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THE EFFECT OF TEMPERATURE ON PRESTRESSED INTEGRAL BRIDGE BEAM

MUHAMMAD LUTFI BIN OTHMAN

A report submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil – Structure)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

NOVEMBER 2009

"I declare that this report entitled "*The Effect of Temperature on Prestressed Integral Bridge Beam"* is a result of my own research except as cited in the references. The research has not been accepted for any degree and is not currently concurrently submitted in candidature of any other degree"

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Karya ini adalah dedikasi teristimewa buat emak yang
dikasihi, Hamidah Bt Ahmad, abah yang disayangi, Othman Bin Mustaffa serta adik
tercinta, Fatimah Azzahrah Bt Othman yang tidak pernah jemu membekalkan nasihat,
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ABSTRACT

Most bridges in Malaysia are pre-stressed concrete type and constructed as simply supported beam. Such structural form has maintenance problems due to the existence of joints and bearings which are easily deteriorated. Therefore, the elimination or the minimizing of bearings and joints is very important in order to increase the durability and life span of bridge structure. The Malaysian authority (Jabatan Kerja Raya) has now regulated that bridges with span length less than 60m should be designed and constructed as integral structure. The integral bridge however, is highly indeterminate and the behavior is affected by the change of temperature. The differential thermal effects can cause transverse bending at the middle pear of integral bridge which can result in the uplift. On the other hand, the continuous construction at the ends may result in crack. This research is aimed to develop a finite element model for integral bridge using LUSAS software. After the model is developed and verified, it is used to study the effect of temperature on prestress force in integral bridge beam. The longer the span of the beam, the more the temperature will affect the prestress change. Even in Malaysian condition where the temperature only ranges from 22℃ to 35℃, it is important to consider temperature effects in designing integral bridge.

ABSTRAK

Kebanyakan jambatan di Malaysia ialah jenis konkrit pra-tegasan dan dibina sebagai rasuk sokong mudah. Struktur jenis ini kebiasaannya terdedah kepada masalah penyelenggaraan disebabkan kewujudan sambungan dan bering yang mudah memburuk. Oleh itu, adalah sangat penting untuk tidak menggunakan sambungan dan bering, atau setidak-tidaknya meminimakan penggunaannya agar kebolehkerjaan dan jangka hayat struktur jambatan boleh ditingkatkan. Pihak berkuasa tempatan (Jabatan Kerja Raya) kini telahpun mensyaratkan supaya jambatan dengan panjang kurang daripada 60m direkabentuk dan dibina sebagai struktur integral. Walaubagaimanapun, jambatan integral mempunyai ketidaktentuan yang tinggi selain dipengaruhi oleh kesan suhu. Kesan suhu yang berbeza boleh menyebabkan lenturan ke atas pada bahagian tengah jambatan. Disebabkan itu, sambungan integral pada hujung rasuk mempunyai kemungkinan untuk retak. Penyelidikan ini mensasarkan pembangunan model unsur terhingga untuk jambatan integral dengan menggunakan perisian LUSAS. Selepas model tersebut berjaya dibangunkan dan dibuktikan, model tersebut kemudiannya digunakan untuk mengkaji kesan suhu terhadap daya pra-tegas pada rasuk jambatan integral. Semakin panjang unjuran rasuk, semakin besar kesan suhu terhadap perubahan daya pra-tegas. Walaupun suhu hanya berubah antara 22˚ C hingga 35˚ C di Malaysia, kesan suhu masih sangat penting untuk diambilkira dalam merekabentuk jambatan integral.

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LUSAS	**-**	London University Stress Analysis System *(engineering software)*
ρ_d	-	Dry density of the backfill
α	-	Coefficient of thermal expansion
G_s	-	Specific gravity
ΔT	-	Increased temperature
p'	-	Horizontal stress
h	-	Section depth
e_{max}	-	Eccentricity at mid-span
e_{min}	-	Eccentricity at support
A	-	Area
I	-	Moment of Inertia
M	-	Moment
T_T	-	Temperature at extreme top of fibre
T_B	-	Temperature at extreme bottom of fibre
E_c	-	Modulus of Elasticity
f_{cu}	-	Characteristic strength
E_s	-	Modulus of Elasticity
Ψ	-	Concrete creep coefficient
Φ	-	Curvature
Coef.	-	Coefficient
Temp.	-	Temperature
IB	-	Integral bridge
SSB	-	Simply supported bridge

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 Background Study

One of the most important structures is bridge. In Malaysia, most of the existing bridges were design as simple spans. In simple span construction, joints and bearings are parts of the bridge structure. It is indeed easier for the engineers to design and easier for the contractors to build simple span bridge but on the other hand, because of the joints between the spans of the bridge, it will not be able to provide a smooth riding surface to the public and furthermore a leaking joint will most certainly cause corrosion. The maintenance is also costly as the bearing needed to be replaced after every few years.

