CONNECTION SYSTEMS FOR BRACED AND UNBRACED PRECAST STRUCTURE DUE TO LATERAL LOADINGS

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ABSTRACT

The connections between precast concrete components play an important role in determining the stabilization of precast concrete framed structures. Despite numerous years of extensive research, no fully fixed design method exists. Many areas of connection behaviour still require investigation. Much of the research has been done, and approximate analytical methods are available for almost all the identifiable regular forms of tall structure. The main objective of this research is to investigate the moment of resistance and the behaviour of simple beam-to-column connections in precast concrete frames by using engineering software. This research methodology mainly consists of finite element static load analysis on braced and unbraced frame which with different connection types. From the analysis result, although the braced structure with fixed connection type is apparently posed the less displacement than other type of model in this analysis, but the value of displacement still not satisfied as a structural to resist all lateral especially seismic forces. Several unsatisfactorily connections, however, still show potentials of reaching the required loading capacity. Therefore, modification and improvement can be made to improve their performances.

ABSTRAK

Kaedah sambungan antara komponen dalam struktur konkrit pratuang memainkan peranan penting dalam menentukan kestabilan kerangka struktur tersebut. Walaupun banyak kajian telah dijalankan, tetapi masih tiada kaedah rekabentuk yang khusus dapat dihasilkan. Masih banyak lagi sifat kelakunan sambungan yang perlu dikaji. Banyak penelitian telah dilakukan, dan sudah tersedia anggaran kaedah analisis bagi hampir semua bentuk bangunan tinggi. Objektif yang utama untuk kajian ini adalah untuk menyiasat rintangan momen dan sifat-sifat sambungan rasuk-tiang di dalam struktur konkrit pratuang dengan menggunakan program komputer. Di dalam kajian ini, analisis beban statik dengan menggunakan kaedah unsur terhingga dikenakan kepada struktur yang dirembat dan tidak dirembat. Berdasarkan keputusan analisis yang dibuat, walaupun struktur yang mempunyai sambungan tegar adalah yang paling kurang anjakan daripada sambungan yang tidak tegar, tetapi nilai untuk anjakan masih tidak memuaskan untuk menahan beban terutamanya beban gempa bumi. Sesetengah sambungan tidak memuaskan, tetapi masih menunjukkan potensi mencapai beban kapasiti yang dikehendaki. Walau bagaimanapun, modifikasi dan pembaikkan untuk sambungan masih boleh dilakukan untuk meningkatkan pretasinya.

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A_g	-	Gross cross-sectional area of concrete (mm^2)
A_e	-	Effective confined area (mm^2)
B	-	Cross-sectional width of concrete(mm)
E	-	Elasticity modulus
E_c	-	Elastic modulus of concrete (MPa)
f_c	-	Axial compressive strength of concrete (MPa)
f_o	-	The intercept stress (MPa)
f_{yt}	-	Yield stress of transverse slope (MPa)
H_n	-	Reaction in bracing
$h\ i$	-	Height of floor *i* measured from base
K	-	Load factor
k_c	-	Concrete material efficiency coefficient
k_{s1}	-	Shape factor for lateral pressure distribution

k_{s2} - Shape factor for strain capacity reduction

M_R - Moment Resistant

P_c - Axial load (kN)

P_{cc} - Axial load at the end of first branch of confined concrete (kN)

P_{cu} - Ultimate axial load of confined concrete (kN)

Q - Design lateral force at floor

Wi - Seismic weight of floor

Z - Level arm

ε_c - Axial strain of concrete member

ε_{cc} - Axial strain of confined concrete

ε_l - Lateral concrete strain

ε_t - Transverse strain

μ' - Effective coefficient of shear friction

Δ - Displacement (mm)

CHAPTER 1

INTRODUCTION

1.1 General Introduction

In the last decade, significant developments in architectural expression and in increasing demand for lighter, economical and taller buildings resulted in a systematical evolution of structural systems. The main design criteria for tall buildings are governed by the lateral stiffness in order to resist wind and earthquake forces.

The structural system of precast concrete frames in multi-storey buildings consists of main components beams and columns and connections. The latter play an important role in joining the beams and columns and it is well known that connections show a variation of behaviour in terms of stiffness and strength. This is turn affects the frames behaviour and the way in which the frames are designed.

