

FLEXURAL BEHAVIOUR OF TRAPEZOID WEB PLATE
GIRDER

HASNI / IHSAN BIN ATAN

UNIVERSITI TEKNOLOGI MALAYSIA

ABTRACT

This project report presents a study on the flexural behaviour of trapezoid web plate girders due to pure bending. Finite element method and analytical method were used to obtain bending stress and deflection at midspan for a known load, of a set of five different sizes of trapezoid web plate girders. As a control the two methods were also applied to a similar set of straight web plate girders. In addition the ultimate moment capacities for each set were obtained using non-linear finite element method and analytical methods. The results from the two methods were compared with each other and with the results from experimental bending tests on trapezoid web plate girders. Analytical method gave equal results of deflection, bending stress and ultimate moment for both trapezoid and straight web plate girders. Finite element anlysis, however, showed that deflection of trapezoid web section is greater than the straight web section for the same load. For the trapezoid section the bending stress values from finite element method approximates the analytical values better if the web contribution is ignored. The increased divergence of deflection value of finite element method over analytical methods for increasing section sizes are concluded to be due to shear deformation which was included in finite element method but not in analytical methods.

ABSTRAK

Laporan projek ini membentangkan kajian tentang kelakunan flexur galang plat dengan web berbentuk trapezoid disebabkan oleh lenturan semata-mata. Kaedah unsur terhingga dan kaedah penyelesaian secara analisis telah digunakan untuk mendapatkan tegasan lenturan dan pesongan di tengah span disebabkan oleh satu nilai beban yang di ketahui, daripada satu set galang plat dengan web berbentuk trapezoid untuk lima saiz yang berlainan. Sebagai satu kawalan, kedua-dua kaedah juga dikenakan ke atas set yang serupa terdiri dari galang plat dengan web yang lurus. Selain itu keupayaan moment muktamat untuk setiap set juga diperolehi dengan menggunakan kaedah unsur terhingga tidak-lelurus dan kaedah penyelesaian secara analisis. Keputusan dari kedua kaedah dibandingkan sesama sendiri dan dengan keputusan ujian lentur secara eksperimen ke atas galang plat dengan web berbentuk trapezoid. Penyelesaian secara analisis memberi keputusan yang sama untuk pesongan, tegasan lenturan dan momen muktamat untuk kedua-dua galang plat dengan web yang lurus dan yang berbentuk trapezoid. Kaedah unsur terhingga pula, menunjukkan bahawa pesongan untuk keratan dengan web berbentuk trapezoid adalah lebih besar dari keratan dengan web yang lurus untuk beban yang sama. Untuk keratan trapezoid tegasan lenturan dari kaedah unsur terhingga menghampiri nilai dari penyelesaian secara analisis sekiranya sumbangan dari web diabaikan. Pertambahan penyimpangan untuk nilai pesongan dari kaedah unsur terhingga berbanding nilai dari kaedah penyelesaian secara analisis untuk keratan yang semakin besar adalah dirumuskan sebagai disebabkan oleh ubah-bentuk akibat dari ricih yang diambilkira oleh kaedah unsur terhingga tetapi tidak di dalam penyelesaian secara analisis.

CONTENTS

CHAPTER	SUBJECT	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	CONTENTS	vii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiv
	LIST OF SYMBOLS	xix
CHAPTER I	INTRODUCTION	1
	1.1 Introduction	1
	1.2 Advantages of Trapezoid Web Plate Girder	2
	1.3 Design guide on Trapezoid Web Plate Girder	2
	1.4 Research objectives	3
CHAPTER II	LITERATURE REVIEW	4
	2.1 Introduction	4
	2.2 Plate Girder designed to BS5950	5
	2.2.1 General	5
	2.2.2 Plate girder with slender webs	5
	2.3 Trapezoid Web Plate Girder	6

2.3	Trapezoid Web Plate Girder	6
2.3.1	General	6
2.3.2	Flexural Strength of Trapezoid Web Plate Girder	7
2.3.3	Shear Strength of Trapezoid Web	7
2.3.3.1	Shear Capacity Based on Local Buckling	9
2.3.3.2	Shear Capacity Based on Global Buckling	10
2.3.4	Finite Element Analysis on Trapezoid Web Plate Girder	10
2.4	Summary	11
CHAPTER III	FINITE ELEMENT METHOD	14
3.1	Introduction	14
3.2	Application of Finite Element Method	14
3.3	Convergence Procedure	15
3.4	Selection of Elements	16
3.5	Linear Analysis	17
3.6	Non-Linear Analysis	19
3.7	Finite Element Software	21
3.7.1	Introduction	21
3.7.2	Element library	21
3.7.2.1	Element Groups	21
3.7.2.2	Element Sub-Groups	24
3.7.3	Linear Elastic Constitutive Models	24
3.7.4	Elasto-Plastic Constitutive Models	26
3.7.5	Modelling in LUSAS	26
3.7.5.1	General	26
3.7.5.2	Loading	28
3.7.5.3	Support conditions	29

