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Review of repair and rehabilitation in RCC buildings

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Abstract-
Buildings and other structures have a certain useful life, which depends on the specifications adopted. The large numbers of monuments, which are cherished heritage structures have stood well over a period of time. But some of these have shown signs of distress due to age, aggressive natural environment/industrial pollution etc. Further, distress gets aggravated due to overloading and misuse of buildings. The main criteria is how to repair a reinforced concrete elements of structures and for this the skills, knowledge, and experience required to repair damaged or deteriorated structures are decidedly different from those required to build new structures. Based on this survey a decision regarding the structural health of building and repair required can be taken. This project with methods of estimating the audit of existing structures whose life has crossed the age of 30 years. Such an investigation can be carried out using the following methods: a) Visual examination b) Non Destructive Testing c) Partial Destructive Testing. The purpose of this paper is to review the latest techniques, advanced materials and various requirements of repairing work to obstruct the deterioration which is necessary and economical than to reconstruct the building.
Keyword- *RCC Building, Rehabilitation, Repair, Retrofitting, Ultrasonic pulse velocity, etc.*

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I. Introduction-

The need to improve the ability of an existing building to withstand from weathering action, chemical attack, embedded metals, alkali-aggregate reactivity, fire, due to overload, seismic forces, etc. arises usually from the evidence of damage and poor behavior. These type of structures are deteriorated with use and time and might have passed their design life and require repair and rehabilitation. Therefore the solutions for RCC structure or structural elements are essential and for this different techniques are utilized. Strength assessment of an existing structure or any element of structures is essential to cover all the criteria in which maintenance is required. Thus, some numbers of non-destructive, partially destructive and destructive techniques in the existing structures are used for assessment of concrete structure and to predict the cause of deterioration of the concrete. Some reasons of deteriorations due to ageing and error in design and detailing can be analyzed.

A few Buildings have also failed due to faulty design or construction. The various causes of structural failure and the principles of rehabilitation of structures are discussed. In the structures, the cracks are generated due to different causes e.g. in some cases cracks are caused after the structure has been completed for a few years which results in shortening of life and strength of structure. The old buildings in which ancient temples, monuments, heritage buildings and some residential buildings are included and need some maintenance of repair due to which the regain of strength, durability and stability of those buildings should be done. Hence, here some specifications are discussed about repair and rehabilitation of residential buildings.

Why needed?

1. To increase life of the building.
2. To know the health of the structure and its expected life.
3. To check the actual reliability of the structure.
4. To recommend rehabilitation techniques.
5. To highlight the critical areas and repairs them immediately.
6. To save life of lives in the building.
7. To know the real condition of the building whether it is safe for dwelling or not.

Objectives-

1. To recognize the types of structural defects.
2. To identify any signs of material deterioration.
3. To identify any signs of structural distress and deformation.
4. To identify any alteration and addition in the structure, misuse this may result in over loading.
5. To identify any signs of material deterioration.

6. To identify any signs of structural distress and deformation.
7. To identify any alteration and addition in the structure.
8. Remedies for the restoration of the structure.

Repair-

The main purpose of repairs is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. Repair does not pretend to improve the structural strength of the building and can be very deceptive for meeting the strength requirements. The objective of any repair should be to produce rehabilitation – which means a repair carried out relatively low cost, with a limited and predictable degree of change with time and without premature deterioration and/or distress throughout its intended life and purpose. To achieve this goal, it is necessary to consider the factors affecting the durability of a repaired structural system as part of a whole, or a component of composite system.

Rehabilitation-

Structural rehabilitation involves the upgrading or changing of a building's foundation in support of changes in the building's owners, its use, design goals or regulatory requirements. In every case it is determined that it is cheaper to rehabilitate the structure and make the building improvements instead of demolishing and constructing a new building in the allotted space.

Retrofitting-

The engineering which involves in modifying the existing buildings for structural behavior without hampering its basic intent of use is termed as retrofitting. It becomes necessary to improve the performance of structures including those facing loss of strength due to deterioration or which have crossed their anticipated lifespan. The realization of retrofitting depends on the authentic cause and measures adopted to prevent its further deterioration. This development includes repair, retrofit, renovation and reconstruction wherever required. A proper load path has to be analyzed by a structural engineer and a decision has to be taken if any additional member like shear walls, etc needs to be added.

