AXIAL LOAD OF SINGLE C-SECTION COLD FORMED STEEL WITH AN OPENING

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Diploma in Civil Engineering

UNIVERSITI MALAYSIA PAHANG

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ABSTRAK

Kertas ini mewakili penyelidikan mengenai tingkah laku struktur tiang keluli terbentuk sejuk yang terjejas oleh interaksi distorsional setempat. Struktur keluli terbentuk sejuk telah digunakan secara meluas dalam industri pembinaan dan telah muncul sebagai penyelesaian pilihan untuk bangunan komersial dan perindustrian satu tingkat. Pada kebiasaan keluli terbentuk sejuk dibuat dengan lubang untutk menampung saluran paip, elektrik dan pemanasan di dinding dan siling bangunan. Kajian ini akan tertumpu pada kesan perforasi pada tiang keluli terbentuk sejuk jenis C. kaedah yang digunakan untuk eksperimen ini adalah ujian mampatan . Dua siri tiang keluli terbentuk sejuk C-section akan digunakan dalam eksperimen ini dengan keadaan di mana satu spesimen mempunyai lubang di bahagian tengah dan satu spesimen lagi tidak mempunyai lubang di bahagian tengah . Terdapat tiga bilangan spesimen untuk setaip siri. Setiap spesimen mempunyai ketebalan nominal 1.2 mm dan panjang lajur 600 mm. Ajakan spesimen semasa ujian dibaca oleh transducer. Hasil kajian ini menunjukkan beban maksimum setiap spesimen berbeza dengan kedudukan pembukaan dan saiz spesimen. Graf beban maximum melawan anjakan akan mengkaji pergerakan bebibir semasa ujian mampatan. Tingkah lakunya boleh dilihat sepanjang kajian dimana keleturan distorsional akan berlaku pada spesimen tersebut. Kebanyakan spesimen akan gagal di lubang.

ABSTRACT

This paper represented a research on the structural behaviour of cold-formed steel columns affected by local-distortional interaction. Cold-formed steel structural have been widely used in the construction industry and have emerged as a preferred solution for single-storey commercial and industrial building. Commonly, cold-formed steel was manufactured with holes to accommodate plumbing, electrical, and heating conduit in the walls and ceilings of the buildings. This research will be concentrated on the effect of the opening on the C-section cold-formed steel column. The method used for this experiment was compression test which are the column specimens were compressed . Two series of single C-section cold formed steel column will be used in this experiment with opening and without opening .There are three numbers of specimens for each series. Each member has nominal thickness of 1.2 mm and the column length of 600 mm. The displacement of the specimen during testing was read by the transducer. The result of this experiment shows the ultimate load of each specimen varies with the position of the opening and the depth. The graph of load-displacement will studied the movement of the flange during the compression test. The buckling behaviour can be seen along the experiment which is the distortional and local buckling will occur on the specimens. Most of the specimen will failed at the hole.

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LIST OF SYMBOLS

LIST OF ABBREVIATIONS

CFS	Cold-Formed Steel
DSM	Direct Shear Method
UTM	Universal Testing Machine
JIS	Japanese Industrial Standard
LVDT	Lateral Vertical Displacement Transducer
CH2	Transducer 2
CH3	Transducer 3
CH4	Transducer 4

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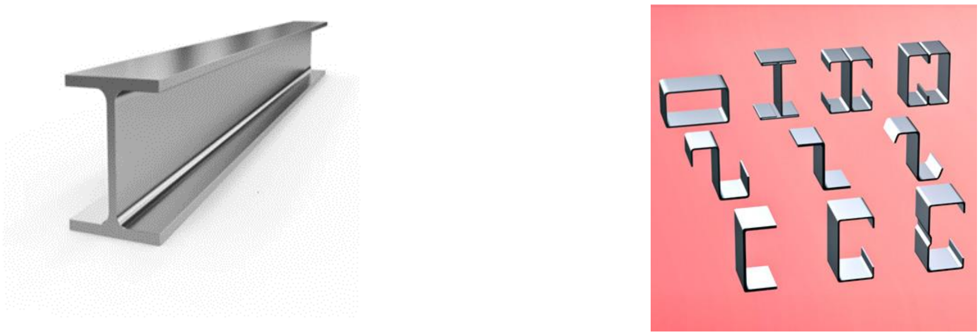
CHAPTER 1

INTRODUCTION

1.1 Introduction

Cold-formed steel (CFS) is widely used in the current industrial sector, particularly in the construction of equipment such as domestic appliances, storage racks, and transportation machinery. Various manufacturing methods, including as folding, press-breaking, and rolling, are used to produce cold-formed steel parts. Cold-formed steel in different sizes and shapes is widely available nowadays (Reddy et al, 2016). Due to its greater strength to weight ratio and simplicity of manufacture, cold formed steel structural members may result in a more fee design than hot-rolled steel members. The variations between hot-rolled and cold-rolled sections used in construction works are shown in Figure 1.1(a) and (b). In steel frame housing, light gauge cold-formed steel sections are frequently utilised as wall framing and chord members of roof trusses.

Building walls and floors typically have holes drilled into them to accommodate wiring for plumbing, electrical, and heating systems. These holes, which are normally found in the web of the C, E, and Z sections, might change a structural member's ultimate strength and elastic stiffness (Moen et al, 2008). the often made holes in cold-formed parts' webs and flanges. The existence of the holes may result in a reduction in both the strength of the member and the strength of its individual individual parts (Sivakumaran, 1987). Local buckling and section buckling influence the final strength. The cross-sectional sizes and column lengths are specially created to examine the relationship between the ultimate strength, the crack pattern, and local, distortional, and global elastic buckling modes (Moen et al., 2008). In order to increase the buckling force, edges stiffeners are frequently employed in cold-formed steel sections. They provide continuous support along the straight edge of the flange. On the free edge of an unstiffened plate, it is simple to brake press or roll shape. As a result of the sections' larger buckling stress, cold-formed sections with edge stiffeners may result in an efficient operation. However, to include intermediate web stiffeners, local buckling stress can be increased (Young, 2008). The strength of the webs' buckling will be strengthened by the presence of holes (Crisan et al, 2012)



(a) Hot-rolled Steel Sections (b) Cold-formed Steel Sections

Figure 1.1 Steel Section used in building industrial / construction .

Sources: civilengineeringbible.com

1.1.1 Application of cold-formed steel

In these days , cold-formed steel member are popularly used in building construction, such as wall studs, floor joists, truss members and other structural application. Figure 1.2 (a) and (b) shows the structural framing that widely used in construction industry . While, Figure 1.3 and Figure 1.4 shows the application of the cold-formed steel member which is residential and rack system.

(a) Commercial Building (b) Residential

Figure 1.2 Structure Framing. Sources : Iron Build Steel Buildings (2017)

(a) House (b) Rack system

Figure 1.3 Common usage of the cold-formed steel . Sources : SRSI

1.2 Problem Statements

The construction industry made heavy use of cold-formed steel. In order to accommodate electrical, plumbing, and heating services, many structural cold-formed steel members are given with cut-outs, and the openings are either pre-punched or punched on site. Compared to hot-rolled steel, cold-formed steel may be produced easily. Cold-formed structural members, which have been used as a fundamental structure like a column, are currently getting popular and importance in the structural building construction industry. As is pretty obvious, a building's major structure, the column acts as the primary structure for carrying load to the foundation and eventually to the ground. As a result, the price of steel has increased due to an increase in steel demand from the construction sector. From the weight that was ordered from the supplier, the price of steel is determined. During the project's design process, the price and weight of the steel used in various sectors are important factors to keep in mind. Less loads will be transferred to the column as a result of lower top-of-the-structure weight, which will also result in smaller other components of the structure. In addition, installing a column structure doesn't need as much manpower, which is yet another method to reduce prices. The 600 mm column of cold-formed steel is used for this experiment. Because of the significant action in buckling and strength properties, the presence of a hole will cause a displacement of surface stresses.

