ADDITION OF CONCRET SHEAR WALLS; A TYPICAL RETROFITTING METHOD FOR MASONRY BUILDINGS

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ABSTRACT

Following the destructive bam earthquake of 2003, the Iranian Government initiated a vast program of seismic retrofitting for existing important buildings throughout the country. Based on the obtained experiences, Seismic vulnerability and rehabilitation studies for each of thousands of existing buildings throughout the country, needs a long-term period of time and would make the project with limited budget, unachievable in the defined period. For this reason some new and typical methods for retrofitting of common type of buildings that would result in higher performance of structures and save the occupant lives in probable future earthquakes. Unreinforced masonry buildings which are widely constructed in urban areas of Iran and in many other countries are the most common type. An advantageous method for retrofitting of this type of construction is “Addition of concrete shear walls”. In this method some concrete shear walls are added to masonry buildings, along with other retrofitting details for the roof, foundation and masonry walls. This article aims to explain the method along with the scientific base, gained experience, details, governing rules and conditions.

INTRODUCTION

Natural disasters have long posed serious challenges for human kind and the efforts in controlling them, made initiatives for numerous progressions and achievements. Earthquake is undoubtedly is one of the most important natural disasters and the studies for understanding its phenomenon and its related disaster management have been placed in high priorities in last century. Iran is one of the most earthquake prone areas in the world and this situation makes it to be at the top of list of the countries with great casualties and financial losses. Statistics show that there is at least one major earthquake in each decade throughout the country. It is obvious that with public education and awareness, determination of vulnerability of the infrastructures and upgrading the seismic safety in dangerous zones, the loss of lives and financial damages can be declined dramatically (Instruction for seismic rehabilitation of existing buildings, 2007). However, this cannot be achieved without the contribution of the government. One of the most important undertakings of Iranian government in reducing the seismic vulnerability of the country against the earthquake is "Study and performing Retrofitting of the Important Buildings and Lifelines" which covers several important structural groups and was enacted in 2003 after the destructive Bam earthquake.

Based on the obtained experiences, Seismic vulnerability and rehabilitation studies for each of thousands of existing buildings throughout the country, needs a long-term period of time and would make the project with limited budget, unachievable in the defined period. For this reason introduction and use of some new methods for retrofitting of common type of buildings that would result in higher performance of structures in probable future earthquakes seems to be necessary (ElGawady, 2004). These approaches are named partial or typical rehabilitation. The main reason for choosing this term is that by retrofitting a building according to these new approaches, major structural deficiencies can be dealt with; however, some minor ones may remain (FEMA428, 2003). In development of these techniques, three main goals are under consideration: (a) Reducing the time of retrofitting projects studies, (b) Increasing the speed and quality of execution, (c) Reducing the cost of retrofitting process.

A REVIEW OF SEISMICITY OF IRAN

The Iranian plateau has a long seismicity record in the past. There are evidences indicating seismic actions before 3000 B.C. The intersection of Saudi Arabia, India and Eurasia caused Iranian plateau which is weaker than the others to deflect and become surrounded by the form of Zagros Mountains in the west, Alborz and kape Dagh in the north and northern east, Makran in the east and southern east. The earthquakes around Zagros is numerous and mean in magnitude. They are from little evaporating forming and without the surface cracking. However, Alborz seismic actions are far different from the Zagros's. The earthquakes in this region is rare but when occur, release enormous amounts of energy. The mountains and wrinkling in Iranian plateau has not yet become stable, so the seismic actions throughout the country are definitely expected. The scattering of the Iranian earthquakes in the past years is depicted in Figure (1). As can be seen in this figure, the difference between the Zagros and Alborz seismic actions is obvious.

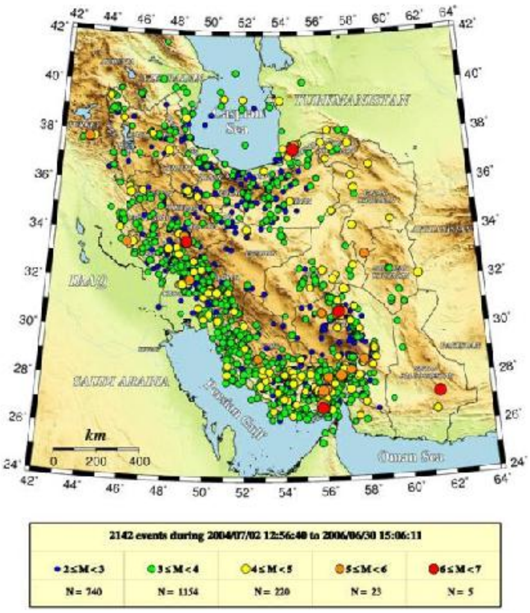

Figure 1. Scattering of the Iranian earthquakes in the past years

The concept of seismic risk is derived from the expected P.G.A of a specific region which is correlated to the size and activeness of nearby faults. By studying the active and inactive faults of each region, the seismicity map of that region can be developed. The seismicity of the world is presented in figure (2). According to this figure, the regions worldwide are categorized into 4 regions: low seismic risk, moderate seismic risk, high seismic risk and very high seismic risk. By taking a brief look at this map, the seismicity of Iran in comparison with other places in the world can be understood.

