Journal of Advances and Scholarly Researches in Allied Education
Vol. 18, Issue No. 3, April-2021, ISSN 2230-7540

Cost Analysis Using New Material, Process and Technique in Rehabilitation Repairs and Retrofitting As a Part of Construction Engineering

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Abstract – The word retrofit means to apply new technologies to an older system. Retrofit is process by adding some new features that were not there before. Retrofitting in construction industry refers to re-strengthening of existing structure to make them seismic resistant. Retrofitting is a technique to improve the structural capacities including the strength, stiffness, ductility, stability of a building that is found to be deficient. In rural side of Pune, most of the residential buildings have been designed only for dead and live loads. Since Pune lies in zone III, the buildings located in this zone needs to be seismic resistant. Seismic retrofitting is necessary in case of any damages in high seismic prone area. The main objective of this thesis is to study various methods used for rehabilitation repairs and retrofitting in construction industry that includes new construction techniques and traditional construction techniques, to minimize retrofitting costs and waste without affecting production & quality and to minimize environmental effects.

This study includes visual inspection and advance technique to rehabilitation repairs and retrofitting survey in which we can find out the factor affecting the repair cost which directly related with material use in retrofitting. The factors affecting the retrofitting cost and time were identified through the literature based on previous research. The comparison of time for both material used in retrofitting work in each material showed that the material which includes advanced method, new techniques, installation process is the most suitable alternative to the existing traditional method like cement slurry.

Keywords — Retrofitting, Seismic Retrofitting, Rehabilitation Repairs, Strengthen

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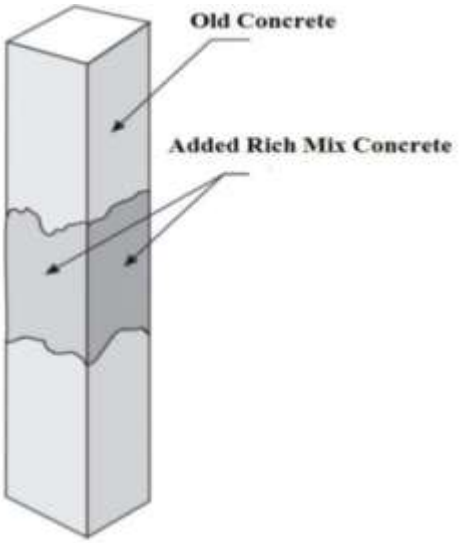
I. INTRODUCTION

Existing concrete structures may be found to perform unsatisfactorily for a variety of reasons. This could manifest itself by poor performance under service loading, in the form of excessive deflections and cracking, or there could be inadequate ultimate strength.

India is one of the most earthquake prone countries in the world and the recent devastation caused due to earthquake has exposed the seismic vulnerability of structures in our country. In rural side of Pune, most of the residential buildings have been designed only for dead and live loads. Since Pune lies in zone III, the buildings located in this zone needs to be seismic resistant. About 50-60% of the total geographical area comes under earthquake prone region. Almost, 4 out of 5 structures are non-engineered made up of earthen walls, stone walls, brick masonry walls etc. Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. These structures cannot even sustain earthquake of minor intensity and result in heavy loss of life and property. The building sector contributes a large proportion of the world's total final energy consumption. As a result, considerable attention has been paid to energy efficiency in the building sector. At the current stage, building retrofitting is the most feasible and cost-effective method to improve building energy efficiency. This paper presents a multi-objective optimization model for life-cycle cost analysis and retrofitting planning of buildings.



Steps of retrofitting

1. Determine as accurate as possible how the building behave when shaken by an earthquake

- check the building
- check building material quality
- list all component of the building that are damaged

2. Perform a dynamic analysis for the building to get an idea of the causes of damage and determine the load paths when shaken by the earthquake.

