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Durability Assessment Methodology For Concrete Structures

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***Abstract*— Present day scenario of land scarcity, increased population and transportation necessity has brought an era wherein construction of infrastructure will have a significant role in India. Durability aspects of these pivotal structures is always challenging due to the perquisite of longer design life of these structures (50 to 100 years). This is also indeed has been a vital field of study and prospective area for research for establishing the various parameters aiding the durability of these structures. Therefore as a rudimentary step, it becomes essential to methodically understand the existing recommendations provided by various codes and literatures for ensuring the durability of these structures. In this study, an effort has been made to arrive at a feasible methodology that can be adopted for a project to attain the envisaged design life of structure through proper mix design and service life modeling.**

***Index Terms*— Concrete, durability, service life modeling.**

I. INTRODUCTION

The concept of durability has been gaining acceptance worldwide, especially so in recent times to cater for the increased service life of the structures. Elaborate standards and codes pertaining to durability of structures are available in international arena and further research is underway. In the Indian context, Bureau of Indian Standards (BIS), Indian Road Congress (IRC), Indian Concrete Institute (ICI) and few other prominent institutions have published standards and literatures relevant to durability. Standards primarily classify environmental exposure conditions and specify limiting values for minimum cement content, maximum water cement ratio and cover for the concrete. These limiting values specified are classified as prescriptive approach and service life prediction falls under the ambit of performance based approach (1). In spite of all the developments, implementation of durability assessment of structures in key infrastructure projects is still in its nascent stage in India. Hence, as per the design life requirement of the project a durability assessment study was implemented which shall be discussed in subsequent sections. An introduction to prevalent standards and literatures pertaining to durability is necessary before the discussion relevant to adopted method of durability assessment.

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II. DURABILTY- RELEVANT TRENDS

EN 206, ACI 318, BS 8500, AS 3600 and few other international codes specify durability requirements for concrete. BS 8500: 2006 specifies durability requirements even for structures with 100 years design life (2). In the Indian context there is an over reliability on prescriptive measures provided in IS 456: 2000 for concrete. Revision of exposure conditions as per Indian environmental conditions on par with the above mentioned international standards and limiting values have been recommended in literatures published by the Indian Concrete Journal (3) (4). IRS 1997, IRC 112:2011, MOST/MoRTH and guidelines for the use of high performance concrete in bridges by Ministry of Railways have incorporated Rapid Chloride Penetration Test (ASTM C 1202) and Water Permeability Test (DIN Part 5 -1991/IS 3085:1965, Sec 1716.5 MOST) for concrete. However, guidelines regarding permissible values of RCPT and clarity in proper test method for permeability are still a matter of contention in the mentioned standards (5).

European standards are fast heading towards a performance based approach known as equivalent durability concept (EDP) which is due to be published in further revisions. EDP aims to help engineers and contractors to produce a concrete that has an equivalent durability to one with a long established record of adequate performance in the local environment. Performance-based test methods are used for the comparison and uncertainty of measurement is also taken into account in this approach (6).

III. REQUIREMENTS OF THE PROJECT

Broadly for simplicity the structures in the infrastructure project were classified as marine and general structures. Structures in direct contact with water are classified as marine structures whereas, which is not in contact with water is classified as general structures. Exposure conditions, material specifications and other relevant factors were adhered to as per the specifications mentioned for the project.

IV. EXPOSURE CONDITIONS

Exposure conditions for marine structures were classified as per BS EN 1992-1-1:2004 Table 4.4 (7).

1. XS1 – For atmospheric zones subjected to marine weather
2. XS2 – Permanently submerged
3. XS3 – Splash and spray zones

Environmental exposure condition for general structures will be considered as severe/Very severe as per IS 456 -2000 Table 3 (8).

IV. CONCRETE COVER AND ITS CALCULATION

A. Case 1. Concrete structures not in contact with soil and ground water

As per BS EN 1992 - 1 - 1:2004, Nominal cover of concrete is defined as a minimum cover Cmin plus an allowance in design for deviation ΔCdev.

$$\mathrm{Cnom} = \mathrm{Cmin} + \Delta\mathrm{Cdev}$$

The value Cmin,dur (min cover due to environment conditions) depends on the “structural class”, which has to be determined first. The finally applying structural class can be calculated with Table 4.3N as per the code. For the considered project, assuming exposure class as XS3 and service a life of 100 years, the final structural class works out to be S5.

Hence from Table 4.4N of BS EN 1992-1-1:2004, for Structural class S5 & exposure condition XS3, Cnom = 60mm. Similarly for exposure conditions XS1 and XS2, Cnom works out to be 50mm and 55mm respectively.

B. Case2: Concrete structures in contact with soil and ground water

EC-2 in section 4.4.1.3 specifies nominal cover of k1 = 40mm for concrete cast against prepared ground (including blinding) and k2 = 75mm for concrete cast directly against soil. Hence, on conservative side concrete cover of 75mm was finalized for marine structures and 50mm for general structures as a conservative approach.

V. SERVICE LIFE MODELLING

A generally accepted definition of a service life model was developed by Tutti as shown in figure 1.

