

Repair and Rehabilitation of RCC Structures

Pawandeep Kaur¹, Jaspal Singh²

¹ Post graduate Student, Department of Civil Engineering

² Professor, Department of Civil Engineering

Punjab Agricultural University, Ludhiana, Punjab, India

Abstract- Concrete is extensively used for the construction of buildings, structures or any other project. However with the passage of time, the structure starts getting older and starts showing some signs like cracking, splitting, delaminating and corrosion of steel etc. which results in shortening of life and strength of structure. As it was well known fact that the structure has been constructed for a service life of more than 50 years but in reality, this life remains elusive. So apart from the regular maintenance, extensive repair and rehabilitation of structures are necessary. In some cases, the repair of the structures are neglected or delayed due to lack of proper knowledge and financial ability which may lead to serious hazards. There is urgent need to understand which repair materials /methods is the best or to be used for a particular structure thus saving enormous time and money. In this paper, different materials and methods used for the repair and rehabilitation of structures have been reviewed. Case studies pertaining to repair and rehabilitation of structures have also been discussed.

Keywords – Concrete, Repair, Rehabilitation and Structures

I. INTRODUCTION

Cement concrete is one of the most important construction materials and it has end up being practically basic to the present day development. Concrete is strong enough mechanically, yet it is vulnerable to deterioration and thus gets damaged and even fails [1]. This deterioration of the structures may be due to the weathering action, fire, soil failure, defects in construction and also due to natural calamities like flood, tsunami, earthquake etc [2]. Sometimes, even engineers do not realize that the reinforced concrete structures require periodic maintenance. That's why the factors important for durability of concrete structures many times not given due importance for construction and maintenance [3]. Due to these reasons, some measures are adopted to reduce the effect of deterioration which greatly enhances the durability of structures. According to the consideration of time and money, repair of the damaged part of structure is the most favorable [4]. Repair is the technical aspect of rehabilitation which refers to the modification of a structure partly or wholly which is damaged in appearance or serviceability. Repair and rehabilitation extended the life time of concrete structure so there is no issue for spending the billions on the repair of concrete structures. Repair of deteriorated structures having situations or conditions which are totally different from those encountered in new construction, although every repair have unique conditions and special requirements [5]. Hence, it is important to select more appropriate repair material for particular type of deterioration. Structure repair and rehabilitating is a technique by which the probability of the existing structure can be enhanced so that it will survive for a long period of time. This can be accomplished through the addition of new structural elements, the strengthening of existing structural elements and/or the addition of base isolators [6]. Repair and rehabilitation for concrete structures can be classified broadly into two categories: a) repair in which damages due to deterioration and cracking is corrected to restore the original structural shape and size while the core is mostly intact and b) repair which is necessary to strengthen the load carrying capacity of members which have become structurally deficient over a period of time [7]. The main purpose of repair 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. The ancient /historical buildings require repair to regain the some strength, durability and stability as it was before. The new technologies and new repair materials which have been extensively being used by the advanced countries are also being tried in developed country like India [1]. Many construction materials are being used for the repair of existing structures so in this paper, different repair materials which are used for the purpose of regaining the strength of structures have been discussed. It also highlights the various methods used for repair and rehabilitation of structures.

II. REPAIR

Repair: Repair is the technical aspect of rehabilitation which refers to the modification of a structure partly or wholly which is damaged in appearance or serviceability.

