Retrofitting buildings with earthquake and crisis management

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Abstract: In order to improve the seismic behavior of buildings against earthquake loads, seismic capacity of existing buildings and required seismic demand including maximum acceleration of earthquakee, response spectra, and seismic design, which may be needed during the lifespan of a building considering its importance and services after the earthquake, are necessary to be estimated and calculated. The main question in retrofitting a building is that which building with which situation should be boosted against which force and for which function. So, retrofitting can be defined as modifying the vulnerable part or replacing a new part in the existing building in order to increase the structural capacity or a series of operations which improves stiffness and strength of a building compared with its original status.

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1. Introduction

Many of the existing structures located in earthquake-prone areas are constructed according to the old seismic design codes that are valid no longer. In addition, a number of major earthquakes that have occurred in recent years make the importance of lightening for seismic risk reduction double. Seismic retrofitting of existing structures is one of the most effective ways to reduce the risk of earthquakes. In recent years, many important researches have been dealt with various strategies for the repair and strengthening of reinforced concrete structures in order to improve their seismic performance. However, the seismic performance of structures can be increased by retrofitting or repair, selected by an engineer based on seismic evaluation of a tructure.So, basic needs of repair should be studied and several studies on retrofitting solutions should be conducted before the selection of retrofitting method. The necessity of retrofitting the vulnerable buildings is a fact that was observed in stability and safety of the buildings after the 1985 Mexico City and the 1995 Kobe earthquakes.

In Iran, retrofitting of old buildings has been done in several earthquakes with respect to the type of building structure, mostly are composed of coil and non-coil materials, and the methods used in retrofitting these buildings were found useful. Some of these methods will be mentioned in this paper. In order to reduce the damage caused by the earthquakes, vulnerable buildings and damaged buildings need to be strengthened, respectively, before and after the earthquake. The main concern in retrofitting buildings is the determination of required seismic level demand for a structure (determination of performance level) which is done by consulting with the landowner. It should be noted that, in general, regulations for seismic design of buildings simply specify the requirements for a building and its components and seismic capacity of a building doesn't need to be assessed explicitly and precisely, because it is not possible. This is due to unknown and uncertain mechanical and dynamic properties of materials and structures, implementation procedure, effect of non-structural elements on the seismic performance of structures, occurrence mode of probable earthquakes, maximum acceleration, dominant period of probable earthquake, and effect of adjacent buildings on seismic performance.

1.1. Crisis management and earthquake phenomenon:

Crisis management involves a series of continuous and dynamic actions and is generally based on classic function of management consisting of planning, organizing, organizations, leadership, and control. Planning is the basis of management and is considered as the main process in the cycle of crisis management. Proper planning can lead us to organizational goals and implementation of the crisis management process by using the maximum power and minimum wastage of resources, of course, if this planning is within the framework of strategic plan of crisis management of a country. Earthquake is one of the natural complications that have continuously caused damage and the loss of many human lives during the history of the earth. As science and technology have gradually developed, especially in construction sector, resistance of structures has increased. For example, in Japan which is an earthquake-prone country, considerable progresses have been achieved and most earthquakes are less able to threaten the life of humans. One of the issues that most major cities around the world are grappling with is the issue of natural disasters. Given the

unexpected nature of most natural disasters and the need to take quick and correct decisions and doing operations, theoretical and fundamental basics have created an area of knowledge called "crisis managementt".

This knowledge involves a set of activities done before, after, and during a crisis in order to reduce the impact of disasters and vulnerability. Crisis managementt has a particular relation with issues of urban planning, urban management, and geography. By applying the principles and standards of urbanization and explaining the concepts of this knowledge such as form, texture, and structure of city; urban lands use; communication networks; urban infrastructures; and etc, impacts and consequences of natural disasters can be greatly reduced.

Geography of Iran is one of the most vulnerable parts of the earth in terms of the occurrence probability of these disasters, especially earthquakes. Each year, the occurrence of these disasters in Iran causes enormous financial and human losses and urban areas have always been facing with bitter experiences of such disasters. Hence, specific planning for more immunization of urban spaces seems necessary. Cities may receive more damages due to concentration of population and economic investments. Such spaces, from the beginning of their formation, have selected specific form and structure for growth and developed over time. Urbanization can execute the management principles required to reduce the vulnerability of cities against such disasters by explaining its own principles and concepts and using geographical data.

2.1. Process of seismic rehabilitation and retrofitting:

After geological, seismological, and geotechnical studies, seismic rehabilitation and retrofitting can be divided into the following four stages:

1- Study of architectural and structural drawings and preliminary seismic evaluation of the existing building.
2- Seismic evaluation considering the set goals.
3- Selection of rehabilitation solutions and evaluation of rehabilitated buildings.
4- Execution of selected plan for rehabilitation.

In other words, inspection of the building and qualitative and initial evaluation are firstly done. Then, full inspection and quantitative studies are performed. At this stage, it may be necessary to perform some tests or carvings on the building. This stage reveals that whether the building needs or doesn't need retrofitting. In the next stage, retrofitting plan should be proposed. After quantitative studies, if needed, building retrofitting plan will be provided in maps and instructions.

3.1. Implementation of retrofitting project:

At this stage, some parts of the building may be temporarily evacuated. Depending on the type of building and number of floors in private buildings, complete evacuation may be needed. Retrofitting cost is divided into three parts:

1- The cost of two above-mentioned steps which is roughly equal to the cost of redesigning the building.
2- The cost of the third stage varies depending on the type of building and retrofitting requirements, ranging from one to several times more than the cost of designing a building.
3- Implementation cost which completely depends on retrofitting project, but it usually costs more than operations in buildings under construction.

