

AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

**"BEHAVIOUR OF COMPOSITE BOX GIRDERS UNDER
STATIC LOADING"**

By

AHMED HASSAN YOUSEF ALY

B.Sc.(Honors), 1991

Structural Division

Ain Shams University

A Thesis

Submitted for the Partial

Fulfillment of the Degree of Master
of Science in Structural Engineering

624.17723
A-H

Supervised by

Prof. Dr. KAMAL HASSAN

Professor of Structural Engineering

Ain Shams University

Dr. KAMAL SAID

Assistant Prof., Structural Division

Ain Shams University

Dr. SAMIR HEKAL

Lecturer, Structural Division

Ain Shams University

CAIRO-1995

بسم الله الرحمن الرحيم

"وما أوتيتم من العلم الا قليلا"

صدق الله العظيم



Examiners Committee

Name, Title & Affiliation

Signature

1- Prof. Dr. Metwalli Hassan Abou-Hamad

Professor of Steel Structures,
Faculty of Engineering,
Cairo University.

M. Abou-Hamad

2- Prof. Dr. Hassan Ahmed Osman

Professor of Steel Structures,
Faculty of Engineering,
Ain Shams University.

H. A. Osman

3- Prof. Dr. Kamal Hassan Mohamed

Professor of Steel Structures,
Faculty of Engineering,
Ain Shams University.

K. H. Mohamed

DATE:

STATEMENT

The dissertation is submitted to Faculty of Engineering, Ain Shams University for degree of MASTER OF SCIENCE in Structural Engineering.

The work included in this thesis was carried out by the author in the Department of Structural Engineering, Faculty of Engineering, Ain Shams University, from 1992 to August 1995.

No part of this thesis has been submitted for a degree or a qualification to any other university or institution.

Name : **Ahmed Hassan Yousef Aly**

DATE : 24/9/1995

SIGNATURE : *AHMED HASSAN Yousef*

TO MY PARENTS

ACKNOWLEDGMENT

The author is deeply indebted to **Prof. Dr. Kamal Hassan Mohamed**, Professor of steel structures, Ain Shams University, for his continued guidance, valuable suggestions, precise advice, and constant encouragement during all phases of this research work.

The author wishes to express his gratitude and sincere appreciation to **Dr. Kamal SAID**, Assistant Professor, structural Engineering Department, Ain Shams University, for his kind supervision, helpful suggestions continued assistance, and valuable advises through all phases of this research work.

The author is also deeply grateful to **Dr. SAMIR HEKAL**, Lecture, structural Engineering Department, Ain Shams University, for his kind co-operation, valuable advises and helpful guidance during all phases of this research work.

Words, however ample, would be insufficient to express the author's gratitude to his parents for their continuous sacrifice and fruitful care.

**Ain Shams University
Faculty of Engineering
Structural Department**

**Abstract for The M. Sc. Thesis Submitted by
Eng. Ahmed Hassan Yousef Aly**

"BEHAVIOUR OF COMPOSITE BOX GIRDERS UNDER STATIC LOADING"

Abstract

Steel-concrete composite box girder bridges have a flexible open box section prior to the placement of the slab. Excessive twist or distortion can arise under construction loading. Bracing systems are usually installed within the girder during construction to increase the torsional and distortional stiffness of the open section. Therefore, the influence of these bracing systems on open box girder behaviour will be discussed.

The analysis of single cell box girder is presented using the torsion-bending analysis. A rigid cross section, neglecting any distortional effect, is assumed. The longitudinal stresses arising from both bending and warping moments are computed. Also, a finite element model is presented to analyze the single cell box girder and the different bracing systems. By comparison of the results from the torsion-bending analysis with those from the finite element program, the effectiveness of the different bracing systems in preventing distortion can be found.

The proposed finite element model has been verified by comparing its results with experimental results of previous work. These results showed a good agreement with the experimental results.

A parametric study is carried out to illustrate the effect of different cross sectional shapes of box girders on the distortion of the cross section. The behaviour of composite box girder bridges, after construction of the reinforced concrete slab, under working loads is studied. The purpose of this study is to show the effect of these bracing systems on the total strength of the cross section.

TABLE OF CONTENTS

	Page
Acknowledgments	i
Abstract.....	ii
Table of contents	iii
Notation	vii
 CHAPTER (1): INTRODUCTION	
1.1 General.....	1
1.2 General Discussion of The Problem.....	3
1.3 Aims of The Research Work	4
1.4 Outline of the Thesis	4
 CHAPTER (2): LITERATURE REVIEW	
2.1 Introduction.....	8
2.2 History of Bridge Development.....	8
2.3 Structural Actions of Composite Box Girders During Construction	10
2.3.1 Longitudinal Bending Effect	11
2.3.2 Mixed Torsion Effect.....	12
2.3.3 Bending Distortion Effect	12
2.3.4 Torsional Distortion Effect	12
2.4 Methods of Analysis of Box Girder Bridges	13
2.4.1 Equivalent Beam Method.....	13
2.4.2 Folded Plate Method.....	14
2.4.3 Finite Strip Method.....	16
2.4.4 Finite Element Method.....	17
2.4.5 Review of Analysis of Thin-Walled Box Girders	19

