FINITE ELEMENT ANALYSIS OF CORRUGATED WEB BEAM WITH OPENINGS

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A thesis submitted in partial fulfillment of the
requirement for the award of the degree of
Bachelor of Civil Engineering

Faculty of Civil Engineering & Earth Resources
Universiti Malaysia Pahang

NOVEMBER 2010

ABSTRACT

In construction application, the web is usually carry most of the compressive stress and transmits shear in the beam while flanges support the major external loads. Therefore, web is usually investigated by comparing the thickness and the shape. There are various types of profile steel sheeting used in Malaysia, such as Spandek and Trimdek. The introduction of an opening in the web of the beam will alter the stress distribution within the members and also cause its collapse behaviour. Therefore, the effective design of web beam with an opening is always investigated. This project is to develop a finite element analysis in studying the web profile of the beam with openings and stiffener by using LUSAS 14.0. Nine models had been conducted in this project by analyse the linear analysis, stress, strain and buckling shape of beam The dimension of each models are1500 mm span with 125mm x 550 mm section. Each models subjected to simply supported test The type of mesh are Quadrilateral Thin Shell with 4 nodes (QTS4) for each model. The results show that Spandek Corrugated Web has the highest strength followed by Trimdek Corrugated Web and Flat Web Beam. Nevertheless, the buckling load analysis shows Trimdek Corrugated Web Beam is the best corrugated to resist linear buckling than Spandek and Flat web beam.

ABSTRAK

Dalam aplikasi pembinaan, rasuk web biasanya membawa beban tegangan tekan dalam rasuk dan kegunaan flange adalah untuk menyokong beban luaran utama kepada rasuk. Oleh itu, rasuk web biasanya diselidiki dengan membandingkan ketebalan dan bentuk untuk meningkatkan. Ada pelbagai jenis profil besi bergelombang digunakan di Malaysia, seperti Spandek dan Trimdek. Selain it, pengenalan bukaan kepada web rasuk akan mengubah pengedaran tegangan di dalam rasuk. Oleh itu, desain rasuk web dengan bukaan selalu dikaji. Projek ini bertujuan untuk mengembangkan kefahaman analisis elemen dalam mempelajari profil web yang berbeza dari rasuk dengan bukaan dan pengaku dengan menggunakan program LUSAS 14.0. Sembilan model telah permodelan dalam projek ini untuk menganalisis nilai regangan dan lokasi dalam linier analisis dan menentukan bentuk buckling dari pelbagai jenis profil web dengan analisis buckling linier. Dimensi setiap model adalah sama, iaitu 1500 mm span, dan 125mm x 550 mm seksyen. Setiap model dikenakan beban uji tiga titik. Sedangkan jenis mesh digunakan adalah Quadrilateral Thin Shell with 4 nodes (QTS4) untuk setiap model. Perbandingan menunjukkan Spandek Bergelombang Web memiliki kekuatan yang paling tinggi diikuti oleh Trimdek Bergelombang Web dan datar Web rasuk. Disamping itu, Trimdek Bergelombang Web adalah terbaik dalam menentang bukling beban.

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LIST OF SYMBOLS

L	Total Span of Beam / Length
B	Width of Flange
D	Overall Depth of Beam
t_w	Thickness of Web
t_f	Thickness of Flange
ε	Strain
ΔL	Change in length
σ	Stress
ϕ	Change In Angle
E	Young Modulus
N	Force
M	Moment
V	Poisson Ratio
σ_{max}	Stress Maximum
ε_{max}	Strain Maximum

LIST OF ABBREVIATIONS

TCWB	Trapezoidal Corrugated Web Beam
LUSAS	London University Structural Analysis Software
FE	Finite Element
QSL8	Quadrilateral Thin Shell Elements with 8 Nodes Clockwise
TSL6	Semiloof Curved Thin Shell Elements
QTS4	Quadrilateral Thick Shell Elements with 4 Nodes Clockwise
QTS8	Quadrilateral Thick Shell Elements with 8 Nodes Clockwise
ABAQUS	Other Program of Finite Element Software
COSMOS/M	Other Program of Finite Element Software

CHAPTER 1

INTRODUCTION

1.1 Introduction

Steel structure building are becoming more and more popular due to their many advantages such as the better satisfaction with the flexible architectural, durability, strength, design, low inclusive cost and environmental protect as steel is manufacture to precise and uniform shapes.

