THE FINITE ELEMENT ANALYSIS OF BEHAVIOR OF BOLTED COLUMN TO I-BEAM CONNECTED WITH CHANNEL STIFFENERS

LEE JIN YEOW

Thesis Submitted in Partial Fulfillment of the Requirement for the Award of the Degree of Bachelor of Civil Engineering

FACULTY OF CIVIL ENGINEERING & EARTH RESOURCES
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

Steel channel as stiffeners is a new stiffening method proposed for moment-resisting beam-to-column connections of steel frames, to meet some architectural needs. This method uses bolted channels as alternatives to both continuity and double plates. This study investigates the behavior of bolted column to I-beam connected with channel stiffeners in steel frames by using finite element analysis (FEA). From the FEA analysis, utilizing LUSAS 14.0.3 software, the interaction between the type of column stiffeners and column flange bolted to beam connections, as well as geometric and material have been considered. Five models had been conducted in this project by using FEA software. Based on the results of FEA, the stress-strain relationship and behavior of bolted column to I-beam connected with channel stiffeners has been presented. Besides, the buckling loads and deformed shapes of the bolted column to I-beam influenced by type of stiffeners have been illustrated. Conclusions are given as that steel channel stiffeners used in steel frames are improve the performance of column connections, but less effective compared with traditional steel plate stiffeners.

ABSTRAK

Keluli saluran berbentuk C sebagai pengukuh ruang adalah suatu kaedah baru dicadangkan kepada sambungan antara rasuk ke ruang dalam rangka keluli yang menahan daya momen untuk memenuhi beberapa keperluan seni bina. Kaedah ini menggunakan saluran yang diperketatkan dengan baut sebagai alternatif kepada pengukuh kesinambungan dan pengukuh plat dua. Kajian ini untuk mengkaji sifat bagi sambungan antara rasuk berbentuk I ke ruang dikaitkan dengan pengukuh ruang dalam rangka keluli yang diperketatkan dengan baut. Di samping itu, kajian dijalankan dengan menggunakan analisis unsur terhingga (FEA). Dengan analisis FEA, perisian LUSAS 14.0.3 digunakan, interaksi antara jenis pengukuh ruang dan ruang flange yang diperketatkan dengan baut dan sambungan rasuk, serta geometri dan bahan telah dipertimbangkan. Lima model telah dijalankan dalam projek ini dengan menggunakan perisian FEA. Berdasarkan keputusan FEA, hubungan tegasan-terikan dan sifat ruang diperketatkan rasuk berbentuk I berkaitan dengan pengukuh saluran telah dibentangkan. Selain itu, bukling beban dan bukling bentuk bagi ruang diperketatkan rasuk berbentuk I yang dipengaruhi oleh jenis pengukuh telah digambarkan. Kesimpulannya, pengukuh saluran keluli yang digunakan dalam kerangka keluli dapat meningkatkan prestasi sambungan ruang, tetapi kurang berkesan berbanding dengan pengukuh plat keluli tradisional.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

SYMBOL	MEANING
M-NS	Mild Steel, Non-Stiffeners
M-PS	Mild Steel, Plate Stiffeners
M-CS	Mild Steel, Channel Stiffeners
et. al.	And Others
h_c	Column Height
h_{ep}	End Plate Height
t_{ep}	End Plate Thickness
m	Meter (Length Unit)
mm	Millimeter (Length Unit)
N	Newton (Load Unit)
kN	Kilo Newton (Load Unit)
W	Weight (Load Unit)
M	Moment (Nm)
E	Young's Modulus
v	Poisson Ratio
σ	Stress (N/mm^2)
ε	Strain
γ	Shear Strain
ψ	Flexural Strain
σ_{max}	Maximum Stress (N/mm^2)
ε_{max}	Maximum Strain
3D	Three Dimensions

