NON-LINEAR ANALYSIS OF RC BRIDGE SLAB ON PRESTRESSED BEAMS IN TRANSVERSE DIRECTION

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A project report submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Structure)

School of Civil Engineeing
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2019

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere appreciation and gratitude towards my project supervisor, Associate Professor Dr. Redzuan Abdullah for his encouragement and guidance throughout the whole project, especially on using the LUSAS software. It is truly an honour to be your supervisee as I've learned a lot along the way. I am also thankful to my chief panel, Associate Professor Dr Izni Syahrizal Ibrahim for his suggestions and constructive criticisms on my project.

Lastly, I would like to express my gratitude towards my family, friends and postgraduate course mates for your words of encouragement and spiritual support throughout my period of study here in Universiti Teknologi Malaysia. This project report will not be made possible without each and every one of you.

ABSTRACT

Construction of bridge decks in Malaysia for typical spans of 10m-40m is mostly made of reinforced concrete slab on wide prestressed T-beam. The function of slab is mainly distribute wheel load to the beams. It is well known that the slab designed by consultants is assumed as continuous beams and they are always conservative. The purpose of this study is to determine the ultimate load capacity of the minimum reinforced concrete bridge slab supported by a wide flange T-section girder by conducting a nonlinear finite element analysis. The analysis results are compared with experiment using traffic loading at notional lane 1 of Load Model 1 (LM1) stipulated in EN 1991-2: 2004. Besides, this study is also meant to confirm the minimum transverse reinforcement as proposed by a previous researcher in accordance to clause 6.2.4. of EN 1992-1-1: 2004. Two beam models were analysed which are T-Beam without slab (flange only) and T-Beam with 200mm thick slab on top of the beam flange. The analysis results were validated against experiment results conducted by previous researcher. The findings of the study confirms that the slab supported by wide flange T-beam with minimum reinforcement is sufficient to support Eurocode traffic load. This study warrants further research for construction of concrete slab on T-Beam girders with minimum reinforcement.

ABSTRAK

Dek jambatan yang dibina di Malaysia yang panjang sekitar 10-40m kebanyakannya dibina menggunakan papak konkrit yang disokong oleh girder-T dengan flang panjang. Fungsi papak konkrit adalah untuk mengagihkan beban kenderaan ke girder. Umumnya, papak direka bentuk oleh jurutera perunding dengan mengangap sebagai rasuk selanjar. Rekabentuk ini selalunya amat konservatif. Tujuan kajian ini dijalankan adalah untuk menentukan kapasiti beban muktamad papak konkrit yang disokong oleh girder T-flange lebar pada sebuah komponen jambatan komposit dengan kaedah analisis tidak lelurus unsur terhingga. Hasil analysis dibandingkan dengan dapatan kajian eksperimen oleh penyelidik terdahulu yang menggunakan beban kenderaan pada lorong nosional 1, Modal Beban 1 (LM1) seperti yang ditentukan oleh EN 1991-2: 2004. Dua model dek yang telah dianalisis iaitu girder-T tanpa papak konkrit dan girder-T yang diletakkan pada papak konkrit 200m tebal di atas flange. Hasil analisis telah menunjukkan bahawa kapasiti yang mempunyai tetulang minimum meyemai data ujikaji. Hasil kajian ini menunjukkan bahawa papak jambatan yang dicadangkan oleh penyelidik terdahulu iaitu dengan meletakkan tetulang minimum sahaja sudah memadai untuk menahan beban trafik LM1. Hal ini telah memberi petunjuk bahawa satu kajian yang lebih mendalam berbaloi untuk dilaksanakan agar papak pada dek jambatan boleh dibina dengan tetulang minimum sahaja.

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LIST OF ABBREVIATIONS

2D	-	Two dimensional
3D	-	Three dimensional
D1	-	T-Beam with slab
EN 1991-2: 2003	-	Eurocode 1
EN 1992-1: 2004	-	Eurocode 2
FEA	-	Finite Element Analysis
FRP	-	Fibre-Reinforced Polymer
kN	-	kilo Newton
LFEA	-	Linear Finite Element Analysis
LM1	-	Load Model 1
LM2	-	Load Model 2
LM3	-	Load Model 3
LVDT	-	Linear Variable Displacement Transducers
mm	-	millimetres
N	-	Newton
N/mm^2	-	Newton per area in millimetres
NLFEA	-	Nonlinear Finite Element Analysis
TB1	-	T-Beam without slab
TS	-	Tandem system

LIST OF SYMBOLS

E	-	Young's Modulus
v_{Ed}	-	Longitudinal Shear Stress at web-flange interface
ΔF_d	-	Change in longitudinal force
h_f	-	Height of flange
Δx	-	Distance measured at zero moment
ΔM	-	Change in moment
b	-	Flange width
b_w	-	Web width
d	-	Effective depth of beam
w	-	Load capacity
L	-	Length of beam at z-direction (1m)
$A_{s,min}$	-	Minimum amount of transverse steel
f_{ctm}	-	Mean tensile stress of transverse steel
f_{yk}	-	Yield stress of transverse steel

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

One of the most common types of bridge decks being constructed in Malaysia is using prestressed beams with reinforced concrete slab commonly known as a beam girder deck. The slab is supporting the wheel load and transfer the load transversely to the prestressed beam or known as girder.

