



AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT

DYNAMIC RESPONSE OF JOINTS OF FLOATING BRIDGES

BY

Eng. Mohamed Sayed Hassan Mohamed

A thesis
Submitted in partial fulfillment for
The requirements for the degree of the Master of Science
In civil engineering(Structural)

Supervised by

Dr. Hisham Ahmed El-Arabaty
Associate professor of Theory of
Structures
Ain Shams University

Dr. Saleh Mohamed El-Mekawy
Assistant professor of Theory of
Structures
Ain Shams University

Dr. Mohamed Fathy Abd El-Aziz
Assistant professor of Theory of Structures
Misr University for Science & Technology

CAIRO (2012)

EXAMINERS COMMITTEE

Signature

- | | |
|--|-------|
| 1- Prof. Dr. Sherif Ahmed Mourad
Professor of Steel Structures and Bridges
Structural Engineering Dept.
Faculty of Engineering
Cairo University | |
| 2- Prof. Dr. Ibrahim Shawky Moharam
Professor of Theory of Structures
Structural Engineering Dept.
Faculty of Engineering
Ain Shams University | |
| 3- Dr. Hisham Ahmed El-Arabaty
Associate Professor of Theory of Structures
Structural Engineering Dept.
Faculty of Engineering
Ain Shams University | |

STATEMENT

This thesis is submitted to Ain Shams University for the degree of Master of Science in Civil Engineering (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.

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

Name : Mohamed Sayed Hassan

Signature :

Date : / / 2012

INFORMATION ABOUT THE RESEARCHER

NAME : Mohamed Sayed Hassan

DATE OF BIRTH : 11/06/1984

PLACE OF BIRTH : Cairo – Egypt

QUALIFICATION :B.Sc.(Civil Engineering), Faculty of
Engineering, Ain Shams University, Cairo,
Egypt, June 2006

ACKNOWLEDGMENT

I wish to express my deep gratitude to **Dr. Hisham Ahmed El-Arabaty**, Associate Professor of theory of structures, Faculty of Engineering, Ain Shams University, for his constant supervision, planning, generous support, helpful advice and constructive criticism throughout this work.

I wish to extend my thanks to my **colleagues and all the staff** of Structural Engineering Department, Ain Shams University, for their help and encouragement. Also, my best thanks to all those who, in one way or another, helped in making this work possible.

Finally, especial appreciation and deep gratitude to **all my family**, for their support and encouragement.

Eng. Mohamed Sayed



Ain Shams University
Faculty of Engineering
Department of Structural Engineering

Eng. Mohamed Sayed Hassan

Title of thesis

Dynamic Response of Joints of Floating Bridges

Supervisors:

Dr. Hisham Ahmed El-Arabaty *Dr. Saleh Mohamed El Mekawy*
Dr. Mohamed Fathy Abd El Aziz

ABSTRACT

The objective of this research work is to study the behavior of joints of the ribbon-type floating bridges under the influence of transverse loading conditions. Practical problems related to the load-carrying capacity and overstressing of these bridges in the field use of these bridges have been addressed, and possible practical solutions proposed and evaluated. The effect of transverse current loads on the straining actions in the bridge body were studied. An analytical algorithm is developed for analyzing the bridge body under transverse loads, while incorporating a nonlinear element representing the behavior of the proposed connection joints.

An existing sophisticated software package (developed in previous research work by the senior authors) developed using the proposed analytical approach is extended, with emphasis placed on the automation of the parameter variation process taking into account different cases, where single or multiple boats are used to support the bridge laterally against the water current forces. The results of this parametric study are used to assess the advantages of using the proposed connection joints. A practical proposal for the modification of the shape of existing joints between the pontoons of floating bridges was made, with the objective of

reducing the bridge's sensitivity to the movements of the supporting boats. The developed software was used to test the efficiency of the proposed modifications in the minimization and control of the transverse moments developed in the bridge body, and to assess the effect of using single or multiple boats to support the bridge laterally.

A practical proposal is developed which enables the site observers to control the bridge movements with a set of criteria easy to follow in the field. Practical recommendations are presented, which can be highly valuable in the field of design and operation of these floating bridges.