3. Determine the causes of damage of components; caused by shear, compression, tension, flexure, anchoring, etc.

4. As soon as the type of damage can be identified, repair and restoration of the

5. Components can be done separately in order that the original strength of the components can be restored.

6. If results of analysis indicate that the building with restored components can withstand the maximum expected earthquake for that area based on the latest code, then there is no need to strengthen.

7. However, if the building with restored components was not designed or designed for a lower than the maximum expected earthquake Specified by the latest code, then the building needs to be strengthened

8. For strengthening, the restored building must be re-analyzed to identify which component must be strengthened.

9. For engineered buildings with severe damage and if the building needs to be strengthened, 3d non-linear analysis performance based design should be done.

10. If cost for strengthening the building to its original function is not feasible, one option that can be chosen is to change the building function with less stringent requirement, therefore cost will be reduced.

11. After the strengthening works is completed, the building must be re-analyzed to ensure that the strengthened building is earthquake resistant.

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

► Before the execution of repair in any structure, one most important factor is to remove the damaged concrete.

► The equipment and tools used for the removal of damaged concrete mostly depend on the damage.

► 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.

- 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:

- Unsound material must be completely removed.
- Undercutting along with the formation of smooth edges.
- Surface cracks must be removed.
- Formation of a well-defined cavity geometry with rounded inside corners.
- Uniform surface but rough for repair can be provided.
- 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:

- To increase the strength
- To improve the performance of structure.
- To provide water tightness.
- To improve appearance of concrete surface.
- To improve durability.
- To prevent access of corrosive materials to reinforcement.

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:-

- √ Shot Crete
- √ Epoxy resins
- √ Epoxy mortar
- √ Gypsum cement mortar

Quick setting cement mortar

- √ The success of repair activity depends on the identification of the root cause of the deterioration of the concrete structures.
- √ If this cause is properly identified, satisfactory repairs can be done for the improvement of strength and durability, thus extending the life of the structure, is not difficult to achieve.
- √ Earthquake creates great devastation in terms of life, money and failures of structures.
- √ Earthquake Mitigation is an important field of study from a long time now.
- √ Seismic Retrofitting is a collection mitigation techniques for Earthquake Engineering.
- √ It is of utmost importance for historic monuments, areas prone to severe earthquakes and tall or expensive structures.

BACKGROUND

Research in the areas of condition assessment and health monitoring of structures involve computational modeling, laboratory experiments, and (or) field investigations. The developments in computing, sensing and actuation technologies are the technological drivers of this field. Notions of “sentient structures” and “digital twins” are emerging. A good proposal in these areas of research needs to include one or more of the following features:

- √ The study should involve combined experimental and computational work elements.
- √ There must be novel element at least in one of the following aspects: system identification methodology, sensing,

actuating, data handling, testing, and prognosis.

√ The assimilation of measurement data typically must be in conjunction with computational tools such as FEM which is widely used in structural engineering.

√ The investigators must have an awareness of relation between structural health monitoring, structural design philosophy, and prognosis of structural behavior.

√ The proposal must display awareness of effects of non-idealities such as measurement noise, nonlinearities, environmental effects, and multiplicity of valid mathematical models.

√ The proposal need to include work elements involving studies with synthetic data, studies with laboratory testing, and studies with field data. Studies which employ only synthetic measurement data are to be discouraged.

√ Projects involving field work need to have collaborative efforts involving structural engineering, sensing & actuation, and instrumentation.

AIM

To perform on the various retrofitting methods and to study on flexure retrofitted RC beams using traditional method like stitching are limited. Further it is required to study the effect of stitch depth on flexure carrying capacity of flexure deficient beams by retrofitting with stitching" also effect on total rehabilitation repair cost and benefits using advanced material and advance construction techniques.

OBJECTIVES

√ The main objective of thesis is to find cost required for rehabilitation repairs and retrofitting using new techniques, method and process. And compare this with traditional method using for retrofitting.

√ To study various methods used for rehabilitation repairs and retrofitting in construction industry, that includes new construction techniques and traditional construction techniques.

