FINITE ELEMENT ANALYSIS OF BRIDGE GIRDER RETROFITTED BY A POST-TENSIONED TECHNIQUE

SITI NORSHAFIQAH AINI BINTI ABD MALEK

SCHOOL OF CIVIL ENGINEERING
UNIVERSITI SAINS MALAYSIA
2021

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This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

As partial fulfilment of requirement for the degree of

BACHELOR OF ENGINEERING (HONS.)
(CIVIL ENGINEERING)

School of Civil Engineering,
Universiti Sains Malaysia

August 2021

Appendix A8

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2020/2021

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: FINITE ELEMENT ANALYSIS OF BRIDGE GIRDER RETROFITTED BY A POST-TENSIONED TECHNIQUE

Name of Student: SITI NORSHAFIQAH AINI BINTI ABD MALEK

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature:

Shafiqah

Date : 4 August 2021

Endorsed by:

(Signature of Supervisor)

Name of Supervisor: DR. MUSTAFASANIE M. YUSSOF
Senior Lecturer
School of Civil Engineering
Universiti Sains Malaysia

Date: 05.08.2021

Approved by:

(Signature of Examiner)

Name of Examiner: PROF. IR. DR. TAKSIAH A.MAJID

Date: 11 / 8 / 2021

ACKNOWLEDGEMENT

First and foremost, Alhamdulillah I am able to finish my final year project with blessing of The Almighty. It is vital to thank both of my supervisor, Dr. Mustafasanie M. Yussof, my supervisor during my final year project and Dr Nurul Hana Mokhtar as my supervisor throughout my study in Universiti Sains Malaysia for the willingness to support and cooperated in assist me successfully to completing my project with their invaluable advice has greatly enriched this research project.

Most importantly, I would like to express my sincere gratitude and love to my mother Faradillah bt Ismail and my brothers for their continuous support and encouragement throughout my life. I would like to take the opportunity to express my gratitude to the USM School of Civil Engineering for providing me with valuable educational knowledge and study experiences, as well as excellent facilities. I see the skills and information I earned as a student over the course of four years as a key component in my future job growth.

Last but not least, I want to thank me, I want to thank me for believing in me. I want to thank me for doing all this hard work and for never quitting. I want to thank me for always being a giver and try give more than I receive. I want to thank me for try do more right than wrong and I want to thank me for just being me at all times.

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ABSTRAK

Pembangunan pesat jambatan multi-rentang yang disokong dibina sebagai infrastruktur pengangkutan dan peningkatan jumlah jambatan kotak gelang yang banyak digunakan sebagai komponen penting dalam struktur. Sebagai struktur perkhidmatan, jambatan sering menghadapi masalah kemerosotan dan kerosakan, akibatnya, jambatan menunjukkan prestasi yang tidak mencukupi, dari segi ketahanan struktur, fungsi, dan keselamatan.

Tujuan kajian ini adalah untuk mengenal pasti kegagalan struktur dan memasang semula jambatan gelang kotak segmen dengan menggunakan teknik pasca ketegangan dan untuk menganalisis jambatan gelang kotak segmen menggunakan perisian elemen terhingga. Jambatan rentang segmen dengan panjang 30 meter dimodelkan. Beban diedarkan seragam dengan nilai 350 kN/m dan beban graviti sebagai berat struktur digunakan pada jambatan. Penilaian keadaan struktur jambatan dilakukan untuk menganalisis anjakan, pesongan, tekanan dan ketegangan struktur jambatan.

Teknik pemasangan pasca ketegangan digunakan untuk mengurangkan kegagalan jambatan dan meningkatkan pengukuhan jambatan. Panjang tendon 12 meter digunakan sebagai tetulang pasca ketegangan. Hasil kajian dan metodologi dibentangkan dan dibincangkan dalam meningkatkan struktur dari segi peningkatan kualiti jambatan. Hasil model yang dikembangkan berkorelasi dengan baik dengan hasil eksperimen model dinilai.

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ABSTRACT

The rapid development of multi-span simply supported bridges is built as transportation infrastructure and the increasing number of box girder bridges widely utilized as important components of the structure. As a service structure, the bridge is always prone to the problem of deterioration and damages as consequence, they indicate insufficient performance, in terms of durability, functionality, and safety.

This study aims to determine the failure of structure and retrofit the segmental box girder bridge by using the post-tension technique and analyze the segmental box girder bridge using the finite element software. The segmental span bridge with a length of 30 meters is modeled. The uniform distributed load of 350 kN/m and the gravity load as the self-weight of the structure is applied on the bridge. The assessment of the bridge structure condition was carried out to analyze the displacement, deflection, stress, and strain of the bridge structure.

