



Cairo University

LIVE LOAD DISTRIBUTION OF PRECAST CONCRETE U-GIRDER BRIDGES

By
Ahmed Zakaria Hanafi Ali

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
STRUCTURAL ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2015

LIVE LOAD DISTRIBUTION OF PRECAST CONCRETE U-GIRDER BRIDGES

By
Ahmed Zakaria Hanafi Ali

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
STRUCTURAL ENGINEERING

Under the Supervision of

Prof. Dr. Ahmed Hassan Amer

Professor of Structural Engineering
Faculty of Engineering, Cairo University

Prof. Dr. Walid Abdel-Latif Attia

Professor of Structural Engineering
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2015

LIVE LOAD DISTRIBUTION OF PRECAST CONCRETE U-GIRDER BRIDGES

By
Ahmed Zakaria Hanafi Ali

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
STRUCTURAL ENGINEERING

Approved by the Examining Committee

Prof. Dr. Essam Sayed Farag Khalifa

Professor of Structural Engineering
Higher Technological Institute in Tenth of Ramadan City

Prof. Dr. Mohamed Naiem Abdel-Mooty

Professor of Structural Engineering
Faculty of Engineering, Cairo University

Prof. Dr. Ahmed Hassan Amer

Professor of Structural Engineering
Faculty of Engineering, Cairo University

Prof. Dr. Walid Abdel-Latif Attia

Professor of Structural Engineering
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2015

Acknowledgements

I would like to express my sincere gratitude to my advisors **Prof. Dr. Ahmed Hassan Amer** and **Prof. Dr. Waleed Abdalateef Attia** for their guidance, support, encouragement, valuable supervision during the development of this research, and their great efforts to accomplish the thesis objectives.

I also wish to express my deepest gratitude to my father, mother, my dear brothers, and my friends who are always behind me for the success. I would not have achieved this work without their help and encouragement.

Dedication

To my parents, and my dear brothers with love

Table Of Contents

Acknowledgements.....	i
Dedication.....	ii
Table Of Contents.....	iii
List Of Tables.....	vii
List Of Figures.....	viii
Notations.....	xix
Abstract.....	xx
1. Introduction.....	1
1.1. Overview of Precast U-Girder Bridges.....	1
1.2. Precast U-Girders Bridge in Egypt (Wali El-Ahd Project).....	8
1.3. Problem of Research.....	13
1.4. Objective of Research.....	13
1.5. Scope of Research.....	13
1.6. Overview of Research.....	14
2. Literature Review.....	16
2.1. General.....	16
2.2. Relevant Studies to Live Load Distribution Factors in Concrete Bridges....	16
2.3. Influencing Parameters on Live Load Distribution Factors.....	19
2.3.1. Girder Spacing.....	19
2.3.2. Span Length.....	20
2.3.3. Girder Location.....	20
2.3.4. Girder Stiffness.....	20
2.3.5. Deck Thickness.....	21
2.3.6. Continuity Condition.....	21

2.3.7. Skew Angle.....	22
2.3.8. Diaphragm Characteristics.....	22
2.3.9. Secondary Elements.....	22
 3. Calculation Of Live Load Distribution Factors For Precast U-Girder Bridges.....	24
3.1. General.....	24
3.2. Design Live Loads at AASHTO-LRFD Specifications.....	25
3.3. Calculation of Live Load Distribution Factors for Precast U-Girders at AASHTO-LRFD Specifications.....	27
3.3.1. AASHTO-LRFD Specifications for Moment.....	27
3.3.2. AASHTO-LRFD Specifications for Shear.....	29
3.4. Finite Element Modeling for Precast U-Girder Bridges.....	30
3.4.1. Material Modeling.....	31
3.4.2. Aspect Ratio.....	32
3.4.3. Geometric Modeling.....	32
3.4.4. Calculation of live load distribution factors.....	34
3.4.5. Models Verification.....	36
 4. Parametric Study For Load Distribution Of Precast U-Girder Bridges.....	38
4.1. General.....	38
4.2. Selection and Modeling Criterion for the Studied Bridges.....	39
4.3. Applied Loads on the Studied Bridges.....	42
4.4. Influence of Different Parameters on the Distribution Factors.....	44
4.4.1. Girder Span Length.....	44
4.4.2. Girder Spacing.....	52
4.4.3. Number of Girders.....	59
4.4.4. Number of Lanes.....	66

4.5. Comparison of AASHTO-LRFD Distribution Factors and Those Obtained From the Finite Element Analyses.....	72
--	----

5. Proposed Equation For Live Load Distribution Factors Of

Precast U-Girder Bridges Based On AASHTO-LRFD Loads... 86

5.1. General.....	86
5.2. Proposed General Equation.....	87
5.3. Influence of Different Parameters on the FEA, AASHTO-LRFD and Proposed Equation Distribution Factors for the Studied Bridges.....	89
5.4. Comparison of the FEA, AASHTO-LRFD and Proposed Equation Distribution Factors for the Studied Bridges.....	100
5.5. Application on Wali El-Ahd Bridge.....	108
5.5.1. Finite Element Modeling.....	108
5.5.1.1. Material Modeling.....	108
5.5.1.2. Aspect Ratio.....	109
5.5.1.3. Geometric Modeling.....	109
5.5.1.4. Applied Loads.....	110
5.5.2. Comparison of the FEA, AASHTO-LRFD and Proposed Equation Distribution Factors for Wali El-Ahd Bridge.....	112

