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Review on Restrengthening of Existing R.C Structure with Consideration of Structure Audit Report

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Abstract- *Catastrophic collapses are common in India as builders try to omit corners by using low quality materials, and multi-storey structures are erected with inadequate supervision. Loss of strength, reduction in durability and deterioration of various materials may result in collapse of an existing structure which is occurring at an alarming rate all over the world. Avoiding demolishing the structures, appropriate measures are required to improve the strength, efficiency and life of the structures i.e. to improve its overall performance and revive its functionality. The basic and important assessing tool which is adopted to determine health of a building is known as "Structure Audit" or "Structure Health Monitoring". Effective methods for monitoring and evaluation of level of deterioration with ageing are Non-destructive test methods. To increase serviceability of an existing structure proper retrofitting practices are employed so that better value of the structure can be received.*

Key words: Catastrophic collapse, Deterioration, Ageing, Structure Audit, Structure Health Monitoring, Serviceability, Retrofitting, Non-destructive testing.

1. INTRODUCTION

The prediction of the service lifetime of infrastructures requires accuracy in prediction of the evolution of the probability of failure with time. Recent studies have shown that the probability of failure of infrastructure systems increases with time with either continuous or discrete supplements. Continuous supplements often result from a gradual deterioration of the system properties due to various deterioration phenomena. Discrete supplements can be due to shocks that cause sudden changes in the system properties which include loads deterioration mechanisms that are active for a short duration of time such as impact loads, seismic events, and other man-made and natural hazards.

1.1 Need of Structural Audit

Structural Audit is the technical survey or health examination of an existing structure which is carried out in order to check its strength and durability parameters. It is an aid for maintenance and repairs of structures.

- Purpose of Structural Audit:

→ To extend durability of structures
→ To assess the actual condition of health of the structures
→ To inspect reliability of the structure
→ To detect and highlight the critically affected areas in order to repair them immediately
→ In order to recommend rehabilitation and retrofitting techniques

1.2 Need of Retrofitting

Retrofitting is technical intervention in structural system of a building that improves the strength, ductility and load carrying capacity. Strength of the building is generated from the structural dimensions, materials, shape, and number of structural elements, etc. Ductility of the building is generated from good detailing, materials used. It is also known as strengthening a structural member for its increasing serviceable life period.

- Performance requirements under retrofitting:

→ Safety: Performance needed to ensure that the structure does not threaten the lives of users or persons in the surrounding area.
→ Serviceability: Performance such that the structure can be used comfortably and does not cause discomfort exceeding allowable levels to users of the structure and persons in the surrounding area, as well as water tightness and other performance requirements for structures.
→ Restorability: Performance such that the structure can be easily restored if damage is suffered during the service life.

2. OBJECTIVE OF PROJECT

→ Perform preliminary inspection or audit of the building.

→ Identify the cause and extent of distress and their sources
→ Preparation of structure audit report of the building.
→ Obtaining actual service life of the building.
→ Implementing retrofitting to priority elements or repair measures if needed.
→ Obtaining a cost-benefit analysis.

3. LITREATURE REVIEW

Suryawanshi Sanket Sanjay et al. (2018) have studied that now-a-days structure gets older before their design period by following faulty mechanism in structure. They proceeded with visual inspection and NDT testing for a 28 years old RCC building situated in Thane, Mumbai with G+4 Floors and their output was investigated as structural health condition is fair. According to NDTs, it was stated as Class 3 damage with main observation was spalling of concrete cover and structural cracks etc where principal repairs were required as early as possible to avoid further deterioration of structure.

