e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:05/Issue:10/October-2023 Impact Factor- 7.868 www.irjmets.com

REVIEW PAPER ON REPAIR, REHABILITATION AND RETROFITTING OF R.C.C STRUCTURES

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DOI : https://www.doi.org/10.56726/IRJMETS45037

ABSTRACT

This review paper presents an experimental study of Repair, Rehabilitation and Retrofitting of R.C.C Structures. Reinforced cement concrete (RCC) as a construction material has come into use for the last one century. In India RCC has been used extensively in the last 50-60 years. During this period we have created large number of infrastructural assets in terms of buildings, bridges, sports stadium etc. which are lifeline for the civilize society. However, the deterioration of Reinforced Concrete structures is recognized as a major problem worldwide. Apart from requiring regular maintenance, many structures require extensive Repair, Rehabilitation & Retrofitting. Over a period of time, as these structures become older. One major flaw, namely its sensitivity to environmental attack, can severely reduce the strength and life of these structures. The purpose of this project is to highlight the various techniques of repair, rehabilitation and retrofitting methods. This project focuses on visible symptoms of the problem rather than on invisible problems as well as the possible causes behind them. The major defects reported are discussed and a suitable and economical solution for a particular defect is identified by a tradeoff between cost, lifetime and adaptability of the solution.

Keywords: Repair, Rehabilitation & Retrofitting Sustainable Development.

I. INTRODUCTION

Repair and Rehabilitation is an Art of Civil Engineering work which enables to extend the service life of a structure. When we look around us, we will found that there are several similarities between human beings & reinforced cement concrete (R.C.C.) structure. Just like human being grows old and need medication and care similarly R.C.C. structure cannot be over loaded and neglected in maintenance. Repair and Rehabilitation technique is used to modify a structure to meet new functional and other requirements.

Concrete is a composite material that consists essentially of a binding medium, within which are embedded particles or fragments of aggregates. A durable concrete is one in which these changes occur at a rate, which does not detrimentally affect its performance within its intended life. Reinforced concrete (RCC), a composite structural material, which is utilized for variety of structural uses. But it has been observed that RCC has not proved to be durable due to large number of factors, including variations in production, loading conditions in service life and subsequent attack by the environmental factors. Many reinforced concrete structures, within a life period of 15 years or so, suffered from of durability distress. The external symptom range from cracking to spalling of concrete, which frequently involved corrosion of reinforcement. It is difficult to generalize the causes of deterioration due to interacting nature of various factors, efforts have been made to group the various types as physical and chemical. This paper highlights the present state of maintenance especially in developing country like India and about the utilization of those new techniques/materials for repair/restoration of the buildings/structures, for long term sustainable development.

II. LITERATURE REVIEW

It is a matter of serious concern of us the civil Engineers, that in some countries, the repair activities of structure done today account for nearly half the total annual expenditure on total construction activities. Such a state of affairs is of great concern mainly for two reasons. Firstly, concrete is, in essence a proven, durable & mostly maintenance free material. This is exemplified by a large number of structures constructed properly

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more than half a century back & is still in good stead today. Secondly, the know-how of making concrete, which does not need major repair/rehabilitation, is already well documented and is known to us. Inspite of all these, the trend of early deterioration of concrete structure continues unabated.

At present there is neither any established existing procedure, mandatory or otherwise, for periodical inspection of buildings/ structures and recording the structural defects and symptoms, like cracks, spalling ,corrosion, and deflection of structure, in a logical manner nor any record of structural repairs/rehabilitations carried out, is maintained properly even for public buildings. We have barged into a repair activity without adequate preparation. Persons involved in repair/rehabilitation need to be better civil engineers. In fact repair/rehabilitation/retrofitting activity is a much more advanced application of science and technology involved in civil engineering, which is the most difficult challenge to engineers. We need to opt for new techniques and materials to resolve these difficulties. We have enough options to select from various construction chemicals, minerals, methods for repairs/rehabilitations, the economics etc. to set right the damage. These all are to be considered in totality before deciding upon the repair/rehabilitation/retrofitting strategy and hence required enough background preparation.

III. FACTORS AFFECTING THE RCC STRUCTURES

RCC structures get deteriorated during its lifetime which somehow decrease the strength of the structure which leads to the loss of life & economy. The various causes for such damages or defects or deterioration can be many such as

Site selection and site development errors:

Failures often result from unwise land use or site selection decisions. Certain sites are more vulnerable to failure. The most obvious examples are sites located in regions of significant seismic activity, in coastal regions, or in flood plains. Other sites pose problems related to specific soil conditions such as expansive soils or permafrost in cold regions.

Design errors:

Many structures fail due to error in their design concept. Some failure includes error in concept, incorrect load calculation, types of load, material durability, bad quality of material used, lack of structural redundancy, calculation errors, insufficient knowledge of computer software and inadequate specifications for materials.

Construction errors:

Construction errors arises due to excavation and equipment accidents, removal of formwork before time, excessive construction loads, improper temporary support to the formwork. All these constructions errors will affect the structure properties hence needs repair to meet the given requirements.

