PREDICTING THE BEHAVIOUR OF FLUSH END PLATE CONNECTIONS USING STRAIN GAUGES

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A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil - Structure)

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November 2009

I declare that this project report entitled "*Predicting the Behaviour of Flush End Plate Connections using Strain Gauges* "is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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TO MY BELOVED

FATHER
TUAH BIN NGAH MOHD

MOTHER
Pn ROSNI BT ISMAIL

SISTER
NURUL QURATU AIN
NURSYAIDATUL NATRAH

MOHD REDZUAN HUSSIN

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ABSTRACT

Connections are commonly designed as simple or rigid although the actual behavior is known to fall between these two extreme cases. This study presents the results of an analysis of strain gauge data from the already conducted experimental work on flush end plate connections for trapezoid web profiled (TWP) steel section. The experimental work on these partial strength connections has been done by Md Tahir, M. *et al*. in 2006. The objective of this study is to manipulate the strain values in predicting the behavior of flush end connections from isolated tests in term of the capacity. The flush endplate connections used in this study are partial strength with TWP steel section as beam and hot rolled U-C section as column. The relationships between moment and rotation of each connection were obtained, and performances were evaluated in terms of the stiffness, moment capacity and ductility. The results show that the pattern and trend of moment rotation curves from the strain gauge analysis are in good agreement with the ones obtained using inclinometers. Therefore, it can be concluded that the strain gauge data can be used to predict the behaviour of the flush end plate connections. Furthermore, the results also show that the moment capacity of the connection increases as the size of beam increases. The small percentage of different between the predicted values and to exact values obtained using the inclinometer shows that strain gauges can be used as the alternative data collecting devices in predicting the behaviour of the flush end plate connections.

ABSTRAK

Rekabentuk sambungan kebiasaan direka sebagai sambungan mudah dan sambungan tegar tetapi kelakuan sambungan yang sebenar adalah separuh tegar. Kajian ini memberi keputusan daripada analisis data ujikaji tolok terikan yang telah dijalankan sebelum ini keatas plat hujung sedatar menggunakan rasuk berprofil trapezoid. Ujikaji keatas sambungan separuh tegar ini telah dijalankan oleh Md Tahir, M. *et al.* pada 2006. Objektif kajian ini adalah memanipulasikan nilai terikan untuk meramalkan kelakuan sambungan keluli jenis plat hujung sedatar dalam bentuk kapasiti. Sambungan keluli jenis plat hujung sedatar telah diguna sebagai sambungan separuh tegar, di samping rasuk berprofil trapezoid dan tiang berbentuk U-C. Hubungan antara momen dan putaran untuk setiap sambungan boleh diperolehi dan prestasi sambungan tersebut dihasilkan dalam bentuk kekukuhan, momen keupayaan dan kemuluran. Daripada keputusan yang diperolehi, ia menunjukkan bentuk lengkungan momen putaran daripada analisis tolok terikan mempunyai keserataan yang baik dengan keputusan yang dihasilkan melalui ujikaji *inclinometer*. Kesimpulannya, data daripata tolok terikan boleh digunakan untuk menganggarkan kelakuan sambungan plat hujung sedatar. Selain itu, keputusan yang diperolehi juga menunjukkan nilai moment keupayaan bertambah bila saiz rasuk bertambah. Peratus perbezaan yang kecil antara nilai jangkaan dan nilai yang sebenar dari *inclinometer* menunjukkan tolok terikan boleh digunakan sebagai salah satu alat dalam menjangka kelakuan sambungan plat hujung sedatar.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURE

CHAPTER 1

INTRODUCTION

1.1 General

Steel as a structural material has several desirable qualities such as high strength, high stiffness and high ductility. It is the strongest, most versatile and economical material available to the construction industry and its high ductility enables it to withstand large deformations at high stress levels without rupture. Strength is the ability of a material to resist stresses; stiffness is the ability of a material to resist deformation; toughness is the ability of a material to absorb energy before failure meanwhile ductility is the ability of a material to undergo large plastic deformation before failure [1].

Steel structures are built using many components, such as tension members, compression members, bending members, combined force members and connections [2]. Amongst the said components, connections are the most critical. Most steel structure failures are caused by inadequate and poorly designed connections, while failure due to main structural members is rare. Poorly or wrongly design connections can lead to a failure and can affect the stresses of the main structural members. They affect the overall behavior of the structure.

