BEHAVIOUR OF UNREINFORCED LIMESTONE BRICK WALLS WITH OPENINGS UNDER IN-PLANE AXIAL LOADS

BY

AMR MOHAMMED SALAH ZAID MAHMOUD SHERIF

A Thesis Submitted to the
Faculty of Engineering, Cairo University
In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

STRUCTURAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

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Title of Thesis : **BEHAVIOUR OF UNREINFORCED LIMESTONE BRICK WALLS WITH OPENINGS UNDER IN-PLANE AXIAL LOADS**

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Summary :

Since the ancient times, Egyptians have used the Limestone Bricks for building most of their structures. This is due to its high strength, durability and availability in the surrounding environment. Nowadays it is widely being used for building small structures (homes and farms) in rural areas especially in the North cost of Egypt, because it is widely available with a relatively low cost and has an adequate Strength for supporting the floors above. People uses unreinforced Limestone masonry walls system to support reinforced concrete slabs; this system is used up to three story buildings but unfortunately with no design calculation .

In this experimental investigation different unreinforced limestone walls were tested. Different properties were measured such as the mode of failure, crack pattern initial modulus of elasticity and maximum strength. There are three main variables tested for the walls, location of the opening, size of the opening and using diagonal reinforcement around the opening.

It was found that, the walls with window opening had 2.43% higher ultimate strength than the walls with door opening. The walls with middle opening had 13.11% higher ultimate strength than the walls with side opening. The walls with reinforcement around the opening had 10.17% higher ultimate strength than the walls with no reinforcement around the opening.

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Amr Mohamed Salah Zaid,

Dedications

In Dedication to my parents for making me who I am, my brother and wife for supporting me all the way also last but not least my angel, my daughter Dalida.

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ABSTRACT

Since the ancient times, Egyptians have used the Limestone Bricks for building most of their structures. This is due to its high strength, durability and availability in the surrounding environment. Nowadays it is widely being used for building small structures (homes and farms) in rural areas especially in the North cost of Egypt, because it is widely available with a relatively low cost and has an adequate Strength for supporting the floors above. People uses unreinforced Limestone masonry walls system to support reinforced concrete slabs; this system is used up to three story buildings but unfortunately with no design calculation.

In this experimental investigation different unreinforced limestone walls were tested. Different properties were measured such as the mode of failure, crack pattern initial modulus of elasticity and maximum strength. There are three main variables tested for the walls, location of the opening, size of the opening and using diagonal reinforcement around the opening.

It was found that, the walls with window opening had 2.43% higher ultimate strength than the walls with door opening. The walls with middle opening had 13.11% higher ultimate strength than the walls with side opening. The walls with reinforcement around the opening had 10.17% higher ultimate strength than the walls with no reinforcement around the opening.

Chapter 1. : Introduction

Builders in the ancient times used rock brick walls to build most of their structures, due to its high strength in supporting vertical loads, durability and availability in the nature with no need for manufacturing. The word masonry is usually used to describe bricks, stones, tiles or combination of them connected with binding material. Also masonry is considered a built-up construction as it is a combination of numerous building materials like the rocks, clay bricks, glass, mortar,…etc.

The rocks are divided from geological point of view to three main types, first the Sedimentary rocks which are formed by deposition of clay particles by water or air then reconnected by a binding martial. The main types of sedimentary rocks are Limestone and sandstones. Second the Igneous rocks which are volcanic rocks, which is formed by the melting of its components then cooling to form the rock, the main types of igneous rocks are granites and basalt. And the third is the metamorphic rocks which are originals sedimentary or igneous rock that are affected by external factors to form a new material. The main types of metamorphic rocks are marble and slates.

The most important Physical properties of rocks for it to be used as a building material, are strength, hardness, durability and shaping. The Strength is the most important property for the rock as a building material as it measures the load capacity carried by the rock till failure. The Hardness is the ability of the rock to resist scratches, it is very important for the rocks used in floors like marble and granite. The durability is the ability of the rock to resist the environmental effects that cause decay or damage to the rock which is very important to external walls where the natural effects like rain, wind, direct sun light and pollution are to the peak. The shaping is the ability to make the rock in a required form (shape and dimensions) to be used as bricks, very hard rock is not preferred to be used as a building rock as it is very hard to shape.

