Condition Assessment and Evaluation of Concrete Structures by Advanced Non-destructive Methods

Syed Azhar Uddin[1], Khaja Omer Uddin[2], Shaik Mohd Ibrahim[3], Kanchala Nanchari [4]

[1, 2, 3] UG Students, Department of Civil Engineering [4] HOD Dept of Civil Engineering
ISL Engineering College, Hyderabad, Telangana, India

---***---

Abstract - *Structures built in India throughout the early 1970s and late 1980s are found to be in bad condition due to weak specifications and poor building procedures. Continuous monitoring of concrete structures using appropriate NDT (Non Destructive Testing) technologies and the use of feasible restoration procedures aid in a significant decrease in the rate of degradation of concrete structures, extending their life lifetime. In analysing the uniformity, homogeneity, approximate compressive strength, durability, the level of rebar corrosion in concrete, and other properties of damaged buildings, NDT technologies have a significant benefit. The goal of this research is to extend the life of a 50-year-old commercial structure in Hyderabad (partly RC and brick masonry). The findings of the condition evaluations are reported in this publication, which include a visual, field, and laboratory examination of samples gathered from the structure. The document also discusses how to measure the strength and durability of concrete in order to determine the amount of the building's distress and damage. Aside from visual inspection, nondestructive evaluations such as UPV and Rebound Hammer values, Half Cell Potential, and chemical tests on chosen undamaged RC columns, beams, and slabs are also shown and discussed. To extend the life of the structure, repair and strengthening procedures employing the most up-to-date materials, as well as feasible restoration works such as column jacketing, shotcreting, anticorrosive coatings, and so on, have been recommended.*

Key Words: (NDT Methods; Condition Assessment; repair and strengthening

1. INTRODUCTION

Globally, concrete is one of the most versatile and commonly utilised construction materials. Reinforced concrete buildings must survive environmental conditions for the duration of their lives if they are correctly constructed and installed. It is exemplified by the vast number of concrete structures constructed during the last century in various regions of the world.

As a ferrous substance, steel implanted in concrete structures, whether as reinforcement or prestressed tendon, is prone to corrosion, which cannot be completely eradicated. In the 1970s and 1980s, all industrialised nations implemented required preventative measures, including revisions to concrete regulations to incorporate appropriate durability practises. However, in India, this process has been extremely sluggish; even the fundamental concrete code IS: 456-2000 has not been fully revised to meet durability requirements. Our infrastructure is heavily reliant on steel reinforced concrete structures. The combination of concrete's strong compression strength and reinforcing steel's high tensile characteristics results in an excellent composite material that, in comparison to other materials, has a broader variety of structural engineering applications.

Steel reinforced concrete is used to construct buildings, slabs, beams, bridge decks, piles, tanks, and pipelines. Corrosion is the degradation of material as a result of its interaction with the environment. Among the different corrosion factors, the most prevalent is air corrosion, which results in steel rusting. Corrosion becomes noticeable when the air's relative humidity hits roughly 65 percent. Corrosion is impossible in dry, clean air and water with a freezing point below zero. Thus, structural health monitoring is critical for determining the extent of deterioration over time. Non-destructive testing (NDT) is a critical component of a comprehensive structural health monitoring system. NDT techniques aid in determining the quality and homogeneity of materials without impairing the structure's performance or serviceability during their examination. Failures in reinforced concrete buildings can be avoided by corrosion monitoring and early identification of cracks utilising a variety of nondestructive testing (NDT) technologies.

Numerous assessment techniques are now employed to obtain data on structural performance metrics such as displacements, strains, and stresses. This data is paired with powerful post-processing methods to derive information about the present operating status and remaining life of the component. The NDT method selected is determined on the property of the concrete being analysed, such as strength, corrosion resistance, and crack monitoring. Corrosion of Reinforcement is influenced by the following factors:

- Concrete Quality
- Concrete Cover Thickness Over Reinforcement
- Reinforcement Condition
- Environmental and other Chemical Effects
- Concrete Porosity
- The Impact of High Thermal Stresses
- Freezing and thawing temperatures
- Total Steel Loss Due to Corrosion
- Reinforcement Steel Storage and Stacking

Structural elements that have been damaged, misaligned, hit, or have lost concrete or steel sections need to be checked out before they can be repaired for corrosion. This is called a condition evaluation. These things could happen, and they could make it hard for the concrete to get stronger after the repair. Degradation processes that may lead to corrosion of the reinforcement (freeze-thaw, sulphate attack, etc.) should also be taken into account.