Steel frame, the connection between the beam and column is either assumed as pinned, where only nominal moment from the beam is transferred to the column or rigid connection where full continuity of moment transfer exists [3]. However, a majority of the actual connections show partial strength behaviour but the ability to predict the behaviour of this connection is still limited. The limited is because to understanding the real behaviour of this connection compares another connection. Same with another connection, semi rigid connection design requires the moment rotation relationships, which include the moment resistance and rotational stiffness to be established prior to its usage in design. The purpose of using Trapezoid Web Profile sections is to take advantage of the benefits offered by the section in general [4].

1.2 Problem Statement

In steel structure, connection is a one a most importance part in structure strength. Mostly connection designed in past are assumed either perfectly pinned or fully rigid connection although the actual behavior is known to fall between these two extreme connections. While the types connection of flush end plate is a semi rigid connection. A semi rigid flush end plate is representing various complexity and undefined problems with many parameters affecting its behavior and structural capacity. The behaviour of semi rigid is not very familiar like other types of connection. So to understand more about real behaviour of the semi rigid connection, one laboratory testing can be conducted. The experiment is strain gauge analysis.

Commonly the behavior of connections can be show in term of moment rotation curve and basically can be obtained from the experiment of inclinometer. When one situation did not have inclinometer equipment or data but only have strain gauge, so at this situation the analysis must be done from the data of strain gauge to predict the behaviour of this connection.

1.3 Objective

The objective of this research is:

1.3.1 To analyse the strain gauge data of flush end plate connection.

1.3.2 To manipulate the strain values of in predicting the behaviour of the flush end connection from isolated tests in term of the capacity.

1.3.3 To obtain the related deformation of the connection.

1.4 Scope of Studies

In this research, a scope of this study is Analytical investigation of the experimental work based on the data obtained from the strain gauge. This study focuses on a bolted flush end plate connection, by connecting the end plate at the end of trapezoidal web profile beam to the flange of an U-C section of a column. The data of strain gauge were obtained from experimental tests done by Md.Tahir *et al.* (2006). The result comparison is choosing with inclinometer experiment done by Md.Tahir *et al.* (2006).

CHAPTER 2

LITERATURE REVIEW

2.1 Beam to Column Connection

Beam-to-column connections are important elements of a steel frame and their behavior influenced its performance under the load. Beam-to-column connections are neither ideally pinned nor ideally fixed and posses a finite non-zero stiffness. However, many researchers reveal that in reality the connections behave in between the two extreme assumptions and possess some rotational stiffness.

Connection between beam and column fall into two broad categories, those intended to carry moment and those intended to carry vertical shear only. End plate connection, framed connections and seat brackets are generally designed to carry vertical shear only, as part of a simply supported design. With web end plate and web framed beam connections is particular, a theory has been expounded whereby yielding of the end plate or angles should be allowed in order to reduce the moment that is transmitted from the beam to the column [5].

Several forms of simple beam-to-column connections are illustrated in Figure 2.1.

