PARAMETRIC STUDY OF BLIND BOLTED END-PLATE CONNECTION ON STRUCTURAL SQUARE HOLLOW SECTION

SEAH IVY

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ABSTRACT

This project involves the parametric study of blind-bolted end-plate connections between square hollow section columns and open beams. Blind bolts are defined as bolts that can be access for installation from one side of the connection only, where the application can referring to the case of connecting the end-plate of a beam to a hollow column. Blind bolts offer many advantages including strengths and sizes comparable to ordinary bolts and therefore it has potential use in tension applications as well as in moment resisting connections. Currently, many research works have been carried out using H or I profiles but not many using structural hollow sections. Furthermore, the theoretical method to predict moment resistance of an I-beam connected to square hollow section column is not established yet. Study has been conducted by firstly, predicting the moment resistance and rotational stiffness using theoretical Gomes method and component method. Secondly, theoretical model and experimental results will be validated. The proposed theoretical model with higher accuracy is used to perform a parametric investigation into the key factors influencing the behaviour of blind-bolted end-plate connections. Parameters such as column face thickness, yield strength, blind-bolt types and sizes, gauge length and end-plate thickness are investigated. Moment resistance and rotational stiffness have been established using theoretical Gomes method and component method. Based on the results, the comparison to the experimental results shows that component approach has over predicted the initial stiffness of the connection by a ratio of 3.93 to 6.02 and underestimated the moment resistance of the connection by ratio of 0.52 to 0.96. The parametric study shows that column thickness, bolt size and end plate thickness are the main key factors that influence the moment resistance and initial stiffness of the connections.

ABSTRAK

Projek ini melibatkan kajian parametrik sambungan plat hujung bolt buta antara tiang keratan geronggong segiempat (SHS) dan rasuk terbuka. Bolt buta ditakrifkan sebagai bolt yang boleh akses untuk pemasangan dari satu sisi sahaja, dimana aplikasinya merujuk kepada kes yang menyambung plat hujung sesuatu rasuk kepada tiang berongga. Bolt buta menawarkan banyak kelebihan termasuk kekuatan dan saiz setanding dengan bolt biasa dan oleh itu ia mempunyai potensi penggunaan dalam aplikasi ketegangan dan juga dalam sambungan momen rintangan. Kini, banyak penyelidikan telah dilakukan dengan menggunakan H atau I profil tetapi tidak banyak menggunakan keratan berongga struktur. Tambahan pula, kaedah teori untuk meramalkan momen rintangan bagi I-rasuk yang disambung kepada tiang SHS tidak ditubuhkan lagi. Kajian telah dijalankan dengan pertamanya, meramalkan momen rintangan dan kekakuan putaran menggunakan teori kaedah Gomes dan kaedah komponen. Kedua, model teori dan keputusan eksperimen akan disahkan. Model teori yang dicadangkan dengan ketepatan yang lebih tinggi digunakan untuk melakukan siasatan parametrik ke dalam faktor-faktor utama yang mempengaruhi tingkah laku sambungan plat hujung bolt buta. Parameter seperti ketebalan tiang muka, kekuatan alah, jenis bolt buta dan saiz, panjang tolok dan ketebalan plat hujung telah disiasat. Momen rintangan dan kekakuan putaran telah ditubuhkan dengan menggunakan teori kaedah Gomes dan kaedah komponen. Berdasarkan kepada keputusan, perbandingan dengan keputusan eksperimen menunjukkan bahawa kaedah komponen telah lebih meramalkan kekukuhan awal sambungan dengan nisbah 3.93 hingga 6.02 dan momen rintangan sambungan di bawah anggaran dengan nisbah 0.52 hingga 0.96. Kajian parametrik menunjukkan bahawa ketebalan tiang, saiz bolt dan ketebalan plat hujung adalah faktor utama yang mempengaruhi rintangan momen dan kekakuan awal dalam sambungan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

SHS	-	Square Hollow Section
RHS	-	Rectangular Hollow Section
EEP	-	Extended End-Plate
FEP	-	Flushed End-Plate

LIST OF SYMBOLS

ϕ	-	Rotation (mRad)
M_{Rd}	-	Moment Resistance (kNm)
$S_{j,ini}$	-	Initial Stiffness (kNm/mRad)
t_c	-	Column Thickness (mm)
f_y	-	Yield Strength (N/mm^2)
d_m	-	Bolt Size (mm)
g	-	Gauge Length (mm)
t_p	-	End Plate Thickness (mm)

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 General

Steel frames are usually designed with hot-rolled or built-up H or I profiles. There are many research works have been carried out in the connection of this field but less in structural hollow sections. In recent years, the focus has been shifted on the connection of I beams to structural hollow section columns. Structural hollow section is a type of metal profile with a hollow tubular cross section. Square and circular hollow sections are suitable as columns because of its uniform geometry that contributes to torsion resistance. Besides that, structural hollow sections have a higher load carrying capacity and light weight in nature, reduces material costs in compared to open sections. In general, structural hollow section has good structural efficiency, reliability and aesthetical values.

