

UNIVERSITI TEKNOLOGI MARA

**DESIGN OF MODULAR MOBILE
HYBRID TIMBER BRIDGE
REINFORCED WITH CARBON
FIBER REINFORCED POLYMER
(CFRP)**

MOHD RIZUWAN BIN MAMAT

Thesis submitted in fulfilment of
the requirements for the degree of
Master of Science

Faculty of Civil Engineering

June 2018

ABSTRACT

Stream crossing or bridge is one of the components in forest road network. Good forest road network and stream crossing will allow for post harvesting activities as monitoring and research activities to be carried out within the schedule. During harvesting period operations, bridges are constructed temporarily and normally will last less than 5 years due storms and floods during monsoon season. Building the permanent bridges incurs high cost if there are numbers of streams to cross and the structure would easily collapse. This study proposes modular and mobile forest bridge with use of lightweight materials that are timber, aluminium and carbon fibre reinforced polymer (CFRP) for easy transportation and installation and at the same could be used at multiple sites. Finite Element Analysis (FEA) had been defined I-shaped cross section of structural shape to be used in the proposed timber bridge. Design Connector 1 was selected to be used to join the five segmented timber beams to develop 10m girder span. 6mm thickness of CFRP found to be an optimum thickness for I-shaped timber beam reinforcement. Considering stress at top side of specimen and deflection at bottom side of specimen, the reinforcement observed decrease stress and displacement for 2m timber beam up to 33.43% and 61.56% consecutively. The reinforcement also observed reduce the stress and displacement value for a single girder up to 29.20% and 58.96% consecutively. Difference of displacement value between FEA and bending test experiment at mid-span of specimen is only 3.29%.

ACKNOWLEDGEMENTS

Alhamdulillah I finally completed my thesis successfully after a long and challenging journey. I would like to express my deepest gratitude and thanks to my supervisor Assoc. Prof Dr Mohd Hisbany Bin Mohd Hashim. I would like to thank you for encouraging my research and for allowing me to grow as a research scientist. Your advice on both research as well as on my career have been invaluable.

I would also like to express my special thanks YBhg Dato' Dr Abd Latif Mohmod, Director General of Forest Research Institute Malaysia (FRIM) for supporting my study and funding the research project until completed.

My appreciation also goes to my colleagues and friends for helping me with this project.

A special thanks to my beloved wife, Fareha Anis Mohd Taib. Thank you for supporting me for everything, and especially I can't thank you enough for encouraging me throughout this experience. To my beloved daughter and son Nur Qurratun Radhiah Abdullah and Muhammad Fadhil Abdullah, I would like to express my thanks for being such a good girl and boy always cheering me up.

Finally, this thesis is dedicated to the loving memory of my very dear late father and mother for the vision and determination to educate me. This piece of victory is dedicated to both of you.

Alhamdulillah

TABLE OF CONTENT

| | Page |
|---|-------------|
| CONFIRMATION BY PANEL OF EXAMINERS | ii |
| AUTHOR'S DECLARATION | iii |
| ABSTRACT | iv |
| ACKNOWLEDGEMENTS | v |
| TABLE OF CONTENT | vi |
| LIST OF TABLES | x |
| LIST OF FIGURES | xiv |
| | |
| CHAPTER ONE: INTRODUCTION | 1 |
| 1.1 Research Background | 1 |
| 1.2 Problem Statement | 4 |
| 1.3 Objectives | 5 |
| 1.4 Scope of Study | 6 |
| 1.5 Significance of Study | 8 |
| | |
| CHAPTER TWO: LITERATURE REVIEW | 11 |
| 2.1 Introduction | 11 |
| 2.2 Forest bridge | 12 |
| 2.3 Portable Bridge | 15 |
| 2.4 Modular Design | 17 |
| 2.5 Stress Transfer Mechanism | 19 |
| 2.6 Hybrid Material of Forest Bridge | 21 |
| 2.6.1 Timber | 23 |
| 2.6.2 Fibre Reinforced Polymer (FRP) | 24 |
| 2.6.3 Aluminium | 28 |
| 2.7 Finite Element Analysis (FEA) | 30 |
| 2.8 Literature Review Conclusion | 34 |

| | |
|--|-----------|
| CHAPTER THREE: RESEARCH METHODOLOGY | 35 |
| 3.1 Introduction | 35 |
| 3.2 Element Type | 38 |
| 3.3 Element Definition | 39 |
| 3.4 Material Properties | 40 |
| 3.5 Loading | 42 |
| 3.6 Study Assumption | 43 |
| 3.7 Structural shape | 43 |
| 3.7.1 Specimen description | 45 |
| 3.7.2 Element details | 46 |
| 3.7.3 Test setup | 47 |
| 3.8 Aluminum connector | 48 |
| 3.8.1 Specimen description | 49 |
| 3.8.2 Element details | 57 |
| 3.8.3 Test set up | 58 |
| 3.9 Number of segments | 59 |
| 3.9.1 Specimen description | 61 |
| 3.9.2 Element detail | 61 |
| 3.9.3 Test setup | 62 |
| 3.10 CFRP Lining Reinforcement | 65 |
| 3.10.1 Specimen description | 65 |
| 3.10.2 Element detail | 66 |
| 3.10.3 Test setup | 68 |
| 3.11 Prediction of 10m Forest Mobile Bridge girder | 69 |
| 3.11.1 Specimen description | 69 |
| 3.11.2 Element detail | 72 |
| 3.11.3 Test setup | 73 |
| 3.12 Bending Test Experiment | 75 |
| 3.12.1 Specimen description | 76 |
| 3.12.2 Test setup | 78 |
| 3.13 Bending Test Simulation | 81 |
| 3.13.1 Specimen description | 82 |
| 3.13.2 Element detail | 85 |
| 3.13.3 Test setup | 86 |