



**UNIVERSITI PUTRA MALAYSIA**

***STRUCTURAL BEHAVIOR OF STRENGTHENED INTERLOCKING  
LOAD-BEARING HOLLOW BLOCK WALL WITH OPENING SUBJECTED TO  
AXIAL AND SEISMIC LOADS***

**CHOY WAI KENT**

**FK 2010 28**

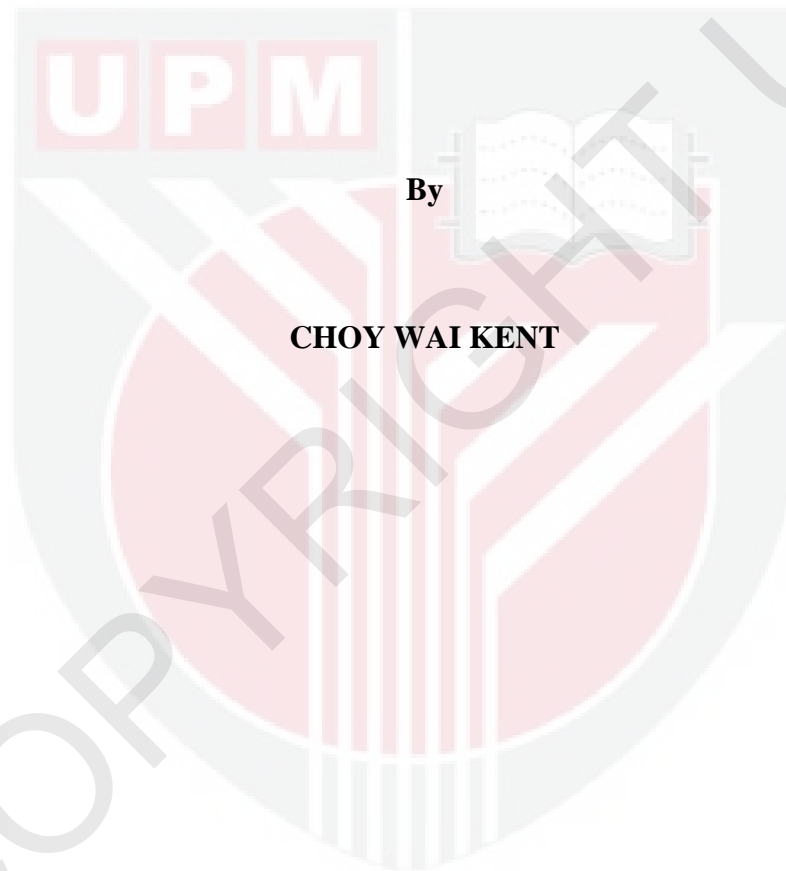
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**MASTER OF SCIENCE  
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2010**

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SUBJECTED TO AXIAL AND SEISMIC LOADS**



**By**

**CHOY WAI KENT**

**Abstract of thesis submitted to School of Graduate Studies, University Putra  
Malaysia, in fulfilment of the requirements for the degree of Master of Science**

**April 2010**

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

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**CHOY WAI KENT**

**April 2010**

**Chairman : Prof. Abang Abdullah Abang Ali**

**Faculty : Engineering**

This thesis presents the results of an investigation on the strengthening of interlocking load bearing hollow block walls with opening subjected to axial and seismic loads. Wall panels built using PUTRA block building system, developed by the Housing Research Centre, Universiti Putra Malaysia, were used in the study.

In this study, 3.0 m × 3.0 m wall panels with four types of openings were analysed with four types of strengthening methods using finite element method. The four types of openings representing openings for a single panel window (0.6 m × 1.2 m), single panel door (0.9 m × 2.0 m), double panel window (1.2 m × 1.2 m) and 1 ½ panel door (1.5 m × 2.0 m) were studied. For axial load study, non-linear analysis method was used to obtain the failure load of each wall. For seismic load study, spectral response analysis was performed based on the seismic intensity to obtain the maximum stress and maximum displacement for the walls with different types of openings and strengthening methods.

The research involved the development of a finite element model of PUTRA block wall panels using the LUSAS software and verification of the compressive strength of the finite element analysis results with those experimental results by earlier researchers. The verification included block, prism, 1.2m wall, 3m wall, 3m wall with stiffener and wall with opening.

