FINITE ELEMENT ANALYSIS OF BUILT-UP CLOSED COLD-FORMED STEEL BEAM SECTION WITH WEB OPENING

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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Civil Engineering

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

Faculty of Civil Engineering and Earth Resources

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JUNE 2018

ACKNOWLEDGEMENTS

In the name of Allah SWT the most gracious and most merciful, Alhamdulillah with His permissions, my research project has been completed. Thanks for giving me strength to accomplished this Final Year Project as a requirement to graduate in Bachelor (Hons.) of Civil Engineering from University Malaysia Pahang.

I wish to convey my appreciation and wholehearted sense of gratitude to my supervisor Mr. Khalimi Johan Bin Abd Hamid for his enthusiastic and expert guidance, valuable suggestions, constructive criticism, friendly discussions, and persistent supervision during my research study. I am indebted to him for his constant encouragement and meticulous efforts in correcting faults and suggesting improvements.

I would like to thank the Faculty of Civil Engineering and Earth Resources of University Malaysia Pahang for giving me an opportunity to conduct this research project, as well as my fellow team members and under-graduate students for their positive suggestions and help throughout this research study. In addition, sincere thanks to everyone that involve in completing my research project either direct or indirectly. You and your kindness is appreciated.

Finally, I have deeply appreciated the continuing patience and sacrifices of my beloved family especially my parents, Ramaino Bin Mohd Yusoff and Siti Fatimah Binti Husain, and also my siblings. Their love and support has been a constant source of encouragement and guidance to me. May Allah SWT rewards all of you with His blessings.

ABSTRAK

Siasatan berangka pada binaan ditutup keluli keratan rasuk sejuk terbentuk dengan pembukaan *web* telah dijalankan menggunakan Analisis Element Terhingga. Pendekatan yang paling tepat untuk memahami tingkah laku seksyen keluli sejuk terbentuk dengan kehadiran lubang adalah dengan ujian makmal. Walau bagaimanapun, ujian makmal adalah mahal dan mengambil masa yang lama. Pembangunan analisis berangka dan pemodelan menggunakan perisian unsur terhingga adalah satu lagi alternatif yang boleh menghapuskan kemahalan dan masa yang diambil oleh ujian makmal. Oleh itu, Kaedah Unsur Terhingga telah digunakan dalam kajian ini untuk melaksanakan dan menganalisis binaan ditutup keluli keratan rasuk sejuk terbentuk dengan pembukaan *web*. Tujuan kajian ini adalah untuk menentukan tegasan maksimum, tekanan maksimum, dan lengkokan beban maksimum binaan ditutup rasuk keluli sejuk terbentuk dengan pembukaan *web*. Selain itu, sifat lengkokan binaan ditutup rasuk keluli sejuk terbentuk disebabkan oleh pelbagai bentuk dan bilangan pembukaan *web* disiasat dalam kajian ini. Untuk tujuan ini, model unsur terhingga telah dibangunkan menggunakan LUSAS Modeller 14.0 yang mempunyai bukaan berbentuk bulat dan segi empat sama. Setiap bentuk mempunyai lima spesimen yang salah satu daripada mereka adalah rasuk tanpa bukaan dan selebihnya mempunyai pelbagai bilangan bukaan *web*. Panjang rasuk digunakan untuk semua spesimen adalah 1600 mm. *Pinned* dan *roller* sokongan ditugaskan untuk mengesahkan Analisis Element Terhingga. Setiap model adalah tertakluk kepada dua mata beban. Jenis bersirat digunakan adalah QSL8 untuk semua spesimen. Simulasi yang terlibat dalam kajian ini ialah analisis linear dan analisis lengkokan linear. Keputusan yang diperolehi daripada analisis unsur terhingga termasuk bentuk cacat, tegasan maksimum, tekanan maksimum, lengkokan tingkah laku, dan maksimum beban lengkokan terbina ditutup seksyen rasuk. Daripada keputusan, ia menunjukkan bahawa kekuatan binaan ditutup keluli keratan rasuk sejuk terbentuk adalah pelbagai bergantung pada parameter pembukaan. Binaan ditutup seksyen rasuk tanpa bukaan *web* adalah lebih kuat tetapi mempunyai kegagalan lengkokan tempatan. Sementara itu, bagi binaan ditutup seksyen rasuk dengan bukaan *web*, kekuatan dikurangkan oleh bukaan. Walau bagaimanapun, ini memberi banyak kelebihan kepada mereka. Kehadiran lubang dalam rasuk adalah penting untuk menampung paip, elektrik, dan perkhidmatan pemanas pada dinding dan siling bangunan, dan lubang boleh menghentikan lengkokan tempatan dari berlaku dalam rasuk. Kesimpulannya, binaan ditutup rasuk keluli seksyen sejuk terbentuk dengan pembukaan *web* boleh digunakan dalam industri pembinaan, tetapi mereka perlu direka dengan prestasi yang terbaik.

