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In-Situ Testing of RCC Structures in Bhopal Region

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ABSTRACT

NDT testing provide detail information about defects and cracks supplemental problems in different field of structure As if RCC structures, pavements blocks, and steel structure . Nondestructive testing of concrete allows the inspection of larger areas of concrete members at lesser cost than coring and provides more information than visual inspection. The deterioration of reinforced concrete structure such as elevated service reservoir is major problem in many countries of the world. Many of the existing building rccs in service today are inadequate to need the present building demand. To ensure safe durable service and selecting the most appropriate repair strategy it is essential to perform in situ inspection for a distressed concrete structure. The main objective of present work is to propose the developed systematic investigation for metrology and a condition based on Analytical process (AP). Upv rating technique is used to find out the condition ranking of Rcc structure in Bhopal The assessment for RCC structure has been carried our using different Non-destructive test methods like surface hardness, ultrasonic pulse velocity test, half cell potential methods and cover depth measure.

Keywords: NDT testing, RCC structure, surface hardness, UPV rating, Bhopal REGION.

INTRODUCTION

Concrete structures judgments process for condition has been performed in last decades mostly by visual examination, surface condition and coring to examine internal concrete conditions. Condition assessments can be done with NDT methods to provide information for the structural performance of the concrete, such as: Member dimensions; Location of cracking, delimitation and deboning; presence of voids and honeycomb; Steel reinforcement location and size; Corrosion activity of reinforcement; and Extent of damage from freezing and thawing, fire, or physical and chemical exposure.

When the actual compressive strength of the concrete in the structure is to be determined core testing as per IS 516:1959 'Method of test of strength of concrete is more reliable. Core tests provide the most reliable in-situ strength assessment but also cause the most damage and are slow and expensive. However these methods are relatively cumbersome therefore use of non-destructive tests which not only provide an estimate of the relative strength and overall quality of concrete in the structure but also helps in deciding whether more rigorous tests like load testing or core drilling at selected conditions are required.

[1] Bogas et al. (2013). In this study almost 84 separate compositions have been tested after 3 and 180 days of curing, compressive strengths of these samples is ranging about 30 to 80 MPa. [2] et.al conducted experimental investigation to evaluate mathematical models for predicting concrete pulse velocity. Bhadauria and Gupta [3] studied In-service durability performance of building rccs. Ayop and Mohamad Ismail [4] presented the development of condition assessment system for assessing the condition statuses of concrete marine structures in Malaysia based on the condition Index method

developed by the U.S Army Corps of Engineers. Ming-Te Liang, Chin -Ming Lin and Chi-Jang Yeh [5] J. P. Joule, The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science 30 (199), 76-87 (1847) [6] established relationships between subjective bridge condition ratings and the FHWA's numeric ratings to find relationships between the numeric condition rating and the expected remaining service life of bridges.

UPV's are large elevated building storage container constructed for the purpose of holding a building supply at a height sufficient to pressurize a building distribution system. RCC UPV's undergoes deterioration due to corrosion of reinforcement, chloride diffusion, alkali aggregate reaction, freezing and thawing etc. which may lead failure of RCC UPV's. Thus, assessment of quality of RCC UPV's is necessary to ensure that the quality of execution is satisfactory and also to identify any deficiencies so that they can be rectified. This can be achieved only by conducting some in-situ tests on the structures besides visual inspection. Rebound hammer test, half cell potential test, rebar locater test, ultrasonic pulse velocity (UPV) test, Carbonation test, pH test and chloride content test are mostly used for the assessment of existing concrete structures. In present work the Condition Ranking of Existing R.C.C. UPV in Karond region using a Non destructive module has been done.

METHODOLOGY

BUILDING C0NDITION RATINGS

It is a numerical index of damage level of the element and the whole structure, on the basis of in-situ tests and visual observation of the intensity and extent of damage and judging the urgency of repair. The assessment is based on physical deterioration as determined by measurable distress. The Condition Ranking / Condition Index (CI) are represented by a quantitative ranking between 0 and 100; 0 being the worst condition and 100 being the best condition. The index serves as guidelines for structures that require immediate repairs and further evaluation. The condition index scales (CI) developed by gleeman and sticker were used to convert the physical state of the structure into quantitative values as shown in Table 1.