6. Proposed Equation For Live Load Distribution Factors Of

Precast U-Girder Bridges Based On The Egyptian Code

Loads..... 116

6.1. General.....	116
6.2. Design Live Loads at ECP 201-2010 Specifications.....	117
6.3. Calculation of Distribution Factors for the Studied Bridges.....	119
6.4. Proposed Equation for Live Load Distribution Factors.....	119
6.5. Comparison of the FEA and Proposed Equation Distribution Factors for the bridges of the Parametric Study.....	122

6.6. Comparison of the FEA and Proposed Equation Distribution Factors for Wali El-Ahd Bridge.....	133
7. Summary, Conclusions And Recommendations For Future Research.....	135
7.1. Summary.....	135
7.2. Conclusions.....	136
7.2.1. AASHTO-LRFD Specifications.....	136
7.2.2. ECP 201-2010 Specifications.....	139
7.3. Recommendations for Future Research.....	140
References.....	141

List Of Tables

Table 1.1. Cost comparison between precast U-girders and steel girders for 270 Ramp Y Bridge at Colorado, USA (Gregg Reese and William N.Nickas, 2010).....	4
Table 1.2. Different span lengths and depths of precast girders along the bridge length.....	9
Table 3.1. Traditional Minimum depths for different types of superstructures (Table 2.5.2.6.3-1 from AASHTO-LRFD Bridge Design Specifications, Copy Right@2007).....	34
Table 3.2. Results obtained from Caltrans study and the current study.....	37
Table 4.1. Girder depth at each span length considered in study.....	40
Table 4.2. Geometric properties of the prototype bridges used in the parametric study.....	41
Table 4.3. Multiple presence factor (Table 3.6.1.1.2-1 from AASHTO-LRFD Bridge Design Specifications, CopyRight@2007).....	42
Table 4.4. Net distributed load on girders.....	67
Table 5.1. Values of constants at equation (5.1).....	88
Table 5.2. Value of lane factor (E).....	88
Table 5.3. Input properties for different structural members.....	108
Table 5.4. Geometric properties of the finite element models of Wali El-Ahd Bridge.....	110
Table 6.1. Truck and distributed loads at ECP 201-2010.....	118
Table 6.2. Values of constants at equation (6.1).....	121
Table 6.3. Value of lane factor (F).....	121

List Of Figures

Figure 1.1. View for a straight precast U-girder bridge (John A. Lobo et al., 2013)..	1
Figure 1.2. View for a curved precast U-girder bridge (Gregg Reese and William N.Nickas, 2010).....	2
Figure 1.3. Typical cross section for a precast U-girder (Gregg Reese and William N.Nickas, 2010).....	2
Figure 1.4. Typical deck cross section for a precast U-girder bridge (PCI, 2005).....	4
Figure 1.5. Different common shapes of U-girders.....	6
Figure 1.6. Elevation for a spliced U-girder at continuous span (PCI, 2005).....	7
Figure 1.7. Elevation for a spliced U-girder at simply supported span (PCI, 2005)...	7
Figure 1.8. Spliced precast U-girders during construction (Gregg Reese and William N.Nickas, 2010).....	7
Figure 1.9. Precast U-girders and cast in-situ box girder of Wali El-Ahd Bridge.....	8
Figure 1.10. Precast U- girders arrangement at Wali El-Ahd Bridge.....	9
Figure 1.11. Deck cross-section of Wali El-Ahd Bridge between axes 21:23 and 26:29.....	10
Figure 1.12. Typical section of precast girders between axes 21:23 and 26:29.....	11
Figure 1.13. Deck cross-section of Wali El-Ahd Bridge between axes 23:26.....	11
Figure 1.14. Typical section of precast girders between axes 23:26.....	11
Figure 1.15. Parabolic path of the pre-stressing strands of span from axis 23 to 24..	12
Figure 3.1.The design truck for AASHTO LRFD Specifications (“LRFD Bridge Design” by James A Swanson and Richard A Miller, 2007, slide no. 63).....	26

Figure 3.2. The design tandem for AASHTO LRFD Specifications (“LRFD Bridge Design” by James A Swanson and Richard A Miller, 2007, slide no. 64).....	26
Figure 3.3. The AASHTO HL-93 design loads (“Design of Highway Bridges” by Richard M. Barker and Jay A. Puckett, 2007, p. 167).....	27
Figure 3.4. Sketches for four-node shell element used in finite element analyses (Wilson and Habibullah, 2010).....	31
Figure 3.5. Spine model for a prototype bridge.....	35
Figure 3.6. Area object model for a prototype bridge.....	35
Figure 3.7. Typical cross section for the prototype bridge.....	36
Figure 3.8. The finite element model for the prototype bridge.....	36
Figure 4.1. Typical cross section for a prototype bridge (all dimensions are in mm.).....	40
Figure 4.2. Typical cross section for a precast U-girder in a prototype bridge (all dimensions are in mm.).....	40
Figure 4.3. Prototype bridge with three traffic lanes.....	43
Figure 4.4. Discretization points for a three-lane prototype bridge.....	43
Figure 4.5. Span length effect on the moment distribution factors of the interior girders for four-lane bridges.....	46
Figure 4.6. Span length effect on the moment distribution factors of the exterior girders for four-lane bridges.....	46
Figure 4.7. Span length effect on the shear distribution factors of the interior girders for four-lane bridges.....	47