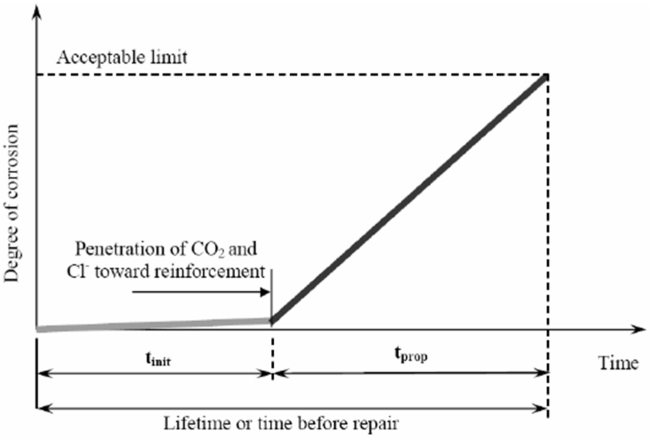

Fig 1 Schematic representation of Tuuti's model

Chloride-induced reinforcement corrosion is the most widespread and costly deterioration mechanism affecting concrete structures especially in marine zones. Hence, "Life 365" a type of diffusion model to estimate chloride ingress was implemented, which adopts the two stages service life model proposed by Tuutti (9). Deterioration mechanisms such as chloride ingress, carbonation etc., and material properties of concrete and admixtures are covered in standard texts. This following section will cover only aspects of service life modeling implemented for the considered project.

VI. DESIGN PARAMETERS FOR LIFE - 365

TABLE I DESIGN PARAMETERS FOR LIFE - 365

S.No	Design parameter	Marine structure	General structure
1.	Thickness of the member	200 mm	200 mm
2.	Reinforcement cover	75 mm	50 mm
3.	Maximum concentration of Chloride	0.8 % weight of concrete for marine tidal zone	0.6 % weight of concrete for within 800m of the ocean
4.	Years to build to maximum surface concentration	1 year	15 year
5.	Temperature of the month	Monthly temperature	Monthly temperature
6.	Water cement ratio	0.32	0.32
7.	Selected mixture	Slag 30%	Fly ash 25% , Silica fume 5%
8.	Rebar steel type	Epoxy coated	NA
9.	Inhibitor	12.5 L/Cub.met	10 L/Cub.met
10.	Rebar Percentage	1.2 %	1.2 %

VII. DISCUSSION

A nominal thickness of 200mm has been assumed for the concrete element with cover as calculated from previous section. Local data was unavailable at the analysis stage, hence surface chloride concentration has been assumed appropriately as shown in the Table 1. Ground granulated blast furnace slag with calcium nitrite inhibitor (CNI) was proposed for marine structures. Similarly fly ash and silica fume with CNI was proposed for general structures as per the specifications. As there is no option of truncated inhibited cement slurry which is proposed, epoxy coating is chosen as corrosion protective coating for rebar steel in the software.

VIII. RESULTS

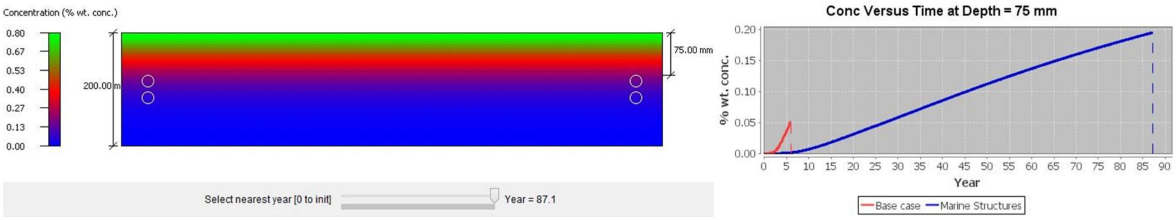

Fig 2 Marine structures

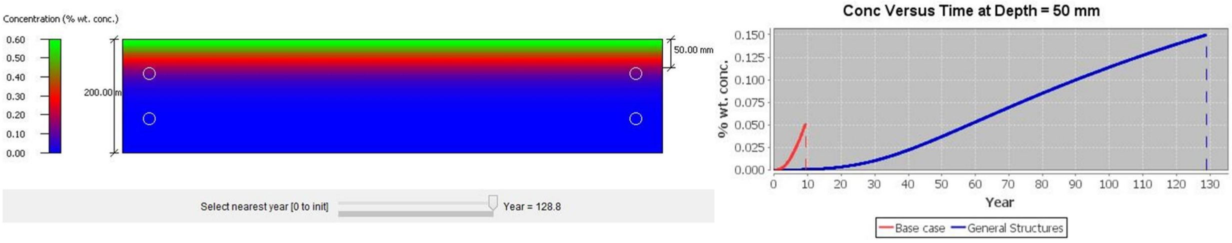

Fig 3 General structures

The time to the first repair tris equal to sum of the initiation (ti) and propagation period (tp). The cross sections tab at the left (Figure 2 and 3) shows the chloride concentration at the point of initiation of corrosion. The right graph (Figure 2 and 3) shows that the base case mixture without proper measures hits initiation at five years at a rebar chloride concentration of about 0.05% weight of concrete, while marine structures attain initiation (ti) in 87 years and general structures at 128 years. Also the propagation periods (tp) of 20 years and 6 years for marine and general structures cater well beyond 100 years of envisaged design life. Thus, the profound effect of increase of initiation period by addition of optimum slag, fly ash, silica fume along with admixtures is clearly demonstrated by this relative simple analysis. Low carbon corrosion resistant steel (CRS) is proposed for rebar as an additional protection. Life-365 service life model has its limitations as the approach mainly depends on theoretical composition of w/c ratio and cover depth for service life prediction (10). Further, durability tests such as RCPT, WPT and carbonation tests are proposed in future to validate the concrete design mix adopted.

IX. CONCLUSION

Quality design mix, conscious selection of material, comprehensive corrosion protection measures have been adopted to achieve the envisaged design life of the considered project.Life-365 service life prediction software has been used for the analysis. Appropriate design mix has been considered, which resulted in achieving 100 year service life for both marine and general structures.

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