ANALYSIS AND DESIGN OF SINGLE SPAN MILITARY BRIDGE USING ALUMINIUM ALLOY

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Thesis Submitted to the Centre for Graduate Studies, Universiti Pertahanan Nasional Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

August 2014

DEDICATION

Alhamdulillah…

"Especially for my beloved parent Ibu & Papa, my beloved wife

Siti Kamariah binti Sulaiman and my beloved son

Muhammad Aqil Saufhi bin Azrul Affandhi…".

Thanks for give me strength to complete this journey…

ABSTRACT

Military bridge is an important asset for mobility support in the military operations or during natural disaster. Malaysia still relies on foreign technology because the country is still not capable in producing our own military bridge. The objective of this research is to design a suitable single span military bridge structure for the intended purpose using 6061-T6 aluminium alloy as the main material. The bridge is a girder type with 41.1 m length, 4 m width, 1.5 m depth and has the capacity to carry a Pendekar tank vehicle load which is classified as MLC 70. The design of the military bridge is based on operational requirements provided by the Malaysian Army and as outlined in Trilateral Design and Test Code (TDTC) for Military Bridge and Gap Crossing Equipment. The girder is preliminary designed by limit states checking based on Eurocode 9: Design of Aluminium Structures and the optimized design are done by Finite Element Analysis (FEA) using MSC PATRAN/NASTRAN simulation software. Structural test was conducted on available girder to validate the simulation works. The testing complied to all procedures as explained in the TDTC. Analysis and design results show that the girder produced safe values of maximum stresses, deflection, buckling and torsion. The additional analysis performed on hybrid girder found that the hybrid girder is capable to withstand heavier load. Structural test results show lower value than results from simulation, which is proven sufficient and reasonable save margin is available between simulation and test outcome. This research has obtained its objectives and justified that military bridge structure can be designed using locally available materials.

ABSTRAK

Jambatan tentera adalah suatu aset yang penting di dalam membantu mobiliti sesuatu operasi ketenteraan atau semasa bencana alam. Malaysia masih bergantung kepada teknologi asing kerana masih tidak mampu menghasilkan jambatan tenteranya sendiri. Objektif kajian ini adalah untuk merekabentuk sebuah jambatan tentera satu rentang yang sesuai untuk kegunaan yang diharapkan menggunakan aluminium aloi 6061-T6 sebagai material utamanya. Jambatan ini adalah jenis jambatan galang dengan dimensi 41.1m panjang, 4m lebar, 1.5m tinggi dan berkeupayaan untuk menanggung beban kereta kebal Pendekar yang diklasifikasikan sebagai MLC 70. Rekabentuk jambatan tentera ini adalah berdasarkan kehendak operasi yang diperlukan oleh Tentera Darat Malaysia dan seperti mana yang digariskan di dalam Trilateral Design and Test Code (TDTC) for Military Bridge and Gap Crossing Equipment. Galang jambatan direkabentuk awalan dengan kaedah semakan keadaan had berpandukan Eurocode 9: Design of Aluminium Structures dan direkabentuk secara optima dengan kaedah Analisis Unsur Terhingga menggunakan perisian MSC PATRAN/NASTRAN. Ujian struktur dijalankan terhadap galang yang ada untuk mengesahkan kerja simulasi Analisis Unsur Terhingga. Ujian tersebut mematuhi semua prosedur yang dinyatakan di dalam TDTC. Keputusan analisis dan reka bentuk menunjukkan galang jambatan menghasilkan nilai selamat bagi tegasan maksimum, pesongan, lekukan dan kilasan. Analisis tambahan yang dijalankan terhadap galang hibrid mendapati galang tersebut berkeupayaan untuk menampung beban kenderaan yang lebih berat. Keputusan ujian struktur memperoleh nilai yang lebih rendah berbanding keputusan simulasi menunjukkan margin selamat yang mencukupi dan boleh diterima di antara keputusan simulasi dan ujian. Kajian ini

telah mencapai objektif dan mengesahkan bahawa struktur jambatan tentera boleh direkabentuk menggunakan bahan tempatan.

ACKNOWLEDGEMENT

I would like to convey my warmest thank to my supervisor, Colonel Professor Ir. Dr. Norazman bin Mohamad Nor for his guidance and encouragement in all aspects of this thesis. His comments and suggestions during the preparation of this thesis are gratefully appreciated. His patience, commitment and availability for any help whenever needed is really appreciated.

My appreciation is also extended to all academic and non-academic member of Universiti Pertahanan Nasional Malaysia for their cooperation either directly or indirectly in completion of this research.

APPROVAL

This thesis was submitted to the Senate of Universiti Pertahanan Nasional Malaysia and has been accepted as fulfillment of the requirements for the degree of Master of Science. The member of the Supervisory Committee were as follows:

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LIST OF ABREVIATIONS

AISI	–	American Iron and Steel Institute
AVLB	–	Armoured Vehicle Launched Bridge
BLF	–	Buckling Loading Factor
BR90	–	Bridge for Nineties
BV	–	Bridging Vehicle
CFRP	–	Carbon Fiber Reinforced Polymer
CS	–	Cross Section
DSB	–	Dry Support Bridge
FE	–	Finite Element
FEA	–	Finite Element Analysis
GSB	–	General Support Bridge
HQ	–	Headquarters
MBT	–	Main Battle Tank
MGB	–	Medium Girder Bridge
MLC	–	Military Load Class
R&D	–	Research and Development
(T)	–	Tracked
TFB	–	Tactical Floating Bridge
TDTC	–	Trilateral Design and Test Code for Military Bridging
TSSB	–	Tactical Single Span Bridge
US	–	United States
UK	–	United Kingdom
(W)	–	Wheeled

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CHAPTER 1

INTRODUCTION

1.1 Background

A bridge is a manmade structure that provides continuous passage over an obstacle such as river, lake and valley. It also functions to connect two separated lands. The bridge is normally constructed by using materials such as reinforced concrete, timber, iron, steel, aluminium or composite material. The bridge must be designed to bear its own weight and expected load to move on it.

