Non Destructive Evaluation Technique In Repair Rehabilitation And Strengthening Of Chlorination Building – A Case Study

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Abstract

The deterioration of concrete structures calls for an effective method of condition evaluation, life assessment and maintenance in its service life. The deterioration process and structure's present condition are essential for maintenance and repair which can be assessed through Non Destructive Evaluation (NDE). The paper presents a case study, which includes use of various Non-Destructive Tests (NDT), to evaluate chlorination building constructed in 1980's, suggest suitable repair, rehabilitation and strengthening technique. The building is a RCC portal framed structure with RC purlins and AC sheeting. The structure deteriorated over the years due to physical causes and aggressive chemical environment, showing signs of distress in the form of cracks in RC members and spalling of concrete, failing to meet the functional requirement of its designed service life, suspending the chlorination operations. Visual inspection and NDT investigations such as Rebound hammer, Ultrasonic pulse velocity, half-cell potential, carbonation depth, resistivity tests, pH measurements, core sampling for chloride content and core compressive strength were done for life assessment, condition evaluation and categorization of distress. Based on the results of NDT field tests, laboratory analysis and visual observations it was concluded that the whole building can be repaired and rehabilitated for future use within its life span without demolishing. Detailed repair methodologies using Fiber Reinforced Polymer (FRP) Composites - glass fiber and carbon laminate system were proposed for repair and strengthening the structure. Periodical inspection and monitoring using NDE techniques were also proposed as structure evaluation is necessary for diagnosis of rehabilitation work.

Keywords: NDE, NDT, Fiber Reinforced Polymer Composite, Chlorination Building.

I. INTRODUCTION

Non Destructive Testing (NDT) methods have been used for more than three decades for monitoring concrete structures. The need for testing of hardened concrete and the deterioration of concrete structures in the last few decades calls for an effective methods for condition evaluation, maintenance and assessment of the integrity of old or new concrete and reinforcement. This resulted in development of several NDT techniques. The assessment of the RCC structures has grown considerably in recent times, due to increase in number of structures, showing signs of distress. Now it has been recognized that NDT methods are known to be better to assess and evaluate the condition of RC structures practically. The standard life of RCC frame structure is considered to be 60 - 80 years. But it is reported that chemical plant buildings survive just 20 - 25 years of their life, because the RCC structures are in distressed condition within a span of only 7 to 10 years due to severe exposure condition.

The paper presents a case study for a Chlorination Building, which was constructed during 1980s, a RC Portal Frame structure with RC Purlins and AC Sheet Roofing with dimensions 31mx12m and height 15m. The building had Structural Steel Mezzanine for the Chlorination Process. Tie beams are existing at intervals along the height of the building. The building was constructed with M15 concrete and CTD Bars as reinforcement. The building had shown signs of distress in the form of cracks in RC Members and spalling of concrete in thin members like sunshade, failing to meet the functional requirement of its designed service life. The operation of Plant was suspended due to fall of one Sunshade due to corrosion of reinforcement.Thesevere exposure condition was seen as the main reason for thisdeterioration.

II METHOD OF INVESTIGATION

The method of investigation work for the present chlorination building consisted of the following

A. Visual observation:

A detailed visual inspection was carried out for all the structural members of the chlorination building. On the basis of visual inspection, the columns and other structural RCC members were categorized as fairly damaged (RCC members exhibiting minor cracks and the crack depth extending up to plaster thickness including delamination of plaster), moderately damaged (RCC members exhibiting crack width between 5mm and 10mm and number of cracks more than fairly damaged condition) and severely damaged (RCC members exhibiting major crack in parent concrete having crack widths more than 15mm) based on which the rehabilitation methodology was suggested. The visual inspection had indicated that;there were 5 fairly, 3 moderately damaged columns and balance 14 columns are without any signs of distress in the building. There were 8 fairly, 4 moderately damaged beams and balance 37 beams are without any signs of distress in the building.

B. Non Destructive Tests on Concrete

Rebound hammer test:

This test was conducted as per IS 13311 Part 2:1992 at 186 locations and the Rebound hammer numbers of primary members are tabulated in Table 1. As can be seen from the tabulation, majority of locations in columns are in the range of 30 to 60 rebound number. However majority of locations in beams are found with rebound number below 30. Compressive strength derived from the rebound number values of primary members are tabulated in table 2. As can be seen from the tabulation, majority of columns have compressive strength in the range of 15 MPa to 40 MPa. However majority of beams are found with compressive strength below 15 MPa.

