SECONDARY BENDING MOMENT OF TRAPEZOID WEB BEAM UNDER SHEAR LOADING

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To my beloved family

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ABSTRACT

In structural and fabrication technology, new techniques of optimized steel structures design have been developed. One of the developments in steel structure design is the introduction of trapezoidal web beam. One of the phenomena being studied for the trapezoid web beam is the secondary bending moment which is induced in the flanges of section subjected to shear loading in the web, due to the corrugation of the web. A parametric study was carried out to develop a formula for the secondary bending moment. The parametric study involved in this study are depth of web, D, width of flange, B, thickness of flange, T and thickness of web, t. This study was carried out by using finite element method. The formula of secondary bending moment has been successfully derived and can be used for any other sections of trapezoid web beam with same corrugation thickness and corrugation angle.

Keywords: trapezoid web beam, secondary bending moment, finite element

ABSTRAK

Dalam stuktur dan teknologi pembuatan, teknik baru rekabentuk optimum struktur keluli telah dimajukan. Salah satu perkembangan dalam struktur keluli ialah pengenalan rasuk dengan *web* trapezoid. Salah satu fenomena yang telah dikaji dalam rasuk *web* trapezoid adalah momen lengkukan kedua yang terhasil dalam bebibir apabila beban rich dikenakan dalam *web*, disebabkan kerutan *web* tersebut. Satu kajian parametrik telah dijalankan untuk menghasilkan satu formula bagi momen lengkukan kedua dalam rasuk *web* trapezoid apabila dikenakan beban ricih. Kajian parametrik ini termasuklah ketigggian *web*, D, kelebaran *web*, B, ketebalan bebibir, T dan ketebalan *web*, t. Kajian ini dijalankan dengan menggunakan kaedah usur terhingga. Formula bagi momen lengkukan kedua telah berjaya dihasilkan dan boleh digunakan untuk apa-apa saja saiz bagi rasuk *web* trapezoid dengan tebal kerutan dan sudut kerutan yang tetap.

Kata kekunci: rasuk *web* trapezoid, momen lengkukan kedua, usur terhingga

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a	-	Length of straight part of the web corrugation
B	-	Width of flange
C_o	-	Secondary bending moment coefficient
D	-	Depth of web
T	-	Thickness of flange
t	-	Thickness of web
M_{cx}	-	Section bending capacity, which is calculated by neglecting the contribution of web
M_{yf}	-	Secondary bending moment of this study
M_{cyf}	-	Secondary bending moment capacity of this study
M_{sec}	-	Secondary bending moment of German
$M_{sec,o}$	-	Secondary bending moment capacity of German
M_x	-	Applied bending moment
V	-	Shear loading
Q	-	Total lateral reactions at each oblique sub-panel
Q_{avr}	-	Average lateral reactions
p_y	-	Design strength
Z_{yf}	-	Elastic modulus of each flange in y axis

CHAPTER 1

INTRODUCTION

1.1 General

Demand for steel structures is increasing dramatically especially in construction industry. A number of new structural and fabrication technology has been developed to optimize the efficient use of steel in construction. One of the developments in steel structures is the introduction of trapezoidal web I-beam.

Trapezoid web beam is a type of steel section to form an I-section which use corrugated web made in trapezoidal form. The beam with corrugated thin web is continuously welded to the flanges at the top and bottom. Trapezoid web beam is a built up section that able to support vertical loads over long spans. The higher bending capacity is achieved by increasing the depth of the section.

Corrugation web in trapezoidal form increases the stability against buckling and can result in very economical designs. Ordinarily, the economic design of steel web I-beam requires thin web. To eliminate the risk of using thicker web of the beam, web stiffeners or by making the web in trapezoidal form is needed for the purpose of strengthening the web. When beams with corrugated webs are compared

with those with stiffened flat webs, it can be found that trapezoidal corrugation in the web enables the use of thinner webs and trapezoidal web beams eliminate costly web stiffeners.

The trapezoid web beam provides a higher resistance against bending moment about the weak axis, high strength-to-weight ratio, less cost and higher load carrying capacity. Furthermore, it also offers its naturally architectural design element with its own aesthetic quality in the various construction projects.

