MONOTONIC BEHAVIOUR OF BEAM-TO-COLUMN CONNECTIONS WITH DOUBLE CHANNEL COLD-FORMED STEEL SECTIONS

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Abstract: Cold-formed steel is a lightweight construction material generally in C or Z shaped produced by cold rolling from strip steel. It can be applied in the Industrialized Building System (IBS) in order to reduce the time and cost in construction project. Partial strength connection is a connection whereby the moment resistance of the connection is less than that of the moment capacity of the connected beam. In this paper, Numerical simulation is conducted by using ANSYS Workbench 14.0 in order to predict the structural behaviors of cold formed steel partial strength connection. The objective of this study is to develop moment rotation curve for flange-web-cleat connection using double channel cold formed steel section under monotonic loading. Experiment test results are then used to compare and validate the results from the finite element modeling. This study aims to understand the behaviour of cold-formed steel connections under monotonic loading. The beam section of 1.5-meter length and column of 3-meter length is modeled in this study. Three different beam depth have been selected in this study, which is 150mm, and the depth of column section is fix to 250mm. Brackets connections were chosen and all connections were formed using bolts. The monotonic load is applied at 1000mm from the column surface. The stiffness and moment capacity is obtained from the moment rotation curve which plotted from the modeling results. As a conclusion, The FEM initial results showed good agreement with experimental results.

Keyword: *Flange-Web-Cleat Connection, Beam to Column Connection, Double Channel Cold-Formed Steel Section, Monotonic, ANSYS Modeling.*

1.0 Introduction

Cold-formed steel (CFS) is categorized as lightweight steel which is widely used in construction attributed to the ease of production and mass production and prefabrication, uniform quality, lightweight designs, economy in transportation and handling, and quick and simple erection or installation. Cold-formed steel is produced by cold reducing hot rolled coil steel and is galvanised to provide adequate protection to avoid corrosion. Typical cold-formed steel members such as studs, track, purlins, girts and angles are mainly used for carrying loads while panels and decks constitute useful surfaces such as floors, roofs and walls, in addition to resisting in-plane and out-of-plane surface loads.

By comparing the benefits of using lightweight steel with the traditional masonry construction, it has been proven that the speed of construction using lightweight steel is faster due to the advantage that the pre-fabrication process can be done off-site. The dimension of the lightweight steel component or modular will provide more accuracy. The cost, quality of product can be predicted easily as the quality control and price are fixed for most of the manufacturers. Furthermore, it would not have problems such as termites' infestation as it is a more stable material which has higher life span. Continuous hot dip galvanized sheet steel affords excellent corrosion resistance compared to the reinforcement steel bar which will get corroded especially for buildings near the sea.

2.0 Problem Statement

In common practice, the cold-formed steel section were only use as roof purlin or wall panel in modular construction. However, there are no noticeable researchers carried out the study to create a design standard for connections on cold-formed steel light framing system. The design code in AISI S100, BS5950-5, and Eurocode 3: Part 1-3 only covers the used of individual fasteners such as bolts, screw, rivets and welds on cold-formed steel section, and not the actual cold-formed steel connection (Bagheri Sabbagh, 2011).

Partial strength connections in steelwork design were focused on application for hot-rolled steel section. Current researches on connection for cold-formed steel were mostly study on pin joints and some in rigid moment connections. The design method for partial strength connections in cold-formed steel section has not been concluded (Tan, 2009).

Therefore, there is a need to carry out a study on the behavior of connection on cold-formed steel section for moment frame buildings.

3.0 Objectives

This research aims on the model analysis the use of double channel cold-formed steel connection and its seismic response by using finite element method. In achieving this aim, the following objectives are formulated: _

(i) To develop moment rotation curve for bolted beam to column connection using double channel cold formed steel section under monotonic loading.

(ii) To compare performance of connection by comparing the laboratory experiment results with the numerical model simulation results generated by ANSYS.