In construction application, the web is usually carry most of the compressive stress and transmits shear in the beam while flanges support the major external loads. Therefore, web is usually investigated by comparing the thickness and the shape. It can decrease the cost and materials without weakening the load-carrying capability of the beam. The corrugated web is proposed to compare with the common plane web. There are different type of corrugated web were propose such the horizontal corrugated web of one arc corrugation, two arcs corrugation and vertically corrugated web, In this thesis, the study of vertically corrugated web beam, will be investigated while ordinary plane web beams were also test to develop the benchmark result.

Corrugated beam with web opening is commonly used where large web openings are provides along the beams. In modern buildings, provision of large ducts and pipes beneath beams and girders of structure steel framing in building structure may lead to unacceptably large construction depths between storeys. There is a tendency to use water pipes and air ducts of increasing sizes, and opening of dimensions up to 75% of the depth of floor beams are often required. (Chung, 2001)

Finite element analysis has widely use by the engineer to do analysis of the structure and solve any real engineering problems with certain degree of complication. There are researchers who successfully use the finite element analysis to analyze structure, such as Beijing national nation, Bird Nest. The finite element analysis widely use rather than running series of laboratory test because the result more precise, and save cost and time.

1.2 Problem Statement

The use of corrugated web beam with opening is commonly used since it makes ducting and services work much more easily. Despite the advantage, the introduction of opening may reduce the strength of the beam if it is not properly design. The opening profile can depend on the shape of the duct to the web. The openings along the web beam will also reduce the strength of the beam

In the case of corrugated web, analysis can be carried out to find out the analysis of the influence of an opening on the web using LUSAS finite element software. This study was carried out to proven the software result about the stress and deflection of the corrugated web influence by the opening in the middle of the beam.

1.3 Objective

The objectives of this studied were:

1. To investigate the behaviour of the corrugated web beam.

2. To study the openings effect of the corrugated beam openings.

3. To analysis of the corrugated web beam with a stiffener.

1.4 Scope of Study

The scope of study will cover the theoretical investigation of corrugated web section with openings. The scope can be divided into several areas:-

i. Study different type of corrugated shape and compare to the flat web beam.
ii. Compare the effect of the openings.
iii. Condition with stiffened/ unstiffened corrugated web beam was studied.

Finite element analysis method is used in this study. The LUSAS Modeling version 14.0 at Computer lab in University Malaysia Pahang (UMP) will be used in order to simulate and directly analyze the effect of the opening in corrugated web beam.

1.5 Significant Of Study

Generally, the rapid growth in the industry is forcing the structure industry struggling to improve their product and service to a higher level. Therefore, series of test require analyzing by the industrial to improve the quality of the material. By saving the time and cost of a product, finite element analysis is always suggested rather than laboratory test.

In Malaysia, the usage of the corrugated web section of beam is not widely used compare to Flat Wed Beam. This is because of the complicated shape of fabricate due to its trapezoidal web shape which require the need to use the state of the art machine. As a result, the initial production of trapezoidal corrugated of web section is quite expensive. Moreover, the only one company produces trapezoidal corrugated web sections are produce by Trapezoidal Web Profile Sdn Bhd based in Pasir Gudang. However the potential of development of usage Trapezoidal corrugated web section of beam in industry will extremely increase due to the increment of the material price likes steel in the market.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Over the past 20 year, corrugated plates have found an increasing application in structural engineering, in aerospace engineering, marine engineering and building industry. In the early 1960s, trapezoidal corrugated web beam have been used for steel buildings and for highway bridges in Europe and Japan since the 1980s (Abbas, 2003).