The size, shape, and location of the opening all affect how strong a steel structure is that has more steel that does not have an opening . As a result, it required complex analysis and design to create structural steel components with opening elements. The design criteria for cold-formed steel members with opening are limited to specific opening sizes, shapes, directions, and positions, based on various studies from the past.

1.3 Objective of Research

The aim of this project is to study the behaviour of cold-formed C-section steel with an opening and without an opening

i. An opening may effect the ultimate strength and elastic stiffness of single C-section with an opening steel .

ii. To study the buckling behavior of single C-section with an opening and without an opening

1.4 Scope of Research

This study will involve conducting three specimen with an opening at the mid-height of cold-formed steel c-section and another three specimen of steel without an opening columns .The steel column stands 600 mm tall. The opening is shaped like an extended circle. As a pinned end support, it will serve. By studying the behavior of the cold-formed steel's buckling mode, the ultimate load of C-section members with with an opening and without an opening is investigated. Figure 1.5 illustrates a cold-formed steel specimen with an opening position from previous research.

1.5 Significance of Research

This study will have positive effects on the construction industry. It is possible to study the behaviour of cold-formed steel in a C-section with an opening . Analyzing the deformation of cold-formed steel of C-section with an opening at the mid-height of the specimen and steel without an opening is thanks to the experimental study. A web size increase from 100 mm to 200 mm will increase the cold-formed steel column's strength.

Additionally, it is possible to analyse the strength compaction of the cold-formed steel column with and without an opening. As a result, the knowledge regarding the maximum load placed on the column can be obtained. Moreover, if the opening is at the midpoint of the column's height and if it is at the edge of the column, the cold-formed steel column will be affected. Depending on where the opening are located, the strength of the cold-formed steel C-section will change. A past study found that when cold-formed materials are loaded under different conditions, they frequently bow locally at stress levels below the material's yield strength. The failure types are rare for the standard structural steel design categorization, nevertheless. Therefore, in order to set a standard for the cold-formed structural members, thorough testing was required.

From this study , by employing high strength steel and recycled steel, the environmental effect of steel structures can be reduced. Steel's concept has many advantages for steel construction's sustainability. Steel buildings can be recycled and used again. Consistent has worked on projects with architects to improve the buildings' heat transfer coefficient. Better thermally stable building materials can reduce HVAC plant capacity by up to 10%. This reduction is made possible by using materials with higher heat transfer rates (SDG11) .

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Since more than a decade ago, cold-formed steel products like sections have been regularly used in the building of metal buildings and may be found in every area of urban world. In contrast to being widely used in residential housing as the major load-bearing structures in North America, Australia, and New Zealand, light-gauge building systems have become more and more common and are competing with the standard building material, wood (Budapest, 2009). Due to the products' applications, low cost, simple manufacturing, and excellent strength-to-weight relationships, their popularity has greatly grown in recent years. The common cold-formed shapes used in industries are shown in Figure 2.1. Also, cold-formed members are created in line with the Specification for the Design of Cold-Formed Steel Structural for the most common applications.

However, until recently, cold-formed steel was not commonly used in Malaysian building construction, despite hot-formed steel's public acceptance as a solution. But the use of cold-formed in construction is still not very common because of specimen limitations. The usage of cold-formed steel in building structure framing is shown in Figure 2.2. However, the majority of local products have limitations due to the lack of accessibility. The limitation of cold-formed will change as long as there is an opening. Thus, this investigation will show if the strength of cold-formed steel will be affected by the presence of opening.

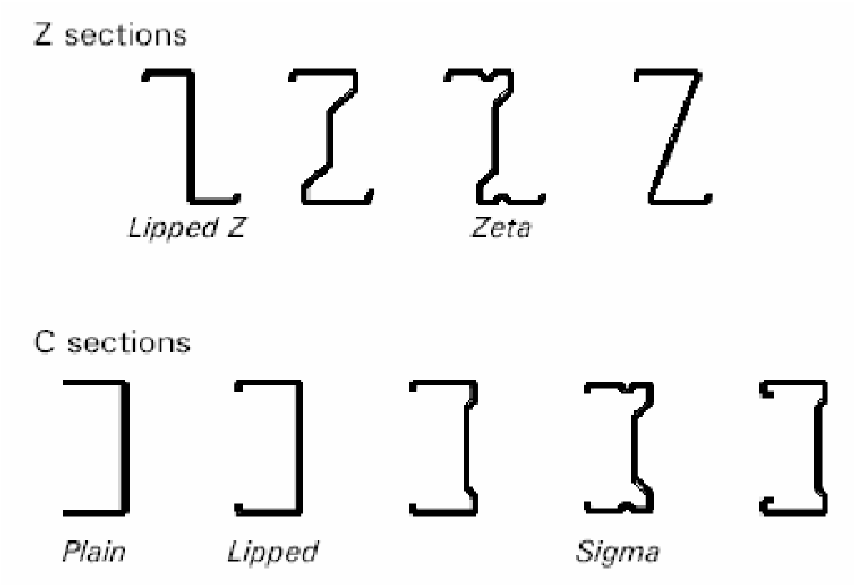


Figure 2.1 Common shapes of cold-formed steel. Sources : Cher Siang Tan (2006)

Figure 2.2 The application of cold-formed steel in structure framing

2.2 Characteristics of C-section Cold -formed Steel

This study will have good impacts on the construction sector. It is possible to study the behaviour of cold-formed steel in a C-section with opening and without opening. It is possible to examine the deformation of cold-formed steel of C-section with an opening from the experimental study. Additionally, it is possible to study the cold-formed steel column's strength compression between openings and without openings. As a conclusion, the data about the maximum load placed on the column can be obtained. Also, the impact of an opening on a cold-formed steel column can be compared between an opening that is situated in the middle of the column and without an opening .Depending on where the opening are located, the strength of the cold-formed steel C-section will differ. A past study found that when cold-formed materials are placed under different conditions, they often bow locally at stress levels below the material's yield strength. The failure modes are uncommon for the standard structural steel design class, however. Therefore, in order to set a standard for the cold-formed structural elements, significant testing was needed.

2.3 Advantaged of Cold-formed Steel

According to Anbarasu et al(2010) .'s study, cold-formed light gauge steel structural members offer the following advantages when building:

(a) Almost any desired shape and length can be created with cold rolling.

(b) Well before or pre-coated metals can be created, giving them a high level of corrosion protection in addition to a lovely surface finish.

(c) All common fixing techniques, including riveting, bolting, welding, and adhesives, are acceptable.

(d) Cold-rolled products are able to reach high strength to weight ratios.

(e) They are typically compact, making them simple to carry and set up.

(f) For generally light loads and/or short spans, more economical design is possible compared to larger hot rolled structures.

(g) Cold forming operations can economically produce unique sectional forms, resulting to excellent strength-to-weight ratios.

(h) Load-bearing panels and boards can act as useful surfaces for building walls, roofs, and floors. In other cases, they can act as enclosures for cables used for electrical and other purposes.

(i) If load-bearing panels and boards are properly interconnected to one another and to supporting members, they can act as shear stiffeners to withstand force in their own planes in addition to overcoming loads normal to their surfaces.