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Table 1. Condition Index Scale

Zone	Condition Index	Condition Description	Recommended Action
1	85-100	Excellent: No noticeable defects. Some aging or wear may be visible.	Immediate action is not required
	70-84	Very Good: Only minor deterioration or defects are evident	
2	55-69	Good: Some deterioration or defects are evident, but function is not significantly affected.	Economic analysis of repair
	40-54	Fair: Moderate deterioration. Function is still adequate.	. recommended to determine appropriate action
	25-39	Poor: Serious deterioration in at least some portions of the structure. Function is inadequate.	Detailed evaluation is required to determine the need for repair,
3	10-24	Very Poor: Extensive deterioration. Barely Functional.	Rehabilitation or reconstruction. Safety evaluation is
	0-9	Failed: No longer functions, General failure or complete failure of major structural component.	

- To determine the feasibility of changing the use of structure or retrofitting the structure of accommodates a different use from the present one. The feasibility of enlarging the structure or changing appearance of thestructure may also to be determined.
- To determine the structure adequacy and integrity of a structure or selected elements.
- To evaluate the structural problem or distresses which result from unusual loading, exposure condition, inadequate design, or poor construction practices.
- To determine the feasibility of modifying the existing structure to conform to current codes and standards
- To determine the service life of existing structures. And To evaluate or determine the cost effectiveness of repairing, replacing and strengthening the existing structural members elements

Nondestructive Evaluation Rating

Nondestructive testing is a technology that need not destroy the reinforced concrete structure but can assess the determination of condition of the reinforced concrete. Here Nondestructive testing methods adopted are as follows,

1) Schmidt hammer test for concrete compressive strength.
2) Cover meter test
3) Rebar corrosion test.

Based on the result obtained from the NDT testing the structural adequacy is calculated using the condition ranking/condition index (CI). The formula for condition index (CI) is based on a point deduction system and weight average method. The building rcc deficiencies score deduction points that are subtracted from a perfect score of 100 resultsin the condition index of each inspection item. In the present approach, each of the predefined elements of building rcc is inspect by NDT and assessed in terms of three aspect of the defect i.e. Degree (D), Extent (E) and Relevancy (R) using a 0 to 4 ranking scheme which can be found out using table 2,3,4 and 5. Degree (D) is defined as the severity of the elementdefect under consideration (if the element has more than one defect then choose the most server defect for ranking). Extent

(E) is the extent to which the defect occurs over the area of the building rcc element. Each of this parameter is combined in the prioritization module to determine a priority ranking of building rccs requiring repair. After NDT inspection, the element condition index (CI) for each component of the building rcc is calculated as follows.

$$I_{c_i} = 100 - 100 \times \frac{[\max(D) + E] \times R^a}{(4+4) \times 4^a} \quad (1)$$

Where,

Ici = Condition index of each components

i = 1~n (n is the number of components of RCC STRUCTURE)

a = Parameter determined by the importance of the RCC STRUCTURE (usually the value of ‘a’ ranges tram 1 to 2).

Wi = Weightings of RCC STRUCTURE components. (Assume that the total weight of an all component group value

Table 2 Re-bar locatr for cover .

D-value rating	Test Results
0	No such item
1	$0.75D_e \le D_t$
2	$0.5D_e \le D_t < 0.75D_e$
3	$0.25D_e \le D_t < 0.5D_e$
4	$D_t < 0.25D_e$

(D_c and D_t are the design concrete cover thickness and in-situ concrete cover thickness)

Table 3.Corrosion test

D-value rating	Test Results
0	No such item
1	$V_2 \le V_e$
2	$V_2 - 0.5\Delta V \le V_e < V_2$
3	$V_1 \le V_e < V_2 - 0.5\Delta V$
4	$V_2 < V_1$

(V_c is the measured electrical potential; V_1 =-350mV, V_2 =-200mV when electrical solution is $CuSO_4$,

while V_1 = -90mV, V_2 = -240mV when electrical solution is $AgNO_3$)

The damage and deterioration of concrete due to corrosion of reinforced is one of the most serious causes for durability problem. Following methodology is adopted to carry out the proposed work.