A. **Stages of repair:** The various stages for the repair of concrete structures are as follows:

- a) Removal of damaged concrete
- b) Pre treatment of surfaces and reinforcement
- c) Application of repair materials
- d) Repair Procedure

a) *Removal of damaged concrete*

- i. Before the execution of repair in any structure, one most important factor is to remove the damaged concrete.
- ii. The equipments and tools used for the removal of damaged concrete mostly depend on the damage.
- iii. Damaged concrete are normally removed by using hand tools sometimes it is impossible to use hand tools then it can be removed with a light or medium weight air hammer fitted with a spade shaped bit.
- iv. Care should be taken while removing the damaged portion that it must not damage the unaffected concrete portions.

b) *Pre treatment of surfaces and reinforcement:* It involves the following steps:

- i. Unsound material must be completely removed.
- ii. Undercutting along with the formation of smooth edges.
- iii. Surface cracks must be removed.
- iv. Formation of a well defined cavity geometry with rounded inside corners.
- v. Uniform surface but rough for repair can be provided.
- vi. Before the repair, dirt, oil and all other loose particles should be removed out from the cavities. It can be accomplished by blowing with compressed air, hosing with water, acid etching, wire brushing, scarifying or a combination. Brooms or brushes will also help to remove loose material.

c) *Application of repair materials*

When the concrete surface is prepared, a bonding coat such as cement slurry, epoxy, resin materials etc. must be applied to the whole exposed surface which was cleaned before without any delay

d) *Repair procedure*

The repair of any damaged structure can be discussed under two categories such as: ordinary or conventional procedures; and sometimes using special procedures including the latest techniques and newer materials. It must be done with one or more objectives which are as follows:

- i. To increase the strength
- ii. To improve the performance of structure.
- iii. To provide water tightness.
- iv. To improve appearance of concrete surface.
- v. To improve durability.
- vi. To prevent access of corrosive materials to reinforcement.

III. REPAIR MATERIALS

Cement and steel are generally used for the repair of various types of damages. Besides these, some special materials and techniques are available for best results in the repair works. They are described below:-

- ❖ Shotcrete
- ❖ Epoxy resins
- ❖ Epoxy mortar
- ❖ Gypsum cement mortar
- ❖ Quick setting cement mortar

Shotcrete

Shotcrete is a strategy for applying a mix of sand and portland concrete which blended pneumatically and passed on in dry state to the nozzle of a pressure gun, where water is blended and hydration takes place only before expulsion. The material bonds splendidly to the arranged surface of masonry and steel. In adaptability of use to curved or

irregular surfaces, its high quality after application and great physical attributes, make for a perfect way to accomplish included auxiliary capacity in dividers and different components. There are some minor limitations of clearance, thickness, course of use, and so on.

Epoxy resins

These have high tensile strength as these are excellent binding agents. Epoxy resins are prepared chemically whose compositions can be changed according to the requirements. These are blended just before the application. The final product obtained is of low viscosity and can also be easily injected in small cracks. While for the filling of larger cracks, higher viscosity epoxy resin may be used.

Epoxy mortar

Epoxy mortar is a combination of epoxy resins with fine aggregates which has higher compressive strength, higher tensile strength and a lower modulus of elasticity than the Ordinary Portland Cement concrete. Epoxy cannot be used alone as it is a combustible material.

Gypsum cement mortar

The structural application of gypsum cement mortar is limited as it has lowest strength at failure.

Quick-setting cement mortar

This material is patented and was originally developed for the use as a repair material for reinforced concrete floors adjacent to steel blast furnaces. It is non-hydrous magnesium phosphate cement with two components, a liquid and a dry, which can be mixed in a manner similar to Portland cement concrete.

IV. METHODOLOGY FOR REPAIR AND REHABILITATION

The methodology for repair and rehabilitation are as follows:

- (a) Grouting
- (b) Guniting
- (c) Routing and sealing
- (d) Stitching
- (e) Drilling and Plugging

(a) Grouting: Grouting as shown in Fig. 1 is the technique by which the material can be placed into cavities or holes present in the structure. It is used for increasing the load bearing capacity of a structure, filling voids around precast connections, stopping leakages, placing adhesives and soil stabilization. It is a mixture of cement, water and some other material such as sand, pozzolons and water reducing admixtures.

