UNIVERSITI PUTRA MALAYSIA

STRUCTURAL BEHAVIOUR OF INTERLOCKING HOLLOW BLOCK PANEL WITH STIFFENER SUBJECTED TO AXIAL AND ECCENTRIC LOAD

FARES A. SHEHAB.

STRUCTURAL BEHAVIOUR OF INTERLOCKING HOLLOW BLOCK PANEL WITH STIFFENER SUBJECTED TO AXIAL AND ECCENTRIC LOAD

By

FARES A. SHEHAB

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, In Partial Fulfillment the Requirement for the Degree Of Master Of Science

October 2005

Dedicated To My Parents, Brother and Sister

Abstract of thesis presented to the Senate of Univerisiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

STRUCTURAL BEHAVIOUR OF INTERLOCKING HOLLOW BLOCK PANEL WITH STIFFENER SUBJECTED TO AXIAL AND ECCENTRIC LOAD

By

FARES A. SHEHAB

October 2005

Chairman: **Associate Professor Waleed A. M. Thanoon, PhD**

Faculty: **Engineering**

The search for more rapid construction that need ordinary labor has led to the development of interlocking masonry system in which the walls can be assembled without using any mortar layer. The assembled hollow blocks in the wall provide continuous hollow voids, which can be used to host stiffeners in vertical and horizontal directions to enhance the integrity of the wall. However the effects of reinforced concrete stiffeners on the structural response of the interlocking walls are still not known and require further investigation.

This research is mainly focused on the structural behavior of interlocking hollow block walls with stiffener constructed using PUTRA interlocking hollow block under axial and eccentric vertical load.

Experimental program includes testing of individual block units, interlocking prism and full scale interlocking walls. Since the compressive capacity of a wall is defined in terms of compressive strength of the block unit used to construct the wall, the compressive strength of different individual block unit was evaluated by testing 40

block units for each type of block used to assemble the wall stretcher ,half and corner block units.

Furthermore three course grouted prisms were tested and compared with un-grouted prisms to explore the effect of grout on prism strength; these results were compared with results presented by other researchers.

Five wall specimens of 1.2 m width and 3.0 m height were tested under the effect of axial and eccentric vertical loads considering different eccentricity of 40 and 55 mm. The research aims to investigate the effect of two different stiffeners layout on their structural response compared to the walls without stiffener highlighting the difference between interlocking walls with stiffener and conventional bonded masonry walls using mortar layers. In the first layout, the reinforced concrete (R.C.) stiffeners were located at the perimeter of wall, while in the second layout the stiffeners were located at wall perimeter as well as horizontal stiffeners at mid height of wall. The structural responses of tested panels were monitored in terms of wall efficiency, deformation characteristics strain distribution reduction in wall capacity due to effect of eccentric load cracking and failure mode.

The testing results show that the presence of stiffeners has improved the behavior of tested panels by increasing the load carrying capacity of stiffened panels by 15% to 30% compared to un-stiffened specimens. Furthermore the horizontal stiffener located at mid height of wall plays important roles in the capacity of wall and its failure mode.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk memperoleh ijazah Master Sains

KELAKUAN BERSTRUKTUR PANEL BLOK BERONGGA KAIT PANCA TERKAKU DI BAWAH BEBAN PAKSI DAN EKSENTRIK

Oleh

FARES A. SHEHAB

October 2005

Pengerusi: **Professor Madya Waleed A. Thanoon, PhD**

Fakulti: **Kejuruteraan**

Pencarian ke arah pembinaan lebih pantas yang bergantung pada kerja tangan yang berkurangan telah menghasilkan pembinaan sistem masonri kait panca yang melibatkan pemasangan dinding tanpa menggunakan sebarang lapisan mortar. Blok geronggang yang terpasang pada dinding menyediakan ruang kosong berongga yang berterusan yang dapat digunakan sebagai tempat pengikat kestabilan (pengkaku) arah menegak dan melintang untuk menambah kestabilan dan integriti dinding. Walau bagaimanapun kesan pengkaku konkrit diperkuat terhadap gerak balas struktur dinding kait panca masih tidak diketahui dan memerlukan penyiasatan lanjut.