1. Collection of details and information about the RCC UPV design, construction, utilization, maintenance in the post. Collecting the complete record of RCC UPV, design details and drawings, architectural details, construction details of the area and foundation particulars, details of any repair or retrofitting done from the time of construction.
2. Visual inspection at site and recording details of distress and deterioration. The visual inspection includes:

- Verification of the accuracy of the original drawings or determination of basic UPV information, if drawings are available.
- Identification of major alternations not shown on the original construction documents.
- Identification of visible structural damage and deterioration such as concrete cracking or spalling andobservations on quality of construction.
- Observation on the condition of soil and the foundation.
- Documentation of existing conditions with photograph at key locations.

3. NDT testing will be carried out on structure UPV.

4. Developed NDT method and Interpretation of the test are interpreted with criteria given in different IS codes, standard. Such as:

- Indian standard code of practice for non destructive testing of concrete- Method of test (Ultra sonic pulse velocity) I. S. 13311 (Part 1, 1992) Bureau of Indian Standard (BIS).
- Indian standard code of practice for non destructive testing, of concrete- method of test (Rebound

hammer)
I. S. 13311 (Part 2, 1992) Bureau of Indian Standard (BIS).

- Indian Standard code of practice for Nondestructive testing of concrete- method of test (Core Cutter) I.S.1199-1959.

Condition ranking is found out with assessment in different IS-CODE. Comparative study is adopted.

CASE STUDY

RCC BUILDING OF COLLEGE ENGINEERING, KAROND BHOPAL

Non Destructive Testing of RCC UPV located at RCC BUILDING of college , Karond was selected for study purpose. The stucture is 23 years old. The load of the UPV is 1.5 . KN/m. Rcc is supported on four columns of size (0.4m x 0.4m) on the periphery. The stagging height approximately is 3.5 m above ground each floor level. It consists of 4 columns and brace beam which are connecting the columns and braces of rectangular shape. Size of brace is 0.4m x 0.5m. For identification purposes, the columns are numbered as column C_1 to Column C_4 in clock wise direction. Brace beams are numbered as brace beam B_1 to brace beam B_4 such that brace B_1 appears after column C_1 in clockwise direction. The UPV consists of RCC top dome, Rcc container and stair case. Fig 1. shows a detailed drawing of building rcc located at Government College of Engineering, Karond.

A detailed visual inspection was carried out on almost all assessable location of the building rcc. This included several visually under damaged member. Cracks developed on column and braces of building rcc were up to the 15 cm in length and 2-4 mm width. The extent of deterioration was more than 75%. Cracks were observed on Top dome and talk wall was 1.0 cm length and 1 mm width. Rebar’s can be seen at all the component of rcc with maximum portion was exposed corroded. Stair case of building rcc was not assessable for movements. It was fully deteriorated and rebar were corroded. The field work was carried out which consists of visual inspection and Nondestructive testing. The tests are as follows.

1) observation
2) Halt-cell potentiometer test
3) Rebar locator test
4) Rebound hammer test
5) Resistivity Meter test

Results of the Profometer test for column C_2 and Staircase of the building rcc is shown in Fig 2. & Fig 3. Respectively. Thus using Profometer test cover for each bar can be directly measured which is helpful in deciding the status of reinforcement in the concrete member.