Procedure of grouting

- i. A mixture of cement sand grout is prepared by employing 1:2 along with the water cement ratio between 0.6 and 0.8 using a mechanical mixer.
- ii. The mixture is sent down under pressure (of about 120 kg/cm²) through a 30-50 mm diameter pipe terminating into steel cages.
- iii. As the grouting continues, the channel is raised slowly up to a stature of not more than 60 cm above its beginning level after which it is pulled back and set into the following cage for additional grouting by a similar methodology.
- iv. After the process of grouting for a height of about 60 cm, this operation is repeated, if necessary, for the next layer of 60 cm and repeated continuously.

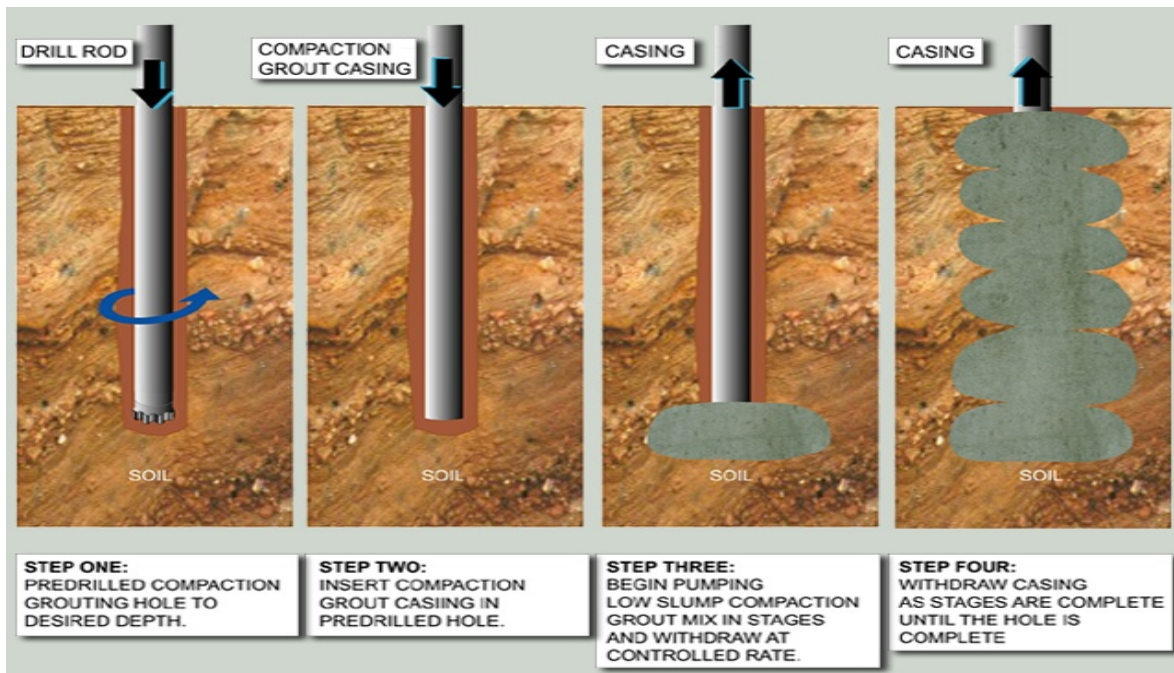


Fig. 1 Grouting

Guniting

It is a process which utilizes dry material from the machine to the surface whichever needs to be repaired through the nozzle by applying high velocity and compressed pressure. It is also called as the dry-mix shotcrete process as shown in Fig.2.

Procedure of Guniting

- i. The cement is mixed with moist sand and afterward required amount of water is added as the admixture comes out from the gun. Quantity of water can be regulated with the help of a regulatory valve.
- ii. Firstly, the surface on which repair work required must be washed and cleaned. Then the nozzle of gun is kept at a distance of about 750 mm to 850 mm from the surface to be repaired and the velocity of nozzle varies from 120 to 160 m/s.
- iii. Sand and cement are initially dry mixed in a mixing chamber and the dry mixture is taken through a pipe to a nozzle, where it is forcibly projected onto the surface to be coated.
- iv. The purpose of regulatory value is to provide a mix of desired stiffness which will adhere to the surface against which it is projected.