Different parts of the structure should be separated into two groups: a) Reinforcement is not corroding yet, because carbonation or chloride penetration has not reached the steel surface. b) Reinforcement is corroding, but the spread of the corrosion is still very small, because the concrete cover is not cracked and the reduction in cross section of rebars is very small. c) Corrosion of steel can cause the concrete cover to crack, split or delaminate, or the rebar to lose more than a small amount of its cross section. This can make the structure less useful.

The main focus of the paper is the condition of a 35-year-old commercial building and the possible rehabilitation works that could make it last longer and be more safe. The first step in determining the condition of a structure is to look at it. This includes probing cracks and spalls to see how far they go, measuring reinforcement cover, and so on. Possible strength measurements, carbonation measurements, and electrode measurements are done by taking samples for lab tests in the second phase. NDT methods have been combined to look at how well structures are made, and possible repair and restoration projects have been suggested.

2. LITERATURE REVIEW

A large number of studies have been carried out all over the globe to examine the degradation of existing concrete buildings. When it comes to analysing such structures, non-destructive approaches are quite significant. A large number of writers from across the world presented their research on non-destructive evaluation techniques and probable strengthening strategies that may become accessible from time to time for aged and degraded structures in various locations.

Gattulli and Chiaramonte [27] used the visual inspection method for the quality determination of a bridge for Italy railways. They conducted inspections on concrete, steel and masonry bridges. The damage levels associated with maintenance and repair was discussed. Four different simulation models have been proposed for the regular assessment of these structures. Abdulkader El Mir et al. [9] emphases on the limitations of rebound hammer method based on the response of the rebound index towards different parameters. The author conducts a series of experimental tests on 795 cubic specimens to understand the repeatability of the rebound index in several concrete type admixtures. The surface hardness test is conducted using the N-type Schmidt hammer according to European standard. The results of his experiment discussed on the parameters such as water binder ratio, the water-powder ratio, SCMs and admixtures. His experiments proved that the coefficient of variation of the rebound index has influence on the parameters such as water binder ratio, the water-powder ratio, SCMs and admixtures of the concrete cubes tested. Jin-Keun Kim et al. [10] determines the strength parameters of concrete and factors affecting the Rebound Number due to carbonation in concrete structures with his experiments. He has established relationships between the Compressive Strength for 28, 90, 180, and 360 days concrete cubes respectively and the Rebound Number. A new equation was derived considering the effect of carbonation on the Rebound Number in determining the strength reduction coefficient.

Abdulkader El Mir et al. [17] has conducted investigations to evaluate the compressive strength of concrete and boundary imitation of Rebound Number using Rebound Hammer equipment. Results showed that, from normally vibrated concrete to Ultra-High Strength concrete and the water powder ratio, the water-binder ratio, and the admixtures relatively has influence on the rebound index number and compressive strengths. Ourania Tsioulou et al. [11] studies shows, the evaluation of tensile strength and the Compressive strength using UPV and Rebound Hammer measurements. Author uses the combination of methods in his analysis. He concluded that the combined use of these methods offers higher accuracy where test errors were found to be below 10% in the determination of compressive strength and modulus of Elasticity. M. Yaqub et al. [12] has conducted experiments to determine the compressive strength in the existing RC columns damaged in a fire accident using UPV Test Method. His experiments showed the variation in compression strength of concrete when subjected to different temperature conditions. Maitham Alwash et al. [16] discuss the techniques like rebound hammer and the Ultra-Sonic Pulse Velocity test. The factors affecting these techniques and measures to develop effective methodology in improving strength parameters using synthetic simulation approach has been proposed. Veerachai Leelalerkiet et al. [13] has used Half-Cell Potential apparatus to determine the probability of rusting of steel in reinforced concrete slabs subjected to cyclic wet and dry conditions. 3D Boundary Element Method is used to study the parameters like, the rate of flow of current and the potential distributions. Corrosion states were evaluated using results of Inverse Boundary Element Method. The results were found to be insignificantly successful, when compared to the analytical results using Boundary Element Method. The results of Inverse Boundary Element Method analysis identify corroded areas more prominently.