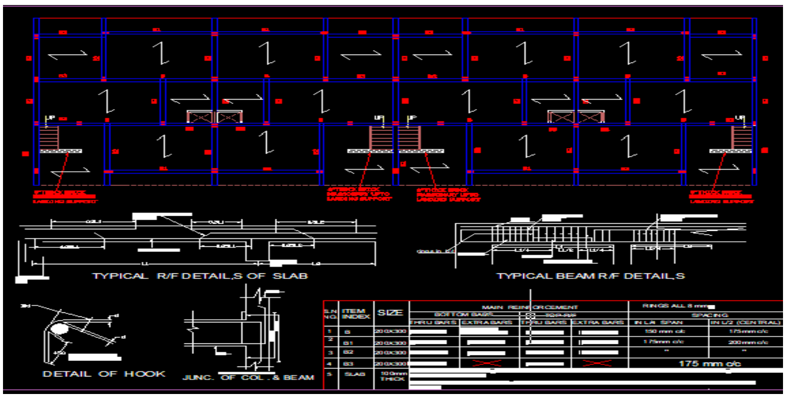
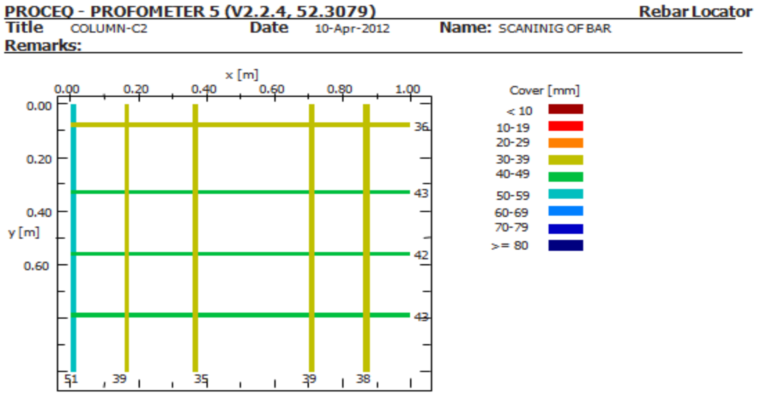


Figure. 1. Plan & Elevation of Building Rcc at B Karond



Set parameters			Statistic		x	y	
Bar diameter	D=16	mm	Number of measured bars	N =	5	4	
X grid width	dX=10	mm	Average measured cover	m =	40.4	41.0	mm
Y grid width	dY=10	mm	Standard deviation	sa =	6.1	3.4	mm
			Maximum of measured covers	Max =	51	43	mm
			Minimum of measured covers	Min =	35	36	mm
			Span	R =	16	7	mm

Fig. 2. Results of Rebar Locator for Column C2, Building Rcc at B Karond

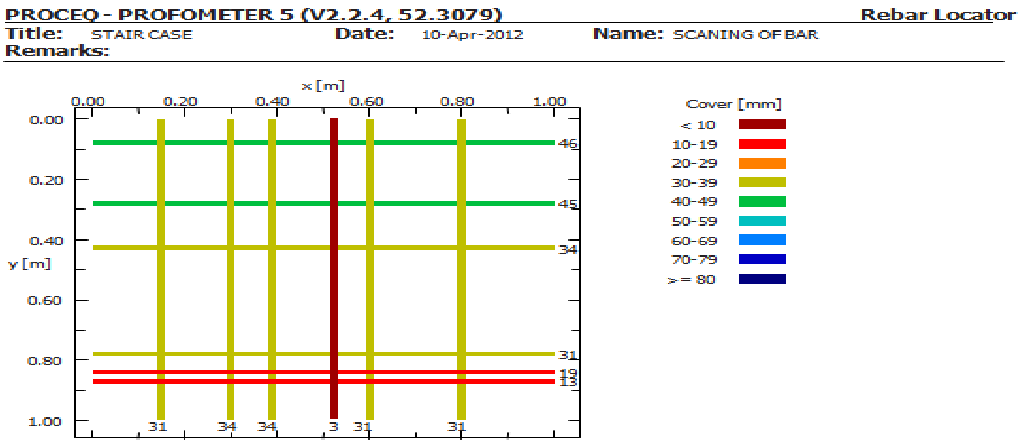


Fig. 3. Results of Rebar Locator for Staircase, Building Rcc at B Karond

Set parameters				Statistic		x	y	
Bar diameter	D =	16	mm	Number of measured bars	N =	6	6	
X grid width	dX =	10	mm	Average measured cover	m =	27.3	31.3	mm
Y grid width	dY =	10	mm	Standard deviation	sa =	12.0	13.4	mm
				Maximum of measured covers	Max =	34	46	mm
				Minimum of measured covers	Min =	3	13	mm
				Span	R =	31	33	mm

