THE CHARACTERISTICS OF A SUSTAINABLE BRIDGE: A CASE STUDY OF SECOND PENANG BRIDGE

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Dedicated to my beloved and patient wife

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ABSTRACT

The aging and deterioration of bridges and the new requirements for sustainable infrastructures and communities require innovative approaches for their management that can achieve an adequate balance between social, economic, and environmental sustainability. This study presents the common criteria which can make a sustainable bridge in the construction industry by considering three objectives, which are, to identify the common criteria for a sustainable structure, then to observe the criteria to the bridges, and to investigate the applications of the criteria in bridge design and construction. The study was carried out through a literature survey and case studies. Result from the study found that there were 29 critical criteria have been identified and significantly influenced on sustainable bridges in the design and construction. The whole criteria, then, were categorized into three aspects such as economic, environmental, and social. A case study was carried out on the under-construction of the Second Penang Bridge. The results of the case study revealed that it has achieved most of the criteria of the sustainability bridge. It rendered useful references in designing sustainable bridges and could be classified as the top ranking of bridges in the case of sustainability. Additionally, the model of ranking for bridge sustainability is suggested.

ABSTRAK

Penuaan dan kemerosotan jambatan dan keperluan baru bagi infrastruktur dan komuniti lestari memerlukan pendekatan yang inovatif bagi pengurusan mereka yang boleh mencapai keseimbangan yang mencukupi di antara kemampanan sosial, ekonomi dan alam sekitar. Kajian ini membentangkan kriteria yang sama yang boleh membuat sebuah jambatan yang mampan dalam industri pembinaan dengan mempertimbangkan tiga objektif, iaitu, untuk mengenal pasti kriteria yang sama untuk struktur yang mapan, maka untuk melihat kriteria untuk jambatan, dan untuk menyiasat permohonan daripada kriteria dalam reka bentuk dan pembinaan jambatan. Kajian ini telah dijalankan melalui kajian literatur dan kajian kes. Keputusan daripada kajian itu mendapati bahawa terdapat 29 kriteria kritikal telah dikenal pasti dan dipengaruhi dengan ketara di atas jambatan yang mampan dalam reka bentuk dan pembinaan. Kriteria keseluruhan, maka, telah dikategorikan kepada tiga aspek seperti ekonomi, alam sekitar dan sosial. Satu kajian kes telah dijalankan di bawah pembinaan Jambatan Pulau Pinang Kedua. Keputusan kajian kes menunjukkan bahawa ia telah mencapai kebanyakan kriteria jambatan kemampanan. Ia diberikan rujukan yang berguna dalam merekabentuk jambatan yang mampan dan boleh diklasifikasikan sebagai ranking atas jambatan dalam hal kemampanan. Selain itu, model ranking untuk kemampanan jambatan yang disyorkan.

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LIST OF ABBREVIATION

BEES	Building for Environmental and Economic Sustainability
BrIM	Bridge Information Model
CFRP	Carbon Fiber Reinforced Polymer
ECC	Engineered Cementitious Composite
EIA	Environmental Impact Assessment
EMA	Environmental Monitoring and Auditing
EMP	Environmental Management Plan
FIA	Fisheries Impact Assessment
GGBS	Ground Granulated Blast Furnace Slag
HDRB	High damping rubber bearing
HSC	High Strength Concrete
ITZ	Interface transition zone
KPI	Key performance indicators
LCA	Life Cycle Assessment
LCC	Life cycle cost
LCCB	Life-cycle cost-benefit
LCSA	Life Cycle Sustainability Analysis
NIST	National Institute of Standards and Technology
NSE	North South Expressway
OPS	Oil palm shell
PFA	Pulverized Fly Ash
PSS	Parallel Strand System
RHA	Rice husk ash
RSPC	Recycled Structural Plastic Composite
SBG	Segmental Box Girder
SEA	Strategic Environmental Assessment
SF	Silica fume
TARRC	Tun Abdul Razak Research Centre
TSS	Total suspended solids
UHPC	Ultra High Performance Concrete
UN	United Nations

CHAPTER 1

INTRODUCTION

1.1. Background of the Study

According to Toor and Ogunlana [1], Success of future projects will be increasingly measured on the criteria of strategy, sustainability, and safety. Future buildings and infrastructure will be evaluated based on their operational flexibility, maintainability, energy efficiency, sustainability, and contribution to the overall well-being of their end users. Bridge all over the world because of maturing and corrosion are facing the task of long-term and costly maintenance with inadequate funds. As it can be observed as they are critical links in the transportation networks that play an important role to support environmental, social, economic development. Furthermore in the planning stage, before design phase, there should be appropriate criteria to select the best characteristics for designing, constructing, maintenance, and demolition of the bridge.