√ To minimize retrofitting costs and waste without affecting production & quality and to minimize environmental effects.

√ Effect on total rehabilitation repair cost and benefits using advanced material and advance construction techniques.

Problem Statement

Nowadays concrete is the main building material used for the construction of structures. Some old buildings are still in good working condition but some modern structures start showing signs of distress in a short time due to poor workmanship, poor maintenance, poor material quality, and improper design. Thus most of the old building are required more maintenance and repair of building also due to increase in population and due to increase in their requirements of shelter, they require more space for new construction of building but required amount of space has not available for the new construction or people may have to pay more amount for purchasing new land and construction of new building thus instead of this it is more economical to use existing building by doing rehabilitation of that building.

It is advisable to rehabilitate distressed structure instead of demolishing it and construct a new one. So in civil engineering, repair and rehabilitation of the existing structure are very famous as it is economical and time-saving process rather than build a new structure. Rehabilitation of existing structures needs lots of knowledge and planning to get the work done. Today there were many types of different methods and material are used for rehabilitation of structure. Some materials used are Cement, Epoxy resins, Polymer concrete composites, Steel fiber reinforced concrete, Asphalt coatings etc.

II. LITERATURE REVIEW

Anurag Mishra, Ashutosh Ranjan review on Analysis, Design and Application of Retrofitting Techniques in Various Structures, International Journal of Engineering Research & Technology (IJERT) Vol. 6 Issue 04, April-2017

In this paper they studied a case study of existing structure in which there main aim was to suggest various methodologies and techniques to access the seismic vulnerability of old structure and to propose suitable retrofit measures for deficient structures with cost consideration. They adopt various methods to determine the damage of structure. First technique was visual inspection of structure. In which they found critical section of the structure. Critical section is the weakest portion which is more vulnerable to damage at the time of earthquake due to heavy stress concentration at those points. Second technique was rebound hammer test. To determine the existing strength of structure we performed the rebound hammer test. It is a Non-destructive test performed on concrete surface to determine the compressive strength of the portion. Compressive strength is obtained by comparing the rebound number with the conversion chart provided by the manufacturer of rebound hammer. Next step was to Additional Testing of structure materials. In which some complimentary tests are performed on the

materials obtained from the site. Key test, Push test and Water spray test are some of the major test performed in this experiment. From above methodology they conclude that critical section in any structure is major area for the concern of seismic analysis and retrofitting assessment. The retrofitting techniques should be applied according to the existing strength of the component of buildings and required standard strength needed as per the building codes. The economy and cost of the structure possess an important aspect to suggest suitable retrofitting techniques.

Shri. Pravin, B. Waghmare review on Materials and Jacketing Technique for Retrofitting of Structures, International Journal of Advanced Engineering Research and Studies (IJAERS), Vol. I, Issue I, October-December 2011

In this paper they studied using jacketing for strengthening of column. The main objective of this paper was jacketing is to increase the seismic capacity of the moment resisting framed structures. In almost every case, the columns as well as beams of the existing structure have been jacketed. In comparison to the jacketing of reinforced concrete columns, jacketing of reinforced concrete beams with slabs is difficult yielding good confinement because slab causes hindrance in the jacket. In structures with waffle slab, the increase in stiffness obtained by jacketing columns and some of the ribs, have improved the efficiency of structures. In some cases, foundation grids are strengthened and stiffened by jacketing their beams.

An increase in strength, stiffness and ductility or a combination of them can be obtained. Jacketing of columns consists of added concrete with longitudinal and transverse reinforcement around the existing columns. This type of strengthening improves the axial and shear strength of columns while the flexural strength of column and strength of the beam-column joints remain the same. It is also observed that the jacketing of columns is not successful for improving the ductility. A major advantage of column jacketing is that it improves the lateral load capacity of the building in a reasonably uniform and distributed way and hence avoiding the concentration of stiffness as in the case of shear walls. This is how major strengthening of foundations may be avoided. In addition the original function of the building can be maintained, as there are no major changes in the original geometry of the building with this technique. The jacketing of columns is generally carried out by two methods: (i) reinforced concrete jacketing and (ii) steel jacketing.

