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

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Abstract – 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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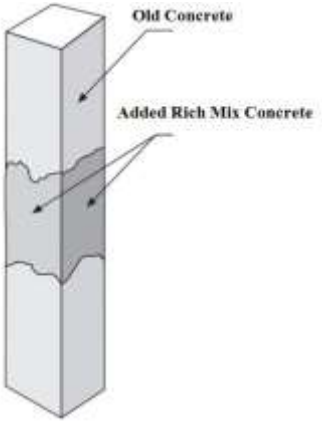
I. INTRODUCTION

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.



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.

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:-

- √ Shotcrete
- √ 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.

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

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. RELATED WORK

Anurag Mishra, Ashutosh Ranjan

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.

A. Pravin, B. Waghmare

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,

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. 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,

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.

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

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.

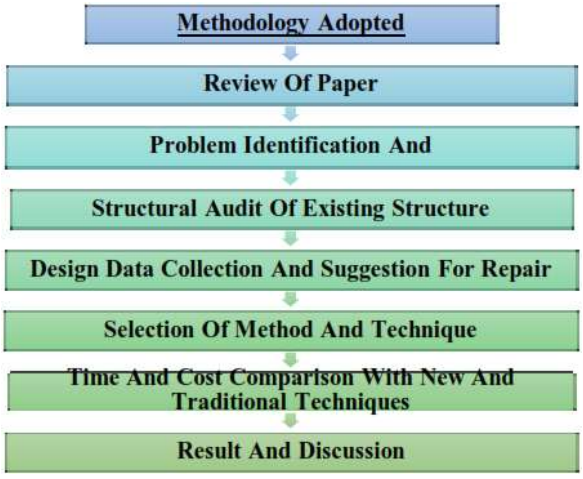
Superstructure characteristics such as height, width, aspect ratio, and stiffness are important in determining the applicability and effectiveness of seismic isolation. The seismicity of the region and the underlying soil conditions should also be considered in the feasibility studies and design process. 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



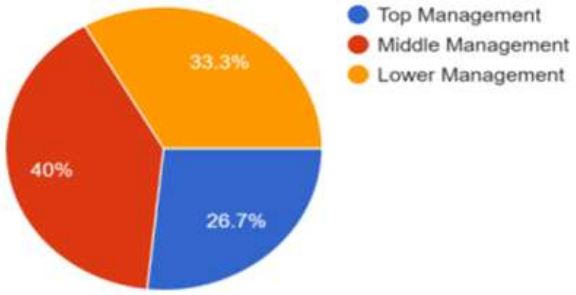
IV. DATA COLLECTION & ANALYSIS

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

V. QUESTIONARY SURVEY

Simple descriptive statistics such as averages ranges and percentages were used to analysis primary data from the construction site. Among 50 questions only 30 questions were considered for survey. The questionnaires were distributed through various electronic media platform to a variety of respondent working around the construction projects. About 50 people have responded to the questionnaire survey.

The respondents were asked to indicate the positions they held in the respective companies and the duration for which the company is in operation. They were provided with options to choose from. About 26.7% of the respondents who participated in the study are from Top management background, 40% were from middle management, while 33.3% were serving as a lower management as shown in the Fig. These respondents are well conversant with effect of construction waste management.



General questions

1. Name
2. Mobile no.
3. Mail id
4. Age
5. Occupation
6. Organizational/college name
7. Position in organization
8. Working experience
9. Location
10. Any other information

Technical Questions

1. Have you ever heard about Structural audit?
2. Do you think structural audit is necessary for future expansion of existing structure?
3. Do you observe any crack in Beam, column at your house?
4. Do you think retrofitting design should be done by structural engineer?
5. Do you think for retrofitting or rehabilitation old/traditional methods are better than new methods?

6. Do you think due to new material and technique cost should be saving for rehabilitation of structures?

7. Do you know main reason of retrofitting and rehabilitation is earthquake?

8. Do you think using new material like Ferro-cement, fibre reinforced polymer etc. reduce cost of retrofitting structure?

9. Do you think new technology such as radiography, electromagnetic technique reduce cost to find properties of structural member?

10. Do you think building should design to resist earthquake forces and create less damage to structure?

11. Do you think in India structural audit should be compulsory to every structure for design life span of structure?

12. Are you aware of retrofitting in construction industry?

13. Do you know main reason of damages of structure was using poor material to structure?

14. Do you think rebound hammer was best method to find strength of structure?

15. Do you think Cost benefits analysis should be done before starting retrofitting work?

16. Do you think by decreasing use of old process of retrofitting we can decrease the project cost?

17. Do you think using recycle material benefit the total project cost?

18. Do you think Cost benefits analysis should be done before starting construction?

19. Do you use new technology of retrofitting for construction of building?

20. By giving proper training to mason increase the productivity of work and decreases the wastages of retrofitting material?

