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JUDUL: **PERFORMANCE OF STAINLESS STEEL PURLIN IN BENDING**

SESI PENGAJIAN: 2005 / 2006

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PERFORMANCE OF STAINLESS STEEL PURLIN IN BENDING

NG ZEE SUM

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

Faculty of Civil Engineering
Universiti Teknologi Malaysia

MAY 2006

I declared that this project report entitled "PERFORMANCE OF STAINLESS STEEL PURLIN IN BENDING" is the result of my own research except as cited in references. This project has not been accepted for any degree and is not concurrently submitted in candidature of any degree.

Signature	:	....
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Date	:	5 MAY 2006

Specially dedicated to
my parents, my dear dear, brother and sisters, and friends...

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ABSTRACT

The results of bending test and lateral buckling test of cold formed stainless steel purlin are presented in this dissertation. Bending test was carried out by simply supporting purlin and loaded on its top flange, while lateral torsional buckling test was done by using cantilevered purlin loaded at the free end of purlin. Theoretical bending capacity of purlin was determined from BS5950 Part 5: Code of practice for design of cold formed sections. While the buckling resistance moments were obtained from BS5950 and from Design Manual for Structural Stainless Steel published by European Stainless Steel Development & Information Group. From the bending test, it was found out that the experimental moment capacities of purlin were slightly higher than the theoretical moment capacities. However, the experimental buckling resistance moments were significantly lower than design buckling resistance moments. Therefore, the bending test method was considered satisfactory, while for lateral torsional buckling test, further studies and other testing methods were needed in order to explore verify the accuracy of cantilever method used in this study.

ABSTRAK

Keputusan ujian lenturan dan ujian lengkokan kilasan bagi purlin keluli tanpa karat yang dibentuk dalam keadaan sejuk. Ujian lenturan telah dilaksana dengan purlin disokong bebas pada kedua-dua hujungnya dan dikenakan beban pada bebibir atas. Manakala ujian lenkokan kilasan dilaksana dengan purlin berkeadaan tergantung dimana satu hujung diikat tegar pada tiang and satu lagi hujung bebas. Nilai kapasiti lenturan purlin teori diperoleh berpandukan *BS5950: Code of practice for design of cold formed sections*. Nilai teori keupayaan lengkokan kilasan bagi purlin diperoleh dari *BS5950* dan dari *Design Manual for Structural Stainless Steel* yang diterbit oleh *European Stainless Steel Development & Information Group*. Daripada ujian lenturan, didapati bahawa keupayaan lenturan purlin yang didapati secara eksperimen adalah lebih tinggi daripada keupayaan lenturan yang diperoleh secara teori. Walaubagaimanapun, keupayaan lengkokan kilasan yang didapati secara eksperimen jejas lebih rendah daripada keupayaan lengkokan kilasan yang didapati secara teori. Oleh itu, cara melaksanakan ujian lenturan dapat dianggap memuaskan. Untuk ujian lengkokan kilasan, lebih banyak lagi kajian dan cara ujikaji diperlukan demi menentukan tahap kebolehpercayaan kejituan cara ujikaji purlin dalam keadaan tergantung.

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LIST OF SYMBOLS

A_n	-	Net area of a section
B	-	Width of flange
b	-	Overall width of an element
b_{eff}	-	Effective width of the stiffened plate element
b_{eu}	-	Effective width of the unstiffened plate element
C_b	-	Coefficient defining the variation of a moment on a beam
C_{bx}	-	C_b factors about x axis
C_{by}	-	C_b factors about y axis
D	-	Overall web depth
E	-	Modulus of elasticity
e_s	-	Distance between the geometric neutral axis and the effective neutral axis of a section
f_c	-	Applied compressive stress
F_c	-	Applied axial load
J	-	Torsion constant
H	-	Warping constant
I_x	-	Moment of inertia of a section about the x-axis
I_y	-	Moment of inertia of a section about the y-axis
K	-	Buckling coefficient
L_E	-	Effective length of a member
L	-	Length of section
λ_{LT}	-	Equivalent slenderness
M_b	-	Buckling resistance moment
M_{cx}	-	Bending moment capacity about x axis in the absent of F_c and M_y
M_{cy}	-	Bending moment capacity about y axis in the absent of F_c and M_x
M_x	-	Applied bending moment about x axis

