Condition Assessment of Bridges by NDT Methods

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***Abstract* - As a structure becomes older and older it shows wear and tear due to ageing, exposure to weather or environment and structurally unplanned modifications which affect the health of the structure significantly. Hence condition assessment of structure is necessity for ensuring that the structure and its premises are safe and under no risks condition. The need of condition assessment is also for maintenance and repairs of existing structures whose life has exceeded the age of 30 years so as to avoid any mishaps and save valuable human life. In this paper condition assessment for bridge structure has been carried out using different Non-destructive test methods like surface ultrasonic pulse velocity test, rebound hammer, half cell potential methods and cover meter. DER rating technique is used to find out the condition of bridge in terms of Condition Index (CI).**

***Index Terms*—Condition Assessment, Non -destructive testing, DER rating, condition-Index.**

I. INTRODUCTION

Present method of condition assessment of structure is Structural health monitoring (SHM). SHM has been a subject of major international research in recent years. The research in this subject covers sensing, communication, signal processing, data management, system identification, information technology, etc; The current challenges for bridge structural health monitoring are being identified as distributed and embedded sensing, data management and storage, data mining and knowledge discovery, diagnostic methods, and presentation of useful and reliable information to bridge owners/managers for decision making on maintenance and management. Structural health monitoring can be made with NDT methods to provide information for structural performance. There are various methods of non destructive testing. Such as:

NDT Methods:

- Visual Inspection
- Ultra Sonic Pulse Velocity (USPV) Test
- Cover Meter.
- Rebound Hammer Test.
- Concrete Core Strength
- Half Cell Potentiometer
- Carbonation Test
- Chemical Analysis : (pH, Cl, SO3)

II. METHODOLOGY FOR FINDING CI

Conditional Ranking

On the basis of visual observation and in-situ tests, It is numerical index of damage level between 0 to 100; 0 being the worst and 100 being the best condition of working. This is used to convert physical state of structure into quantitative values. This index serves as guidelines for structure for further analysis. The condition index developed by Gleeman and Sticker is used to convert physical state of structure into qualitative values as shown in table 1.

Purpose and Significance of Condition Ranking/Condition Rating

Condition ranking evaluation work is generally performed for the following purpose,

- To determine the structural stability and integrity of a structure or selected elements.
- To determine whether extra strengthening is required for the structure.
- To determine service life of structure.
- To evaluate structural problem arise due to unusual loading, poor constructional practices

As per Wankhade and Landage (2012) ,

Table1. 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 alternatives is recommended to determine appropriate action
	40-54	Fair: Moderate deterioration. Function is still adequate.	
3	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, Rehabilitation or reconstruction. Safety evaluation is recommended.
	10-24	Very Poor: Extensive deterioration. Barely Functional.	
	0-9	Failed: No longer functions, General failure or complete failure of major structural component.	

III. NONDESTRUCTIVE EVALUATION RATING

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

Based on NDT testing results, conditional ranking of the bridges is calculated. The formula for conditional ranking is based on point deduction formula and weight average method. Bridge score deduction points is subtracted from perfect score of 100, and conditional index is assigned to each inspected item. In this approach each element is inspected by NDT and assessed in terms of three aspect of defect i.e. Degree (D), Extent (E) and Relevancy (R) using 0 to 4 ranking scheme. Degree (D) is defined as the severity of the element defect 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 bridge element. Each of this parameter is combined in the prioritization module to determine a priority ranking of bridges requiring repair. After NDT inspection, the element condition index (CI) for each component of the bridge is calculated as follows.

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

Then the conditional index of bridge is calculated by:

$$CI = \frac{\sum_{i=1}^{n} I_{c_i} \times w_i}{\sum_{i=1}^{n} w_i}, \quad where \sum_{i=1}^{n} w_i = 100 \qquad (2)$$

Where,

I_{ci} = Condition index of each components

I = 1~n (n is the number of components of bridge)

A = Parameter determined by the importance of the bridges (usually the value of 'a' ranges tram 1 to 2).