Key words: Floating bridges - Ribbon bridges – Fluid structure interaction
– dynamic analysis

LIST OF CONTENTS

Chapter (1): INTRODUCTION	
1.1 INTRODUCTION	1
1.2 TYPES OF FLOATING BRIDGES	2
1.2.1 Pontoon bridges	2
1.2.2 Ribbon bridges	3
1.3 MAIN LOADS ON FLOATING BRIDGES	5
1.3.1 Own weight.....	5
1.3.2 Traffic loads.....	5
1.3.3 Buoyancy.....	5
1.3.4 Current load.....	5
1.3.5 Wave loads.....	5
1.3.6 Wind loads.....	6
1.3.7 Earthquake load.....	6
1.4 FLUID-BRIDGE INTERACTION PROBLEM	6
1.5 OBJECTIVE OF THE WORK	6
1.6 OUTLINE OF THE THESIS	7
Chapter (2): LITERATURE REVIEW	
2.1 INTRODUCTION.....	10
2.2 DESIGN AND ANALYSIS OF FLOATING BRIDGES	10
2.3 FLUID STRUCTURE INTERACTION.....	20
2.4. BRIDGES SUBJECTED TO MOVING LOADS	24
2.5 DESIGN AND ANALYSIS OF FLOATING BRIDGE CONNECTIONS.....	39
Chapter (3): CONNECTIONS CONCEPT	
3.1 INTRODUCTION	47
3.2 CONNECTOR CONCEPTS	47
3.2.1. Concept A, Western-bumper and retractable latches.....	48
3.2.2. Concept B, Bed on the string connector.....	51

3.2.3. Concept C, Flexor-in house connector.....	54
3.2.4. Concept D, Flexor – variation	56
3.2.5. Concept E, Western – Hinged modules.....	57
3.2.6. Concept F, Flexor – Pontoon and pipe connection.....	58
3.2.7. Concept G, NFESC – rigid connector.....	61
3.2.8. Concept H, ARC – Keel connector.....	64
3.2.9. Concept I, McDermott –compression only nonlinear compliant connector.....	65
3.2.10. Concept J, Simple hinge connector concept.....	66
3.2.11. Concept K, Stroking center connector.....	68
3.2.12. Concept L, Roller connector.....	69
3.2.13. Concept M, Han’s fender connector.....	70
3.2.14. Concept N, Han’s frictional locking connector.....	73
Chapter (4): ANALYTICAL ALGORITHM	
4.1 INTRODUCTION	76
4.2 BRIDGE JOINTS DESCRIPTION	77
4.2.1. Floating bridges with fixed connections.....	78
4.2.2. Floating bridges with hinged connections....	80
4.3 CURRENT LOADS.....	82
4.3.1. Basic hypotheses in channel flow.....	83
4.3.2. Description of current flow velocity.....	84
4.3.3. Thrust function due to current load on floating bridges.....	86
4.3.4 Drag forces.....	87
4.4 EFFECT OF BOATS ON FLOATING BRIDGES IN THE TRANSVERSE DIRECTION.....	88
4.5 ANALYTICAL MODEL	91
4.6 PROPOSED TECHNIQUE FOR SIMULATION OF JOINTS BETWEEN PONTOONS.....	94
4.7 ANALYTICAL ALGORITHM.....	95
4.7.1. Idealization of proposed bridge joints	97
4.7.2. Nonlinear analysis of bridge body	99
4.8 STEP BY STEP PROCEDURE.....	101

Chapter (5): PARAMETRIC STUDY AND RESULTS	
5.1 INTRODUCTION.....	104
5.2 PARAMETRIC STUDY.....	104
5.2.1 Number of boats.....	104
5.2.2 Gap Size(d).....	118
5.2.3 Bridge Length.....	123
5.2.4 Current velocity.....	128
 Chapter(6): PRACTICAL PROPOSAL FOR REDUCTION OF TRANSVERSE MOMENT LEVELS IN FLOATING BRIDGES	
6.1 INTRODUCTION.....	137
6.2 DESIGN PHILOSOPHY.....	137
6.3 ANALYTICAL PROGRAM MODIFICATION.....	139
6.4 GAP SIZE.....	140
6.5 BOAT LOCATION.....	147
 Chapter (7): SUMMARY AND CONCLUSIONS	
7.1 SUMMARY	155
7.2 CONCLUSIONS.....	156
7.3 RECOMMENDATIONS FOR FUTURE WORK.....	158
REFERENCES	159