LIST OF ABBREVIATIONS

ABBREVIATION	MEANING
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Method
LUSAS	London University Structural Analysis Software
ANSYS	Acronym to Analysis System
MAC	Acronym for Media Access Control
ABAQUS	Other Program of Finite Element Analysis Software
COSMOS/M	Other Program of Finite Element Analysis Software
SAMCEF	Other Program of Finite Element Analysis Software
QSL8	Quadrilateral Thin Shell Elements with 8 Nodes Clockwise
QTS8	Quadrilateral Thick Shell Element with 8 Nodes Clockwise
QSL6	Quadrilateral Thin Shell Elements with 6 Nodes Clockwise
JSL4	3D Joint Element which Connected 2 Nodes by 3 Springs in LUSAS Analysis
rad	Radian, θ

CHAPTER 1

INTRODUCTION

1.1 Introduction

In steel structures, beam – column joints are the most critical parts in a moment- resisting steel frame subjected to vertical load. The vertical forces received by beam will convert to moment forces and transfer through the beam flanges to the column in the form of a couple. The couple is formed from this moment and acts at a moment arm equal to the depth of the beam (center-to-center of the flanges if directly welded). The beam is therefore exerting a tensile force through one flange and a compressive force through the other as shown in Figure below. (Tagawa and Gurel, 2005).

The joints must have high strength to resists the moment forces resulted by the high stress and stain acting on the beam and column. The burdened moments received by the connection access the capable of the design beam – column joints will make the structures fail. There are two types of joints using in the beam – column connection, which are welded connection and bolted connection.

Welded connection is common joint used in steel structure but the strength of the joints will affected by the welding skills used. Welded connections are direct and efficient means of transferring forces from one member to the adjacent member. Welded connections are generally made by melting base metal from parts to be joined with weld metal, which upon cooling form the connection. Welding is also has disadvantages to implemented for construction, such as that is more costly to deposit a given quantity of metal for welding, relatively high metal wastage (electrode stubs).

Bolted connections have become an important alternative in consideration of their good performance. Bolting is common in field connections, since it is simple and economical to make. Bolting is also regarded as being more appropriate in field connections from considerations of safety. Two types of bolts are used in bolted connection which is bearing bolts and high strength friction grip HSFG bolts..

Besides the connection of the beam-column joint, column stiffeners are important to support the moment's forces of the connection directly. The forces resulting from the transfer of moment from the beam to the column are relatively large concentrated forces. At the beam tension flange of the connection, the pull created on the column flange may be great enough to cause slight deformation of the flange. The strength of the column will therefore be impaired. Similarly, the compressive force entering through the other flange may be large enough to cause instability in the column web. (Tagawa and Gurel, 2005).

The connection can be improved by providing additional strength to the column connection where the load is being transferred in the form of stiffeners as shown in Figure 1.1. Stiffeners are placed on the column at the locations of the beam flange forces to add extra absorption membrane prevent distortion of the column flange where the beam exerts the tensile loading and web yielding and crippling at the compression loading.

Stiffeners are therefore designed to prevent local column failure created by large beam forces at the moment connection. In order to increase the performance of column – beam connection and match with architectural design at the same time, steel channel stiffener has been proposes in this study due to the large area of the absorption membrane in the channel as shown in Figure 1.2. This study has been carried out to investigate the steel channels used as stiffeners for the beam – column connection subjected to vertical load.

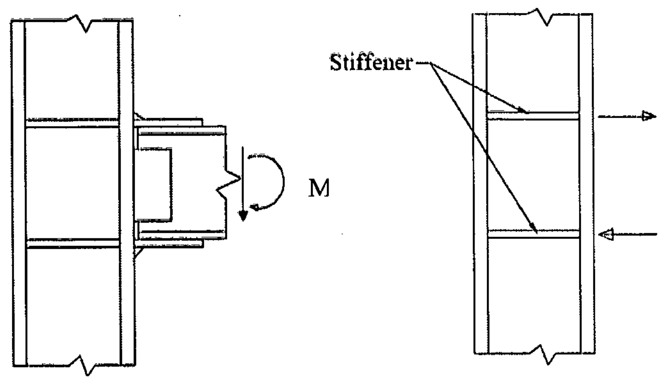

Figure 1.1: Moment Transfer Couple (Shi *et. al.*, 2008)

