UNIVERSITI PUTRA MALAYSIA

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The interlocking hollow block system (IHB) is used recently for the construction of loadbearing and non loadbearing walls. The IHB system draws the attention of engineers and scientists all over the world due to its simplicity and lower construction cost, in addition to its good structural performance. The mechanical interlocking between different block units are designed to replace the mortar layers.

This study covers the theoretical investigation of different hollow block systems in terms of their mechanical, physical and structural properties. The research focus mainly on the structural analysis of " Putra block " which is an interlocking hollow block system developed recently by the Housing Research Centre at UPM. The analysis of the putra interlocking hollow block has been carried out using the finite element method. The Finite Element analysis covers the structural behaviour of an individual block, interlocking prism and panel walls using different types of interlocking blocks i.e. stretcher, half and corner block, under vertical and horizontal loads.

The structural behaviour of individual blocks , prisms and wall panels are studied in terms of stress distribution, deformation and the location of the maximum stresses as

well as failure load. In addition, the effect of eccentricity of the vertical axial load on the ultimate load capacity of the wall panel has been investigated.

The maximum compressive stresses developed in the individual blocks (stretcher, half and corner block) are 3.92 MPa, 3.16 MPa and 2.95 MPa respectively, while the maximum tensile stresses are 1.47 MPa, 1.43 MPa and 0.92 MPa respectively.

Interlocking block prism has been modeled using interface elements between blocks. The maximum compressive and tensile stresses have been found to be equal to 4.65 MPa and 2.38 MPa respectively.

A panel wall with dimensions of 1200 mm W x 1200 mm H x 150 mm T has been elastically analysed under uniformly distributed load. The result obtained indicates that the stress distribution is similar to the stress distribution observed in the prism.

Interlocking block panel has been nonlinearly analyzed under concentric and different eccentricities loading (0.05t, 0.1t, 0.2t, and 0.3t). The failure loads obtained were 25.63, 24.0, 22.4, 19.95 and 17.96 N/mm^2 respectively. The efficiency of the panel wall with the increase of the eccentricity of the load have been compared with the experimental observations.

Panel walls with heights of 2.0 m, 2.4 m and 3.0 m have been nonlinearly analysed under lateral load and the maximum lateral displacements observed in different walls are 6.96 mm, 8.28 mm and 11.89 mm respectively. The failure load decrease with increasing the height of the panel. The joint opening in the tensile side of the wall has been observed. The opening suddenly increases to a large value when the applied load approaches the failure stress, indicating a brittle failure mechanism.

The overall conclusions drawn from this investigation indicates that the theoretical analysis performed in this study indicates possible cracking in the webs when the putra block is used to construct loadbearing walls in 5-storey buildings and considered critical. This is due to neglecting the geometric nonlinearity and initial imperfection, which is quite possible in the construction field.

the construction of loadbearing walls in 1-2 storey buildings. While, more comprehensive experimental and theoretical study is required to ensure the applicability of putra block in 5- storey building.

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

ANALISIS UNSUR TERHAD BAGI BATU BLOK MENYANGGA BEBAN PANCA BERONGGA

Oleh

IDIB S. SADOUN
Disember 2000

Pengerusi : Profesor Madya Waleed A. Thanoon, PhD

Fakulti : Kejuruteraan

Sistem Batu Blok Panca Beronggga (BBPB) digunakan untuk membina dinding sama ada yang menyangga beban atau yang tidak. Sistem BBPB ini telah menarik perhatian para jurutera dan saintis di seluruh dunia mamandangkan pembinaannya yang mudah dan murah, malah dapat membina struktur yang baik. Panca mekanikal antara unit batu blok yang berlainan direka bentuk khusus untuk menggantikan lapisan motar.

Kajian ini mencakupi penyelidikan teori tentang sistem batu blok berongga yang berlainan dari aspek ciri mekanikal, fizikal dan strukturnya. Fokus kajian ini terutamanya ialah analisis struktur batu blok Putra yang merupakan batu blok panca berongga yang direka bentuk oleh Pusat Penyelidikan Perumahan di UPM baru-baru ini. Analisis terhadap batu Blok Panca Berongga Putra telah dijalankan dengan menggunakan kaedah Unsur Terhad. Analisis Unsur Terhad merangkumi gelagat struktur setiap batu blok, prisma panca dan panel dinding yang menggunakan jenis batu blok panca berongga yang berlainan; iaitu blok peregang, blok sudut dan separuh; dan dinding yang menyangga beban secara menegak dan melintang.