W_i = Weightings of bridge components. (Assume that the total weight of an all component group value is 10, 100, 1000 ------ so on, it is not unique).

Table 2: DER Rating Scale for Visual Inspection

Rating	0	1	2	3	4
D	No Such item	Good	Fair	Poor	Severe
E	Cannot be inspected	<10%	<30%	<60%	<high
R	Cannot be decided	Minor	Small	Medium	High

Table 3: Schmidt hammer test for concrete compression strength

D value Rating	Test Results
0	No Such Item
1	$P_d \le p_t$
2	$0.85P_d \le p_t < p_d$
3	$0.75P_d \le p_t < 0.85\,p_d$
4	$p_t < 0.75\,p_d$

(P_d and P_t are the design and test results of the concrete compression strength)

Table 4: Rebar locator for cover thickness

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	$D_t < 0.25D_e$

(De and Dt are the design concrete cover thickness and in-situ concrete cover thickness)

Table 5.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	$V_2 < V_1$

(Ve is the measured electrical potential; V1 =-350mV, V2 =-200mV when electrical solution is CuSO4, while V1 = -90mV, V2 = -240mV when electrical solution is AgNO3)

IV. CASE STUDY

The Sambhaji Bridge is a RCC arch bridge on Jayanti Nalha located at Shahupuri, Kolhapur (Maharashtra). Bridge is having two RCC piers and RCC Abutments at ends and total 3 Spans. The Bridge was constructed in the Year 1970 as per the records of Kolhapur Municipal Corporation. The Bridge Length is approximately 30.00 M. with carriageway width of 17.50 M. Span length between Abutments to Pier is 6.60 M. The depth of RCC Arch Ring is 350 MM. Steel Railing is provided of height 1.00 M. Service lines are available parallel to the length of bridge throughout on one side. Spouts are not provided at both sides of Carriageway to drain out Storm Water. Lighting arrangements & Footpaths are provided throughout the length of the Bridge.

