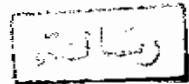


Ain Shams University
Faculty of Engineering

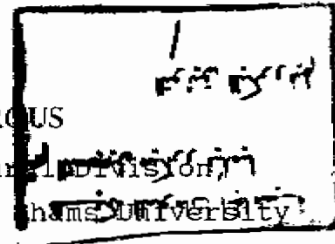


BEHAVIOUR OF BOX GIRDERS WITH OPENINGS

By

EVETT NASIEF TAWADROUS

B. Sc. (Honours) 1983, Structural Division,
Civil Engineering Department, Ain Shams University



A Thesis

Submitted in partial fulfillment for the
requirements of the Degree of Master of Science
in Civil Engineering
Structural Department

624.17723
E. N

44220

Supervised by

Prof. Dr.

Ahmed A. Korashy

Prof. Theory of structure
Faculty of Engineering
Ain-Shams Univ.

Prof. Dr.

Abdel-Raouf W. Beshara

Prof. Theory of structure
Faculty of Engineering
Ain-Shams Univ.

Dr.

Ibrahim Shawky Moharram

Assoc. Prof.

Structural Department
Faculty of Engineering
Ain-Shams Univ.



1993

STATEMENT

This dissertation is submitted to Ain Shams University for the 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, Ain Shams University , from September 1985 to March 1993.

No part of this thesis has been submitted for a degree or a qualification at any other uUniversity or Institution .

Date : March 1993

Signature :

Name : Evett N.Tawadrous



Examiners Committee

Name , Title & Affiliation

Signature

1 - Prof. Dr. Sabri Samaan

Prof. Theory of Strucutre
Faculty of Engineering
Cairo Univ.

Sabri Samaan

2 - Prof. Dr. Mahmoud G. Hashish

Prof. Theory of Strucutre
Faculty of Engineering
Ain-Shams Univ.



3 - Prof. Dr. Ahmed A. Korashy

Prof. Theory of Strucutre
Faculty of Engineering
Ain-Shams Univ.

Ahmed Korashy

4 - Prof. Dr. Abdel-Raouf W. Beshara

Prof. Theory of Strucutre
Faculty of Engineering
Ain-Shams Univ.

A. W. Beshara

Date : / / 1993

Acknowledgement

The author wishes to express his sincere thanks to Prof. Dr. Abedel-Raouf W. Beshara for his invaluable supervision , advices and suggestions during the research and thesis works .

Equal appreciations go to Prof. Dr. Ahmed A. Korashy for his invaluable support , patience and instructions on the research .

ABSTRACT

The present research is concerned with the behaviour of box beams with openings in either the webs or in the lower flange . The effect of varying the opening location in the longitudinal or transversal directions on the box behaviour is studied . Also the effect of symmetrical and distortional loading is studied . The research objective is to find the best location of openings in webs or lower flange that has the least effect on deflections and stresses . It aims also to overcome the problem of concentrated stresses and excessive deformations arising from certain openings location . Openings located near the junction lines between webs and flanges , in unstiffened box beams , have shown a dangerous effect on deformations and stresses . Special treatment is needed for such openings .

Keywords :

Box girders , Finite element analysis , Openings , Symmetric loading , Distortional loading , Stiffeners
Stresses , Deflections , Transversal moments .

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENT	i
ABSTRACT	ii
TABLE OF CONTENTS	iii
LIST OF FIGURES	iv
CHAPTER 1 :	
INTRODUCTION	1
1.1 General	1
1.2 Aim of present study	4
CHAPTER 2 :	
REVIEW OF PREVIOUS RESEARCH	
2.1 Introduction	8
2.2 Methods Of Analysis	8
2.2.1 Approximate Method Of Analysis	9
2.2.2 Procedures Based On Folded Plate Methods ..	10
2.2.2.1 Approximate Or Ordinary Method	10

2.2.2.2	Elasticity Method	11
2.2.3	Numerical Methods	13
2.2.3.1	Finite Difference Method	13
2.2.3.2	Finite Element Method	14
2.2.3.3	Finite Stripe Method	18

CHAPTER 3 :