A typical corrugate web steel I-beam is build up of two steel flanges welded to a corrugated web as shown in Figure 2.1.The web and flanges can be made from different type of steel grade depending on design requirement. There are two types of web corrugation profile web used in web I-beams, which are the trapezoidal profile and sinusoidal profile as shown in Figure 2.1 and 2.2 respectively, which used in structures that has special requirement to avoid fatigue failure. (Wang, 2003)

Figure 2.1 Trapezoidal Corrugation

Figure 2.2 Sinusoidal Corrugation

Corrugated steel web I-beam introduces the use of thin plates without stiffeners to improve both aesthetics and the economy of the buildings and bridges. Research has shown that corrugated web I-beam have improved shear stability and better fatigue resistance than conventional I-beam with flat webs (Abbas, 2003).It can eliminate the use of larger thickness stiffeners plate that allow the reduction in beam weight and result in economic design. When the corrugated webs are compared with stiffened flats webs, it can be found that the corrugated steel web I-beam enables the use of thinner webs. It was found that corrugated steel web I-beam have 9 to 13 % less weight than current traditionally stiffened girders with flat webs, see table 2.1 (Hamada, 1984)

Table 2.1 Lightweight fabrication by corrugated web I-beam, Hamada (1984)

Welded I-beam (mm) Depth, web width, web Thickness, flange Thickness	Corrugated web I-beam (corrugation width) (mm)	Section modulus ratio per unit width (corrugated web I-beam/welded I-beam)
H 200 x 100 x 3.2 x 4.5	200 x 100 x 1.6 x 2.5 (150)	1.09
H 250 x 125 x 4.5 x 6.0	250 x 125 x 2.0 x 6.0 (180)	1.13
H 300 x 150 x 4.5 x 6.0	300 x 150 x 2.3 x 6.0 (220)	1.10
H 400 x 200 x 4.0 x 12.0	400 x 150 x 2.7 12.0 (300)	1.09

The supplication of trapezoidal corrugated web beam suitable to apply to building such as below:

(a) Industrial Building and warehouse (see Figure 2.3)
(b) Bridge construction for road and railways (see Figure 2.4)
(c) Crane Bridged, Crane ways and crane supports (see Figure 2.5)
(d) Floating construction and offshore projects
(e) Shipbuilding works.

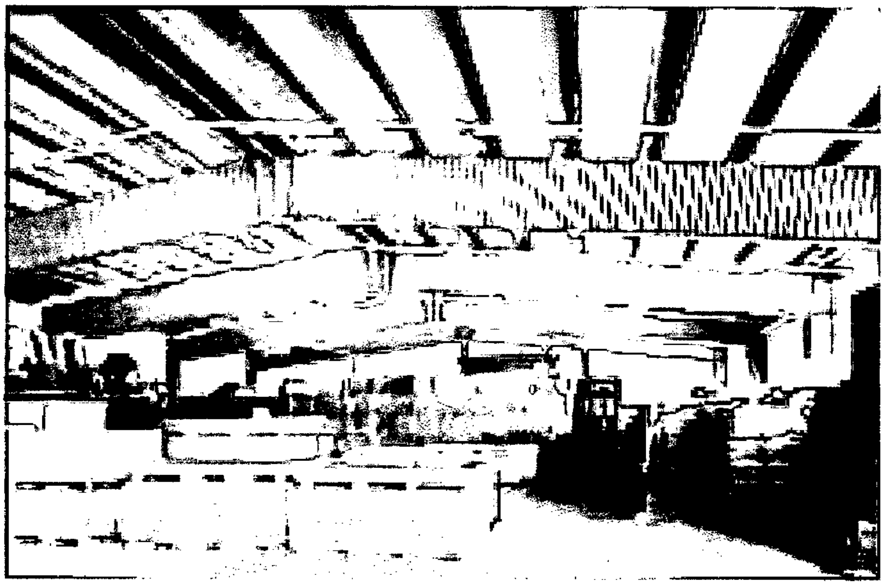

Figure 2.3 Industrial Building and warehouse (Zeman International)