In the military field, the bridge is an essential asset especially in mobility of military forces. In military operation, the bridge is urgently needed by military forces consisting of personnels, vehicles and other military assets to cross any obstacles. It is also needed to replace a damaged bridge destroyed by enemy forces. During peacetime, military bridging asset is needed by the public to temporarily replace damaged bridge caused by natural disaster such as flood, landslide, earthquake or tsunami while waiting for a new bridge to be constructed. In this situation, a portable and rapidly deployed bridge which is known as military bridge can be utilised.

There are various types of military bridges that have been designed and currently used by military forces around the world. Based on U.S Army Field Manual for Military Nonstandard Fixed Bridging (2002) and Trilateral Design and Test Code (TDTC) for Military Bridging and Gap Crossing Equipment (1996), military bridges are divided into three categories that are assault bridges, support bridges and logistic (line of communication) bridges. Malaysian Armed Forces (MAF) itself has used several types of military bridges, changing from time to time in line with the changes of the world's technology and current need. Among the types of the military bridges that have been used by MAF include Bailey Bridge, Medium Girder Bridge (MGB), BR90 Tactical Single Span Bridge (TSSB) and PFM SIR Tactical Floating Bridge (TFB). All military bridges used in Malaysia are imported from foreign countries.

Military bridges must be designed thoroughly to meet the military and special requirements. Design is a process of identifying the best material and size of the structural element. The aim of military bridge design is to create a safe, light, portable and easy to maintain structure. Lightness and corrosion resistance play a fundamental role in military bridge structure (Mazzolani, 1994). In this research, aluminum alloy is being considered as the main material for the military bridge structure. Aluminum alloy is known for its high strength to weight ratio and corrosion resistance compared to steel.

1.2 Problem Statement

Utilization of military bridges is very much needed in the country and specifically for the military forces either for war or during natural disaster. Until now, Malaysia still relies on foreign technology because our country is still not capable of producing our own military needs for current and future military operation requirement, except for the launching rail module for BR 90 which is manufactured by Composite Technology Research Malaysia (CTRM). The Malaysian government spent millions of ringgit to procure the military bridges from foreign countries. This indirectly has provided a good platform for foreign countries to conduct research and development (R&D) and business prior to production of military bridges for Malaysia.

Malaysia also has its own expertise and technologies to design, develop and produce locally made military bridges. But research on military bridges in Malaysia is still at its infancy level. Therefore, the purpose of this research is to conduct research and investigation to design a new locally made military bridge to replace the foreign product and technology. In this research, material used for the military bridge structure will focus on aluminum alloy as the main material due to its high strength to weight ratio and corrosion resistance.

1.3 Objective

The objectives of this research are as follow:

a. To design a suitable single span military bridge structure for the intended purpose using selected aluminum alloy as the main material.

b. To simulate and analyse performance of the military bridge structure.

c. To validate the Finite Element Analysis (FEA) simulation results by conduct physical testing in the structural laboratory.

1.4 Scope of Research

The scopes of this research are as follow:

a. Design of the military bridge structure using the best aluminium alloy available in the country.

b. Conduct FEA works using MSC PATRAN and MSC NASTRAN simulation software.

c. Conduct physical testing using available specimen in the Engineering Faculty of the Universiti Pertahanan Nasional Malaysia (UPNM).

1.5 Significance of the Study

Research on military bridge is very important as our country is still not capable in producing its own military bridge. There are many advantages if we can produce our own military bridge. This research will enhance our capability to produce our own military bridge using local expertise, equipment and technology.

This research can trigger interest to Malaysian expertise and academicians to explore and conduct detail research and development (R&D) on military bridges. This bridging asset is not just to be used in military operation, but also for other agencies dealing with disaster relief operations.

1.7 Thesis Outline

This thesis is organized into eight chapters. Chapter 1 introduces the problem addressed by the researcher and established the objectives and scopes for the research. Chapter 2 summarizes the literature review about current military bridge system around the world and aluminum alloy for military bridge structure and its design basis. Chapter 3 presents the research methodology. Chapter 4 presents the conceptual design for the new military bridge system. Chapter 5 presents the structural analysis and design of the military bridge structure. Chapter 6 presents the structural testing of the bridge girder. Finally Chapter 7 discusses the conclusions and recommendations with respect to the research objectives.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the current military bridge system that covers characteristics and capabilities of each military bridge. The finding of aluminium alloy for military bridge structure also reviewed here. The explanation includes production process, material properties and availability of selected aluminium alloy in the country. The design basis used in design military bridge structure will also presented in this chapter.

2.1 Military Bridge System

Based on U.S Army Field Manual for Military Nonstandard Fixed Bridging (2002) and Trilateral Design and Test Code (TDTC) for Military Bridging and Gap Crossing Equipment (2005), military bridges is divided into three categories that are assault bridges, support bridges and logistic (line of communication) bridges. Each classification is based on its function and location of the bridge in the battlefield. The assault bridge is designed for use by the most forward element. The support bridge is used by the main body and the logistic bridge is designed for use in line of communication (L of C) zone.