There is one more property which is not a physical property but is very important in selection of rocks which is the availability and the presence of the rock in the environment near where it will be used to reduce the transfer or shipping cost.

The main types of bricks used in buildings are the burnt clay bricks, the lime stone bricks and the concrete blocks. The limestone bricks are the most commonly used in Egypt as a bearing wall in the rural places and north cost of Egypt where it is widely available with an economic price and has an adequate strength for supporting the floors above.

People use limestone as a brick wall system carrying a reinforced concrete slab, in the rural places. This system is used for building up to three story structures but unfortunately with no structural design calculations made to verify the safety of the structure which puts the human lives in these structures at risk.

1.1. OBJECTIVES

The main objective of this thesis is to study the behavior of unreinforced limestone masonry walls with different opening size and location with or without diagonal reinforcement around the opening. Lime stone bricks 120 mm x 120 mm x 400 mm extracted from a quarry in Hammam city in the north coast of Egypt were used for this experiment.

Nine walls were tested under uniform vertical distributed load at the top of the wall. This study focused on the effect of the opening size, location and the diagonal reinforcement around the opening.

1.2. Thesis layout

This thesis is organized in five chapters as follows:

Chapter (1): is the introduction to the thesis which contains general data about the building stones, then discretion of the research plan.

Chapter (2): is the literature review of the thesis including the history of previous works done in the area of the research.

Chapter (3): describes the experimental work of this study, including description of the tested walls, material properties, the prism results, test setup and procedure.

Chapter (4): explains the test results of each wall, discussion and comparison between different walls to observe the effect of studied variables.

Chapter (5): is the conclusion of the thesis and recommendation for future research.

Chapter 2. LITERATURE REVEIW

2.1. General

Ancient builders used masonry walls made of rock to build their homes, temples and all other buildings because of their high strength in vertical loads, high durability and its availability in the nature with no need for manufacturing.

The Structural designers nowadays consider the masonry walls as a non-structural element that can only carry its own weight in a vertical direction, and consider it as additional load on the building, which is uneconomic and illogic as the strength of the walls if taken into consideration in the design phase can reduce the total cost of the building. In some rural places builders use the brick walls as the main vertical supporting element for their residential buildings and farms, the problem is that they don't use any structural design procedures to check the safety of the walls and their load capacity to reach the most economic and safe design. The main types of bricks used in buildings are the burnt clay bricks, the lime stone bricks and the concrete blocks. The limestone bricks are the most commonly used in Egypt as a bearing wall in the rural places.

N. Taly [1] classified the types of masonry from structural point of view, as two types, reinforced and plain masonry. The plain masonry are the natural or fabricated bricks made of burned clay, concrete, stone, glass, gypsum and any other similar type of bricks connected by cementitious material. Plain masonry is a type of building depending on the compressive strength of the bricks. The plain masonry have very low tensile strength which makes it not adequate to be used in members resisting tensile forces like horizontal structural elements (slabs and beams) or eccentrically loaded columns. To overcome this issue reinforced masonry is used to increase the tensile strength of the masonry formation. Masonry can be used as a structural or non-structural element, it also can be hollow or soild, reinforced or unreinforced, single or multi-Wythe, depending on the designer selection.

2.2. Load capacity of masonry walls

Load bearing wall is one of the most ancient building techniques. Man has laid one stone upon another and constructed walls to support the rooftop. This structural system was then changed to frame structures for coast issues. M. Maroliya [2] studied the construction of hollow concrete block masonry. Three sets of wall built with various mortar ratios 1:3, 1:4, 1:5 were tested in the compression testing machine. Each set consists of three walls. The concrete blocks gave different results when tested under the same conditions because it is a non-homogeneous material. The load carrying capacity of the walls and the crack patterns developed due to the load were studied. The hollow concrete blocks were tested in compression testing machine. The two surfaces of each block were termed as faces.

T.T. Bui and A. Limam [3] studied the effectiveness of the discrete element method (DEM) to simulate the behavior of masonry walls subjected to in plane and out of plane bending moment loading. The effectiveness of the DEM was estimated for all nonlinear behavior from the appearance of cracks, related stress redistributions, cracks out of plane and maximum load. The toughness was also