups. Spacing of stirrups is obtained as 90 mm. One of the 10 mm steel bar kept projecting from the face of the mould which is necessary to provide sufficient length of bar for passing current for corroding. Mould with Reinforcement bars are given in the Fig-1

Fig-1: Mould with reinforcement bars

2.5. Accelerated Corrosion Setup

Accelerated corrosion was induced by means of impressed current technique. Fig-2 shows the schematic diagram of accelerated corrosion setup. Various levels of corrosion (5%, 10%, and 15%) induce to steel rebar using an electrolytic cell. The rebar is connected as anode and stainless steel plate as cathode. 5% NaCl solution was used as electrolyte. A constant DC voltage was applied to the electrolytic cell. The time required for achieving different levels of corrosion by mass loss was calculated using Faraday's Law as per the equation (1).

$$m = \frac{MIt}{zF}$$

where,
m is the mass of steel consumed (g),
M is the atomic weight of metal (55.8 g for Fe),
I is the current (amperes),
t is the time (seconds),
z is the ionic charge (2), and
F is the Faraday's constant (96,485 A/sec).

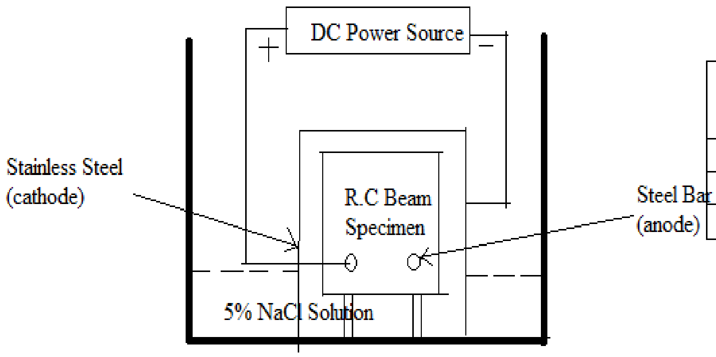

Fig-2: Schematic diagram of accelerated corrosion setup

2.5.1 Validation of corrosion

Inorder to validate corrosion, rebars of length 800 mm and varying diameters 6 mm, 8 mm, and 10 mm (3 samples each), were subjected to different levels of corrosion (5, 10 and 15% of mass loss), using accelerated corrosion technique. For this study constant current of 6A was provided. The rebars were connected to anode which is positive and metal plate was used as cathode which is connected as negative. They were dipped in 5% electrolyte solution. Using Faraday's law, the time taken for each level of corrosion in all diameters of bars were calculated. The actual mass loss was measured and compared with theoretical mass loss which is given in Table-4. The value shows almost same percentage of corrosion.

Table- 4: Time and mass loss of single bars

Diameter(mm)	Theoretical mass loss (%)	Time (s)	Actual mass loss(%)
6	5	5400	5.0
	10	10800	10.1
	15	16200	15.1
8	5	6480	5.6
	10	12960	10.05
	15	19440	14.99
10	5	9720	5.64
	10	19800	9.8
	15	29880	14.8

Actual corrosion of bundle of bars were also calculated inorder to check the feasibility of impressed current technique in group of bars. 2 numbers of 10 mm dia bars were used in tension and 2 numbers of 8 mm dia bars in compression. Length of bars were 250 mm and 6 mm dia bars were used as stirrups. Constant current of 6 A was provided and theoretical and actual mass loss was compared in Table-5

Table-5: Time and mass loss of bars in groups

Theoretical mass loss (%)	Actual mass loss (%)	Time (s)
5	5.3	21325.83
10	9.9	42651.67
15	15.2	63977.5

It was observed that each bar had almost equal and same corrosion and actual mass loss was almost equal to theoretical corrosion.

Effect of accelerated corrosion technique on concrete cover is tested by using concrete beams of size 100×100×300 mm. 2 numbers of 10 mm dia bars were used in tension and 2 numbers of 8 mm dia bars in compression and 6 mm dia stirrups was used. Concrete used was M30 grade. Initial weight of beams and bars was noted and subjected to impressed current technique. 6 A constant DC supply was given. Rebars in beams is connected to anode and metal plate was cathode and 5% NaCl solution was used as electrolyte. Actual mass loss and theoretical mass loss were compared and found error which is given in Table-5.