ABSTRACT

A numerical investigation on built-up closed cold-formed steel beam section with web opening was undertaken using Finite Element Analysis. The most accurate approach to understand the behaviour of cold-formed steel sections with the presence of perforations is by laboratory testing. However, the laboratory testing is expensive and take a long time. The development of numerical analysis and modelling using Finite Element software is another alternative that can eliminate the expensiveness and time taken by laboratory testing. Thus, Finite Element Method was used in this study to model and analyse the built-up closed cold-formed steel beam section with web opening. The aim of this study are to determine the maximum stress, maximum strain, and maximum buckling load of built-up closed cold-formed steel beam with web opening. Besides, the buckling modes of built-up closed cold-formed steel beam due to various shapes and numbers of web opening was investigated in this study. For this purpose, finite element model was developed using LUSAS Modeller 14.0 which having circular and square shapes of opening. Each shape has five specimens which one of them is beam without perforation and the rest having various numbers of web opening. The beam length used for all specimens is 1600 mm. Pinned and roller ended support was assigned to validate the Finite Element Analysis. Each model was subjected to two points loading. The type of meshing used was QSL8 for all specimen. The simulation involved in this study are linear analysis and linear buckling analysis. The results obtained from finite element analysis includes deformed shapes, maximum stress, maximum strain, buckling behaviour, and maximum buckling load of built-up closed section beam. From the results, it is shown that the strength of built-up closed cold-formed steel beam was greatly varied with the perforation parameters. The built-up closed section beam without web opening was stronger in strength but had failure in local buckling. Meanwhile, for the built-up closed section beam with web opening, the strength was reduced by the perforations. However, this gives many advantages to them. The presence of perforation in beam are important to accommodate plumbing, electrical, and heating services to the walls and ceilings of the buildings, and perforations can stop the local buckling from occur in the beam. In conclusion, the built-up closed cold-formed steel beam section with web opening can be used in construction industry, but they need to be designed with the best performance.

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LIST OF SYMBOLS

E	Young Modulus
V	Poisson Ratio
N_{max}	Stress Maximum
E_{max}	Strain Maximum
et. al.	And Other
m	Meter (Length Unit)
mm	Millimetre (Length Unit)
N	Newton (Load Unit)
KN	Kilo Newton (Load Unit)

LIST OF ABBREVIATIONS

LUSAS	London University Stress Analysis System
CFS	Cold-formed Steel
FE	Finite Element
FEM	Finite Element Method
FEA	Finite Element Analysis
QSL8	Quadrilateral Thin Shell Elements with 8 Nodes Clockwise
ABAQUS	A software suite for Finite Element Analysis (FEA)
ANSYS	Analysis Systems

CHAPTER 1

INTRODUCTION

1.1 Introduction

In pre-engineered metal buildings, the overall structure of a building is made from steel products, and around 40-60% of the total steel used is cold-formed steel. In civil engineering applications, the use of cold-formed steel members has been increase significantly in recent years due to its high strength-to-weight ratio and high stiffness-to-weight ratio compared to other traditional materials such as concrete, masonry, and timber. However, a main consideration in design is the resistance against the local instability of plate elements when subjected to compressive, shearing, bending and bearing loads (Chen et. al., 2016). The design of cold-formed steel members includes the post-local buckling strength. It is different with the design of hot rolled steel members where buckling constitutes a failure. In fact, the actual strength of cold-formed steel members can be many times bigger than the actual buckling loads (Gardner and Baddoo, 2009). Thus, it is necessary to include the post-buckling strength in design to achieve maximum benefit.

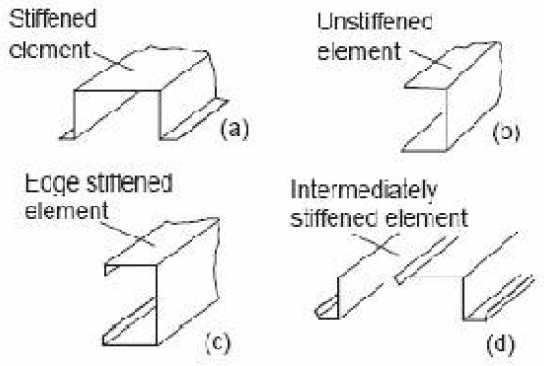

Figure 1.1 Types of cold-formed steel elements

Source: Gilbert et. al., (2012)

In building construction industry, cold-formed steel products are mainly used as structural members, diaphragms, and coverings for roofs, walls and floors. There are varieties shape of cold-formed available as structural members such as open sections, closed sections, and built-up sections. Open sections including cee-, zee-, double channel I-sections, hat, and angle sections while box sections and pipes are closed sections. Open built-up and closed built-up section are one of the several sections that can be built using standard single sections available such as C-section, U-section, and Z-section as shown in Figure 1.2.

