ANALYSIS OF CORROSION IN SUBMERGED CONCRETE STRUCTURE

Sheela Dangi[1], Prof. Kapil Soni[2]
[1]Scholar M.Tech (Structure) Department of Civil Engineering, RNTU, Bhopal (M.P).
[2]Guide & HOD , Department of Civil Engineering, RNTU, Bhopal (M.P).

ABSTRACT: Non destructive testing is applied to both old and new concrete structures, for new structures the principal application are likely to be for quality control or the resolution of doubts about the quality of materials and construction. The testing of existing structures usually related to the assessment of structural integrity and adequacy of structure service.Half-cell potentiometer data are useful to find out corrosion rate and to establish the remaining life service of the reinforced concrete structures. The reinforced Concrete structures deteriorates under water in Marine exposed environment. It is not the disintegration of concrete itself, but the electrochemical corrosion of the reinforced steel. Corrosion of steel reinforcement is one of the main causes of damage in concrete structures. The most critical and serious problems to the durability and safety of concrete structures. The corrosion of reinforcement in under water of R.C.C. structures depends on the factors of steel, cement, water cement ratio, concrete cover, salinity of water, design and construction methodology. Under water concrete structures are subject to deterioration due to their continuous exposure to marine environment. The electrochemical corrosion of the reinforcing steel results in disintegration of concrete structures. The various models available on prediction of service life of structure is reviewed in the present study and selected a model with reviewing certain parameter as applicable in this case study. Service life predicted of case study and the cases used for validation of their service life is compared and found workable. The service life model to predict the end of service function of structures, the datas are used for strategic plan to rehabilitee major repairs to avoid total loss.

Keywords: Steel, Corrosion, NDT, Bridge, USPVT, etc.

I. PROBLEM STATEMENTS

Corrosion of steel in concrete is an electrochemical process. The electrochemical potentials to form the corrosion cells may be generated in two ways:

Composition cells may be formed when two dissimilar metals are embedded in concrete, such as steel rebars and aluminum conduit pipes, or when significant variations exist in surface characteristics of the steel.

Concentration cells may be formed due to differences in concentration of dissolved ions near steel, such as alkalies, chlorides, and oxygen.

The differences in electrochemical potential can arise from differences in the environment of the concrete. Electrochemical cells form also due to a variation in salt concentration in the pore water or due to a non-uniform access to oxygen. Thus, one of the two metals (or some parts of the metal when only one metal is present) becomes anodic and the other cathodic. When there exists a difference in electrical potential along the steel in concrete, an electrochemical cell is set up: there form anodic and cathodic regions, connected by the electrolyte in the form of the pore water in the hardened cement paste.It is recognized that steel embedded in a heavily alkaline medium with pH values from 9 upwards will not rust. During the setting of concrete, cement begins to hydrate, this chemical reaction between cement and water in the concrete causes calcium hydroxide to be formed from the cement clinker. This ensures the concrete's alkalinity, producing a pH value of more than 12.6 which renders the steel surface passive.

II. OBJECTIVES OF THE RESEARCH

The specific objectives of the research are:

- To appropriately find out the root causes of concrete structures deterioration under marine environment.
- To investigate the factors influencing the corrosion ingression of embedded steel in concrete structures through non-destructive test.
- Prediction of the service life of marine concrete structures with the help of suitable established mathematical models.
- To develop an ovel method of integrating the conventional methods of NDT with the advanced and established service life models in accurately determining the service life of marine structures.

Methods for NDT of Concrete Structures

The following methods, with some typical applications, have been used for the NDT of concrete:

- Visual inspection, which is an essential precursor to any intended non- destructive test.
- An experienced civil or structural engineer may be able to establish the possible cause(s) of damage to a concrete structure and hence identify the required test among the various NDT methods
- Half-cell electrical potential method, used to detect the corrosion potential of reinforcing bars in concrete.
- Schmidt/rebound hammer test, used to evaluate the surface hardness of concrete.
- Carbonation depth measurement test, used to determine whether moisture has reached the depth of the reinforcing bars and hence corrosion may be occurring