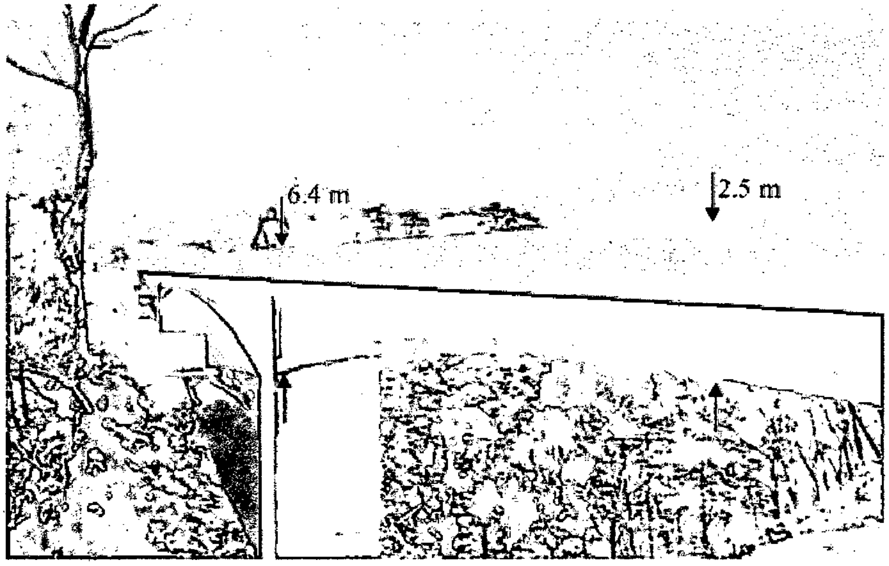

Figure 2.4: The Hondani Bridge in Japan (Ezzeldin, 2007)

Figure 2.5 : Crane Way Using Trapezoidal Corrugated Web Beam (Usman, 2001)

2.2 Advantages of Trapezoidal Corrugated Web Beam (TCWB)

Engineers have realized that corrugation in webs increase their stability against buckling and can result in very economical designs. Less cost and higher load carrying capacity, corrugated web beam provide a high strength-to-weight ratio. Furthermore, erection cost is reduced, since the corrugation in the web provides a higher resistance against bending about the weak axis.

2.3 Previous Research

Extensive research has been directed, toward the study of corrugated steel web. The early study on the corrugated web was concentrate on vertically trapezoidal corrugation. Elgaaly investigated the failure mechanisms of these beams under different loading modes, namely shear mode, bending mode and compressive loads. They found that the web could be neglected in the beam design calculation due to insignificant contribution to the beam's load-carrying capability. (Khalid et.al, 2004)

2.3.1 Shear behavior of steel beam with corrugated webs.

Elgaaly, Hamilton and Seshadri (1996) verified the test results done by Smith (1992) and Hamilton (1993) using nonlinear finite element method. They compared the finite element analysis results with those of the tests and found that the finite element analysis results were very close to the test results.

Luo and Edlund (1996) use a non-linear finite element method to investigate the geometric parameters of corrugated web and compare the numerical result with existing formula. The parametric range studied concludes the ultimate shear capacity increase proportionally with the depth and not to be dependent on the ratio of girder length over girder depth. The post-buckling shear capacity also increases with girder depth but seems to be dependent on the ratio of girder length over girder depth. They also found that the corrugation depth does not significant to the ultimate shear capacity but it affects the buckling mode in the early post-buckling range.

2.4 Profiled Web Beam

In order to provide higher strength for the beam, a profile of trapezoidal corrugated beam is introduced. There are various types of profile steel sheeting used in Malaysia, such as Spandek and Trimdek.

2.4.1 Lysaght Spandek

Lysaght Spandek is a trapezoidal profile which is given a strong, bolder, and modern corrugated appearance. It was original design as a strong attractive roofing material for industrial, commercial construction, homes and public buildings underlining its versatility and pleasing appearance.

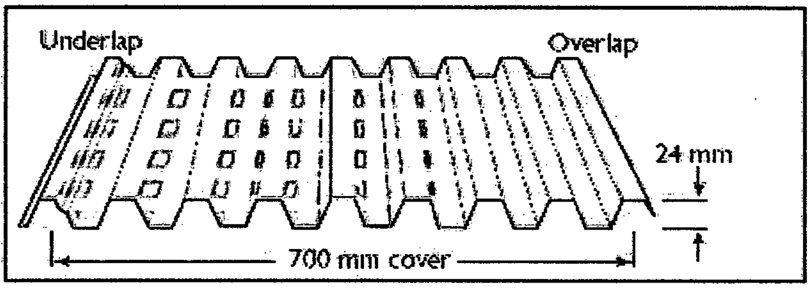

Figure 2.6: Profile of Lysaght Spandek