UNIVERSITI PUTRA MALAYSIA

STRUCTURAL BEHAVIOUR OF LOAD-BEARING INTERLOCKING HOLLOW BLOCK MASONRY

AMAD M.S. NAJM

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By

AMAD M.S. NAJM

Thesis Submitted in Fulfilment of the Requirement for the Degree of Master of Science in the Faculty of Engineering

Universiti Putra Malaysia

May 2001

Dedicated to my beloved

Family and Friends

Abstract of thesis submitted to Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Associate Professor Waleed Abdel Malik Thanoon, Ph.D.

Faculty : Engineering

The structural behaviour of an interlocking block system has been investigated in this research. The interlocking blocks developed by the Housing Research Center, Universiti Putra Malaysia have been used to assemble a number of prisms and wall panels. This interlocking block system has been filed for a patent. Three types of individual blocks are utilized in this research, these are stretcher, corner and half block units.

The research covers the production of the block using a manually controlled machine which has been developed for the production of the three different types of block. The test program includes testing of individual blocks, prisms and different wall panels.

Forty individual blocks have been tested under axial compression. Ten prisms have been tested under axial load. The failure mechanism were recorded for each type of

specimen. Sixteen wall specimens having different height (slenderness ratio), subjected to load applied at different eccentricities, have been tested. The selected heights of the tested walls are 1.2, 1.8, 2.4 and 3.0m. The eccentricity of the applied load is another important parameter considered in testing the wall specimens to simulate the actual nature of the applied load in construction. The values are 0, 20, 40 and 55mm measured from the centerline of the wall panels. The structural behaviour of the wall panel specimens were studied in terms of the load-deflection characteristic, strain-stress distribution, efficiency of the wall and the failure mode of the interlocking walls.

The study focuses on the differences and similarities of the behaviour of interlocking walls compared to bonded walls. BS 5628: Part 1: 1978 was used to explore the behaviour of the bonded walls. The study showed that the strength of the interlocking block and its interlocking mechanism were sufficient and that the block can be used for construction of load bearing walls.

Based on the test results, a number of mathematical equations have been proposed to predict the reduction in the wall efficiency with the increases of the eccentricity of the applied load and the slenderness ratio of the wall. A design procedure has also been proposed to be used in the design of load bearing interlocking hollow block system.

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

KELAKUAN STRUKTUR
SISTEM BLOK BERONGGA TANGGUNG BEBAN KAIT PANCA

Oleh

AMAD M.S. NAJM

Mei 2001

Pengerusi : Profesor MadyaWaleed Abdel Malik Thanoon, Ph.D.

Fakulti : Kejuruteraan

Dalam penyelidikan ini, kelakuan struktur sistem blok berongga kait panca telah dikajkan. Blok kait panca ini yang telah dibangunkan oleh Housing Research Centre, Universiti Putra Malaysia telah diguna untuk menghimpunkan beberapa panel prisma dan dinding. Ianya juga telah difailkan untuk tujuan paten. Tiga jenis blok individu telah digunakan dalam penyelidikan iaitu unit blok 'stretcher', 'corner' dan 'half'.

Penyelidikan ini merangkumi pengeluaran blok dengan menggunakan mesin kawalan manual yang menghasilkan ketiga-tiga jenis blok tersebut. Program ujian termasuk pengujian ke atas blok individu, prisma dan dinding panel yang berbeza.

Sebanyak 40 blok individu telah diuji di bawah mampatan paksi bersama-sama dengan kiub. Manakala 10 prisma telah diuji di bawah beban paksi. Mekanisme kegagalan telah direkodkan untuk setiap spesimen. 16 spesimen dinding yang berlainan

ketinggian (nisbah kelangsingan), bergantung kepada beban yang dikenakan pada sifat atau kelakuan yang berbeza juga telah diuji. Ketinggian yang dipilih untuk dinding adalah 1.2m, 1.8m, 2.4m dan 3.0m. Sifat beban yang dikenakan merupakan salah satu parameter penting dengan mengambilkira ujian dalam spesimen dinding yang menyerupai keadaan sebenar yang digunakan dalam pembinaan. Nilai yang digunakan adalah 0, 20, 40 dan 55mm; diukur dari garisan tengah panel dinding tersebut. Kelakuan struktur untuk spesimen panel telah dikaji dari segi ciri-ciri beban pesongan, pengagihan daya regangan-tegangan, kecekapan dan mod kegagalan dinding saling mengunci.

Kajian ini juga difokuskan pada perbezaan dan persamaan kelakuan dinding kait panca berbanding dinding terikat. BS 5628:Part 1; 1978 telah digunakan untuk mengkaji kelakuan ikatan dinding tersebut. Kajian ini menunjukkan bahawa kekuatan dan mekanisme blok ini adalah sangat sesuai dan boleh digunakan dalam pembinaan dinding tanggung beban.

Berdasarkan kepada keputusan ujian, berapa persamaan matematik telah digunakan untuk melihat pengurangan dalam keupayaan dinding dengan menambah sifat beban yang dikenakan dan nisbah kelangsingan pada dinding. Prosedur rekabentuk telah dicadangkan untuk digunakan dalam merekabentuk 'Sistem Blok Berongga Kait Panca Tanggung Beban'.