Condition index is determined by NDT evaluation by DER Rating approach for all the component/ element of building rcc.
Assume,

- Design strength of concrete (M_{25})=25 N/mm^2
- Design concrete cover for columns, D_c=50mm
- Design concrete cover for brace beams, D_c=30 mm
- Design concrete cover for rcc container, top dome and stair case, D_c = 25 mm
- Parameter 'a' is related to importance of building rcc = 2

1) Condition Ranking/condition index for column – 1 (I_{c1})P_d=25 N/ mm^2, a=2, D_c= 50mm
Value of E and R from DER Rating Visual inspection table 2, E=3 and R=4

i) Concrete compressive strength measured by rebound hammer test = P_t=17 N/mm^2, from table 3, D=4
ii) Average cover measured by rebar locator = D_t = 39.5 mm, from Table 11, D=1
iii) Average potential difference measured by half-cell potential V_e = -250mv, from table 4, D=1
Above three value of 'D' – max D = 4

In the same way for columns – C_2, C_3, C_4 I_{ci} is calculated.
Condition Index for bracing beams- 1 (I_{C5}) Assume P_d = 25 N/mm^2, D_c=30 mm, a=2 Value of E and R from Table 2, E=4 and R=4

i) Average compressive strength measured for bracing beam B_1 by rebound hammer P_d=07 N/mm^2, from table 3, D=4
ii) Average cover measured by rebar locator D_t = 215.5, from table 4, D=2
iii) Average potential difference measured by to half-cell potential V_e = -250mV, from table 5, D=1From above three values, D_{max} = 4 I_{c5} = 0

In the same manner condition index for bracing beams – B_2, B_3, B_4, Stair Case, Top Dome and Building rcc container iscalculated.

Finally,

Condition index (CI) of building rcc is

$$CI = \frac{\sum_{i=1}^{n} I_{c_i} \times w_i}{\sum_{i=1}^{n} w_i}, \quad where \sum_{i=1}^{n} w_i = 100$$

CI = 16.48

From Table 1 of condition index scales, for CI =16.48 which lies between CI = 10 to 24, it means that condition of building rcc is very poor, extensive deterioration and barely functional.

UPV at Bhopal, Karond

Fig 4. shows the RCC UPV at Bhopal Karond which was selected for the detailed study of the work. The load of the RCC UPV is 3.0 . KN/m. It is supported on 4 columns. These columns are circular in shape. For identification purposes, the columns are numbered as column C_1 to column C_4. Braces are numbered as brace B_1 to brace B_4 such that brace B_1 appears after column C_1 in anticlockwise direction. The diameter of column is 0.4 m and size of rectangular brace is 0.4m x 0.5m. UPV consists of steel stair case. A detail visual inspection was carried out on almost all assessable location. This included several visually under damaged member. Cracks developed on building rcc were up to 10 cm length and 0.5m width on column and braces. The extent of deterioration was more than 40%. The minor cracks were observed on top dome and rcc wall. Results of the profometer test for column C_1 and bracing B_1 is as shown in Fig 5. and Fig 6. respectively.

