Managing Retrofit Project.

[1]Diwan Usama, [2]Sakib Khan, [3]Dhaval S. Shah

[1,2,3]Civil Engg. Dept-AIKTC, Panvel

Abstract— Many existing reinforced concrete structure in present world are inadequate for earthquakes. Recent earthquakes which occurred during last decades have indicates that major damage occurred was not directly due to the poor performance of structure during earthquakes.it is recognized that the most effective method of reducing risk of damaging structure is sesmic retrofitting. In recent year significant improvement of retrofitting techniques. Thus study highlights the principals of assessing and retrofitting of structure against seismic events.. Finite Element Method used to investigate the performance of the building during the earthquake and to check the behavior of the structure after applying retrofitting techniques. The methods such as steel and concrete jacketing and application of fiber reinforced polymer (FRP) composites, which are used to improve the load bearing capacity of individual structural elements, are highlighted and methods such as shear walls & shear cores, which can be used to improve overall stability, are enlisted and the factors that governs the decision for retrofitting of the structures are discussed.

Index Terms—Retrofit, Sesmic zone, Non Destructive testing, structural analysis ,seismic analysis, vulnerability assessment

I. INTRODUCTION

Retrofitting and strengthening of the reinforced concrete structure is dynamically growing division of engineering. Strengthening of reinforced concrete structure structures is one of the most difficult task civil engineering practices.

- Earthquake damaged buildings
- Earthquake vulnerable building that have not yet experienced severe earthquake.
- Old building that have not maintained for a long time

It is important to distinguish between the terms retrofit, repairs and rehabilitation of a building. All three terms refer to modification carried out on a building, a but in different context. 'Repairs' is closely used to describe any intervention that is nonstructural in nature. On the other hand, both 'retrofit' and rehabilitation refer to structural intervention aimed at strengthening the building. The difference between the two terms is very fine. Rehabilitation aims to regain the original strength of a building a building, which may have been damaged or deteriorated. Retrofit aims to strengthen a building to satisfy the requirement of the current codes for seismic design. The building may not be damaged or deteriorated. Concrete construction is generally expected to give trouble free service throughout its intended design life. However, these expectations are not realized in many constructions because of structural deficiency, material deterioration, unanticipated overloading or physical damage. Premature material deterioration can arise from number of causes, the most common when construction specification are violated or when the facility is exposed to harsher service environment than those expected during the planning and design stages. Expect in extreme cases, most of the structure requires restoration to meet its functional requirements by appropriate repair techniques. Concrete construction requires proper care in the form of regular maintenance. Building remains for several years without getting attention. Waste stagnation, paint peelings, plaster break off, fungus growth, cracking rendering and cover concrete are common widespread. Penetration of moisture into reinforced concrete promotes corrosion process and further damages the concrete cover. The aftermath of an earthquake manifests great devastation due to unpredicted seismic motion striking extensive damage to innumerable buildings of varying degree i.e either full or partial or slight. This damage to structure in its turn causes irreparable loss of life with a large number of casualties. As a result, frightened occupant refuse to enter the building unless assured of the safety of the building from earthquakes. It has been observed that majority of such earthquake damaged the building may be safely reused, if they are converted into seismically resistant structure by employing few retrofitting measures. This proves to be a better option catering to economic considerations and immediate shelter problems rather than replacement of buildings. Moreover, it has been often seen that retrofitting of building is generally more economical as compared to demolition and reconstruction even in the case of severe structural damage.

II. BACKGROUND

A large number of existing buildings across the country do not seem to have adequate earthquake resistant features specified in IS Codes. Some reasons given for this include non-availability of competent technical man power, lack of regulatory mechanisms to check earthquake resistance of proposed constructions, and economic constraints. The effort and technical input required to retrofit a building are much higher than that to make a new earthquake-resistant building. In the present scenario, sufficient technical manpower is not available even for designing and constructing new buildings. Further, infrequent occurrence of earthquakes (though devastating) has not helped the cause of making the country realize the extreme shortage of technical inputs to take corrective steps towards ensuring that the built environment is made capable to resist expected earthquake shaking in each region. Over 95% of fatalities in past earthquakes in India have occurred in non-engineered houses and structures; significant gains can be made towards reducing (if not eliminating) loss of life by undertaking seismic strengthening of these non-engineered structures. This is by far the most critical step in earthquake disaster mitigation in India.

