



Faculty of Engineering

**PARAMETRIC STUDY ON THE LOAD BEARING CAPACITY OF
LIGHTWEIGHT STEEL FRAMING SYSTEM**

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To my beloved parents

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ABSTRACT

Cold-formed steel members, a type of light weight steel have been widely used in building applications for the years in countries like United States, British and Australia as primary and secondary elements. Primary structural elements include beams and columns whereas the secondary element includes cladding and purlin. Cold-formed steel framing system (modular frames) has been engineered and designed into panels system of different shapes and sizes. However there are yet to be researches carried out by local manufacturers to determine the optimum shapes and configuration in terms of load bearing capacity. Therefore, this research aims at identifying the optimum configuration of the modular frame that is not only economical in terms of material used but also it is also effective in load bearing. Further more, other aspect will be studied as well. Research was carried out by finite element modelling using the finite element analysis software ANSYS for configuration optimisation. The work involves a wide parametric study in which single unit models and modular frames were analysed. The results or findings reveal how the models are configured to obtain the optimum configuration based on the applied loadings. Thus, the results show that the modular frame configuration of 500 mm x 1000mm has the optimum configuration where the frame has the effectiveness or ability to carry more load per unit mass with less amount of material used.

ABSTRAK

Keluli dibentuk secara dingin merupakan sejenis keluli jisim ringan. Ia telah lama digunakan secara meluas di negara – negara seperti Amerika Syarikat, British dan Australia sebagai elemen yang utama dan kedua. Elemen struktur utama adalah rasuk dan tiang, manakala elemen kedua adalah papan atau lapisan logam sebagai perlindungan dan sinar lintang sepanjang atap. Keluli jisim ringan juga telah dibentuk ke dalam sistem panel dalam bentuk dan saiz yang berbeza. Walau bagaimanapun, masih ada kajian lanjutan yang boleh dan patut dilakukan oleh pengeluar tempatan untuk mengenalpasti bentuk dan konfigurasi optima dalam kapasiti beban yang wujud. Oleh itu, kajian ini digunakan untuk mengenalpasti konfigurasi optima rangka modul yang bukan sahaja menjimatkan penggunaan bahan malah juga sangat berkesan dalam menampung beban. Disamping itu, aspek lain juga akan dikaji. Untuk konfigurasi yang optima, kajian akan dijalankan dalam elemen modul terhad dengan menggunakan program komputer analisis elemen terhad (ANSYS). Kerja yang melibatkan kajian dalam model unit tunggal dan rangka modul juga dianalisis. Keputusan atau pembuktian cara modul dibentuk untuk mendapatkan konfigurasi optima bergantung kepada beban yang ditindakan. Dengan itu, keputusan menggunakan rangka modul dengan konfigurasi 500mm x 1000mm mempunyai konfigurasi optima yang memiliki keberkesanan atau kebolehan menampung beban per unit berat dengan kurang daripada bahan yang digunakan.

TABLE OF CONTENTS

		Page
Chapter 1	INTRODUCTION	
1.1	Background	1
1.2	Statement Of Problem	5
1.3	Aim And Objectives	6
1.4	Scope Of Study	7
Chapter 2	LITERATURE REVIEW	
2.1	Introduction	9
2.2	Advantages Of Using Cold-Formed Steel	10
2.3	Cold-Formed Steel Sections	12
2.4	Uses/Application Of Cold-Formed Steel	14
2.5	Design Standards	16
2.6	Design Methods/Approach	17
2.7	Design Criteria	19
2.8	Cold-Formed Steel Modular Framing System (Modular Construction)	22
2.9	Types Of Bracings	24
2.10	Concept Of Optimization	28