Material Deficiencies:

While it is true that most problems with materials are the result of human errors involving a lack of understanding about materials, there are failures that can be attributed to unexpected inconsistencies in materials.

Operational Errors:

Failures can occur after occupancy of a facility as the result of owner/operator errors. These may include alterations made to the structure, change in use, negligent overloading and inadequate maintenance.

IV. REPAIR, REHABILITATION AND RETROFITTING CONCEPTS

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.

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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.

V. VARIOUS KIND & CAUSE OF DETERIORATION

Capillary Porosity:

The volume of hydrated cement product is significantly higher than the volume of its constituents. This increased volume fills part of capillary volume. 100 gm of anhydrous Portland cement requires about 23 gm of water (a water/cement ratio of 0.23) after about a month's hydration under normal conditions. However, for achieving full hydration as well as to render the mortar/ concrete workable, excess water is required. This extra volume of water entrapped in the cement paste after completion of hydration leaves interconnected pores, called capillaries in hardened concrete, which become means of passage for external/environmental chemicals into the concrete. This increased volume fills part of capillary volume. This porosity is termed as capillary porosity which increases with the increase in w/c ratio.

Air Voids:

Air voids (much larger than capillary pores) form due to inadequate compaction in the form of discrete air bubbles (as in air entrained concrete) of much larger size than capillary pores. These air voids may get inter-connected by capillary pores system.

Micro Cracks:

During service life of a reinforced structure, it is subjected to various types of loading conditions (static and/or of cyclic nature) and also exposed to extreme exposure conditions of temperature variations (diurnal and seasonal). Micro-cracking combined with capillary porosity is generally responsible for ingress of aggressive chemicals in RCC.

Macro Cracks:

Some minor cracking in concrete structures would occur within the normal practice. Proper design and detailing coupled with proper construction practice can control the crack widths. The threshold limiting crack width, as per RCC design code vary from 0.1mm to 0.3 mm. Any crack in concrete, which is wider than this, is likely to cause durability problems.

Carbonation:

The alkalinity in concrete is provided by hydroxides of calcium, sodium and potassium present in the hardened cement gel. Permeation of carbon dioxide into concrete through interconnected pores and its reaction with these hydroxides causes chemical reaction as under:

$$CO_2 + H_2O = H_2CO_3 \text{ (Acid)}$$

$$Ca(OH)_2 + H_2CO_3 = CaCO_3 + 2H_2O$$

(Alkali) + (Acid) = (Salt) + (Water)

Chloride Ingress:

These may be present in the fresh mix or may penetrate from external source into the hardened concrete. Due to the deleterious effect of chlorides on the corrosion protection of the reinforcement, the chloride content of

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the mix is limited to certain values in relation to cement in almost all standards. During use of the structures, chlorides may penetrate into the concrete from various sources. The most important of these are sea water.

Sulphate Attack:

The term, Sulphate attack, is generally used to mean the deterioration of concrete as a result of physical-chemical interactions between the minerals in hardened Portland cement paste and sulfate ions from the environment. Soils containing sulfates of calcium, sodium, potassium and magnesium are the primary source of sulfate ions in groundwater.

Alkali Silica Reaction:

Chemical reactions between aggregates containing certain reactive constituents and alkalis and hydroxyl ions released by the hydration of cement can have a deleterious effect on concrete. When the aggregates in cement concrete contain reactive forms of silica, the phenomenon of chemical reaction is referred to as Alkali-Silica reaction (ASR). Expansion and cracking, leading to loss of strength, elasticity and durability are among the physical manifestations of ASR.

VI. OVERVIEW OF NON DESTRUCTIVE TESTS

In – Situ Field Test:

1. ULTRASONIC PULSE VELOCITY.
2. SCHMIDT HAMMER TEST.
3. COVER METER/ STRUCTURAL SCAN.
4. IMPACT ECHO TEST.
5. CORROSION TEST –

- The probability of Chloride Content in Concrete.
- Moist Determination.
- Rebar status.

6. GROUND PENETRATING RADAR (GPR) –

- Member consistency.
- Deep voids and cracks identifications inside the concrete structure.
- Rebar location and condition monitoring.
- Identification of hidden concrete joint.
- Utility identification inside the concrete.

7. LABORATORY TESTS ON CONCRETE CORE –

- Compressive Strength (cube).
- Strength equivalent.
- Carbonation.
- PH Value.
- Chlorination.
- Visual cracks.

8. LABORATORY TESTS ON REINFORCEMENT STEEL –

- Yield Strength.
- Elongation.
- Chemical properties.
- Visual corrosion level.