Further, a special class of buildings has emerged in a big way across the country, called Open Ground Storey Buildings (or Buildings on Stilts). These do not conform to prevalent Indian Standards for earthquake safety. These buildings are flexible and weak in the open ground storey compared to the storeys above. A large number of these low-strength reinforced concrete (RC) buildings collapsed during 2001 Bhuj earthquake. Most of these buildings, not designed properly, may be able to carry gravity loads, but could be deficient in strength to withstand deformations imposed on them during strong earthquake shaking. During the 2001 Bhuj earthquake, many such buildings with open ground storey, owned by government did not collapse, because they were designed as per Indian Seismic Code. A large number of similar buildings exist in urban and semi-urban areas of India, which require seismic retrofitting, at least to prevent collapse during the next earthquake.

III. BUILDING MATERIAL

Natural materials (like mud, stone, bricks, timber and bamboo) form the major chunk of the buildings materials (up to about 95%) in construction across India. There is a larger use of cement-based materials in urban areas than in rural areas. Over the last two decades, there has been an increasing trend of use of RC slabs in roofs; the sheet roofs in existing buildings are being replaced at a rapid pace with RC slabs. On the other hand, the buildings with modern materials (like reinforced concrete and structural steel) still constitute only about 3.6% of the entire building stock though their absolute number is on the rise. Table 1.4.1 shows the summary of choices of wall material in wall construction in rural, urban and entire country [Census 1991; 2001 and 2011]. The cumulative dominant materials of choice by 2011 are: (1) mud and un-burnt brick (about 22%), (2) burnt brick (about 48%); and (3) Stone (about 14%). These three materials together account for 84% of housing material used in the country. But, civil engineering and architecture education imparted across India does not account this in the curriculum. On the one hand, the housing construction materials listed above are reflected in only 3% of the courses taught to the undergraduate students. In particular, the course on masonry is almost extinct in the curriculum across the engineering colleges in the country. On the other hand, 97% of the curriculum is addressing the small minority of 3.6% of reinforced concrete houses in the country.

Recognizing the above skewed situation, clear understanding is required of this vulnerability of the building stock in the country by

1. Identifying measures that can retrofit the existing building stock to earthquake-resistant standard
2. Ensuring that new houses constructed are not vulnerable
3. Making systemic changes (as part of capacity building and preparedness initiatives of disaster management) towards mitigating impending earthquake disasters. Hence, a systematic methodology is required for

a) Documenting Housing Typologies in the Moderate-Severe Seismic Zones of India, with a view to understand the extent of loss that is expected in each existing housing type, and developing guidelines for all new constructions
b) Retrofitting the vulnerable housing stock in the Moderate-Severe Seismic Zones of India

Table 1: 2011 summary of choice of wall material used in house construction in India

Wall material	Number of houses as per 2011 cesus					
	Rural India	%	Urban India	%	India	%
Mud, unburt brick	58330614	28.2	8119213	8.3	66449827	21.8
Burnt brick	8361846	40.5	62927369	64.0	146545805	48.1
Stone	28685790	13.9	14797142	15.1	43482932	14.3
Grass, thatched, bamboos etc	26417331	12.8	2530263	2.6	28947594	9.5
concrete	3699096	1.8	7284583	7.4	10983679	3.6
wood	2132342	1.0	648929	0.7	2781271	0.9
GI, metal, asbestos sheets	126359	0.6	1062510	1.1	2331869	0.8
Plastics, polythene	762256	0.4	335575	0.3	1097831	0.4
others	1648466	0.8	613174	0.6	2261640	0.7
Total	**206563690**	100	**98318758**	100	**304882448**	100

IV. METHODOLOGY

A) Concept of Retrofitting.

Retrofitting is technical interventions in structural system of a building that improve the resistance to earthquake by optimizing the strength, ductility and earthquake loads. Strength of the building is generated from the structural dimensions, materials, shape, and number of structural elements, etc. Ductility of the building is generated from good detailing, materials used, degree of seismic resistant, etc. Earthquake load is generated from the site seismicity, mass of the structures, important of buildings, degree of seismic resistant, etc. Due to the variety of structural condition of building, it is hard to develop typical rules for retrofitting. Each building has different approaches depending on the structural deficiencies. Hence, it is needed to prepare and design the retrofitting approaches. In the design of retrofitting approach, the engineer must comply with the building codes. The results generated by the adopted retrofitting techniques must fulfill the minimum requirements on the buildings codes, such as deformation, detailing, strength, etc.