Yun Yong Kim et al. [19] have used Half-Cell Potential Test method in his experimental studies to evaluate the crack in concrete when exposed to chloride attack. The test results are obtained considering the effects of water-cement ratio, crack width and cover depth. Anti-corrosive techniques to withstand chloride attack are proposed from the results. Jin Xia et al. [15], study show the performance of RC columns when it is embedded with corroded steel. 6mm and 20mm hot-rolled reinforcing steel bars were used in the RC column sections. The compressive strengths were determined using cubes of size (150X150X150) mm with same mix proportions. Corrosion was induced using the electrochemical process. The columns were tested for eccentric-compressive loading. Relationships concerning the average c/s area, strength loss, and the maximum crack width of concrete cover were established. The quantitative estimate of the residual compressive strength of the corroded reinforced concrete column was obtained using load-carrying capacity models. Lamya Amleh et al. [8] have conducted investigations on the existing Montreal Dickson Bridge. Spans of 0.25m by 0.25 m on four randomly selected 5 m by 6 m deck patches are considered for analysis. A detailed research was conducted to understand the reason behind the rapid deterioration of the bridge. J. Helal et al. [18] discusses the most common non-destructive test methods used in structural engineering industry. The limitations, potential, inspection techniques and interpretations are discussed. Katalin Szilágyi et al. [36] have developed of a constitutive model, i.e. SBZ-model that can formulate the surface hardness of the concrete. The relationship between the water–cement ratio, the Rebound Number and the compressive strength of concrete has been established considering 28days strength of concrete. It also relates to the depth of carbonation and its influence on the rebound index.

Shamsad Ahmad [37] discusses about various internal and external factors causing corrosion in RC structures. The rate of corrosion is measured using Linear Polarization Method for in-situ concrete. Corrosion Mechanism and parameters affecting corrosion in reinforced concrete structures are also illustrated. With the use of different models and experimental techniques, the enduring life of RC structures can be predicted. Eugen BRÜHWILER et al. [38] proposes three methods to reduce corrosion risk in concrete i.e. by providing sufficient cover thickness to concrete structures, or use of concrete with low permeability properties, or by reducing the early age cracking of concrete. Numerical models that allow the prediction of the initiation phase of corrosion and early-age cracking of concrete elements are also discussed in his study. The factors affecting the hydration rate of concrete and its permeability properties are also described in the paper. Tarek Uddin Mohammed et al. [39] discusses about, the corrosion of steel in RC structures when exposed to a marine environment. Experiments include evaluation physical and chemical properties of corrosion, presence of chloride ion, and permeability properties of concrete. He concludes, the W/C ratio has great influence on the magnitudes of corrosion. As the narrow cracks heals considerably fast in the marine environment, chances of reduction in corrosion rate can be seen. Viktor Urban et al. [40] paper deal with experimental tests on weathering steel bridges. The effects on the steel bar when subjected to exposed the surface, and damage of surfaces due liking water is discussed. It also explains the relationship and dependence factors between measured corrosion loss and the average thickness of corrosion products. Razmjoo et al. [41] studied the relationship between the location of the steel bar and the coarse aggregate present in concrete. In the experimental process there different samples were casted placing aggregates at three different distances from the steel bar.

Results showed that, the location of the coarse aggregate from the steel bar has significant influence on the chloride ion penetration and the initiation of corrosion in steel. It was concluded that, by decreasing the distance between the coarse aggregate and the steel bar can lower the initiation of corrosion in reinforced structures. M. Goueygou et al. [42] has conducted experiments on concrete cubes having surface breaking cracks. The combination of non-destructive test methods like Resistivity Method and Ultrasonic Pulse Velocity method has been used. Three different mix concrete specimens were used in his studies. Cracks were induced in the section using Three Point Bending Setup apparatus. He concludes as, both the tests was capable in detecting the main crack. However, a compound crack pattern and depth of the crack was not considerably analyzed. Ngoc Tan Nguyen et al. [43] studies involve the assessment of spatial variability, i.e. the non-homogeneity of mechanical and physical properties of concrete structures. It also briefs about the possible NDT methods used for the assessment of these structural components. The method of analysis adopted for the NDT measurement is the variographic analysis. He concludes that, combined NDT techniques developed has improved the evaluation of concrete properties and also the assessment of spatial variability in concrete structures.