To approach sustainable bridge management, all aspects of the social, environment, and economic should be used as the drivers for asset management at all levels of decision-making. According to Lounis and Daigle [2], the multi-objective optimization is the actual bridge management problems.

Also the Brundtland [3] mentioned that the sustainable development defined as a ‘development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs.’

The past few years have seen increasing technological advance in sustainability. Furthermore the Native Americans defined that “we do not inherit the Earth from our ancestors; we borrow it from our children.” [4]

The need for increasingly more sustainable infrastructure is growing [5]. “American’s transportation system has served the US well, but now faces the challenges of congestion, energy supply, environmental impacts, climate change, and sprawl that threatens to undermine the economic, social, and environmental future of the nation.” (AASHTO 2009).

In a challenging issue, a new design framework for the design of sustainable infrastructure systems has been developed. This paradigm integrates materials science and structural engineering with overall system design to meet targets of sustainable infrastructure performance measured through sustainability indicators such as global warming potential, total energy consumption, acidification potential, or total material consumption [6].

In 2010, Daniel mentioned that currently there is no national standard for quantifying sustainable bridges in the Unites States. In addition, the number of bridges conceived and branded with “sustainable” labels as of the time of this writing is minimal. Sustainable design is a modern day topic that requires academic study, modeling, and thought to move forward in a meaningful way [7].

The Lounis [2] indicates that, although, most of the current decision-making approaches and bridge management systems are based on the optimization of a single objective , minimization of life cycle costs, a multi-objective approach for decision-making, which can incorporate all relevant objectives, is proposed to enable the satisfying strategies for the design and management of highway bridge decks, which are direct or indirect measures of social, economic and environmental sustainability for highway bridges and neighboring communities.

The durability of (ECC) Engineered Cementitious Composite materials plays a key role in the design of more sustainable bridge infrastructure using ECC materials [5].

The engineering is becoming a non-stop field that is growing up daily, especially in the field of bridges. So far no research has been done on the characteristics of a sustainable bridge. Additionally, because of increasing the traffic volume and inadequate repairing funds, it seems that the characteristic of technology should integrate to the triple line of sustainability to make more engineering sustainable concern to develop the economic, environmental, social, and the technological aspects of designing the bridge.

The characteristics of a sustainable bridge will meet the needs and necessaries of the current and future generations by ensuring:

- To balance the economy
- To protect the environment
- To improve and defend the social

- To use the most useful technological issues in the design stage of the bridge.

1.2. Statement of Problem

It is the responsibility of humanity to ensure that resources are available for the next generation, and for many generations to come. Furthermore the numbers of bridges are increasing and concurrently the fast development may have a serious impact on them that impacts could be environmentally, economically and socially. Additionally, that problems are in need of identifying before the bridge could be constructed. As it can be observed, the sustainable design is responsible design, and the duty of design falls on engineers. According to the green road guideline 2011, although there are a lot of studies relating to the green road, the lack of investigating in the field of bridge is obvious. Besides, According to the Daniel 2011, currently there is no national standard for quantifying sustainable bridges in the Unites States.

The purpose of this study is to determine the characteristics of a sustainable bridge to cope with these economic, social and environmental problems, also, how to achieve a sustainable bridge design? By implementing the 2nd Penang Bridge as the case study to ensure that to what extend this bridge will carry these characteristics.

1.3. Aim and Objectives of the Study

The aim of this study is to determine the standard criteria that can make a sustainable bridge during construction. Thus, to achieve this aim, there are three (3) objectives that have been established as follows:

1. To identify common criteria for the sustainable structures
2. To describe the criteria for the sustainable bridges, and
3. To investigate the strategies to achieve sustainable bridge design.

1.4. Significance of the Study

Although currently there is no study that shows the characteristics of a sustainable bridge, the findings of this study are important to help the construction industry, engineers, architectures, owners, and even government to find out the best sustainable benchmarking for bridges in order to plan a new bridge or maintenance the existing bridges.

1.5. Scope of the Study

The long-span bridges are in need of more site preparation and material uses in comparison to short-span. Therefore the largest impact and even benefit from sustainable plan are likely to long-span bridges.

The scope of this study is the Superstructure and Substructure parts of the marine bridges, the 2nd Penang Bridge, which is top-priority project in the Ninth Malaysia Plan is selected as the case study. Besides, most of the data of this case study were collected from its published data[8], while some were obtained via informal discussions or interviews with the project personnel and the bridge experts. The 2nd Penang Bridge will be the longest in Southeast Asia that connect Batu Maung on the island to the Batu Kawan on the mainland.

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