Structural hollow sections have been used commonly as tubular trusses in the construction of some of the well known public landmarks such as the Helix Bridge in Singapore and the Melbourne Sports and Aquatic Centre (MSAC). Figure 1.1 shows the Helix Bridge that comprises two delicate helix structures that act together as a tubular truss to resist the design loads as inspired by the form of the curved DNA structure. As for the reconstruction of MSAC for the 2006 Commonwealth Games, it has used over 800 tonnes of pipe and rectangular hollow section (RHS) (Orrcon Steel, 2013). Figure 1.2 shows part of the MSAC which is constructed using steel pipes and RHS.

Figure 1.1: Helix Bridge in Singapore (Core77, 2012)

Figure 1.2: Melbourne Sports and Aquatic Centre (MSAC) (Panoramio, 2009)

Until recently, welding has been the popular method to connect open beams to structural hollow sections. The high costs and labour-intensive procedures involved with welding have limited the use of hollow section as structural members.

Furthermore, welding is difficult to inspect, needs high quality control and must be performed in dry weather. One of the ways to connect I-beams to structural hollow section columns is by using the blind bolting system to replace the conventional method of welding. Blind fasteners have been developed as a fixing for blind hole applications, providing more flexibility in those applications where space and accessibility is limited. Blind fasteners are unique in its design, requiring no special tools for fittings and no oversize hole diameters, thus allowing fewer fixings to be used, yet retaining rigidity and shear and tensile strength in application. Besides, blind fasteners can be removed, allowing maintenance activity to take place.

Blind fasteners offer many advantages including strengths and sizes comparable to ordinary bolts and therefore it has potential use in tension applications as well as in moment resisting connections. There are many types of blind fasteners including Lindapter Hollo-bolt, flowdrilled bolts, blind-bolt and Ultra-twist blind fasteners. Each type of fastener differs in the bolt components, resistance mechanism and method of installation. Besides, blind fasteners are also very flexible in its fixing, which can be used in vertical and horizontal fittings. Hence, it is obvious that the restrictions and limitations imposed by welding can be overcome by using blind bolting system in hollow structures to facilitate easier fabrication, transportation and erection. Figure 1.3 depicts how open section is connected to hollow section by using blind bolt.

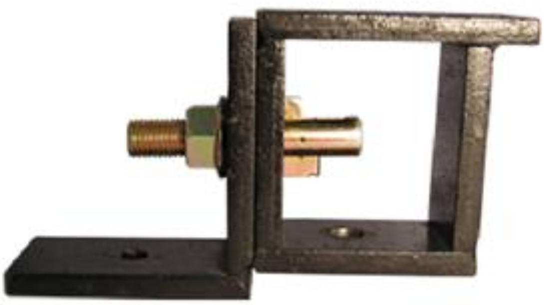
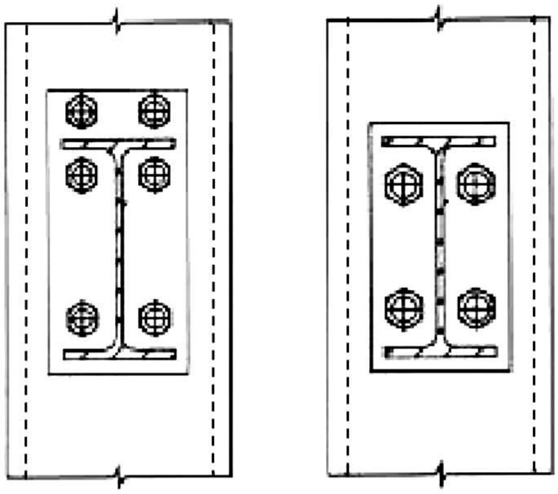


Figure 1.3: Blind bolts that connects open section to hollow section (Blind Bolt, 2009)

Connections determined ways moment and axial load are being transferred between structural members. There are three types of connections that reflect the degree of moment transferred between members, such as rigid-connections, semi-rigid connections and simple connections. The rigid connection and simple connection are the idealized assumptions that indicating full-moment transfer and zero moment transfer; the semi-rigid connection is in actual condition which stand in between. Semi-rigid or also known as partial strength is usually associated with a connection having a moment capacity less than the moment capacity of the connected beam (SCI & BCSA, 1995). Two typical types of semi-rigid connections are Flush End-Plate (FEP) and Extended End-Plate (EEP) as shown in Figure 1.4. Both semi-rigid connections will be studied in this project.



(a) Extended End-Plate (b) Flush End-Plate

Figure 1.4: Beam to Square Hollow Section Joint (Weynard and Jaspart, 2003)

1.2 Problem Statement

Various methods may be used for the establishment of moment-rotation curves and initial stiffness of semi-rigid joints such as empirical, mechanical, analytical and experimental tests. Many studies involving bolted EEP and FEP connections with open section column and I shaped cross sections have been conducted in the past few years. By assembling the contribution of the individual components, the recognised component method is used to represent the behaviour of a connection. This analytical method has been adopted in Eurocode 3 part 1-8 (BSI, 2005).