3. CONDITION ASSESSMENT OF STRUCTURAL MEMBERS

3.1 VISUAL INSPECTION

Visual inspection is a very powerful tool, and it is one of the most common and oldest non-destructive testing methods that people have at home. A visual inspection can give you a lot of information about the structure and its condition, but it has some limitations and rules. The only person who can do a visual inspection is someone who is very knowledgeable about structures, construction methods, and materials. In this case, a visual inspection only gives an impression of the visible problems, and the hidden problems go unnoticed. It also doesn't give us any quantitative information about how the material works. Because of these limitations, visual inspection is not enough on its own. It needs to be paired with other nondestructive and partly destructive testing methods. With the help of BS1881: Part 201:1986.

The following are the physical observations made during the inspection;

- Dampness was observed on walls below sill level at many locations.

• Growth of Vegetation was observed at a few locations nearer to the plinth.

• Dampness was observed on sunshades at many locations.

• Plinth protection was observed to be damaged at some locations.

• False ceiling was observed to be damaged at many locations.

• Separation crack was observed between CRS and brick masonry.

• Separation cracks were observed between masonry joints at a few locations.

• Corrosion cracks were observed.

• Spalling and exposure of reinforcement was observed in slabs at a few locations.

• Wooden purlins were observed to be decayed at some locations.

• Cracks were observed in the existing WPC on the terrace.

• Severe leakages & dampness was observed in the roof & walls of the newly constructed toilet block.

• It was reported that, severe leakage was observed from the expansion joint during monsoon season.

Fig -1: No Plinth Protection

Fig -2: Loosening of Motor

Fig -3: Distressed in wooden members

Fig -4: Dampness in columns

Fig -5: Cracks near Expansion Joint

Fig -6: Damaged false roofing and Truss

Fig -7: a) In-situ Non-destructive Tests

4. NON-DESTRUCTIVE TECHNIQUES

In the present scenario, it is observed that many important reinforced and pre-stressed structures show distress within a short period. These conditions are usually inspected and restored only when the embedded steel is highly corroded, followed by cracking and spalling of concrete. Quality of structure can be maintained by Continues monitoring and conducting periodic surveys. In order to protect rusting and erosion of steel in reinforced concrete structures, few of the major non-destructive techniques are proposed in this study.

Fig -7: b) In-situ Non-destructive Tests

4.1 REBOUND HAMMER TEST

Rebound Hammer Test is a quick method to evaluate the quality of concrete based on surface hardness of the existing structure. The rebound number gives the average surface compressive strength of the concrete. Rebound Hammer Test was carried out on all accessible locations of R.C. slab panels, beams, and columns in order to assess the surface hardness / quality of in-situ concrete. Initially the surface was prepared by removing the Plaster and dusting the surface to get better results. The test was conducted by using 'Schmidt Rebound Hammer' The results are presented in Figure. And corresponding reference strength is presented in Table 1.

Table -1: As per IS: 13311-(Part-II)-1992 (Reaffirmed in 2013) and Instrument manual furnished by M/s. Proceq, Switzerland

Rebound Number	Estimated Compressive Strength Range (N/Sq.mm)
22 to 26	10 to 14
26 to 30	14 to 18
30 to 34	18 to 22
34 to 38	22 to 26
38 to 42	26 to 30
42 to 46	30 to 34

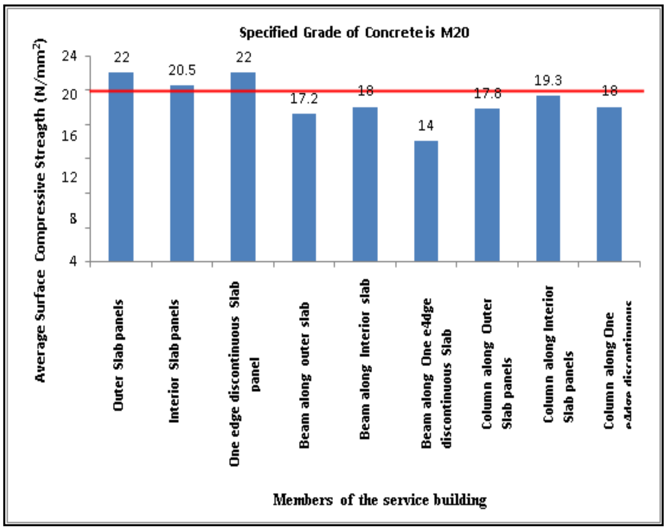

Fig -8: Shows Average Surface Compressive Strength of RCC Columns. Beams and Slab

4.2 ULTRASONIC PULSE VELOCITY METHOD

Ultrasonic Pulse Velocity Test is being extensively used to assess the quality of concrete in general. This test is generally used to check uniformity of concrete, determination of cracks in the interior concrete, honeycombing and assessment of concrete deterioration.