M_y	-	Applied bending moment about y axis
M_{cr}	-	Critical moment
M_E	-	Eleastic lateral buckling moment of a beam
m	-	Equivalent uniform moment's factor
n	-	Slenderness correction factor
η	-	Perry coefficient
γ_m	-	Material strength factor
p_b	-	Bending strength
P_c	-	Buckling resistance under axial load
P_c'	-	Buckling resistance under axial load for singly symmetrical sections
p_{cr}	-	Local buckling stress of an element
P_{cs}	-	Short strut capacity
P_E	-	Elestic flexural buckling load (Euler load) for a column
p_o	-	Limiting compressive stress in a flat web
P_t	-	Tension capacity
p_y	-	Design strength of steel
r_y	-	radius of gyration of section about the y axis
S_x	-	Plastic section modulus
t	-	Net material thickness
t_w	-	Thickness of web
t_f	-	Thickness of flange
u	-	Buckling parameter
x	-	Torsional constant
χ_{LT}	-	a reduction factor accounting for lateral torsional buckling
Y_s	-	Yield strength of material
Z_x	-	Elastic section modulus
Z_{eff}	-	Effective section modulus
Z_c	-	Compressive section modulus of the effective cross-section

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CHAPTER 1

INTRODUCTION

1.1 Introduction to Cold Formed Purlin

Purlin is a horizontal structural member spanning between beams or trusses to support a roof deck. In slope glazing, purlins are the horizontal framing members. Purlins have been used in roofing system for decades. Roof purlins account for a substantial proportion of cold formed steel usage in buildings. Purlins are ideally suited for production as cold rolled sections and over 60000 tonnes of cold formed steel purlins are produced annually in United Kingdom.

There are various types of purlins available in the market; the most commonly are Cee and Zed purlins which take the form of C and Z letter. The Zed shape purlin was introduced from USA around 1960. Another type of purlins shape is the Sigma shape which was introduced a few years later after the Zed shape. In recent years the fierce competition between purlin manufacturers has led to substantial research and development effort in the field of purlin design to produce purlin with even greater efficiency. This has lead to further developments of the Zed shape in particular such as Zeta shape and the UltraZED shape. All the typical shapes of purlins are shown in Figure 1.1. Most purlins are produced from steel and most recently galvanized steel which has a greater advantage over steel in terms of strength. Most purlins are cold formed which means that they are formed in the cold state from a strip of uniform thickness.

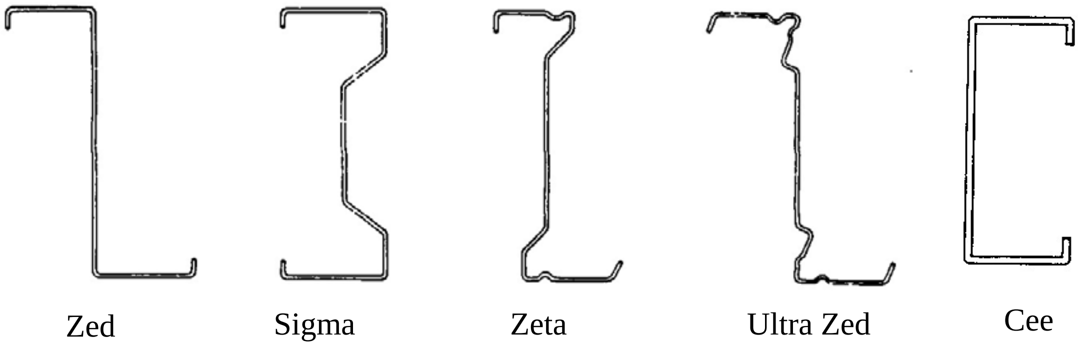

Figure 1.1: Types of roof purlin in common use at the present

At present, the Zed shape and its derivatives accounts for approximately two thirds of the markets in purlins, with the other one third being accounted for by Sigma shape. Purlin thickness used range from about 1.2 mm to 3.2 mm and material of yield strength of 350 N/mm^2 is commonly used in the production of purlins.