Theoretical approach based on the mechanical component method has been developed in the case of joints between H or I sections. It allows a theoretical evaluation of the stiffness and resistance properties of a wide range of joint configurations and connection types. However, the design rules for joints between tubular hollow sections are based on simple theoretical models where they are fitted through comparisons with experimental tests but only cater for shear resistance. The formulae generally give estimation of the resistance but no stiffness evaluation is provided. For "mixed" configurations such as I beam to structural hollow section connections, Annex K of Eurocode 3 (EC3) gives some guidelines for welded connections but not bolted connections (Weynard and Jaspart, 2003).

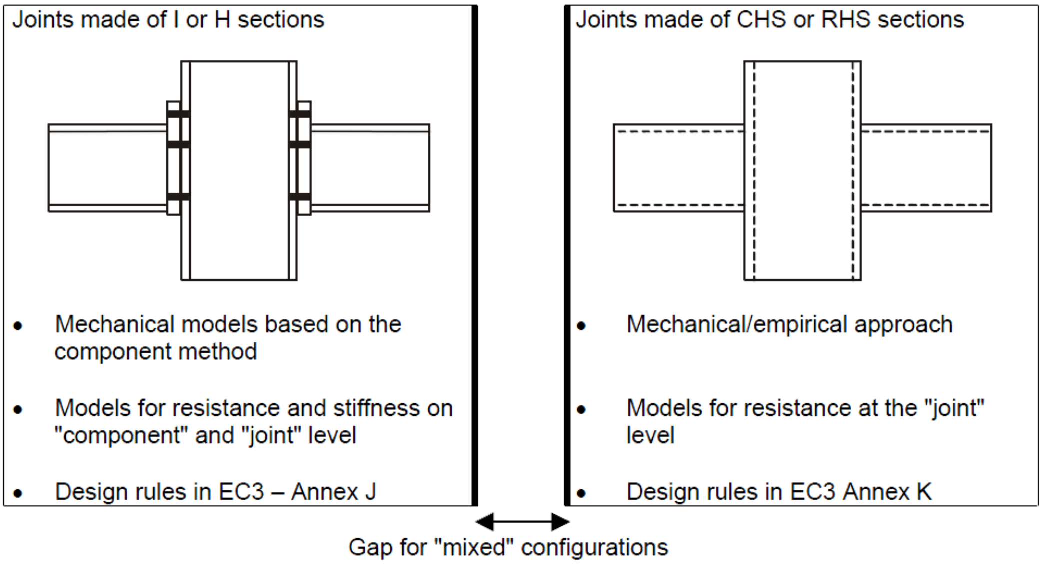


Figure 1.5: Present situation for the design of steel joints based on Eurocode 3 (Weynard and Jaspart, 2003)

Actual behaviour of joints using blind bolt between open beams and tubular columns should include moment resistance and initial stiffness and categorised as moment connection. Besides that, Steel Construction Institute (SCI) has also built a standardized connection table to ease convenience of engineers in designing connections of I beam to open sections. To date, there are still no design formulations for joint of an I-beam to square hollow section column. Therefore, a study must be carried out on the formulation of these joint. After validation against component method results and experimental results, a parametric investigation will be conducted into several key factors influencing the behaviour of blind-bolted connections.

1.3 Objectives of the Study

The objectives of this study are:

(i) To predict the moment resistance and rotational stiffness using theoretical component method and Gomes method.

(ii) To validate theoretical model with experimental results.

(iii) To carry out parametric study with different configuration.

1.4 Scope of Study

This parametric study involves blind-bolted end-plate connections between tubular columns and open beams using theoretical models. A total of eight specimens which comprise of four Flushed End-Plate (FEP) specimens and four Extended End-Plate (EEP) specimens are proposed. The proposed models are based on the Gomes method and component method to predict the initial stiffness and moment resistance of blind-bolted end-plate connections. After validation against experimental results, the model is employed in a parametric investigation into several key factors influencing the behaviour of blind-bolted end-plate connections, namely: the column face thickness, yield strength, various bolt types and sizes, gauge length (defined here as the horizontal distance between two bolts) and end plate thickness. Based on these findings, optimization can be carried out for the configuration of blind-bolted end-plate connections by considering the influence of each key factor.

1.5 Expected Findings

In this research, the behaviour of the connection will be studied based on theoretical component and Gomes method. Moment-rotation curves will be developed from formulation to investigate the initial stiffness and strength of the connection.

This theoretical study will be compared with experimental results. The outcome can be used in determining the suitability of blind bolts in connecting the hollow section and also suggestions for improvement in formulation. After completion of the parametric study , it will also determine the key factors influencing the behaviour of blind-bolted end-plate connections.

1.6 Significance of Study

The significance of this study is to establish formulation based on Gomes method and develop a reliable analytical model for blind bolted connection. It is also to investigate the performance of blind bolt Flushed End-Plate (FEP) and Extended End-Plate (EEP) in term of strength and stiffness based on Gomes method.

Besides that, this study involves the investigation of the connection with different parameters. A standardized connection table for blind bolt Flushed End-Plate (FEP) and Extended End-Plate (EEP) connection on square hollow section column can be developed in future. The standardized connection table will give convenience and ease practicing engineers in designing the connection between I–beam and square hollow section.

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