Ultrasonic pulse velocity test:

This test was conducted IS 13311 Part 1: 1992 at 186 locations and the Ultrasonic Pulse Velocity values of primary members are tabulated in table 3. As can be seen from the tabulation, majority of columns have Ultrasonic Pulse Velocity in the range of 3 to 3.5 Km/sec. However majority of beams are found with Ultrasonic Pulse Velocity below 3 Km/sec. Compressive strength derived from the Ultrasonic Pulse Velocity values of primary members are tabulated in table 4. As can be seen from the tabulation, majority of locations in columns have compressive strength worked out from Ultrasonic Pulse Velocity value in the range of 15 MPa to 30 MPa. However majority of locations in beams are found with compressive strength in the range of 15 MPa to 20 MPa.

Core Cutting – compression strength:

This test was carried out for 3 samples and the range of values is tabulated in table 5.As can be seen from the tabulation, the cube compressive strength derived from core test has yielded good result for M15 concrete.

Chloride content Test:

Chloride content values are measured in 47 points and the range of values is tabulated in table 6.As can be seen from the tabulation, majority of columns have Chloride value below 200 ppm and few are in the range of 300 ppm to 500 ppm whereas in beams the values are uniform from 100 ppm to 500 ppm.

Alkalinity Test (pH):

pH values are measured in 47 points and the range of values is tabulated in table 7.As can be seen from the tabulation, majority of columns have pH value in the range of 11 to 12 whereas in beams the values are in 10 to 12 range.

Carbonation Test:

Depth of Carbonation is measured in 47 points and the range of values are tabulated in table 8.As can be seen from the tabulation, majority of locations in columns have carbonation depth value below 10mm or between 40mm to 60mm. However all the beams tested are found with carbonation depth value between 20mm to 40mm.

Electro- chemical parameters for corrosion mapping of reinforcement

Half-cell Potentiometer:

Half-cell potential values are measured in 47 points and the range of values is tabulated in table 9.As can be seen from the tabulation, majority of columns and Beams have Half Cell

Potential value in the range of -250mV to -400mV indicating 50 to 90% corrosion probability.

Resistivity meter:

Resistivity values are measured in 5 points and the range of values is tabulated in table 10.As can be seen from the tabulation, majority of columns have resistivity value below 5 indicating very high corrosion possibility.

III ANALYSIS OF NDT RESULTS

One of the very important aspect of Non Destructive Evaluation is the analysis of results. The results of various tests are to be analyzed together and the condition of the structure is to be predicted as RC Structures are made up of heterogeneous material and many types of deteriorations are possible.Based on the above tabulations it is concluded that;

- The Portal Frames of the structure are in good condition and some tie beams along the length of building (connecting the portal frames) are in distressed condition which needs repair as per the visual observation.
- Compressive strength of concrete which was observed in UPV (average 18.61 MPa), Rebound Hammer (average 24.21 MPa) and Core Tests (average 28.33 MPa) which is comparable with M15 grade of concrete used for the construction.
- Carbonation depth is exceeding the cover concrete at few places and hence needs attention.
- pH value by and large are in alkaline range (above 11).
- Corrosion of reinforcement is set in and hence needs repair especially in tie beams.
- Chloride content in concrete is within the permissible limits.

In view of the above the building was attempted for repair.

IV REPAIR METHODOLOGY IN BRIEF

The building was modelled as 3D structure and was analysed for all the loads and load combinations which are likely to come on the structure using renowned computer software. Existing details of the structures based on the drawings and details available was used. Based on the analysis result, the adequacy of the structural sizes were estimated. Following repair methodology was suggested to bring back the structure to serviceability.