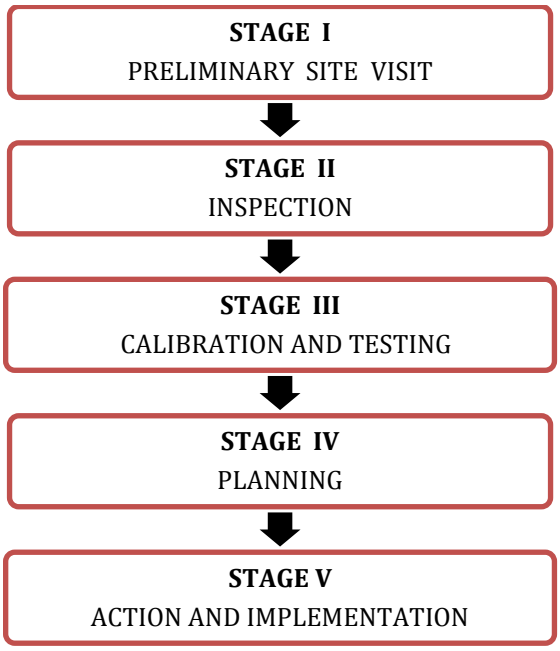
Er.Neha Goyal et al. (2018) have studied to highlight the importance and significance of various NDTs tests involved to be employed to find out the present condition of RCC structures which differs in type and age. For strength estimation in concrete Rebound hammer test and Ultrasonic pulse velocity tester is used. For assessment of corrosion bond of reinforcement or to determine reinforcement diameter and concrete cover Resistivity meter test, carbonation of concrete test, Ferro-scan is used. Ferro-scan HILTI PS 200 was a portable system used to detect rebar. They also stated that relationship between hardness and strength is dependent upon factors such as degree of carbonation, temperature, location, surface finish etc. They also recommended conducting these test for newly made structures. UPV test was conducted for deciding uniformity of concrete or to detect cracks.

Saiesh.L.Naik et al. (2017) performed structural audit over a 49 years aged building. They stated structural audit is the technical survey of building, a first step towards repairing procedure of the building and also recommended as for older buildings which was first introduced by Indian society of structural engineers. Also, ETABS is used for modeling and analyzing. Visual and tapping observation was initially recorded. It was a residential apartment with G+2 Floors having Earthquake zone: 3, for rebar location Profometer was used. Mainly cracks were observed due to leakage of the water through the wall. Strength of RCC members can be restored by polymer modified mortar method. Seepage can be repaired by external plaster or terrace water proofing, recasting of slab etc. So the strength and serviceability requirement can be achieved likewise.

Anjali N Satbhai (2017) studied that structure is a system of interconnected elements which needs to carry loads safely. To check its safety for further use its heath examination called structure audit is performed and also repair and rehabilitation is suggested if necessary. It is done to save human life, also to understand the present condition of building. There are some basic requirements of audit like structural and architectural plans and details of existing building like its age, no. of floors, materials used for construction etc. then a proper inspection is performed visually revealing each and every feature of building externally. Also, NDTs are required for internal inspection after that audit report is being prepared in a format and measures for repairs are suggested. This is the basic procedure which is illustrated here as a review.

Devdas Menon (2016) studied that a reinforced concrete (RC) lighthouse at Little Andaman Island, built during 1973-1980, was struck by the tsunami. This 45m high cylindrical tower was badly damaged in the lower portion, with extensive spalling and crushing of concrete and buckling of the vertical reinforcement on one side, and fracturing of reinforcement on the other side facing towards sea, along with severe damage and tilting of the RC portion structure connected to the tower at the entrance. The remedies consisted primarily of concrete jacketing of the lower portion of the shell structure from outside and inside, with additional thickening on the outside (to correct the eccentricity in vertical alignment) and provision of additional vertical rebar's, properly anchored to the well cap below and the undamaged portion above. The repaired lighthouse has safely resisted several high intensity tremors in the region, without any visible damage.

4. REASEARCH METHODOLOGY



4.1 STAGE I

Preliminary site visit:

It helps to understand the past record of the structure in terms of the distress and repair carried out if any. It is also helps to assess the apparent physical condition, robustness, structural integrity and strength of structure.

The main objective of preliminary investigation include

→ To obtain the initial information regarding the condition of structure by studying past records based on the information obtained from the owners, occupants of the buildings and general public.
→ To get an overview of the existing state of the structure to obtain a reliable assessment of the available structural capacity.
→ To understand the type and the seriousness of the problems affecting the structure.
→ To determine the feasibility of performing the required repairs and rehabilitation works.
→ To identify the need for detailed investigation.
→ To plan the necessary site preparations, procurement of the required field-testing equipment and tools for sampling.
→ It can be broadly classified into two headings: Review of records and Condition survey.
→ Review of record: A thorough review of data related to design, construction and service life of the structure is assessed in evaluating the condition of structure. For example: The original plans & specifications, the original design and construction documents like design, drawings, specifications, structural calculations, and record of modification if any.
→ Condition survey: Condition survey is a qualitative and systematic visual inspection of the structure which provides a fair idea about the signs of distress and deterioration, the structural and non-structural deficiencies, irregularities in building configuration and construction defects.
→ The criterion undertaken for surveying the sites is based on age factor i.e. how much old the construction is, as condition and performance of RC structures deteriorate with age.