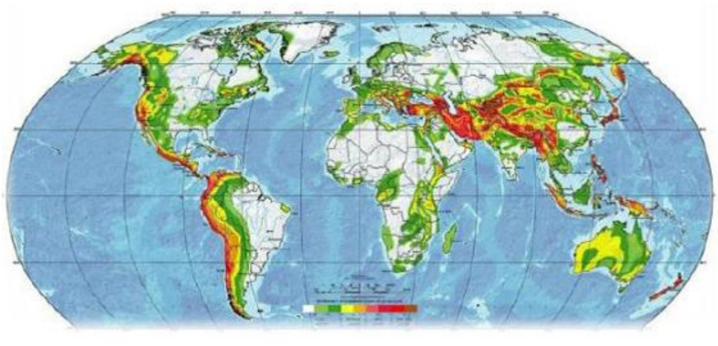

Figure 2. World seismicity

The more specific seismicity of Iran is shown in figure (3) based on the code 2800 (Iranian Code of Practice for Seismic Resistant Design of Buildings, 2005). As observed most of the regions are areas with high and very high seismic risk and almost nowhere in the country is immune from the earthquake danger.

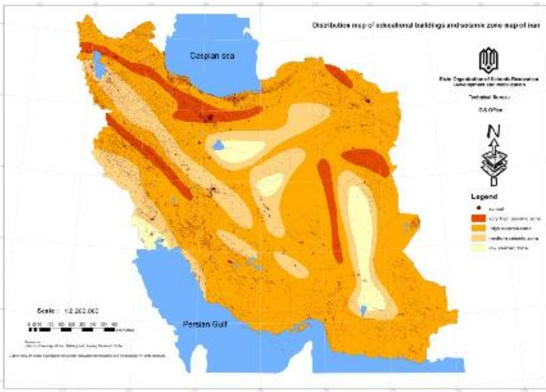

Figure 3. Seismicity of Iran

MASONRY BUILDINGS

Unreinforced masonry buildings are widely constructed in many countries. According to domestic statistics, most of the existing buildings in Iran and many other counties are masonry. This construction practice is widely used for the following reasons. (a) It is based on traditional masonry construction practice. (b) It does not require highly qualified labor. (c) It is cost-effective. (d) It has a broad range of application.

This construction type is addressed by the codes of the country. The first official issue about this type of building was in 1987. The Iranian Code of Practice for Seismic Resistant Design of Buildings (Standard 2800) addressed this type of construction. These types of building basically consist of unreinforced masonry wall panels. The wall panels are usually made of clay brick and cement-aggregate mortar. According to present seismic codes of masonry buildings in Iran, to maintain the integrity of the structure during an earthquake, wall panels must be confined at intervals and corners with reinforced concrete tie-columns and horizontal upper and lower tie-beams which the latter ones also act like foundation strips. The ties must be reinforced with longitudinal bars tied with stirrups. The gravity load-resisting system in this kind of structure is confined bearing masonry brick walls. In both directions of the buildings lateral load resisting systems are provided by masonry brick shear walls which are confined with concrete tie column and beams, too.

Existing unreinforced buildings, especially those constructed before the enforcement of seismic codes usually lack the necessary standards such as tie-columns and tie-beams. For this reason, they have long been recognized as the structures much vulnerable to earthquakes. The loss of life attributable to their collapse during earthquakes is well documented in many countries and most of the structural damage produced by earthquakes was suffered by URM buildings. These buildings dangerously lack structural integrity mostly because of tie columns and tie-beams absence. Many structural components just rely on contact and friction to transfer gravity and lateral forces. Thus, beyond a certain threshold of seismic excitation, the various structural elements especially the brick walls risk to separate and behave independently during an earthquake (Roy et al, 2013). Typically, walls especially the exterior ones may behave as cantilevers and fail in an out-of-plane manner, or global structural failure can occur by slippage of the joists and roof beams from their supports. Many visible separations of walls and floors have been reported after earthquakes. These buildings are also vulnerable to flexural out-of-plane failure. The unstable and explosive-like out-of-plane failure of URM walls can endanger the gravity-load-carrying capabilities of a wall and can seriously injure or kill occupants and passers-by. Excessive bending or shear may produce in-plane failures and familiar through-thickness cracks in masonry walls. In many cases, these more common cracks are over shadowed by simultaneous more spectacular type of failures, but nonetheless present. For URM walls, in-plane shear failures are expressed by diagonal shear cracking. Fortunately, until the shear cracks become unduly severe, the gravity-load-carrying capacity of the walls is not jeopardized. However, in-plane shear cracking which can produce triangular cantilever wedges can therefore help precipitate out-of-plane failure of the weakened wall (Dhanasekar, 2011). In addition, in many facades having numerous window openings, spandrels and the short peers between them may also fail in shear. Flexural failure is also possible for those slender unreinforced masonry elements.

