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THE EFFECT OF CREEP ON PRESTRESSED SIMPLY SUPPORTED AND INTEGRAL BRIDGE BEAMS

MOHD FAIRUZ BIN OMAR

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

Faculty of Civil Engineering
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NOVEMBER 2009

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Dedikasi khas buat ayah bonda dan keluarga tersayang
yang sentiasa mendoakan kejayaanku siang dan malam.
Terima kasih juga kepada rakan-rakan atas sokongan
yang tidak berpenghujung. Moga dilindungi-Nya
dunia dan akhirat.

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ABSTRACT

Bridge construction is one of the most important components of infrastructure development of the country. As the country develops, construction of the bridges is also increases. In Malaysia, most bridge decks are built using prestressed concrete beams supported either simply or integrally with the abutment. Under sustained compressive load due to prestressing force, the concrete beams will creep. As the result, the effective prestressing force may reduce. This thesis presents the results of a study on the effect of creep on the effective prestress force in prestressed beam. Both simply support and integral construction beams are considered. From the analysis, it is found that the integral bridge system is better than simple supported system in term of creep resistance. As indicated by vertical displacement and prestress loss, the creep is active in the prestressed beams up to 7 to 10 years for 20 to 40 meter span beams. Beyond this period, the creep gradually stops. Besides, the beam span length does not affect the amount of creep.

ABSTRAK

Pembinaan jambatan merupakan salah satu komponen yg sangat penting dalam pembangunan infrastruktur sesebuah negara. Seiring dengan pembangunan infrastruktur ini, permintaan terhadap pembinaan jambatan juga turut meningkat. Di Malaysia, kebanyakan jambatan dibina menggunakan konkrit prategas yang dibina secata disokong mudah mahupun secara terkamir. Di bawah beban manpatan yang lama seperti daya prategas, rasuk konkrit ini akan memendek atau mengecut. Lantaran itu, daya prategas berkesan mungkin berkurangan. Tesis ini mengkaji kesan *creep* terhadap daya prategas berkesan dalam rasuk prategas. Kedua-dua jambatan jenis disokong mudah dan rasuk terkamir diambil kira. Daripada analisa yang dilakukan, didapati jambatan rasuk terkamir lebih baik dalam menangani masalah *creep* berbanding jambatan disokong mudah. Seperti yang ditunjukkan oleh lenturan pugak dan kehilangan prategas, fenomena *creep* hanya aktif pada 7 hingga 10 tahun pertama bagi panjang rentang 20 hingga 40 meter selepas beban dikenakan pada rasuk. Selepas itu, kesan *creep* berkurangan secara perlahan. Selain itu, perbezaan panjang rentang jambatan juga tidak mempengaruhi jumlah *creep*.

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CHAPTER I

INTRODUCTION

1.1 Background of Study

Instead of simple span, recent bridges are designed and constructed in continuous spans and the number of such bridges design is increasing. This is because the number of joints in a bridge, corrosion caused by leaking joints can be reduced and the traveling public receives a better riding surface. In addition, a continuous system is tougher because it create redundancy in the system.

In general, integral bridge can be defined as a structure where the superstructure and substructures are continuous of integral with each other[1]. Conventional bridge system usually required more rehabilitation due to serviceability problems associated with the joints. Consequently, integral construction has recently received a great deal of attention and this form is likely to become more widespread in the future. Since the structure is designed to be continuous, it becomes much more difficult to predict the structural response of the system. Thus, further study on this area should be considered to ensure the design is safe and cost effective.

1.2 Problem Statements

Conventional prestressed concrete beam used for bridge deck are usually constructed by simple support at both ends. This type of construction requires the joint system to connect between two spans, from beam to pier and as well as beam to abutment. This joint system will automatically involve the maintenance work such as joint inspection and replacement of bearing pad. At the same time, the equipment for this maintenance is so expensive and need proper provision from expertise.