The Post-tension technique of retrofitting is used to reduce the failure of the bridge and increase the strengthening of the bridge. The tendon length of 12 meters is used as the post-tension reinforcement. The result of the study and methodology will be presented and discussed in improving the structure in terms of enhancing the quality of the bridge. The results of the developed models were in good correlation with the experimental results of the model were evaluated.

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The increasing of bridge infrastructure that generally facilitate the users to commute from one place to another and this infrastructure is known as the most dependable modes of transportation for peoples. Many changes in the use and construction of various types of bridges have occurred as a result of the extension. To reduce the dead load, the unnecessary material, which is not used to its full capacity, is removed from the section, resulting in shape of the box girder or cellular structures.

The cross section of the box-girder emerged from the hollow cell-deck or the T-beam bridge structurally. The enlargement of the compression zone at the central platform was extended across the full length of the bridge due to the advantages of transversal characteristics (Rama, 2015). The loading and internal design forces of structural members are also influenced by the track and bridge geometry when designing a bridge. The dynamic impacts of traffic activities have a significant impact on bridge loading, both because of the type of the traffic and the structure's reaction (Iles, 2004).

Each structure has its standard set of requirements that need to comply such as span clearance, traffic flow, geometry and building site characteristics. As a result, a wide range of bridges can be built. Common construction materials used are reinforced concrete, structural steel, pre-stressed concrete and post-tensioned concrete. The process of improving structures to enhance efficiency under existing loads or to increase the strength of structural members to support additional loads is structural strengthening. Many studies, specifically with bridges, have explored into post tensioning as one of the most effective methods for strengthening an existing structure to overcome an increase in service load without having to replace parts of it (Ghannam et al. 2014).

Post-tensioning is ideal for cases where major load capacity increases are required or when excessive deflection and cracking are an issue. High-strength steel reinforcement connects to the structure at the anchor points in post-tensioning systems. Profiling the tendons or utilizing deviators to produce high and low points along the span of the member provides the desired post-tensioning force. The uplift force can be modified by varying the profile of the tendons to obtain different levels of capacity and serviceability improvement.

1.2 Problem Statement

In general, there are many ways of strengthening the bridge superstructure. The static strengthening of bridge structural members can take different procedure, but they all aim to increase live-load capacity and ensure long- term durability. For this study, the effective ways to improve and retrofit the segmental bridge box girder is discussed. The post-tension is explored and its various advantages for controlling corrosion of pre-stressing steel, to control deflection of member, to increase the structure ductility and to strengthen bridges are addressed (Dahal et al, 2020).

The segmental prestressed concrete bridge is used in this study to determine the failure mode of the bridge when the uniform distributed load is applied along the bridge. The retrofitting by post-tension technique in box girder bridge to encounter the failure mode of the structure is being consider either it suitable to improve the bridge structure. Plus, the comparison between before the retrofit and after the retrofit using post-tension technique result is discuss to determine the durability of the strengthening of bridge, displacement and the deflection that might occur on bridge.

The Finite Element Analysis by using the LUSAS Software, it helps to investigate the accuracy and reliability of the impact factors used to design bridge. Adopting the numerical analysis with suitable boundary condition Finite Element helps to identified the condition of structure in Three-dimensional Mode and display the results by using different layers for diagram, contour, vector and discrete value data for all or selected parts of a model.

1.3 Objectives

i. To determine the failure of structure and retrofit the segmental box girder bridge by using the post-tension technique.

ii. To analyze the segmental box girder bridge model using finite element software.

1.4 Scope of Research

This study focusses on the common failure occur on bridge structure such as displacement, deflection and etc., and the post-tension technique is used as retrofitting method for the trapezoidal type of segmental box girder bridge. By able to construct software model by using Finite Element Analysis and able to show the simulation data of the design segmental bridge, the uniform distributed load and gravity load will be applied on the structure to analyze the failure mode of the structure.

Once the failure mode of the segmental bridge is determined, the structure will be retrofit by using the post-tension technique to reduce failure effect that encounter from the load given. Thus, the two model bridge structures before and after retrofitting result will be compared and discussed.