1. Loose concrete shall be removed by hand held breaker / hammer. The area around distress shall be cleaned with wire brush.
2. The exposed reinforcement shall be cleaned with wire brush and with de-ruster compound to remove the rust. The rust remover shall be applied with cotton swap to bring back the original colour of the reinforcement.
3. BONDING AGENT: Epoxy Resin based bonding agent shall be applied by brush to the surface of concrete to receive polymer modified mortar.
4. POLYMER MODIFIED MORTAR: Polymer modified mortar shall be applied to the surface with suitable supporting arrangement.
5. GLASS FIBER WRAPPING: The Glass fiber shall be wrapped around the members where the repair was carried out for the entire span of the member with Primer, high

build Epoxy Saturant and sealant etc, as per standard manufacturer's practice, procedures and products available in market. The fibre system was designed based on ACI 440; American Concrete Institute guide for the design and construction of externally bounded FRP system for strengthening of concrete structures. Unidirectional glass fibers of adequate thickness were proposed for wrapping.

6. PAINTING WITH PROTECTIVE COATING: The RC Elements of whole building shall be painted with breathable zinc rich aliphatic acrylic protective coating for 150 micron DFT after cleaning the surface to be painted of oil, grease and any other foreign matter. The surface shall be rubbed with emery paper (No. 60 to 80) and the dust removed thoroughly with clean cotton cloth. The pin holes etc., if any shall be filled with cement paste and excess mortar shall be removed after drying by rubbing with emery paper followed by wiping with clean cloth.

V CONCLUSION

The non-destructive testing methods are very effective in understanding the present condition of concrete, reinforcement and the structure as a whole. By systematic analysis of the findings of the test results effective rehabilitation methodology can be suggested to bring back the distressed structure to serviceable condition. Through this study, one such building which is in distress due to chloride induced deterioration is rehabilitated

Table 1. Rebound Number

Range of Rebound Number (↓)	**Number of locations in Columns**	**Number of locations in Beams**
Below 30	4	19
Between 30 to 40	28	12
Between 40 to 50	52	7
Between 50 to 60	43	1
Above 60	6	Nil

Table 2. Compressive Strength of Concrete derived from Rebound Number

Compressive strength in MPa (↓)	**Number of locations in Columns**	**Number of locations in Beams**
Below 15	11	26
Between 15 to 20	17	7
Between 20 to 30	49	6
Between 30 to 40	38	2
Above 40	14	Nil

Table 3. Ultrasonic Pulse Velocity Value

Range of Ultrasonic Pulse Velocity (↓)	**Number of locations in Columns**	**Number of locations in Beams**
Below 3 Km/Sec.	94	40
Between 3 to 3.5 Km/Sec.	30	1
Between 3.5 to 4.5 Km/Sec.	5	Nil

Table 4. Compressive Strength based on UPV value

Compressive strength in MPa (↓)	**Number of locations in Columns**	**Number of locations in Beams**
Below 15	Nil	Nil
Between 15 to 20	78	40
Between 20 to 30	51	1
Above 30	Nil	Nil

Table 5. Concrete core sample test value

Equivalent cube Compressive Strength in MPa (↓)	**Number of locations in Columns**
Between 20 to 30	2
Above 30	1

Table 6. Chloride content

Chloride values in ppm (↓)	**Number of locations in Columns**	**Number of locations in Beams**
Up to 100	11	-
Between 100 to 200	10	1
Between 200 to 300	3	2
Between 300 to 500	9	2
Above 500	3	1

Table 7. pH value test result

pH values (↓)	**Number of locations in Columns**	**Number of locations in Beams**
Up to 10	4	1
Between 10 to 11	4	3
Between 11 to 12	27	2
Above 12	3	-

Table 8. Carbonation test result

Depth of carbonation in mm (↓)	**Number of locations in Columns**	**Number of locations in Beams**
Up to 10 (10 inclusive)	12	-
Between 10 to 20 (20 inclusive)	1	-
Between 20 to 40 (40 inclusive)	6	5
Between 40 to 60 (60 inclusive)	14	-
Above 60	4	-

Table 9. Half Cell Potential Test results

Half Cell Potential values in mV (↓)	**Number of locations in Columns**	**Number of locations in Beams**
Up to -250	1	-
Between -250 to -350	11	2
Between -350 to -400	27	2
Above -400	-	1

Table 10.Concrete Resistivity Test Result

Resistivity in KOhm (↓)	**Number of locations in Columns**
Up to 5	4
Above 5	1

VIREFERENCES

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