Table-5: Time and mass loss of steel embedded in concrete

Theoretical mass loss (%)	Actual mass loss (%)	Time (s)	Value of λ
5	3.2	216140.23	1.56
10	6.55	432280.4	1.52
15	9.75	8648420.7	1.53

Thus a ratio of theoretical and actual mass loss is taken.

$$\lambda = \frac{\text{Theoretical mass l}}{\text{Actual mass los}}$$

Thus the average value of λ will be multiplied with Faraday's law. Then the modified equation will be,

$$t = \frac{\lambda mzF}{IM}$$

2.5.2 Accelerated Corrosion in Beams

Beams of size 100 × 150 × 700 mm after 28 days of curing taken. The rebar which was already extended outwards before casting is connected to the positive terminal that is, anode. A metal plate of 3 mm thickness and 50 mm width was used as cathode which is connected to negative. Electrolytic solution was 5% NaCl solution and a constant DC source of 6A was given. The setup was left undisturbed until the time required for particular corrosion is attained. The test setup was given in the Fig-3.

Fig-3: Test setup of accelerated corrosion of beams

The change in colour of the electrolytic solution can be visually observed and is shown in Fig-4. The amount of rust is found increasing as the number of days increasing.

(a)

(b)

Fig-4: Corrosion Process at (a) day 1 and (b) day3

2.6 Flexural Test

All the beams were tested under 2 point loading frame in a Universal Testing Machine of 1000 kN capacity and the experimental setup is shown in Fig-5. Span of beams are kept 640 mm. Dial gauges are placed to measure deflection

Fig-5: Loading setup

2.7 Ultimate Load and Flexural Behavior

The ultimate load of corroded and control beam specimens are shown in Chart-1

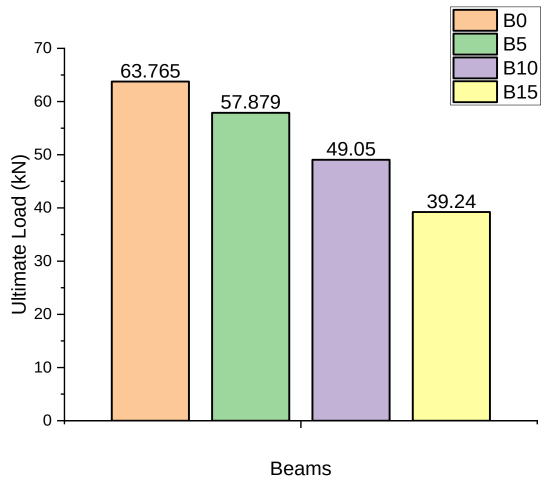

Chart -1: Ultimate Load Graph

The ultimate load was found decreasing as the percentage of corrosion increasing. The load of 5% corroded beams decreased 10% of control beam. The ultimate load of 10% corroded beams was found decreasing 23%of control beam and the load of 15% corrosion was decreased about 39% of control beam

Load deflection graph of control and corroded beams were plotted and is shown in Chart-2

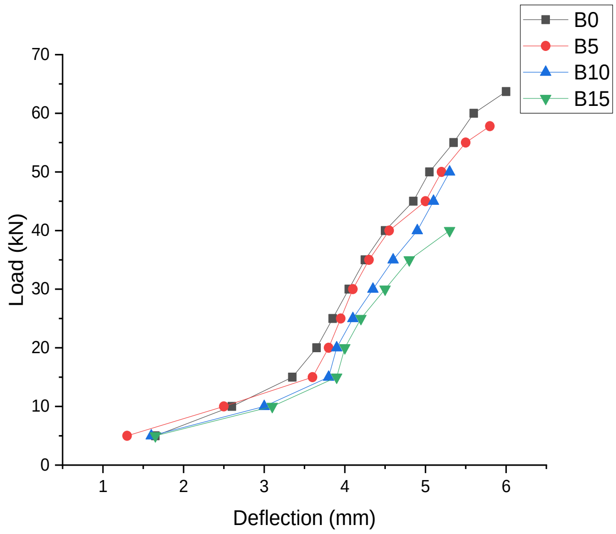

Chart-2: Load deflection graph

From the load deflection graph the trend of deflection was found increasing as the level of corrosion increasing and the ultimate load decreasing as the percentage of corrosion increasing.

3. CONCLUSIONS

After completing the experimental programme, the following conclusions can be inferred:-

- The effect of concrete cover in accelerating corrosion test can be nullified by modifying Faraday's equation with λ
- The ultimate load values are found decreasing as the percentage of corrosion increasing.
- The load of 5% corroded beams decreased 10% of control beam. The ultimate load of 10% corroded beams was found decreasing 23%of control beam and the load of 15% corrosion was decreased about 39% of control beam.

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