Repair, Rehabilitation &Retrofitting of RCC Structures For Sustainable Development With Three Different Case Studies

THIYAHESWARAN.P [1], SOUNDHARYA.G[2]
[1, 2] Dept of Civl Engineering
[1, 2] Anna University

Abstract- *In this paper we have discussed about the case study of repair and rehabilitation work carried out for a G+3 residential apartments located very close to sea shore, Besant Nagar, Tamil Nadu, India. The Repair strategy involved, removal of delaminated concrete cover, anti corrosive coating, polymer modified mortar, injection of epoxy grout for the repair of beam column junction and masonry crack, self sacrificial anode to prevent corrosion of reinforcement, micro concrete for slab and column, additional reinforcement with anti corrosive coating, glass fibre wrapping for column to increase ductility, and polymer modified mortar for repair of RCC and Masonry cracks.*

I. 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.

II. 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.

III. 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

IV. ORIGN OF DETORIATION

- Drying Shrinkage
- Temperature stresses
- Absorption of moisture by concrete
- Corrosion of reinforcement
- Aggressive action of chemical
- Weathering action
- Errors in design
- Overloading
- External influences such as earthquake, wind, fire, cyclones etc.

CASE STUDY 1: G+3 BUILDING NEAR SEA SHORE AREA

In this paper we have discussed the repair and rehabilitation work carried out in a G+3 residential building located very close to sea shore (Near Besan Nagar Beach, Chennai). The building is severely damaged due to salt water and chloride attack, suffer with corrosion of reinforcement, spalling of concrete in floor and roof slabs, major cracks at staircase landing and cracks in RCC and Masonry structures.
A detailed visual observation was made on all the columns, beams and slabs of the above said location and the following observations were made, excessive spalling was noticed in few of the columns and beams in the ground floor

Repair strategy involved, removal of delaminated concrete cover, anti corrosive coating, polymer modified mortar, injection of epoxy grout for the repair of beam column junction and masonry crack, self-sacrificial anode to prevent corrosion of reinforcement, micro concrete for slab and column, additional reinforcement with anti corrosive coating, glass fibre wrapping for column to increase ductility, and polymer modified mortar for repair of RCC and Masonry crack.

(Figure 1a), Excessive spalling was noticed in all the stair case landing slab portion (Figure 1b), in many places the slab portions has dampness (Figure 1c), and corrosion traces (Figure 1d), cracks were noticed at the concrete and brick work joints (Figure 1e), major cracks seen in masonry wall (Figure 1f).

DETAILED INVESTIGATION

Ultrasonic and rebound hammer test were carried out to assess the condition of concrete in the column, beam and slab at various locations.

Test for chloride and carbonation was carried out for verifying the present status of the cover concrete.
Half cell potential survey was caried out to identify the extent and severity of corrosion activity.

The extraction of core sampling and testing for compressive strength was carried out to assess the homogeneity and actual insitu strength of concrete


Figure 1(a)


Figure 1(b).


Figure 1(c)


Figure 1(d).


Figure 1(e).


Figure1(f).

METHODOLOGY

I. PREPARATION OF SURFACE

At the places where the concrete cover had already spalled, (column corner, slab, step landing, beams) loose concrete was removed 25 cm more than the length of spall.
For the other areas hammer sounding method was used to locate delaminated concrete and marked with paint.

The beam and slab portions were supported with props before the removal of damaged concrete.

The surface to which polymer modified concrete has to be applied was cleaned off all loose materials by means of wire brush . All the loose particles were removed by washing with water under pressure

II. REINFORCEMENT CLEANING AND ANTI COROSING

All the concrete sticking to the rebar was removed by hammering and manual chipping.

Rust remover coating was applied on the reinforcement steel bars and care was taken that the back side of the bars also get coated.

It was allowed to act for 24 hrs. Wire brush were used to remove the rust from the steel bars followed by washing with water jet for the complete removal of rust.

Anti-corrosive zinc primer coating was applied completely surrounding the periphery of the reinforcing steel and allowed it to dry for 4 hrs.

Second coat of primer was applied after 4 hours and care was taken to cover all the steel area without leaving a small portion of the steel uncovered .

The rein forcing steel which were highly corroded were replaced with additional reinforcement by welding with existing bars or drilling holes into concrete and inserting aditional steel bars with epoxy motor

III. APPLICATION OF POLYMER MODIFIED MORTAR

The polymer modified mortar was prepared such that it has a minimum compressive strength of 25MN/m^2 .

The proportion of cement, sand and acrylic polymer by weight was 50Kg: 150Kg: 20-25% of cement content.