Penyelidikan ini terutamanya berfokus pada tingkah laku struktur dinding blok berongga kait panca yang dibina dengan menggunakan blok berongga kait panca Putra di bawah beban tegak paksi eksentrik.

Program eksperimen termasuk pengujian unit blok individu prisma kait panca dan dinding kait panca skala penuh. Oleh kerana keupayaan kompresif sebuah dinding itu didefinisikan dari segi kekuatan kompresif unit blok yang digunakan untuk membina dinding, kekuatan kompresif unit blok individu yang berlainan telah dinilai dengan cara menguji 40 unit blok bagi setiap jenis blok yang digunakan bagi memasang dinding iatu unit blok stretcher, corner dan half.

Seterusnya tiga prisma campuran cair diuji dan disbanding dengan prisma bukan campuran cair untuk meneroka kesan grot terhadap kekuatan prisma. Semua keputusan ini dibandingkan dengan keputusan yang diperoleh daripada penyelidik lain.

Lima spesimen dinding berukuran 1.20m lebar dan 3.00m tinggi telah diuji di bawah kesan beban paksi menegak dan eksentrik dengan mengambil kira keessentrikan berbeza 40 dan 55 mm. Penyelidikan ini bertujuan untuk menyiasat kesan dua susun atur pengkaku yang berbeza dari segi gerak balas struktur mereka berbanding dengan dinding tidak berpengkukuh dengan mengutamakan perbezaan antara dinding berpengkukuh perbezaan antara kait panca dan masonri terikat konvensional menggunakan lapisan mortar. Dalam susun atur pertama pengkaku konkrit terkukuh ditempatkan pada perimeter dinding di samping pengkaku melintang pada ketinggian tengah dinding. Gerak balas struktur bagi panel yang diuji telah dipantau dari segi keberkesanan dinding, ciri-ciri deformasi, pengurangan penyebaran terikan bagi keupayaan dinding disebabkan kesan rekahan beban eksentrik dan mod kegagalan.

Keputusan ujian menunjukkan bahawa kehadiran pengkukuh telah menambah baik tingkah laku panel yang diuji dengan menambah keupayaan membawa panel terkukuh sebanyak 15% hingga 30% berbanding dengan specimen yang tidak terkukuh. Tambahan pula pengkukuh yang terletak pada ketinggian tengah dinding memainkan peranan penting dalam keupayaan dinding dan mod kegagalannya.

ACKNOLDGEMENT

In The Name of ALLAH Most Gracious Most Merciful

It's my pleasure to express my deep thanks and gratitude to my Supervisor Assoc. Prof. Dr Waleed A Thanoon, who introduce me to this field, for his valuable time of discussion and supervision, my great thanks to Assoc. Prof. Ir. Dr. Mohd Saleh Jafaar, Assoc. Prof. Ir. Dr. Mohd Razali A Kadir, and Assoc. Prof. Dr. Jamaluddin Noorzae for their valuable time, direct supervision and discussion.

Many great thanks to structural laboratory staff for their valuable assistance, especially Mr. Hadi for his assistance in producing of blocks, Mr. Halim for the valuable time in helping fixing test set up.

I would like to express my deep gratitude to my parents' brother and sister for their kind support

Finally ALLAH will bless all friends in UPM.

FARES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATION

f_k:	is the compressive strength of masonry.
γ_{mm}	is the partial safety factor for masonry
b	is the width of masonry section
d_c	is the effective depth of masonry section
t	is the thickness of wall section
f_y	is the yield stress for steel reinforcement
A_{s1}	is area of steel under compression
A_{s2}	is area of steel under tension
γ_{ms}	is partial safety factor for steel reinforcement
N	is design axial load
h_{ef}	is effective height
b_t	is cross section width

CHAPTER I

INTRODUCTION

General

Masonry is one of man's oldest building materials used in construction. Interlocking hollow block is recently used in construction of non-load and load bearing walls. The main concept of this new masonry system is the elimination of mortar layers in the wall, and instead blocks are stacked to assemble the wall.

