Condition Assessment and Structure Analysis of P.C.C Railway Bridge

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Abstract - *Concrete structure reduce its strength with time and to insure serviceability and safety the Condition Assessment of the structure is to be carried out and determine the current behavior and extent of repair required Nondestructive method of testing is a rapid method and gives us an overview of condition of structure in lesser time. The various cause that can be considered for the reduction in strength are Negligence during Construction , quality of raw material, unskilled workmanship, low maintenance, etc. for older structure the condition assessment need to be perform in regular interval.*

In this paper the Condition assessment of the 35 year old railway deck bridge which is situated in devapur, Telangana is carried out along with its structural Analysis. Visual inspection and Various Nondestructive testing and partial destructive testing such as Rebound Hammer Test, Ultrasonic pulse velocity test, Cover meter test, Half-cell potentiometer, Core test and pH and Depth of Carbonation test have been performed and based on all test results it is found that the structure needs to be repaired.

Key Words: **Strength, serviceability repair, Nondestructive Testing, Concrete.**

1. INTRODUCTION

The Non-Destructive Testing (NDT) method that are widely used to find out the quality and defects in structure and to evaluate the present strength of the structure with or without destroying any part of the structure. As we know that strength of concrete structure affected by many conditions such as over age of structure, quality of material used in construction, unskilled workmanship, improper maintenance, improper design mix therefore it's necessary to examine the condition, quality of concrete & performance of structure from time to time. This method have various advantages like, defects can be detected without damaging or destroying the part of structural components, the equipment are easy to handle and it gives appropriate results with the help of NDT. It requires to know the varied methods available, their capabilities and limitations, knowledge of the relevant standard and specification for performing the test. These techniques are often used to monitor the reliability of the item of structure throughout its design life.

1.1 Objective of the Case Study

Determine condition of structure by evaluating strength and Quality of 35 years old Concrete Railway Bridge No 7 situated in devapur telangana and to obtain Structural stability certificate after performing repair as specified

2. Methodology

2.1 Visual Inspection

Visual inspection plays important role in understanding structure, it is the first step of evaluation in NDT method to understand the concrete structure that are visually accessible, it gives an idea about overall health of structure when investigate thoroughly. The visual inspection were applied on different structure members and that we have observed Reinforcement exposed at slab base of bridge, corrosion, major cracks, minor cracks, honeycombing, concrete deterioration etc.

Fig -1: Reinforcement exposed, corrosion, cracks observed in slab

Fig -2: Major cracks observed in abutment

2.2 Rebound Hammer Test

Rebound hammer test gives the rebound number when the plunger of rebound hammer pressed against the concrete surface. This rebound number has relation with compressive strength by using standard graph.

The device measures the rebound value R which have a specific relation between this value and the hardness and strength of concrete. The rebound numbers can be affected by a various factor like, surface condition and moisture content, age of concrete type of material and extent of carbonation of concrete. The direction of hammer with the surface

Table -1: Rebound hammer grading

Average Rebound	Quality of Concrete
>40	Very Good hard layer
30-40	Good
20-30	Fair
<20	Poor concrete
0	Delaminated

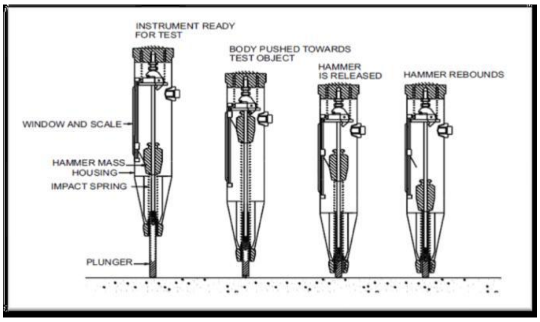

Fig -3: Rebound Hammer Test.

Fig -4: Rebound Hammer Test.

2.3 Ultrasonic Pulse Velocity Test

Ultrasonic Pulse Velocity Test is used to determine the quality of concrete, presence of cracks, voids and other imperfections in structure.

This is one of the most commonly used method in which the ultrasonic pulses generated by electro-acoustical transducer are transmitted through the concrete & measuring the time taken. The ratio of path length to transit time gives the pulse velocity of concrete member being tested. The ultrasonic pulse velocity is influenced by path length, lateral dimension of specimen tested, presence of reinforcing steel, and moisture content of the concrete.

The various method of performing ultrasonic pulse velocity through concrete are

a) Direct Transmission (Cross Probing).

b) Semi-Direct Transmission

c) Indirect Transmission (Surface Probing)

Canopus CUTE 103 is used for testing.

