Condition Assessment of Existing Distress Concrete Structures for Effective Restoration/Strengthening Measures

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Abstract— Corrosion is generally found in many RCC structures in India. This corrosion in the form reinforcing corrosion and cracking of cover concrete is found due to free ingress of water, oxygen and carbon dioxide through concrete cover kept to protect reinforcing bars corrosion in these structures. This process of specially apply to save their structure is safe and effective to many years to calculate our structure efficiency to how to know damages. Due to inadequate specifications to different deteriorating influences to resist durability, many RCC structures constructed during early 1990's & late 2000's & even upto 2011 in India, till the revision of codal provision on strength and durability as laid down according to IS 456:2000, are we got it to be in partly distressed conditions. With the objective of enhancing the Residual life of RCC members of the 57 year old framed structure, condition assessment carried out through survey, and laboratory analysis of samples collected from building or structure to analysis. Remedial measures & specifications required for restoration and strengthening of the RCC elements of the structure are also represent in this paper. The paper highlights the assessment of strength and durability of concrete to evaluate the extent of distress in this service structure. Apart from visual survey, residual strength and durability of distressed RCC structures, chemical effect of carbonation, chloride content & pH value of concrete as obtained on representative and selected RCC Columns/ beams/slabs is highlighted in this paper. The Non Destructive Evaluation covering UPV & Rebound Hammer values and Half Cell Potential with respect to status of corrosion of reinforcing bars on selected undistressed RCC Columns/ beams/slabs is also presented.

Key words: Dismantle, Condition Assessment of Existing Distress Concrete Structures

I. INTRODUCTION

Durability of Portland cement concrete in general is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration; that, durable concrete will retain its original form, quality, and serviceability when exposed to its environment. With different weather conditions such as temperature, water falling in drops from vapor condensed in the atmosphere, wetness in the atmosphere, sunlight exposure & sea water, over a period of time due to aging & usage conditions of the structure, the minute isolated voids present in concrete get interconnected to each other. Due to continuous passage for external rancorous environmental substances, such as, water, carbon dioxide, oxygen, chlorides, Sulphate etc. slowly penetrate into the concrete cover and affects steel which gets corroded. Over a hundred years ago in 1907 Knudson showed in his paper entitled 'Electrolytic Corrosion of Iron and Steel in Concrete' that a passage of a small current through the reinforcement in concrete would cause corrosion. Later on Rosa, McCullom & Peters shared the opinion of Knudson that stray currents were the cause of the problem and concluded that 'the presence of chlorides always facilitated trouble' (Electrolysis of Concrete, 1912). It was not until half a century later (after lab finding by Knudson in 1907), the problem of chloride attack was detected while use of deicing salting became widespread when deterioration of bridge and highway structure were detected.

Numerous research highlighting the corrosion damage are reported thereafter. Today engineers & technologist all over the world are concerned about the structural problems of RCC structures and are looking for enhancing the service life of existing structures. Now-a-days new structure of engineering importance related to service life are being designed using performance specifications. In this paper In-situ non-destructive Evaluation in the field and laboratory test on representative samples from different structural elements of 21 years old Service school Building (G+2) at Simpkins Public School Gwalior, Madhya Pradesh (India) is reported. The field assessment included the estimation of surface compressive strength using rebound hammer, quality assessment of hardened concrete in structure using Ultrasonic Pulse Velocity technique, study of concrete cover and carbonation and corrosion status. Evaluating equivalent cube compressive strength and chemical composition of concrete powder sample is also reported. Apart from field & lab study, this paper also highlights the different methodologies adopted for repair, restoration & strengthening of distressed RCC elements of the service structure.