4.0 Scope of Study

The scope in this research covers on the behaviour of double channel cold-formed steel connections in cold-formed lipped Double Channel (DC) section with thickness of 2mm. Brackets, angle and gusset plate connections were chosen and all connections were formed using bolts, where no welding work is required. The scopes of this study include: _

(i) Modeling analysis for proposed connection under monotonic loading using ANSYS.

(ii) Experimental testing for proposed connection under monotonic loading for validation.

(iii)Result comparison on experimental vs numerical

5.0 Significance of Study

The significant of this research study which will be achieved is shown below: _

(i) Understanding on behavior of proposed connection under monotonic loading.

(ii) Procedures of numerical modeling

6.0 Literature Review

Industrialized Building System (IBS) is a modular construction method which has been used widely in construction industry ever since it is introduced to the construction world. Generally, cold-formed steel is useful as light steel framing to contribute to modular construction. Therefore, understanding on the properties and behaviour of cold-formed steel is important before conducting the study on the double back to back channel cold-formed steel connection.

This section of writing will focus on properties of cold-formed steel (CFS), development of steel research related seismic behavior and research in cold-formed steel. Critical review to the related research will be summarized at the end of this chapter.

6.1 Properties of Cold-formed Steel

The cold-formed steel section manufactured by press-braking blanks sheared from sheets, cut lengths of coils or plates, or by roll forming cold- or hot-rolled coils or sheets; both forming operations being performed at ambient room temperature, with thickness ranging between 0.4 and 7 mm (Yu, 2010). Cold-formed steel structural members may lead to a more economic design than hot-rolled steel members as a result of their superior strength to weight ratio and ease of construction (Young, 2008). Cold-formed steel is extensively use as roof deck, floor and wall panels, studs, floor joists, roof joists and other structural elements.

Generally, the grades of carbon steel and high strength low alloy steel used for cold-formed steel products are characterized by the yield point and tensile strength. The yield point of the steels commonly used for cold-forming ranges from 33 to 55 ksi (230 to 380 MPa), and may be higher. The ratio of tensile strength to yield strength for cold-formed steels commonly ranges from 1.2 to 1.8 (F.Muftah, 2013). Tensile strength and ductility are important because it could affect the local deformation of the connection and needed to specify and its applications.

6.2 Development of Steel Research Related Seismic Behavior

For structure able to resist the earthquake, there are three main criteria need to be highlighted: strength, stiffness and ductility. The strength of the structure is often less than that needed to remain completely elastic during a severe earthquake. Consequently, ductility must be provided to sustain he anticipated inelastic deformations. Stiffness requirements are established by code specified drift limits (Engelhardt et.al, 1992).

In order to facilitate the cold-formed steel design in seismic area, laboratory testing such as cyclic loading test had been conducted by some of the researchers. Cyclic loading tests apply oscillating loads, often until specimen failure, using load schemes which involve either cyclical tension, compression or both. It intended to measure the resisting system of elements subjected to earthquake loads. ASTM E2126–11 shows the standard test method for cyclic (reverse) load test for shear resistance of vertical elements of the lateral force resisting system for buildings.

Cyclic loading test simulates the actions and effect of an earthquake. The behaviour and the results obtained from the test can be affected by the type, spacing, and edge distance of fasteners attaching sheathing to framing and spacing of the shear connections and hold-down connectors. The tightness of the fasteners that attaches the specimen to the test base will also influenced the test results (ASTM E2126-11).

7.0 Analysis and Results

The connection in this study is flange-cleat connection on double channel cold-formed steel sections.

7.1 ANSYS Model Analysis

First the specimen was modeled using the ANSYS Design Modeler by following the actual configuration of laboratory experiments. After that, the engineering data which is a resource for material properties used in an analysis system was created for the material used in the experiments. The data is obtained from the tensile couple test done on the specimens and it was shown below in Table 1.

Table 1: Material Properties for ANSYS Model.