Bo Wang, Xiaohua Xia, Jiangfeng Zhang, A multi-objective optimization model for the life-cycle cost analysisand retrofitting planning of buildings, Energy and Buildings 77 (2014) 227–235, March 2014

In this paper they studied the building sector contributes a large proportion of the world's total final energy consumption. As a result, considerable attention has been paid to energy efficiency in the building sector. At the current stage, building retrofitting is the most feasible and cost-effective method to improve building energy efficiency. This paper presents a multi-objective optimization model for life-cycle cost analysis and retrofitting planning of buildings. A net present value (NPV) based economic analysis taking life-cycle cost into account is introduced to formulate the objective functions. In addition, a combination of multiple alternative measures for each retrofitting intervention is considered in determining the optimal solution. The result of the case study illustrates the effectiveness of the multi-objective optimization model to support the planning of energy-efficient and cost-effective building retrofitting projects. This paper presents an optimization model for building retrofitting planning.

While maximizing the energy savings and the economic benefits of the project as proposed in the existing research the present model introduces a building investment analysis method associated with life-cycle cost analysis. The new method takes maintenance costs of retrofitted items into account to evaluate the overall cost-effectiveness of the solution within a specific time frame. Furthermore, more available retrofitting options in a building retrofitting project are introduced. A range of possible alternative measures as well as the quantities of retrofitted facilities using the selected measures are evaluated. Considering a combination of alternative measures allows the best cost-effectiveness of retrofitting plan under the budget limit. The illustrative results and analysis show that with the present model, it is possible to find the most cost-effective long-term solution that includes life-cycle cost analysis and multiple options of retrofitting measures, unlike the existing studies that exclude these; there are several topics which call for further studies on the investigated topic: a power saving profile can be more informative than the annual energy saving estimation; the impact of the retrofitting project, e.g., the influence on occupants' behaviors has not yet been investigated; more criteria, such as the comfort requirements can be introduced in the future optimization model.

Kirtika Gupta, Abhishek Kumar, Mohd. Afaque Khan, Review Paper on Seismic Retrofitting of Structures, International Research Journal of Engineering and Technology (IRJET), volume 04 Issue 04, Apr -2017

Earthquake around the world are single-handedly responsible for the destruction to life and property in large numbers. In order to mitigate such hazards, it is important to incorporate norms that will enhance the seismic performance of structures. This paper represents the change of Reinforced concrete structural components which are found to exhibit

distress because of earthquake loading. Such unserviceable structures require immediate attention. And it was done by using the shear wall mechanism in the software .It can be used as a seismic retrofitting technique because it can be applied quickly to the surface of the damaged element without the requirement of any special bonding material and also it requires less skilled labor, as compared to other retrofitting solutions presently existing. It was determined that load carrying capacity for beam-column joint retrofitted with shear wall is increased. In this paper we use analytical approach. In this we use stadd pro v8i software.

Jacketing construction is the most preferred method of retrofitting that can be applied by the following techniques. Confinement with fibre reinforced polymers such as aramid fibres, carbon fibres and glass fiber reinforced composite.

Komal Bedi, Study on Various Methods and Techniques of Retrofitting, International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 9, September – 2013

In this paper they studied Rehabilitation provisions require selecting the rehabilitation objectives and acquiring current building information prior to performing rehabilitation design. At the stage of selecting the retrofitting method, the current status of the existing structure and its performance are known, and the performance required for the structure after retrofitting. Factors that should be considered in selecting the method include the effectiveness of the various retrofitting methods with respect to the required performance improvements, the viability of execution of the retrofitting work, the impact of the retrofitting work on the surrounding environment, the ease of maintenance after retrofitting, economy and other factors. Base is generally suitable for low to medium rise buildings, usually up to 10- 12 stories high, which have their fundamental frequencies in the range of expected dominant frequencies of earthquakes.