II. LITERATURE SURVEY OF ASSESSMENT RESTORATION OF CONCRETE STRUCTURES

Extensive research on the complex phenomenon of downturn of concrete in service and preterm durability issues has been reported around the world. P.E. Gratten-Bellew[1]studied the microstructure investigation of deteriorated Portland Cement Concretes. D.C.K. Tay et. al. [2] reported the In situ investigation of the strength of deteriorated concrete. Predictive models for deterioration of concrete structures has been studied by P.A.M. Basheer et. al. [3]. Kenneth C. Hover [4] covered special problems in evaluating the safety of concrete bridges and concrete bridge components. A wide range of repair options to repair and rehabilitate damaged reinforced concrete structures is reported by John Broomfield [5]. John Bickley et. al. [6] investigated the Issues related to performance based specifications for concrete. Satish Sharma et al. [7] reported the Distress Assessment, Repair and Strengthening of RCC members of Turbo Generator Foundation of Anpara Thermal Power Station at Uttar Pradesh (India) .A case study on Non Destructive Evaluation and repair and strengthening of corrosion distressed RCC structure was done by Satish Sharma et.al [8]. .A study on Quantities and Durability of concrete for revetment in Gunkanjima Island after long term service has been done by Yoshikazu Akira et. al. [9]. Ryoichi Tanaka et al. [10] studied the Soundness of Histrical Concrete revetment Gunkanjima Island in Japan. Roberto Torrent et al. [11] studied site testing of Air Permeability as indicator for Carbonation rate in old structures. The study on Influence of construction work condition on the relationship between concrete carbonation rate and the air permeability of surface concrete was done by Kazuaki Nishimura et al. [12].

III. PRESENT INVESTIGATION ON 21 YEARS OLD SCHOOL BUILDING (G+2) AT GWALIOR MUNICIPAL CORPORATION SIMPKINS PUBLIC SCHOOL GWALIOR, MADHYA PRADESH (INDIA)

The Service and school Building at GMC as shown in fig 1 was a framed structure and was constructed in the year 1996. As per the drawings, the grade of concrete used at the time of construction was M25. The main objective was to investigate the cause and extent of damage that has occurred due to ageing, using the methodology comprised of (a) visual survey, (b) Determination of Surface compressive strength using Rebound hammer technique as per IS: 13311 (Part – II) -1992 [19], (c) Core Extraction to determine equivalent cube compressive (d) Carbonation and Concrete cover study: and (e) Chemical analysis study of concrete powder

Fig. 1: Sectional Elevation of School Building at GMC Gwalior (India)

Fig. 2: Front part of School Building at GMC Gwalior (India)

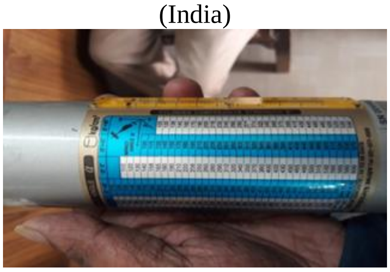

Fig. 3: Reading(1)of rebound hammer

Fig. 3(a): Reading (2)of rebound hammer

Fig. 4: Field test with rebound hammer

Fig. 5: Field test applying point

Fig. 6: Shows vertical crack & spoiling of concrete in RCC Beams

Fig. 7: spalling of concrete in RCC Chajjahs

A. Visual Survey

During the visual survey, mischief in the form of vertical cracks and exposure of corroded reinforcement observed at some other places and points on external RCC Columns and RCC beams is shown in fig. 6. No signs of cracks and spoilling of concrete observed in RCC Slabs. All the chajjahs were found to be severely damaged with exposed corroded reinforcing bar with 15-25% diameter reduction as shown in fig. 7.

B. Determination of Surface Compressive Strength as per IS 13311 Part-I-1992

In this, assessment of surface compressive strength covering tiles wall area by using Rebound Hammer Testing is

Highlighted in fig. The values of surface compressive strength obtained after removal of tiles, plaster and cleaning of surface using carborundum stone are found to vary from 28.1 N/mm^2 to 32.3 N/mm^2 (average = 30.2 N/mm^2) on RCC Columns, from 30.4 N/mm^2 to 33.9 N/mm^2 (average = 32.15 N/mm^2) on RCC Beams and from 32 N/mm^2 to 36.7 N/mm^2 (average = 34.35 N/mm^2) on RCC Slabs. The average surface compressive strength was found to meet specified M25 grade of concrete. Data as obtained on different RCC members is shown in fig 8.

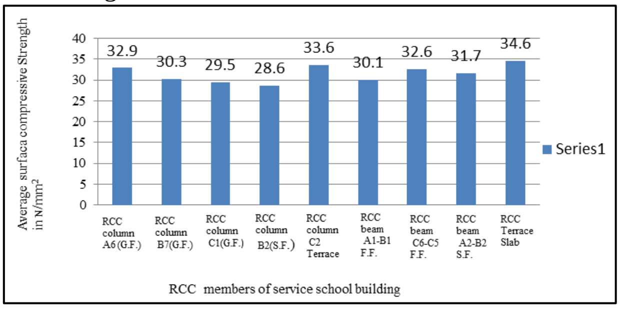

Fig. 8: Shows Average Surface Compressive Strength of RCC Columns. Beams and Slabs