Answer type

1. Yes

2. No

3. Other/ Can't say

Figure: Data Analysis

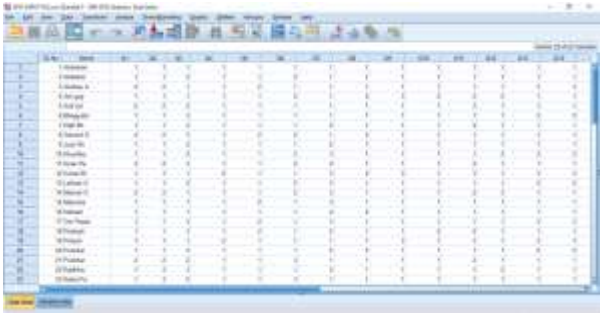


Figure: Data View

Figure: Variable View

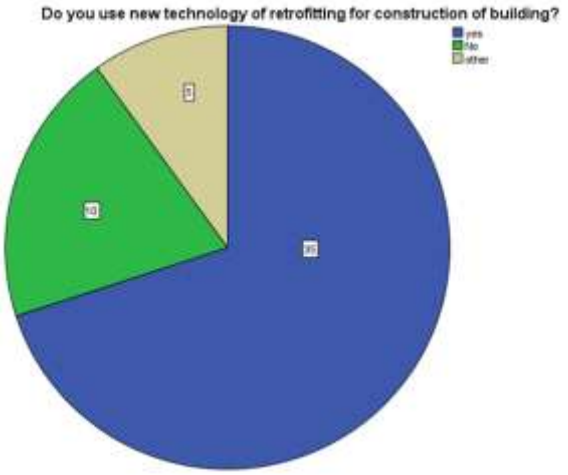
Figure: Output Window

Questions	YES(N	No(N2)	ANT SAYIN	Total
Are you aware of retrofitting in construction industry?	38	9	3	50
Have you ever heard about Structural audit?	36	12	2	50
Do you know main reason of retrofitting and rehabilitation is earthquake?	21	20	9	50
Do you think building should design to resist earthquake forces and cracks face damage to structure?	45	5	0	50
Do you know main reason of damages of structure are using poor material's in structure?	35	15	0	50
Do you aware new technology of retrofitting for construction of building?	35	10	5	50
Do you think rebound hammer one best method to find strength of structure?	24	21	5	50
Do you think structural audit is necessary for future expansion of existing structure?	38	12	0	50
Do you observe any cracks in Beam, column of your house?	43	0	7	50
Do you think retrofitting design should be done by structural engineer?	44	3	3	50
Do you think For retrofitting or rehabilitation old/traditional methods are better than new methods?	29	14	7	50
Do you think due to new material and technique cost should be saving for rehabilitation of structures?	40	7	3	50
Do you think using new material like Ferro-cement, fibre reinforced polymer etc. reduce cost of retrofitting structure?	32	7	11	50
Do you think new technology such as radiography, electromagnetic technique reduce cost to find properties of structural mem	29	9	12	50
Do you think in India structural audit should be compulsory to every structure for design life span of structure?	43	0	7	50
Do you think Cost benefits analysis should be done before starting retrofitting work?	41	5	4	50
Do you think by decreasing size of old process of retrofitting we can decrease the project cost?	42	0	8	50
Do you think using recycle material benefit the total project cost?	32	12	6	50
Do you think Cost benefits analysis should be done before starting construction?	41	7	2	50
By giving proper training to masons increase the productivity of work and decrease the wastages of retrofitting material?	22	22	6	50

Sr. No.	Question	YES(1)	No(2)	Other(3)	Total	al Numbe	A x N	RII	Ranks
1	Q1	38	18	9	65	50	150	**0.43**	10
2	Q2	36	24	6	66	50	150	**0.44**	9
3	Q3	21	40	27	88	50	150	**0.59**	1
4	Q4	45	10	0	55	50	150	**0.37**	15
5	Q5	35	30	0	65	50	150	**0.43**	11
6	Q6	35	20	15	70	50	150	**0.47**	8
7	Q7	24	42	15	81	50	150	**0.54**	4
8	Q8	38	24	0	62	50	150	**0.41**	13
9	Q9	43	0	21	64	50	150	**0.43**	10
10	Q10	44	6	9	59	50	150	**0.39**	14
11	Q11	29	28	21	78	50	150	**0.52**	6
12	Q12	40	14	9	63	50	150	**0.42**	12
13	Q13	32	14	33	79	50	150	**0.53**	5
14	Q14	29	18	36	83	50	150	**0.55**	3
15	Q15	43	0	21	64	50	150	**0.43**	10
16	Q16	41	10	12	63	50	150	**0.42**	12
17	Q17	42	0	24	66	50	150	**0.44**	9
18	Q18	32	24	18	74	50	150	**0.49**	7
19	Q19	41	14	6	61	50	150	**0.41**	13
20	Q20	22	44	18	84	50	150	**0.56**	2

Do you use new technology of retrofitting for construction of building?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	35	70.0	70.0	70.0
	No	10	20.0	20.0	90.0
	other	5	10.0	10.0	100.0
	Total	50	100.0	100.0	



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

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