4.2 STAGE II

Inspection: Visual examination is probably the most effective qualitative method of evaluation of structural soundness. It can often provide valuable information to the well trained eye. Visual features may be related to workmanship, structural serviceability, and material deterioration and it is particularly important that the engineer is able to differentiate between the various signs of distress which may be encountered are shown below through respective images.

Basic steps involved are as follows:
→ Mapping the site condition
→ Sketching of the overall layout, include the structural system, dimension and geometry of elements, spacing, loading system, etc.
→ Mapping of the detail structural damage, e.g. spalling, pops-out, cracking and its pattern, corrosion, discoloration, etc.
→ Observation of deflection and displacement on the structural elements
→ Observation of the deterioration of materials.

Fig.1 Spalling of concrete

Fig.2 Corrosion action

Fig.3 Structural cracks due to loading

Fig.4Scaling of concrete

4.3 STAGE III

Calibration and Testing: Calibration refers to the act of evaluating and adjusting the precision and accuracy of measurement equipment.

Non-destructive testing (NDT) methods are techniques used to obtain information about the properties or internal condition of an object without damaging the object. Non-destructive testing is a descriptive term used for the examination of materials and components in such way that allows materials to be examined without changing or destroying their usefulness. NDT is a quality assurance management tool which can give impressive results when used correctly.

- **Evaluation of concrete cover and reinforcement detection by BOSCH Rebar Detector**: This instrument has a unique real-time visualization mechanism, which works on the principle that the steel within the concrete will be affected by a magnetic field that is applied by the detector. The signal received will increase with increasing bar size and decrease with increasing cover. The instrument is laid at the surface of column or slab and then moved from left to right and bottom to top to get the position of reinforcement.

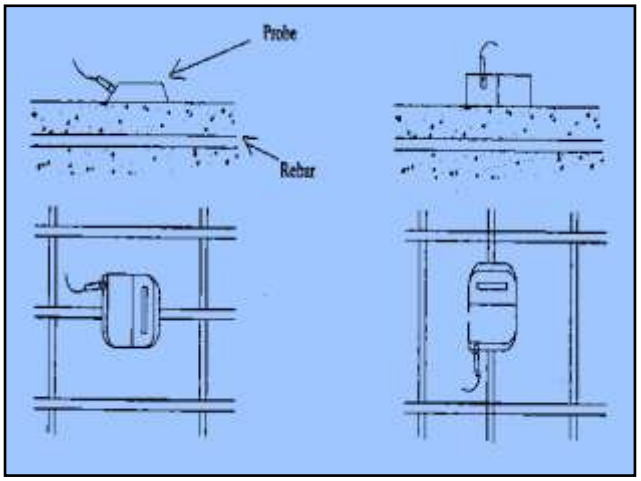


Fig.5 process of reinforcement detection

- **Measuring the depth of carbonation by phenolphthalein indicator solution:** Carbonation of concrete occurs when the carbon dioxide, in the atmosphere in the presence of moisture, reacts with hydrated cement minerals to produce carbonates, e.g. calcium carbonate. Carbonation penetrates below the exposed surface of concrete extremely slowly. When these reactions take place the pH value will start falling. The normal pH-value of concrete is above 13 and the pH-value of fully carbonated concrete is below 9. It has been estimated that the process will proceed at a rate up to 0.04in. (1mm) per year.

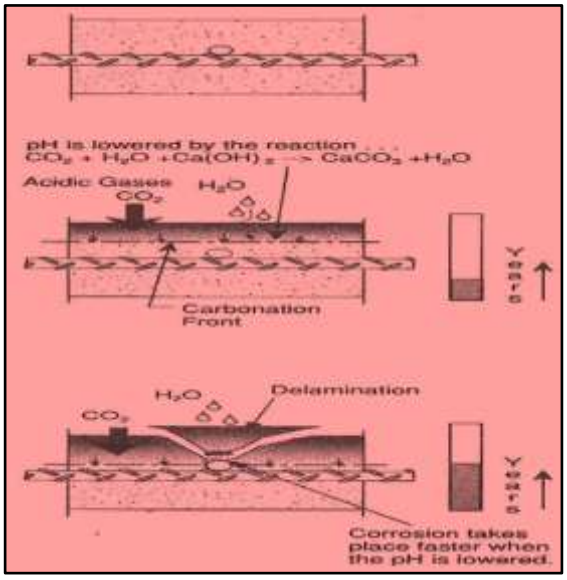


Fig.6 process of carbonation of concrete

- **Assessing the compressive strength of concrete by rebound hammer:** The test is based on the principle that the rebound of an elastic mass depends on the hardness of the surface upon which it impinges. When the plunger of the rebound hammer pressed against the surface of the concrete, the spring controlled mass rebounds and the extent of such rebound depend upon the surface hardness of concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of concrete. The rebound is read off along a graduated scale and is designated as the rebound number or rebound index. Mainly finds the surface hardness of the inspected area.