C. Core Extraction to determine equivalent cube compressive strength

Concrete cores extracted by random sampling technique from five nos. RCC Columns, three nos. RCC Beams and one no. RCC Slab panels were tested in laboratory as per IS516 and IS 456.Concrete cores of 55mm dia and length upto 200mm were extracted. The test results indicate that the equivalent cube compressive strength values for RCC Columns is found to vary from 17.55N/mm^2 to 36.14N/mm^2(avg: 26.84N/mm^2), RCC Beams is found to vary from 14.28N/mm^2 to 30.11N/mm^2(avg: 22.19N/mm^2) and RCC slabs is found to vary from 16.78N/mm^2 to 24.46N/mm^2 (avg: 20.62N/mm^2). Out of 16 nos. tested cores 11 nos. concrete cores were found to have equivalent cube compressive strength more than specified characteristic compressive strength of M25 grade concrete. Data as obtained on selected RCC members is shown in fig 9,10 & 11.

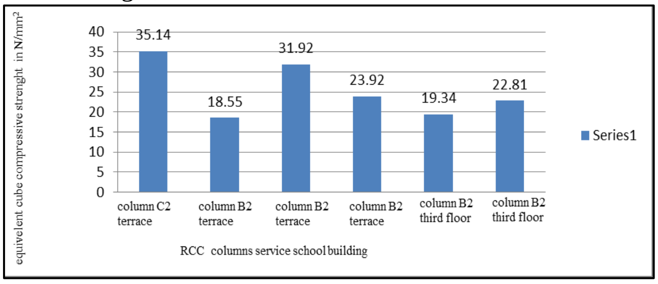

Fig. 9: Shows Equivalent Cube

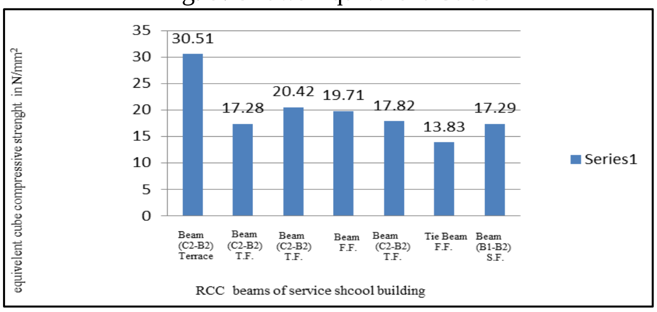

Fig. 10: Showing Equivalent Cube Compressive Strength obtained in Compressive Strength obtained in selected RCC Columns selected RCC beams

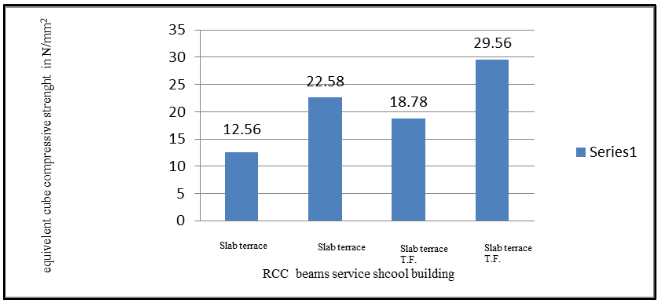

Fig. 11: Shows Equivalent Cube Compressive Strength obtained in selected RCC Slabs

D. Carbonation and Concrete cover study

Carbonation study was done at different members to determine the extent of carbonation. The concrete cover depth to rebars in RCC members were measured with Ferro-scanner and a measuring tape/scale in the places where concrete is exposed and accessible for direct measurement. Carbonation in cover concrete is found to vary from 35 mm to 40 mm in RCC columns which is touching the average concrete cover of 37.5 mm. Carbonation is found to vary from 40 mm to 50 mm in RCC beams which is beyond the average concrete cover of 23 mm. Carbonation is found to vary from 25 mm to 40 mm in RCC slab which is beyond the average concrete cover of 16 mm.

E. Chemical analysis study of concrete powder

The chemical analysis was done on powdered samples extracted from different elements of RCC members collected by random sampling technique. This covered chloride content, sulphate content per cum of concrete as well pH value of powdered samples. The amount of Soluble Sulphates and Chlorides in the concrete of RCC members are within the specified limits but pH values are lower than the specified limit of 11.5 given in NCB technology digest, April-May 1988, covering 'Corrosion in reinforced concrete structures'. Data obtained on pH value and chloride content is shown in fig 12 & 13 respectively.