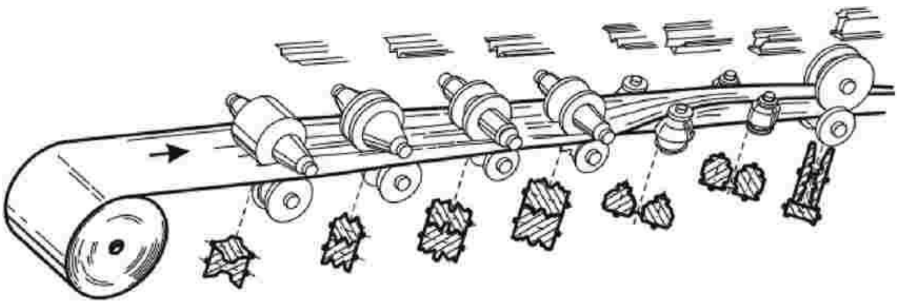


Figure 2.3 Cold-roll forming method. Sources : LOTOS (2019)

Figure 2.4 Press braking method. Sources : MechStuff

2.4 Cold-formed Method

There are three common techniques used in the production of cold-formed sections: cold roll forming, press brake operation, and bending brake operation (Yu, 2000). According to studies by (Kulatunga & Macdonald ,2013), these methods increase the yield strength and tensile strength while also limiting the ductility of cold-formed steel sections, especially at the corners where these properties can differentiate from those of the flat steel sheet, plate, strip, or bar prior to forming.

Roll-forming is the most common type of cold forming. A roll of steel is run through a series of rollers in this process, each of which slowly bends the sheet until the final shape is reached at the last roll stand. The procedure of cold rolling is shown in Figure 2.3. When press stopping, one full folds is commonly generated at a time along the whole length of a section. As a reason, press braking can be used to create a variety of shapes at small supply volumes. Figure 2.4 shows the press braking method in action.

2.5 Buckling mode of C-section Cold -formed Steel In Compression

When exposed to different loading situations, cold-formed thin-walled sections, unlike heavier hot-rolled steel sections, have a tendency to bow locally at stress levels below the material's yield strength. These members, however, continue to handle heavier loads despite being under such stress. The relationship between elastic buckling and load deformation response in thin-walled cold-formed steel structures is complicated. Moreover, the effect of opening may encourage various buckling modes and can increase failure mechanisms at the final state (MacDonald & Kulatunga, 2013).

According to Liu et al. (2004), local buckling dominates for a typical C-shaped column in pure axial compression. Cold-formed members can show local, distortional, and flexural or flexural-torsional buckling instability in compression. The main design methods generally address local modes and global modes (i.e., flexural and flexural-torsional buckling) using effective widths for the plate elements and column design equations for global buckling (Rondal, 2000). Local buckling, distortional buckling, and Euler buckling (flexural or torsional-flexural) are three different buckling modes that are shown in Figure 2.6. (MacDonald & Kulatunga, 2013).

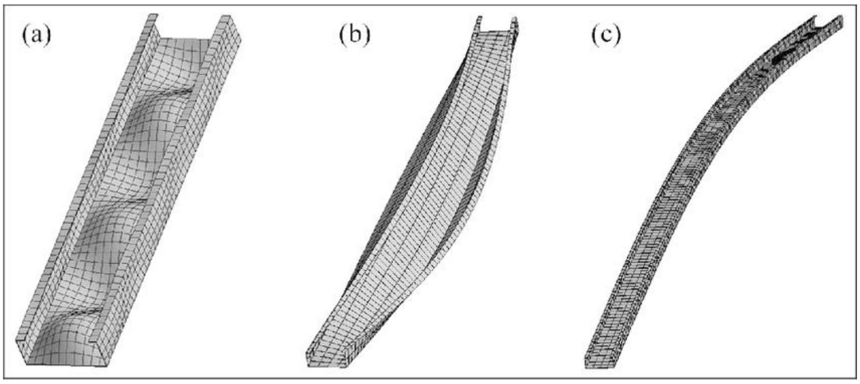


Figure 2.5 Types of buckling mode . Source : Bin He (2016)

2.6 Effect of Axially Loaded C-section Cold – formed steel column

Wang et al. (2016) found that local buckling and distortional buckling are typical failure modes for short columns. However, Kulatunga & Macdonald (2013) found that most of the tested columns buckled locally and distortionally. In their work, Moen et al. (2008) found that the existence of opening only minimally affected the ultimate compressive strength.

The relationship of local and overall column buckling, according to Yu Wei-Wen (2000), affected the overall column strength. As a result, the AISI Specification now includes the design provision for overall flexural buckling as well as the impact of local buckling on column strength. The factors listed usually affect how local buckling affects column strength:

a) Shape of cross section

b) Slenderness ratio of column

c) The types of overall buckling that can develop (flexural, torsional, or flexural-torsional buckling)

d) The type of steel that was selected and its mechanical properties

e) Cold work's consequence

f) Imperfection's influence

g) Impact of opening residual stress, residual stress after welding, and welding interaction on plane components.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Experimental compression testing is the methodology used in this investigation. The transducer is put in place firstly to begin the process of preparing the samples for testing. The specimen is then put on the machine after the transducer has been set. The transducer is then positioned in according to the findings of the focusing investigation. Three transducers are applied, the first of which is placed on top of the specimens, the second on the left side, and the third on the right side. The Universal Testing Machine's loading rate then must be set up. The specimen will be compressed by the Universal Testing Machine at a time rate of 2mm/min.

The experiment was conducted using research by Moen and Schafer (2009), titled Direct strength design of cold-formed steel members with perforations. This study also became the basis for all multiple studies on cold-formed steel members.

Through an experimental investigation in the lab, the behaviour and performance between a cold-formed steel C-section and the position of the opening with an axial load applied to the cold-formed steel column were determined. The experiment's goal is to determine how opening position impacts a single C-section column's final strength and failure modes.

The analysis was based on cold-formed C- channel sections that were exposed to compression loading. An overview of the procedure in which the experiment will be run is shown in Figure 3.1 below.