BEHAVIOUR OF BOX GIRDERS WITH WEB OPENINGS UNDER SYMMETRIC LOADING

3.1	Introduction	22
3.2	Cases Studied	23
3.2.1	Dimensions & Loading	23
3.2.2	Opening Locations	24
3.3	Method of Analysis	30
3.3.1	General	30
3.3.2	Accuracy Assessment	31
3.3.3	Symmetric Loading and Boundary Conditions .	35
3.4	Results and Discussion	37
3.4.1	Results of Case 1	37
3.4.1.1	Deflections	37
3.4.1.2	Normal Stresses	38

3.4.1.3	Transverse Moments	41
3.4.2	Results Of Case 2	49
3.4.2.1	Deflections	49
3.4.2.2	Normal Stresses	49
3.4.2.3	Transverse Moments	50

CHAPTER 4 :

BEHAVIOUR OF BOX GIRDERS WITH LOWER FLANGE OPENINGS UNDER SYMMETRIC LOADING

4.1	Introduction	57
4.2	Cases Studied	57
4.3	Method Of Analysis	58
4.4	Results And Discussion	62
4.4.1	Results of case 1	62
4.4.1.1	Deflections	62
4.4.1.2	Normal Stresses	63
4.4.1.3	Transverse Bending Moment	64
4.4.2	Results of case 2	70
4.4.2.1	Deflections	70
4.4.2.2	Normal Stresses	70
4.4.2.3	Transverse Bending Moment	72

CHAPTER 5 :

BOX GIRDERS UNDER DISTORTIONAL LOADING WITH WEB OR LOWER FLANGE OPENINGS

5.1	Introduction	79
5.2	Box Girders With Web Openings	80
5.2.1	Web Opening Location	80
5.2.2	Results	87
5.2.2.1	Results of case 1	87
5.2.2.2	Results of case 2	89
5.3	Box Girders With Lower Flange Openings ...	104
5.3.1	Flange Opening Location	104
5.3.2	Results	104
5.3.2.1	Results of case 3	105
5.3.2.2	Results of case 4	106
5.4	Transverse Bending Moments	122
5.4.1	Transverse Bending Moments For case 1	122
5.4.2	Transverse Bending Moments For case 2	122
5.4.3	Transverse Bending Moments For case 3	124
5.4.4	Transverse Bending Moments For case 4	125

CHAPTER 6 :

CONCLUSIONS

6.1	Stiffened Box Girders Under Symmetric loading	130
6.2	Box Girders Under Distortional Loadings ..	131
6.3	Future Extension of the Subject	132

REFERENCES 133

LIST OF FIGURES

Figures	Page
1.1 Single & Multi Cell Bridges	6
1.2 Multi Beam Bridges	6
1.3 Polygonal Shaped Bridges	7
1.4 Bridges Without Diaphragms	7
 3.1 Typical Cross Section , Symmetric Load & Dimensions	26
3.2 One Span Box Girder Bridge	27
3.3 Web Opening Location Case 1	28
3.4 Web Opening Location Case 2	29
3.5 Finite Element Used Positive Displacements & Forces	32
3.6 Finite Element Mesh by SAWAKO (22)	33
3.7 Present Analysis Finite Element Mesh	34
3.8 Finite Element Mesh For the Studied Cases ...	36
3.9 Relative Deflection (δ_y / δ_y) at the Middle of Web Hieght Case 1	42
3.10 Vertical Deflection (δ_y / δ_y) of Midspan Section Case 1a	43
3.11 Relative Normal Stress (σ_x / σ_{x_0}) at Lower Flange Edge (n) Case 1	44
3.12 Relative Normal Stress (σ_x / σ_{x_0}) at Midspan Case 1	45