TABLE -2: Quality of Concrete Grading referring pulse velocity

Pulse Velocity	Quality of Concrete
Above 4.5 Km/Sec	Excellent
3.5 - 4.5 Km/Sec	Good
3.0 - 3.5 Km/Sec	Satisfactory
Below 3.0 Km/Sec	Doubtful

Fig -5: Ultrasonic Testing Machine Canopus CUTE 103

Fig -6 Ultrasonic Pulse Velocity Test Machine.

2.4 Half Cell Potentiometer Test

Half-cell test is used determine the probability of corrosion associated with steel in concrete. Instrument consists of copper or Copper Sulphate electrode or silver or silver chloride electrode for half-cell test.

Half-cell makes contact with concrete by means of porous plug and sponge. One end of wire is connected to steel reinforcement after it's cleaned and other end is connected to provided electrode and readings are noted as seen on voltmeter. More negative value indicated more corrosion.

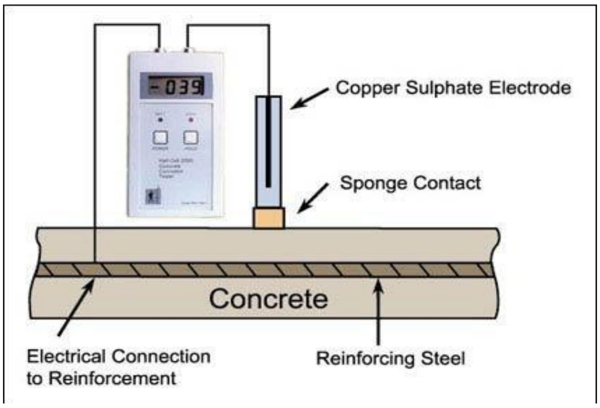

Fig -7 Schematic View of Half Cell Potentiometer

[http://www.standardtecengineers.in/surface_potential_test.html]

Fig -8 Half Cell Potentiometer Test.

Table -3: Corrosion Condition of Reinforcing Bar

Copper / Copper Sulphate	Corrosion Condition
> -200 Mv	Low (10% chances)
-200 to -350 mV	Intermediate
< -350 Mv	High (<90 %)
< -500 Mv	Severe Corrosion

2.5 Core test

The Drilled concrete core is use for determining the in-situ compressive strength of concrete as well as fck value of concrete also use to determine the quality of concrete by performing the ultrasonic pulse velocity test on the core samples

The core test performed and the correction factors are applied according to the sp24:1983

Fig -9- compressive testing machine

2.6 PH test

The pH value is use to determine the alkalinity of concrete if the pH of concrete is near to 10.5 for old structure the structure is consider as safe zone.

Fig -10 Testing of pH of concrete sample

3. TEST RESULTS

3.1 Rebound Hammer Test Results

Table -4: Rebound hammer test result.

Sr. No.	No. of Points	Rebound number		
		Max	Min	Avg
Abutment (1)				
1	36	38	18	26.5
Pier (2)				
2	24	32	18	26.6
Abutment (3)				
3	120	34	27	28.3
Rcc slab (4)				
4	48	40	24	33.58

As per Rebound Hammer Test results it is observed that maximum readings are confirming M22 to M29 grade of concrete for slab and M15 to M27 for all substructure

3.2 Ultrasonic Pulse Velocity Test Results

Table -5: upv result.

Sr. No.	No. of Points	Ultrasonic Pulse velocity Test (Km/SEC)		
		Max	Min	Avg
Abutment (1)				
1	36	3.9	3.08	3.54
Pier (2)				
2	24	4.25	3.38	3.78
Abutment (3)				
3	120	3.47	2.84	3.09
Rcc slab (4)				
4	48	4.04	3.22	3.48

As per Ultrasonic Pulse Velocity test results it is observed that maximum readings are Above 3.0 Km/sec that indicated the quality of concrete is satisfactory.

3.3 Half Cell Potentiometer Test Results

Table -6: half cell test result.

Sr. No.	Description	Half Cell Potentiometer Test	
		Half Cell Readings (mV)	Average (mV)
1	**Slab No 1 between Pier-3 to Pier-2**	-431,-396,-481,-510,-515,-482,-469,-450	-466.75
2	**Slab No 2 between Pier-3 to Pier-2**	-480,-520,-481,-486, -449,-458,-469,-481	-478
3	**Slab No 3 between Pier-1 to Pier-2**	-373,-328,-380,-351, -426,-393,-410,-395	-382
4	**Slab No 4 between Pier-1 to Pier-2**	-376,-326,-283,-270, -361,-410,-349,-385	-345

As per Half cell Potentiometer Test results maximum readings are in between -270 and -510 that indicate there is severe corrosion at most of the locations.

3.4 Core test

3.4.1. Compressive strength

Table -7: Rebound hammer test result.