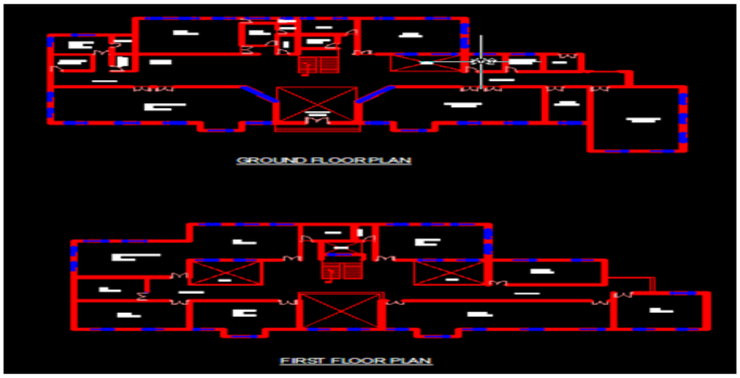


Fig. 4. Plan and Elevation for RCC college building structure at Bhopal, Karond

Results of rebar locator

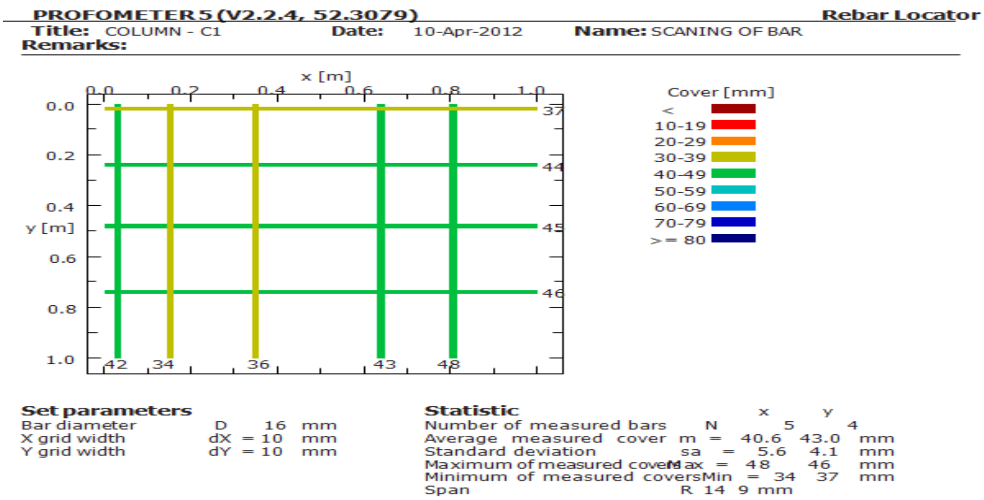


Fig. 5. Results of Rebar Locator for Column C1, Building Rcc at Bhopal Karond

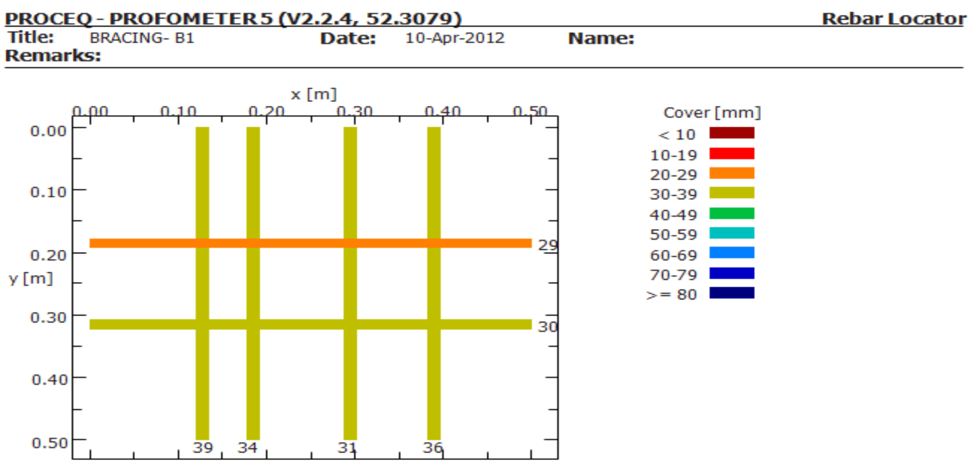


Fig. 6. Results of Rebar Locator for Bracing B1, Building Rcc at Bhopal Karond

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Set parameters			**Statistic**		x	y	
Bar diameter	D = 16	mm	Number of measured bars	N =	4	2	
X grid width	dX = 5	mm	Average measured cover	m =	35.0	29.5	mm
Y grid width	dY = 5	mm	Standard deviation	sa =	3.4	0.7	mm
			Maximum of measured covers	Max =	39	30	mm
			Minimum of measured covers	Min =	31	29	mm
			Span	R =	8	1	mm