3.13	Relative Longitudinal Stress (σ_x / σ_{x_0}) at Node (n) Case 1	46
3.14	Contour Lines For (σ_x / σ_{x_0}) in Different Cases Of Opening at Midspan Case 1	47
3.15	Transverse B.M. in Cross Frame at Midspan Case 1 ..	48
3.16	Relative Deflection (δ_y / δ_{y_0}) at the Middle of web Height Case 2	51
3.17	Relative Normal Stress (σ_x / σ_{x_0}) at Lower flange edge (n) Case 2	52
3.18	Relative Normal Stress (σ_x / σ_{x_0}) at L/3 or 2L/3 case 2	53
3.19	Relative Longitudinal stress (σ_x / σ_{x_0}) at nodes (n & n1) Case 2	54
3.20a	Transverse B.M in cross frame at midspan L/2 ..	55
3.20b	Transverse B.M in cross frame at L/3 or 2L/3 ..	56
4.1	Lower Flange Opening Location Case 1	60
4.2	Lower Flange Opening Location Case 2	61
4.3	Relative Deflection (δ_y / δ_{y_0}) at the Middle of Web Height-Case 1	65
4.4	Relative Normal Stress (σ_x / σ_{x_0}) at Lower Edge of Web Case 1	66
4.5	Relative Normal Stress (σ_x / σ_{x_0}) at Midspan case 1	67
4.6	Relative Longitudinal Stress (σ_x / σ_{x_0}) at Node (m) case 1	68
4.7	Transverse B.M. in cross frame at midspan case 1 ..	69
4.8	Relative Deflection (δ_y / δ_{y_0}) at the Middle of web Height case 2	73

4.9	Relative Normal Stress (σ_x/σ_{x_0}) at Lower Edge of web Case 2	74
4.10	Relative Normal Stress (σ_x/σ_{x_0}) at L/3 or 2L/3 case 2	75
4.11	Relative Longitudinal Stress (σ_x/σ_{x_0}) at Nodes (m ,m1) case 2	76
4.12a	Transverse B.M. in Cross Frame at Midspan L/2 Case 2	77
4.12b	Transverse B.M. in cross Frame at L/3 case 2 ..	78
5.1	Distortional Loading	82
5.2	One Span Box Girder Bridge	83
5.3	Web Opening Location W.r.t X-axis case 1	84
5.4	Web Opening Location W.r.t Y-axis case 2	85
5.5	Finite Element Mesh For the studied cases	86
5.6	Relative Deflection (δ_y/δ_{y_0}) at lower Edge case 1	94
5.7	Relative Normal Stress (σ_x/σ_{x_0}) at Lower Edge Case 1	95
5.8	Relative Deflection (δ_y/δ_{y_0}) at Midspan Case 1a	96
5.9	Relative Normal Stress (σ_x/σ_{x_0}) at Midspan Case 1a	96
5.10	Variation of (δ_y/δ_{y_0}) at Midspan Lower Edge (n) Case 1	97
5.11	Variation of (σ_x/σ_{x_0}) at Midspan Lower Edge (n) Case 1	97
5.12	Relative Defflection (δ_y/δ_{y_0}) at Lower Edge Case 2	98

5.13	Relative Normal Stress (σ_x / σ_{x_0}) at lower Edge Case 2	99
5.14	Relative Deflection at Midspan Case 2a	100
5.15	Relative Normal Stress (σ_x / σ_{x_0}) at Midspan case 2	101
5.16a	Variation of ($\delta y / \delta y_0$) at Midspan lower and upper Edges case 2	102
5.16b	Variation of ($\delta z / \delta z_0$) at Midspan lower and upper Edges case 2	102
5.17	Variation of (σ_x / σ_{x_0}) at Midspan cross section Case 2	103
5.18	Lower Flange opening Location w.r.t X-axis Case 3	109
5.19	Lower Flange opening Location w.r.t Z-axis Case 4	110
5.20	Relative Deflection ($\delta y / \delta y_0$) at lower Edge Case 3	111
5.21	Relative Normal Stress (σ_x / σ_{x_0}) at Lower Edge Case 3	112
5.22	Relative Deflection ($\delta y / \delta y_0$) at Midspan Case 3a	113
5.23	Relative Normal Stress (σ_x / σ_{x_0}) at Midspan Case 3a	113
5.24	Variation of ($\delta y / \delta y_0$) at Midspan Lower Edge (n) Case 3	114
5.25	Variation of (σ_x / σ_{x_0}) at Midspan Lower Edge (n) case 3	114
5.26a	Relative Deflection ($\delta y / \delta y_0$) at lower Edge (p) Case 4	115
5.26b	Relative Deflection ($\delta z / \delta z_0$) at lower Edge (p) Case 4	116
5.27	Relative Normal Stress (σ_x / σ_{x_0}) at lower Edge (p) Case 4	117