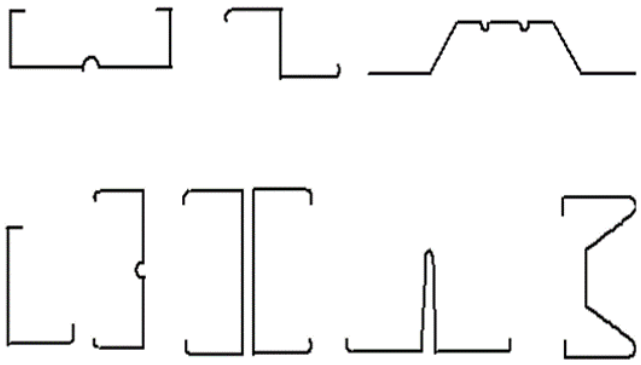

Figure 1.2 Typical cold formed steel profiles

Source: Craveiro et. al., (2016)

The built-up section is formed by connecting two or more cold-formed steel members together, such as an I-section member built up by connecting two channel sections back-to-back. Basically, these structural shapes used in buildings as eave struts, purlins, studs, girts, headers, braces, floor joists, and other building components. There are variety of shapes also available for wall, floor, and roof diaphragms and coverings. Compare to the single sections, built-up sections are more popular in construction industry because they have many advantage such as can span larger distance, have higher torsional stiffness, and also higher load bearing capacity. Furthermore, the use of built-up sections can be a major economic advantage since the overall manufacture process remains the same.

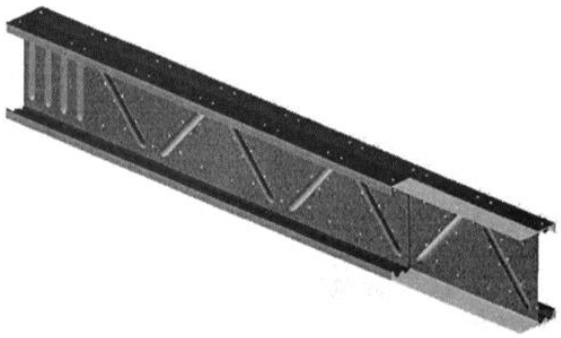

Figure 1.3 Built-up cold-formed steel beam

Source: Di Lorenzo and Landolfo (2010)

Nowadays, steel demand increased in many construction industries that causing the price of steel increased. As the price of steel depends on the weight ordered from manufacturer, the cost and weight of steel become main consideration in the design stage of a project. The overall cost of project can be reduced by introducing the web opening concept for steel section to decrease its weight. When the top of structure has lower weight, the smaller loads transferred to the column. Therefore, the size of other part of the structure can be reduced. Based on the study of cost analysis in the design of open-web castellated beams that was carried out by Estrada et. al., the application of web openings can cut down the substantial materials and hence reduce the construction cost.

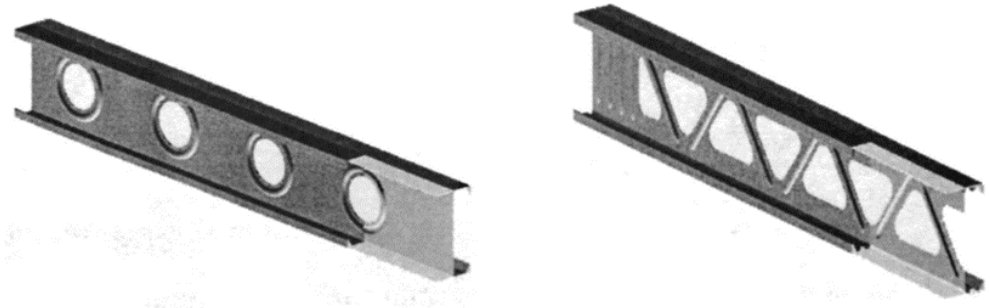

Figure 1.4 Built-up beams with web opening

Source: Di Lorenzo and Landolfo (2010)

Finite Element Analysis (FEA) is a powerful tool that commonly used in investigating the strength and complex behaviour of cold-formed steel structural members. A parametric study performed by FEA has the advantages of higher efficiency

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