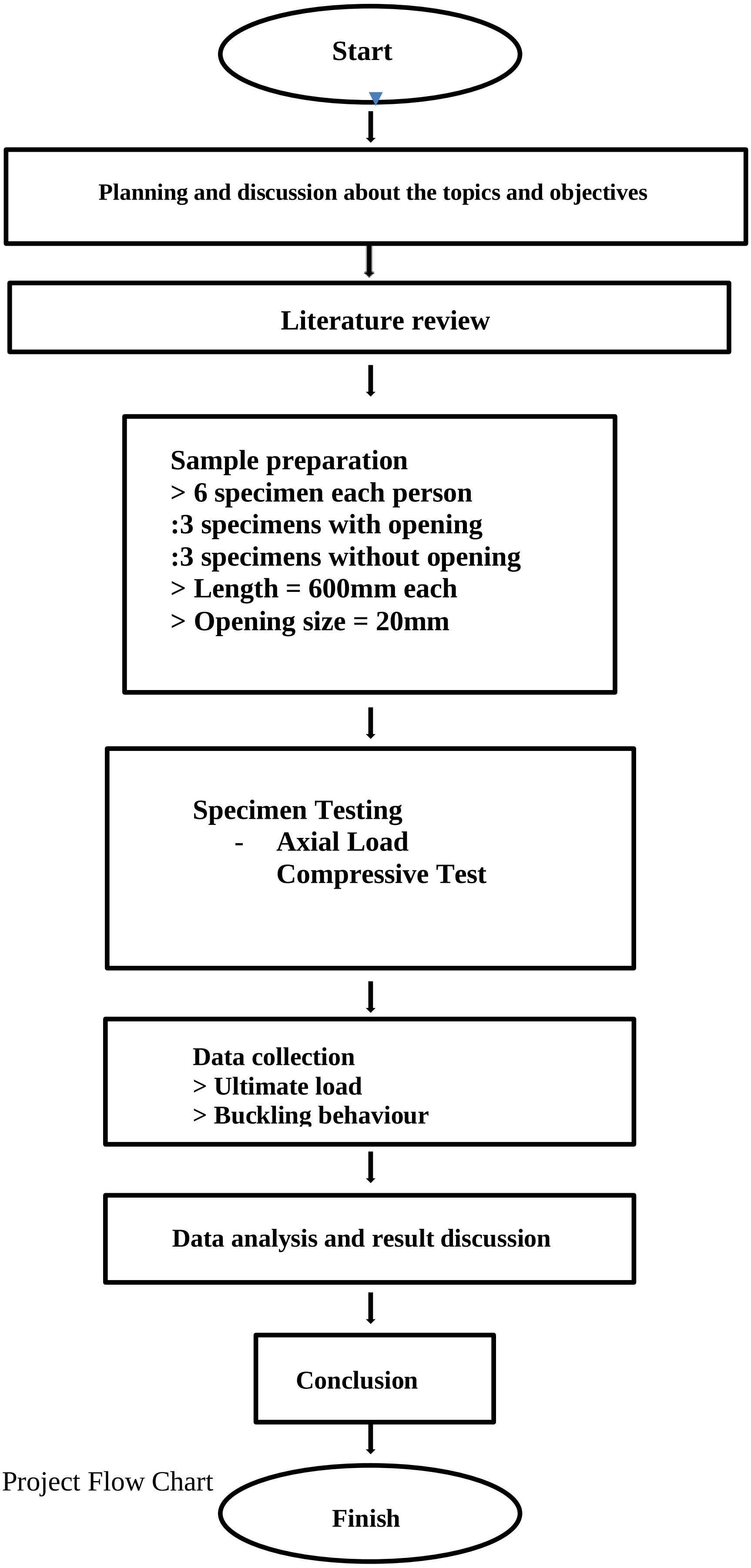


Figure 3.1 Project Flow Chart

3.2 Preparation of specimen

The specimens that will be utilised in the experiment must first be prepared before testing can begin. Figure 3.5 below illustrates how the PIC's lab used a grinding machine to cut the specimen to 600mm . With assistance from the PIC's lab assistant, a hole was then made in the middle of the cold-formed steel c-section. Figure 3.6 illustrates the process of drilling a hole into cold-formed steel, and Figure 3.7 shows the method's evident outcome. The specimens will then be named and measured, as indicated in Figure 3

Figure 3.2 Shows the PIC cut half of the specimen to 600mm

Figure 3.3 Shows the method's evident outcome

3.2.1 Section Parameter

Table 3.1 Parameter and magnitude of the cross-section

Parameter	C-section with an opening	C-section without an opening
Thickness, t	0.8 mm	0.8 mm
Length, l	600 mm	600 mm

3.2.2 Material Used

For this test, a cold-formed C-section is selected. The decision of the material took into account both previous research and the laboratory's Universal Testing Machine (UTM). The cold-formed sections were brake-pressed from steel plate cold rolled common (SPCC) cold rolled sheet, which is in accordance with JIS G 3141, the Japanese Industrial Standard for "Cold-Reduced Carbon Steel Sheets and Strips." The SPCC Steels' tensile strength must be at least 270 MPa. The greatest specimen height that the laboratory's universal testing machine can support is typically 700 mm. The specimen's height covers the base plate.

3.3 Operation Set-up and loading

Transducers and the Universal Testing Machine will be used in this experiment. The axial load will be applied to the specimens by the universal testing machine, which will then read it and collect the data on it. The displacement on the specimens will be read by the transducers. The laptop will capture the data. There will be three transducers utilised to collect data. The most appropriate loading rate for these specimens was 2 mm per minute, which is what was employed. Figure 3.8 demonstrates how the machine-prepared specimens were made.

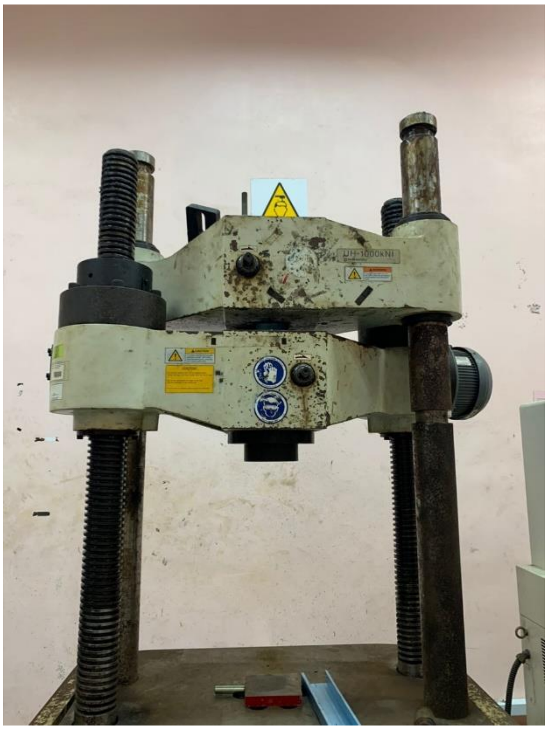


Figure 3.4 Shows the UTM machine , a machine we used to do the axial load test

Figure 3.5 Apparatus set-up in laboratory

Figure 3.6 Process of measuring and naming specimens

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

The results of the compression test will be discussed in this chapter. During testing, the specimen's vertical and horizontal displacement results were recorded. In addition, the specimen's maximum axial load is measured. Data was collected using a data lodger connected to a transducer. Two transducers are positioned at either side of the column's flange for deflections, while one transducer was placed at the top plate of the specimen for vertical displacement. The goal of the experiment conducted was to figure out how the various opening positions impacted the ultimate load and the buckling behaviour of the C-section column. The opening positions were changed but the opening size kept same.

4.2 Ultimate Strength

The crest tried compression stack for column examples are given in Table 1. The stack applied on the example from the All inclusive Testing Machine was collected by the computer. Table 1 appears the estimation of examples measurement and exploratory result of single without an opening and single with an opening Concurring to (Moen et al., 2008) the habitations of gaps has as it were a little impact on compressive quality. The remove between the opening has impacts to the extreme quality where the higher the remove between the opening, the higher the extreme quality.

Table 4.1 Measured Specimen Dimensions and Experimental Results

	No.	Thickness, t (mm)	Length, L (mm)	Experimental ultimate load, P (kN)
Single with an opening	S1	0.8	600	27.80
	S2	0.8	600	27.03
	S3	0.8	600	22.59
Single without an opening	SWO1	0.8	600	22.85
	SWO2	0.8	600	27.59
	SWO3	0.8	600	25.58

The extreme quality values of compression individuals are outlined in buckling conduct by utilizing direct vertical relocation transducer (LVDT) gadget. For the vertical uprooting, transducer 1 was utilized to degree the relocation from the beat plate of examples. The load-displacement chart was utilized to decide the extreme quality.