A variety of different purlin systems are also available to enable the designer to exercise a choice between simple inexpensive and easy to erect systems or more complex but more efficient systems. The main systems in use today are shown in Figure 1.2. Figure 1.2(a) shows the simple non-continuous system in which the purlins are more or less simply supported at each rafter. Figure 1.2(b) shows the double spanning system in which the purlins span continuously over a central rafter. This system is generally stronger and much less flexible than the non-continuous system, but is subject to some restrictions on the lengths of double spanning purlins which can be transported. Figure 1.2(c) shows the sleeved system in which purlins are jointed at alternate rafters by semi-rigid sleeve connections, with the sleeves being, in most cases, of the same cross-section as the purlin. This system is most widely used at the present moment. Of the sleeves are designed correctly the ideal moment distribution can be obtained due to the moment redistribution capabilities of the semi-rigid connections. In the overlap system, Figure 1.2(d), the purlins are “overlapped” at each rafter to provide double the strength at the supports. This system gives the best performance, but necessitates care in erection and the use of end purlins of different thickness to interior purlins.

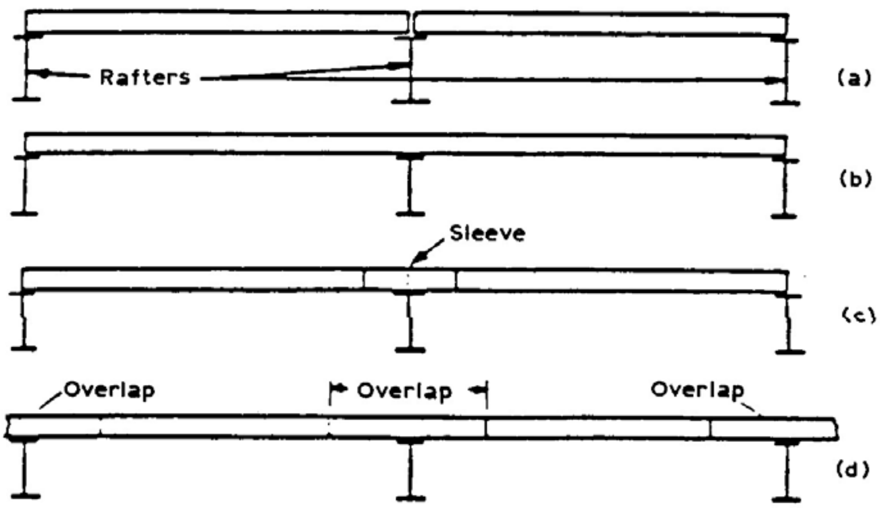

Figure 1.2: Roof purlin system in common use

While steel and galvanized steel are common material in purlin, there is another less popular material that can be used in purlin production which is stainless steel. Until now, little has been studied about the behavior of cold formed stainless steel purlin. The focus of research is to study the behavior of stainless steel Cee-purlin using experimental method, and to produce a draft design guide for stainless steel Cee-purlin.

1.2 Advantages of Cold Formed Steel Section

Generally, cold formed steel sections have several advantages over hot rolled steel sections, timber sections and concrete. The main advantages are listed as follows:

1. *No insect and fungal infection*: The problems such as rotten or decomposed due to insect and fungal infection are eliminated, therefore the material curing and maintenance costs which is necessary for the timber and concrete construction could also be eliminated.

2. *Consistency and accuracy of profile*: The nature of the manufacturing process – cold rolling – enables the desired profile to be maintained and repeated for as long as it required, in a very close tolerances. Moreover, the very little tool wear and the cold rolling process is ideally suited to computerized operation which assists to the maintenance of accuracy.

3. *Versatility of profile shape*: Almost any desired cross-sectional shape can be produced by cold rolling.

4. *It could be pre-galvanized or pre-coated*: The steel material may be galvanized or coated by plastic materials either to enhance its resistance to corrosion or as an attractive surface finish.

5. *Variety of connection and jointing methods*: All conventional methods of connecting components, e.g. riveting, bolting, welding, and adhesives are suitable for cold formed section.

6. *Speedy in construction, and suit for site erection*: Generally the steel construction has eliminated the curing time which is unavoidable in concrete construction; therefore cold formed steel construction in certain parts of a structure is far faster than concrete construction. The cold formed steel may have an edge over hot rolled steel since it can be easily be cut and erected with very light machine or manually.

7. *Increase in yield strength due to cold forming*: The cold forming process introduces local work hardening in the strip being formed in the vicinity of the formed corners. This local work hardening may results in an increment of ultimate yield strength to about 25% from its virgin strength.

8. *Minimization of material usage*: Since the material used can be very thin in comparison with the lower thickness limits of hot rolled steel sections, it allows the material usage for a given strength or stiffness requirement to be much less than that of the smallest hot rolled sections. The material thickness, or even the cross-sectional

geometries could be controlled to achieve the structural features with minimum material weight.