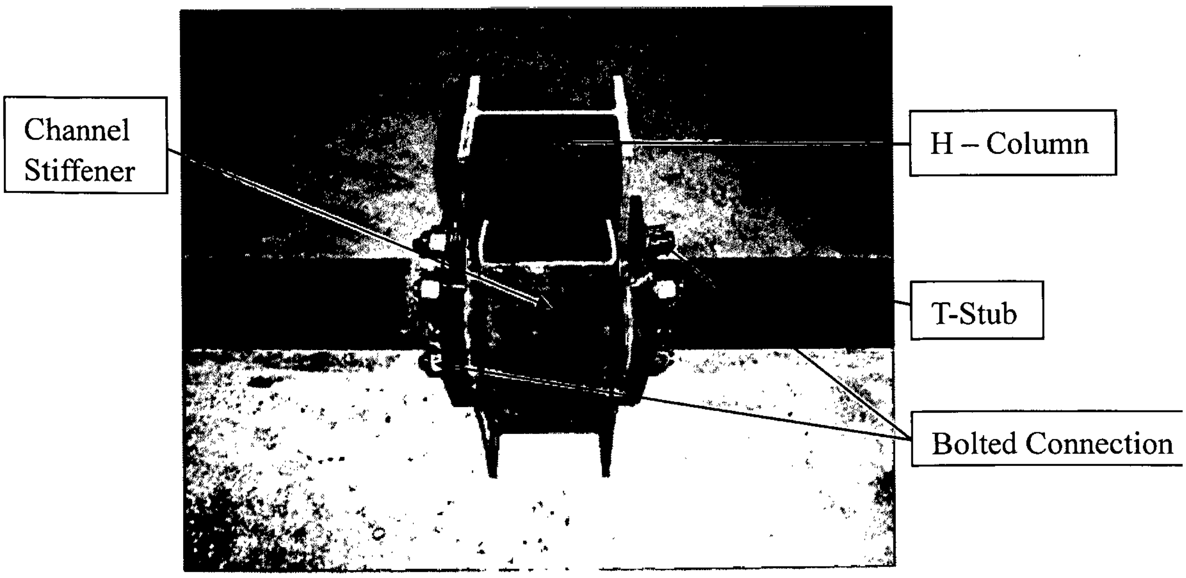

Figure1.2: Channel Stiffener (Tagawa and Gurel, 2005)

1.2 Problem Statement

In the beam – column connections, the large moment force transferred from the beam to the column resulting large force acts to column. The column web will be the critical part receiving the forces from the beam that will cause the instability of the column web and deform the structure at the connection part in column web. Hence, the design doesn't match with the actual requirements for the structure, collapse of the structure and failure of support at the connection with using wrong design.

Column stiffener is provided in the column connection area to withstand the forces acting on the section. The normal stiffener is plate stiffeners which is located at the both end connection area as shown in the Figure 1.2. But the intersection area between column web and stiffener used to transfer load of the plate stiffeners are limited, that is restricting the maximum loads burdened by the column before buckling.

1.3 Objective

The objective of this project is to study the performance of bolted column to I-beam connection with channel stiffeners as shown below.

i. To investigate the behavior of channels as stiffeners by using finite element method.

ii. To identify stress – strain relationship of the bolted column to beam connection attached with channel stiffeners.

iii. To study the buckling load and deformation shape of beam – column connection under vertical load.

1.4 Scope of Study

The scope of work of this project is to analyze the performance of bolted column to I-beam connection with channel stiffener and without stiffener by using finite element computer package which is LUSAS Modeling version 14.0. In this study, five members of models of bolted column to I-beam connection with different parameter of hot-rolled channel stiffener (standard size), traditional plate stiffener and without stiffener are prepared to analyze the performance of channel stiffeners.

All models were applied with similar magnitude of axial load at the same location of beam connected with bolted column. After that, the reactions of the connection area at bolted column were recorded and analyzed and obtain the stress – strain distribution data, buckling magnitude, and deformation shape for each of the models. The results are shown in two-dimensional finite element simulations in LUSAS. Table below shows the sizing of the models based on its stiffener type.

