

SENSITIVITY STUDY OF ARCH AND CABLE STAYED PEDESTRIAN BRIDGES

N.N.PAULUSZ
199209E

M.Sc.IN STRUCTURAL ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY OF MORATUWA
SRI LANKA

DECEMBER 2023

SENSITIVITY STUDY OF ARCH AND CABLE STAYED PEDESTRIAN BRIDGES

NATALIE NADEESHA PAULUSZ
199209E

DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE
MASTER OF SCIENCE IN STRUCTURAL ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY OF MORATUWA
SRI LANKA

DECEMBER 2023

Declaration

I declare that this is my own work, and this dissertation does not incorporate without acknowledgment any material previously submitted for a degree or diploma at any other university or institute of higher learning, and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to the University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part, in print, electronic, or other medium. I retain the right to use this content in whole or in part in future works (such as articles or books).

Signature of the Candidate:

Date:

The above candidate has carried out research for the master's dissertation under my supervision.

Name of the Supervisor: Dr. K. Baskaran

Signature of the Supervisor:

Date:

Abstract

The configuration of pedestrian bridges varies from project to project due to project requirements. However, no single structural form can be employed for every configuration of pedestrian bridge because different structural forms have varying degrees of effectiveness. Because the functional requirements for pedestrian bridges are less constrained, designers are free to develop unique solutions that cater for potential unanticipated problems. By carefully analyzing multiple design options and engineering principles, construction professionals and civil engineers can select the optimal structural form that meets project objectives, maximizes structural efficiency, and ensures the long-term safety and durability of the built environment. Regretfully, there is still a lack of adequate instruction in these skills in engineering programs; certain small and medium-sized bridges serve as examples of this. Structural design sensitivity analysis focuses on the relationship between the design variables that the engineer can manipulate and the structural reaction that is determined by the laws of mechanics. Using this method will help you narrow down the possibilities to the ideal design solution. The research focused on several geometries and examined how different geometric requirements support structural performances in different forms, starting with alterations to a pedestrian bridge. The study's objective was to assess two possibilities and make recommendations for how they might be used to different geometric requirements. A review of the literature was done to learn more about the various types of footbridges, their functions in daily life, their significance, the evolution of bridge structures, and the components that made them up, with an emphasis on both architectural and engineering viewpoints. Found footbridges with structural forms that have been studied in literature in various locations, took pictures of them, looked at geometry fundamentals, investigated the mechanism of load transmission, observed the structural details of the structures, and chose for analysis bridges with two different structural forms arch and cable stayed bridges that are believed to adhere to the social and architectural values discussed in the literature. Following an observation of the existing footbridges, a new instance was formed, design rules were developed, and two structurally similar alternatives an arch and a cable stayed bridge were presented. The modifications were made to a select few existing footbridges in compliance with the project requirements. Modified the geometry of both options by half to twice the original width, height, and span while keeping the same other measurements. After that, computer structural models were created for every scenario. By contrasting the two possibilities based on how sensitively the structural performance responds to changes in geometry, it was possible to determine the adaptability of each structural form to different geometric requirements in a project. The sensitivity analysis's findings indicate that the design changes will primarily address the arch bridge's rise to span ratio. In the short-to-medium span range, the 1:12 height-to-span ratio acts as a threshold to regulate the structure's susceptibility to geometric alterations. This indicates that if the arch bridge's rise to span ratio varies by a factor less than 1, the structure may be operating with a sizable safety margin. The analysis indicated that shallow-medium spanned arches would be efficient. In a cable-stayed bridge, the irregularity of the shape resulting from a change in geometry is evident, in contrast to arch bridges. Therefore, when constructing a cable-stayed bridge, proper proportions must be considered in addition to achieving the maximum level of structural performance. Nonetheless, it is clear that performance of the cable-stayed bridge's structure is not fully realized in the short to medium span range.

Keywords: Pedestrian Bridge, Sensitivity Analysis, Bridge Form, Structural Efficiency

Acknowledgement

The coordinator of the postgraduate research project, my supervisor, Dr. K. Baskaran, deserves a special note of thanks and gratitude for his guidance and invaluable knowledge in helping me successfully complete this dissertation. Then, I'd like to take this chance to thank Prof. (Mrs.) Chintha Jayasinghe, Head of the Department of Civil Engineering at the University of Moratuwa, Prof. S. A. S. Kulathilaka, Former Head of the Department of Civil Engineering at the University of Moratuwa, Prof. H. M. Y. C. Mallikarachchi, Head of the Building & Structural Engineering Division at the University of Moratuwa and Prof. I. R. A. Weerasekera, former Head of Building & Structural Engineering Division, University of Moratuwa, for providing this great opportunity for postgraduate students.

I'd also like to thank Prof. H. M. Y. C. Mallikarachchi and Dr. H. D. Hidallana Gamage, the course coordinators, for their assistance and direction. Then, I would like to thank all of the lecturers from the Civil Engineering Department at the University of Moratuwa for providing a solid theoretical foundation and providing support and advice in a variety of methods to ensure the accomplishment of this assignment.