The conventional design practices of bridge slab is by assuming the slab as continuous beam supported by the girder as minimum support (Figure 1.1). This type of assumption is very conservative. Hence, bridge decks are often designed with higher amounts of reinforcement areas due to this negligence, making the cost of bridge construction expensive.

This statement is supported by Najiyu (2018) on a modified approach of designing a bridge deck slab on prestressed concrete T-Beam girders. His findings showed that the conventional design method was too conservative due to the neglecting of the strength and geometry of the flange and web thicknesses of the prestressed beams in the analysis of bridge deck structures.

Najiyu (2018) have modified the design approach for the transverse reinforcement of a bridge deck slab, where the geometries and material properties of the flanges and webs of the prestressed T-Beams are considered and tested with both finite element analysis and experiments.

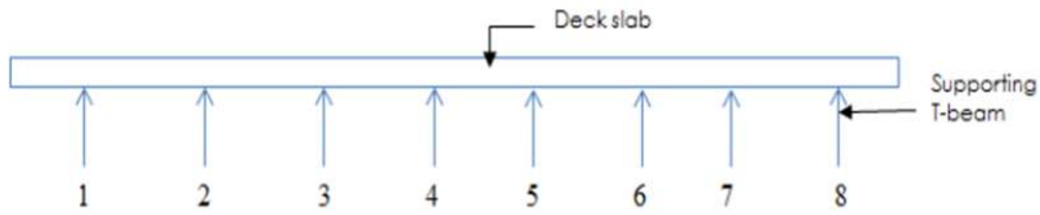

Figure 1.1 Conventional Design Approach of Bridge Deck Slabs with Prestressed T-Beams (Source : Modified Approach for Transverse Reinforcement Design of Bridge Deck Slab on Prestressed Concrete T-Beam Girders, A.Najiyu et al).

The findings of this study have shown that the results from the bridge deck slab analysed with the modified approach produced a significantly lower amount of internal reactions and moments than the conventional design considerations. The percentage difference of the internal reactions, moments and reinforcement area between the conventional and modified approach lies between 190% and 200%. This shows that lesser amount of transverse steel reinforcement in the slab is possible to be done on a bridge deck slab and thus, reducing its cost of construction.

1.2 Problem Statement

Najiyu's (2018) study found that the percentage difference of internal reactions, moments and required steel reinforcement areas at each cases of the analysed bridge girder between the conventional method (consideration of beam girders as supports) and modified method (consideration of the geometries of the prestressed beam's web and flange) has shown significant difference in its results, where the percentage difference of each results obtained ranges from 190 – 200%. Najiyu (2018) then conduct further study by experiment and nonlinear finite element analysis (NLFEA).

The experimental study conducted by Najiyu was following the actual bridge structure but with minimum reinforcement in the slab. It was found that the reduced reinforcement of the bridge deck girders are able to withstand ultimate loadings as high as 489kN (with slab) and is far exceeding the Eurocode vehicle loads. Consequently, this study is conducted to validate the results obtained by the experiment conducting by Najiyu (2018) by conducting NLFEA using LUSAS 14.0.

1.3 Objectives of Study

The objectives of this study includes the following:

1. To determine the ultimate moment capacity of the reinforced concrete bridge deck slab supported by a wide flange T-section girder by conducting a nonlinear finite element analysis (NLFEA).

2. To compare the results obtained from the NLFEA with the experimental results and the Eurocode traffic loading standards.

3. To compare the transverse reinforcement proposed to the bridge deck with the requirements stipulated in EN 1992-1: 2004.

1.4 Scope of Study

The scopes of this study are:

- To conduct a 2D plane stress NLFEA of a bridge deck with and without slab while neglecting the prestressing forces inside the girder.

- The dimensions and material properties of the bridge deck model are based on the experiment conducted by Najiyu (2018).

- The load-displacement curves and the T-Beam's behaviour obtained from NLFEA will be compared with the experimental results by Najiyu Abubakar and the tandem system of Load Model 1 (LM1) bridge loadings in accordance to Eurocode 1 (EN 1991-2:2003).

- The minimum transverse reinforcement proposed by Najiyu Abubakar are validated based on clause 6.2.4 of EN 1992-1: 2004.

1.5 Outline of Thesis

This thesis consists of five chapters. Chapter 1 of this thesis will be the introduction of this study along with the background of the study, problem statements, objectives and scopes of this study.

Chapter 2 will be the literature review of the prior study from Najiyu Abubakar, past researches or findings from similar studies and relevant information to this study such as compressive membrane actions, stress and strain of materials, bond strengths of materials and finite element analysis.

Chapter 3 will discuss the method of conducting this study. The details of the dimensions and materials used on the proposed bridge girder from the experiment will be shown here along with the method to conduct NLFEA with LUSAS. The procedures to determine and validate the minimum transverse reinforcement required according to clause 6.2.4 of EN 1992-1: 2004 are discussed in this chapter also.

Chapter 4 will discuss the findings obtained from NLFEA and the comparison of results with the experiment. This chapter will also discuss the transverse reinforcement provided in the proposed bridge girder from the numerical calculations obtained according to clause 6.2.4 of EN 1992-1: 2004.

Chapter 5 will conclude from the results obtained in this study and provide recommendations for further improvements to this study. This is followed by references and appendices.

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