Construction and Building Materials 25 (2011) 851–858

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Rehabilitating destructed reinforced concrete T connections by steel straps

M.N.S. Hadi *

School of Civil, Mining and Env. Eng., University of Wollongong, Wollongong, NSW 2522, Australia

ARTICLE INFO

Article history:
Received 26 February 2008
Received in revised form 23 June 2010
Accepted 29 June 2010

Keywords:
Rehabilitation
T connections
Steel straps
Reinforced concrete connections

ABSTRACT

The aim of this paper is to present results of testing a full scale reinforced concrete T connection by static loading. The connection represents a beam–column connection. The beam and column had a square cross section with a 300 mm dimension. The height of the column was 2.9 m and the clear beam length was 1.4 m. The connection was initially tested to failure. Galvanised steel straps were used to rehabilitate the connection. Epoxy resin was used to fix the steel straps to the concrete surface. The connection was tested after the rehabilitation. Results of testing the rehabilitated connection show that the yield and ultimate loads were 65 kN and 95 kN, respectively, compared with the original test results of 75 kN and 84 kN, respectively. Based on results of the tests, it can be concluded that the rehabilitating method used in this study was effective in increasing the ultimate strength of the T connection.

1. Introduction

Connections are defined as a common point of intersection of the columns and beams and provide resistance to applied external loads due to the bending moment encountered at the joint. Therefore, connections play an important part in structures. The loading on structures pass through the beam–column connections. Load paths are developed in the concrete members and this allows the transfer of the externally applied loads to the support structures. Connections are critical components of structures and they have to be designed so that the possible failure due to shear, torsion and moment are minimised or eliminated. Research studies have indicated that some of the factors that have an important influence on the beam–column RC connections are: concrete confinement, confinement of reinforcement, axial compression on columns and the panel geometry of the connection. Past events have shown that the collapses of structures are due mainly to the failure of the beam–column connections. Therefore, it is vital that beam–column connections are designed to the optimum possible ability. Research has been done to highlight the different factors that attribute to the failure of concrete connections and the methods used to counteract these failures.

This paper presents an investigation of testing a T connection. This T connection was originally cast and tested to failure in 2006. In 2007, the same connection was rehabilitated and tested to failure with the aim to test the viability of the strengthening technique. The rehabilitation technique composed of using galvanised steel straps with epoxy. Results of the test showed that the rehabilitation technique is an effective technique.

2. Review of literature

The Portland Cement Association conducted the first experimental tests on beam–column connections in the early 1960s [1]. Since then other research studies have been done to provide applicable data for beam–column connection design problems. Some of these research studies are discussed below.

One such study was done to investigate the shear strength of reinforced concrete beam–column connections by Meinheit and Jirsa [2]. The objective of this investigation was to examine the methods to improve the shear strength and measure the basic shear strength characteristics of beam–column connections. Several reinforced concrete beam–column connections were developed and tested under cyclic loads. Meinheit and Jirsa [2] found that the strength of the connection differed according to the axial load on the column, the presence of transverse beams and the amount of closed hoop reinforcement within the connection. Meinheit and Jirsa [2] concluded that the shear capacity improved due to transverse reinforcement in the connection, unloaded transverse beams improved the shear capacity, the columns' axial load did not influence ultimate shear capacity of the connection, the connection geometry had no influence on the shear strength of the joint if the shear area of the connection remained constant and the increase in column longitudinal reinforcement did not result in an increase in shear strength.

Scott [3] investigated the behaviour of reinforced concrete beam–column connections due to the different detailing methods of reinforcement. This study made detailed measurements occur-

* Tel.: +61 2 4221 4762; fax: +61 2 4221 3238.
E-mail address: mhadi@uow.edu.au

0950-0618/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.conbuildmat.2010.06.102

ring inside the connection specimen by using internally strain-gauged reinforcement. This was done to obtain detailed distributions of strain along the column and beam reinforcement bars. As such, the intrinsic mechanisms of the connection behaviour could be comprehended.

Adetifa and Polak [4] presented a technique of using shear bolts to retrofit slab column interior connections. Binici and Bayrak [5] used fibre reinforced polymers (FRP) for upgrading slab-column connections. Shannag and Alhassan [6] used high-performance fibre reinforced concrete jackets to seismically upgrade interior beam–column subassemblies.

Harajli et al. [7] presented a technique of using a combination of FRP sheets and steel bolts to strengthen interior slab-column connections. Engindeniz et al. [8] presented a review of the state of the art of the repair and strengthening of reinforced concrete beam–column joints.

It is clear that many researchers have used novel materials to upgrade the performance of connections, for example FRP. Clearly connections are important components in structures. This paper shows the behaviour of a connection when it is tested to failure then rehabilitated using a combination of steel sheets, epoxy and steel straps; and then being tested to failure.