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ALLHAMDULILAH

I certify that an Examination Committee met on 26th May 2001 to conduct the final examination of Amad M.S. Najm on his Master of science thesis entitled "Structural Behaviour Of Load-Bearing Interlocking Hollow Block Masonary" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science.

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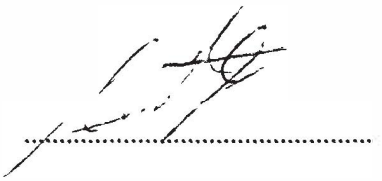
Date: 12 JUL 2001

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or other institutions.



AMAD M.S. NAJM

DATE: 8 / 6 / 2001

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LIST OF SYMBOLS

f_{cu} Compression strength of the cube.

f_{cb} Compression strength of the individual block unit.

f_{cp} Compression strength of the prism.

f_k Design strength of the interlocking load bearing wall.

SR Slenderness ratio of the wall equal to height divided by the least dimension of the wall (height / thickness of the wall).

β Strength reduction factor (efficiency) of the wall. It is equal to f_k / f_{cb}.

e Eccentricity of the applied load measured from the centerline of the wall in (mm) and it is equal to the moment divided by the axial load (M/P).

SF Appropriate safety factor (1.5-2.5) depend on the quality control of manufacturing the interlocking block.

CHAPTER 1

INTRODUCTION

1.1 General

The world started to use the hollow blocks as building materials at the beginning of the 20th century. Throughout the eighty years of application, it has been shown that hollow blocks can be used as structural, fencing and decorative materials. Hollow block has good heat, sound and fire insulation properties. Moreover earthquake resistance can be greatly improved after the introduction of steel bars in the hollow block construction for multistory structures. In addition to the above, its simplicity, efficiency, flexibility low cost of production are also responsible for it to being popularly used in the construction industry.

The use of structural masonry may result in cheaper and faster construction of structures compared with the conventional approach of framed building construction. Structural masonry eliminates the need for beams and columns of the framed structure hence it leads to a significant saving on costly formwork and construction material in addition to reducing the construction time. The concrete blocks in use today which are not of the interlocking type look quite uniform but their dimensions actually vary so much that mortar is necessary not only to hold them together but also to adjust the level at each layer.

Interlocking block work system is promoted as a new building technique that may result to a more economical construction. The use of interlocking load bearing hollow blocks in building construction will further speed up the construction process as a result of the elimination of mortar layers. Being light and with self-aligning features, the interlocking hollow blocks can be assembled much faster compared to the conventional mortar masonry construction. New parameters have arisen in using the new block system and considerable research is required to understand the structural behavior of the system and to establish the design procedure. The alignment of the interlocking system can be achieved by suitable and efficient design. Moreover, the interconnection between the blocks has to be designed to withstand the different stresses developed in the wall due to the applied load. Practically the shapes of the block must be as simple as possible for easy production and construction.

1.2 Significance of the research

In Malaysia, the supply of houses by both public and private sectors is still far from meeting the demand, especially in the low cost housing sector. For the purpose of developing and promoting a new system, that is fast in construction and more economical, the use of interlocking hollow block systems is adopted. This research is aimed at assessing the feasibility of using the new design of interlocking hollow block in the construction of residential or official buildings.

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1.3 Scope

To understand the load-bearing characteristics of the Putra block and to develop design procedures for the load bearing walls using interlocking hollow blocks.

1.4 Objective

The purpose of this research is:

- To study the structural behavior of interlocking block system in terms of crack pattern, load-deflection, strain-stress distribution, ultimate load capacity and modes of failure.
- To study the effects of slenderness of the interlocked block wall on its structural behaviour.
- To study the effects of different eccentricities observed in walls have been considered.
- To provide design recommendations for un-stiffened interlocking load bearing walls subjected to axial and eccentric loading.

The tests include individual block units, prisms and wall panels.

1.5 Layout of the thesis

This thesis is divided into 5 chapters; a brief description of the content of these chapters is presented below:

The first chapter contains the introduction and the scope of the study. Chapter II is devoted to the literature review, which includes topics related to the development of the interlocking system. Chapter III covers the methodology employed in this study presenting the procedures implemented to conduct the experimental work. In chapter IV results of the experimental works were demonstrated and discussed. Chapter V is devoted to the conclusion and recommendations for future work.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Presently, hollow block construction is adopted as one of the building construction systems in many countries in the world. It is used quite substantially in the construction of high-rise and apartment buildings. According to practical experience hollow block construction system is most economical for four to seventeen story buildings. The advanced facilities in the hollow block production plant leads to better quality and quantity of the produced block. The search for more rapid and less workman ship dependent building system has led to the development of interlocking dry stackable block masonry units which can be laid without mortar layers. Interlocking hollow block system (IHBS) is a new concept to render the hollow block construction more economical and faster compared with the framed structure. If the interlocking mechanism in the interlocked block is capable of developing good bonding between the blocks and the courses to withstand all the stresses developed due to the applied load, it will be crucial competitor in the construction industry. In the last thirty years many countries are known to be interested of developing and implementing this system in the low cost housing scheme. Many claimed in saving cost and time when this construction system is implemented.