CHAPTER (3): ANALYSIS OF THIN-WALLED GIRDERS

3.1 Introduction.....	26
3.2 Torsion-Bending Analysis	26
3.2.1 Bending Analysis	27
3.2.1.1 Bending Normal Stress	27
3.2.1.2 Bending Shear Stress	30
3.2.1.3 Shear Lag Phenomenon	33
3.2.2 Torsion Analysis.....	36
3.2.2.1 Pure Torsion of Thin-Walled Girder.....	36
3.2.2.1.1 Pure torsion in open thin-walled cross section	38
3.2.2.1.2 Pure torsion in thin-walled closed section.....	39
3.2.2.1.3 Stress Resultant displacement for pure torsion	40
3.2.2.2 Torsion Warping of Thin-Walled Girder	41
3.2.2.2.1 Stress resultant and displacement for torsional warping	51
3.2.3 Computer Program For Torsion-Bending Analysis.....	54
3.3 Finite Element Method.....	54
3.3.1 Finite Element Model Used in Analysis	55
3.3.2 Bracing Systems Used During Construction.....	55
3.3.2.1 Types of the Bracing Systems	56
3.3.2.2 Representation of the Bracing Systems	56
Figures	58

CHAPTER (4): VERIFICATION OF THE PROPOSED MODEL USED IN THE ANALYSIS

4.1 Introduction.....	70
4.2 Discussion of the Experimental Model.....	70
4.3 Applications.....	71

4.3.1 Open Box Girder Without Any Bracing	72
4.3.2 Tie Bracing	73
4.3.3 Cross Bracing	74
4.3.4 Seven Ties Bracing Under Eccentric Load	75
4.4 Comparison Between Analytical and Experimental Results.....	75
4.4.1 Using Tie Bracing	75
4.4.2 Using Cross Bracing	77
4.4.3 Using Seven Ties Bracing Under Eccentric Load	78
Figures.....	79

CHAPTER (5): EFFECTS OF DIFFERENT BRACING SYSTEMS USED DURING CONSTRUCTION

5.1 Introduction	109
5.2 Effect of Different Bracing Systems	109
5.2.1 Five Ties Bracing Under Bending Load.....	110
5.2.2 Seven Ties Bracing Under Torsion Load.....	111
5.2.3 Web Stiffeners	111
5.2.4 Torsion Boxes Bracing Under Torsional Load	112
5.2.5 Torsion Boxes Bracing With Seven Ties	113
5.2.6 Top Chord Bracing Without Ties.....	114
5.2.7 Top Chord Bracing With Seven Ties.....	114
5.3 Discussion of Results	115
5.4 Parametric Study.....	116
5.4.1 Effect of Span to Depth Ratio	117
5.5 Composite Box Girder Bridges Under Working Loads.....	118
5.5.1 Composite Box Girder Bridges with Ties Bracing	118
5.5.2 Composite Box Girder Bridges with Cross Bracing.....	119

Figures.....	121
--------------	-----

CHAPTER (6): SUMMARY AND CONCLUSIONS

6.1 Summary	170
6.2 Conclusions	171
6.3 Suggested Areas for Further Research.....	172

APPENDIX (A)	174
---------------------------	-----

REFERENCES	193
-------------------------	-----

NOTATION

The following symbols are used in this thesis:

A	The total cross-sectional area of the girder.
t	The thickness of the girder, at the point considered.
s	The curvilinear coordinates taken along the perimeter of the cross section.
σ_b	Bending normal stress.
E	Young's modulus.
τ_b	Bending shear stress.
q_b	Shear flow due to bending.
G	Shear modulus of elasticity.
θ	Twisting angle.
θ'	The change of twisting angle in the longitudinal direction of the girder.
K	Pure torsion constant.
τ_s	Shear stress due to pure torsional moment.
q_s	Shear flow for a girder with single cell cross section in St. Venant torsion.
\bar{q}_s	The torsional function. (in units of cm^2)
m_t	Uniform distributed torque moment applied to the girder.
M_T	Concentrated torque moment applied to the girder.
μ	Poisson's ratio.
F	The area surrounded by the closed cross section.
σ_w	The longitudinal normal warping stress.
u	The warping displacement in the longitudinal direction.
γ	The shear deformation of the segment ($dz ds$).
r_s	The perpendicular distance from the shear center (S) to the segment ($dz ds$).
r_o	The perpendicular distance from the centroid (C) to the element ($dz ds$).

$u(s)$	The warping displacement at any point in the cross section depending on it's coordinate s .
u'	The warping displacement at the origin ($s=0$).
$\omega(s)$	The torsional warping function. (in units of cm^2)
ω'	An unknown torsional warping function at the origin ($s=0$).
q_ω	The secondary torsional shear flow.
S_ω	The static moment with respect to the warping function.
I_ω	The torsional warping constant, and represents the geometric moment of inertia with respect to the warping function ω . (in units of cm^6)
T_s	The pure torsional moment.
M_ω	The torsional warping moment.
T_ω	The secondary torsional moment.
σ_B	Bending normal stress under symmetric construction loads.
σ_{DB}	Distortional bending normal stress under symmetric construction loads.
σ_W	Warping normal stress under torsion construction loads.
σ_{DW}	Distortional warping normal stress under torsion construction loads.
σ_{TB}	Total normal stress under symmetric construction loads.
σ_{TW}	Total warping normal stress under unsymmetric construction loads.
σ_T	Total normal stress under eccentric construction loads.
σ_{LB}	Bending normal stress under symmetric working loads.
σ_{LW}	Warping normal stress under eccentric working loads.
σ_{LT}	Total normal stress under eccentric construction loads.

CHAPTER (1)
INTRODUCTION