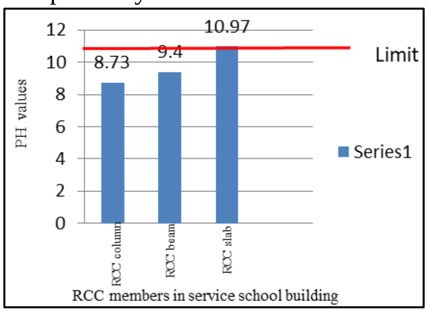

Fig. 12: Shows pH values of concrete powders extracted from Different RCC members

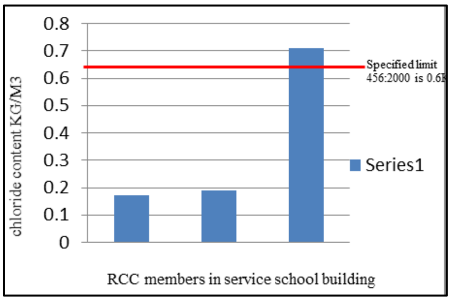

Fig. 13: Shows chloride content of concrete powders extracted from Different RCC member

IV. Test Results and Discussion

The test results were analyzed to work out the cause and extent of damage and find out the suitable specifications for repair. Based on Ultrasonic Pulse Velocity & Rebound Hammer testing done on representative samples by random sampling technique on RCC Columns, RCC Beams and RCC Slabs,tiles walls overall quality of concrete is graded as ' Good' and 'Medium' at some locations. The test results of concrete cores indicate that the equivalent cube compressive strength values for RCC Columns/beams/slabs is found to meet the specified characteristic compressive strength of M25 grade concrete .Carbonation is found to reach beyond the cover of concrete. Hence the cause of damage for distress in structure is found to be carbonation. Chloride was not the cause of corrosion as it was within the specified value. Based on the cause & extent of damage, repair & strengthening measures are recommended.

V. Repair and Strengthening Measures

In the present investigation most of the distresses in the RCC structural members of service structure are caused by carbonation of cover concrete, leading to corrosion of reinforcing steel. To carry out repair & restoration of corrosion effected RCC Columns/Beams/Slabs and based on similar work done by NCB, systematic procedure for repairing is suggested. This includes,

- Removal of all soft and loose concrete from the visible distressed RCC Chajjahs and chipping using light hammer (2lb hammer) from RCC Columns/beams and slabs.
- Grouting with high molecular weight low viscosity epoxy indigenously available grout to fill the cracked portion &to fill the voids.
- Cleaning of rust from corroded reinforcing steel and providing additional steel bars wherever required to compensate for corrosion losses followed by anticorrosive treatment.
- Applying two component epoxy bond coat conforming to specifications of ASTM C 881 - 13 TYPE II to ensure the effective bond old substrate obtained after chisel cutting of conver concrete and new concrete.
- Applying the Polymer Modified Mortar (PMM) to build the profile of structural members in damaged cover portion by using Styrene Butadiene Resin (SBR) latex conforming to ASTM C-1059-13 Type-I (1 Cement-3 part graded cleaned river sand + 20 % latex by weight of cement) with 0.35 w/c ratio mixed with Polypropylene fibres, in 15-20 mm thick layers by applying bond coat between successive/each layers.
- Applying concrete penetrating corrosion inhibitor (CPCI) as per manufacturer/supplier specifications over the entire finished surface.
- Strengthening of distressed RCC Columns using nonmetallic composite fiber wrapping system.
- Applying protective coating on surface of RCC Columns/beams/slabs to protect from the further corrosion to reinforcing bars.

VI. Conclusion

- Visual observations indicate wide spread distress in form of cracking, spoilling of concrete and reinforcement corrosion in many external RCC columns, beams & chajjahs.
- Based on Ultrasonic Pulse Velocity & Rebound Hammer testing done on representative samples (by random sampling technique) on RCC Columns, RCC Beams and RCC Slabs, overall quality of concrete is graded as ' Good' an d 'Medium' at some locations. Equivalent cube compressive strength is found to meet the specified requirements of structural grade of concrete.
- Primary cause of the distress in the RCC structural members is carbonation of cover concrete leading to corrosion of reinforcement steel. Chloride is not the cause for corrosion.
- Keeping in view the excessive carbonation of ageing cover concrete and active signs of corrosion observed on representative samples of testing done on RCC Columns, beams and slabs, suitable remedial and strengthening measures to arrest the corrosion are suggested.

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