III. RESULTS AND DISCUSSION ON NDT TESTS

- The tests carried on R.C.C. concrete surface which depicts the conditions and status of concrete quality to encompass the surrounding environment further deteriorations. The aggressive chemical ingredient present in the concrete compositions. The design and material quality adopted for the durability and serviceability of the structures.
- The probability of the corrosion occurrence in the steel reinforcement embedded In Concrete attract the attention. The material and grade of steel used reflects the corrosion process in progress to deteriorate the structures.The test-report on concrete of carbonation, chloride and sulphate shows the concrete leaching out and due to the presence of inter force of the chemical ingredient which aid to timely control and rectify the concrete structures.
- As the quality of concrete and chemical ingredient present assessed through Non-Destructive Test.
- The Ultra Sonic Pulse velocity test on concrete surface and the Half Cell Potential test on R.C.C. piers in splash zone are used and aids to find out the concrete strength quality and the probability of corrosion. Initial and advance conditions with the effect of salinity and marine environment on concrete cover leading to deterioration of concrete. The NDT tests are conducted for a period of 30 months to monitor the time and environment effect in the interval of 9-10 months on bridge and results compared.

Schmidt Rebound Hammer Test

Pier	Position	Apr.-2019		Jan.-2020	
		Avg. Rebound No.	Approximate Compressive Strength (kg/sq.cm)	Avg. Rebound No.	Approximate Compressive Strength (kg/sq.cm)
P1 (Top)	Column - 1	50	580	48	550
	Column - 2	47	540	45	490
	Column - 3	49	580	47	530
	Column - 4	52	600	5 1	600

Table 4.1: Rebound Number and corresponding Compressive Strength on PI (Top)

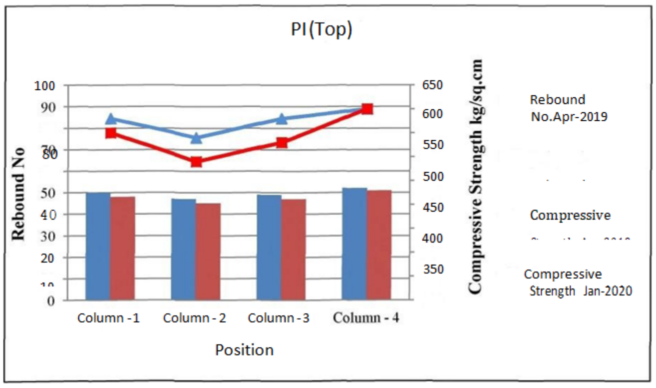

Figure 4.1: Rebound Number and corresponding Compressive Strength on P1 (Top)

Pier	Position	Apr.-2019		Jan-20	
		Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)	Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)
P1 (Bottom)	Column — 1	47	540	45	490
	Column—2	52	600	50	590
	Column — 3	51	590	52	600
	Column — 4	48	540	46	510

Table 4.2 : Rebound No. and corresponding Compressive strength on P1 (Bottom)

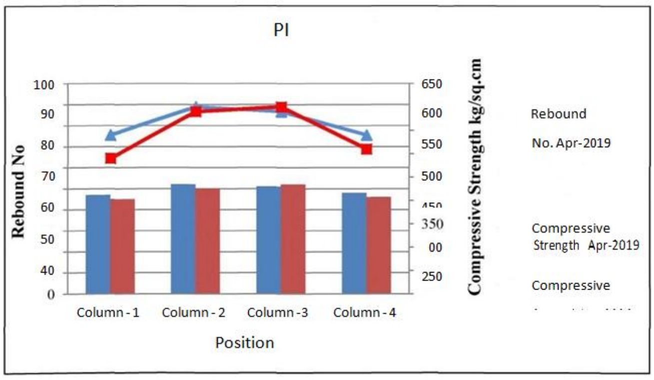

Figure 4.2 : Rebound No. and corresponding Compressive strength on PI (Bottom)

Pier	Position	Apr.-2019		Jan-20	
		Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)	Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)
PI (Beam Between Column No. 3-4)	Left	50	580	49	565
	Centre	50	580	49	565
	Right	49	575	48	550

Table 4.3 : Rebound No. and corresponding Compressive strength on P1 (Beam Between Column No.3-4)