Ultrasonic Pulse Velocity Test was conducted on accessible locations of R.C. Beams and Columns such as Beam along outer slab panels, Beam along interior slab panels, Column along outer slab panels, Column along interior slab panels, Beam along edge discontinuous Slab panel, Column along edge discontinuous Slab panel. The transducers were coated with grease and placed on the opposite side of beams and columns for better electrical conductivity. Direct / Indirect method of scanning was adopted at site. The tests were conducted using 'PUNDIT LAB+' (Portable Ultrasonic Non-Destructive Digital Indicating Tester) equipment from M/s. Proceq, Switzerland.

The results are presented in Figure 11. and the corresponding reference quality grade chart is presented in Table 2.

Table -2: Concrete quality grading for different velocity criterion as reproduced from IS: 13311 (Part 1) – 1992

(Reaffirmed 2013)

Pulse Velocity (km/sec)	Concrete Quality Grading
Below 3.0	Doubtful*
3.0 to 3.5	Medium
3.5 to 4.5	Good
Above 4.5	Excellent

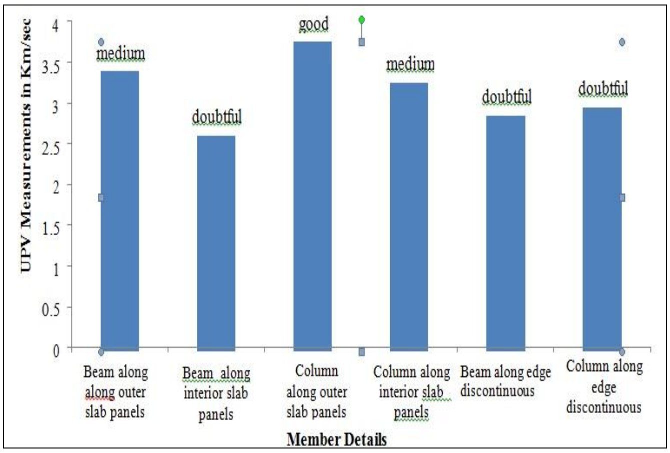

Fig -9: Ultrasonic Pulse Velocity Measurements results on selected members

4.3 HALF-CELL POTENTIAL TEST

In order to assess the extent of corrosion in reinforcing bars of R.C members, 'Half-cell Potential Difference Measurement test' was carried out on randomly selected accessible locations of R.C members. The test was conducted using copper-copper sulphate half-cell solution. The test results are presented in Figure 10.

Table -3: As per ASTM C876-91 Standards

Potential over an area	Most likely outcome
more positive than -200MV	90% probability that no reinforcing steel is corroded at the time of test
-200 to -350 MV	corrosion activity of the reinforcing steel
more negative than -350 MV	90 % probability that reinforcing steel is corroded

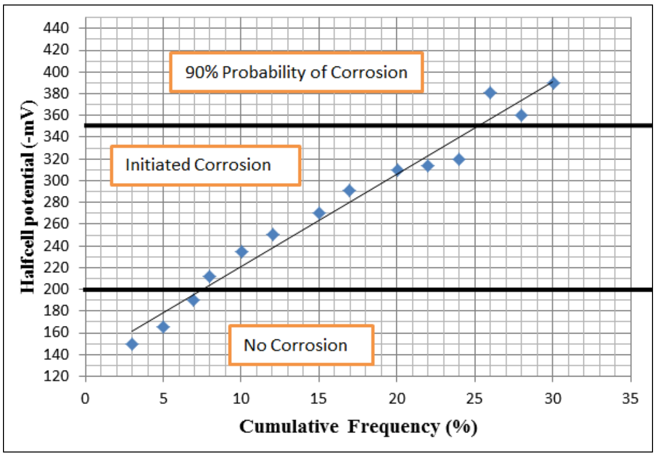

Fig -10: Half-cell Potential Test Results of selected Members

4.4 CARBONATION DEPTH MEASUREMENTS

To assess the extent of carbonation, i.e. the loss of alkalinity (which is essential to protect the steel against potential corrosion) in the cover concrete, colorimetric test was carried out on randomly selected accessible locations of R.C members using Phenolphthalein as indicator in dilute methyl alcohol solution. This test was carried out by removing the plaster and cover concrete to the required depth. The exposed area was then drenched with the sample solution prepared to check the amount of carbonation. The test results are presented in Figure 11.