Origin of Deterioration-

1) Drying Shrinkage
2) Temperature stresses - This may be due to difference in temperatures between the inside of the building with its environment and variation in internal temperature of the building or structure.
3) Absorption of moisture by concrete
4) Corrosion of reinforcement - This could be caused by entry of moisture through cracks or pores and Electrolytic action.
5) Aggressive action of chemical.
6) Weathering action
7) Poor design details at re-entrant corners, changes in cross section, rigid joints in precast elements, deflections - this lead to leakage through joints, inadequate drainage, inefficient drainage slopes, unanticipated shear stresses in piers, columns and abutments etc, incompatibility of materials of sections, neglect in design.
8) Errors in design
9) Errors in earlier repairs
10) Overloading
11) External influences such as earthquake, wind, fire, cyclones etc.

❖ **Case Studies-**

1) Coimbra, Portugal.

The year 2000 was an unusually rainy year. Just three days before the new millennium, at 19:00 h, a substantial landslide occurred, causing severe damage in the RC structure of a 16-story residential building, erected in the beginning of the 1980s in Coimbra, Portugal. The first two levels of three columns were completely destroyed and, as a result, the rear body of the building supported by these, with a dimension in plant of 9.5 × 6.7 m2 , became a 7.0 m span cantilever with 12 stories . However, the damage could have been much more severe if the flow of that significant mass of soil and debris had not been damped by part of the 2-story parking garage located on the building's backyard that completely vanished.

Fig. (a) Rear (West) façade of the building, a few days after the accident.
(b) Detail of the total collapse of the outer columns of the damaged rear body of the building.

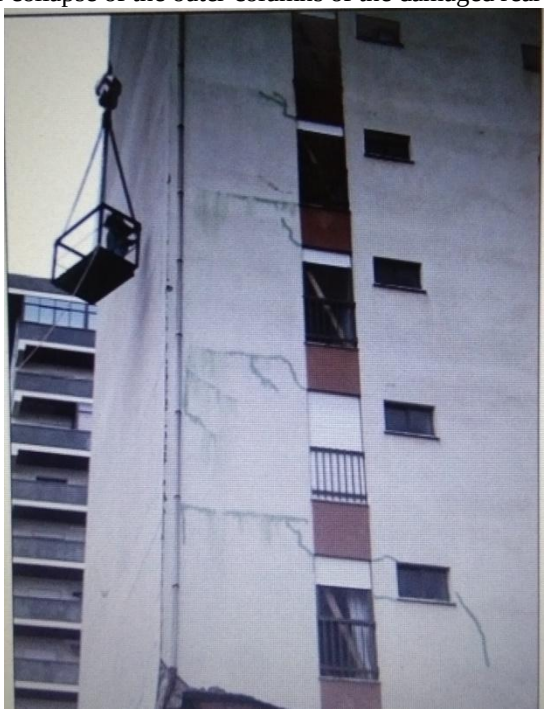

Fig. Mapping cracks on the outer walls

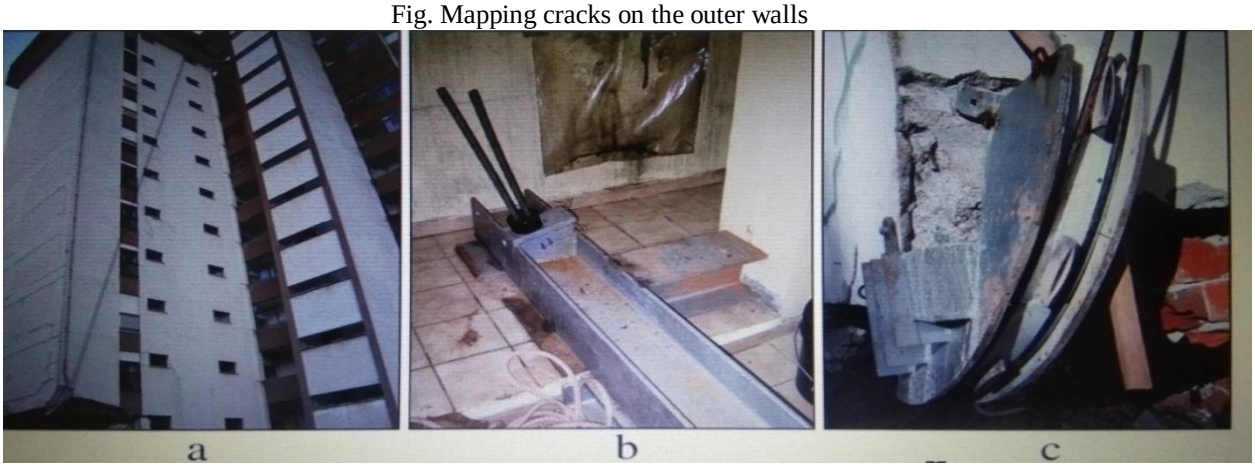

Fig. (a) Prestressing consolidation system. (b) Steel beam on top of the building and anchorage of prestressing tendons. (c) Steel deviation device