Material	Young Modulus (MPa)	Tensile Yield Strength (MPa)	Tensile Ultimate Strength (MPa)
Beam DC150	236600	380	448.5
Column DC250	220100	393	490.7
Steel Bracket	227300	381	446.5
Bolts and Nuts	200000	365	440.0

The material is assigned with the corresponding material properties and then the contact of surface is set to be frictional type with coefficient value of 0.3 for metal under Augmented Lagrange formulation. The model was meshed with tetrahedron shaped but control with Mapped Face Meshing. The max face size for the meshing is 50mm. Figure 1 show the meshing of the model.

Figure 1: Mesh of the Model

7.2 Laboratory Testing

The actual experiment is conducted by Dr. C.S.Tan by following the configuration shown in Figure 2.

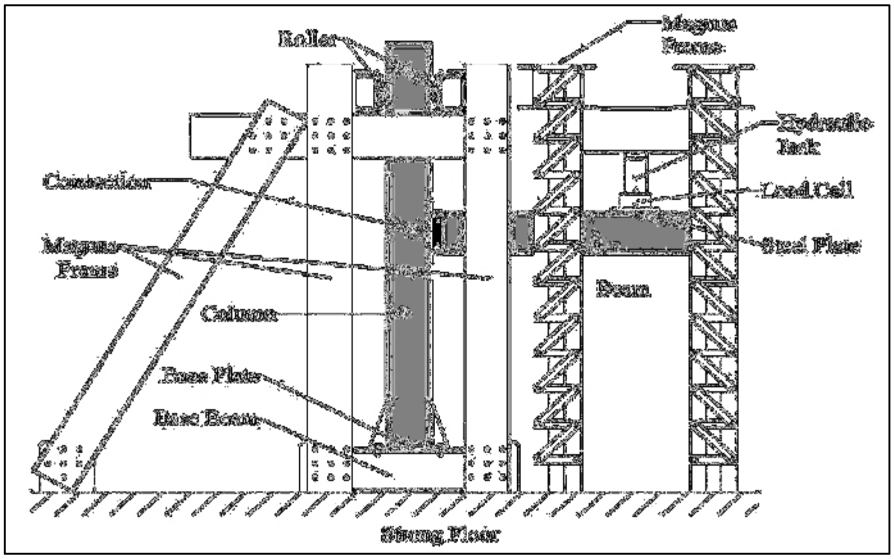
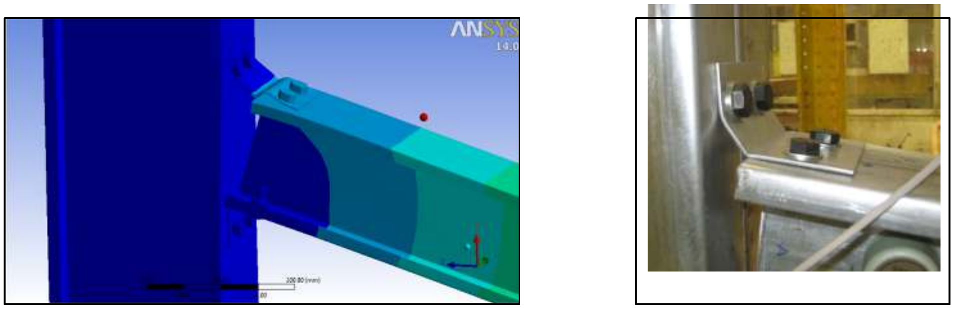


Figure 2: Configuration of Laboratory Texting Specimen

The beam depth used is 150mm with 67mm width and 2mm thickness, and the column used is 250mm with 77mm width and 2mm thickness. The steel bracket as the flange-cleat is 60mm length and 100 width. 8 number of bolts with 12mm diameter is used in this study.

7.3 Results and Discussions

The mode of failure occurred on the specimens were bending of flange-cleat and bending of column flange. When the top-flange yielded until the bolted part, it caused large deformation and reduced the strength. The bended flange-cleat started to pull the bolts at the column flange, caused a slight increment of load capacity, but did not reduce the deflection. The tests stopped due to excessive deflection. The modes of failure are explained in detail, assisted by Figure 3.