In traditional methods of design, the connections are normally assumed as either perfectly pinned or perfectly rigid. The assumption of pinned connections implies no rotation continuity within the frame, in other words, no moment is transmitted from the beam to the column. The assumption of perfectly pinned connections as normally adopted in non-sway frames may lead to over-estimated of beam moments, over-estimated of services deflections in beams and under-estimated of column end moments.

On the other hand, the assumption of perfectly rigid connection implies full moment continuity. The assumption of perfectly rigid connections may lead to over-estimated of column end moment and over-estimated of connection moments.

1.2 Problem statement

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.

For most design, the connections are normally assumed as either perfectly pinned or perfectly rigid. In real a situation, a connection behaves in between the two cases above which is call semi-rigid. The most accurate method to study the non-linear behaviour of a connection is to fabricate the full-scale connection and test these to fail. Unfortunately, this is time consuming, expensive to undertake and has the disadvantage of only recording strain readings at pre-defined gauge locations on the test connection.

In this research, the understanding of the actual connection behaviour is very important, especially designed and constructed for resisting lateral load such as wind, seismic loads.

1.3 Aim and Objectives

The objectives of this study are as follows:

i) To study the behaviour of beam-to-column connections in precast concrete frames by using computer software.

ii) To present finite element analysis and analytical results for structural frames that include the material, geometry and connection nonlinearities.

iii) To investigate the bending moment at the base of the frames at ultimate loads with fully fixed ,semi-rigid and flexible connection.

iv) To demonstrate, through a series of analysis under different structural frame configurations, loads and joint conditions, the influence of the connections to the load carrying capacity and stability of the frames.

1.4 Scope and Limitation

The scopes of this research are:

i. The scope of this study is limited to beam-to-column connections in precast concrete frames.

ii. The precast beams, corbels and columns for this research were designed using BS 8110:1997.

iii. The frame is subjected to static lateral loads.

iv. The stiffness of the connection from the finite element analysis is input in 3D frame for modal and simulation of linear time history analysis (seismic load) under 0.15g and 0.50g intensity (Elcentro).

v. Types of connection for this study are rigid connection, semi-rigid connection and flexible connection.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

In Malaysia, precast concrete structure is relatively new but the Malaysia Government is currently encouraging the construction industry to venture in this technology. Precast concrete means concrete which has been prepared for casting and the concrete either is statically reinforced or prestressed. Meanwhile a precast concrete element is of a finite size and must therefore connect with other elements to form a complete structure.

2.2 Precast Concrete System

There are three types of precast building system. The most common is the skeletal structure. The skeletal structure is the combination of beams and columns which are able and strong enough to resist vertical and horizontal loads. Sometimes, this system needs vertical wall (shear wall) to sustain horizontal load. The second type is precast wall system or known as panel system. This system is normally built on ground and depends on load bearing wall to resist vertical and horizontal loads.

The last system is portal frame. This type of system normally used in industrial building and warehouse.

2.3 Stability

It is essential that the building and its various component elements are stable and the candidate is likely to fail if the stability of the structure is not adequately demonstrated. There are two stability criteria to consider; lateral stability and uplift due to wind pressure.

2.4 Lateral Stability

The following are examples of loads that may impose lateral forces on the structure:

a) Wind loads.
b) Earthquakes.
c) Lateral loads due to geometric imperfections.
d) Horizontal component of soil loads.
e) Accidental loads.

The structure should be designed to resist these loads in two orthogonal directions. For a multistorey building this can be achieved by using:

a) Shear walls (braced)or;
b) Moment-resisting frames (i.e. sway frame or unbraced).

2.5 Unbraced Frame

The unbraced frame is normally for frame up to three storeys and it is uneconomical for frame above three storeys. The reason is columns in unbraced frame act as cantilever beam to sustain the horizontal load as shown in Figure 2.1.