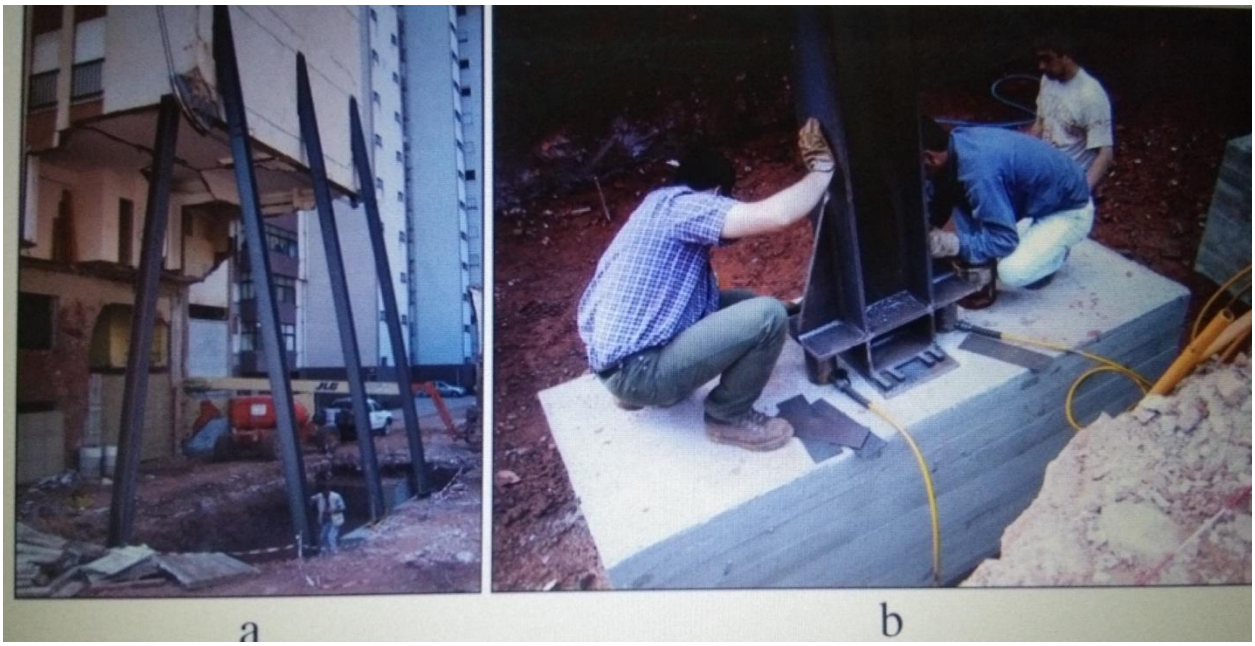

Fig. (a) Provisional steel shores. (b) Prestressing the shores with hydraulic jacks

Fig. (a) Foundation for the retrofitting steel frame and shear wall. (b) Assembling the retrofitting steel frame. (c) Additional bracing steel shores

2) Ahmedabad-

In Ahmedabad Asset of ONGC, three no. multi-storeyed (G+8) buildings viz. Heera (C3), Panna (B5) and Ratna (B6) each having 68 quarters with half G.F as parking were constructed in year 1989-1990. These buildings were already sick due to severe reinforcement corrosion as evident from so many spalls, delaminations on column corners located at different heights, beam/ fin soffits, slab soffits, leached plaster on parapets corroded and leaking drainage pipes, water supply lines and stagnated water on terraces due to improper gradient etc. These were further damaged by the Bhuj earthquake on 26th Jan, 2001 in the form of separation cracks at beam-column junctions, RCCmasonry wall interfaces (Fig 6), cracks in masonry in-fills(Fig 5); even complete crumbling at some places, heavy de-bonding and dismantling of plaster at both exterior and interior surfaces etc. Due to fast deterioration, it was decided to rehabilitate these buildings at the earliest.