Chapter 3	METHODOLOGY	
3.1	Introduction	30
3.2	Modeling And Analyses	34
3.2.1	Modeling And Analysis Procedures	37
Chapter 4	RESULTS AND DISCUSSION	
4.1	Introduction	40
4.2	Validation Of Results	42
4.3	Single Unit Model Of A Frame	48
4.3.1	Result	48
4.3.2	Discussion	53
4.4	8 m x 3 m Frame	55
4.4.1	Result	55
4.4.2	Discussion	60
4.5	Application	64
Chapter 5	CONCLUSION AND RECOMMENDATION	
5.1	Conclusion	67
5.2	Recommendation	69
	REFERENCE	70
	APPENDIX	73

LIST OF TABLES

Table		Page
3.1	The configurations and dimensions of each single unit model	33
3.2	Cross-sectional properties of plain C-channel	35
4.1	Results tabulated from the analysis of each model using ANSYS (based on deflection limit $L/360$)	41
4.2	Comparisons of result from theoretical value and ANSYS simulation	48
4.3	Total mass and maximum applied loading of each model	49
4.4	Total mass and maximum applied loading of each model (arranged according to the height of column)	50
4.5	Total mass, maximum applied loading and ratio of each modular frame of 8m x 3m for each model	56
4.6	Total mass, maximum applied loading and ratio of each modular frame of 8m x 3m for each model (rearranged according to effective heights)	57
4.7	Total mass, maximum applied loading and ratio of each modular frame for beam with span of 500mm	62

LIST OF FIGURES

Figure		Page
1.1	A residential house built with cold-formed steel	3
1.2	A building unit or modular unit formed by cold-formed steel members	4
2.1	Channel and Z sections. (a) plain sections; (b) sections with flange stiffeners; (c) sections with web stiffeners; (d) sections with flange and web stiffeners.	13
2.2	Example of a single storey house built with cold-formed structural steel	14
2.3	Metal stud designed for vertical studs for framing	15
2.4	Metal track used for moisture barrier for contact to concrete foundation	15
2.5	Angle runner designed for support for steel framing joist	15
2.6	Bridging designed for bridging between studs	15
2.7	Frequency distribution curves	18
2.8(a)	Modular units stacked to form cellular rooms	23
2.8(b)	Modular units combined to form larger spaces	23
2.9	Through-the-punchout bridging	25
2.10	Steel strap face bridging	25
2.11	Sheeting (gypsum drywall) as bracing	26
2.12	Bracing provided for axial load bearing studs	27
3.1	A common modular frame assembly	31

3.2	Single plain channel section	34
3.3	Flow chart of the modeling or optimization process	39
4.1	Diagram displaying the maximum deflection (deformed shape)	44
4.2	Diagram displaying the maximum bending stress	45
4.3	Diagram displaying the moments of the members	46
4.4	Diagram displaying the direct shear stress	47
4.5	Total mass versus maximum applied loading of each model	52
4.6	Total mass of each frame versus its w/m ratio	59
4.7	Maximum applied loading of each frame versus its w/m ratio	63

LIST OF SYMBOLS

S^*	-	Design action effect (Design action in New Zealand)
ϕ	-	Capacity factor (strength reduction factor in New Zealand)
A	-	Cross-sectional area of member
B	-	Breadth
D	-	Depth
E	-	Young's Modulus
F	-	Shear Force
f_u	-	Tensile strength
f_y	-	Minimum yield stress
G	-	Shear Modulus
H	-	Height
H_e	-	Effective height
I	-	Moment of Inertia of the cross section of the beam with respect to the neutral axis
I_{xx}		Moment of Inertia about x-axis
I_{yy}		Moment of Inertia about y-axis
L	-	Total length of the span
M	-	Maximum Bending Moment
R_u	-	Nominal capacity of structural member or connection
t	-	Thickness
w	-	Distributed applied load (N/m per metre width)
W		Width
w/m		Ratio of the Maximum applied loading to total mass of the model
y	-	Distance from the centroidal axis of the beam to the outermost fiber
δ_{lim}	-	Deflection limit
δ_{max}	-	Maximum deflection at mid-span
ρ		Density of steel (7850kg/m ³)
σ_{lim}	-	Ultimate tensile strength
σ_{shear}	-	Direct shear stress

