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Assessment of loss in durability of structures by NDT Methods

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1. SYNOPSIS

The deterioration of concrete structures is a major problem in many countries throughout the world. It is obviously not possible to conduct load tests in an occupied structure to arrive at the quality of the concrete or to evaluate its performance. Many times it may not be really necessary to carry out load testing even if possible. Apart from the time & cost involved, load tests are carried out only on a limited number of elements. This cannot give relative comparisons between the quality of concrete at different locations in the structure. Furthermore load tests can give indication only about the strength parameter of the concrete & remain silent on the durability aspects.

This has prompted the use of methods for predicting the service life of both the existing & new structures by assessing the quality of concrete & measuring other properties that govern the durability. In this paper using a range of Non-destructive Test (NDT) methods an attempt has been made to determine the loss in durability in existing structures.

2. KEYWORDS: Concrete; durability; deterioration; NDT; steel; corrosion; resistivity; carbonation, cover concrete; chlorides

3. INTRODUCTION

It is always thought that NDT is synonymous with assessing the quality of concrete alone. However in the broad sense it is a tool for investigation that can measure a lot of other properties of concrete & can help build confidence in the structural engineer. A proper selection of NDT methods can really be useful to assess or locate the problem & based on the results, methods can be suggested to overcome or minimise the problem.

A study was undertaken from February-September 2000 to assess the loss in durability of three structures over a period of time. The study was conducted on different types of structures built during different periods. Hence a load bearing residential structure about 60 years old, a RCC residential structure about 25 years old & a RCC commercial structure about 40 years old were taken for the study. The study was conducted on structures situated in Mumbai.

All three structures were showing distress in the form of cracks & exposed reinforcement at a few places. It was decided to assess the quality of concrete in general for the portion constituted by concrete for the three structures. A combination of two NDT methods was preferred for assessment of concrete quality. NDT methods were also used for determining the probability of corrosion in the embedded steel & to measure the cover concrete thickness. Some laboratory tests were also conducted on drilled samples of concrete.

4. NON-DESTRUCTIVE TESTING

The following tests were carried out.

1. Ultrasonic Pulse Velocity Test
2. Electrical Resistivity Test
3. Half-cell Potential Test
4. Covermeter Test
5. Carbonation Depth Measurement
6. Chlorides (as Cl) Determination Test

5. DISCUSSIONS

The summary of results of NDT for the three structures is given in Table 1.

1. From the observations of the structures it was noted that some structural members had developed cracks. From the nature of the cracks & other observations it was seen that the reinforcement had undergone corrosion & that had primarily led to cracking of cover concrete. In some places, it had resulted in spalling of concrete, cover concrete actually falling down.

2. The results of UPV indicated that the average velocity varied from 2.3 - 3.5 km/s in columns, beams & slabs for all the three structures.

3. The electrical resistivity varied from 3.5 - 728 kilo-ohm cm for structure 1 for beams & slabs & it varied from 7 - 366 kilo-ohm cm for columns, beams & slabs for the structure 2 & structure 3.

4. Considering all factors including the possibility of the cover concrete portion being adversely affected by cracking, lowering the velocity, it was estimated that the concrete had an average compressive strength ranging from 9 - 15 MPa. The strengths were found to be upto 40% lower.

5. The results of the half-cell potential indicated probability of corrosion of 90% in more than 50% of the results in structure 1 & structure 2.

6. The cover was adequately provided for different members in structure 1 & structure 3. In structure 2 it was less than the minimum specified in Indian codes of practice.

7. The average depth of carbonation ranged from 29-73 mm which was more than the cover.

8. The average concentration of chlorides varied from 200-350 ppm, which was not very high & as such not a cause for corrosion.

In all the three structures it was observed that the basic cause of corrosion was the carbonation of cover concrete & the resulting loss of protection to steel by alkaline environment. The carbonation was accelerated due to lower strength of concrete.

6. CONCLUSIONS

The estimated strengths of concrete which were subjected to testing in the three structures were upto 40% lower than the minimum required as per Indian codes of practice. The carbonation of concrete had taken place in moist environment over a period of time going beyond the steel reinforcement at many locations, thus initiating corrosion. Once the corrosion sets in, it continues resulting in progressive damage to the structure & reduction in its useful life.

7. REFERENCES

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TABLE 1 : SUMMARY OF RESULTS OF NDT

	Structure 1	Structure 2	Structure 3
Type	**Load Bearing**	**RCC**	**RCC**
Usage	**Residential**	**Residential**	**Commercial**
Approx. Age (years)	60	25	40
Type of Test			
Ultrasonic Pulse Velocity (UPV), (km/s)	B & S : 2.5-3.1	C : 2.4-3.4 B : 2.4-3.5 S : 2.4-3.3	C : 2.3-3.4 B : 2.3-3.2 S : 2.3-3.1
Electrical Resistivity, (kilo-ohm cm)	B & S : 3.5-728	C : 7.9-356 B : 7.0-366 S : 8.6-314	C : 51-335 B : 112-351 S : 40-235
Estimated Average Strength of Concrete by Combined Methods, (MPa)	**B & S : 9-13.5 (10%-40% lower)**	**C : 9-14 B : 9.5-13 S : 10-12 (10%-40% lower)**	**C : 9-15 B : 9-12 S : 9-12 (Adequate to 40% lower)**
Half-cell Potential (% of total results)	P10 : 21.5% P50 : 19% P90 : 59.5%	P10 : 19% P50 : 30% P90 : 51%	P10 : 32% P50 : 38% P90 : 30%
Concrete cover, (mm)	Minimum 15mm for slabs & 25mm for beams provided	C : Average 20mm B : Average 21mm S : 42% results less than 15mm	C : Minimum 40mm B : minimum 25mm S : minimum 15mm
Depth of Carbonation, (mm)	B & S : 35-73	C : 33 B : 32 S : 29	C : 36 B : 43 S : 48
Chlorides (as Cl), (ppm)	B & S : 244-370	C : 291 B : 208 S : 200	C : 350 B : 333 S : 333

C=Column, B=Beam, S=Slab