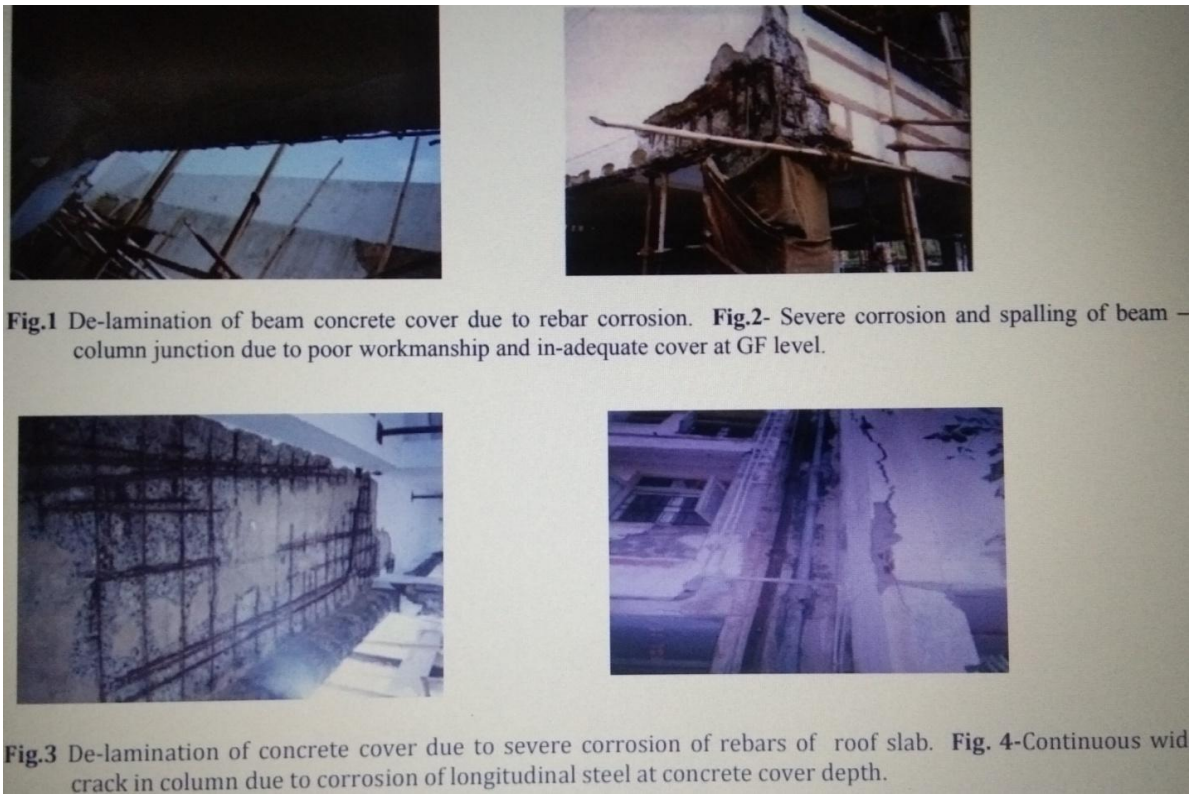

Fig.1 De-lamination of beam concrete cover due to rebar corrosion. **Fig.2**- Severe corrosion and spalling of beam – column junction due to poor workmanship and in-adequate cover at GF level.

Fig.3 De-lamination of concrete cover due to severe corrosion of rebars of roof slab. **Fig. 4**-Continuous wid crack in column due to corrosion of longitudinal steel at concrete cover depth.

Visual inspection of the buildings indicated heavy rebar corrosion as a result of carbonation due to environmental attacks. At certain locations of beams, columns, fins and slabs concrete cover had got spalled (Fig 3) and some shear stirrups were totally eaten up by corrosion (Fig1). Beam - column junctions were badly cracked (Fig 2). Some masonry walls at GF level were totally cracked due to earthquake. A number of columns had continuous vertical cracks along the line of concrete cover thickness (Fig 4). The visual inspection necessitated the need for detailed evaluation for design of the rehabilitation design.

Fig. Column rebars with anti -corrosive coating

Fig. Jacketing of columns from the footing level.

3) Rehabilitation of RCC Overhead Reservoir at Siliguri, WB, India

A study was carried out in March-April 96 for an overhead tank of 50,000 gallons capacity resting on staging of 16 RCC columns braced together at different levels. The tank is located in North Bengal. The tank was constructed in the year 77-78. The tank having dimension of 9.3 x 9.3 x 3.4 m is resting on columns of size 300 x 300 mm. The columns are interconnected at 3 different levels through bracings of size 250 x 250 mm; Record drgs/CA drgs were not available. The distress in staging was noticed in the beginning of 1994. The distress was manifested in the form of cracks, spalling of concrete, rusting of steel in the bracings & columns. The cover to reinforcement of column & bracing was grossly inadequate. In most of the cases, the spalling of concrete occurred from the bottom of bracings. Horizontal cracks were also observed at several places of a number of bracings. Exposed reinforcements are badly rusted. At the Zone of lapping of reinforcement, the quantum of reinforcement is very high & there is inadequate bonding between concrete & reinforcement at that zone. Similarly spalling of concrete has occurred from the corner of column along with vertical cracks. There was no sign of tilting or settlement of foundations. However, some seepage from the bottom of tank was observed. The water container was otherwise found in sound condition, as there was no visible sign of distress on external or internal surface except top slab cover of tank (from inside), which is having exposed rusted steel. The process of rusting of reinforcement and deterioration of concrete is observed to be progressing at a rapid speed, by comparing with the distresses noticed first time in the beginning of 1994, due to severe weather condition in that area. Any further delay in repair might cause sudden collapse of the structure due to the external forces like heavy wind & earthquake etc.