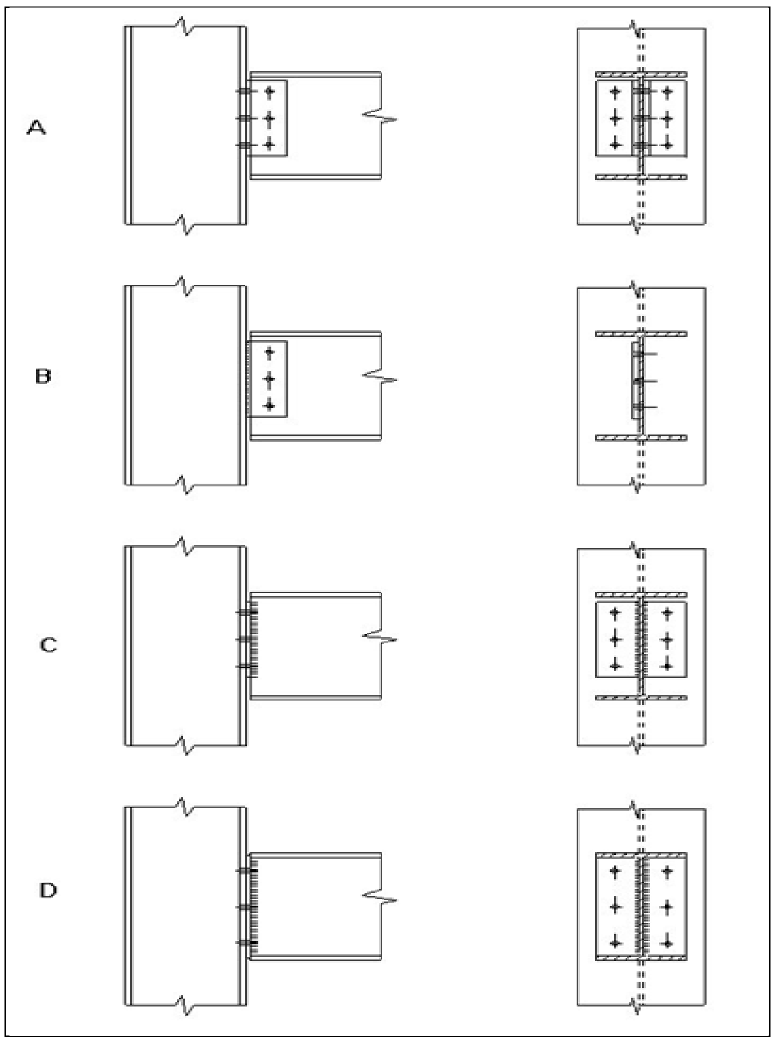

Figure 2.1: Beam to column connection, A) fully bolted, B) Finplate C) Endplate, D) Flush Endplate