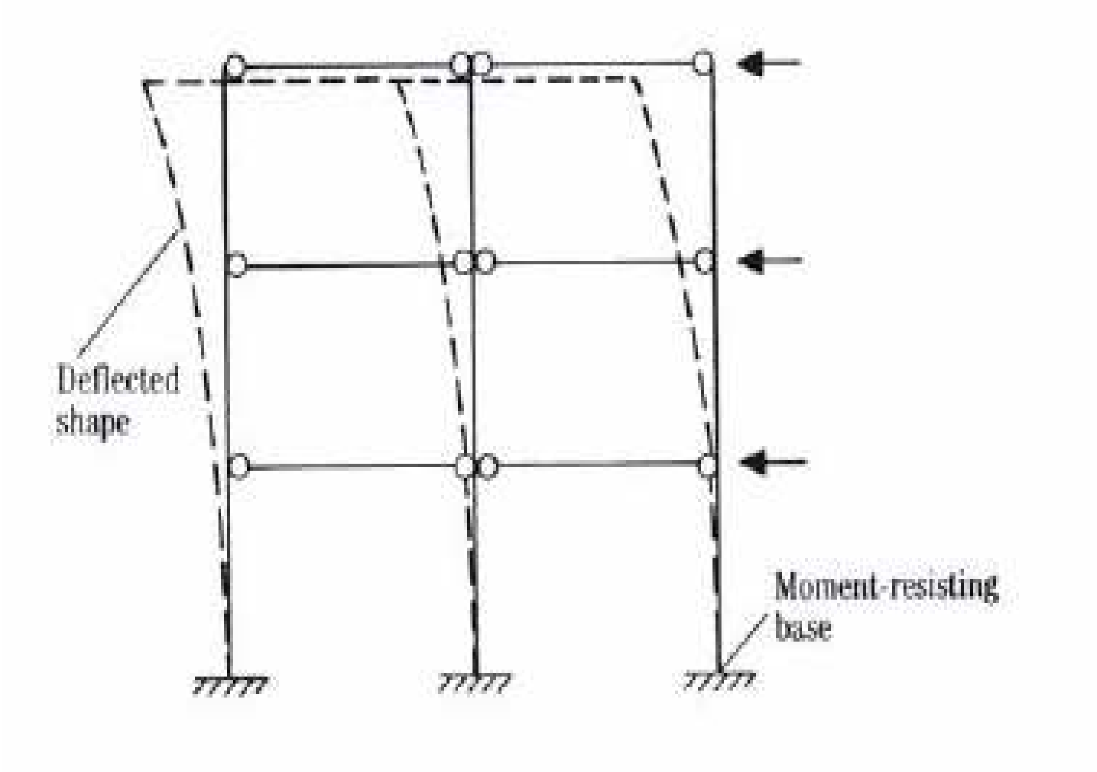

Figure 2.1 Unbraced Frame

2.6 Braced Frame

Braced frame is introduced for highrise building. For medium rise building, partially braced could be the suitable option as shown in Figure 2.2.