Superstructure characteristics such as height, width, aspect ratio, and stiffness are important in determining the applicability and effectiveness of seismic isolation. The seismicity of the region and the underlying soil conditions should also be considered in the feasibility studies and design process. Constraint in the application of base isolation is the large relative displacements between the superstructure and the supporting ground at the isolation level. A clearance around the building must be provided and maintained through the life of the structure to accommodate the expected large displacements. Such displacements may be reduced with the incorporation of additional stiffness and energy dissipation mechanisms in the isolation system. Isolators have low horizontal stiffness and they are placed between the structure and foundation.

Retrofitting of Reinforced Concrete structural elements - Recent Technologies and Future Scope

Conducted an investigation is based on flexural behavior of RC beam wrapped with GFRP sheets, an experimental study is carried out by externally bonded GFRP sheets to the RC beam and to tested under the two point static loading system. For this they prepared six reinforced concrete beams, noted that all six beams are weak in flexural and having same reinforcement detailing.

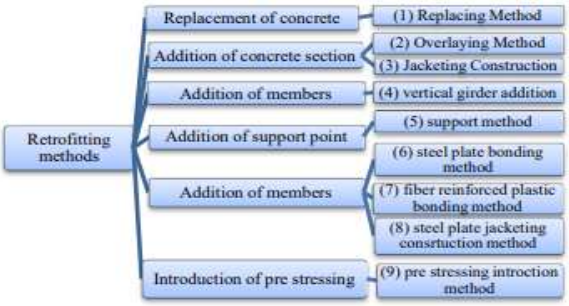
III. RESEARCH METHODOLOGY

IV. DATA COLLECTION & ANALYSIS

The issues related to the seismic performance of the existing building stock are broad and encompass almost every aspect of earthquake research and professional practice. Although risk assessment or retrofit of individual buildings are at the heart of most of these issues, it should be acknowledged that there are areas of related study that stand on their own and will not be covered in detail here. Some of these separate areas of study are described below.

V. METHODS AND MATERIAL

Some of the retrofitting methods are explained below. Figure shows the methods of retrofitting techniques. And they are discussed in the detailed as below.



Concrete replacement Concrete replacement is the simplest and cheapest technique that can be used to restore strength and ductility of RC structures. In this technique, the damaged concrete is removed, the

aggregate of the old concrete is exposed and the surface of the old concrete should be cleaned to remove any loose material and to ensure a strong bond between the old concrete and the new one. If the reinforcing steel bars in the compression zone were slightly buckled after concrete crushing, they should be straightened. The formwork of the web is prepared; the new concrete is mixed and poured from one side of the structure. The top part can be completed using a high-strength epoxy grout to ensure a proper bond with the old concrete. After the removal of formwork, the new concrete should be cured. Therefore, repairing the shear structure by concrete replacement is causing disturbance to the building function, and hence it is not suitable if the building has to be accessible during repair.

VI. CONCLUSION

1. We have investigated economic aspects of both material used in retrofitting work. A structure of repair costs was proposed for the evaluation of management scenarios.

2. The comparison of time for both material used in retrofitting work in each material showed that the material which includes advanced method, new techniques, installation process is the most suitable alternative to the existing traditional method like cement slury.

3. In addition, the calculation of benefits would be necessary in an integrated cost-benefit analysis, in order to establish the economic feasibility associated with the implementation of different material. Subsequently, the benefits can be compared with the costs, and the net profit of each management alternative can be also determined.

VII. ACKNOWLEDGMENT

We express our sincere thanks to Project Guide Prof U. J. Phatak for his continuous support. We also thankful to our Head of Department of Civil Dr. R. R. Sorate For support

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