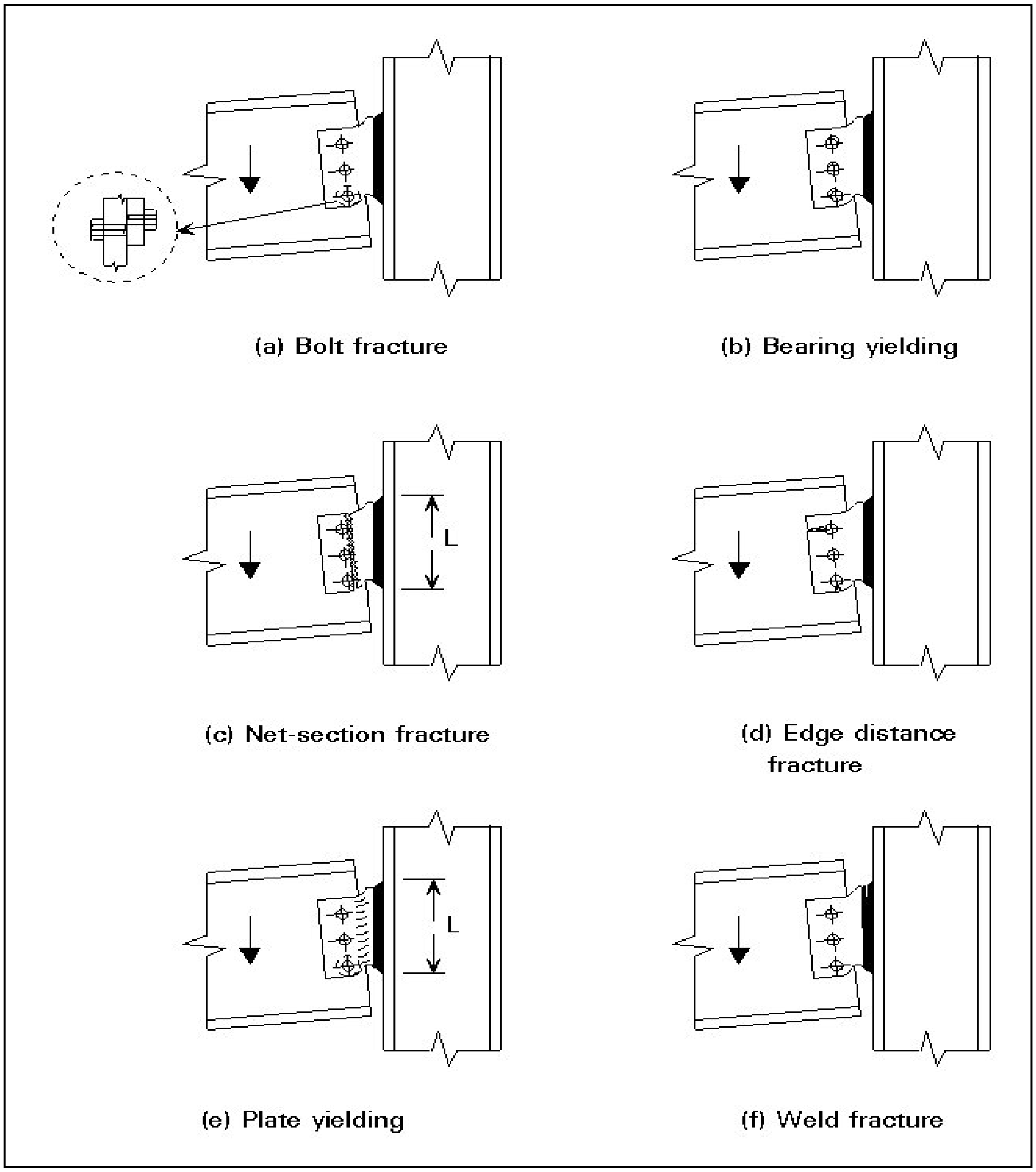

Figure 2.2: Illustrates the 6 possible failure modes for a fin plate connection

The characteristics of a connection can be best understood by considering its rotation under load. The connections rotate at an angle due to applied bending moment as shown in Figure 2.3. This connection deformation will increase the drift of the frame and causes a decrease in effective stiffness of the connected member. An increase in the frame drift will multiply the second-order (P-Δ) effects of beam-column members and thus will affect the overall stability of the frame.

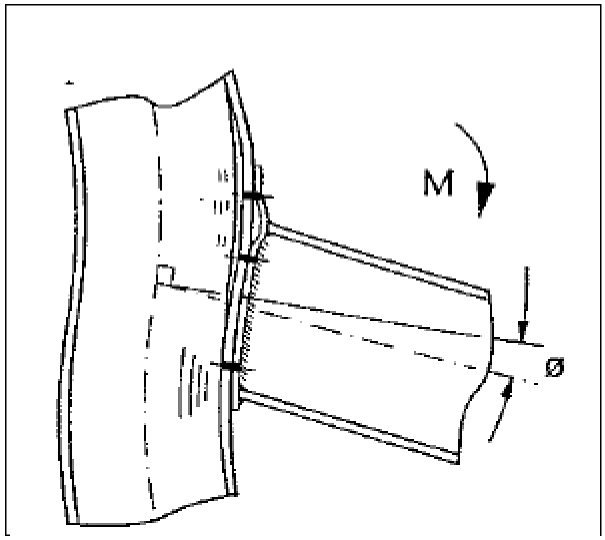

Figure 2.3: Moment-Rotation of connection [6].

2.2 Types of Connection

The stability and performance of a steel structure will be influenced by the connection between beam and column. The connections are used to transfer forces and moment due to the applied loading. Connections in steelworks are classified based on the capability of the connection in resisting moments. With this criterion, connections are divided into three types: simple connection, semi-rigid connection and rigid connection.

2.2.1 Simple Connection

Simple connections are only designed to transmit shear from the beam to the column, at some nominal eccentricity from the face of the column [7, 8, and 10]. Simple connection is providing zero rotational restraint at connections; they possess sufficiently low stiffness and are thus incapable of transmitting significant moments at ultimate limit state. Simple connection are designed can transmit end shear and axial force only. Under simple connections, there are three common types of connections that are frequently been used: web angle cleat, flexible endplate and fin plate. The simple connection is adapted to the steel structure because is easy to design and construct. Figure 2.4 show the characteristic of simple connection.