LIST OF ABBREVIATION

AISI	-	American Iron and Steel Institute
AS/NZS	-	Australian/New Zealand Standard
BS	-	British Standard
CIDB		Construction Industry Development Board
CSA	-	Canadian Standards Association
DMAX	-	Maximum Deflection
Load _{max}	-	Maximum Applied Loading
MMOMZ	-	Member's Moment
Ref	-	Reference
SDIR	-	Maximum Direct Shear Stress
SMAX	-	Maximum Flexural/Bending Stress

LIST OF APPENDICES

Appendix	Page
A Results obtained from ANSYS (analysis based on deflection limit $L/360$)	73
B Diagrams displaying the results in graphic forms	75
C Formulae for beam deflections and slopes	98
D Minimum strengths of steels complying with AS 1163, AS 1397, AS 1594, AS 1595 and AS/NZS 3678	99
E Deflection limits other than for pitched roof portal frames (extracted from BS 5950: Part 1: 1990)	101
F Section properties : various cold rolled sections	102

CHAPTER 1

INTRODUCTION

1.1 Background

This final year project discusses on the *Parametric Study On The Load Bearing Capacity Of Lightweight Steel Framing System*. It begins with an introduction to lightweight steel in general and then the modular framing system.

Cold-formed steel is a type of lightweight steel that is widely used in the construction industry. There is an increase in acceptance of lightweight steel in the construction industry as primary and secondary structural elements such as beams (top track, bottom track, joists) and columns (studs) for buildings, and purlins and cladding for roof trusses (El-Kassas et al. 2002).

Cold-formed steel are used extensively mainly because of the high strength to weight ratio and high stiffness to weight ratio. This facilitates the increased use in the industry which make them a better choice of material over traditional materials for modular framing system and roof trusses system.

Cold-formed steel is not only light in weight but their section is thin which made fabrication easier as compared to hot-rolled steel. A simple process of producing cold-formed

steel section involves the cold rolling process of thin steel plate at very high speed without heating. This results in producing a brighter and shinier surface and most importantly it increases in strength of the steel (Newby and Sulfianda 2003). According to AS/NZS 4600: 1996, Table 1.5 shows the value of the minimum strengths of steel complying with different applicable standard and the different grade of cold forming steel (See Appendix D).

Cold-formed steel can be produced into various sectional profiles depending on the usage. Examples of some common sections used for buildings and roof trusses are the C-Channels, which can be plain without lipped or with lipped, Z sections and hat sections.

Cold-formed steel sections and hot-rolled steel sections are easily distinguishable by its appearance and feature. The former is galvanized with zinc, aluminium and a small portion of silicon alloy to give a long lifespan as well as to prevent them from being corroded when exposed to the harsh weather (Newby and Sulfianda 2003).

Cold-formed steel sections can be used in the design of roof trusses, light commercial industry, framing system, homes and other residential purposes. In countries like Australia, United Kingdom, United States and Japan, most structures such as houses and trusses are built with cold-formed steel and it has been very well accepted because of its consistent strength, quality and other major advantages over traditional materials. Figure 1.1 shows a residential house built with cold-formed steel.



**Figure 1.1 A residential house built with cold-formed steel
(Source: BHPSteel 2002)**

According to Corusgroup (2003), the definition of modular framing or construction is “a term that is used for the factory production of pre-engineered building units that are delivered to site and assembled as large volumetric components or as substantial elements of a building. The modular units may form complete rooms, parts of rooms, or separate highly serviced units such as toilets or lifts.” It means the prefabrication of modular or panel frames using cold-formed steel members in the factory into building units or modular units which eventually delivered to the site and then assembled into a larger volumetric components such as dwelling rooms, toilet units, hotel extensions, plant rooms for commercial buildings and other building purposes. An example of light steel framing used in modular construction is shown in Figure 1.2.



Figure 1.2 A building unit or modular unit formed by cold-formed Steel Members (Source: Corusgroup 2003)

The design of the cold-formed steel framing system is flexible and therefore any sizes and shapes can be fabricated in the factory according to the specification of the architect. Panels are pre-designed and pre-cut in the factory before it is brought to site for installation. They are more easily installed as compared to the assembly of each individual member (Corusgroup 2003).