4) A British building, 1871

The author identified various problems such as structural cracks in masonry walls, crack in lime concrete slab, collapse of column portion and roof leakages. These are caused due to poor load distribution, poor waterproofing, seepage of water and water logging.

Fig. Roof Leackages

Author suggested several suitable solutions for the above said problems. Epoxy grouting is used for strengthening of weakened and cracked masonry walls. Jacketing of wall surfaces was made by applying mesh nonferrous steel reinforcements and by filling the gaps with lime mortar. Cracks in lime concrete slab were fixed by welding of steel members. Collapse of column portion was restored by removing the collapsed portion and reconstructing the portion was carried out using same type of stone and mortar. Roof leakages were restored by providing proper slopes and by replacing the corroded members using Lead flashing.

5) Repair/Rehabilitation of Jetty at Mumbai, India

The two wharves (Contiguous to each other) having width of 16.45 m and total length of 500 m, was constructed during 1957 and 1967 (one having length of 350 m and other of 150 m). The damages observed were excessive spalling of concrete, formation of wide cracks, excessive corrosion, falling of fenders and shearing off of piles etc. The two wharves were composed of fender portals, bollard portals, curtain wall (on one side of wharf only), wailings (connecting piles at the bottom of the bracing level), Deck slab (37.5 cm thick) and wearing coat (17.5 cm thick) over deck slab. Apart from a visual and dimensional survey, various other tests were carried out to diagnose distresses. Cover meter test, half-cell potential survey, ultrasonic pulse velocity test, petrography test, core test, water permeability test, chloride sulphate test and porosity test were carried out. In addition, analytical assessment of residual strength was also made. The structure being very old, design calculation/details were not available. Using a computer, a structural analysis was carried out that showed that all structural members were adequately designed based on earlier codal provisions. Because of the extent of deterioration repairs were required to wharf portals frames, curtain wall, wailings, deck slab, wearing coat and fenders.

. The repair methodology adopted for different types of defects are as follows:- +All cracks at various locations were filled with epoxy grouting under pressure. The stages involved in grouting are:-

• Cutting ‘V’ grooves with pneumatic cutter.
• Drilling of holes, at intervals.
• Fixing of entry ports.
• Application of epoxy sealant.
• Cleaning of grooves with compressed air.
• Injection of Epoxy under pressure
• Cutting of entry ports.
• Grinding of sealant

+ Spalling of concrete was repaired by various methods depending on locations. For soffit of slabs & fenders where the depth of deterioration was less than 75 mm, epoxy mortars were used. The sequences of activities involved were as follows:-

• Square cutting the boundary of damaged concrete.
• Chipping the spalled surface by pneumatic chipper.
• Removing rust from existing reinforcement by wire brushing.
• Welding of additional reinforcement after carrying out anti-corrosive treatment and an epoxy coating.
• Removing dust from surface of concrete and reinforcement by compressed air, drying of the surface before applying coating of epoxy.

• Applying an epoxy coat within an interval of 15 to 30 mins after mixing of resin & hardener and quartz sand, in the proportion of 100, 50 & 800 by weight. Air curing, for 48 hrs.

II. Conclusion

1. Rehabilitation of structures embroils contribution of high end technology, advanced skills and calculations. This is a very responsible job to be done to save hazardous failure of structures due to deterioration. The success of this subject totally depends on gaining expertise in the field and day to day advancements. Rehabilitation is highly recommended for age-old buildings showing signs of decent and save human lives from failures.

2. To modify/improve the properties of concrete or mortar, a large number of polymers/admixtures have been tried and extensively used in other countries. World over polymers/admixtures have been in use for over 45-50 years and their long term behaviour patterns are known. The superiority of polymer modified mortars/concretes over normal mortars/concretes in repair/rehabilitation field is established beyond doubt. In India, such effective polymers/admixtures have only become available during last two decade mainly. Now a number of internationally known and time tested polymers/admixtures are available all over India.

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