The first step is the prioritization of vulnerable buildings for rehabilitation by the employer. This will be the case when the employer is looking for a long-term program for seismic evaluation and rehabilitation of a series of existing buildings. Gathering raw data collected by seismic evaluation form, an experienced engineer and evaluator proposes an executive program for rehabilitation of assessed buildings to the employer. The second step deals with investigation of engineering, mechanical, and dynamical specifications of a building. Understanding the characteristics of a building would lead to a more accurate evaluation and providing a more appropriate retrofitting solution. Building features include characteristics of stairs and sections, the lineup and position of structural and non-structural components, performance and quality of the materials used, seismic and geotechnical hazards, and the results from a preliminary seismic evaluation that should be assessed by the project and informed to the employer. In the third step, in order to prepare implementation plans, the best options of rehabilitation meeting the acceptable standards are selected. Some of these standards are as follows:

1- Affordability
2- Feasibility
3- Possibility of supplying the materials in the area where the building is located
4- No need for heavy tools and equipment
5- It should have a short time of implementation and doesn't disturb the residents

In the fourth step, after consultation with the employer and also studying the rehabilitation plans and their economic justification, rehabilitation plan will be selected and implementation phase of operation will start with preparation of executive plans maps and appointing the contractor. Finally, the building will be rehabilitated and it would be known

that how much of the provided needs are feasible in this regard.

4.1. Objective of seismic rehabilitation and retrofitting:

The best rehabilitation and retrofitting program of reinforced concrete buildings should cover the appropriate performance (specified in the plan). Hence, the foundation of all steps of seismic rehabilitation and retrofitting should be well understood and recognized.

The main goals of seismic rehabilitation and retrofitting are as follows:

1- Providing resistance to minor earthquakes without damage.

2- Providing resistance to moderate earthquakes without any structural damage (However, some non-structural damages are probable).

3- Providing resistance to severe earthquakes that have already occurred in the building site or are likely to take place without collapse (However, some structural and non-structural damages are probable).

5.1. General criteria for seismic retrofitting:

In order to improve the seismic performance of buildings, structural elements present in their system can be enhanced or other elements can be added to them, so that their lateral strength and ductility are increased. When strengthening the existing elements or creating new ones, it should be noted that earthquake forces are not equally divided among the elements, so torsion effects on the structure should be prevented. When strengthening each structural element, other elements usually become weaker or more ductile.

Implementation of seismic rehabilitation in a structural system should be based on safety rules and regulations. Several methods can be expressed for structural reinforcement, most of them emphasize on issues such as usage change (reducing the importance of the building), structural weight reduction (removing a number of floors), lightening the building (non-structural elements), reducing the forces caused by earthquake, and demand reduction in the building. For example, if the seismic evaluation of the building reveals that the building is not adequate for the expected level of performance and rehabilitation cost to achieve a desired performance level is not justified, the loss of life and property in the building can be reduced by changing the usage of building or providing a weaker performance level. This is possible for governmental buildings or other similar one but not for apartments that each unit is owned by a particular person. For instance, by converting a hospital into an office building or an office building to a warehouse, the expected performance level of a building and its coefficient of importance can be decreased. Coefficient of importance is effective in the calculation of earthquake forces and the amount of base shear. As the coefficient of importance of a building is decreased, reduction in seismic design forces would be also effective. In proposing a rehabilitation plan for a building, the following items should be also mentioned and emphasized:

1- Prevention of destruction

2- Maintenance of output paths

3- Preventing the fall of the walls around the building like shelter wall

Finally, all studies and operations must satisfy the following equation:

Inventories > Requirements

This results in a balance between optimal and appropriate behavior of a building in order to achieve the required safety margin and minimizing uncertainties in determination of requirements and inventories. Above-mentioned equation shows that the following procedure should be observed for seismic strengthening of buildings:

1- Reducing the needs of the risks caused by earthquake.

2- Improving the behavioral characteristics and capacity of a building

3- Or a combination of these two

6.1. Practical strategies for seismic retrofitting:

Seismic retrofitting strategies aimed at increasing the strength, the hardness, ductility or decreasing the seismic force are implemented with the help one or a combination of aforesaid methods. The use of polymer fibers is a method that is currently being used in most countries for rehabilitation of vulnerable structures. Various reasons for the increasing trend of using polymer fibers in rehabilitation of buildings are related to the advantages of this system over the conventional materials. Some of these advantages are as follows:

1- Low weight

2- High resistance

3- Good strength-to-weight ratio

4- Faster operations

5- No need to heavy machinery for operation and installation

6- Ease of cut and installation

7- Affordability

8- Appropriate resistance to corrosion

9- Coordination with the architecture of building

10- Acceptable ductility

11- The ability to be pre-woven or post-woven

Polymer fibers are used as sheets and bars and the easiest way to use it is to enwrap them around the desired part of the building. This way, not only the compressive strength of that part but also the shear strength of column is increased. This method can

effectively prevent the mechanism of failure in short columns

2. Discussions

Study and proposing new methods for assessment of the seismic capacity of buildings in earthquake-prone countries are of great importance. Hence, in some of these countries, including the U.S. some projects to reduce damage caused by the earthquake have been started. However, it is difficult to provide an efficient and highly accurate method capable of full determination of earthquake risks and identification of vulnerable buildings. Given that Iran is an earthquake-prone country, the culture of retrofitting should be promoted throughout the country by governmental agencies including Civil Engineering Organization, municipalities, Housing Foundation of Islamic Revolution, etc. For example, municipalities in giving permits for mezzanines and usage changes and Engineering Organization, municipalities and Housing Foundation of Islamic Revolution in approving the plans and supervision of urban and rural buildings and also by employing professional and committed forces can play an important role in this regard.

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