The study focused on the structural behaviour of the strengthened interlocking load bearing hollow block wall with opening when subjected to axial load and seismic loads. For axial load analysis, the structural behaviour was studied in terms of ultimate strength, stress-strain distribution, deflection shape, maximum principal and shear stresses. For seismic load analysis, the structural behaviour was studied in terms of maximum displacement, maximum principal stress, maximum strain, maximum shear stress, stress-strain distribution and displacement shape of the wall.

The study showed that the strength of interlocking load bearing hollow block wall is significantly affected by the presence of openings. Based on the axial load analysis results, efficiency of each type of strengthening method was evaluated and the best method based on the height of the building was proposed. With the proposed strengthening methods, for opening type 1 and 2, the wall was able to sustain up to 5 storey loading while for opening type 3 and 4, the wall was able to sustain up to 4 and 2 storey loadings respectively. For seismic load analysis, efficiency of each type of strengthening method was evaluated and the best method depending on the intensity of the seismic load was proposed. With single storey load and the proposed strengthening methods, for all four types of openings, the wall is able to sustain high seismic load (up to 0.4g).

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

**PERILAKU STRUKTUR DINDING TANGGUNG BEBAN BLOK  
BERONGGA SALING KAIT PANCA TERKUKUH DENGAN PEMBUKAAN  
DI BAWAH BEBAN PAKSI DAN SEISMIK**

Oleh

**CHOY WAI KENT**

**April 2010**

**Pengerusi : Prof. Abang Abdullah Abang Ali**

**Fakulti : Kejuruteraan**

Tesis ini menyampaikan keputusan hasil penyasatan tentang kekuatan dinding tanggung beban blok berongga saling kait panca dengan pembukaan apabila dikenakan beban paksi dan seismik. Dinding dibina menggunakan sistem bangunan blok PUTRA yang dibangunkan oleh Housing Research Centre, Universiti Putra Malaysia.

Dalam kajian ini, dinding  $3.0 \text{ m} \times 3.0 \text{ m}$  dengan empat jenis pembukaan dan empat jenis kaedah pengukuhan dianalisa dengan menggunakan kaedah unsur terhingga.

Empat jenis pembukaan mewakili satu panel tingkap ( $0.6 \text{ m} \times 1.2 \text{ m}$ ), satu panel pintu ( $0.9 \text{ m} \times 2.0 \text{ m}$ ), dua panel tingkap ( $1.2 \text{ m} \times 1.2 \text{ m}$ ) dan  $1 \frac{1}{2}$  panel pintu ( $1.5 \text{ m} \times 2.0 \text{ m}$ ) dikaji. Untuk kajian beban paksi, kaedah analisis tidak-linear digunakan untuk mendapatkan beban kegagalan bagi setiap dinding masing-masing. Untuk kajian beban seismik, analisis tindak balas spektrum dijalankan berdasarkan

kekuatan seismik untuk mendapatkan tegasan, terikan dan anjakan maksimum untuk setiap dinding dengan bukaan yang menggunakan kaedah pengukuhan yang berbeza.

Kajian melibati pembangunan model unsur terhingga untuk dinding blok PUTRA dengan menggunakan LUSAS dan pengesahan keputusan analisa unsur terhingga dilakukan dengan membuat perbandingan membandingkan dengan keputusan eksperimen penyelidik-penyelidik terdahulu. Pengesahan ini termasuk blok, prisma, dinding 1.2 m, dinding 3 m, dinding 3 m dengan pengukuh dan dinding dengan pembukaan.

Penyelidikan ini memfokuskan kepada perilaku struktur dinding tanggung beban blok berongga saling kait panca dengan bukaan ketika mengalami beban paksi dan beban paksi. Untuk analisa beban paksi, perilaku struktur yang diperhatikan adalah kekuatan utama, taburan tegasan dan terikan, tegasan prinsipal maksimum, tegasan luncur maksimum dan bentuk anjakan pada dinding. Untuk analisis beban seismik, perilaku struktur diperhatikan adalah anjakan, tegasan prinsipal maksimum, terikan maksimum, tegasan luncur maksimum, taburan tegasan dan terikan serta bentuk anjakan pada dinding.