There is actually limited research on the behavior of interlocking wall systems which is essential in order to compare the behavior of the interlocking wall systems to the conventional masonry using mortar layer. This study highlights the structural behavior of the stiffened interlocking hollow block walls in which the tested wall panel is categorized into two groups; the first one is stiffened with perimeter stiffener while second one stiffened with perimeter stiffener and mid height bond beam.

Problem Statement

Currently there is no standard available for the design of load bearing interlocking block system. the structural behaviour and design parameters for this system are expected to be different than the conventional load bearing wall system. This research is mainly focused on the structural behavior of interlocking hollow block walls with stiffeners constructed using PUTRA interlocking hollow block under effect of axial and eccentric vertical load at the top of wall.

For load bearing walls the designer can provide **stiffener** in order to improve the axial stiffness or lateral stiffness or the both for structure. (Mckenzie 2001)

Building codes state that situation should be avoided where damage to small area or failure of single element could lead to collapse of major parts of the structure. The provision of effective ties is necessary precaution to prevent progressive collapse. The layout also must be such as to give a stable and robust structure. However there are several types of ties as peripheral ties, internal ties, horizontal ties to column and walls, and vertical ties. (Macgniley and Choo 1990)

Scope and Objective

The main scopes and objectives of this study are:

1) To investigate the structural behavior of interlocking hollow block wall with stiffener under axial and eccentric loads.
2) To study the structural behavior for the two groups of tested panels in which the first group is reinforced with perimeter stiffener and the second one is reinforced with perimeter stiffeners and mid height horizontal stiffener.
3) To study the effect of eccentricity in reducing the strength of tested panels.
4) To investigate the failure mode of interlocking hollow block walls.

Organization of Thesis

The thesis is divided into five chapters; a brief description on the content of these chapters is presented below:

Chapter One: highlights the definition of the problem along with the scope and objectives of the study

Chapter Two: highlights the critical literature review on interlocking block and traditional masonry.

The experimental program will be highlighted in Chapter Three, with all necessary information regarding the specimens, boundary conditions, and method of test.

Chapter Four: The outcome of the results provides a clear picture about the strength capacity and behavior of the tested specimens.

The reached conclusions along with the recommendations for future research are highlighted in Chapter Five.

CHAPTER II

LITERATURE REVIEW

General

The traditional method of masonry construction is a time consuming process due to the presence of a large number of mortar joints. Early attempts were made to increase the size of the masonry units (blocks instead of brick) thereby it would reduce the number of mortar joints. The use of bedding mortar imposed constraints on the number of layers to be constructed daily.

The need to accelerate the rate of construction led to the elimination of bedding mortar and the development of non conventional methods in masonry construction, interlocking block system was one of these developments. The elimination of bedding mortar accelerates construction by reducing cost, and eliminates variations results from workmanship and moisture penetration.

This chapter covers the structural behaviour of bonded masonry as well as interlocking masonry system.

Conventional Masonry System

Prism Test

Drysdale and Hamid (1983) investigated the effect of void percentage and grout strength on the behaviour of prism. The prism was half unit width (390 mm) three courses high (570 mm) with thickness of 190 mm using eight however The considered eccentricities were t/6, t/3 and 5t/12.

The result shows that the failure mode of the prism is not influenced by the percentage of voids in the block, when the load was applied at eccentricity of 0 and t/6. At t/6 eccentricity, splitting tension failure occurred at the compression side of grouted prisms. Tensile debonding of mortar at tension side was observed when the load applied at higher eccentricity of t/3 and 5t/12. The failure started by the development of crack along mortar joint followed by compression failure on opposite side. The results show that the grout increases the ultimate capacity particularly for small eccentricity of applied load.

Figure 2.1 shows that the eccentricity prism strength relation by using different types of grout. Comparing the test results of the same eccentricity shows that even very large changes in the quality of grout do not result in significant changes in relative strengths.