THE INFLUENCE OF CONCRETE STRENGTHS ON THE BEHAVIOUR OF EXTERNAL BEAM-COLUMN JOINTS

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ABSTRACT

The casting of the beams and slabs at a particular floor level is carried out together with the beam-column connection zone using the same grade of concrete. In the case of the columns designed with markedly higher concrete strength compared to that of the beams, such casting sequence forms beam-column connection zones with significantly lower concrete strength than that in the upper and lower columns. When the connection zone is subjected to large shear stresses as in the case of external columns, the capacity of the columns might wrongly be assessed if it is based solely on their higher concrete strength. This paper presents the results of tests on three external beam-column specimens in which the influence of lower concrete strength in the connection zone and the horizontal links, on the ultimate capacity of the joint was investigated. All specimens were provided with identical reinforcement in the beam and column portions. The concrete in the columns was of Grade C80 while that in the beam was of Grade C30. Connection zone had concrete of the same grade as in the beam except in one of the specimen, which was cast with the same grade as in the columns. . One of the specimens with Grade C30 concrete in the connection zone was provided with additional links in joint zone. The failure of the specimens was due to diagonal cracking in the connection zone. The results show that lower concrete strength (Grade C30) in the connection zone reduces the ultimate capacity and shear stress of connection zone. It was also found that additional links in the connection zone cast with Grade C30 concrete improves the shear capacity of the joint beyond that achieved by the specimen with Grade C80 concrete in the zone.

ABSTRAK

Pengkonkritan rasuk dan papak pada sesuatu aras dilakukan sekali dengan zon sambungan rasuk-tiang mengunakan konkrit dari gred yang sama. Dalam kes tiang direkabentuk dengan menggunakan konkrit berkekuatan lebih tinggi dari rasuk, seperti langkah pengkonkritan zon sambungan rasuk-tiang dengan menggunakan konkrit berkekuatan lebih rendah dari tiang atas dan bawah. Apabila zon sambungan rasuk-tiang terdedah kepada tegasan ricih yang besar terutamanya dalam sambungan rasuk-tiang luaran, keupayaan tiang kemungkinan tidak begitu tepat sekiranya dinilai berdasarkan kekuatan konkritnya yang lebih tinggi. Tesis ini menunjukkan keputusan ujikaji ke atas 3 spesimen sambungan rasuk-tiang luaran, di mana pengaruh kekuatan konkrit yang lebih rendah serta pengaruh perangkai tambahan dalam zon sambungan ke atas keupayaan muktamadnya. Semua spesimen disediakan dengan jumlah tetulang yang sama dalam rasuk dan tiang. Tiang terdiri dari konkrit Gred C80 manakala rasuk dari konkrit Gred C30. Zon sambungan pula dari konkrit yang sama pada rasuk kecuali pada 1 spesimen dengan menggunakan kekuatan konkrit yang sama dalam tiang. Satu spesimen terdiri dari konkrit Gred C80 untuk tiang dan konkrit Gred C30 untuk rasuk manakala zon sambungan disediakan dengan perangkai tambahan. Keputusan ujikaji menunjukkan spesimen gagal disebabkan keretakan penjuru dalam zon sambungan. Keputusan ujikaji menunjukkan bahawa spesimen dengan kekutan konkrit lebih rendah (Gred C30) dalam zon sambungan mengurangkan beban muktamad dan tegasan ricih zon sambungan tersebut. Keputusan juga menunjukkan bahawa dengan adanya perangkai tambahan dalam zon sambungan dengan kekuatan konkrit Gred C30 dapat meningkatkan keupayaan zon sambungan ke tahap melebihi keupayaan zon dengan konkrit Gred C80 dalam zon sambungan.

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CHAPTER 1

INTRODUCTION

1.1 Background

In the last 20 years or so designers have become aware of the fact that beam-column joints in reinforced concrete ductile frames that may be exposed to large loading such as earthquake require special attention. Extensive research work carried out in several countries has led to the identification of critical features of joint behaviour. Beam-to-column joints should have sufficient stiffness and strength to resist and sustain the load induced from adjacent beams and columns.