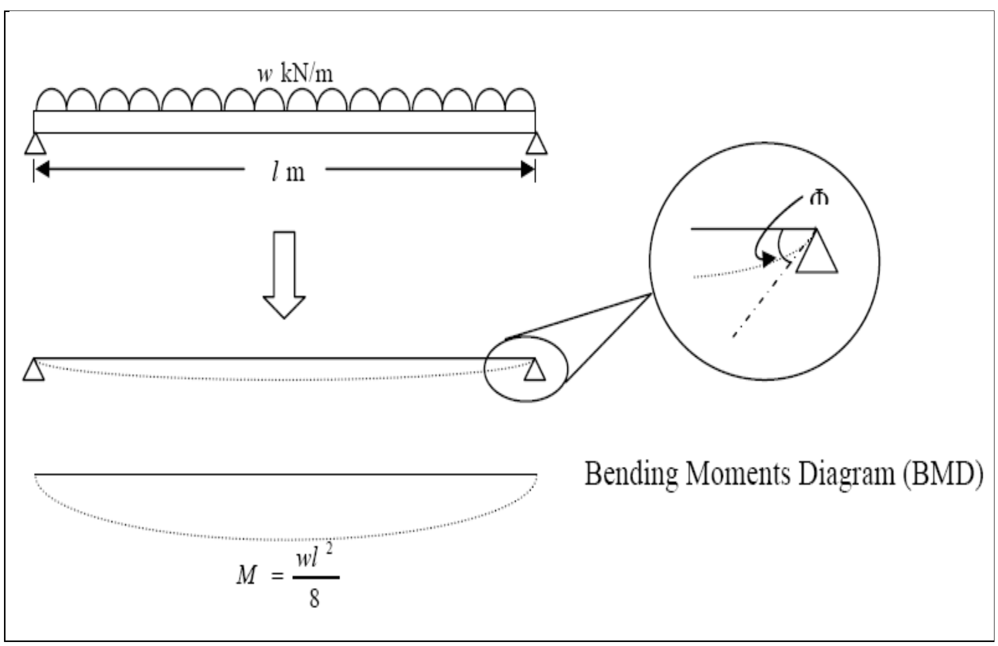

Figure 2.4: Simple connections

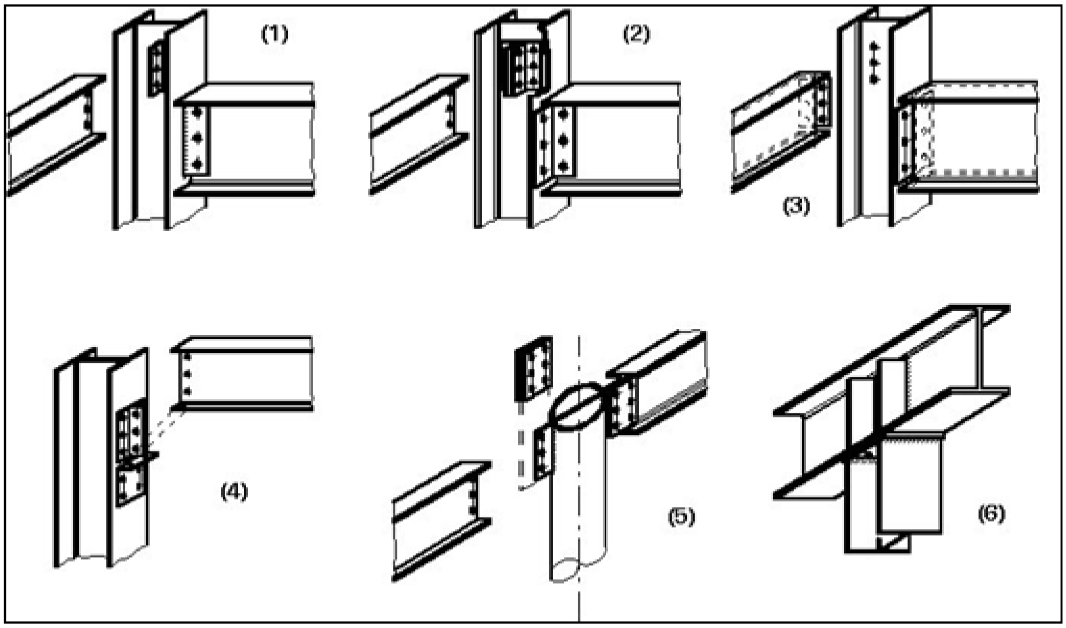

Figure 2.5: Simple beam to column connection,1) fin plates, 2) angle cleats, 3)flexible endplate welded, 4)bolted with angle cleats, 5) tube, 6) stiffness plate

Simple connection is those which comply with the following five conditions [8]:

a) Are assumed to transfer the design shear reaction only between members.

b) Are incapable of transmitting significant moments which might adversely affect members of the structure.

c) Are capable of accepting the resulting rotation.

d) Provide the directional restraint to members which have been assumed in the member design.

e) Have sufficient robustness to satisfy the structural integrity requirement.