Kajian menunjukkan bahawa kekuatan dinding tanggung beban blok berongga saling kait panca dipengaruhi secara ketara dengan kewujudan bukaan. Berdasarkan keputusan analisa beban paksi, kecekapan setiap jenis kaedah pengukuhan telah dikaji dan kaedah pengukuhan terbaik dicadangkan berdasarkan ketinggian bangunan. Dengan kaedah pengukuhan yang dicadangkan, untuk pembukaan jenis 1 dan 2, dinding tersebut mampu menanggung beban sehingga 5 tingkat, manakala

untuk pembukaan jenis 3 dan 4, dinding tersebut mampu menanggung beban sehingga 4 dan 2 tingkat masing-masing. Untuk analisa beban seismik, kecukupan setiap jenis kaedah pengukuhan dikaji dan kaedah pengukuhan terbaik dicadangkan berdasarkan kekuatan beban seismik. Dengan beban satu tingkat dan kaedah pengukuhan yang dicadangkan, untuk keempat-empat jenis pembukaan yang dikaji, dinding tersebut mampu menanggung beban seismic sehingga 0.4g (beban seismic tinggi).





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I would also like to express my gratitude to the Housing Research Center, Faculty of Engineering, School of Graduate Studies and the Library of University Putra Malaysia for providing great facility, assistant and service during this study.

I certify that an Examination Committee has met on 2<sup>nd</sup> April 2010 to conduct the final examination of Choy Wai Kent on his Master of Science thesis entitled “Analysis of Strengthened interlocking load bearing hollow block wall with opening subjected to axial and seismic load” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the student be awarded the degree of Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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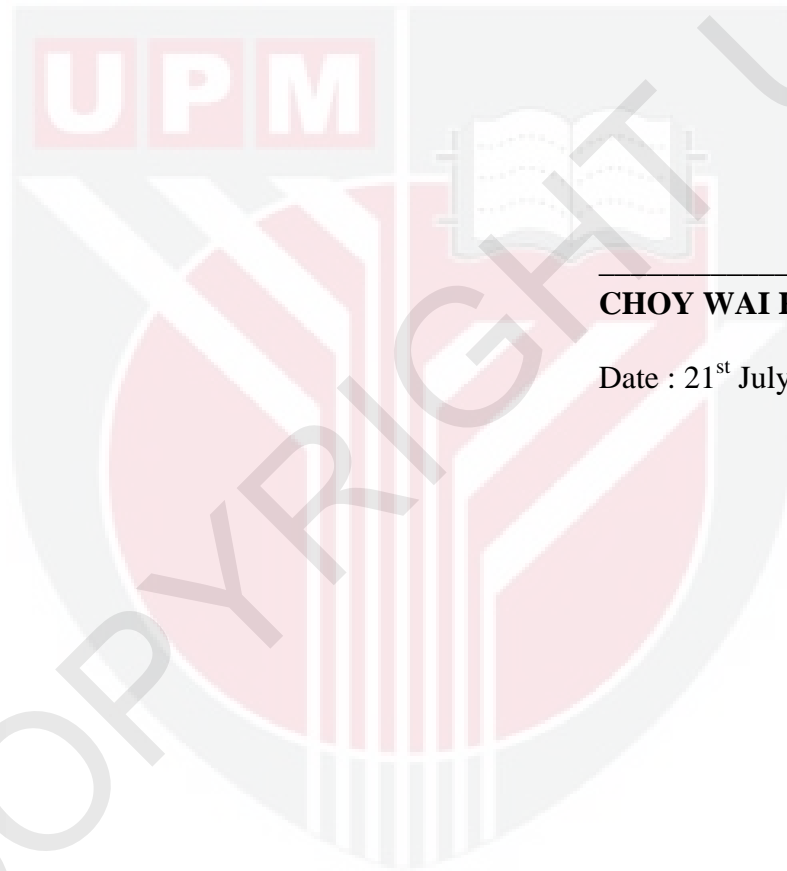
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Date : 12<sup>th</sup> August 2010

## DECLARATION

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



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**CHOY WAI KENT**

Date : 21<sup>st</sup> July 2010

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