CHAPTER 1

INTRODUCTION

1.1 GENERAL

Masonry is defined as “the art of shaping, arranging and uniting stone, brick, building blocks and other materials to form walls and other parts of a building”. It is one of the most important construction material. It has been used for public and residential buildings during the past several thousands of years. A great number of well-preserved old masonry structures still exists proving that this form of construction can successfully resist loads and environmental impact.

Masonry has been popular through the ages for its fire resistance, strength and durability. However, the combination of weight, stiffness, and weakness against tensile forces makes traditional masonry buildings highly vulnerable to extreme loading such as earthquakes. This is not only the case in developing countries. It is also the case in most of the developed regions of the world. Vibrations caused by earthquakes generate additional loading, the consequent stresses developed also cause damage to structural elements. Since the masonry, which can be stressed relatively high in compression, is weak in resisting bending and shear and hence it very often collapses. Therefore, masonry has been considered unsuitable in earthquake resisting constructions since long time.
However, in the last few decades, considerable research on the behaviour of masonry walls and buildings subjected to seismic actions has been carried out in many countries. Use of strong mortars, high strength masonry, added reinforcement, improved detailing and the introduction of good anchorage between masonry walls and floors, masonry walls and roof have enhanced the resistance of masonry to seismic loadings. These improvements enable the masonry building to act as a box-type structure. Vertical gravity loads are transferred from the floor and roof which act as horizontal tension element to the bearing walls, which in turn support the floors and act as vertical compression members. During earthquakes, floors and roofs act as horizontal diaphragms that transfer the seismic forces that are developed at floor level, and are transferred to the walls. In addition to this, floors and roofs connect the structural walls together and distribute the horizontal seismic forces among the structural walls in proportion to their lateral stiffness.

1.1.1 Un-reinforced Masonry

Un-reinforced masonry can be defined generally as masonry with no reinforcement in it. The terms “un-reinforced” and “masonry” both are more precisely described in the present chapter. Masonry is made of earthen materials and includes the sub-types such as bricks, stones, adobes, etc. The most common un-reinforced masonry materials used for the walls of buildings are bricks and hollow concrete blocks.

1.2 NECESSITY OF STRENGTHENING

Masonry structures were built during ancient times when no appropriate theory and good knowledge were available. People usually built their houses according to the knowledge and experience in vogue at that time. So, many buildings which still exist do not satisfy the present guidelines.
Also, the recent worldwide earthquakes make people more conscious about the safety of life and property. Some of the famous buildings which become valuable in terms of culture and history demand a longer service life.

It is also a common issue that the place which used to be a residential area some years ago might now become an industrial area. Therefore, people would usually desire to change the use of their previous building. Sometimes there may be mistakes during construction. So, a number of reasons may be attributed for strengthening the existing buildings.

Masonry structures are the oldest civil engineering structures. Due to lack of scientific and modern knowledge, they were really built with the available knowledge, experiences and empirical evidence in vogue. These structures are vulnerable to extreme loadings such as blasting, earthquake, wind, etc. With the passage of time, restoration and strengthening are needed, many of the structures are of cultural value and also possess good social characteristics. At the beginning of the restoration process, many strengthening techniques had been suggested by the researchers. Some of them might have improved structural performance very much. Also, depending on the structures, site and local availability of materials, many strengthening techniques were developed and used in different locations of the world. Recently, FRP (Fibre Reinforced Polymer) has become the most popular material for strengthening, as it overcomes many disadvantages compared to other techniques. FRP can be applied to almost all types of structures despite uniqueness of every structure. At the time of selecting possible repair or strengthening solutions, it is also essential to consider the principles of conservation and the modern criteria for the analysis and restoration of historical structures. These criteria are: minimum intervention, reversibility, non-invasiveness, durability and compatibility with the original materials and structure. Cost should also be considered though; it is not within the criteria. Generally, considering these principles and criteria, the
best solution is found out among a set of alternative possibilities or a combination of different techniques.

1.3 BACKGROUND AND NEED FOR RESEARCH

Un-reinforced masonry (URM) structures comprise a considerable proportion of the building stock worldwide. Many existing URM structures around the world are vulnerable to failure due to out-of-plane and in-plane loading from extreme wind or earthquakes. Due to several failures of masonry structures during earthquakes, the development of new techniques for strengthening or repairing masonry structures is in high demand. The URM structures are often in need of repair due to degradation by environmental factors or increased live loading.