The flange of trapezoid web beam carries the bending moment and the trapezoidal web carries the shear force. Due to the shear force subjected at the trapezoidal web, a lateral bending moment is induced in the flange, which is known as secondary bending moment, M_{yf}. It may cause a minor reduction in the bending moment capacity of the web.

This study consists of finite element analysis by using a computer software which is known as LUSAS, to determine the lateral reactions at the flange of the trapezoidal web beam. The lateral reaction depends on the section properties and increase linearly with the applied shear force. Thus, secondary bending moment coefficient, C_o is induced.

A series of analysis on finite element has been done on various sizes and properties of the beams to determine the value of secondary bending moment coefficient, C_o by compared the value between finite element analysis and German existing table properties.

In the past, German table properties was developed on the specific size section of trapezoid web beam. From the derivation of formula C_o, it is to be used to determine M_{sec} for any size sections. Apart from that, local engineers have widen choice on size section while doing design work.

1.2 Problem Statement

There is not much work has been done for the secondary bending behavior of trapezoid web beam. From the German table properties of the trapezoid web beam, there is no explanation and formula on how the value of secondary bending moment coefficient, C_o and secondary bending moment, M_{sec} is obtained and the information is limited.

The behavior of C_o can be determined by lateral reaction by using finite element analysis with applied lateral support at the section. The value of secondary bending moment coefficient is acceptable if it is comparable with existing German table properties. Therefore, the study is necessary to determine the clear explanation on the value of C_o and derive the formula of C_o and extend the knowledge.

1.3 Objective of Study

This study has been conducted to address the problem statement mentioned above. This study will give a better understanding on C_o and M_{yf} due to various geometric properties by using LUSAS finite element software. The main objectives of this study are:

a) To determine the secondary bending moment, M_{yf} in the flange.
b) To derive the formula of secondary bending moment coefficient, C_o

1.4 Scope of Study

The scopes in this study consist of:

a) Determine the lateral reaction in the flanges of the trapezoidal web beams when subjected to shear loading by using LUSAS finite element software.
b) Determine the secondary bending moment, M_{yf} induced at the flanges and the value of C_o due to the lateral forces adopted by finite element analysis.
c) Carrying out parametric study by varying:
    i) Flange width
    ii) Flange thickness
    iii) Web depth
    iv) Web thickness
    v) Aspect ratio of sub-panel
    vi) Corrugation thickness
    vii) Corrugation angle and etc.
d) Derive the formula of C_o from the parametric study using manual calculation.
e) Verify the values of M_{yf} and C_o by comparing with the German table properties.

REFERENCES

1. Hussein, W.Q. (1997), "Design Concept of Trapezoid Web Profile", Lecture notes and technical report, Johor: Antara Steel Mill Sdn. Bhd.
2. Nina Imelda (2003), "The Effect of Opening on the Strength of Corrugated Web Plate Girder Subjected to Shear", Master Thesis, Skudai: Universiti Teknologi Malaysia.
3. R. C. Hibbeler (2003), "Mechanics of Materials" fifth edition, Upper Saddle River, New Jersey: Pearson Education, Inc.
4. Ferdinand P. Beer, E. Russell Johnston, Jr. (1981), "Mechanics of Materials", United States of America: McGraw-Hill, Inc.
5. Hussein, W.Q. (1998), "Design Concept for Steel Plate Girder with Corrugated Webs (TWP)", Pasir Gudang, Johor: Trapezoid Web Profile (TWP) Sdn. Bhd.
6. Tirupathi R.C., Ashok D.B. (2002), "Introduction to Finite Elements in Engineering", New Jersey, Prentice Hall.
7. LUSAS Modeller User Manual, Version 13.5 (2002), United Kingdom: FEA Ltd.
8. M.H. Osman, "Secondary Bending Moment in Corrugated Steel Section", to be presented in Seminar Penyelidikan Kejuruteraan Awam (SEPKA), Dec 2006, UTM Skudai.