UNIVERSITI PUTRA MALAYSIA

STRUCTURAL BEHAVIOUR OF PRECAST CONCRETE SANDWICH PANELS WITH OPENINGS UNDER AXIAL LOAD

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By

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Thesis Submitted to the School of Graduate Studies,
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Very grateful to ALLAH for the blessing…..
To my family and everyone involved in my life,
Thank you….

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

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Chairman: Professor Abang Abdullah Abang Ali, Ir.

Faculty: Institute of Advanced Technology

This research was conducted to study the structural behaviour of precast concrete sandwich panels with opening. Four types of sandwich panels involving panels without opening, panels with door opening, panels with window opening and panels with both door and window opening were studied. The size of the panels was 900mm x 1000mm x 120mm thick. The 120mm thickness consists of two concrete layers with a sandwich insulation layer 40mm thick.

The panels were tested under axial load until failure. During the experiment, the development of cracks was observed and the strain and dial gauges reading recorded. The values of experimental ultimate load for the panel without opening were compared to the theoretical ultimate load by a few researchers. For panels with opening, the experimental ultimate loads were compared to the theoretical equation for panels with opening by Saheb and Desayi. The

theoretical equation used was actually meant to estimate the ultimate load of ordinary reinforced concrete walls with opening. It was used in sandwich panels with the assumption that the total thickness of the panels was equal to the thickness of the concrete layers only.

From the calculations it was found that the theoretical equation by Saheb and Desayi for the ultimate load of ordinary reinforced concrete walls with opening gave very close values to the experimental results for panels with opening. This showed that the ultimate load equation for ordinary reinforced concrete wall with opening by Saheb and Desayi could be used to estimate the ultimate load of sandwich panels with opening. Beside the ultimate load, the lateral deflection and the strain distribution in the reinforcement and concrete surface were also observed and recorded.

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

KELAKUAN STUKTUR PANEL APIT KONKRIT PASANG SIAP DENGAN BUKAAN DI BAWAH BEBANAN PAKSI

Oleh

FARAH NORA AZNIETA BTE ABDUL AZIZ

Januari 2002

Pengerusi: **Profesor Abang Abdullah Abang Ali, Ir.**

Fakulti: **Institut Teknologi Maju**

Penyelidikan ini dijalankan untuk mengkaji dan mempelajari kelakuan stuktur panel apit konkrit pasang siap dengan bukaan. Terdapat empat jenis stuktur apit konkrit pasang saip di dalam kajian ini; panel tanpa bukaan, panel dengan bukaan pintu, panel dengan bukaan tingkap dan panel dengan bukaan pintu dan tingkap. Saiz setiap panel 900mm x 1000mm x 120mm tebal. Ketebalan 120mm adalah terdiri daripada satu lapisan penebatan yang diapit oleh dua lapisan konkrit pasang siap. Ketebalan tiap-tiap lapisan adalah 40mm.

Stuktur panel ini diuji dibawah beban paksi sehingga gagal. Sepanjang ujikaji, perkembangan retakan diperhatikan dan bacaan tolok dail dan tolok terikan direkodkan. Bagi stuktur panel tanpa bukaan, nilai beban muktamad yang diperolehi daripada ujikaji dibandingkan dengan beban muktamad daripada persamaan teori dari beberapa penyelidik. Bagi stuktur dengan bukaan, nilai

beban muktamad daripada ujikaji dibandingkan dengan nilai beban muktamad daripada persamaan teori bagi panel dengan bukaan. oleh Saheb dan Desayi. Persamaan teori yang digunakan sebenarnya adalah untuk menganggar beban muktamad stuktur dinding konkrit tetulang biasa dengan bukaan. Persamaan ini digunakan untuk stuktur panel apit konkrit dengan anggapan ketebalan keseluruhan panel adalah bersamaan dengan ketebalan dua lapisan konkrit sahaja.

Daripada pengiraan, didapati persamaan teori oleh Saheb dan Desayi bagi beban muktamad dinding konkrit tetulang biasa dengan bukaan memberikan nilai yang sangat hampir dengan nilai yang diperolehi daripada ujikaji bagi panel dengan bukaan. Ini menunjukkan persamaan beban muktamad bagi dinding konkrit tetulang biasa oleh Saheb dan Desayi boleh digunakan untuk menganggar beban muktamad panel apit konkrit dengan bukaan. Selain beban muktamad, pesongan sisi dan agihan terikan keatas tetulang dan permukaan konkrit juga diperhatikan dan direkodkan.

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a	distance between centres of gravity of panels with and without opening
a_o	horizontal distance between centre of gravity of opening(s) and left vertical edge of panel
$\bar{a}$	horizontal distance of centre of gravity of panel with opening(s) and left vertical edge of opening
A_g	Lt, gross area of the wall panel section (mm^2)
A_o	L_ot, area of panel opening
A_{sv}	ρ_v(Lt), area of vertical steel in wall section
C	an empirical constant or equation derived from tests
e	eccentricity of the load measured at right angles to the plane of the wall
f_{cu}	cube strength of concrete (N/mm^2)
f_c'	cylinder strength of the concrete (N/mm^2)
f_y	yield strength of steel (N/mm^2)
F_a	allowable direct compressive stress
F_1	0.55 is a capacity factor, a function of eccentricity
$F_2 = [1-(l_c/40h)^2]$,	represent the function of slenderness
H, l_c, h	height of the wall (mm)
h_o	height of opening
k	effective length factor, depends on length condition
k_1, k_2, k_3 and k_4	statistical constants derived from test data
L	length of wall panel
L_o	length of panel opening