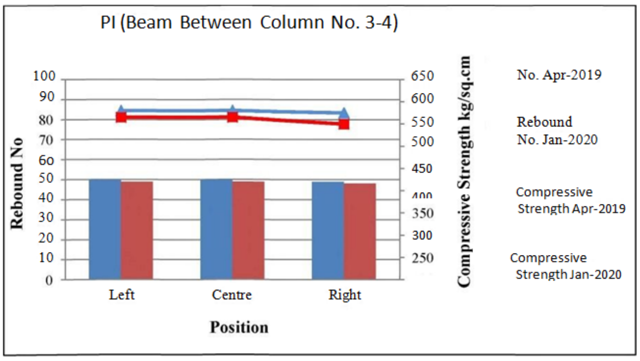

Figure 4.3 : Rebound No. and corresponding Compressive strength on PI (Beam Between Column No.3-4)

Pier	Position	Apr.-2019		Jan-20	
		Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)	Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)
PI (Beam Between Column No. 1-2)	Left	52	614	51	600
	Centre	47	540	47	530
	Right	47	540	47	530

Table 4.4 : Rebound No. and corresponding Compressive strength on P1 (Beam Between Column No.1-2)

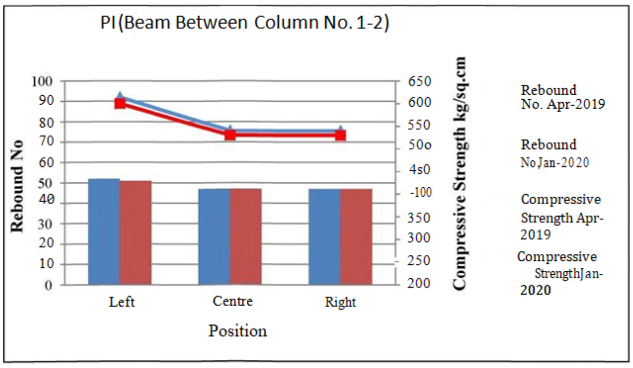

Figure 4.4 : Rebound No. and corresponding Compressive strength on P1 (Beam Between Column No.1-2)

Pier	Position	Apr.-2019		Jan-20	
		Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)	Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)
P2 (Top)	Column - 1	50	580	49	565
	Column - 2	50	600	48	550
	Column - 3	47	540	47	530
	Column - 4	50	580	49	565

Table 4.5 : Rebound No. and corresponding Compressive strength on P2 (Top)

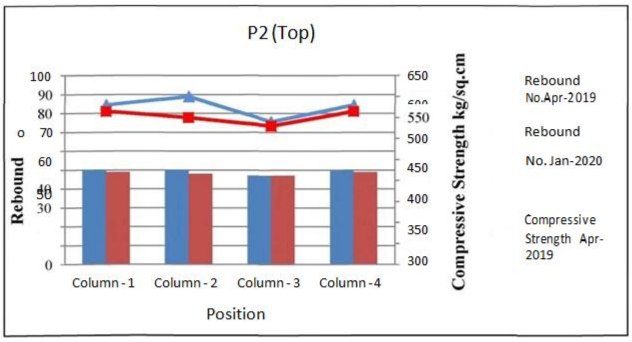

Figure 4.5 : Rebound No. and corresponding Compressive strength on P2 (Top)

Pier	Position	Apr.-2019		Jan-20	
		Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)	Ave. Rebound No.	Approximate Compressive Strength (kg/sq.cm)
P2 (Bottom)	Column - 1	50	580	49	565
	Column-2	49	575	48	550
	Column -3	51	600	50	590
	Column -4	50	580	49	565

Table 4.6 : Rebound No. and corresponding Compressive strength on P1 (Bottom)