B) Decision for Retrofitting

Retrofitting is needed when the assessment of structural capacity results in insufficient capacity to resist the forces of expected intensity and acceptable limit of damages. It is not merely poor quality of materials and damage of structural elements serves as the reasons to retrofit a building. Change of the building's function, change of environmental conditions, and change of valid building codes could also be the reasons for retrofitting. Retrofitting must be conducted by experts from each field. In most retrofitting process, an engineer plays the main role. An engineer must assess and analyze the structural capacity. An engineer must also design the best retrofitting techniques to strengthen the structural deficiencies. The role of the novice is restricted to identify the possibility of insufficiency of building capacity. Some factors that should be considered in order to decide whether to retrofit or not are:

1. Technical aspect

The technical aspects include the testing of materials and structural analysis. These measures are important to understand the condition of the structures related to the recent building codes.

2. Cost intervention

Cost and benefit analysis must be conducted before the decision is made.

3. Importance of building

Each building is built for its own purpose. Some old buildings have extra values, such as historical values, that will strongly affect the final decision.

4. Availability of adequate technology

Some of retrofitting techniques need a "modern" technology to implement it. A decision of retrofitting must consider whether the region provides such technology.

5. Skilled workmanship to implement the proposed measures

Some of retrofitting techniques need unusual construction method to implement it. A skilled workmanship must be provided to implement the proposed measures.

6. Duration of works

Some of retrofitting works will consume less time to finish it, but others take more time to complete. Hence, it is important to take into the consideration the duration of works

C) Cost-benefit of retrofitting

Cost-Benefit analysis is conducted to determine whether retrofit or rebuild the building is more feasible. Most studies imply that retrofitting of an existing structure is more feasible than to build a new building. Retrofitting is a also a favorable approach to strengthen the building capacity to the external loads, e.g. earthquake. The advantages of adopting retrofitting approach, despite of reconstructing the building, can be listed as follows:

Table2: Cost based decision making of three level of technical options

Sr. No.	Decision	Cost of Seismic Retrofitting as a percentage of cost of reconstruction at current rate	
		Building part of critical & Lifeline Facilities	Office and Residential Facilities
1	Retrofit, If cost of retrofit is	<50%	<30%
2	Detailed technical assessment to determine vulnerability of the building or structure (including analysis of the implication on cost, age, heritage value	50% -70%	30% -50%

	/ importance, proximity to archeological structure, criticality of the building , current and projected Floor area ratio, residual life, disruption, expansion and up gradation of services, and improve function). If cost of retrofitting is in the range		
3	Reconstruct. If cost of retrofitting is	> 70%	> 50%

V. RETROFITTING PROCESS

The retrofitting of a structure involves improving its performance under earthquake loadings through one or more of these following measures:

1) Increasing its strength and/or stiffness

2) Increasing its ductility

3) Reducing the seismic forces.

The following techniques can be adopted for retrofitting of the structure.

1) Steel jacketing.

2) Application of Fiber Reinforced Polymer (FRP).

3) Addition of Shear wall and Shear core.

The measures can be done through modification to one or more of the following parameters:

1) Columns
2) Beams
3) Bracings
4) Walls
5) Foundation
6) Horizontal diaphragms
7) Joints between structural elements

When implementing these measures to buildings, it is importance that:

1) The buildings provide the required degree of seismic resistance

2) The chosen approaches are simple and economical to implement

It is important to note that the retrofitting of structural elements should not be conducted for only an individual element or groups of elements. The good performance of the whole structural system must be ensured. For example, when retrofitting is only conducted for some columns, attention should be placed to prevent worsening distribution of earthquake forces in the structural elements.

In general, the retrofitting process can be categorized into 3 categories as follows:

1. Assessment and Analysis

2. Design of Retrofitting Techniques/Approach

3. Construction/Implementation of Retrofitting

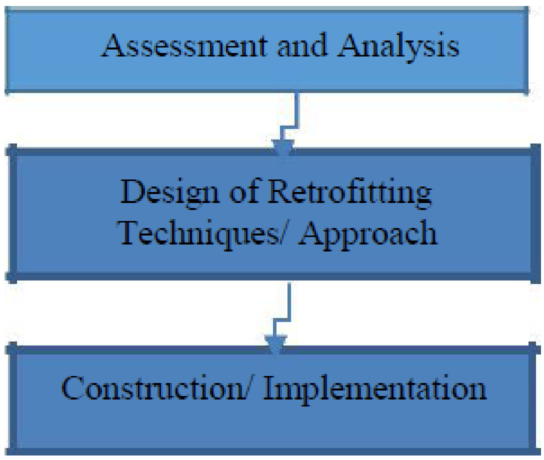

Figure1: General process of Retrofitting.