Table 1.1: Stiffeners Thickness

Test	Type of Stiffener	Stiffener Thickness (mm)
M-NS	None	-
M-PS-10	Plate Stiffener	10
M-CS-6	Channel Stiffener	6
M-CS-10	Channel Stiffener	10
M-CS-20	Channel Stiffener	20

1.5 Significance of Study

This project is conduct to study the performance of steel channel used as stiffeners for bolted column to I-beam connection. The performance of steel channel used as stiffeners is determined in term of strength in the stress – strain distribution resulted with the forced transferred by beam to column. The buckling stress and deformation shape of the column resulting by the forced obtained from the transferred moment by beam gained from the analysis also indicates the effectiveness of channel stiffener. By comparing with the bolted column to I-beam attach to plate stiffener and without stiffener.

Besides, the performance of the channel stiffener is also depending to its thickness and type of stiffener. Comparison between the size of the channel stiffener, and the type of the stiffeners from the models is useful to identify the capability of steel channel stiffener. Furthermore, this study also conducted to learn the important of FE used in industrial sector to analysis structure behavior compared with laboratory testing, which are saving cost and man power of laboratory testing.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In steel structures, beam-to-column connections, often significantly influence the behavior of steel frames, with deformation of the connection in combination with the P-delta effect contributing to excessive lateral drift in un-braced multi-storey frames. For most connections under ambient conditions, the axial and shearing deformations are usually small compared to the rotational deformation and consequently the rotational deformation is the most important characteristic of the connection. This rotational deformation is customarily expressed as a function of the moment in the connection as described by Shi *et. al.*, (2008). Hence, moment loading is typical loads considered in beam-to-column connections.

Beam to column connections of moment-resisting frames has receives critical moment loading in the structure. Beam to column connection without stiffeners is lack of capability withstand for the critical moment loads. Thus, the connections are traditionally stiffened with transverse continuity plates, and if necessary, web double plates. Besides those traditional plate column stiffeners used, new stiffening method which is bolted channels are used as alternatives to both continuity and double plates. That application of steel channel as stiffener is described by Tagawa and Gurel, (2005) and shown in Figure 2.1.

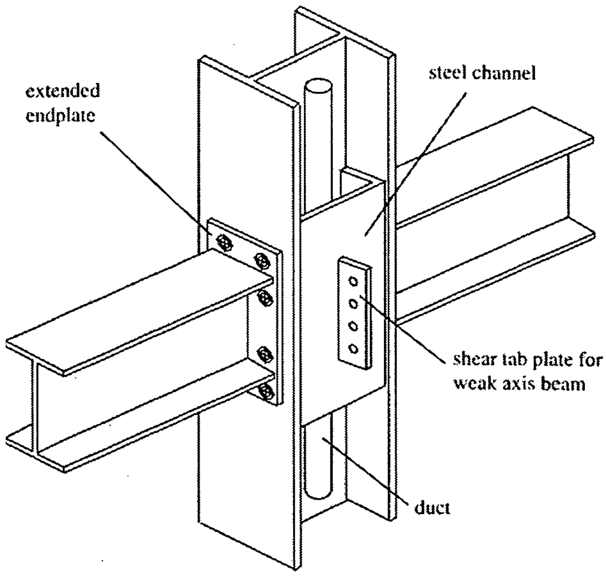

Figure 2.1: Application of Steel Channel as Stiffener
(Tagawa and Gurel, 2005)

According to Tagawa and Gurel, (2005), channel as stiffeners is increasing yield load in the tension zone of connection between beam and column, gradually increase overall moment capacity of connection, and avert shear failure of the column web panel zone. Using T-stubs or extended end-plates, beam-ends connect to the column flanges with bolts shared by the channel connection. Tension region of the connection loaded from T-stubs shows the stiffness improvement in the method of stiffening with channels compare with traditionally stiffener.

Therefore, this thesis is to study the advantages and disadvantages of steel channel as stiffeners compare with the traditional steel plate stiffeners and non-stiffeners. Steel channel stiffener has big cross section area which allows it to absorb the moment loads more effectively and high yield strength to resists tension forces and compression forces applied for the connection section. Besides, traditional stiffener consisted of steel plate connection between end of the flanges in column is