Selain itu, kajian ini turut melihat kesan percapahan paksi beban secara menegak terhadap keupayaan menanggung beban maksimum pada panel dinding.

Asakan kompresif maksimum yang diletakkan pada setiap satu batu blok (blok peregang, blok separuh dan blok sudut) masing-masing ialah 3.92 MPa, 3.16 Mpa, dan 2.95 MPa, manakala asakan regangan maksimum masing-masing 1.47 MPa, 1.43 MPa, dan 0.92 MPa.

Prisma batu blok panca yang dijadikan model telah menggunakan unsur antaramuka pada blok . Asakan kompresif dan regangan didapati seimbang, iaitu masing-masing dengan 4.65 MPa dan 2.38 MPa. Panel dinding dengan ukuran 1200 lebar X 1200 mm tinggi X 150 mm panjang telah dianalisis dengan keadaan yang berbeza-beza berdasarkan bebanan yang disebarkan secara seragam. Hasilnya menunjukkan bahawa taburan asakan tersebut adalah sama seperti taburan asakan yang ditinjau pada prisma.

Panel batu blok panca telah dianalisis secara tidak linear dengan asakan beban secara berpusat dan asakan beban bercapah yang berbeza-beza (0.05t, 0.1t, 0.2t, dan 0.3t). Bebanan yang tidak dapat disangga masing-masing 25.63, 24.0, 22.4, 19.95 dan 17.96 N/mm². Pengurangan keupayaan panel apabila percapahan beban bertambah telah dibandingkan dengan BS 5628 Bahagian 1 1978 kod keperluan bagi tembok mortar bangunan batu, dan tinjauan melalui uji kaji.

Panel dinding dengan ketinggian 2.0m, 2.4m, dan 3.0m telah dianalisis dengan bebanan pada bahagian sisi dan Sesaran sisi maksimum yang didapati pada tembok yang berlainan masing-masing 6.96 mm, 8.28 mm, dan 11.89 mm. Beban yang tidak dapat disangga semakin kurang apabila ketinggian panel bertambah. Keterbukaan penyambung pada bahagian regangan dinding turut ditinjau. Bahagian yang terbuka menjadi lebih luas apabila beban yang disanggakan menghampiri asakan tepu, dan ini menunjukkan mekanisme yang tidak mantap.

Keseluruhannya dapat disimpulkan bahawa daripada kajian ini menvnjukan bahawa analisis teoritikal yg dijalonkan dalam kajion ini menunjukan adanya veretakan pada jarring apabila blok putra digvnakan untuk membina menyangga beban pada bangvnan stinguat adalah dijanguauan kiritikal. Ini adalah disebabkan pangabaian ketidaksamaan geometric dan ketidak sempponaan podo awa pembinaan bagaimarapor, blok ini masih boleh digunav-an didalam pembinaan tembok yong boleh merampong beban didalam pembinaan bangunan I-2 tingkat. Namun, kajian yang lebih mendalam dan kajian teori diperlukan untuk menjamin keupayaan blok Putra sebagai bahan binaan untuk bangunan lima tingkat.

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A	Cross section of area
L	Length
W	Width
H	Height
h	Horizontal direction
v	Vertical direction
e	Eccentricity
Ec	Modulus of elasticity of concrete
f_{cu}	Characteristic strength of concrete
Z	Global z-direction
Y	Global y-direction
X	Global x-direction
SZ	Stress in global z-direction
SY	Stress in global y-direction
SX	Stress in global x-direction
Sy	Stress in local y-direction
Sx	Stress in local x-direction
f_g	Grout compressive strength
f_m	Masonry compressive strength
ß	Capacity reduction factor
σ_{tu}	Characteristic tensile cube strength of concrete in MPa
σ_{cu}	Characteristic compressive cube strength of concrete in MPa

CHAPTER I

INTRODUCTION

General

Due to rapid development in Malaysia. There is a need to build different categories of houses within a limited time to meet the increasing demand in the housing sector. Hence, a number of building systems have been developed in Malaysia by different overseas companies.