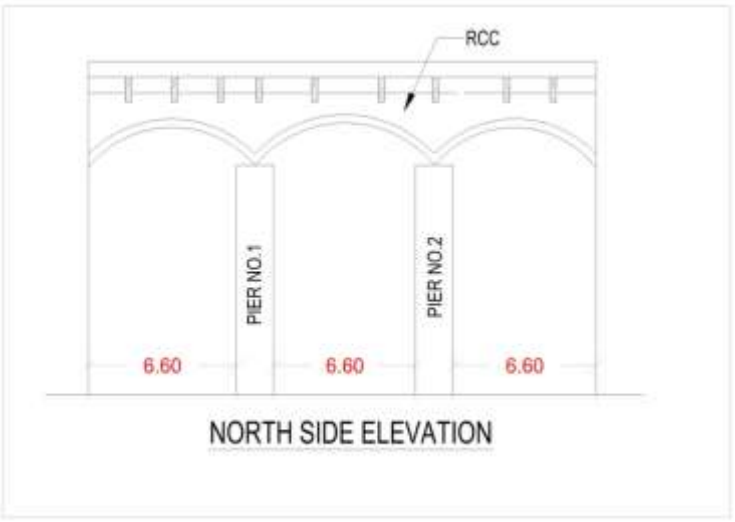

Fig.1 Elevation of Sambhaji Bridge

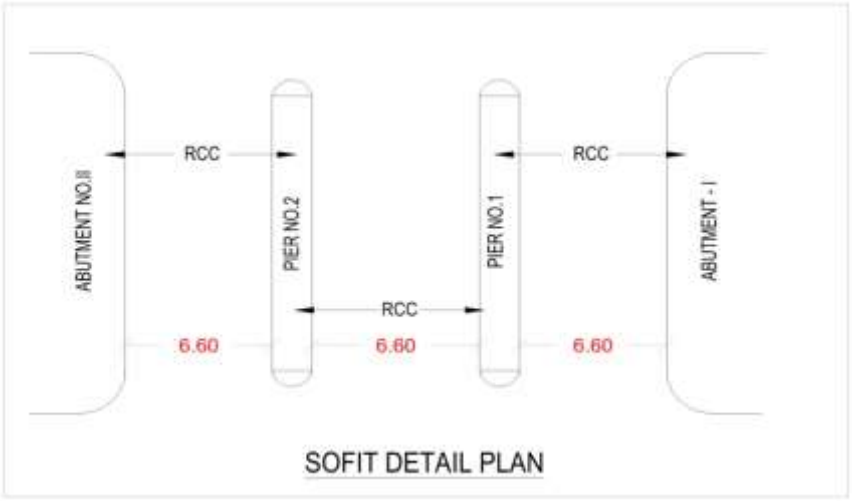

Fig.2 Soffit Detail Plan of Sambhaji Bridge

Condition index is determined by NDT evaluation by DER Rating approach for all the component/ element of Bridge

Assume,

- Design strength of concrete (M_{25})=30 N/mm^2
- Concrete cover for Pier, D_c=50mm
- Concrete cover for Abutment, D_c=50 mm
- Concrete cover for slab, D_c=50 mm
- Parameter 'a' is related to importance of bridge = 1.2

1) Condition Ranking / Condition Index for Pier- P_1 (Ic_1)

P_d=30 N/ mm^2, a=1.2, D_c= 50mm

Value of E and R from DER Rating Visual inspection table 2, E=2 and R=2

i) Concrete comp. strength measured by rebound hammer test = P_t = 39 N/mm^2
From table 3, D = 1
ii) Avg. Concrete cover measured by Cover meter = D_c= 50
From table 4, D = 1
From above two values of D, D_{max}= 1

Hence, I_{c1}= 83.68

2) *Condition Ranking / Condition Index for Abutment – A_1 (Ic_2)*

P_d=30 N/ mm^2, a=1.2, D_c= 50mm
Value of E and R from DER Rating Visual inspection table 2, E=2 and R=2
i) Concrete comp. strength measured by rebound hammer test = P_t = 40 N/mm^2
From table 3, D = 1
ii) Avg. Concrete cover measured by Cover meter = D_c= 50
From table 4, D = 1
From above two values of D, D_{max}= 1

Hence, I_{c1}= 83.68

3) *Condition Ranking for Soffit (I_{C3})*

P_d=30 N/ mm^2, a=1.2, D_c= 50mm
Value of E and R from DER Rating Visual inspection table 2, E=3 and R=4
i) Concrete comp. strength measured by rebound hammer test = P_t = 13.5 N/mm^2
From table 3, D = 4
ii) Avg. Concrete cover measured by Cover meter = D_c= 50
From table 4, D = 1
iii) Avg. corrosion measured by half cell potentiometer = V_e = - 435
From table 5, D = 4
From above two values of D, D_{max}= 4

Hence I_{c3}= 12.5

Finally,
Condition index (CI) of bridge 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 =55.21

From Table 1 of condition index scales, for CI =55.21, which lies between CI = 55 to 69, it means that condition of bridge is good, some deterioration in at some portions of the structure.

Table No. 6

Sr. No	Structural Member	CI (DER Method)
1	Pier	83.68
2	Abutment	83.68
3	Soffit	12.55
4	For total bridge	55.21

V. CONCLUSIONS

Based on visual inspection and non destructive testing, following conclusions are made:

1. Condition rating is a suitable method for assessing the overall condition of concrete structures because the condition of

each component can be monitored continuously.

2. Rebound hammer test, Cover Meter, Half cell potentiometer and various other NDT methods are useful in evaluating the structural stability of structure.
3. The ranking assessment of bridge considered here is carried out using rebound hammer, Cover meter, half cell potentiometer and its C.I. =55.21, which implies condition of bridge is good but there is requirement of economic analysis of repair.

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