9. *High profitability*: In cold rolled process, the manufacturing cists of cold rolled steel section mainly involve the initial modal of purchasing the rolling machine and the costs of steel strip material later. The machinery cost is only needed once, then the cost can be recovered back from the continuous production. The cold formed purlin normally used for roof building purposes involves only simple and fast erection with light erection tools, therefore it is gaining the preference of local constractors and fabricators since the investment is little and the profits return is faster than other constructional parts.

1.3 Objectives

The objectives of this research are as follows:

i) To develop experimental method to study the behavior of Lipped Channel sections subjected to moment and lateral torsional buckling moment.

ii) To obtain experimental data of section and member capacities of the stainless steel purlin subjected to flexural load (bending and lateral torsional buckling)

iii) To analyze the results of the test in comparison with the design capacity according to relevance standard reference based on the tested yield strength of the materials.

1.4 Scope of Study

The scope of study will cover both the experimental and theoretical investigation of stainless steel cold formed lipped channel (Cee Purlin) subjected to bending moment and lateral torsional buckling moment. The size ranges of purlin samples tested are of thickness from 1.0 to 2.7mm, width of 71 mm, depth of 160 mm and lip depth of 16.5 mm. The scopes of study in this research are:

i) Determination of the design yield strength of stainless steel of purlin sections using tensile coupon test.

ii) Determination of the ultimate moment capacity of stainless steel lipped channel experimentally* and theoretically**.

iii) Stainless steel lipped channel are tested in simply supported condition for bending failure.

iv) Determination of the buckling resistance moment, M_b of stainless steel lipped channel experimentally* and theoretically**.

v) Stainless steel lipped channel are tested in cantilevered condition for lateral torsional buckling failure.

vi) To study the behavior of stainless steel lipped channel under the effects of lateral torsional buckling experimentally* (most critical load point, torsional profile).

* Conducted in the structural laboratory of civil engineering faculty, UTM

** Based on BS5950 - Part 5: Code of Practice For the Design of Cold Formed Sections and Design Manual for Structural Stainless Steel by European stainless steel development & information group.

CHAPTER 2

LITERATURE REVIEW

2.1 Cold Formed-Steel

Cold formed steel products are used in all aspects of modern life. Besides being used as structural members, cold formed steel are also used in automobile bodies, kitchen appliances, furniture, corrugated sheets for farm buildings, corrugated culverts, round grain bins, retaining walls, rails and many other uses. With the help of cold forming processes, cold formed steel products come with a diversity of shapes, sizes and applications. Cold formed steel for industrial and commercial buildings began about mid-20th century, and widespread usage of cold formed steel in residential buildings only started in the 1980s.

2.1.1 Applications of Cold Formed Steel

Cold formed steel structural members are normally used in the following applications:

i) Roof and wall systems of industrial, commercial and agricultural buildings

Typical sections for use in roof and wall systems are Z- (zee) or C- (channel) sections, used as purlins and girts, or sometimes beams and columns. Typically, formed steel sheathing or decking spans across these members and is fastened to them with self-drilling screws through the “valley” of the deck. In most cases, glass fiber insulation is sandwiched between the deck and the purlins or girts.

ii) Steel racks for supporting storage pallets

The uprights are usually channels with or without additional rear flanges, or tubular sections. Tubular or pseudotubular sections such as lipped channels intermittently welded toe-to-toe are normally used as pallet beams. In the United States the braces are usually welded to the uprights, whereas in Europe, the braces are normally bolted to the uprights.

iii) Structural members for plane and space trusses

Typical members are circular, square, or rectangular hollow sections both as chords and webs, usually with welded joints. Bolted joints can also be achieved by bolting onto splice plates welded to the tubular sections. Channel section chord members can also be used with tubular braces bolted or welded into the open sections. Cold formed channel and Z sections are commonly used for the chord members of roof trusses of steel-fromed houding, Trusses can also be fabricated from cold-formed angles.

iv) Frameless stressed-skin structures

Corrugated sheets or sheeting profiles with stiffened edges are used ti form small structures up to a 30-ft clear span with no interior framework. Form buildings, storage sheds, and grain bins are typical applications.

v) Residential framing

Lipped and unlipped channels, made to the same dimensions as nominal 2 x 4s are typically used in the walls of residential buildings. Larger channel sections are used as floor and ceiling joists, and roof trusses are commonly made of small channel sections screwed or bolted together.

vi) Steel floor and roof deck

Formed steel deck is laid across steel beams to provide a safe working platform and a form for concrete. It is normally designated as a wide rib, intermediate rib, or narrow rib deck. Some deck types have a flat sheet attached to the bottom of the ribs which creates hollow cells providing raceways for electrical and other cables. This bottom sheet may be perforated for an acoustical ceiling.