The building system must satisfy all the normal building construction requirements, such as to be structurally efficient, durable and environmentally friendly. In addition, the building system required for housing construction must be developed fast enough to meet the time limit required for development. The cost is another important factor which everybody is interested in.

Interlocking Hollow Blocks (IHB) are recently used in the construction of non-loadbearing walls and loadbearing walls. The main concepts of Interlocking Hollow Block system (IHBS) are the elimination of the mortar layers and instead the blocks are interconnected through providing key connection (protrusion and groove). The elimination of the mortar layers in the IHBS will speed up the construction and reduce the number of skilled and unskilled workers required to construct similar mortar blocks constructions.

The stresses developed in the wall due to the applied loads will be resisted by the connected parts of the blocks. The complex interaction between different parts of the block under different types of stresses requires more comprehensive investigation in order to provide the designer a clear picture on the mechanism of load transfer. Most of the published research focus on testing the Interlocking Hollow Block systems experimentally, Published data are available on the theoretical analysis on normal masonry but no published data are available on the theoretical analysis and design procedures of Interlocking Hollow Block system.

Significance of the study

In the absence of any theoretical analysis to provide sufficient technical information about the IHBS, this study will highlight the properties which affect the structural behaviour of different IHBS.

The interlocking mechanism plays a significant role in the distribution of the stresses developed in the block due to the applied load.

This study will provide useful information regarding the properties and interlocking mechanisms of the blocks. In addition, the F.E. modelling and results will clarify the mechanism of the stress distribution under different loading conditions.

Furthermore, the non-linear analysis will identify the failure load and hence, will be very useful for the design of the wall.

SCOPE AND OBJECTIVES

The main scope of this study include:

1. A critical review of literature on:
   a. The existing IHB systems and their design parameters.
   b. Finite element modelling of interlocking masonry walls.
2. Analysis of different interlocking block units.
3. Modelling and analyzing individual blocks, prism and wall panels under vertical and lateral loading using the finite element method within elastic and inelastic range of loading.
4. Analysis of the effect of eccentric vertical load on the overall response of the panel wall.
5. Prediction the failure load and/or the maximum tensile stresses in the block system.

The main objective of this study are:

1. To investigate the structural response of the interlocking hollow individual block, prisms and panels subjected to different loading conditions.
2. To investigate the structural behaviour of IHB system to trace the mechanism of stress transfer between the blocks through the interlocking keys.

Organization of the Thesis

The thesis is divided into five chapters. A brief description of the content of these chapters is presented below:

The importance and the definition of the problem chosen for the present investigation have been highlighted in chapter I along with the scope of the study. In chapter II a critical review of literature of the interlocking hollow block system is presented. The review covers experimental work done on the different interlocking hollow block systems and the theoretical work on the masonry walls using Finite Element Method. Chapter III deals with the analysis of different interlocking hollow block units which consider physical, structural and constructional requirements. The finite element models used to simulate the interlocking block system for individual blocks , prism and panel wall is also presented in chapter III. The analysis of results obtained from the finite element analysis are presented and discussed in chapter IV. Chapter V is devoted to the conclusions drawn from the study carried out in this thesis, together with suggestions for further research in this area.

CHAPTER II

LITERATURE REVIEW

Introduction

Techniques for casting hollow blocks in wooden moulds were developed about 1866. A fairly dry mixture of sand, cement and water was placed in the mould and tamped manually. Hollow block manufacture using simple machines was gradually improved, but it was not used until 1914, when the power tamping replaced hand tamping. In 1924 , a stripper machine for remolding was successfully introduced (Chai, K.S.,

Hollow blocks are used widely for the construction of non loadbearing walls in reinforced concrete structures. This chapter reviews the development and performance of interlocking hollow block available in different parts of the world. Moreover, the analysis of different block walls subjected to different load using finite element is discussed.

The Development of Interlocking Hollow Blocks

Thallon (1983) used interlocking blocks developed in USA to construct a house. The interlocking blocks used are shown in Figure 2.1. During the manufacturing process, the blocks went through a machine that grinds the top and bottom surfaces to a tolerance of 0.12 mm. These parallel and smoothly ground surfaces allowed the block to be laid