VII. REPAIR TECHNIQUES FOR RCC STRUCTURES

Every structure is designed with proper calculation and designing requirements given in IS code. Even though due to some errors or damages, these structure needs repairs as reconstruction of new structure is very costlier process and also time consuming. Hence various repair techniques are used to repair the deteriorated structure that is economical to meet the designing requirements. These techniques are discussed below:

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Grouting:

Grouting is a process of filling the cracks or voids under pressure in concrete or masonry structural member to change its physical characteristics. Grout is a flow able plastic material with negligible shrinkage to fill the voids completely. In this technique Grouting machine, mixture (cement, sand, water) are used to fill the cracks and voids in the structure. Grouting is suitable where soil permeability creates a very heavy demand on pumping.

Various methods for grouting are:

- **Compaction grouting**

Compaction Grouting is also known as Low Mobility Grouting. Compaction Grouting involves injection of low mobility grout with the help of drill casings that are drilled or driven to pre-set depths. The grout, usually consists of cement, sand, fly ash and water, is placed from the bottom-up with pressure-based criteria [2]. After each consecutive stage, the drill casing is lifted upwards to the point till it is entirely taken out.

- **Permeation grouting**

Permeation grouting which is also known as penetration grouting. It is the most common and conventional grouting method to repair the deteriorated structure. It involves filling of any cracks, joints or voids in rock, concrete, soil and other porous materials. The objective is to avoid without displacing the formation or creating any change in volume or configuration in the medium. This is typically useful to strengthen the existing formation, creating an impermeable water barrier or both.

- **Fracture grouting**

Fracture grouting also known as compensation grouting. In Fracture grouting, a low viscosity grout that splits through the ground by hydraulic fracturing is used which penetrates into the fractures. The in situ soils are displaced and Soil immediately next to the fractures are densified, but to a lesser extent as compare to the compaction grouting.

Epoxy Injection:

This method is suitable for repairing of cracks that are narrower than 0.002 inch (0.05mm). Cracks in concrete are bonded by the process of injection in which epoxy bonding compound is injected under pressure. Epoxies have higher dimensional stability. Epoxies does not melt i.e. they have thermosetting properties. This method is used to repair of cracks in building, bridge, dams and tunnels. Wet cracks are injected by using moisture tolerant materials. This technique requires high skilled labour with high tech instruments.

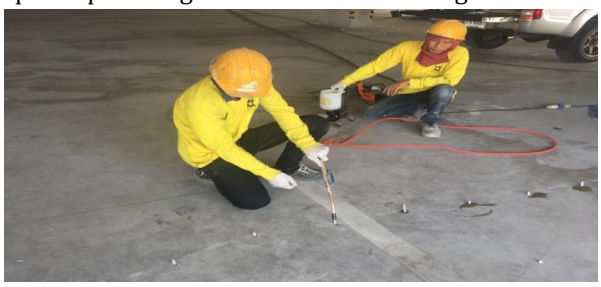

Fig.(a) Concrete Structure Crack repair by epoxy injection.

Jacketing:

Jacketing is the most popular method used for strengthening of columns. Jacketing consist of adding concrete with transverse and longitudinal reinforcement around the existing column. It helps in providing strength to column. Jacketing increases the seismic capacity of column. Frame is added around the existing column and then is poured with concrete. The grout used is having a cement-sand ratio by volume, between 1:2 and 1:3.

Fig.(b) Jacketing of reinforced concrete (RC) columns.

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Routing & Sealing:

Routing and sealing of cracks in concrete can be used for dormant cracks not involving the restoration of tensile strength of the structure. In this method the crack is expanded along its exposed face to form a Vshaped groove up to a minimum width of 6 mm and a depth of 6 to 25 mm and sealing it with a joint sealant. This method is commonly used for both fine pattern cracks as well as large isolated cracks but dormant cracks.

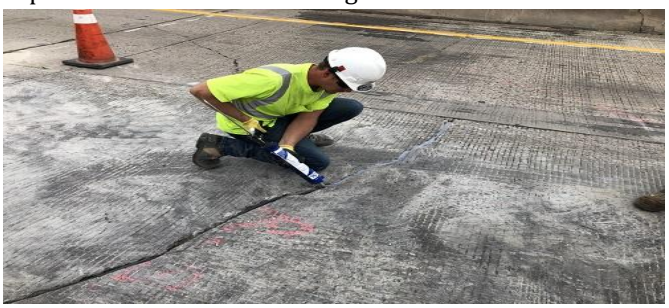

Fig.(c) Routing and sealing pavement cracks.

Shotcrete:

Shotcrete is high performance concrete sprayed on a surface under suitable pressure through a hose at high velocity. Shotcrete is used in repair work of various structures such as bridges, buildings, tunnels and marine structures. It is primarily used for beam repairs of variable depths, abutments, damage caused by fire or earthquakes.

Fig.(d) Shotcrete work.

VIII. CONCLUSION

- Periodic maintenance of structures is essential.
- Each and every problem should be properly analyzed and then the appropriate repair methods undertaken.
- Primary design of the building reflects its performance in long run.
- Each repair technique is suitable only for the particular application for which it is meant for.
- Form and Pump technique which has become the alternative for grouting, gunneting nowadays is also cost effective in large scale operations.
- Cost should not be significant planning factor in rehabilitation though it is a deciding factor.

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