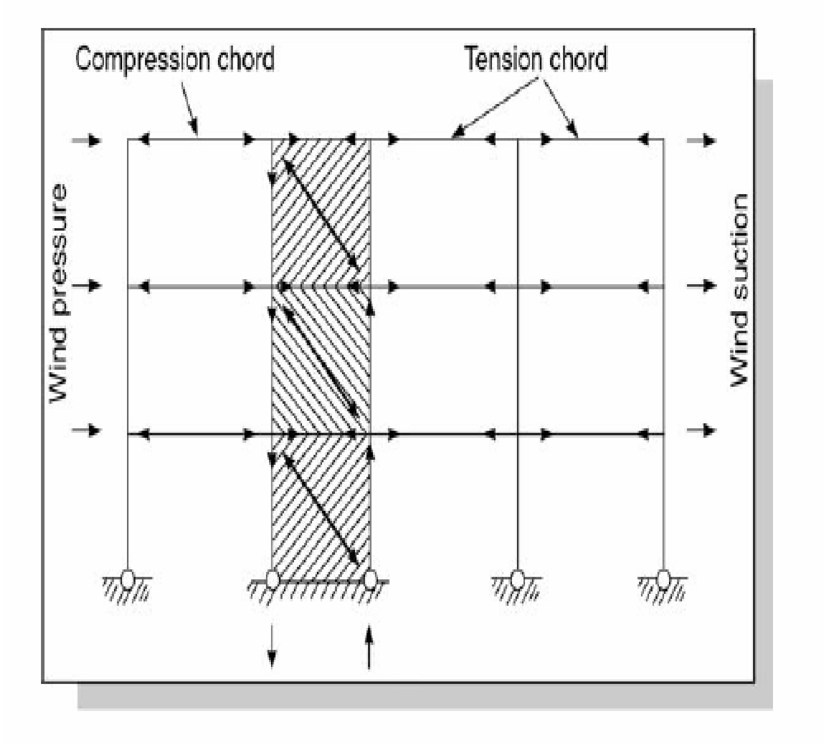

Figure 2.2 Braced Frame

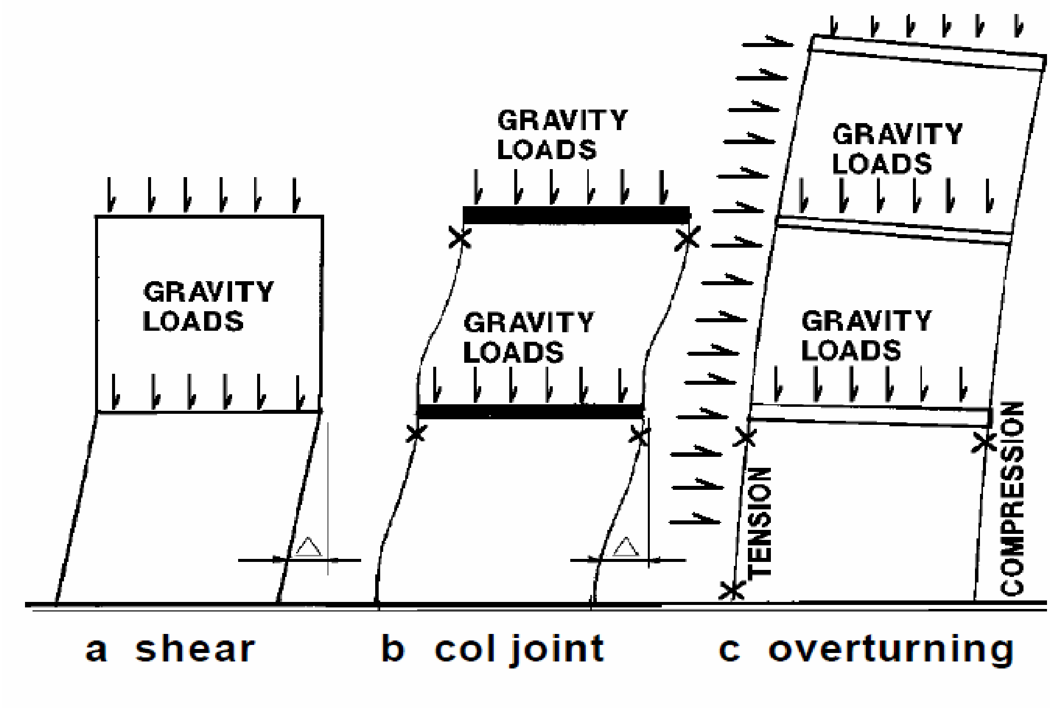

Figure 2.3 Collapse Patterns

2.7 Shear Frame

Moment resistant beam to column connections create shear frames or Vierendeel frames which provide lateral stiffness in both orthogonal directions. The efficiency towards lateral stiffness is controlled by the individual stiffness of the members depending on the section and the length of girders and columns. The resistance to sway deflection in mainly governed by the bending of beams and columns due to wind forces and less from column shortening or cantilever action. The figure below shows the theoretical sway deflection of this framing system under the action of wind forces.

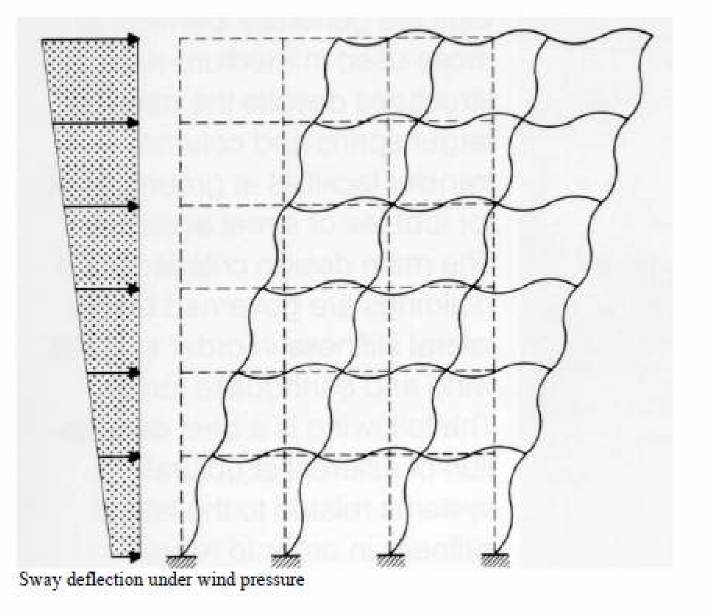

Figure 2.4 Sway deflection under wind pressure (Taranath, 1988)