m	$\frac{f_y}{f_c^{'}}$ = yield strength ratio of steel to concrete
n	E_s / E_c ,as modular ratio
P_u	design ultimate load of a wall in compression
P_{uo}, P_{uo}^{e}, P_{uo}^{c}	ultimate load of panel with opening and of those experimental and theoretical loads
P_{uc}^{e}, P_{uc}^{c}	experimental and theoretical ultimate load for panel without opening
P_{co}	experimental cracking load of panel with openings
t	thickness of the wall (mm)
α	non diamensional parameter
ϕ	capacity reduction factor
σ_m	ratio of yielded steel area to concrete gross area
σ_n	ratio of steel area which remain in elastic stress state
ρ_v	vertical reinforcement ratio in wall
ρ_h	horizontal reinforcement ratio in a wall
ACI	American Concrete Institute
BS	British Standard

CHAPTER 1

INTRODUCTION

1.1 General

Precast concrete components are widely used throughout the world, primarily in the building sector. The rapid growth of the building industry plus the increasing demand for quality buildings necessitates the building industry to continuously seek improvement, leading to industrialisation. The advent of industrial methods had shown that mass production of precast concrete components had increased the quality as well as reduced the cost of production. Cost is reduced due to lesser construction time and amount of labour.

Precast concrete is defined as concrete which is cast in some location other than its position in the finished structure. One of the building elements in a precast building system is precast concrete sandwich wall panel. The difference between precast concrete wall panel and precast concrete sandwich wall panel is the presence of an intervening layer of insulation.

1.2 Precast Concrete Sandwich Panel

Interest in precast concrete sandwich panel has been increasing in the past few years because manufacturers are looking for new products. Architects and engineers are pleased with the energy performance and general aesthetics of the panels and contractors have found that the use of sandwich panels allow their project site to be cleaner and easier to manage[1].

Precast concrete sandwich wall panel consists of a single layer of insulation sandwiched between two precast concrete layers. The two layers of precast concrete interconnected by a series of shear connectors, concrete webs or a combination of the two. The thickness of each layer depends on the function of the panel. Based on the application of the panel, the precast concrete sandwich wall panel could be categorised as non-composite, partially composite or fully composite.

The non-composite panel referred to the panels with two concrete layers acting independently when load is applied. The connectors have no capacity for longitudinal shear transfer. Normally, the two concrete layers have different thicknesses. The thicker layer resists the applied load and acts as the structural layer.

Partially composite panels are analysed and designed as composite or semi composite during handling but as non-composite for in-place loads. In the PCI Committee Report, it was mentioned that experience showed that early bond between certain insulation types and the concrete layers provide shear transfer for composite action during handling, but the bond is considered unreliable for the long term. The shear connectors can transfer between 0 to 100 percent of the longitudinal shear required for a composite panel.

The composite or fully composite panels referred to panels with two concrete layers acting as one unit when load is applied. This is accomplished by providing full shear transfer between the two layers. This type of panel may be used as load bearing structural panels.

1.3 Precast Concrete Sandwich Panel with Opening

This investigation involves the study of the behaviour of load bearing precast concrete sandwich panel with opening under static loading. The opening referred to a void in the panel, which represents the door or window. Twelve panels were prepared and tested. Three types of sandwich panels with openings were;

1) Precast concrete sandwich panel with door opening
2) Precast concrete sandwich panel with window opening
3) Precast concrete sandwich panel with window & door opening.

For each panel type, three speciments were tested. The size of these panels was fixed at 900mm x 1000mm by 120mm thick. This size was chosen due to the capacity limitation of the test equipment. The thickness of the panels consists of 40mm of polystyrene sandwiched by two layers of concrete of same thickness. The sizes of the openings were;

1) 700mm x 300mm for the door
2) 460mm x 400mm for the window
3) 700mm x 300mm and 360mm x 400mm for the door and the window respectively.

Two concrete layers are connected through the insulation layer by continuous shear truss connector along the length of the panel.

1.4 Objective

The objective of this research work is to study the behaviour of precast concrete sandwich panels with openings under axial loading.

This involves:

1. Comparing the theoretical formulae for ultimate strength of the reinforced concrete wall with the experimental ultimate load of precast concrete sandwich panel tested.
2. Observing the mode of failure, cracking pattern, load-deflection relationship and strain distribution of the test specimens.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Precast concrete sandwich panel consists of two layer of high-density material sandwiched by a layer of low-density core material. Reinforced concrete is normally used as the high-density material while many different types of insulation material can be used as the low-density core material. The important criterion in selecting the insulation material is its heat transmissibility. Generally, the minimum thickness of 25mm is used[(2)]. The outer layers are connected to the insulation by the shear connector.

The structural behaviour of the panels depends on the strength and stiffness of the connectors. When the strength and stiffness of the connectors are sufficient to transfer the shear forces caused by bending between the outer and inner concrete layers, the panel is considered fully composite. Connectors with low shear resistance typically transfer minimal shear force from one concrete layer to the other. Panels utilising such connecting system are considered non-composite. Partially composite panels lie in between these two extremes and provide some shear transfer between the layers.