In addition, the present of joint will trap the rain water and this will increase the tendency of water absorption into the structure. This will induce the probability of steel corrosion to the structure. Moreover, the joint will make the travelling public feel uncomfortable riding surface since the material to seal the joint is not as smooth as the road pavement.

At the same time, shrinkage and creep are also affecting the prestress force in prestressed beam. This creep will reduce the prestress force and can lead to beam or bridge failure specifically. Proper prestress design must be carried out to ensure that the effect creep in prestress loss can be minimized to avoid any possibility.

The integral bridge or also known as jointless bridge, has achieved wide application in many countries due to its low construction and maintenance costs. Thus, with this research, the behavior of integral bridge can be understood and new model can be developed to suit the construction demand nowadays.

1.3 Research Objectives

The objectives of this study are:

1. To study the ability of integral bridge system in overcoming the prestress loss due to creep.

2. To determine the minimum time for creep to affect the prestress force of the beam.

3. To determine whether length of span will affect the amount of creep.

1.4 Research Questions

Based on this research, it is a hope so that the following research questions will be answered clearly:

1. Is it possible to use integral bridge system to overcome creep problem in bridge prestressed beam?

2. What is the maximum time for creep to affect the bridge structure?

3. Does the length of span influence the amount of creep?

1.5 Significant of Study

The purpose of this model development study is to see how far this creep affecting prestress force in beam and how this creep and prestress force react in integral bridge. As we know, the phenomenon of creep is the source of many problems in design. Consequently, there is a need for the designer to predict whether the components operating in the creep range will sustain the life required of the structure.

This creep effect in structure especially in beam will cause the following;

1. Excessive deformation of structure.
2. Rupture in structure.
3. Unacceptable rates of latent flaws or initiated crack caused by creep.
4. Prestress loss due to creep.
5. Additional moment and axial force in members for integral structure.

With this research, new model of integral bridge can be developed with approximately accurate prediction which will give a positive respond to construction cost and also can improved the construction speed.

Through this research, the prestress loss due to creep can be determined and understand. If this behavior can be understand, all the design process for integral bridge can be easily and we can get a better design from the previous design.

1.6 Scope of Study

Since the research has its own time constrain, several limitation have been made to ensure that the research can be completed within the time given. Follows are the limitations of this research;

1. The study is only interested in simply supported and integral bridge with prestressed beam.
2. The prestress loss is based in vertical displacement.
3. The prestressed beam is considering only single post-tension tendon.
4. The cross-section of beam considered is same along the span.
5. The model is a single span bridge.
6. The model is only for 20, 30 and 40 meters span.
7. The creep model is based on CEB-FIP Model Code 1990.
8. The model is developed using LUSAS 14 and all the result is based on the capability of this software.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Integral bridge can be defined as a bridge which the substructures and superstructure are continuous or integral with each other. Recently, integral construction has received a great deal of attention and this can be predicted to become much more widespread in the future. Previously, many bridges were constructed with expansion joints and bearings to separate the superstructure from substructure as well as the surrounding soil. This old method will leads to periodic rehabilitation due to serviceability problems associated with the joints and bearings. Consequently, bridge engineers have been trying to design bridges as jointless structure to minimize the cost of maintenance. In Malaysia particularly, the designers are now required to consider the use of the integral form for most bridges less than 60 m span.

There are many types of basic integral bridge. For example, Figure 2.0 shows the deck is composed of separate precast beams in each span. Previously, such deck might have had a joint over the central support. In-situ concrete is used to form a jointless span so that a more durable construction can be archived. Figure 2.1 show the deck is continuous over interior support and integral with abutments at the ends. Meanwhile, Figure 2.2 illustrates another variation of integral bridge with both abutments and the pier is homogenous.