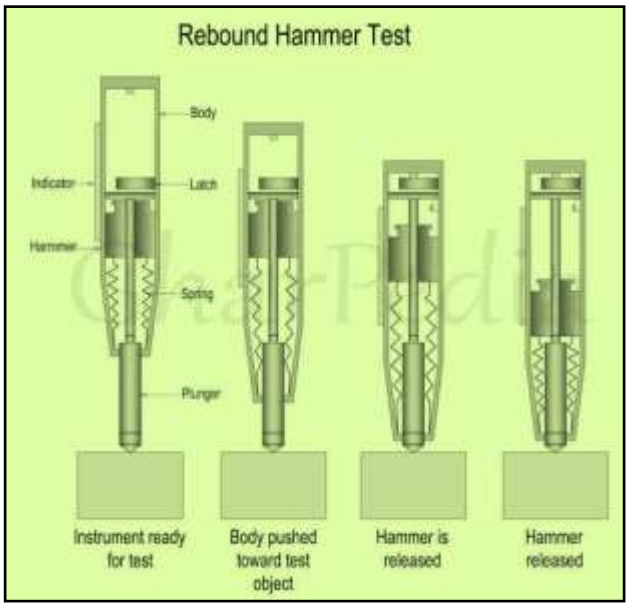


Fig.7 Rebound hammer test procedure

Table.1
Comparative hardness of the cover zone

Instrument	Average rebound number	Quality of concrete
Rebound hammer readings	>40	Very good
	30 to 40	Hard layer
	20 to 30	Good layer
	10 to 20	Fair
	<10	Poor concrete
	0	Delaminated

- Advantages and Limitations:

→ Result is influenced by type of cement, type of aggregate, type of surface condition and moisture content of concrete, due to curing and age of concrete, also due carbonation of concrete.

→ Results are affected by the angle of test, surface smoothness and mix proportions of concrete. It does not provide a reliable prediction of the strength of concrete. The possible error may be up to ± 25%.

→ Advantages: Less expensive, produce fast results, simple, well established, direct results, unlikely to damage the concrete structure.

4.4 STAGE IV

Planning: Planning stage involves preparation of field documents, grouping of structural members and classification of damage as under in table 4.4.1:

Table .2 Classification of Damage

Class of Damage	**Repair Classification**	**Condition Observed**	**Repair Requirements**
'Class 0'	Cosmetic	Only final finishes, no distress observed	Redecoration, if required
'Class 1'	Superficial	Skin alone damaged, no carbonation observed	Plaster repairs
'Class 2'	Patch repair	Minor structural cracks, carbonation depths reached reinforcement level	Restore the lost concrete cover, carbonation resistant surface protective coating
'Class 3'	Principal repair	Spalling of concrete cover, major structural cracks due to corrosion also, reduction of load carrying capacity	Strengthening repair
'Class 4'	Major repair	Major structural loss,	Replacement/ recasting structural member

4.5 STAGE V

Action and Implementation: Structure repair and rehabilitation is a process whereby an existing structure is enhanced to increase the probability that the structure will survive for a long period of time and also against earthquake forces. This can be accomplished through the addition of new structural elements, the strengthening of existing structural elements.

- **Retrofitting** is a technical intervention in structural system of a building that improves the resistance to earthquake by optimizing the strength, ductility and earthquake loads.
- **Retrofitting materials:** Injection Grouts, Polymer grouts, Fibre-reinforced grouts, Cement - Sand grouts, Gas-forming grouts, Shotcrete, Fibre-reinforced plastics, Epoxy mortar, a steel jacket, collar, shear connectors, brackets.