The water cement ratio was kept as 0.4 (by weight). Masonry surface with polymer modified mortar

After the application of polymer modified mortar and proper drying of surface, curing compound was sprayed on the concrete surface

Concrete surfaces must be clean and dry with all stains, oil, grease, dust, and dirt removed prior to application of curing compound. The concrete surface was cleaned with degreaser.

IV. REHABLITATION OF COLUMNS

Place suitable supporting system in position.

The support should be as close to the column as possible (atleast over a distance of effective depth of beam from column, where maximum shear present) and should be designed to with-stand the floor loading coming on the column and shall be placed on a firm ground, without any settlement. The strengthening should be carried out on alternate columns in the first stage.

V. MICRO/SELF COMPACTING CONCRETE FOR JACKETING THE COLUMN

Remove the damaged concrete portion of the column completely, till the reinforcement is exposed. Spray phenolphthalein to check the alkalinity of the concrete. On spraying the phenolphthalein if the concrete does not turn to pink colour, continue the chipping further. Drill holes of 16mm dia and 75mm deep into the column. The positioning of the holes has to be staggered along the perimeter and height of the column. The vertical spacing of shear connector should be not more than 250mm for all four sides of the column. Clean the holes with a jet of water and clean the same thoroughly. Use chemical polyester anchor resin for anchoring the shear connector.

VI. GFRP WRAPPING OF COLUMNS

Compression load carrying capacity of column increases once confined with FRP sheets. The FRP wrap stiffness plays a major role in the column jacket design. In order to develop appropriate confinement forces, the jacket must be stiff enough at a relatively low axial strain in the column. For eccentrically loaded columns, smaller enhancement factor should be considered in design of FRP-wrapped concrete columns. Corrosion damage to deficient RC columns can be reduced or completely prevented by applying unidirectional fiber composite sheet along the longitudinal direction to increase flexural capacity, and by wrapping the columns in the lateral direction to improve their ductility and energy absorption capacity.

To withstand impact loadings, concrete columns should be properly strengthened to achieve adequate level of energy absorption capacity and ductility. The FRP repair of corrosion damaged RC columns not only provides strength and ductility, but also could slow down the rate of the corrosion reaction.

VII. CEMENT GROUTING

Support the slab which is contributing the load for the beam under rehabilitation.

Provide cores from the slab of about 77mm diameter to facilitate the pouring of micro/self-compacting concrete. Cement grouts were injected through the holes drilled in the slab

VIII. CATHODIC PROTECTION

Cathodic protection of steel in concrete is a technique that has been demonstrated to be successful in appropriate applications in providing cost effective long term corrosion control for steel in concrete. Cathodic protection is the only known means of mitigating the corrosion of reinforcing steel, which is caused by the presence of the chloride ion in existing structures. It is a technique that requires specific design calculations and definition of installation procedures in order to be successfully implemented.

IX. CRACK REPAIR AND PROTECTIVE COATING

Acid wash and water wash the entire repaired surface as well as the existing good members. Apply acrylic asphaltic based protective coating to the members to prevent the damage in future. Plasticized expanding grout admixture with acrylic polymer modified mortar was used for sealing of all masonry and RCC cracks.

CASE STUDY 2 : REPAIR OF REHABILITATION OF INDUSTRIAL STRUCTURE

Name and address of building/ year of construction	Transit shed no1 / 1972-73
Type of building	Partially RCC
No of storey of building	single
Description of usage of building	warehouse
Type of roofing	AC sheets with steel truss
Maintenance history of building if known	------

Hairline cracks: The hairline cracks are observed in highest number on the structure. Mainly we can observe hairline cracks on the horizontal members and these hairline cracks are formed mainly due to temperature stress. The hairline cracks are also called as lighter cracks which are not so hazardous and can repaired easily.

Wider cracks: The wider cracks are observed mainly on the vertical members(columns) which are caused by stress

developed inside the column due to corrosion. These cracks are also even responsible for higher structural damage.

Spalling: Spalling of concrete cover as well as plaster can be seen extremely mainly in columns as well as masonry walls and also lightly in beams. The spalling of concrete covers happened due to debonding of concrete from the reinforcement bar.

Cavity: The cavity is observed in vertical member(column) mainly at the bottom. Acid and chemical attacks are responsible for internal cavity as well as honeycombing of concrete.

Corrosion: The corrosion of reinforcement is in high range on the exposed face of the structure which is directly responsible for formation of internal stresses inside the reinforced concrete members. The roof truss is also corroded completely and may fall any time

Hairline Cracks on column Wider cracks on Column Corrosion of Rebar

ROOF TRUSS

The proposed trusses are highly damaged due to corrosion and the bracing joints are broken as the proposed truss becomes more wrinkled and, due to high stress the truss started bending as well as braking along with truss the roof sheets are also damaged and started spalling.