(a) (b)

Figure 3: Failure Mode by (a) ANSYS Analysis (b) Experimental

The load versus deflection graph explains the physical behaviour of the joint specimens along the test's progress and the strength, rotational stiffness and ductility of a connection can obtained from moment versus rotation graph. The initial stiffness obtained from the ANSYS which is 47 kNm/rad agree with the experimental results, 46 kNm/rad. At 50mrad of rotation, the normalized bending moment obtained from experiments is 0.78 kNm, but ANSYS obtained the result of 1.12 kNm, which is 30% inaccurate.

Figure 4 shows the comparison of moment-rotation curve of ANSYS model and experiments results. Figure 5 shows the comparison of load-deflection curve of ANSYS model and experiments results.

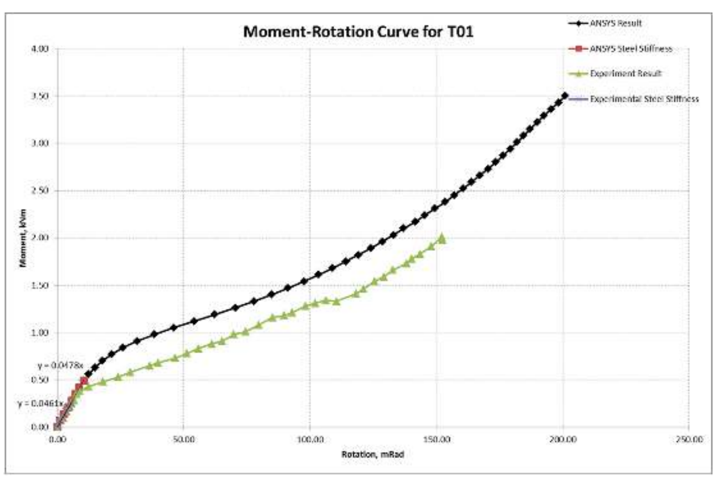


Figure 4: Comparison of Moment-Rotation Curve

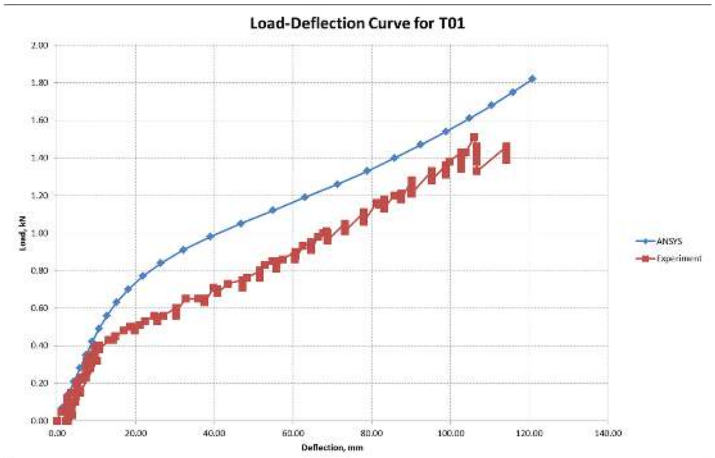


Figure 5: Comparison of Load-Deflection Curve

8.0 Conclusion

This paper presents the investigation on the behaviour and the application of flange-cleat connection on double channel cold-formed steel sections. It also had shown the steps of analytic modeling by using ANSYS Workbench 14.0. The validation of ANSYS results were made through the experimental investigation. Summary of the ANSYS analysis on connections showed that: _

- The initial bending moment and stiffness obtained from ANSYS model completely agree to the experiments results.
- The normalized bending moment and stiffness under plastic condition were 30% inaccurate compared to the experimental results.

In order to improve the accuracy of modeling results, ANSYS model analysis with different meshing method can be conducted to do the checking of results. The type of connections will also be investigated in experimental program and also the ANSYS model analysis.

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