In countries like United Kingdom and Japan, modular framing system, made from lightweight steel are highly used and developed. Modular construction is used for a wide range of building types such as residential houses and buildings of up to 4 storeys high (BHPSteel 2002). Demands for this system are quite high and it dominates most of the

residential housing in Japan in which over 150,000 houses are built annually in modular form (Corusgroup 2003). In United Kingdom, statistic shows that over 400,000 tonnes of cold-formed steels are used annually in the construction industry (El-Kassas et al. 2002).

1.2 Statement of Problem

The most common use of cold-formed steel structure in Malaysia is still roof trusses. Malaysia's builders, architects and design engineers have not really venture into modular framing system because of their limited exposure to lightweight steel (MBAM 2003). However, the government hopes to gradually move towards the use of cold-formed steel in design and construction not only for roof trusses but also for homes and light commercial industry.

Although lightweight steel framing system has been engineered and designed into panels system of different sizes and shapes, presently there are yet to be researches carried out by local manufacturers to determine the optimum shapes and configurations based on the load bearing capacity. For this reason, research on the optimization of the steel framing system is essential to minimize the wastage of material yet maintaining its effectiveness in load bearing capacity so that the structure will be more economical. This can be done by analyzing the load-bearing capacity on a number of configurations based current existing configurations available in the market with other additional designed configurations identified by the researcher.

1.3 Aim and Objectives

The aim of this project is to study the load bearing capacity of rectangular modular frames, which have been used widely in the market. Research will be carried out to determine the optimum configurations of the lightweight (cold-formed) steel framing systems in terms of the load bearing capacity in Malaysia. Expectantly through this research, lightweight modular steel framing system would really play an important role in Malaysia construction industry.

There are a few objectives in carrying out this project/thesis:

- a. To study the behavior of single unit models with respect to the load bearing capacity by using ANSYS (Finite Element Method).
- b. To study the behavior and performance of the different modular frames with different configurations.
- c. To analyze and determine the optimum configuration for the cold-formed steel framing systems of 8m x 3m modular frames assembled by each of the respective designed configurations with respect to the load bearing capacity where the optimum structural frame is able to carry heavy loads with the use of less material ("to do more with less").
- d. To develop a graph in which an engineer can estimate the size of the model or configuration based on the required or desired loading conditions appropriate to the different uses of the parts of a building or structure. This can help to avoid an over-designed structural frame.
- e. To expose more options in order to have a more economical and stronger modular frames designs.
- f. To promote the awareness of lightweight steel in the educational sector as well as to the industry.

1.4 Scope of Study

A closer look into the parametric study of lightweight (cold-formed) steel with respect to the load bearing capacity and its related past researches will enable the project to be carried out successfully. Hence, the scope of the project is then limited to: -

- i. Steel framing especially cold-formed modular steel framing,
- ii. Two-dimensional models will be taken into account in this research.
- iii. All the modular frames are modeled into rectangular shape with different configurations,
- iv. The sections that are used to form the structural beams and columns are plain C-Channel without flange stiffeners or lips.
- v. Only vertical loads are applied to the structural frames. It is uniformly distributed throughout the top of the beam.
- vi. The effect of wind load or lateral load is not taken into consideration in the analysis of this project.
- vii. The design criteria are based on the Australian/New Zealand Standard For Cold-Formed Steel Structure (AS/NZS 4600: 1996).
- viii. The connections for all the joints are assumed to be pinned-joint for the modular frames. Connections between the members will either be screwed, bolted or riveted.
- ix. The supports for the frames are assumed to be pinned between the bottom beam/chord and the slab.
- x. The analysis of this research does not consider the factor of stability during construction/erection.

xi. ANSYS software will be utilized as a tool to accomplish this project because it has the ability to perform static analyses, to simulate different loading conditions as well as to solve variety of problems.