VI. VULNERABILITY ASSESSMENT

Seismic retrofitting becomes an important issue because it includes protecting life and property in future earthquake as well as protecting investments, lengthening building's usable life, reducing demands on post-earthquake rescue resources, protecting historic structures, shortening business interruption, and reducing relocation needs/demands. Based on the large scope of the impacts of seismic retrofitting, all parameters regarding the impacts should be considered in the decision-making.

Vulnerability assessment plays an important role in decision-making measures. The purpose of carrying out a vulnerability assessment analysis of an existing building is to determine the level of risk associated with loss of serviceability and severe damage or collapse. With the risk quantified, rational decisions can be made as to whether the buildings should be retrofitted or replaced.

The vulnerability assessment is usually conducted in 3 stages:

A) Visual investigation

This assessment is to determine the existing structural condition, based on the age of the buildings, environment condition, structural type, site of seismicity, etc. The visual assessment is usually conducted together with structural investigation. The results of the investigation will assist in conducting detailed structural analysis.

In general, the visual investigation measures can be listed as follows:

1. Mapping the site condition

2. Sketching of the overall layout, include the structural system, dimension and geometry of elements, spacing, loading system, etc.

3. Mapping of the detail structural damage, e.g. spalling, pops-out, cracking and its pattern, corrosion, discoloration, etc.

4. Observation of deflection and displacement on the structural elements

5. Observation of the deterioration of materials.

It is suggested that the investigation is documented by either camera or video camera for further evaluation and analysis.

B) Structural investigation:

The structural investigation can be divided into structural investigation for upper structure and structural investigation for sub-structure.

1. Structural investigation for upper structure:

There are many methods/techniques available for upper structure structural investigation.

In general, the methods are divided into 2 categories, non-destructive test (NDT) and semi-destructive/destructive test (DT). Non Destructive Test is conducted to assess the upper structure condition, and suggested to be conducted as much as possible to give proper description and evaluation on material properties. Some of the commonly used NDT are Schmidt Hammer Test and Ultrasonic Pulse Velocity Test (UPV). Schmidt Hammer Test is not intended to get the concrete strength directly, and a correlation formula should be used to obtain the compressive strength. The procedure of Schmidt hammer test refers to ASTM C 805. Ultrasonic Pulse Velocity Test (UPV) is intended to check crack depths by measuring the concrete density. The procedure of UPV test refers to ASTM C 597. On many occasions, semi-destructive/destructive test ((S)-DT) is also conducted. The most common (S)-DT is Core Drill Test. The purpose of this test is to get the concrete's strength by drilling the existing concrete on site and testing it at the laboratory. Semidestructive/ destructive test should be conducted carefully to prevent the excessive deterioration of structural elements. To get a good result of structural testing, it is suggested to combine both non-destructive test and destructive test.

2. Structural investigation for sub-structure:

Structural investigation for sub-structure includes the investigation for soil properties and foundation. There are many techniques for investigating soil properties. The most common used techniques for single story structure are hand boring and soil penetration test.

Investigation of the foundation can be carried out by digging the soil to check the existence of the foundation, including the dimensions and the bearing area.

3. Detailed structural analysis.

Detailed structural analysis is conducted to estimate the structural behaviour when subjected to applicable loads. Results from structural investigations should be used for the detailed structural analysis. The results of structural analysis will be used for designing of retrofitting approaches/strategy.

VII. ADVANTAGES OF RETROFITTING

1. When retrofitting approach is adopted, retrofitted building can still be operated.

2. Retrofitting will take relatively less construction cost with the same structural performance achievement.

3. Retrofitting will involve relatively less resources, either human resources or natural resources.

4. Retrofitting will not significantly change the building configuration and shape. It is preferable when the retrofitted building has historical values.

5. Retrofitting the building will produce less debris than reconstructing the building.

VIII. LIMITATIONS OF RETROFITTING

1. The skill of the worker must comply with the adopted retrofitting approaches.

2. Limited access of the construction site since the building could be still in function. It is important to note that the analysis must consider all parameters that can affect the decision. All costs and savings (including casualties and serviceability period) over a long period should also be taken into account.

IX. CONCLUSION

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1. Retrofitting is suitable technology for protection of variety of structure.

2. It has matured in the recent years to a highly reliable technology. However, the expertise is needed.

3. The main aim is achieve a desired performance at minimum level, which can be achieved from detailed nonlinear analysis.

4. Optimization techniques are required for successful and efficient completion of retrofit project.

5. Proper design codes are needed to be published as code of practice for professionals related to this field.

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