MEASUREMENT OF CRACK WIDTH AND DEPTH

The crack width and depth of each structural element is measured. The width of wider cracks is measured by measuring scale and the depth of crack is measured with the help of sharp thin tool. The maximum and minimum crack width is found to be 12.7mm and <1mm, and maximum and minimum crack depth is 28mm and <1mm.

CARBONATION TEST

As per obtained result the depth of carbonation is more than reinforcement level i.e. >60mm. The carbonation test gives the depth of carbon attack on the structural member. *From the obtained result it is noticed that the depth of carbon is up-to reinforcement level, so the structure is considered as completely carbonated.*

SOUNDING METHOD

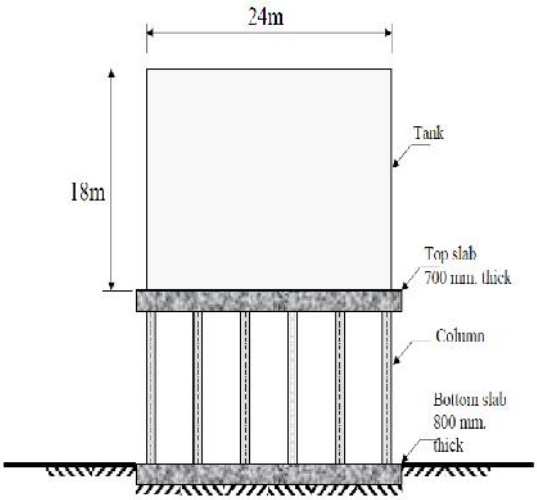
The Sounding survey clearly reveals the quality of surface in different position. *It is more of often hollow sounds at the bottom rather than top portions.*

REPAIR REPORT

- Based on the results obtained from the study the following conclusions made are as follows,
- It is noticed that, the roof of the existing structure was highly hazardous and the replacement is mandatory.
- The existing masonries are highly damaged and are significant for instant repair.
- The vertical members(column) lost their strength due to high range of cracks, spalling of concrete and internal cavity.
- The bottom portion of vertical members are impaired majorly as compared to other portions.
- The central columns are highly impaired and faced for quick retrofitting.
- The corrosion rate in existing RC members along with roof truss found to be extremely high.

CASE STUDY –III STRENGTHENING OF THE SUPPORTING SYSTEM OF A CYLINDRICAL LIQUID STORAGE TANK

- Steel cylindrical tanks of 24 meters diameter and 18-meter height rest on an elevated support .
- The supports consist of two reinforced concrete slabs connected by columns.
- Following the hydro testing of the tanks, numerous cracks were observed in the top slab and columns supporting the elevated tank foundations. Significant differential settlement in the tank foundation base slabs was also observed.
- The foundation for each tank is constructed in reinforced concrete and takes the form of two flat slabs of octagonal shape in plan separated by a total of 25 columns of approximately 3.91 m height.
- The upper slab is 700 mm thick whilst the lower slab is of 800 mm thickness



MANIFESTATION OF DISTRESS AND CRACKING PATTERNS

- With the exception of the four central columns, flexural cracking was observed within each existing reinforced concrete column.
- Cracking has been observed at the soffit of the upper slab.
- The width of these latter cracks has been estimated to be in the range of 0.3–1.0 mm.
- These cracks join together to form a grid pattern around the central four columns. A level survey of the base slab has been carried out.
- This revealed that the structure underwent significant differential settlement when loaded.
- Furthermore, much of this settlement remained as a permanent set when the load was removed.

FINITE ELEMENT MODELING OF THE STRUCTURE

- The finite element modelling of the supporting structure has carried out by the original consultant using ANSYS (Version 5.6)
- From the results of the finite element analysis of the tank foundation, it can be seen that the bending moment of resistance of the top and bottom slabs were exceeded in localized areas
- Out of all the options considered: (thickening the columns, or slabs), adding shear walls and using carbon fiber reinforced polymer CFRP for slab strengthening, the solution comprising of shear walls indicated a suitable method for enhancing the capacity of the structure

CONCLUSION

- Repair and Rehabilitation and Retrofitting is necessary to save hazardous failure of structures due to deterioration.
- It is recommended for old buildings which have some signs like cracks, corrosion of embedded materials, etc.
- Therefore timely maintenance of structures is required. The selection of technique is used as per cost, location of site and other factors.
- Thus for proper maintenance, the techniques likewise Rebound Hammer Testing, Ultrasonic Pulse Velocity Evaluation, etc. are utilized.
- After analyzing the problem of building, we can apply the appropriate repair methods which are described above i.e. Grunting, Routing, CRPF Sheets and Epoxy Injection.

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