SINGLE WITH AN OPENING 1 (S1)

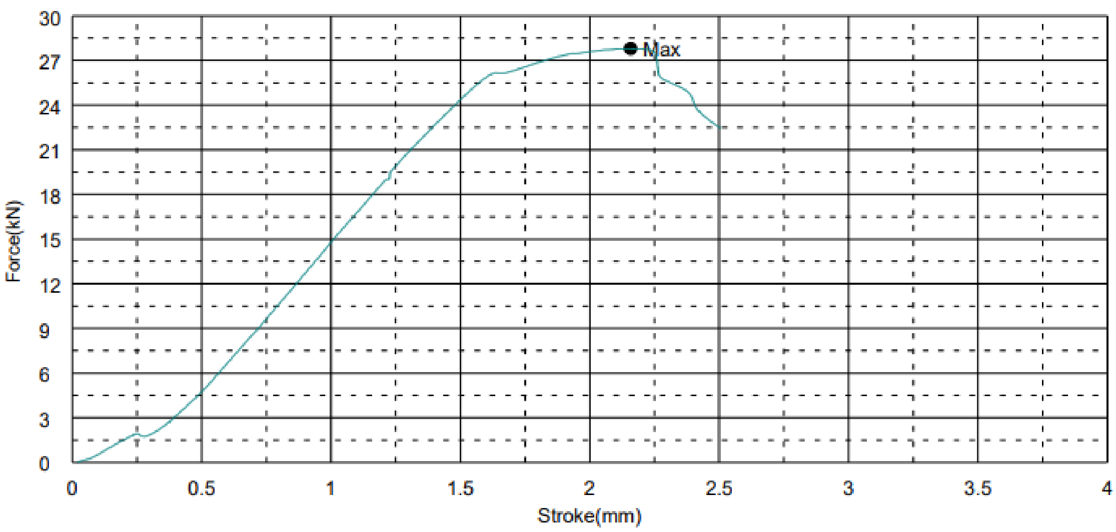


Figure 4.1 Force versus Stroke graph

SINGLE WITH AN OPENING 2 (S2)

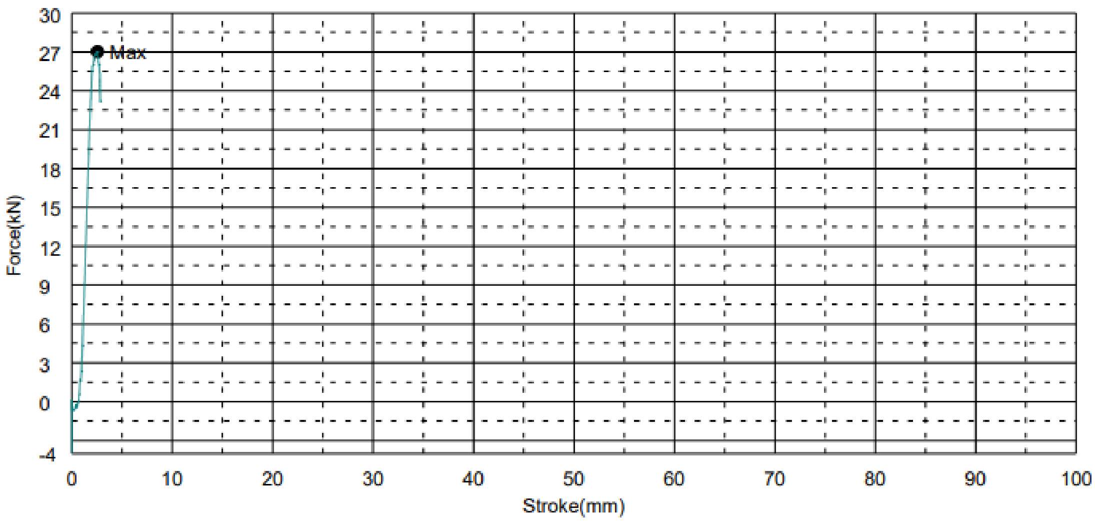


Figure 4.2 Force versus Stroke graph

SINGLE WITH AN OPENING 3 (S3)

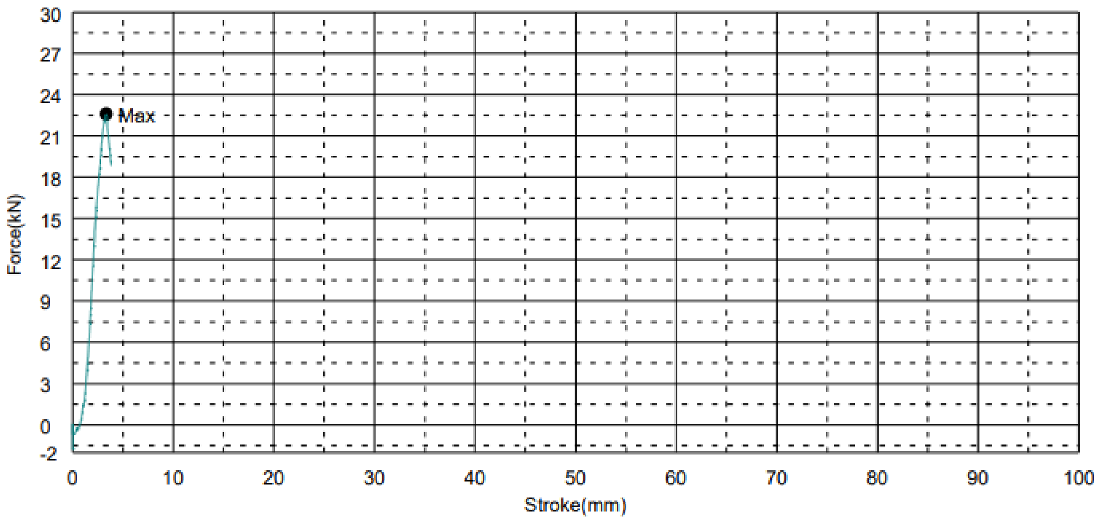


Figure 4.3 Force versus Stroke graph

SINGLE WITHOUT AN OPENING (SWO1)

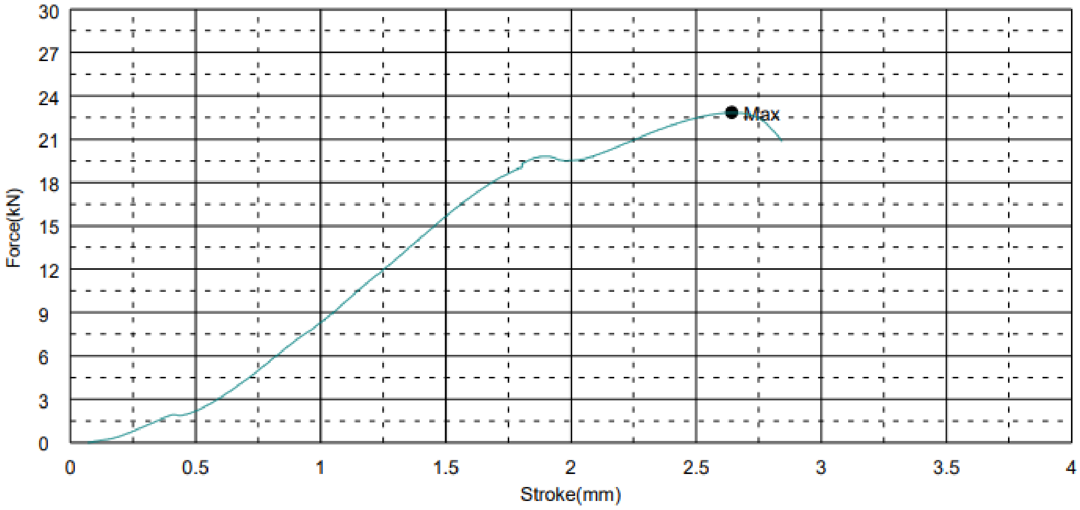


Figure 4.4 Force versus Stroke graph

SINGLE WITHOUT AN OPENING (SWO2)