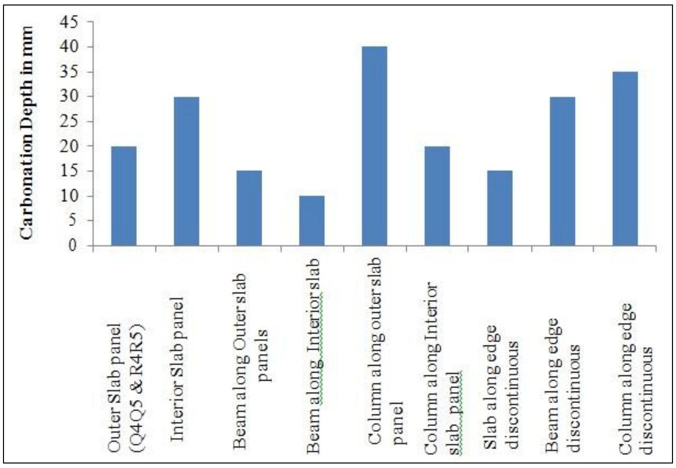

Fig -11: Carbonation depth measured at different members

5. RESULTS AND DISCUSSION

• Based on the results obtained from Figure 8. for the Rebound Hammer Test conducted on selected structural members of the building, it is inferred that the strength of the cover concrete of R.C Slab panels in Ground floor is only satisfactory and also at few locations delamination of cover concrete was observed. The results were concluded in reference to Table 1.

• The results of Ultrasonic Pulse Velocity Test obtained from Figure 9. inferred that the quality of in-situ concrete in the tested locations of the R.C. beams in Ground Floor was found to be "Medium to Good" grade, as per Table 2.

• The Half-cell Potential Difference Measurement Test, was carried out on the selected RC members and the results obtained from Figure 10. inferred that, the corrosion of reinforcing bars in the structure was observed to in the "Initial Stage" (where no corrosion was observed) but in the lintel beam it was observed to be in the "Moderate Stage" (where corrosion was observed) with a need of proper supervision. The results were concluded in reference to Table 3.

• The Carbonation test results obtained from Figure 11. showed that the cover concrete in the tested R.C. Slabs and beams was carbonated up to reinforcement level and initiation of corrosion can be observed.

6. REPAIR AND RESTORATION MEASURES

The building investigated in the study consists of many distressed structural members leading to the corrosion of reinforced steel. In order to increase the residual life of this structure suitable repair and restoration measures have been proposed based on the damage in the respective structural members.

The building investigated in the study consists of many distressed structural members leading to the corrosion of reinforced steel. In order to increase the residual life of this structure suitable repair and restoration measures have been proposed based on the damage in the respective structural members.

a) Replacing of existing AC sheets in the corridor region:

In corridor areas the existing AC sheets at the first floor level shall be replaced with metal sheets and the damaged wooden joists shall be removed and replaced with new wooden joists with existing dimensions.

b) Treatment for distressed madras roofing in the corridor region:

In view of severe distress observed in the rear side corridor region of Portion -7 consisting of madras roofing system with wooden rafters, it is recommended to remove the madras roofing system. It shall be replaced with R.C precast slab panels with structural steel (ISMC) beams.

c) Treatment for Dampness and Spalling of cover concrete in slab panels:

In view of the dampness and spalling of cover concrete in slab panels, it is recommended to remove the existing plastering & loosen the cover concrete up to the extent of distress in a definite shape, i.e. square / rectangle. After a thorough cleaning of the surface, if there is any presence of corroded reinforcement, it is recommended to apply anticorrosion chemical paints to the rebar and then the portion shall be redone using polymer modified mortar.

d) Treatment for Damp patches & Peeling of plaster in Walls:

The deteriorated plaster on masonry walls at exterior face of the building shall be totally removed by gentle chipping. The mortar joints in walls shall be deep racked and repointed with CM 1:4 as per standard practice followed by re-plastering with CM 1:6 mixed with water proofing agents.