List of Table and Figures

Chapter (1)		
Figure (1.1) :	Pontoon Bridge	2
Figure (1.2) :	Martwa Wisla Pontoon Bridge	3
Figure (1.3) :	Ribbon Bridge	4
Figure (1.4) :	Croatia and Bosnia Ribbon Bridge	4
Chapter (2)		
Figure (2.1) :	Osaka bridge.....	13
Figure (2.1.a) :	Port of Osaka bridge.....	13
Figure (2.1.b) :	Layout of the bridge of Port of Osaka.....	13
Figure (2.2) :	Finite element model for the floating bridge..	14
Figure (2.2.a) :	Finite element model of global floating bridge..	14
Figure (2.2.b) :	Finite element model of bridge module.....	24
Figure (2.2.c) :	Super-element model of bridge module.....	15
Figure (2.2.d) :	Super-element model of the global floating bridge.....	15
Figure (2.3) :	Truss pontoon semi-submersible platform (TSP) prototype.....	19
Figure (2.4) :	Two axle sprung mass with pitching inertia and viscous dampers.....	25
Figure (2.5) :	Three axle suspension with interleaf friction damper.....	27
Figure (2.6) :	Single sprung mass.....	29
Figure (2.7) :	Single spring mass with a suspension system....	30
Figure (2.8) :	Non linear vehicle model of 7 degrees of freedom.....	33
Figure (2.9) :	Aurele's design.....	40
Figure (2.10) :	Gardner's design.....	41
Figure (2.11) :	Armin's design.....	42
Figure (2.12) :	Bargeco's design.....	43
Figure (2.13) :	Willy's design.....	44
Figure (2.14) :	Zwagerman's design.....	45
Figure (2.15) :	Au-Yeong's design.....	46
Chapter (3)		
Table (3.1) :	Summary of connection concepts	48
Figure (3.1) :	Layouts of the connection concept (Concept A) developed by Western Instrument Corporation (Plackett,1993).....	49

Figure (3.2) :	Retractable latches (Concept A),Plackett 1993..	50
Figure (3.3) :	Possible concepts for the compliant deadman, (Plackett 1993).....	50
Figure (3.4) :	Layouts of the bed on the string connector (Plackett 1993).....	51
Figure (3.5) :	Possible arrangement of inflatable fenders.....	52
Figure (3.6) :	Sphere connectors aligned with receptacles.....	53
Figure (3.7) :	Details of connector pins and components	53
Figure (3.8) :	Structural layouts of the in-house connection (Hatch 1985).....	54
Figure (3.9) :	Variation of the flexor connector(Hatch 1985)..	56
Figure (3.10) :	Hinged modules (Plackett 1993).....	57
Figure (3.11) :	P-8 Pontoon Flexor and Pipe Connector, (Hatch, 1985).....	59
Figure (3.12) :	Nominal dimensions of the Flexor connector, [Hatch, 1985].....	59
Figure (3.13) :	Components of the P-8 Male and P-8 Female Pontoons, (Hatch, 1985).....	60
Figure (3.14) :	Cutaway showing interior Flexor components, (Hatch, 1985).....	61
Figure (3.15) :	General layout of the rigid connection system, (Huang,1985).....	62
Figure (3.16) :	Detailed structural layout of the rigid connector, (Huang, 1985).....	62
Figure (3.17) :	Alignment pin concept, (Huang, 1985).....	63
Figure (3.18) :	Keel connector concept, (Derstine, 1999).....	65
Figure (3.19) :	Schematics of the compression-only non-linear compliant connector,(Mills, 1999).....	66
Figure (3.20) :	Simple hinge connector concept, (Haney,1999).	67
Figure (3.21) :	Pin and toggle assembly, (Haney, 1999).....	68
Figure (3.22) :	Stroking center connector, (Haney, 1999).....	69
Figure (3.23) :	Roller connector, (Haney, 1999).....	70
Figure (3.24) :	Han's Fender Connector.....	72
Figure (3.25) :	Fender Connector engagement in progress.....	73
Figure (3.26) :	Han's frictional locking connector.....	74
Chapter (4)		
Figure (4.1) :	Bi-directional loading of “ ribbon – type” floating bridge.....	78

Figure (4.1.a) :	Vertical loading.....	78
Figure (4.1.b) :	Transverse loading	78
Figure (4.2) :	Typical deformations and bending moments in a floating bridge with “fixed joints”, under vertical loading.....	79
Figure (4.3) :	Typical deformations and bending moments in a floating bridge with “hinged joints”, under vertical loading.....	80
Figure (4.4) :	Original configuration of “commonly-used” bridge joints.....	81
Figure (4.5) :	The Cartesian coordinate system used for open channel flow.....	84
Figure (4.6) :	The current forces acting on bridge side.....	87
Figure (4.7) :	Forces in bridge joints due to effect of transverse current loading.....	88
Figure (4.8) :	Variation of moments profile along bridge length with the magnitude of the boats supporting force.....	90
Figure (4.8.a) :	Single supporting bridge boat.....	90
Figure (4.8.b) :	Multiple supporting bridge boat.....	90
Figure (4.9) :	The relationships between loads , shearing force and bending moment.....	94
Figure (4.10) :	Action of “newly” proposed joints.....	96
Figure (4.11) :	Relative movements of connected pontoons, after joint modification.....	96
Figure (4.12) :	Possible displaced positions of pontoons and sign convention for joint rotation angles.....	97
Figure(4.12.a) :	Moments in +ve direction.....	97
Figure(4.12.b) :	Moments in - ve direction.....	97
Figure(4.13) :	Nonlinear behavior of the proposed joints.....	98
Figure(4.14) :	Flow charts of analytical algorithm.....	101
Chapter (5)		
Table (5.1) :	Input parameters for runs with different values in total boat reaction(single boat)	105
Table (5.2) :	Input parameters for runs with different values in total boats reactions(Double boat)	109
Table (5.3) :	Input parameters for runs with different values in total boats reactions(Triple boat).....	112