Today, integral bridges have been constructed all over the world instead of the conventional simple spans bridges. The advantages of integral bridge have been realized as early as the 60’s. The use of integral deck eliminates the need for deck expansion joints and bearings. More significantly, maintenance costs are also reduced since deck joints, which allow water to leak onto substructures elements and accelerate deterioration, are totally eliminated. In addition, future widening or bridge replacement becomes easier, since the simple design of the integral abutment lends itself to simple structural modification.

1.2 Problem Statement

In recent years, it has been established that a significant portion of the world's bridges are not performing as they should. In some cases, bridges are carrying significantly more traffic load than originally intended. However, in many others, the problem is one of durability. This is often associated with joints that are leaking or with details that have resulted in chloride-contaminated water dripping onto substructures. Problems have also been reported with post-tensioned concrete bridges in which inadequate grouting of the ducts has lead to corrosion of the tendons.

The new awareness of the need to design durable bridges has led to dramatic changes of attitude towards bridge design. There is now a significant move away from bridges that are easy to design towards bridges that will require little maintenance. The bridges that were easy to design were usually determinate, e.g. simply supported spans and cantilevers. However, such structural forms have many joints which are prone to leakage and also have many bearings which require replacement many times over the lifetime of the bridge.

The move now is towards bridges which are highly indeterminate and which have few joints or bearings. The structural forms of bridges are closely interlinked with the methods of construction. The methods of construction in turn are often dictated by the particular conditions on site. For example, when a bridge is to be located over an inaccessible place, such as a railway yard or a deep valley, the construction must be carried out without support from below. This immediately limits the structural forms to those that can be constructed in this way. The method of construction also influences the distributions of moment and force in a bridge. For example, in some bridges, steel beams carry the self weight of the deck while composite steel and in-situ concrete carry the imposed traffic loading.

Integral bridge is advantageous in term of maintenance and long term planning if compared to the conventional bridge. This type of bridge can also be seen as the future bridge as it is stiffer and has been observed that the deflection and moments can be greatly reduced as in case of integral bridge. The elimination or minimizing of bearings and joints is important as they are fragile elements and represent the weakest links in bridge structures. Joints are expensive to buy, install, maintain and repair. Sometimes repair costs can run as high as replacement costs. Successive paving will ultimately require that joints be replaced or raised. Even waterproof joints will leak over time, allowing water salt-laden or otherwise, to pour through the joints accelerating corrosion damage to girder ends bearings and supporting reinforced concrete substructures. Accumulated dirt, rocks and trash fill Elastomeric glands leading to failure.

Bearings are also expensive to buy and install and more costly to replace. Over time, steel bearings may tip over and seize up due to loss of lubrication or buildup of corrosion. Elastomeric bearings can split and rupture due to unanticipated movements or ratchet out of position. Teflon sliding surfaces are fragile for bridge applications and can fail prematurely due to excessive wear from dirt and other contaminants, or due to poor fabrication and construction tolerances. Pot bearings also suffer frequent damage due to poor fabrication and construction techniques.

Integral bridges are characterized by monolithic connection between the deck and the substructure. Such bridges are the answer for small and medium length bridges where bearings and joints are either eliminated or reduced to minimum. The integral bridge concept is an excellent option to incorporating reduced inspection and maintenance features in the bridge structures. However, it is more complicated to design and the secondary restraint moments can develop at the connection due to creep, shrinkage, and thermal effects.

In Malaysia, this type of bridge is still not widely used because of its complexity and the lack of knowledge and experience within Malaysian construction industry.

The purpose of experimental study presented in this paper was to compare the restraint moments that developed during the early ages of continuity to the predicted restraint moments using finite element program, LUSAS. It is important to be able to accurately predict the restraint moment because:

i. Underprediction leads to unconservative designs and the potential for damage to cracking at the continuity connection
ii. Overprediction may force the designer to use simple span design instead of continuous design

1.3 Research Objectives

The objectives of this research are:

1. To study the effect of temperature gradient on the prestressing force in prestressed integral bridge beam
2. To study the effect of uniform temperature change on the prestressing force in prestressed integral bridge beam
3. To determine whether temperature effects can be neglected in integral bridge design considering Malaysian condition

1.4 Research Questions

By the end of this research, it is aimed that the following questions will be answered

1. How integral bridge response to temperature effect?
2. How does the prestress force reacts to temperature loadings?
3. Is it true that integral bridge beam is better than simply supported beam?
4. Can the temperature effects be neglected at certain span of the integral bridge?

1.5 Scope of The Research

In order to finish this research within the limited time, the following scopes are being considered:

a. The simulation of the integral bridge will be developed using LUSAS program and will be verified by consulting superior LUSAS users

b. The temperature gradient is fixed between 0 ˚C to 40 ˚C and the span length between 20m to 40m
c. Typical design of integral bridge consists of the beams, piers and abutments is used
d. The temperature effect studied only consider Malaysian condition