Condition index of building rcc is determined by NDT evaluation by DER rating approach for all the component/element of building rcc.
Assume,

- Design comp. strength of concrete = P_d = 25N/mm2
- Design concrete cover for column = D_c = 50mm
- Design concrete cover for brace beams = D_c = 30mm
- Design concrete cover for top dome, rcc container = D_C= 25mm
- Parameter 'a' is related to importance of building rcc = 2

1) Condition Ranking/condition Index for column – C_1 (I_{c1})P_d = 25 N/mm^2 , a=2, D_c=50mm
Value of E and R from Table 2 DER rating visual inspection E=3, and R=3

i) Concrete comp. strength measured by rebound hammer test = P_t = 12.4 N/mm^{2}From table 3 is D=4
ii) Avg. concrete cover measured by Rebar locator = D_c = 38mmFrom table 4 is D=1
iii) Arg. corrosion measured by halt-cell potentiometer =V_e=-280mVFrom table 5, D=1
From above three values of D, D_{max} =4

$$Ic1 = 100 - 100x\frac{[4+3]x3^2}{(4+4)x4^2} = 50.78$$

Hence,

Similarly, columns – C_2, C_3 and C_4, condition index is calculated.

2) Condition Ranking/condition Index for bracing beams – B_1 (I_{C5})Assume,

P_d = 25 N/mm^2, D_c=30mm, a=2, Value of E and R from table 2 is E = 4 and R=4

i) Concrete comp. strength measured by rebound hammer test, P_t = 26.50 N/mm^2, From table 3, D=1
ii) Avg. concrete cover measured by rebar locator = D_c =37.3mm, From table 4, D=1
iii) Avg. corrosion measured by halt-cell potentiometer = V_e= -205mV, From table 5, D=3From above three value of D, D_{max} =4

$$Ic5 = 100 - 100x\frac{[4+3]x3^2}{(4+4)x4^2} = 50.78$$

Similarly, condition Index for brace beams B_2, B_3 and B_4 and Top dome and rcc wall is calculated.
Finally, The condition index of building rcc

$$CI = \frac{\sum_{i=1}^{10} IC_1 \, x \, w_i}{\sum_{i=1}^{10} w_i}, \quad Where \sum_{i=1}^{10} w_i = 100$$

$$= \frac{610.24 + 692.71 + 610.24 + 225 + 225 + 577.78 + 577.78 + 356.81 + 65.0 + 65}{12 + 12 + 12 + 12 + 10 + 10 + 10 + 10 + 7 + 5}$$

$$= 40.05$$

From the table 1 of condition index scale, CI=40.05 which is between 40 and 54, it means that condition of building rcc isfair, moderate deterioration occurred and function is still adequate.

CONCLUSION

When challenged to develop for metrology and a condition procedure based on Analytical process (AP) has been proposed. upv technique is used to find out the condition ranking of RCC structure in bhopal region in (India). The assessment for RCC structure has been carried our using different Non-destructive test methods like half cell potential methods, cover depth measure, surface hardness and ultrasonic pulse velocity test. The condition for RCC, bhopal is found to be CI =16.48 which implies that condition of RCC struture is very poor there and extensive deterioration is occurred and the building barely functional. For building at bhopal region, CI=40.05, it means that condition of building structure is fair, moderate deterioration occurred and function is still adequate. Thus using DER rating technique Condition Ranking of RCC UPV's are found out.

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