A masonry building with openings at different locations is a complex structure and it is very difficult to understand its behaviour when it is subjected to ground induced lateral vibrations. To understand the complex behaviour of masonry buildings during ground motion, sophisticated facilities such as a shaking table with data acquisition systems are needed. However, the test on a full-scale prototype is an expensive proposition, especially when parametric studies are to be carried out. In the context of the study of earthquake resistant features, test on small scale model becomes indispensable. Here, tests are conducted on small scale models in order to obtain the response characteristics of a geometrically similar full scale prototype. Also, in order to observe improved performance and modes of failure, URM panels were strengthened with different patterns of externally bonded FRP laminates to be tested under out-of-plane loads.

1.4 RESEARCH SIGNIFICANCE

The research presented herein describes a methodology for the repair and retrofit of URM buildings using fiber reinforced polymer (FRP)
composites. This methodology can be directly applied to structures that have been damaged due to significant lateral loading or structures that are substandard and need to be retrofitted and, as seen in this thesis, can significantly enhance the strength and performance characteristics of these structures. As compared to traditional repair/retrofit methods, this new methodology is appreciably more cost-effective as well as less intrusive.

1.5 IMPORTANCE OF THE STUDY

One of the greatest threats from a blast or an earthquake comes in fragmentation of pieces of walls, windows, furniture and equipment which can result in extensive injury, cause damage to the properties and prove fatal too. A key tactic in mitigation of such catastrophic effect is to eliminate or reduce the fragmentation resulting from the Unreinforced Masonry Wall (UMW) by making them act as one unit, rather than as small bricks. There are several conventional methods available to strengthen the UMW to improve its resistance to blast and earthquake stresses. In recent years, however, strengthening of UMW with FRP sheets has received quite a lot of attention from researchers and practitioners and is regarded by many engineering societies as the best and the most economical alternative to provide the needed protection.

1.6 OBJECTIVES OF THE STUDY

- To study the failure pattern of simple masonry elements with and without GFRP wrapping subjected to base shock vibrations for out-of-plane loadings.
- The behaviour of GFRP wrapped masonry elements compared with conventional masonry elements in terms of first crack load, Energy Absorption, Velocity of Impact,
Cumulative Energy, Peak Base Acceleration (PBA) and Peak Response Acceleration (PRA).

- To investigate the interaction between different schemes of FRP laminates used to strengthen Unreinforced Masonry Wall (UMW) and the increase in capacity and ductility of the UMW when subjected to out-of-plane loading.

- To carry out analysis using a general purpose FEA software and to deduce the acceleration for a predefined fixed frequency.

- To assess the accuracy and performance of available analytical formulations from masonry standards of masonry walls and to compare the experimental results with the values obtained from numerical and analytical study and to understand the failure modes.

1.7 **SCOPE OF THE INVESTIGATION**

1. To construct 1/3 model of unreinforced masonry panels without and with plastering.

2. To develop a shock table.

3. To install the model masonry panel on the shock table.

4. By using a pendulum of varying mass and height of fall, give repeated impacts to the base of the table.

5. For each impact, record time-history of acceleration, calculate energy absorption, and to note failure pattern.

6. To strengthen the masonry panels with GFRP wrappings of different patterns.
7. Repeat the base impact tests as in step 4 in the case of GFRP strengthened panels also.

8. Establish the failure patterns of GFRP strengthened panels.

9. Simulate both un-strengthened and strengthened panels using FEA software package.

10. To perform numerical analysis and collect all the parameter that was recorded in the experiments.

11. Compare both values and draw conclusions.

1.8 ORGANIZATION OF THE THESIS

This thesis consists of 8 chapters.

Chapter 1 comprises general and formal requirements of the thesis. The background, scope and objectives of this thesis have been discussed.

Chapter 2 presents a comprehensive state-of-the-art literature review conducted on FRP reinforcement. The review includes published reports and articles on completed research pertinent to the use of FRP used for URM.

Chapter 3 deals with the various types of FRP materials, its uses, advantages in improving the stability of URM by retrofitting with FRP.

Chapter 4 discusses the various tests conducted with bricks, cement and sand.

Chapter 5 presents the details of the experimental program including the design of the test specimens, the construction of the specimens, the test setup, the instrumentation and the test program.
Chapter 6 consists of an analytical approach during the finite element model analysis programme using ABAQUS to identify the key parameters influencing the impact response on un-strengthened and GFRP strengthened masonry wall specimens with and without plastering conditions.

Chapter 7 discusses in detail the experimental and numerical results, and the observed behaviour of the URM walls investigated in this study.

Chapter 8 summarizes the major findings of the research and presents recommendations for the possible future research in the field. It also presents a brief and concise conclusion and recommendation for further studies.