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Comparison on Repair and Strengthening Techniques for Unreinforced Masonry Structures

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ABSTRACT
Masonry structures are estimated to include more than 70% of the residential unreinforced masonry buildings (URM) in the world. The structures are highly vulnerable to earthquake shaking which leads to unacceptably many losses, even in moderate earthquakes. Most of the losses are gave rise to by failure of masonry structures. As destruction of the masonry structures is usually not possible owing to several factors, this increases the question if the buildings had better to be retrofitted. Therefore, comparative study on repair and retrofitting methods safety of masonry structure has important advantages and drawbacks. This paper aims to investigate into repair and strengthening methods of masonry structures, advantages and disadvantages. In addition, we presented most suitable seismic retrofitting methods for unreinforced masonry structures considering efficiency and economic problems. It has been show that surface treatment methods and Re-pointing are more preferable for unreinforced masonry structures owing to their low cost as well as a no requirement for high working capacity.

Keywords: Masonry structures, rehabilitation, earthquake, buildings, safety

I. INTRODUCTION

Stone masonry is a traditional form of the structure that has been practiced for hundreds of years in regions where stone is locally available [1]. The predicted that approximately 80% of the structures inventory worldwide is the buildings [2]. There is formed losses in masonry structures owing to external effects. Most of the losses are caused by failure of URM buildings. Therefore, it is important that strengthening techniques of the masonry structure. [3]. The main aim of the seismic retrofitting is to advance the resistance of a damaged construction while repairing thus it becomes reliable under coming earthquake occurrences [4].

Masonry structures represent a large portion of the residential masonry buildings in the world. Previous studies have showed that many researchers have focused their studies on reinforced concrete structures. However, research into seismic retrofitting of masonry structure is rare while URM is one of the most popular types of construction. Thus, repair and strengthening techniques is important for masonry structures. In this study, the basic concept and the general procedures of seismic retrofitting were discussed first, followed by an extensive review and comparison of various retrofitting techniques. It is expected that the review and discussion provide useful information to practising engineers on how to choose a suitable technique to retrofit the building effectively.

II. RETROFITTING METHODS FOR MASONRY STRUCTURES

2.1. Surface Treatment

Surface treatment is a common method developed significantly through the experience. The approach of strengthening method the surface of unreinforced masonry walls, it is used for old buildings with architectural worth. The strengthening techniques are shotcrete, bamboo and fiber reinforced polymer. Many researchers have studied for shotcrete method advantages and disadvantages [2-9]. Retrofitting using shotcrete significantly increases both shear and flexural capacities ultimate load of the retrofitted walls. The mesh aids to restrict the masonry units later cracking and so improves inelastic deformation capacity. However, shotcrete is expensive because considerable materials and labour are involved with placement. Bamboo-band mesh is obtained from this fiber. The strengthening techniques improve the seismic capacity of the unreinforced masonry building significantly. The method has also high strength and no need for special workers [10-12].

Many researchers have carried out experiments to investigate the efficiency of different types of FRP rehabilitation techniques for enhancement of the seismic resistance of the masonry walls. Some of the major contributions in this regard are available [11–21]. Many studies revealed that there could be significant increase in load carrying capacity, energy absorption and ductility in case of retrofitted walls as compared

with unretrofitted URM walls. However, FRP strengthening technique has high cost, high electric conductivity and low impact resistance. Since, the of the surface the method is not appropriate for old masonry buildings with architectural value.

2.2. Stitching and Grout/Epoxy Injection

Grout injection method is one of the most widely used strengthing methods for masonry structures. Most of time, the method is used for reestablishing the bond in the cracks of the wall. The popularity use of this technique is because of minimal cost, availability of material and ease of implementation without requiring much technical rigor. The method is a classical method of rehabilition, which has the advantage of not changing the architectural aspect of the building [20-24]. Nevertheless, the main disadvantage of the method has been high shrinkage and segredation.

2.3. Re-pointing

Re-pointing is a traditional retrofitting technique commonly used especially historic masonry structures. The technique consists in washing, removing, cleaning, filling the mortar joints with a new mortar. This mortar should have been compatible with the characteristics of the masonry units, resistant to agents of deterioration and almost the same mechanical properties and durability as the original one [5,31].The advantages in the use of the technique may be enlisted as minimal cost and convenience of implementation [11]. The technique reduced surface preparation and preservation of aesthetics, the application of steel bars in the grout matrix across the joint cracks [5,14].

2.4. Post-Tensioning

Post-tensioning of structural masonry has been advanced by recent research and is increasingly being used for new construction as well as the strengthening of existing structures. The technique has reduced cracking deflection under service loads; significant increase in strength and ductility. It does not also alter the appearance of the structure historical structures [25-27]. However, the method has been somewhat costly and shrinkage of masonry. In addition, the biggest disadvantages of the method are that external straps and connections might affect the architectural aspect of the buildings and post tensioning elements being external are exposed to corrosion.