1.5 Thesis Structure

The study thesis that was conducted is divided into five orderly chapters. The first chapter is about the introduction of research comprising background studies, problem statement, objectives and scope of research. For Chapter 2 deals with the review of literature that is associated with research or similarity. Then, Chapter 3 clarify the research methodology of the software modelling research, and the data were acquired during the study. Chapter 4 shows the data and results of the experiments performed and assessed in order to achieve the stated purpose. Finally, Chapter 5 concludes the recommends for future improvements.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There are different design shapes of bridges and each of them features a particular purpose. The main designs of bridge such as the beam bridge, arch bridge, suspension bridge, and cantilever bridge are the most common types of bridges used and there is increasing use of precast concrete as the span deck of the bridge. Pre-stressed concrete is a type of concrete whereby the stress from external loads is compensated for by initial compression of the concrete over the service duration before external loading is applied.

To analyze the retrofit approach method that suitable for the box girder bridge, a few techniques is discussed. For the segmental box girder bridge, the system of post-tensioning is implemented into the structure. One of the efficient approaches in the post-tension procedure offered is the retrofitting method. The post-tensioning system is through tensioning the steel reinforcement in reinforced concrete elements.

2.2 Bridge Structure System

Bridges are unique structures by outnumber the buildings and other facilities in the environment not just in terms of size, but also in terms of service life and the number of people that use it. To design the bridge as a modern city landmark that satisfy the requirements of heavy vehicle traffic, light urban rail, and intensive yet convenient for pedestrian transportation an advanced type of bridge designed are required. To assist with this preliminary analysis, it was necessary to comprehend the basic components of a bridge as well as develop a firm understanding of various design specifications.

The major parts of bridges can be divided broadly into three parts which is the superstructure, substructure and foundation as shown in the Figure 2.1. Pier is a structure commonly used to any type of substructure that is placed between horizontal spans and foundations. Piers provide vertical support for spans at intermediate points and represent two purposes: transferring vertical loads from the superstructure to the foundations and resisting horizontal forces acting on the bridge. Abutments are used to connect the span of a bridge to embankments. It combines the bridge's deck to the ground, and it carries loads of the bridge deck.

On the other hand, the foundation is the component which transfers loads from the substructure to the bearing strata. Then, depending on the geotechnical properties of the bearing strata, shallow or deep foundations are adopted (Balasubramaniam, 2017). Usually, piles and well foundations are adopted for bridge foundations. The superstructure is a part of the structure which supports the traffic that includes deck, slab and girders.

Figure 2. 1: The segmental bridge structure (Sauvegot, 2000)

2.2.1 Superstructure

2.2.1.1 Deck

The surface of the bridge which act as a roadway for cars, bicycles, or pedestrians is known as the bridge deck. These decks must be strong enough to sustain constant pressure in order to ensure the traffic safety. For bridge decks, there are two basic structure types: Superstructure structures in which the top of the superstructure supports the top of the driving surface and bridge decks placed on top of beams or stringers. At the joints connecting the bridge deck to the abutments, the bridge deck components are designed with a continuous frame action in view. A connection information must be given that is consistent with the degree of consistency assumed at the joints (Dicleli et al., 2016).

There are two types of concrete bridge deck systems which is cast in place system and precast system. The precast system is when the concrete bridge decks are cast manually and then transported to the bridge site for installation into the final structure. While for the cast in place, is a concreting of bridge technique is undertaken in situ. As shown in Figure 2.2 is the typical cast in place systems and precast system for the bridge:

(a) Cast in place segmental construction;

(b) Precast full- depth concrete slab superstructure;

(c) The precast multicell box girder; and

(d) Bridge decks on beam or stringers.

(a) (b)

(c) (d)

Figure 2. 2: The cast in-place system of concrete bridge deck (Bos.W 2020)

In typical bridge system's, bridge deck is one of the most expensive maintenance items. As shown in the Figure 2.3, there are certain factors may contribute to the bridge deck reduced it service life (1) obsolescence, which is a functional planning problem and not a factor that associate to durability and (2) is a material service life performance insufficiency which may be the load induced that caused by human activity or a natural hazard, or they can be caused by production defects in the building process, operating procedure, or design details.