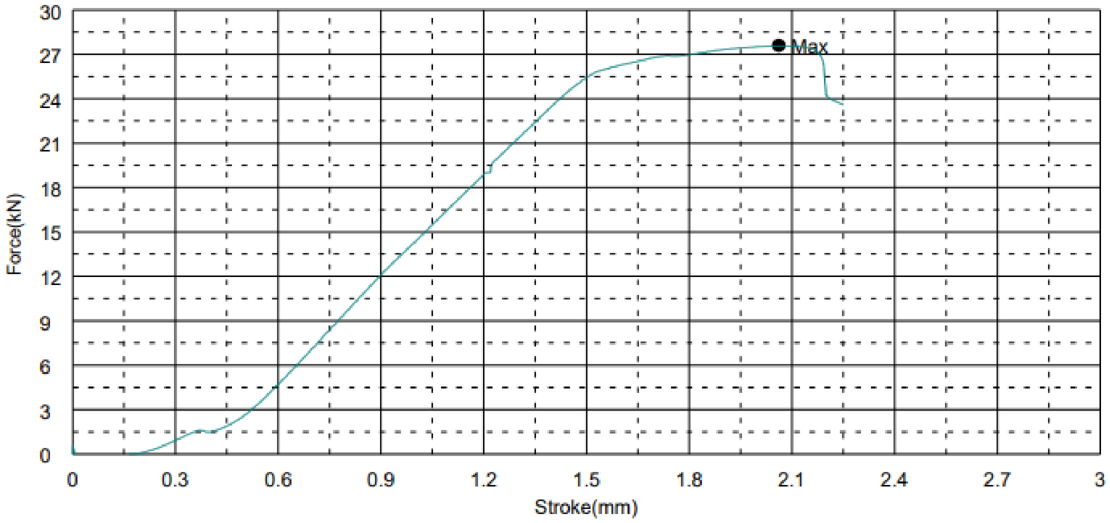


Figure 4.5 Force versus Stroke graph

SINGLE WITHOUT AN OPENING (SWO3)

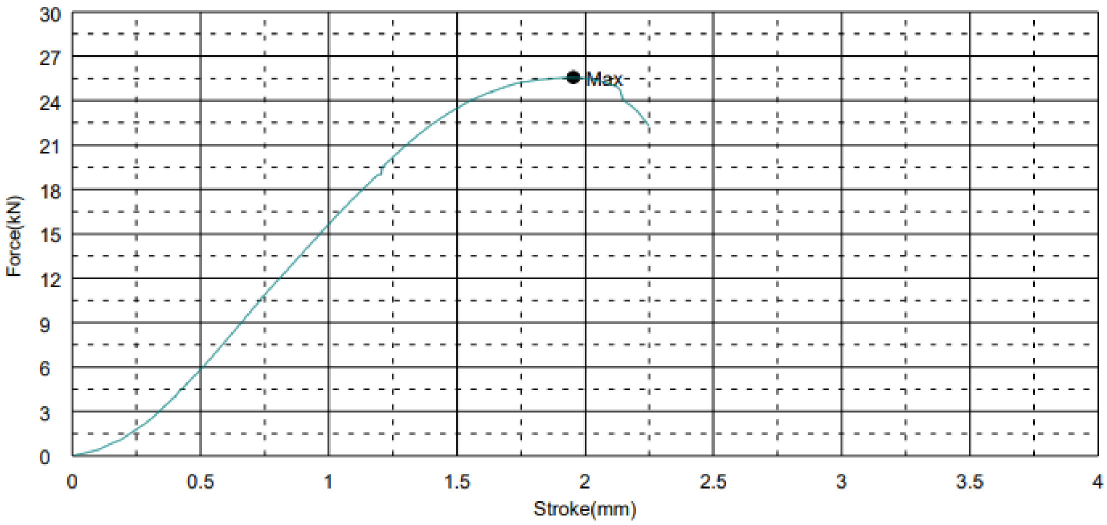


Figure 4.6 Force versus Stroke graph

For specimen single c-section with and without opening there is 6 specimens that are tested under compression load. Figure 4.1 until 4.6 below shows the force versus stroke graph while Table 4.2 shows the maximum load of the specimens.

Specimen	**Load(kN)**
S1	27.80
S2	27.03
S3	22.59
SWO1	22.85
SWO2	27.59
SW03	25.58

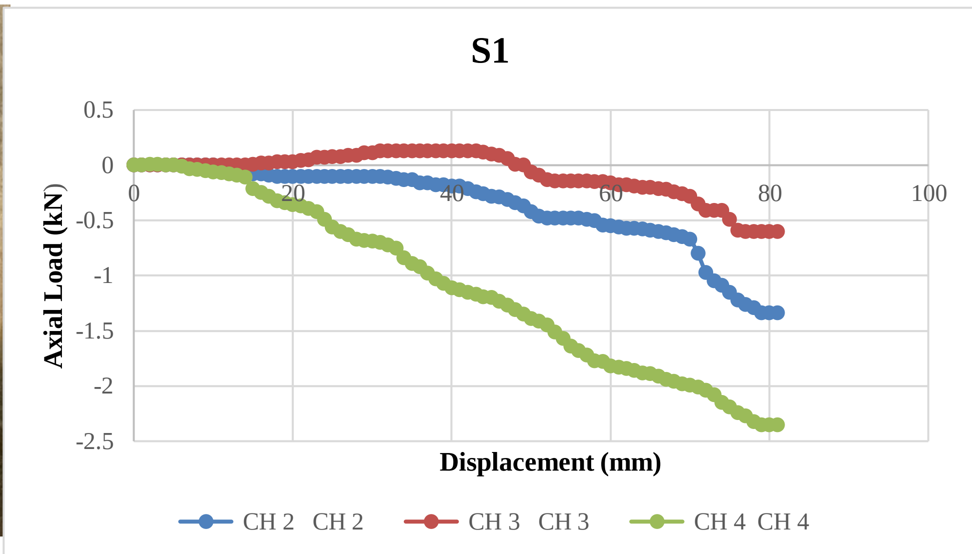
As illustrated in Figure 4.1 until 4.6 it shows that the specimens will reach it maximum point when the load exerted on it. From the graph in Figure 4.1 until 4.6 it shows that S3 has the lowest ultimate load with 22.59 kN. Based on Figure 4.1 until 4.6 and Table 4.2, the specimen that has the highest ultimate load is S1 with 27.80 kN.

4.3 Buckling Behaviour

The tests on the sample columns were done to see how opening affected the ultimate strength of the columns. Crisan, Ungureanu, and Dubina (2012)b claim that the column will buckle locally at its greatest strength. The Load-Lateral Displacement graph can be used to observe the column's buckling behaviour.

The linear vertical displacement transducer (LVDT) installed on the specimen's right and left sides was used to measure the lateral displacement. The front of the specimen had the label CH3, the left transducer had the label CH2, and the right transducer had the label CH1. The distortional deformation for the column, according to (Wang et al., 2016), primarily occurred at the mid-height of the column and displayed a symmetrical internal concave deformation.