Unreinforced masonry buildings which are widely constructed in urban areas of Iran and in many other countries are very common. Most of them in Iran are constructed out of brick walls. Existing unreinforced masonry buildings, especially those constructed before the enforcement of enhanced seismic codes, have long been recognized as the structures vulnerable to earthquakes. Masonry materials such as brick are intrinsically strong when compressed under the usual gravity loads but are weak in resisting earthquake forces, which make materials flex and also shear; 'shear' describes the tendency for a portion of the wall to slide (Magenes et al, 1997). When an earthquake shakes an unreinforced masonry building, it causes the building's walls to flex out-of-plane and to shear in-plane. Unreinforced masonry is weak in resisting both of those types of forces. Mortar is the "glue" that holds the masonry units together; however, when it eventually cracks, it does so in a brittle manner, similar to the way that the bricks crack. Generally speaking, older masonry construction was built using much weaker mortar than current building codes require. Mortar also tends to deteriorate in strength over time more than the masonry units themselves do (Hendry et al., 1997).

PARTIAL REHABILATION TREND

The results of the studies reveal that the retrofitting process in Iran is a very time consuming and costly one. Covering all the stages in this process for structures with close details and specifications is difficult and complicated. As a result, new methods and criteria for retrofitting projects are needed. The term of "partial rehabilitation" is applied to a new approach. The main reason for choosing this term is that by retrofitting a building according to this new approach, some minor structural deficiencies may remain in the aftermath. In this approach the time-consuming process of study are eliminated. Instead, very simple and fast methods are used to evaluate the capacity of the building and upgrading it to a determined level.

ADDITION OF COCNRETE SHEAR WALL METHOD

In this method there are some pre-prepared tables containing the capacity of the shear walls and the piles with known details of the reinforcements and concrete in different soils. In the following, the standard specifications have been presented. A typical engineer can simply calculate the base shear of the building and in doing so, can evaluate the required number and length of shear wall(s) for reaching the calculated base shear. In the calculation of the number and length of shear wall(s), the load-bearing capacity of the masonry walls is neglected. The roof of the buildings which should be retrofitted cording to this instruction is jack-arch and should be converted to the composite concrete one. Also specifications have been designed for the connection of the roof and the walls which leads to improvement of the in-plane and out-of-plane wall performance. In this method, 1m of the upper area of the wall is reinforced.

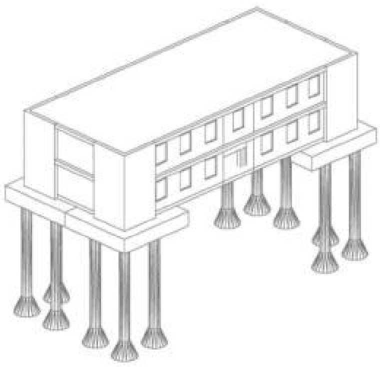

Figure 4. A perspective of retrofitted building by adding shear walls

The necessary conditions for the buildings chosen to be retrofitted by this method are as follows: (a) masonry buildings, preferably constructed by brick walls, (b) symmetric, (c) roof type must be jack-arch or concrete waffle slabs. The retrofitting design includes these stages:

A. Making the jack-arch slabs rigid by changing them to concrete composite roofs (Figures 5, 6).

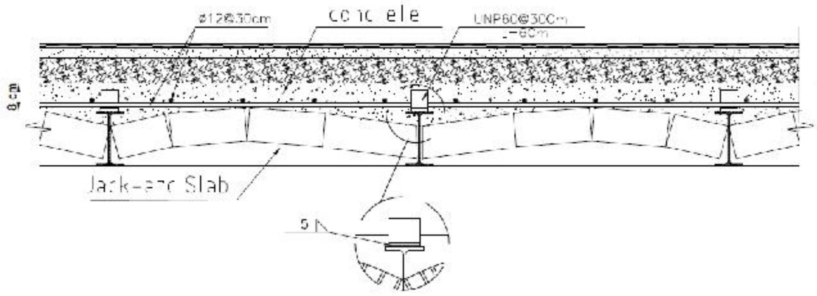

Figure 5. A sample detail for retrofitting of roofs

Figure 6. Sample pictures of retrofitting roofs

B. Restricting and controlling and reducing the free height of masonry walls by planting vertical bars in them (Figure 7).