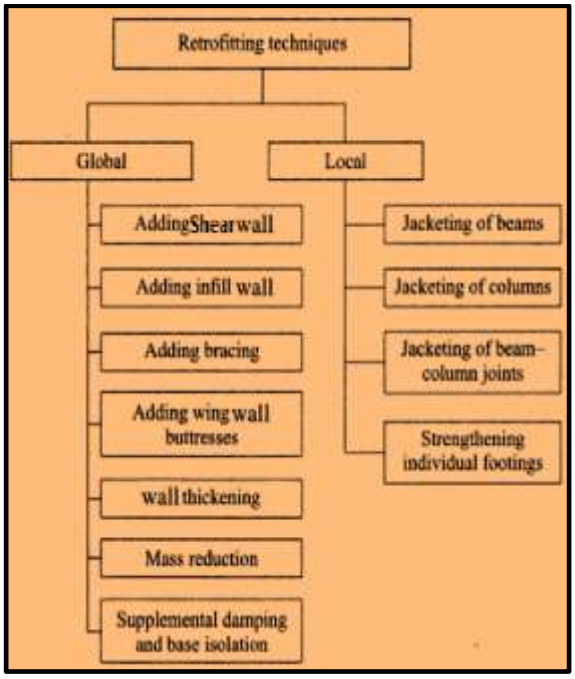


Fig.8 Classification of Retrofitting

- **Global retrofitting methods or structural retrofitting (GRM)**: It means retrofitting of the whole structure. The structures which are not strengthened for seismic forces can be retrofied by GRM such as global structural stiffening, global structural strengthening and mass reduction.
- **Local retrofitting methods or member retrofitting (LRM):** Retrofitting the deficient elements or by improvement of connections, member strength and component deformation capacity. It is said to very economical as few members are retrofied. Here it does not require to retrofit whole structure, only it needs to modify the deficient element up to a required strength. This can be achieved by adding cover plates to the bottom of beam, adding additional steel to cover the columns called steel jacketing, provide clip angles to strengthen connections.

→ **Steel Jacketing**: Local strengthening of columns has been frequently accomplished by jacketing with steel plates. This technique is chosen when the loads applied to the column will be increased, and at the same time, increasing the cross sectional area of the column is not permitted.

→ Jacketing is used for purposes other than covering the deteriorated concrete and providing lateral confinement, such as to bear longitudinal loads, needs special considerations. The existing column may have undergone full shrinkage and most of the creep and also has elastic strains due to carried loads, whereas the shrinkage and creep of the new material has to occur. The load transfer to jacketing is also a big issue. It is better to use jacking to release the load on the member before jacketing, to use non-shrinking materials for jacketing and to hammer steel shims at the transfer points of the jacketing after curing.

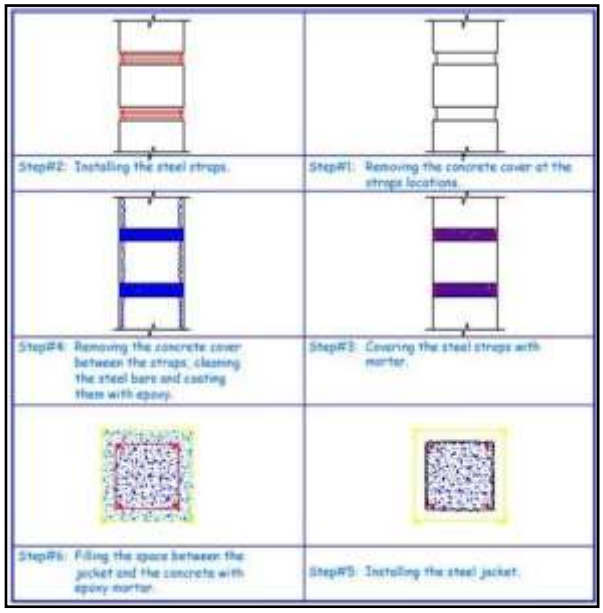


Fig.9 Steel Jacketing of a Column

5. CONCLUSION

Generally, concrete structures are getting neglected in every sector. We must carry out inspection and maintenance at required period of time for every R.C structure. Reliability and Durability of structures can be ensured if all care as mentioned in clause can be ensured. From the consideration of all the above points we conclude that the defects of structural members are due to age which leads the combined effects of carbonation, corrosion & effect of continuous drying and wetting. The result of visual survey prompt us to conclude the distress level is wide spread and is an ongoing process thus need to be stopped at this stage and proper retrofitting measure should be designed and applied to provide stability against any man-made or natural disaster.

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