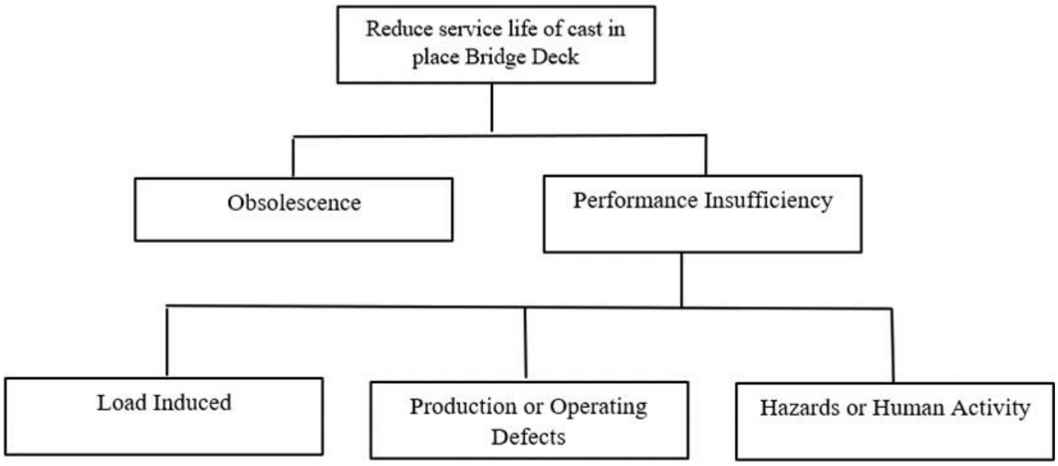

Figure 2. 3: Factors may contribute to the bridge deck reduced it service life (Dicleli et al., 2016).

Several interrelated issues must be taken during the design, development, and management phases of the bridge deck's service life to build long-lasting, cost-effective bridge decks,

2.2.2 Bridge Girder

The superstructure and the substructure are the two main components of a girder bridge. The superstructure is the visible part of the bridge that supports the loads, while the substructure is the base that transfers the loads from the superstructure to the underlying ground underneath it. To work efficiently and last for a longer period of time, there must be proper balance and coordination between two sections of the bridge.

Concrete bridges were often constructed of multiple precast girders placed side by side, with joints between girders parallel to the bridge's longitudinal axis until the advent of segmental construction as shown in Figure 2.4. The segments in the modern segmental definition are slices of a structural feature between joints that are perpendicular to the structure's longitudinal axis (Sauvegot, 2000).

Figure 2. 4: The concrete bridge girder (Sauvegot, 2000)

2.2.2.1 Plate Girder Bridge

A bridge with two or more plate girders is recognized as a plate girder bridge. Plate girders are usually I-beams made up of separate structural steel plates that are welded, bolted, or riveted together to form a vertical web and horizontal flanges of the beam (rather than rolled as a single cross section). These bridges can support railroads, highways, and other types of traffic and are ideal for short and medium spans. The length limit is determined by the type of transportation used to transport the girder from the fabricator to the construction site.

As shown in Figure 2.5 is the typical plate girder bridge. The vertical middle segment, known as the web. While the upper and lower horizontal members, known as the upper and lower flanges. It is the most important parts of a plate girder. Stiffeners is vertical parts that ran perpendicular to the plate girder bridges and act to keep the web from buckling or twisting.

Figure 2. 5: The plate girder bridge (Ehab E. 2014)

2.2.2.2 Box Girder Bridge

A beam or box girder bridge is basically a rigid horizontal structure that is resting on two piers, one at each end. The weight of the bridge and any traffic on it is directly supported by the piers. The weight is traveling directly downward. Box girder bridge is one in which the main beams are made up of hollow box-shaped girders. The box girder is typically made of prestressed concrete, structural steel, or a steel-reinforced concrete structure.

The box's cross-section is typically design as rectangular or trapezoidal shape. Highway flyovers and modern elevated light rail transport structures often use box girder bridges. Although a box girder bridge is typically a type of beam bridge, it can also be used on cable-stayed bridges and other different structures. Box girder bridges is made of concrete and be cast in place of falsework supports, and removed after the completion, or built-in sections as segmental bridge (Muhammad Fawad et al, 2019). Box girders may also be prefabricated in a fabrication yard before being transported and mounted by cranes to the site.

2.2.3 Slab

The cast-in-situ concrete slab is by far the most popular type of deck on highway overpasses. This slab is reinforced with steel rebar to offer extra strength that concrete alone could not offer. The slab also usually functions in composite with the bridge structure, making it a common choice when creating a bridge with steel or concrete stringers. As shown in Figure 2.6 is the slab casting in situ on steel girder bridge.

Figure 2. 6: The slab casting on steel girder bridge (Ehab E. 2014)

2.2.4 Substructure

2.2.4.1 Pier

Many factors to determine the form of pier that is chosen. It is based on the type of superstructure. Cantilevered piers, for example, are used to support steel girder superstructures, while monolithic bents are used to support cast-in-place concrete superstructures. Second, it depends whether the bridges are across a waterway or not. Plus, the type of piers is often determined by the height of the piers. To minimize the weight of the substructure, taller piers often require hollow cross sections as shown in Figure 2.7 (Wang, 2000).