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BEAM-TO-COLUMN CONNECTION USING HOLLOW STEEL SECTION FOR PRECAST CONCRETE FRAMES

MOHAMAD ZAKI BIN MAJID

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
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APRIL 2010

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DEDICATION

To my beloved parents, wife and daughter

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ABSTRACT

The performance of precast concrete frames depends on the behaviour of connection. The configuration of connections between beam-to-column affects the constructability, stability, strength, flexibility and residual force in the structure. In addition, connections play a key role in the dissipation of energy and redistribution of loads. This paper describes the comparative study on testing between rigid and precast beam-to-column connections to obtain the important characteristics of the connections such as the load-displacement and moment-rotation relationship. The objective of the study is to propose a beam-to-column connection using hollow steel section for precast concrete frames and to determine experimentally the moment resistance and rotation of the proposed beam-to-column connection. In this study, three specimens comprised two precast concrete beam-to-column connection using hollow steel section and one rigid beam-to-column connection were considered. The behaviour of load displacement, moment rotation relationships and type of failure in connections are also investigated. The result indicates that the precast connection using hollow steel section provides very minimum moment resistance and hence the connection can be best model as pinned.

ABSTRAK

Keupayaan kerangka konkrit pra-tuang adalah bergantung kepada sifat sambungannya. Kaedah sambungan rasuk kepada tiang akan mempengaruhi kebolehbinaan, kestabilan, kekukuhan, kebolehlenturan dan kebolehtahanan daya dalam sesuatu struktur. Tambahan pula, sambungan memainkan peranan penting dalam pengagihan beban. Kajian ini menerangkan perbandingan ujian di antara sambungan rasuk kepada tiang konkrit kekal dan pra-tuang untuk memperolehi sifat-sifat penting sambungan tersebut seperti hubungan beban-lenturan dan putaran-momen lentur. Objektif kajian ini adalah untuk mencadangkan sambungan rasuk kepada tiang menggunakan *"hollow steel section"* pada kerangka konkrit pra-tuang dan untuk menentukan secara eksperimen rintangan momen dan putaran sambungan rasuk kepada tiang. Dalam kajian ini sebanyak tiga spesimen dipertimbangkan di mana dua daripadanya adalah spesimen rasuk kepada tiang konkrit pra-tuang menggunakan sambungan *"hollow steel section"* dan satu spesimen sambungan rasuk kepada tiang kekal. Sifat hubungan beban-lenturan, putaran-momen lentur dan bentuk kegagalan turut dikaji. Kajian mendapati sambungan pra-tuang menggunakan *"hollow steel section"* menghasilkan rintangan momen yang minimum dan ianya boleh dimodelkan sebagai *"pinned'.*

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LIST OF ABBREVIATIONS

%	- percentage
°	- degree
A_s	- area of tension steel reinforcement
a_v	- level arm distance to shear force
b	- breadth of section
d	- effective depth of section to tension steel
f_{cu}	- characteristic compressive strength of concrete
f_y	- ultimate yield stress of steel
h	- depth of section
kg	- kilograms
kN	- kilo Newton
kNm	- kilo Newton meter
m	- meter
M	- bending moment
m^3	- meter cubes
milirad	- miliradian
mm	- millimeter
N/mm^2	- Newton per millimeter square
N_u	- horizontal force
ϕ	- rotation
rad	- radian
V	-shear force
v	- shear stress
v_c	- design concrete shear stress
V_u	- gravity load

Δ	- deflection
Δu	- ultimate deflection
Δy	- initial yield deflection
μm	- micrometer
ϕu	- ultimate rotation
ϕy	- initial yield rotation
π	- “pi”, mathematical constant equal to 3.141592654
Φ	- diameter

CHAPTER 1

INTRODUCTION

1.1 Introduction

Precast concrete is one of the elements being associated with IBS constructions. The use of precast concrete multi-storey framed buildings is now widely regarded as an economic, structurally sound and architecturally versatile form of construction. It combines the benefits of very rapid construction and high quality materials with the advantaged of production line economy and quality assurance. Design is carried out to the concrete industry and yet the knowledge remains essentially within the precast concrete industry itself.