Table (5.4) :	Effect of number of boats on the moment fraction	117
Table (5.5) :	Input parameters for runs with different values in gap size for different number of supporting boats	118
Table (5.6) :	Effect of gap size on the moment fraction for different number of supporting boats	122
Table (5.7) :	Input parameters for runs with different bridge lengths for different number of supporting boats	124
Table (5.8) :	Effect of bridge length on the moment fraction for different number of supporting boats	126
Table (5.9) :	Input parameters for runs with different current velocity for different number of supporting boats	128
Table (5.10) :	Effect of current velocity on the moment fraction for different number of supporting boats	131
Table (5.11) :	Input parameters for runs with different gap location for different number of supporting boats	132
Table (5.12) :	Effect of gap location on the moment fraction for different number of supporting boats	135
Figure (5.1) :	Effect of changes in supporting boat force on bridge behavior(Single boat).....	106
Figure (5.1.a) :	Bending moment.....	106
Figure (5.1.b) :	Shear force.....	106
Figure (5.1.c) :	Slope.....	107
Figure (5.1.d) :	Displacement.....	107
Figure (5.2) :	Effect of changes in supporting boats forces on bridge behavior(Double boat).....	110
Figure (5.2.a) :	Bending moment.....	110
Figure (5.2.b) :	Shear force.....	110
Figure (5.2.c) :	Slope.....	111
Figure (5.2.d) :	Displacement.....	111
Figure (5.3) :	Effect of changes in supporting boats forces on Bridge behavior(Triple boat).....	113
Figure (5.3.a) :	Bending moment.....	113
Figure (5.3.b) :	Shear Force.....	113

Figure (5.3.c) :	Slope.....	114
Figure (5.3.d) :	Displacement.....	114
Figure (5.4) :	Effect of number of boats on bridge behavior....	116
Figure (5.5) :	Effect of number of boats on the moment fraction	117
Figure (5.5.a) :	Variation of MPF with number of boats.....	117
Figure (5.5.b) :	Variation of MNF with number of boats.....	118
Figure (5.6) :	Effect of gap size on bridge behavior.....	120
Figure (5.6.a) :	Effect of Gap size on bridge behavior in presence of one boat.....	120
Figure (5.6.b) :	Effect of Gap size on bridge behavior in presence of two boats.....	120
Figure (5.6.c) :	Effect of Gap size on bridge behavior in presence of three boats.....	121
Figure (5.7) :	Effect of gap size on bridge flexibility.....	123
Figure (5.8) :	Effect of bridge length on bridge behavior.....	125
Figure (5.8.a):	Effect of bridge length on bridge behavior in presence of one boat.....	125
Figure (5.8.b):	Effect of bridge length on bridge behavior in presence of two boats.....	125
Figure (5.8.c):	Effect of bridge length on bridge behavior in presence of three boats.....	126
Figure (5.9) :	Effect of bridge length on bridge flexibility.....	127
Figure (5.10) :	Effect of current velocity on bridge behavior....	129
Figure (5.10.a) :	Effect of current velocity on bridge behavior in presence of one boat.....	129
Figure (5.10.b) :	Effect of current velocity on bridge behavior in presence of two boats.....	130
Figure (5.10.c) :	Effect of current velocity on bridge behavior in presence of three boats.....	130
Figure (5.11) :	Effect of gap location on bridge behavior.....	133
Figure (5.11.a) :	Effect of gap location on bridge behavior in presence of one boat.....	133
Figure (5.11.b) :	Effect of gap location on bridge behavior in presence of two boats.....	133
Figure (5.11.c) :	Effect of gap location on bridge behavior in presence of three boats.....	134
Figure (5.12) :	Effect of gap location on bridge behavior.....	136
Chapter (6)		
Figure (6.1) :	Design philosophy of "Joint Correction System"	138