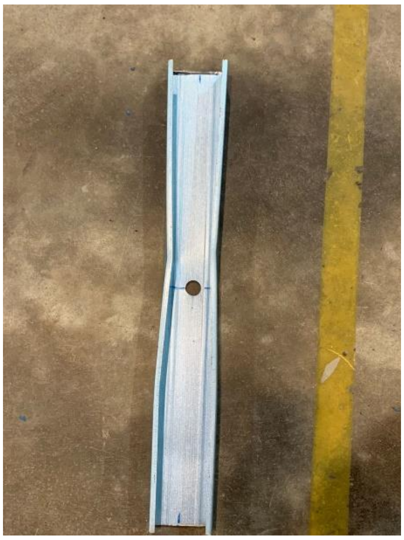
4.3.1 Single with an opening

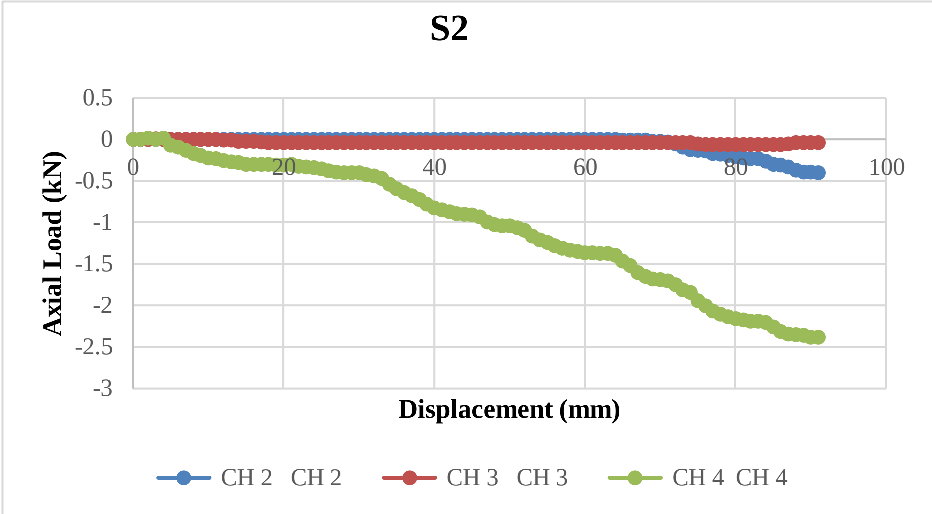


(a Post peak load (b)

Figure 4.7 (a) and (b) S1-Single with an opening

Figure 4.7 (a) shows the buckling behaviour of column during the peak load while Figure 4.7 (b) shows the axial load versus horizontal displacement. From Figure 4.7 (b) it can be seen that the displacement value for CH2 , CH3 and CH4 are positive.

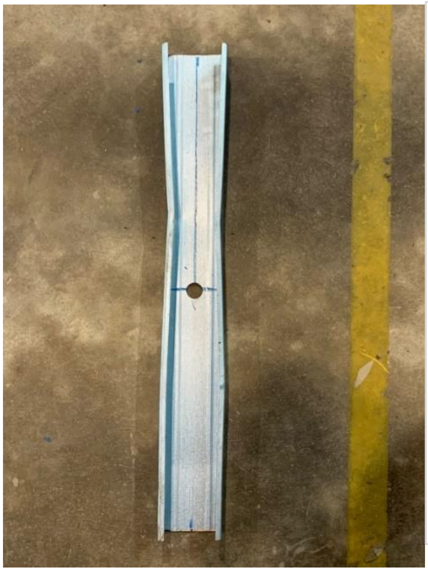


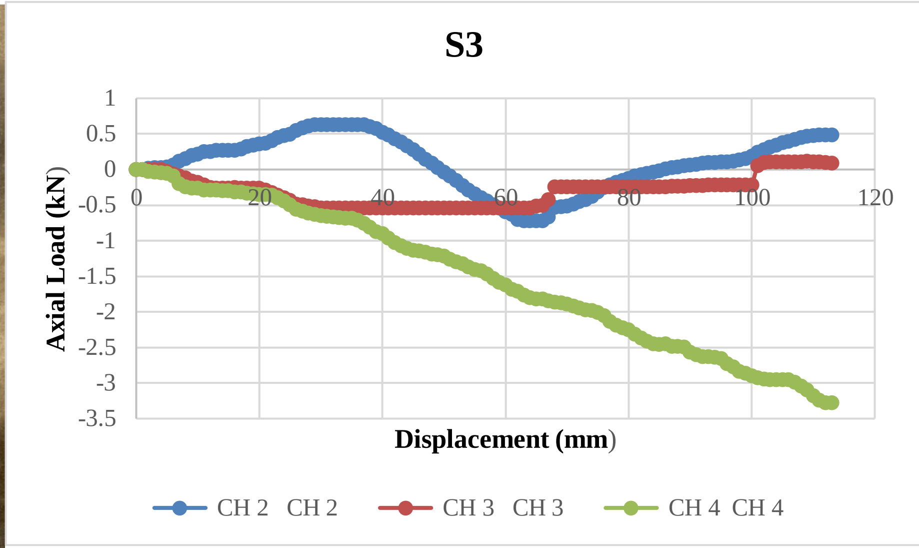


(a) Initial buckling mode (b)

Figure 4.8 (a) and (b) S2-Single with an opening

From Figure 4.8 (b), result shows the displacement moving towards negative displacement for all the transducers until it reach the failure. It shows that the displacement slowly moving towards negative . From Figure 4.8 (a) web buckling occur at the initial load. The result after the post load shows that the warping and distortional buckling occurs at the flange and web buckling occur at the hole.



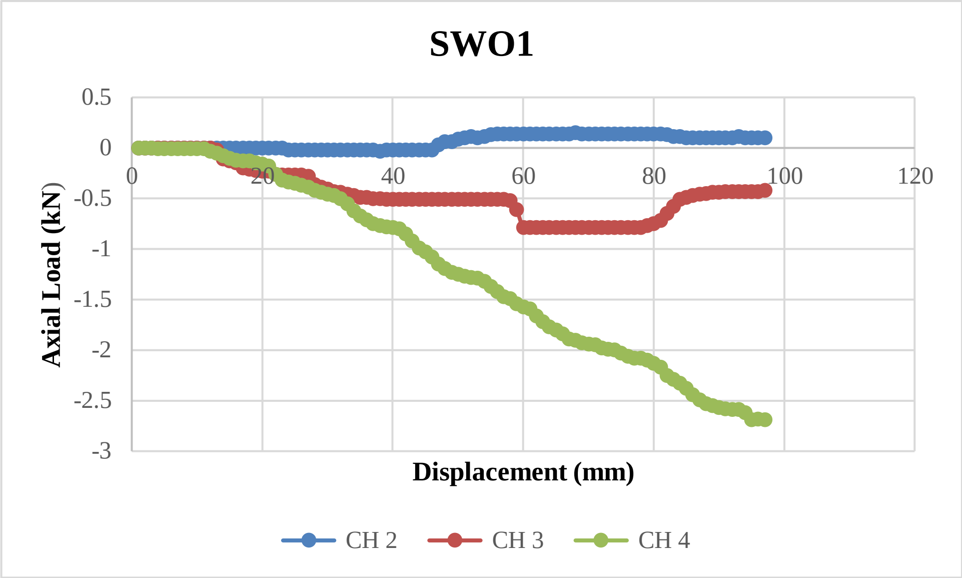


(a) Initial buckling mode (b)

Figure 4.9 (a) and (b) S3-Single with an opening

Figure 4.9 (a) shows that during the initial load the specimens experience an intial buckling mode . Figure 4.9 (b) where the transducer moving into negative displacement and some others moving to positive displacement .