2.5. Confinement

Confinement strengthening technique, tie columns confine the masonry structure wall at intersection, corners, and the border of openings. Scientists have done many studies regard to the performance of the technique [20,28]. The method improves the in-plane deformability and energy dissipation of a masonry structure The retrofitting method has improved flexural strength, ductility and in-plane shear strength of the wall However, confinement method in rehabilition is that its labor requirements are very large.

2.6. Center Core

Center Core method is improved method for strengthening of unreinforced masonry structures. The method is a non-destructive method which might be reached without evacuation of the structures. The method is related to the possibility to preserve the architectural aspect of the building and intervention can be carried externally. However, the main disadvantage is given by the fact that highly qualified personel, high tech equipment and strict quality control are needed. Moreover, the technique tends to create zones with common varying stiffness and strengthing properties [12,20].

2.7. L-Shaped reinforcement

A recent study has been carried out to investigate the performance improvement in URM by strengthening the junction, the most vulnerable part of a masonry wall, using L-shaped reinforcement. For L-shaped reinforcement, steel bars of was used in alternate layers to strengthen the junction. The method has clearly shown about fold increases in strength due to the retrofitting options adopted [11,32]. L-Shaped composite material strengthening system include high flexural strength and shear strength. It has provided strength and stiffness in the in-plane direction. However, the method causes corrosion**.**

2.8. External reinforcement using steel bars

Steel tie rods are the most common and most ancient retrofit solution. If properly designed in terms of posttension force, tie rods allow a better connection between orthogonal walls, ensuring a universal type of structural response. They should be anchored to the wall through steel plates, with appropriate dimensions to allow the correct distribution of stresses to the wall [28]. The application of steel bar method is used in case of the structures with poor interconnections between the intersecting walls, flexible roofs and floors. The main advantages are developing the overall structural behaviour by ensuring seismic cooperation between structural elements [30].

2.9. Three dimensional tying system

Strengthening of masonry system can also be achieved by means of tying masonry together with 3D Tying System [33]. The most improvement technique in the behaviour of the walls was observed

in terms of increase of ductility and energy dissipation.The energy dissipation is reported to have increased 30-60 times.

The seismic retrofitting and rehabilitation techniques are important to understand the seismic performance of unreinforced structures in order to retrofit existing buildings. [34-44]. The aim of the seismic strengthening is to advance the seismic resistance of a damaged construction while repairing so as to becomes safer under future earthquake occurrences.

III. RETROFITTING METHODS FOR MASONRY STRUCTURES

Seismic retrofitting is important for unreinforced masonry buildings. There are some techniques in practice or under research that are also suitable for implementation. Each the retrofitting technique has its own advantages and drawbacks, when a technique is appropriate for one building. The selected method should be consistent with aesthetics, strength, ductility and the cost requirements. According to literature survey, Table 1 summarizes advantages and drawbacks of each strengthening method for unreinforced masonry structures.

Table 1. Advantages and disadvantages of each strengthening method for URM

Method	Advantages	Drawbacks
Shotcrete	-high deformation - high stability -high ultimate load	- expensive - labour placement - high mass
Bamboo	- low cost - high strength - high input energy	- high disturbance - affects architecture
FRP	- improve resistance - easy application - increase ductility	- high cost - high electric conductivity
Stitching and grout injection	- easy application - not changing the architectural aspect - minimum cost	-high segredation - high shrinkage - irreversible action
Re-pointing	- minimal cost - low deformation	- lead corrosion
Post tensioning	- increase ductility - easy to apply - reducing cracking	-somewhat costly -shrinkage and creep - corrosion -anchorage problem
Confinement	- high energy - increase ductility - increase flexural strength	- labor requirements - high disturbance - high cost
Center core	- safe resistance - not alter appearance	- high cost - high technology requires
L-Shaped Reinforcement	-high resistance - high strength	- corrosion
Steel bars	-overall structural behaviour -no corrosion	- loss of historical material
3D Tying System	- increase of ductility - high energy dissipation	- corrosion

IV. CONCLUSION

The main aim of the seismic retrofitting is to advance the resistance of a damaged building while repairing so it becomes safer under the coming seismic formations. There are many advantages and disadvantages of these methods.

- Epoxy injection method, increase in strength the confinement improved the lateral deformations and energy dissipation. Nevertheless, the main disadvantage of this method has been high shrinkage and segredation.
- Re-pointing improve the shear and bending moment and minimal cost of masonry structures. In addition, this technique o reduced surface preparation and preservation of aesthetics.

- Confinement technique has improved flexural strength, ductility and in-plane shear strength of the wall. However, confinement method in rehabilition is that its labor requirements are very large.
- Center Core method that highly qualified personel, high tech equipment and strict quality control are needed.
- L-Shaped reinforcement increases the resistance of building by preventing junction failure. Nevertheless, the method causes corrosion.
- Shotcrete is more suitable and less costly than cast-in-situ jackets.
- The methods of strengthening among should be recommended surface treatment methods and Re-pointing for unreinforced masonry structures owing to its low cost as well as a no requirement for high working capacity.

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