I owe my special appreciation to my family for giving me both spiritual and emotional support, and to my fellow colleagues who assisted me in numerous ways to make this task a success.

Table of Contents

1.0 Introduction	1
1.1 Research Background	1
1.2 Scope of Research	1
1.3 Research Objectives	2
1.4 Research Significance	3
1.5 Research Methodology	3
1.6 Arrangement of Dissertation	4
2.0 Literature Review	5
2.1 Basis of Bridge Design	5
2.2 Historical Revolution of Bridge Forms	7
2.3 Structural Mechanisms of Different Bridge Forms	12
2.4 Foot Bridges	15
2.5 Review of Literature	19
2.6 Summary of Literature	22
2.7 Gaps in Literature	23
3.0 Methodology	25
3.1 Analysis of Selected Foot Bridges	25
3.2 Structural Modeling	46
3.3 Structural Analysis	53
4.0 Results and Discussion	55
4.1 Analytical Model for Predicting Evaluation Measures	55
4.2 Results Analysis 1: Form Vs. Displacement	55
4.3 Results Analysis 2: Form Vs. Internal Forces	57
5.0 Conclusion and Recommendations	63
5.1 Conclusion	63
5.2 Recommendation	63
References	64
Appendix A: Basis of Design	70
Appendix B: Design Specification	73
Appendix C: Loads	75
Appendix D: Initial Member Sizing	82

List of Figures

Figure 2.01: Forces on Beam Bridge	12
Figure 2.02: Forces on Arch Bridge	13
Figure 2.03: Forces on Suspension Bridge	14
Figure 2.04: Forces on Cable Stayed Bridge	14
Figure3.01: Glass Bridge in a Research Centre, Lisbon	25
Figure 3.02: Pedestrian Bridge Simone de Beauvoir	26
Figure 3.03: B9 Bridge Telekom	27
Figure 3.04: Hessenring Footbridge	28
Figure 3.05: Footbridge over Neckar River	29
Figure3.06: Millennium Bridge	30
Figure3.07: Nesse Bridge	31
Figure3.08: Innenhafen Footbridge	32
Figure 3.09: Poplar High Level Walkway	33
Figure 3.10: Passerelle La Défense	34
Figure 3.11: Melkweg Bridge	35
Figure 3.12: Three Countries Bridge	36
Figure 3.13: General View of Phoenix Lake Footbridge	37
Figure 3.14: Ripshorst Pedestrian Bridge	38
Figure 3.15: Gateshead Millennium Bridge	39
Figure 3.16: Stone Bridge over Malwathu Oya	40
Figure 3.17: Remains of the Ancient Kayyankerni Stone Bridge	40
Figure 3.18: Bogoda Bridge	41
Figure 3.19: Peradeniya Suspension Bridge	42
Figure 3.20: Manampitiya Road-Rail Bridge	42
Figure 3.21: Halaba Bridge	43
Figure 3.22: Ulapane Fool's Bridge	43
Figure 3.23: The Beautiful Metal Footbridge Leads to Small Parey Dewa Temple	44
Figure 3.24: Footbridge over Hamilton Canal	45
Figure 3.25: Galle Butterfly Bridge	45
Figure 3.26: Plan View of Arch Bridge	47
Figure 3.27: Elevation of Arch Bridge	47
Figure 3.28: Section A-A of Arch Bridge	47
Figure 3.29: Section B-B of Arch Bridge	47
Figure 3.30: Plan View of Cable Stayed Bridge	48
Figure 3.31: Elevation of Cable Stayed Bridge	48
Figure 3.32: Section A-A of Cable Stayed Bridge	49
Figure 3.33: Section B-B of Cable Stayed Bridge	49
Figure 3.34: Structural Concept of Arch Bridge	51
Figure 3.35: Section X-X	51
Figure 3.36: Load Transfer from Bridge Deck to Main Girder	51
Figure 3.37: Load Transfer from Main Girder to Foundation	51
Figure 3.38: Structural Concept of Cable Stayed Bridge	52
Figure 3.39: Section X-X	52
Figure 3.40: Load Transfer from Bridge Deck to Main Girder	52
Figure 3.41: Load Transfer from Main Girder to Foundation	53
Figure 3.42: Structural Models in Sap 2000	54
Figure 4.01: Maximum Deflections vs Allowable Deflections	56
Figure 4.02: M Diagrams of B1,B2 and Corresponding Cases	58
Figure 4.03: N Diagrams of B1,B2 and Corresponding Cases	59

List of Tables

Table 3.1: Load Combinations for ULS and SLS	54
Table 4.1: Interpretation of Structural Efficiencies	60

List of Abbreviations

BC - Before Christ
AD - Anno Domini
3D - Three Dimensional
DL - Dead Load
LL - Live Load
WL - Wind Load
FEM - Finite Element Model
BM - Bending Moment
AF - Axial Force

List of Appendices

Appendix A: Basis of Design	70
Appendix B: Design Specification	73
Appendix C: Loads	75
Appendix D: Initial Member Sizing	82