Sr no	Description	No of core	Max compressive strength (N/mm2)	Average compressive strength (N/mm2)
1	**Abutment 1**	3	16.35	14.54
2	**Pier 2**	3	15.53	14.22
3	**Abutment 3**	3	14.95	14.5

As per compressive test on core there is small amount of reduction in strength of core and the grade of concrete in abutment and pier is expected to be M15

3.4.2. Upv test on core

Table -8: UPV test result.

Sr no	description	No of core	Ultrasonic Pulse velocity Test (Km/SEC)
			Average
1	**Abutment 1**	3	3.22
2	**Pier 2**	3	3.11
3	**Abutment 3**	3	3.48

As per Ultrasonic Pulse Velocity test results it is observed that maximum readings are Above 3.0 Km/sec that indicated the quality of concrete of core is satisfactory.

3.5 pH Test Results

Table -9: pH test result.

Sr no	Description	No of pH sample	Average ph
1	**Abutment 1**	6	11.25
2	**Pier 2**	6	10.84
3	**Abutment 3**	6	10.47
4	**Deck slab**	4	10.7

4. DESIGN AND ANALYSIS

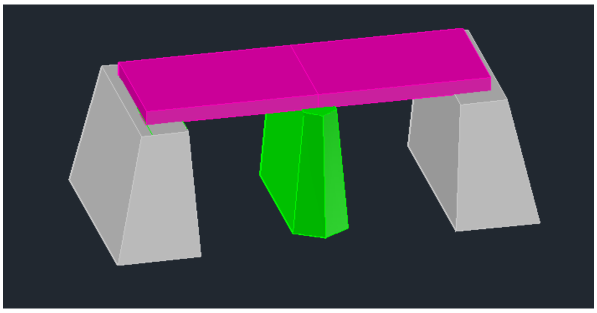

Fig 11: -3D structure model.

The existing structure consist of 2 abutment 1 pier and 2 simply supported slab, abutment and pier is only checked for foundation level

4.1 Slab design

Input

Clear span =4.3 m

Width of bearing (assume) =600mm

Total depth =600mm dia=25 mm

Effective depth =557.5mm depth =cover-.5 x dia

Say 560mm cover =30mm

Effective span (less of) =4.9m or 4.86m =4.86 m

Density of Concrete =25 kn/m2

Depth of cussion =400 mm

Load calculation

A) self wt of slab (depth*width*Density) =15kn/m

B) SIDL(Ballast+ Sleeper+ Rail) =15kn/m

Total DL(A+B) =30kn/m

C)Live load

Eudl for BM=780.4 kn (bridge code1964)

Eudl for SF=973.6 kn

CDA factor 0.69 2-(d/.9)*.5*(.15+8/(6+l))

For BM =780.4/(3*4.86)=53.52 kn/m2

For SF =973.6/(3*4.86)= 66.77 kn/m2

Maintance live load =5 kn/m2

dl+ll	total load for BM	SF
	125.43 kn	147.84 kn
wl2/8		wl/2
	370.32 kn-m	359.25 kn

Grade of cocrete = M30

Grade of steel = Fe415

4.2 Abutment design

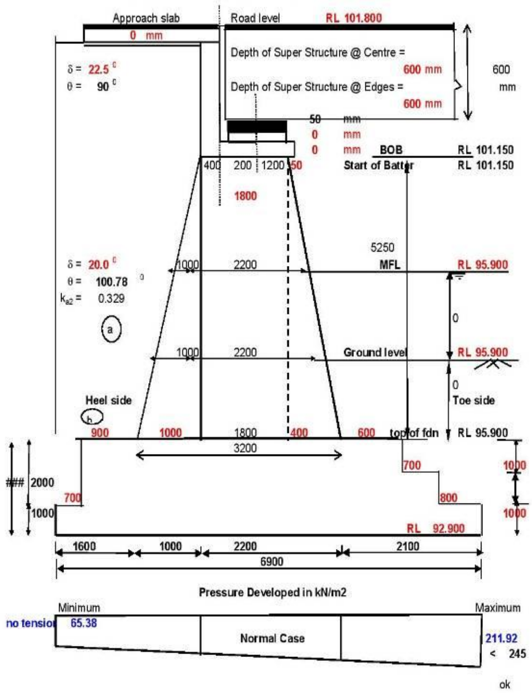

Fig 12 - Abutment dimension

General Data:

clear length of the bridge =4.3m

Overall Length of span =6.0m

Width of abutment in roadway direction =6.0m

BACKFILL SOIL PROPERTIES

Unit wt of soil =18 kN/m²

Angle of internal friction =35 º

Slope of earth fill =0 º

Coeff of friction between Concrete and Founding Soil/rock=0.5 (cl706.3.4 IRC78)