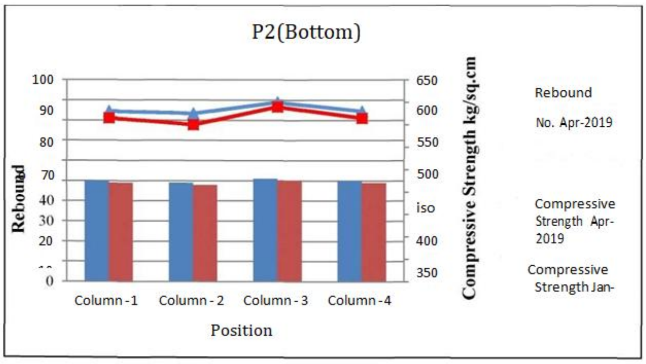

Figure 4.6 : Rebound No. and corresponding Compressive strength on P1 (Bottom)

Chloride, sulphate content and pH value of concrete

Chloride CI (Kg./m)				
Sr. No.	Pier No.	APRIL-MAY 2019	MAY-JUNE 2019	JAN-MAR 2020
1	3	0 33	0.345	0 35
2	4	0.28	0.285	0.29
3	5	0.28	0.29	0.295
4	6	0.23	0.245	0.26
5	7	0.21	0.225	0.25

Table 4.7 : Chloride Content in Concrète Sample

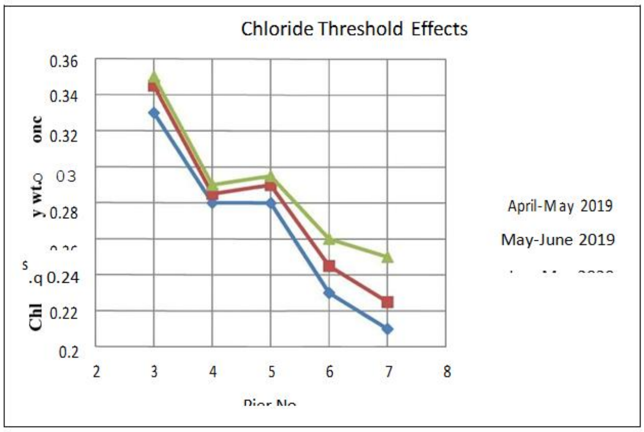

Figure 4.7 : Chloride content measured over a period of three years

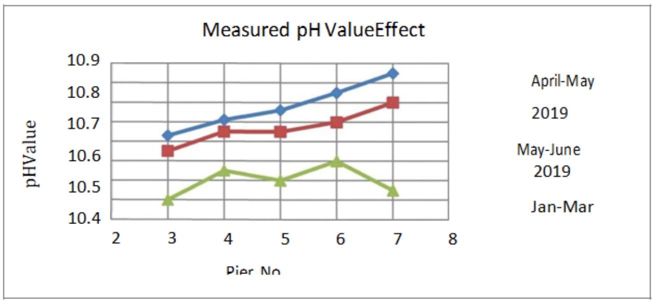

Figure 4.8 : Measured pH value at various location of piers over a period of three years

Ultra Sonic Pulse Velocity Test

Structure Unit		Location			
Pier	Column	Top	Quality	Bottom	Quality
P1	Column - 1	2.9	Poor	2.22	Poor
	Column - 2	2.45	Poor	2.82	Poor
	Column - 3	2.18	Poor	2.65	Poor
	Column - 4	2.12	Poor	3.05	Medium
Struc	ture Unit		Location		
Pier	Column	Top	Quality	Bottom	Quality
P2	Column - 1	2.9	Poor	3.75	Good
	Column - 2	3.15	Medium	2.9	Poor
	Column - 3	3.25	Medium	1.85	Poor
	Column - 4	2.95	Poor	2.5	Poor

Table Ultrasonic Pulse Velocity Readings (km/s) in the Columns

IV. CONCLUSIONS

The chloride content determined over the period of three years on Panvel Creek Bridge with an interval of one year from different piers of the bridge is being increased with time. There is a remarkable change of chloride content in the concrete. The increment is highest in pier no. 7 as the change is around 20% from 0.21 in 2019 to 0.25 in 2020.

The test-report on Panvel Creek Bridge for chloride and sulphate shows the concrete leaching out very fast and timely measure need to be taken to rectify the concrete structure. Within a three year period of time the drop in pH happens to be 0.6 which is a matter of great concern if this kind of pattern continues over the period of time. Adequate measure need to be taken to prevent the further corrosion of steel bars inside the concrete. A routine and periodical check is required to access the bridge's integrity.

