Forensic Investigation of Concrete Structures

Karishma Tiwari[1], Anubhav Rai[2]
[1]Dept of Civil Engineering
[2]HOD, Dept of Civil Engineering
[1, 2] GGITS, Jabalpur (M.P), India

Abstract- *Structural forensic engineering deals with the investigation and reconstruction of failures of RCC structures. It is a highly specialized field of engineering practice. With the help of forensic engineering, it is easy to provide further rehabilitation of concrete structures. The practice involves engineering investigations, rendering opinions and giving expert testimony in judicial proceedings if required.*

The term "forensic" itself justifies the application of scientific methods and techniques to the investigation of any problem. This paper represents the investigation of a RCC structure with the help of forensic investigation. The two NDT methods which have been taken are Half-cell potentiometer and Carbonation test. The main aim is trying to root out faulty mechanisms in structure to overcome the failure of structure.

Keywords- Forensic, Repair, Nondestructive test, RCC Structure.

I. INTRODUCTION

Structural forensic investigation is becoming an interest in structural engineering. Concrete, its components and its properties at various stages of maturity can be tested in many ways. Assessments are to be made of the defects in a concrete structure, to identify their causes and the ability of the structure to continue to perform its function, so that a suitable repair and protection option can be chosen.

- It is usually concerned with material selection, design product usage, methods of production and the mechanics of the failure within the part itself.
- A familiarity with the codes, standards and usual work practices is also required. Building codes, mechanical equipment codes, fire safety codes, electrical codes, material storage specifications, product codes and other more specifications.
- Installation methodologies and various safety rules, work rules, laws, regulations and company policies.

FACTORS AFFECTING DETERIORATION-

The major causes of deterioration of structures are the following:

- The presence of water, the most important factor being the moisture state within the concrete rather than that of the surrounding atmosphere.
- The chemical reactions which are accelerated by increase and decrease of temperature variations.
- Problems such as inadequate design, poor workmanship, the use of unsuitable aggregates or cement, or inappropriate concrete mix design which causes deterioration.
- Features which appear during construction or shortly afterwards.

OBJECTIVE OF THE PAPER-

The main aim of this paper is to-

- A review of the current literature papers on structural forensic engineering, definition and causes of structural failures.
- The proposed methodology, NDT methods as half-cell potentiometer and carbonation test are used in the experiment process.
- All the data and results of different tests are analyzed to give a proper technical report for knowing the root cause of the damaged structure.

II. METHODOLOGY

The method which has been adopted-

1. NDT (Nondestructive tests) method

1. NDT (Nondestructive tests) method- During an investigation, different NDT test methods are used to provide information for condition assessment and prediction of future performance.

a. Half-cell potentiometer test
b. Carbonation test

a. Half-cell potentiometer-

The instrument measures the potential and the electrical resistance between the reinforcement and the surface to evaluate the corrosion activity as well as the actual condition of the cover layer during testing. The test results can be interpreted based on the following table from IS 516 (PART 5 / SEC 2): 2021. Table below showing Half Cell Potential Corresponding to Percentage Chance of Corrosion Activity. This method may be used to indicate the corrosion activity associated with steel embedded in concrete. This method can be applied to members regardless of their size or the depth of concrete cover. This method can be used at any time during the life of a concrete member.

Table 1 Criteria for Corrosion Condition of Rebar in Concrete for Different Half-Cells

(Clauses 4 and 6.11)

Sl No.	$Cu/CuSO_4$ Electrode	$Hg/HgCl_2$ Electrode	Ag/AgCl Electrode	Likely Corrosion Condition
(1)	(2)	(3)	(4)	(5)
i)	> – 200 mV or less negative than – 200 mV	> – 126 mV	> – 106 mV	Low (there is a greater than 90 percent probability that no reinforcing steel corrosion is occurring in that area at the time of measurement)
ii)	– 200 mV to – 350 mV	– 126 mV to – 276 mV	– 106 mV to – 256 mV	Corrosion activity of the reinforcing steel in that area is uncertain
iii)	< – 350 mV or more negative than – 350 mV	< – 276 mV	< – 256 mV	High (there is a greater than 90 percent probability that reinforcing steel corrosion is occurring in that area at the time of measurement)
iv)	< – 500 mV	< – 426 mV	< – 406 mV	Severe corrosion

b. Carbonation Test-

Carbonation of concrete is one of the main reasons for corrosion of reinforcement. The reference for carbonation test has been taken from IS 516 (Part 5/Sec 3): 2021. Oxygen and moisture are the other components required for corrosion of embedded steel. In this test, the depth of carbonation is determined. The rate of carbonation depends on the grade of concrete, permeability of concrete, whether the concrete is protected or not, depth of cover, time, etc.

Carbonation is a process in which carbon dioxide from the atmosphere diffuses through the porous cover concrete and may reduce the pH to 8 or 9, at which the passivating/oxide film is no longer stable.

