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JUDUL: **BEHAVIOUR OF PINNED BEAM-TO-COLUMN CONNECTIONS FOR PRECAST CONCRETE FRAMES**

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Signature	:
Name of Supervisor	: Assoc. Prof. Dr. Ahmad Baharuddin Abd. Rahman
Date	: 19 October 2006

BEHAVIOUR OF PINNED BEAM-TO-COLUMN CONNECTIONS FOR PRECAST CONCRETE FRAMES

DENNIS CHAN PAUL LEONG

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
Universiti Teknologi Malaysia

OCTOBER, 2006

I declare that this project entitled “Behaviour of Pinned Beam-to-Column Connections for Precast Concrete Frames” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	Dennis Chan Paul Leong
Date	:	19 October 2006

To my beloved parents and family

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ABSTRACT

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. However, lack of experimental data and analytical proof accounts for the ductile connection details for beam-to-column connections are major problems in precast concrete structure. Reliable connection behaviour can only be properly assessed by laboratory testing or proven performance. Therefore, in this research project, laboratory testing was conducted to determine the moment of resistance of beam-to-column connections and to study the behaviour of beam-to-column connections in precast concrete frames. This research project involved a total of four specimens which was limited to simple beam-to-column connections in precast concrete frames. At the end of research, it is found that the performance of precast concrete simple beam-to-column connection had been improved using top fixing angle cleats. Furthermore, ductility of connection was not significantly reduced after this modification.

ABSTRAK

Rekabentuk sambungan rasuk-tiang merupakan suatu elemen yang mustahak dan tidak boleh diabaikan dalam struktur konkrit pratuang. Perincian serta sifat sambungannya akan menentukan kekuatan, kestabilan, kebolehbinaan serta agihan beban keseluruhan struktur. Namun, kekurangan data dan analisis tentang sambungan rasuk-tiang dalam struktur konkrit pratuang masih merupakan suatu cabaran dan masalah. Sifat-sifat sambungan hanya boleh dinilai sepenuhnya melalui ujian-ujian makmal yang terkawal. Justeru, kajian ini telah dijalankan menerusi ujian makmal untuk menentukan rintangan momen and sifat-sifat sambungan rasuk-tiang dalam struktur konkrit pratuang. Walau bagaimanapun, kajian ini hanya memberi tumpuan terhadap jenis sambungan mudah dan melibatkan empat spesimen sahaja. Pada akhir kajian, didapati bahawa sambungan mudah rasuk-tiang yang menggunakan "*top fixing angle cleat*" telah memberikan prestasi yang baik. Di samping itu, sifat kemuluran sambungan didapati tidak banyak berubah selepas perubahan tersebut.

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%	- 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	- force
f_{cu}	- characteristic compressive strength of concrete
f_y	- ultimate yield stress of steel
h	- depth of section
k	- depth at outer edge of corbel
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
z	- lever arm
Z	- section modulus of dowel
δ	- deflection
Δu	- ultimate deflection
Δy	- initial yield deflection
μm	- micrometer
Φu	- ultimate rotation
Φy	- initial yield rotation
tan	- tangent
π	- "pi", mathematical constant equal to 3.141592654

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CHAPTER I

INTRODUCTION

1.1 Introduction

Precast concrete construction have been getting popular and being widely applied in construction sector today. The rapid growth of the building industry together with increasing demand for quality buildings necessitates the construction industry to continuously seek for improvement, leading to industrialization in this industry. Cost reduction is achieved through lesser construction time and amount of labour (Farah *et al.*, 2004).

The history of precast concrete dates back to few decades ago in which several factors such as rising steel costs, material shortages during the Korean conflict, the expanded highway construction program, and the development of mass production methods to minimize labor costs have all been factors leading to the use of precast concrete in United States (Sheppard and Philips, 1989).

The first precast concrete skeletal frame in United Kingdom was Weaver's Mill in Swansea which was constructed in 1897-98 (Elliot, 1996). Meanwhile,

precast concrete was first introduced in Malaysia in 1964 with the construction of flat houses at the intersection of Jalan Pekeliling and Jalan Pahang, located opposite General Hospital Kuala Lumpur. The second project was 6 blocks of 17-storey flat and 3 blocks of 18-storey flat, 66 units shop houses at Jalan Riffle Range, Pulau Pinang (Zubir, 2004).