3. Testing the initial connection

In 2006, a reinforced T connection was tested to failure. The dimensions for the beam–column connection and the testing geometry are shown in Table 1 and Fig. 1, respectively.

3.1. Materials used

The concrete used in the experimental programme was provided by a local supplier. The average concrete strength at 29 days was found to be 46.78 MPa.

D500N deformed steel bars were used in building the beam–column connection. The steel bar had a specified yield stress of 500 MPa and had normal ductility. R10 plain steel bars were used for the stirrups, having a specified yield stress of 250 MPa and normal ductility. Three samples 300 mm long were tested in the Instron testing machine. The steel bars were found to have an average tensile strength of 538.6 MPa. This tensile strength was above the specified value of 500 MPa.

3.2. Reinforcement

The connection specimen was reinforced with N20 (20 mm diameter deformed bars with 500 MPa nominal tensile strength and normal ductility) and N16 (16 mm diameter deformed bars with 500 MPa nominal tensile strength and normal ductility) bars as shown in Table 2 and Fig. 2.

3.3. Testing the specimen

The testing frame shown in Fig. 3 was used to test the specimen both the initial specimen in 2006 and the rehabilitated specimen in 2007. The loading regime was chosen in line with the capabilities of the frame and the loading jack. An increasing single load was adopted.

The hydraulic jack applied a downward vertical load onto the beam to create a large turning moment within the concrete connection. The load was applied at a distance of 1100 mm from the column–beam interface while the column was held securely in place.

The hydraulic jack applied a constantly increasing point load at the end of the beam until the beam reached ultimate failure. The loading rate was determined by the increase or decrease in pressure applied to the hydraulic jack by the hydraulic pump. The hydraulic pressure supplied to the jack was adjusted by using the turning knob on the hydraulic pump and was constantly increased to keep the deflection rate of around 2.5–5 mm per minute until the beam yielded, at which point the applied pressure was kept constant as the beam continued to deflect at approximately 3–5 mm per minute. The pressure began to decrease as the beam reached ultimate failure and the internal tensile steel ruptured.

The beam was loaded with a 550 kN universal hydraulic jack from 0 kN to the ultimate load point whilst deflection and rotation measurements were taken throughout the test. All measurements

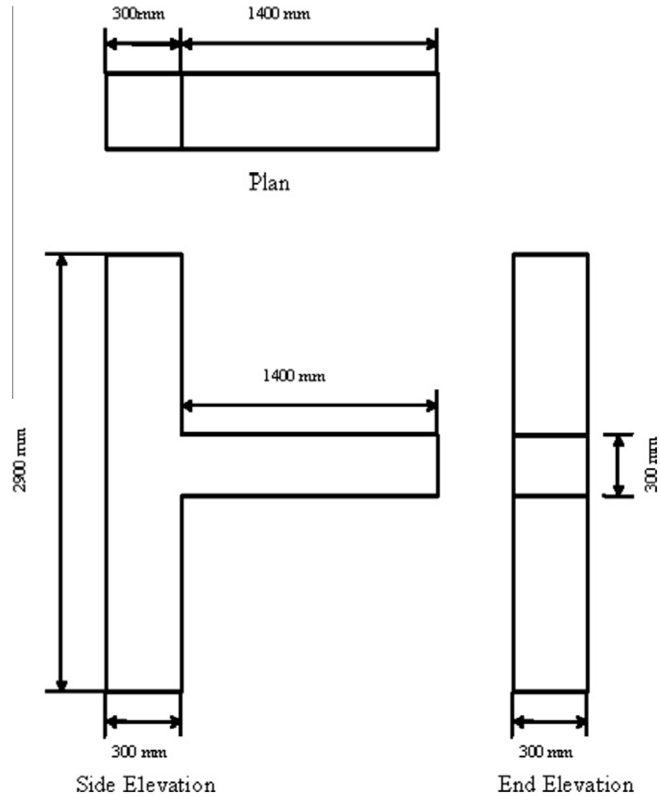

Fig. 1. Dimensions of the beam–column connection.

Table 1
Dimensions of the structural elements.

Structural element	Dimension (mm)
Column length	2900
Beam length	1400
Column cross section	300 × 300
Beam cross section	300 × 300

Table 2
Specimen reinforcement.

Member	Reinforcement location	Steel used
Beam	Tensile reinforcement	2N20
	Compressive reinforcement	2N16
	Stirrups-normal spacing	150 mm
	Stirrups-joint spacing	50 mm
Column	Tensile reinforcement	2N20
	Compressive reinforcement	2N16
	Stirrups-normal spacing	150 mm
	Stirrups-joint spacing	50 mm