Figure 4.8. Span length effect on the shear distribution factors of the exterior girders for four-lane bridges.....	47
Figure 4.9. Span length effect on the moment distribution factors of the interior girders for five-lane bridges.....	48
Figure 4.10. Span length effect on the moment distribution factors of the exterior girders for five-lane bridges.....	48
Figure 4.11. Span length effect on the shear distribution factors of the interior girders for five-lane bridges.....	49
Figure 4.12. Span length effect on the shear distribution factors of the exterior girders for five-lane bridges.....	49
Figure 4.13. Difference between the moment distribution factors of 15 and 60m-span bridges of four lanes (as a percentage).....	50
Figure 4.14. Difference between the moment distribution factors of 15 and 60m-span bridges of five lanes (as a percentage).....	50
Figure 4.15. Difference between the shear distribution factors of 15 and 60m-span bridges of four lanes (as a percentage).....	51
Figure 4.16. Difference between the shear distribution factors of 15 and 60m-span bridges of five lanes (as a percentage).....	51
Figure 4.17. Girder spacing effect on the moment distribution factors of the interior girders for four-lane bridges.....	54
Figure 4.18. Girder spacing effect on the moment distribution factors of the exterior girders for four-lane bridges.....	54
Figure 4.19. Girder spacing effect on the shear distribution factors of the interior girders for four-lane bridges.....	55
Figure 4.20. Girder spacing effect on the shear distribution factors of the exterior girders for four-lane bridges.....	55

Figure 4.21. Girder spacing effect on the moment distribution factors of the interior girders for five-lane bridges.....	56
Figure 4.22. Girder spacing effect on the moment distribution factors of the exterior girders for five-lane bridges.....	56
Figure 4.23. Girder spacing effect on the shear distribution factors of the interior girders for five-lane bridges.....	57
Figure 4.24. Girder spacing effect on the shear distribution factors of the exterior girders for five-lane bridges.....	57
Figure 4.25. Error obtained from manually estimating the moment distribution factors for five-lane bridges of 30m span (as a percentage).....	58
Figure 4.26. Error obtained from manually estimating the shear distribution factors for five-lane bridges of 30m span (as a percentage).....	58
Figure 4.27. Number of girders effect on the moment distribution factors of the interior girders for four-lane bridges.....	61
Figure 4.28. Number of girders effect on the moment distribution factors of the exterior girders for four-lane bridges.....	61
Figure 4.29. Number of girders effect on the shear distribution factors of the interior girders for four-lane bridges.....	62
Figure 4.30. Number of girders effect on the shear distribution factors of the exterior girders for four-lane bridges.....	62
Figure 4.31. Number of girders effect on the moment distribution factors of the interior girders for five-lane bridges.....	63
Figure 4.32. Number of girders effect on the moment distribution factors of the exterior girders for five-lane bridges.....	63
Figure 4.33. Number of girders effect on the shear distribution factors of the interior girders for five-lane bridges.....	64

Figure 4.34. Number of girders effect on the shear distribution factors of the exterior girders for five-lane bridges.....	64
Figure 4.35. Error obtained from manually estimating the moment distribution factors for five-lane bridges of 45m span (as a percentage).....	65
Figure 4.36. Error obtained from manually estimating the shear distribution factors for five-lane bridges of 45m span (as a percentage).....	65
Figure 4.37. Number of lanes effect on the moment distribution factors of the interior girders for three-girder bridges.....	68
Figure 4.38. Number of lanes effect on the moment distribution factors of the exterior girders for three-girder bridges.....	68
Figure 4.39. Number of lanes effect on the shear distribution factors of the interior girders for three-girder bridges.....	69
Figure 4.40. Number of lanes effect on the shear distribution factors of the exterior girders for three-girder bridges.....	69
Figure 4.41. Number of lanes effect on the moment distribution factors of the interior girders for four-girder bridges.....	70
Figure 4.42. Number of lanes effect on the moment distribution factors of the exterior girders for four-girder bridges.....	70
Figure 4.43. Number of lanes effect on the shear distribution factors of the interior girders for four-girder bridges.....	71
Figure 4.44. Number of lanes effect on the shear distribution factors of the exterior girders for four-girder bridges.....	71
Figure 4.45. Comparison of the moment distribution factors for the interior girders of two-lane bridges.....	76
Figure 4.46. Comparison of the moment distribution factors for the exterior girders of two-lane bridges.....	76