3.7.6	Lusas Analysis Types	29
3.7.7	Equations solving in LUSAS	31
3.7.7.1	LUSAS Frontal Solver	31
3.7.7.2	Iterative Solver	33
3.7.8	Results processing	33
3.7.8.1	General	33
3.7.8.2	Results Files	34
3.8	Summary	35
3.3	Finite Element Models	27
3.3.1	Girder Sections	27
3.3.2	Material Properties	28
3.3.3	Loading arrangement	29
3.3.4	Type of elements	29
3.3.5	Finite element mesh	30
3.3.6	Linear finite element analysis	31
3.3.7	Non-linear finite element analysis	32

CHAPTER IV STUDY OF FLEXURAL BEHAVIOUR BY FINITE ELEMENT METHOD

4.1	Introduction	36
4.2	Girder Sections	36
4.3	Material Properties	37
4.4	Loading arrangement	37
4.5	Analytical Calculations	38
4.5.1	Flexural properties of Girders	39
4.5.2	Moment of Inertia and Elastic Section Modulus of Girders	40
4.6	Numerical study using LUSAS Finite element software	45
4.6.1	Computer Hardware	45
4.6.2	Girder Geometric Modelling in LUSAS	45
4.6.3	Element type	47

4.6.4 Preliminary Element Meshing	48
4.6.5 Supports and loading for full-span models	49
4.6.6 Supports and loading for half-span models	50
4.6.7 Linear finite element analysis	53
4.6.8 Preliminary Results of Linear Analysis	53
4.6.8.1 Equivalence of Full-span and and half-span models	53
4.6.8.2 Convergence tests	55
4.6.8.3 Support Conditions Modification	55
4.6.9 Final Linear Analysis Results	62
4.6.10 Non-Linear finite element analysis	75
4.6.11 Results from Non-linear analysis	76
4.7 Summary of Results and Discussion	82
4.7.1 Deflection and Bending Stress	82
4.7.2 Ultimate Moment	85
4.7.3 Comparison of Deflection and Bending Stress results	85
4.7.4 Comparison of Ultimate Moment Capacity	91
4.7.5 Discussions	91
4.7.5.1 Observations on results	91
4.7.5.2 Implications of results	93
4.7.5.3 Reliability of results	94
CHAPTER V EXPERIMENTAL METHOD	96
5.1 Introduction	96
5.2 Bending Test on TS400-2	97
5.2.1 Test Equipment and Instruments	97
5.2.2 Strain Gauges and Transducers location	98
5.2.3 Testing procedures	99
5.2.4 Results	100
5.3 Bending Test on TS1300-3/2	102
5.3.1 Test Equipment and Instruments	102

5.3.2 Results	102
5.4 Discussion	104
5.4.1 Deflection	104
5.4.2 Bending Stress	105

CHAPTER VI CONCLUSIONS AND RECOMMENDATION FOR FUTURE WORK	107
--	------------

8.1 Introductions	107
8.2 Conclusions	108
8.3 Guide to flexural design	109
8.2 Recommendations For Future Work	109

REFERENCES	110
-------------------	------------

CHAPTER I

INTRODUCTION

1.1 Introduction

Beams with corrugated webs have been used in buildings and bridges, and have been proven to be economical. The use of corrugated webs allows for the use of thin plates without the need for stiffeners; thus, it considerably reduces the cost of the beam fabrication and improves its fatigue life [1].

In particular, a popular choice for the shape of corrugation is the trapezoid. In Malaysia, trapezoid web plate girders were introduced by Trapezoidal Web Profile Sdn. Bhd., based in Pasir Gudang (see figure 1.1). These beams are fabricated from steel plates and coils and it offers an alternative to conventional hot rolled and conventional welded beams.

A series of testing on trapezoid web profile girder sections is being conducted by the Steel Technology Centre of University Teknologi Malaysia. The purpose of the test is to determine the ultimate load capacity of trapezoid web profile girder sections of different dimensions, ranging from 375 mm to 1600 mm depth [2]. The series of test is part of a program to develop a design guide for the section.