e) Treatment for Expansion Joint:

In view of leakages from the expansion joint, it is recommended to clean the joint and fill it with Polyurethane sealant and redo the portion as per IS 5256-1992 provisions.

f) Treatment for CRS masonry:

In view of dampness observed in CRS masonry, it is recommended to remove the loosen mortar between the masonry joints and redo it with cement mortar prior to grouting.

g) Treatment for Terrace Slab:

To seal the cracks and also to improve the durability, it is recommended to provide reinforcement concrete screed on terrace integral with providing fillet at required corners of the slab.

h) Strengthening beams and columns:

• RC beams can be strengthened by providing additional cage of longitudinal and transverse reinforcement around the beam and casting the concrete. The stirrups can be held in position by drilling holes into the slab.

• The strengthening of RC beams can also be done by inducing prestress to counteract the opposite moments encountered during loading. To induce this prestress, wires are introduced on both sides of the web and are anchored against the end of the beam through a steel plate.

• Inadequate sections of RC column and beams can also be strengthened by removing the cover concrete up to the reinforcement level and welding new steel to present rebar with the replacement of cover concrete. Initially the surface shall be roughed and prepared for the effective replacement of new steel with the introduction of grooves to facilitate shear transfer.

7. CONCLUSION

The present paper focused on the condition assessment, safety evaluation and possible repair and restoration methods for existing aged RC building.

• Visual inspection showed that most of the region in the building is subjected to distress due to spalling of concrete cover; cracks near expansion joint, dampness and initiation of corrosion in structural members have led to deterioration of the structure.

• The proper maintenance and periodic surveys helps in the restoration of aged RC buildings. The cracks in concrete appeared on the concrete surface due the chemical reaction can be eliminated by using proper grade of concrete, curing and good compaction.

• Knowing the probability of corrosion, the buildings can be restored by using different chemical treatments proposed for steel. The embedded steel can also be protected using cathodic protection of steel method, but the process may not be cost effective.

• Coating over steel bars is a short time solution for buildings. This results in causing weak bonding between steel and concrete. It is always recommended to use steel before it reacts with the environment.

• The use of polymer modified mortar, paints with water proofing compounds on the surfaces affected to dampness and distress results in reuse of these building with minimum expenditures.

• It can be seen that detailed visual inspection and Non Destructive Testing (NDT) play an important role in condition assessment of existing buildings. It is emphasized that using suitable NDT methods along with thorough observations we can understand the level of distress and with proper restoration measures under technical supervision the residual life of the structure can be enhanced.

REFERENCES

[1] [1] Chunhua Lu, Weiliang Jin, Ronggui Liu, "Reinforcement Corrosion-Induced Cover Cracking Ans Its Time Prediction for Reinforced Concrete Structures" Corrosion Science, 53, (2011) 1337-1347.

[2] Amir Poursaee, "Corrosion measurement and evaluation techniques of steel in concrete structures" Clemson University, Clemson, SC, USA.edition, year of publication..

[3] John P Brromfield, "Corrosion of Steel in Concrete-Understanding- investigation and repair" 2nd edition, year of publication, Taylor and Francis publications.

[4] M. Torres-Luque, E. Bastidas-Arteaga, F. Schoefs, M. Sánchez-Silva, J.F. Osma, "Non-destructive methods for measuring chloride ingress into concrete: State-of-the-art and future challenges", Construction and Building Materials, Volume 68, 15 October 2014, Pages 68-81, ISSN 0950-0618.

[5] Malcolm K. Lim, Honggang Cao, "Combining multiple NDT methods to improve testing effectiveness", Construction and Building Materials, Volume 38, January 2013, Pages 1310-1315, ISSN 0950-0618.

BIOGRAPHIES

Syed Azhar Uddin
(UG Student, Department of Civil Engineering,
ISL Engineering College, Hyderabad, Telangana)

Khaja Omer Uddin
(UG Student, Department of Civil Engineering,
ISL Engineering College, Hyderabad, Telangana)

Shaik Mohd Ibrahim
(UG Student, Department of Civil Engineering,
ISL Engineering College, Hyderabad, Telangana)

Kanchala Nanchari
(HOD, Department of Civil Engineering,
ISL Engineering College, Hyderabad, Telangana)