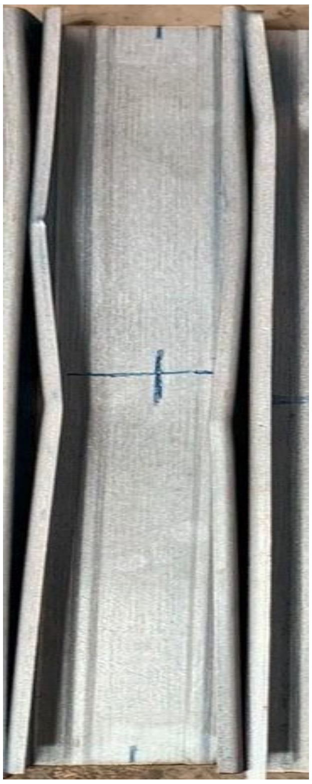
4.3.2 Single without an opening

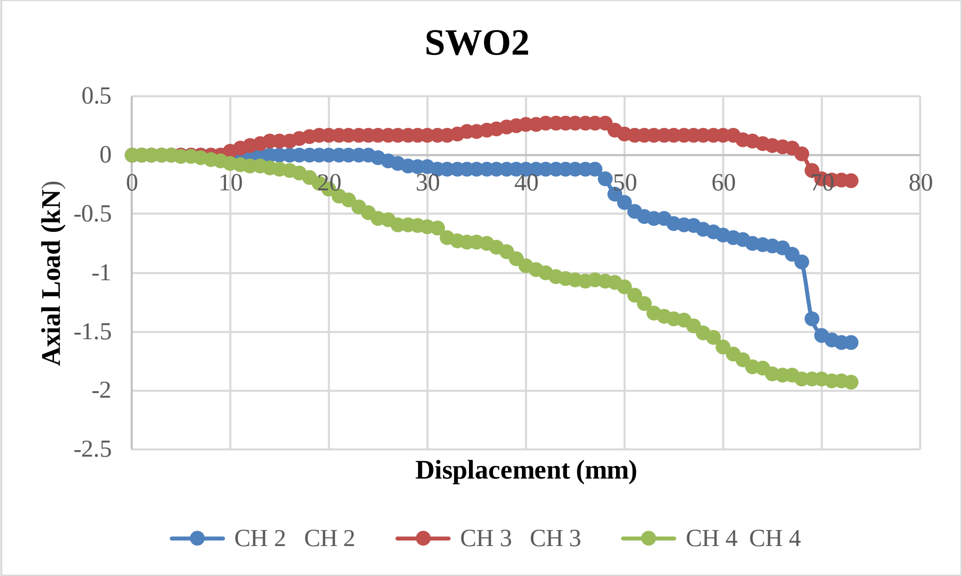


(a) (b)

Figure 4.10 (a) and (b) SWO1-Single without an opening

Figure 4.10 (a) shows that the buckling happened at the bottom of the specimen ,then the transducers data based on figure 4.10 (b) moving to negative displacement .

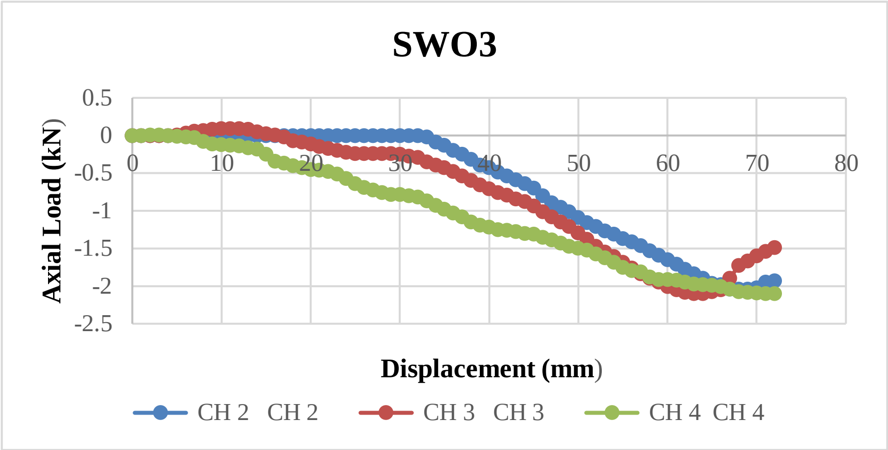




(a) (b)

Figure 4.11 (a) and (b) SWO2 -Single without an opening

Figure 4.11 (a) indicate that there are a buckling at the web during the initial load and it can be seen clearly at the peak load where the buckling occur at the mid height . The result at the post load shows that specimen SWO2 experience web buckling at at the middle and the Figure (b) shows the displacement move to the negative .



(a) (b)

Figure 4.12 (a) and (b) SWO3-Single without an opening

From Figure 4.11 (a) it can be seen clearly that during the initial load the specimen experience buckling at peak load .The result from the Figure 4.11 (b) shows that the direction of the graph was going on the same way as it move to the negative displacement. It is because at the post load, CH2 , CH3 Aand CH4 facing distortional as shown in Figure 4.11 (a).

CHAPTER 5

CONCLUSION

5.1 Introduction

This work presents an experimental examination and an axially loaded approach for the cold-formed C-section columns. Applying a universal testing machine, the maximum load for each specimen was calculated, and a linear vertical displacement transducer (LVDT) device was used to read the displacement of the buckling behaviour. Six identical specimens, each measuring 600 mm, were evaluated. In order to examine the deformed shape, displacement, maximum stresses, and maximum value buckling load, linear analysis and linear buckling analysis have been performed. The specimens' buckling behaviour was detected through the analysis, and the impact of opening was established. Maximum stresses and axial loads are shown in detail, especially.

5.2 Conclusion

Several conclusions can be taken from the overall project analysis and results based on the results that have been presented:

i. The ultimate strength of the specimens is affected by their size.

ii. Steel with an opening arrangement will buckle, but this behaviour can be foreseen. Through the data test research, the deformation response of the member with a hole is comparable, and the presence of holes only clearly reduced the ultimate strength of the tested columns.

iii. The outcome showed that all specimens failed by local, distortional, and web buckling at the hole in an axially loaded column with a constant opening arrangement. The hole makes the web's post-peak resistance lessened, which allows the flange and lips to support more of the column load.

5.3 Recommendation

Future research on this topic must be carried out in order to provide better and beneficial results. The following suggestions are made for future research to achieve the goals of this study:

i. Use specimens of various lengths.

ii. Widen the web to a greater depth to avoid distortional buckling.

iii. Utilize additional cold-formed steel shapes, such as E- and Z-sections.

iv. Use apertures in various shapes, such as rectangles, ovals, and so forth.

v. More openings should be created.

vi. To compare the outcomes of an experimental investigation, use software like ANSYS.

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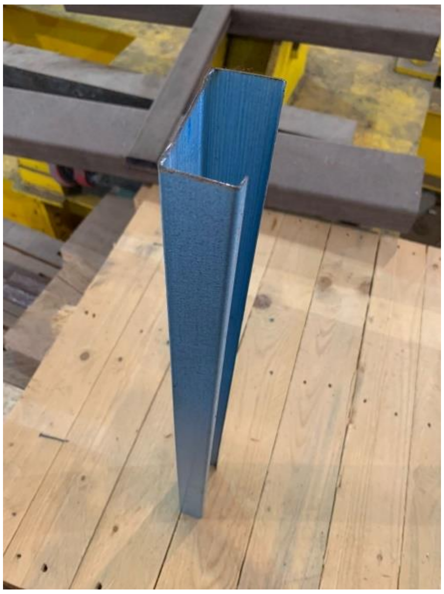
APPENDICES A

SINGLE C-SECTION SPECIMEN OVERVIEW



PLAN VIEW OF SINGLE C-SECTION

SINGLE C-SECTION WITH AN OPENING OVERVIEW

SINGLE C-SECTION WITHOUT AN OPENING OVERVIEW

SINGLE C-SECTION WITH AN OPENING SIDE VIEW