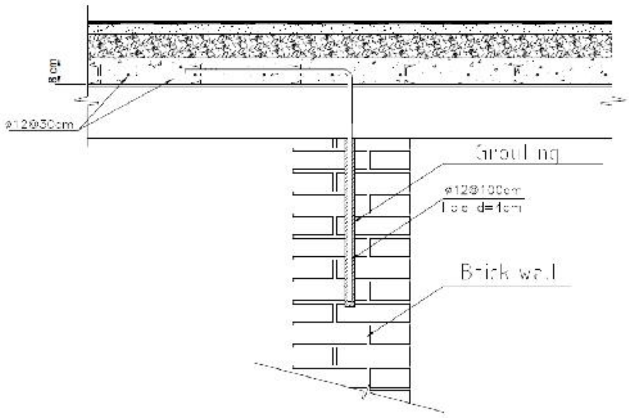

Figure 7. A sample detail of retrofitting brick walls

C. Designing the shear wall choices including the number, height, thickness, length, location of the shear walls and the details of the reinforcement. To accelerate the process of design, typical charts, regulations and drawings for various possible cases have been prepared (Figures 8, 9).

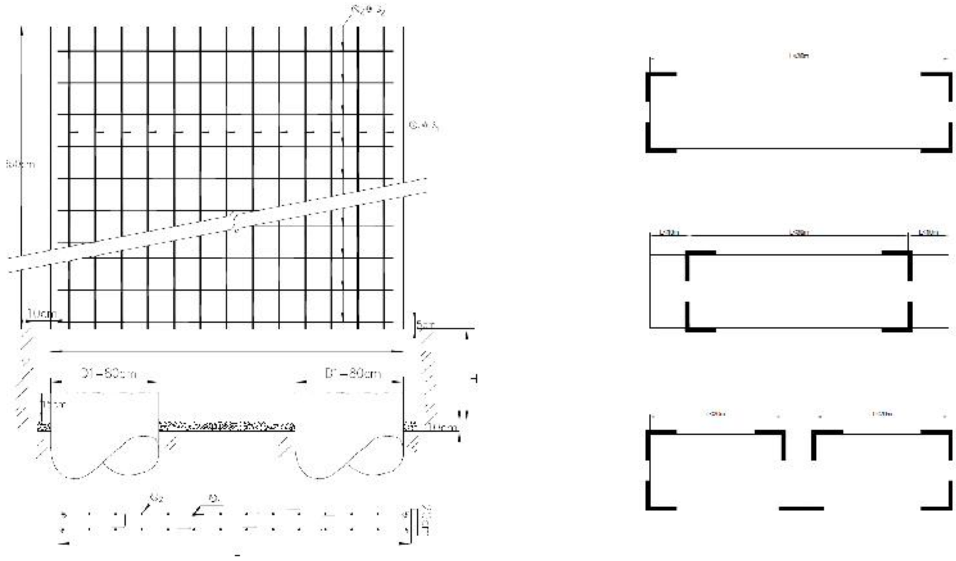

Figure 8. A sample detail of shear walls

Figure 9. Sample pictures of shear walls

D. Designing the foundation and piles needed for the shear walls. To accelerate the process of design, typical charts, regulations and drawings for various possible cases have been prepared.

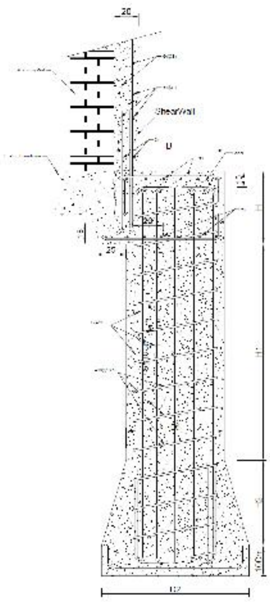

Figure 10. Sample details of piles

Figure 11. Sample pictures of piles

CONCLUSION

Iran is one of the most earthquake prone areas in the world and this situation makes it to be at the top of list of the countries with great casualties and financial losses. Vulnerability study and seismic retrofitting of existing buildings throughout the country is an important process for reduction of earthquake danger risk. Siesmic vulnerability and rehabilation studies for each of thousands of existing buildings throughout the country, needs a long-term period of time and would make this process with limited budget, unachievable in short period of time. For this reason some typical methods for retrofitting of common type of buildings, that would result in higher performance of structures in probable future earthquakes, seems to be useful. "Addition of concrete shear walls" described in this article, is a powerful typical retrofitting method for masonry buildings. The investigations done and experiences show that this method can improve the performance of structures against earthquakes greatly. It can also reduce the time of retrofitting studies, cost of retrofitting process and increase the speed and quality of execution.

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