Half cell potentiometer data are useful to find out corrosion rate and to establish remaining life service of reinforced concrete structures.

The service life model is a very much useful to accurately predict the end of service function of structures. The result obtained can be effectively used for strategic planning of rehabilitation to avoid total loss of life.

Suggestions

Suitable adoption of corrosion protection measures, pre construction period such as use of adequate design and good construction practices, adopting standard quality control techniques, adequate concrete cover depth, low-permeability concrete, corrosion inhibitors, coated reinforced steel bars and corrosion resistance steel bars in new construction will help in significantly delaying the occurrence of corrosion in reinforced concrete bridge structures.

The structures design and construction methodology needs utmost precision while executing new structures in the aggressive and marine environment which is major preventive measure to durability and safety of offshore and coastal concrete structures.

Traditional practice of restricting the field studies to the half-cell potentiometer need to be extended for accurately determining the remaining service life of the reinforced concrete structures.

REFERENCES

[1] A.A. Padilla — Viveros. E Garcia — Uchoa, NACE — Corrosion — 2004, Paper No. 04583, —Electrochemical of Behavior of localized corrosion in steel, by sulphate — reducing bacteria under oligotrophic condition‖, PP — 01-10.

[2] A.K. Agarwal M, S.A1ampalli, Z.Yi., —Advances in corrosion monitoring systems for highway bridges.‖ Structures congress (2005)@ASCE (2005)

[3] 3 Allan P. Crane (1983), —Corrosion of Reinforcement in concrete construction‖.(ED), PP119-141

[4] Akimova K.M.(1977), —Metallic Corrosion‖, Protection ofMetals Vol. 13, PP157-159.

[5] Andres A. Torres — Acosta, Miguel Martinez Madrid, —Residual life of corroding Reinforced concrete structures in Marine Environment.‖, Journal of Materials in Civil Engg. ASCE(2003) 15:344-355

[6] Annky and Song HW, 2007, —Chloride threshold level for corrosion of steel in concrete, corrosion science‖, 49, PP4113-4133.

[7] B. T. Patil (1985), —Investigation on corrosion of steel and deterioration and protection of RCC structures in marine environment‖, Ph.D. thesis MysoreUniversity.

[8] B.G. Dykstra, J.E.Wehling, J.l. Piazza II, NACE — Corrosion — 2002, Paper No. 02269, —Cathodic protection of steel reinforced concrete structures using A Galvanic Zinc Hydrogel system.‖ PP — 01-13

[9] Bardal,E.,DrugliJ.M.(2010),—Corrosiondetectionanddiagnosis‖, MaterialScienceand Engineering — iVol-III.

[10] BazantZ.P.(1979),—Physical ModelforsteelCorrosioninSeaStructureTheory‖,Journal of the Structual Division June, PP. 1137-166.

[11] Beeby , A.W. (1978), —Concrete in ocean cracking and corrosion‖ Technical Report No.1 URIA/VEG, Construction Industry Research Deptt., of Energy,London.

[12] Blin F, Law D, Dacre MC, Op't Hoog, C.J. Gray (2008), —Extension of design life of existing maritime infrastructure — a durability perspective‖,

paper 068, corrosion and prevention, wellington, New Zealand.

[13] Boijeost and G. E. Monfere (1966), ―Penetration of chloride into concrete Journal o the PCA Research and Development laboratories‖, PP-46-53

[14] Broomfield JP. ―Corrosion of steel in concrete, understanding, investigation and repair.‖ London, UK: Eandamp; FN Spon; 1997.

[15] Browne R.D. (1982), ―Design prediction of the life of reinforced concrete in Marine and other chloride environment in Marine and other chloride environment‖, durability of building materials Elsevier — Vol.-3.

[16] C.Q. Li, ―Life Cycle modeling of corrosion — Affected concrete structures Propagation .‖ Journal of Structural Engg. — ASCE (2003)- 129 : 753 — 761.

[17] CadyP.D.,andWeyersR.E.(1984),―Deteriorationrat esofconcretebridgedecks‖,Journal of Transportation Engineering Vol. 110, No.1, January, PP.34-45.