The advantages of precast construction are inherent in the precast beam-to-column connections, as these are jointed connection as apposed to cast-in-situ emulation type connection. This study to investigate the behaviour of precast beam-to-column connection using hollow steel section by conducting experimental tests that will show that the performance of this connection is as good as conventional cast-in-place connection.

Connection design is one of the most important considerations for the successful construction of precast reinforced concrete structures (Loo and Yao, 1995). This is because the structural performance of precast concrete systems depends on the

connection behaviour. Connection can be rigid (continuous design), semi-rigid (semi-continuous design) and simple (simple design). These three terms indicate the degree of moment to be transferred between members. The rigid connection and simple connection transfer full moment and zero moment between members. The degree of moment transfer for semi-rigid connection stands between rigid and simple connection.

In this study, experimental tests were conducted to assess the behaviour and performance of the beam-to-column connection by studying the load-displacement relationship, moment-rotation relationship and types of failure in the connections.

The significance of precast structures has gained further recognition through the launching of Industrialized Building System (IBS) in Malaysia. To date, precast concrete components in our country is supplied by several companies such as Associated Structural Concrete Sdn. Bhd. (ACPI), Hume Concrete Marketing Sdn. Bhd., IJM Building System Sdn. Bhd., Setia Precast Sdn. Bhd., Sunway Precast Industries Sdn. Bhd., Eastern Pretech (M) Sdn. Bhd., Baktian Sdn. Bhd., Zenbes Sdn. Bhd., Integrated Brickworks Sdn. Bhd., Multi Usage (Holding) Sdn. Bhd. and PJD Concrete Sdn. Bhd. (CIDB, 2004).

1.2 Statement of Problem

In Malaysia, the industrialised building system had started forty years ago but until today it is still experimenting with various prefabricated method. Recently, The Government of Malaysia encourages the use of IBS especially in new government office building projects. For the start, the government insist that the office building shall have at least 70% IBS components. To make the IBS industry materialised, research has to be carried out to standardise the IBS components especially the beams and column. This will make IBS more marketable.

According to Elliot (1996), some 24 tests have been conducted using welded plate and concrete corbel, however, the section connectors and stiffened cleat types have not widely carried out. Although the Pre-stressed Concrete Institute (PCI) manuals contain descriptions of typical beam-to-column connections fulfilling many functions, the published test results are available for only a few of them (Loo and Yao, 1995).

Thus, the main statement of problem is as follows;

- Lack of experimental data and analytical proof accounts for the ductile connection details for beam-to-column connection in precast structure. In addition, reliable connection behaviour can only be properly assessed by laboratory testing or proven performance.

1.3 Objective of the Study

The objectives of the study are as follows:

i) To propose a beam-to-column connection using hollow steel section for precast concrete frames.

ii) To determine experimentally the moment resistance and rotation of the proposed beam-to-column connection.

1.4 Scope of Study

The scope of this study is limited to simple beam-to-column connections in rigid and precast concrete frames. The precast beams, columns and steel section for this testing were designed using BS 8110:1997. According to BS 8110: Part 1: 1997 Clause 5.1.2, the

recommended methods of design and detailing for reinforced concrete and pre-stressed concrete also applied to precast concrete. Apart from that, the connectors such as angles, plates and bolts were designed based on BS 5950: 2000. The testing consisted of three specimens. Each specimen contained of a beam 200 x 300 x 1000 mm in a 200 x 200 x 2000 mm column. The concrete strength for all specimens was 40 N/mm2 at 28 days. The testing was conducted to study the behaviour and performance of beam-to-column connections in precast concrete frames.

1.5 Significant of the Study

The connection design plays a vital role in determining the successful of the precast concrete structure. The detailing and structural behaviour of the connection such as beam-to-column connections will affect the strength, stability and constructability as well as load distribution of the structure under load. In this research, laboratory testing was conducted to assess the behaviour and performance of the beam-to-column connections by studying load displacement relationships, moment-rotation relationships and types of failure in connections. Based on the results obtained, the use of the proposed connections with either precast concrete braced frame (with lateral stability systems such as shear walls) or un-braced frame (without lateral stability systems) can be studied.