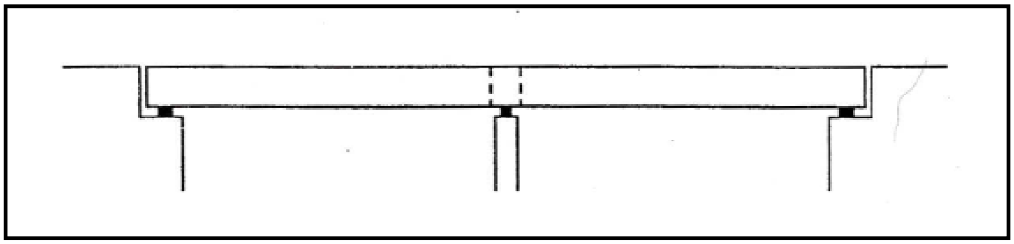

Figure 2.0: Precast beams made integral over the interior support (O'Brien E. J., 1999)

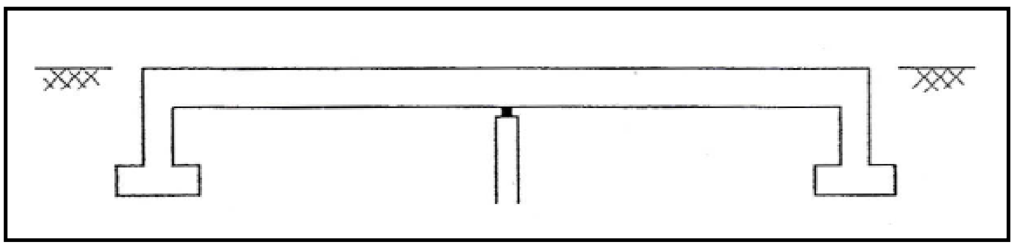

Figure 2.1: Deck continuous over interior support and integral with abutments (O'Brien E. J., 1999)

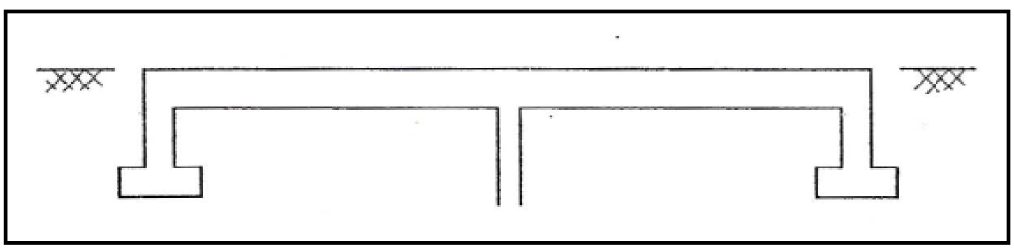

Figure 2.2: Deck integral with abutments and pier (O'Brien E. J., 1999)

2.2 Integral Bridge Behavior

Since the joints and bearings are removed, their removal does affect the bridge behavior. Basically, the contraction and the expansion of the deck are restrained with the result that additional stresses are induced and must be resisted by the bridge structure. The most obvious cause of expansion and contraction in bridges of all forms is temperature change but the other causes exist, such as creep and shrinkage.

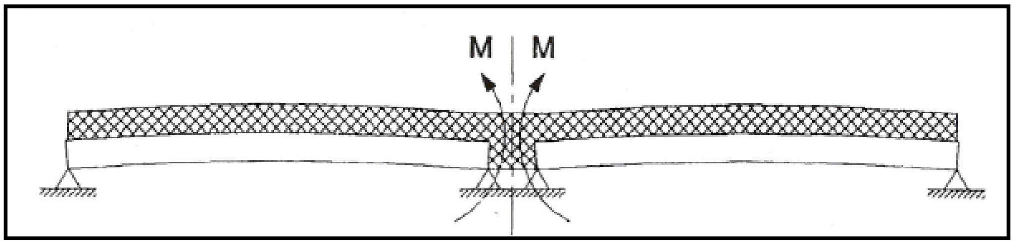

Figure 2.3: Restraint against upward movement, positive secondary moment (O'Brien E. J., 1999)

It has long been recognized that positive secondary moments developed at piers of continuous prestressed concrete bridges when the deck is cast at a relatively young beam age. In this instance, creep of the beam under the influence of prestressing predominates the response and causes an upward bow. The restraints from pier and adjacent spans result in positive secondary moments at these supports as shown in Figure 2.3. Conversely, differential shrinkage, with newer deck slab concrete shrinkage more than the beam, causes the continuous structure to bow download and result in negative secondary moments at the supports.