Nowadays, in the construction of high-rise building, normally were designed using the high strength concrete in the columns rather than that in the beams and slabs (Siao, 1994). This was because columns can resist higher load compared by beams. In construction process of the beams and slabs at a particular floor level that was practiced until now consists of three stages; first the lower column up to the sofit of the beam and followed by the beam and slab and finally followed by the upper column.

In the case of external columns, the connection zone was subjected to large shear stresses due to the load in the beams. For the internal columns also caused to shear stresses due to the load differences at both side beams. This shear failure caused to diagonal cracking in the connection zone. The connection zone normally failed at lower ultimate load rather than the capacity of the column itself and it might be failed at early stage loading. The constructions practiced nowadays that led to the possibility of shear failure were by not providing any horizontal links or additional bars in the connection zone.

In non-seismic regions, structures are mainly designed to resist gravity loads with little consideration of the effect of lateral loads. Although they are not located in seismic zone, these structures can be subjected to lateral loads from the long distance earthquake or explosions. On contrary to seismic design concept, the beam-column joints in these structures may become the most vulnerable component when significant lateral load are present.

1.2 Problem Statement

In the case of the columns designed with markedly higher concrete strength compared to that of the beams that was practiced nowadays, such casting sequence forms beam-column connection zones with significantly lower concrete strength than that in the upper and lower columns, produced columns with lower concrete strength in the connection zone. All this while, the construction practiced nowadays had neglected the lower concrete strength of the columns at the floor level that is in the connection zones. Columns were assumed had the same concrete strength at through height of the columns. For the external columns, with lower concrete strength in the connection zones caused to the large shear force that significantly led to joint failure.

In particular, the use of longitudinal reinforcing bars with high strength or large diameter in a relatively smaller column section, sometimes preferred in the design of buildings, causes high stress in the beam-column connections. A structural designer should carefully examine this increased stress in beam-column connection, or problems related to strength and/or stiffness may result. For example, the development of a lower strength than that based on full flexural strength of beams may result.

Previous researches on the beam-column joints (Parker and Bullman, 1997 ; Sarsam and Phipps, 1985 ; Scott *et. al.,* 1994) concentrated on the behaviour of the connection zones whether under static or seismic loading. In his research, the specimen was of the same concrete strength in the columns and beams. There were researches on the specimens of beam-column joint or slab-column joint (Marzouk *et. al*., 1996 ; shu and Hawkins, 1992 ; Siao, 1994) that concentrated with the used of higher concrete strength in the columns. This investigation concentrated on the behaviour and the capacity of beam-column joint that subjected to shear stresses with different concrete strength in the columns and in the beams.

1.3 Research Objectives

In general this investigation was carried out to study the behaviour of the external beam-column joint under gravity load. In more specific terms this research was conducted to achieve the following objectives:

a) To study the behaviour of the beam-column joints with different strengths of concrete in the beam and columns.

b) To study the contribution of the horizontal links in the connection zone in strengthening the joints with lower concrete strength.

1.4 Scope of Work

This laboratory investigation was carried out within the scope stated below:

a) The study was an experimental investigation on the exterior beam-column joints.

b) The concrete in the beam was of Grade C30 while that for the column was of Grade C80. The concrete in the connection zone of two of the specimens was from Grade C30 and that of the other specimens was from Grade C80.

c) Three specimens were tested. All specimens were provided with identical amount of main reinforcement and links. Horizontal links were also provided in the connection zone of one specimen.

d) The specimen was subjected to monotonic load. An axial compression load was fixed at the top of the column and the load on the beam was increased gradually until the specimen failed.

e) High yield steel reinforcement (f_y = 460 N/mm^2) was used for main bars and mild steel reinforcement (f_y = 250 N/mm^2) was used as links.