MATERIAL DATA

Grade of concrete =M15

Dead load (total dead load of 1 span) =756 KN

Unit weight of RCC = 25 kN/m³

Unit weight of PCC = 22 kN/m³

Effective span of super structure =4.89 m

Depth of Superstructure =.600 m

Thickness of expansion gap = 40mm

Permissible tensile stress in concrete =-0.4 N/mm² (irc78-2000

If surface reinforcement is not provided, permissible stress =-0.36 N/mm² cl 701.1.1)

Stress due to active Earth pressure

$\beta=0^0$

$\Phi=35^0$

$\theta=90-\tan^{-1}(1/5.2)=79.11$

$\delta=20^0$

Coefficient of active earth pressure

$$K_a = \frac{\sin^2(\theta+\phi)}{\sin^2\theta\sin(\theta-\delta)\left[1+\sqrt{\{\sin(\phi+\delta)\sin(\phi-\beta)\}/\{\sin(\theta-\delta)\sin(\theta+\beta)\}}\right]^2}$$

The PCC Abutment is also checked for overturning sliding and base pressure

3) Pier design

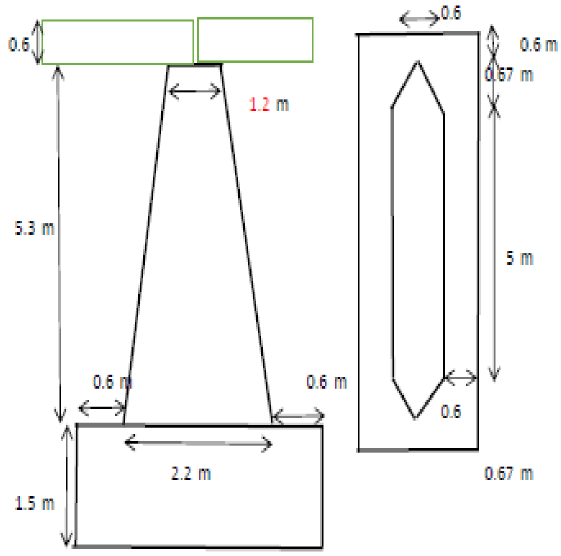

Fig 13 –intermediate pier

Grade of Concrete =M15

Permissible tensile stress in concrete =-0.4n/mm²

If surface reinforcement is not provided, permissible stress =-0.36 n/mm²

The Pier is designed as PCC with considering the effect of Self weight, dead load, live load SIDL along with impact factor.

The stresses formed is checked with the permissible stresses

5. Design summary

a)Rcc slab

Table -10: Rcc slab.

Thickness of slab	1000m
Longitudinal steel Top Bottom	25mm dia @150 mm
Transver steel Distribution(top bottom)	12mm dia @125 mm
Links (15.89)	8mm 6legged 250mm c/c in both direction

b)Abutment

Table -11: Without seismic (with live load condition)

Stress due to	**Dry condition Mpa**	
	At Heel	**At Toe**
Active earth	-0.0747	0.0747

pressure		
Dead load &Live load surcharge	0.0000	0.0000
Dead load	0.0054	0.0043
Live load	0.0117	0.0093
Self weight	0.2141	0.0535
Net stress	0.1565	0.1418

Table -12: Without seismic (without live load condition)

Stress due to	**Dry condition Mpa**	
	At Heel	**At Toe**
Active earth pressure	-0.0747	0.0747
Dead load &Live load surcharge	0.0000	0.0000
Dead load	0.0054	0.0043
Live load	0.0117	0.0093
Self weight	0.2141	0.0535
Net stress	0.1565	0.1418

c)pier

Foundation check

Maximum stress = 103 + 49.09

= 152 kn/m2

Minimum stress = 103 + 15.17

= 118.17 kn/m2

Less than 245 kn/m2SBC of soil Hence ok

6. CONCLUSIONS

In this paper various Non-Destructive Tests such as Rebound Hammer Test, Ultrasonic Pulse Velocity Test and Half cell Potentiometer Test, core test and ph test including visual inspection. have been performed on existing bridge structure As per the visual inspection, Rebound Hammer test & Ultrasonic Pulse velocity test results it is observed that readings shows the strength and quality of concrete is satisfactory and for the structure with minor cracks carbon wrapping should be done . According to the half cell potentiometer test results severe corrosion are observed at slab of the bridge. Test results conclude that Repairs should be done as per the specification to keep up the present structure in good shape. As per the manual analysis it is observed that structure is safe for stability point of view for various type of loads Bridge structure shall require strengthening to improve the quality of concrete using various strengthening technique for repair and retrofitted with proper grouting, micro-concrete carbon wrapping required at some location.

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