2.3 Creep

Creep and shrinkage of concrete are complex phenomenon which is not yet understood completely. Therefore, research in this area still continues actively until recently. Based on past experimental findings on creep and shrinkage, it is believed that the origin of creep is in the microstructure of the cement paste binding the aggregate and the sand grains. The basis of this binding agent is the cement gel, which is very homogeneous material with a colloidal character. It contains chemically bonded water, colloidal water in the gel pores and free water in the capillaries and macropores. Under the effect of a long-term stress in concrete, the water, which is not bonded chemically, is extruded from the gel micropores into the capillaries, from which it evaporates. The extrusion of water is determined by the stress of concrete whereas the evaporation depends on the hygrometric conditions of the ambiance. The time-dependent deformation under sustained load due to loss of water is termed drying creep. Hence, the magnitude of creep depends on the stress in concrete, concrete mix properties and degree of hydration of concrete. It is also affected by the ambient conditions and temperature.

Wittmann F.H. (1982) claims that short-time creep is caused by a stress induced redistribution of capillary water within the structure of hardened cement paste and as well as the water movement and redistribution in the porous structure. For short-time creep we could identify one creep mechanism. For long-time creep the situation is far more complex. The xerogel forms a solid skeleton in hardened cement paste. This porous system interacts with adsorbed and capillary condensed water. In the unloaded state all gel particles are fixed to their surroundings partly by primary bonds and partly by secondary bonds. It is impossible to indicate quantitatively and in detail the bonding of an individual gel particle. But we can estimate the average coupling force.

If creep takes place the coupling force of a larger number of gel particles has to be overcome so that these particles can leave their original position in the xerogel. This movement can be looked upon as playing the role of displacement of dislocation, and vacancies in crystalline materials. Long-time creep in hardened cement paste is in fact the consequence of displacement of gel particles and to some extent creep within particles under high concentrated stress. To describe the creep process realistically we do not necessarily need to know all the different processes involved. If we know well enough the average values and if the number of particles and events is high enough we can apply rate theory. In a colloidal system such as hardened cement paste these two conditions are fulfilled. Therefore we will try to characterize the essential creep mechanisms by introducing basic elements of rate theory.

2.3.1 Factors Influencing Creep

Concrete that exhibits high shrinkage generally also shows a high creep, but how the two phenomena are connected is still not understood. Evidence suggests that they are closely related. When hydrated cement is completely dried, little or no creep occurs. For a given concrete the lower the relative humidity, the higher the creep. Strength of concrete has a considerable influence on creep and within a wide range creep is inversely proportional to the strength of concrete at the time of application of load. From this it follows that creep is closely related to the water-cement ratio. There is no doubt also that the modulus of elasticity of aggregate controls the amount of creep that can be realized and concretes made with different aggregates exhibit creep of varying magnitudes.

Creep of plain concrete does not by itself affect strength, although under very high stresses creep hastens the approach of the limiting strain at which failure takes place. The influence of creep on the ultimate strength of a simply supported, reinforced concrete beam subjected to a sustained load is insignificant, but deflection increases considerably and may in many cases be a critical consideration in design. Another instance of the adverse effects of creep is its influence on the stability of the structure through increase in deformation and consequent transfer of load to other components. Thus, even when creep does not affect the ultimate strength of the component in which it takes place, its effect may be extremely serious as far as the performance of the structure as a whole is concerned.

The loss of prestress due to creep is well known and accounted for the failure of all early attempts at prestressing. Only with the introduction of high tensile steel did prestressing become a successful operation. The effects of creep may thus be harmful. On the whole, however, creep unlike shrinkage is beneficial in relieving stress concentrations and has contributed to the success of concrete as a structural material.