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

Many types of beam-to-column connections have been developed to join precast beam elements to column elements. Twenty five typical precast beam-to-column connections details have been recommended by the Prestressed Concrete Institute (PCI) were based on simplicity, durability and construction tolerance rather than strength and stiffness. However, all these details indicate one or more of these disadvantages, such as slow erection, no reliable moment capacity, construction tolerance problem and expansive connection hardware (Seckin and Fu, 1990).

To remain competitive, precast structures must be erected quickly and with minimum site presence. The structural elements (columns, beams, floors and walls) must be erected simply and safely, through efficient connector design (Elliot, 2000).

Furthermore**,** the Institution of Structural Engineers (ISE) report mentions that a lack of appreciation of essential differences between precast concrete and in-situ has led to failure of joints and connections on the processes of manufacture and erection. Joints and connections in precast concrete and their influence on local and overall action of the structure, both during and after construction, have resulted in such failures (Richardson, 1991).

According to Elliot *et al.* (1998), some 24 tests have been conducted using welded plate and billet connectors, however, the concrete corbel and stiffened cleat types have not widely carried out. Although the Prestressed 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 Study

The objectives of this study are as follows:

i. To determine the moment of resistance of beam-to-column connections in precast concrete frames by laboratory testing.

ii. To study the behaviour of beam-to-column connections in precast concrete frames by laboratory testing.

1.4 Scope of Study

The scope of this study is limited to simple beam-to-column connections in precast concrete frames. The precast beams, corbels and columns 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 prestressed 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 four specimens. Each specimen contained of a beam 200 x 300 x 1000 mm, and was jointed with a supported corbel of 200 mm wide and 220 mm depth in a 200 x 200 x 2000 mm column. The concrete strength for all specimens was 40 N/mm^2 at 28 days. The testing was conducted to study the behaviour and performance of beam-to-column connections in precast concrete frames.

1.5 Importance of 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 unbraced frame (without lateral stability systems) can be studied. Furthermore, it is expected that the proposed connections can be utilized in future precast concrete construction, as shown in Figure 1.1 and Figure 1.2. Moreover, the formation of safe, economical and ductile precast beam-to-column connections conforming to building code requirements can be utilized.

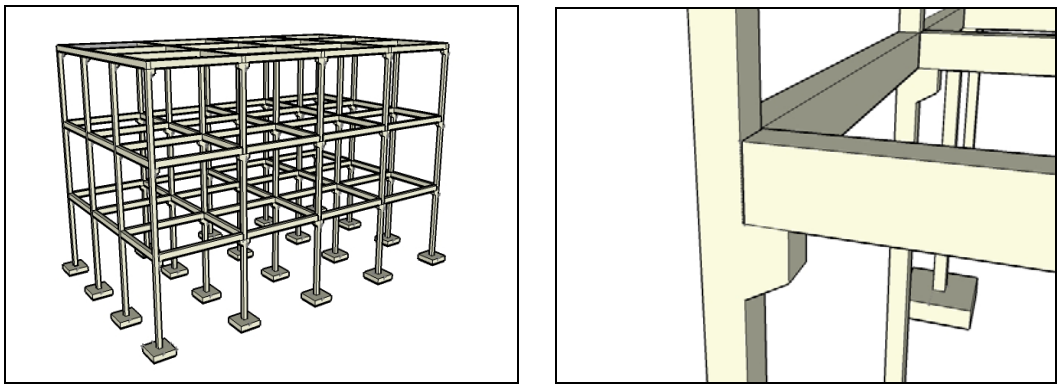

Figure 1.1: The application of simple beam-to-column connections in precast concrete skeletal frame.

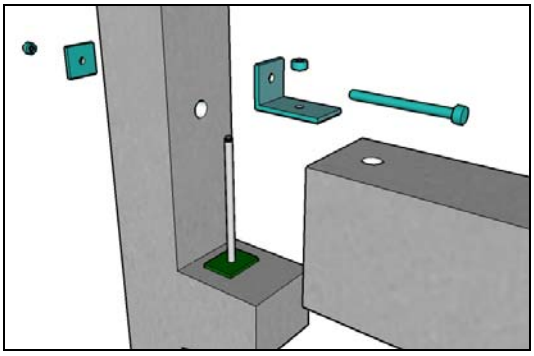

Figure 1.2: Proposed hybrid beam-to-column connection in precast concrete frame.