Some decks have embossments in the sloping sides of the rib that engage the concrete slab as a kind of shear key and permit the deck to act compositely with the concrete.

vii) Cold-formed tubular members

Hollow structural sections (HSS) may be made by cold-rolling to produce a round, which is then closed by electric resistance welding (ERW). The round shape can then be used as is or further formed into a square or rectangular.

2.1.2 Manufacturing Processes

Cold-formed members are usually manufactured by one of two processes which are roll forming and brake forming.

Roll forming consists of feeding a continuous steel strip through a series of opposing rolls to progressively deform the steel plastically to form the desired shape. Each pair of rolls produces a fixed amount of deformation in a sequence of the type shown in Figure 2.1. For example, a Z section is formed by first developing the bends to form the flanges. Each pair of opposing rolls is called a stage, as shown in Figure 2.2. In general, the more complex the cross-sectional shape, the greater the number of stages that required.

Brake forming involves producing one complete fold at a time along the full length of the section, using a machine called as press brake such as one shown in Figure 2.3. For sections with several folds, it is necessary to move the steel plate in the press and to repeat the braking operation several times. The completed section is then removed from the press and a new piece of plate is inserted for manufacturing of the next section.

Roll forming is the more popular process for producing large quantities of a given shape. The initial tooling costs are high, but the subsequent labor content is low. Press braking is normally used for low-volume production where a variety of shapes are required and the roll-forming tooling costs cannot be justified. Press braking has the further limitation that it is difficult to produce continuous lengths exceeding 20ft.

A significant limitation of roll forming is the time it takes to change rolls for a different size section, Consequently, adjustable rolls are often used which allow a rapid change to a different section width or depth. Roll forming may produce a different set of residual stresses in the section when compared with braking, so the section strength may be different in cases where buckling and yielding interact. In addition, corner radii tend to be much larger in roll-formed sections, and this can affect structural actions such as web crippling.

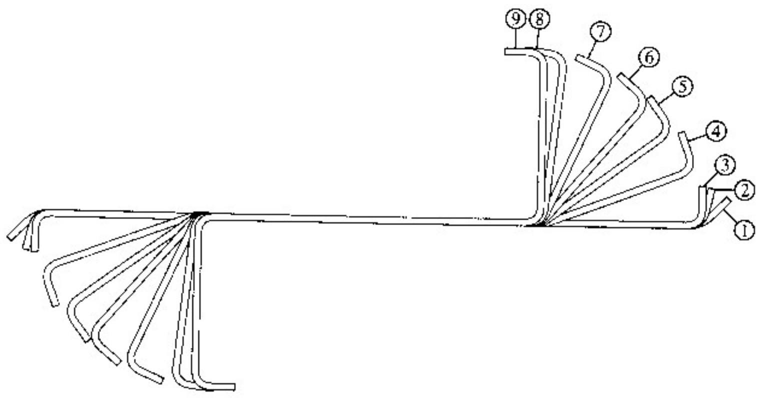

Figure 2.1: Typical roll-forming sequence for a Z-section

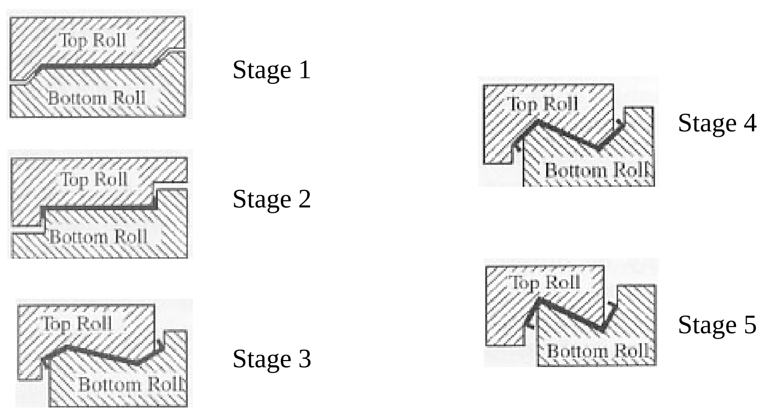

Figure 2.2: Roll forming tools by stages