Fig. 2. Guniting

Routing and sealing

It is used for treating both larger and fine pattern. This treatment reduces the chances of moisture to reach the reinforcing steel or pass through the concrete which can cause surface stains or other problems. For floors, the sealant should be sufficiently rigid to support the anticipated traffic. Routing and sealing was done as shown in Fig. 3.

Procedure for Routing and Sealing

- a. First a groove of depth ranging from 6 to 25 mm at the surface is prepared.
- b. Then this groove must be cleaned by air blasting, sandblasting, or water blasting and further it was dried.
- c. On the dry groove, a sealant is placed which is further allowed to cure.



Fig. 3. Routing and Sealing

Stitching

When the tensile strength of any structure needs to re-established across the major cracks, stitching as shown in Fig. 4 must be used. It involves the process of drilling the holes on both sides of the crack and grouting in U-shaped metal units with short legs (staples or stitching dogs).



Fig. 4. Stitching

Drilling and Plugging

Drilling and plugging a crack consists of drilling down the length of the crack and grouting it to form a key. This technique is applicable only when cracks run in reasonable straight lines and are accessible at one end. This method is often used to repair vertical cracks in retaining walls.

V. CASE STUDIES

Case Study I: Rehabilitation of RCC Overhead Reservoir at Siliguri, West bengal, India

An investigation was done in March-April 96 for an overhead tank of 50,000 gallons limit laying on organizing of 16 RCC columns supported together at various levels. The tank is situated in North Bengal. The tank was built in the year 77-78. The tank having measurement of 9.3 x 9.3 x 3.4 m is laying on columns of size 300 x 300 mm which are interconnected at 3 distinct levels through bracings of size 250 x 250 mm. 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 1994, distress was first shown in staging. The distress was shown in the form of cracks, spalling of concrete, rusting of steel in the bracings and sections. The cover which was provided to reinforcement of columns and bracing was horribly lacking. The spalling of concrete occurred in mostly cases from the bottom of bracings. Horizontal cracks were also seen at a few spots of various bracings. The reinforcements which are exposed are badly rusted. There was deficiency shown in the bonding between the concrete & reinforcement at the lapping zone. The foundation of tank was found to be in

good order. Although at the bottom of tank, some seepage was shown. The water container was in any case found in sound condition, as there was no obvious indication of distress on outside or inner surface with the exception of top section front of tank (from inside), which is having uncovered rusted steel. The way toward rusting of fortification and disintegration of cement is seen to advance at a quick speed, by contrasting and the troubles saw first time in the start of 1994, because of extreme climate condition around there. Any further postponement in repair may cause abrupt breakdown of the structure because of the external forces like substantial breeze and earthquake and so forth.

Case Study II: G+3 Residential Building, Basant Nagar, Tamil Nadu

The Building was constructed in proximity to the seashore and exposed to saline environment. The building was shown some signs of distress in accordance to other cases, such as spalling, corrosion of reinforcement, cracks etc. Also, there were signs of dampness underneath the slab. Findings for the probable causes

- As the building was situated near the sea shore and exposed to saline environment which increase the chances of deterioration.
- No earlier treatment for reinforcing bars was given.
- High chloride content was found except this the quality of concrete found satisfactory.
- Chloride penetration was considerable and removal of entire affected concrete was not feasible



Spalling and Corrosion

The Remedial Measures were given as:

- Spalled concrete was replaced with the polymer modified mortar.
- According to the requirement, new reinforcing bars were welded and treated. Also, the rust was removed from it.
- Epoxy pressure grouting.
- Concrete jacketing of affected columns was done.
- The Surface sealing was also done
- As chloride penetration was considerable, the protection to rebars against corrosion was provided by provisioning of sacrificial zinc anodes.

VI. CONCLUSIONS

- Repair and Rehabilitation 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.
- Selection & evaluation of right repair material and protective coatings will save enormous money & time by reducing the repair costs of concrete buildings/structures.

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