Carbonation process involves the following two stages: First, the atmospheric carbon dioxide (CO2) reacts with water in the concrete pores to form carbonic acid (H2CO3). This is followed by reaction of the carbonic acid with calcium hydroxide [Ca (OH)2] to form calcium carbonate (CaCO3).

This process leads to a reduction in the pH value of the pore solution from 12.5 to 13.5 to around 8 to 9, which causes passivation of the protective layer of the reinforcement bars and initiates their corrosion.

III. TESTING WORK

Work Details

Name of building- Namratana
Type of Structure - RCC Building of G+5 floors
Address - Navi Mumbai-400614
Age – 30

Visual Inspection-

INSPECTION REPORT							
		Gr. Floor	1st floor	2nd floor	3rd floor	4th floor	5th floor
a.	Painting	Good	Good	Good	Good	Good	Good
b.	Windows	Good	Good	Good	Good	Good	Good
c.	Cracks	Minor	Yes	Not visible	Not visible	Not visible	Not visible
d.	Leakage Refer defects list	No	Yes	No	No	No	No
e.	Any dangerous object/Hazard. Refer defects	No	No	No	No	No	No
g.	Overall appearance-	Looks good from outside. Cracks are observed in beams and columns of ground floor and first floor respectively.					

IV. NDT OBSERVATION

We have performed a Half-cell potentiometer test and carbonation test to check performance of the structural components like beams, slabs, columns, internal and external walls.

TEST- HALF CELL POTENTIOMETER (HCP)

TEST Reference code- IS 516 (PART 5 / SEC 2): 2021

Half Cell Potentiometer Test Criteria as per IS 516 (PART 5 / SEC 2) : 2021		HCP Results Interpretation
Half Cell Potential Reading (Cu/CuSO4)	Probability of active corrosion	No. of readings
– 200mV or less negative than – 200mV	Low (10%)	1
– 200mV to – 350mV	Uncertain (50%)	7
< – 350mV or more negative than – 350mV	High (90%)	0
< – 500mV	Severe corrosion	0

TEST- CARBONATION TEST

Reference Code- IS 516 (Part 5/Sec 3): 2021

Carbonation Results Summary	
Element Type	Average Carbonation Value (mm)
Column	17
Beam	28
Slab	30

V. TEST ANALYSIS AND RESULT DISCUSSION

Member	Half-cell potentiometer	Carbonation test	Remark	
			HCP	CT
Column-				
C4	-224	Depth= 20 mm (about 0.79 in)	Uncertain	Presence of Carbonation
C10	-254	Depth= 20 mm (about 0.79 in)	Uncertain	Presence of Carbonation
C23	-168	Depth= 5 mm (about 0.2 in)	Low	Presence of Carbonation
C24	-281	Depth= 30 mm (about 1.18 in)	Uncertain	Presence of Carbonation
Beam-				

B (C8-C9)	-259	Depth=30 mm (about 1.18 in)	Uncertain	Presence of Carbonation
B(C18-C19)	-243	Depth=25 mm (about 0.98 in)	Uncertain	Presence of Carbonation
B(C3-C12)	-200	Depth= 15 mm (about 0.59 in)	Uncertain	Presence of Carbonation
B(C5-C6)	-225	Depth= 20 mm (about 0.79 in)	Uncertain	Presence of Carbonation

Summary- From the above investigation we have come to conclude that the structure health condition is fair. The presence of carbonation is the reason for the deterioration of some structural members.

VI. CONCLUSION

- This structure is suffering from class 3 damage. According to CPWD (Central public works department) class 3 damage stands for observation like spalling of concrete cover, structural cracks etc., in which principal repairs are required.
- In case the delay in structural repair work will result in more deterioration and quantity of work will become more long.
- Corroded steel must be replaced wherever necessary, if steel cannot be removed then it should be clean to remove rusting and additional reinforcement is to be provided.
- Minor cracks should be repaired by injection of epoxy or by using a grouting method.

REFERENCES

[1] Responding to failure: An introduction to forensic structural engineering- by RJ Heywood, Brady Heywood Pty Ltd, Brisbane, Queensland.
[2] Forensic Investigation for Sustainability Issues in Structure by Prof. D.S.Bhosale.
[3] Repair and Rehabilitation of RCC Structures - by Rathod Ravinder, A.Vittalaiah and Akula Prakash.
[4] Repair and Rehabilitation of RCC Structures: A Case Study - by Kajol Mevawala, Liza Hirpara, Kavita Choksi and Darshan Mehta.
[5] Tools for forensic analysis of concrete structures - By Evan Bentz.
[6] A Review of the Repair of Reinforced Concrete Beams by M.Z. Jumaat, M. H. Kabir and M. Obaydullah.
[7] Forensic engineering and the importance of the human factor – by Hana Vykopalová, Martin Cupal.
[8] An Overview of Forensic Structural Engineering - by Robert T. Ratay.
[9] Responding to failure: An introduction to forensic structural engineering – by RJ Heywood.
[10] Applying Forensic Investigations of Failures of Structural Performance – by Jonathan G M Wood