UNIVERSITI PUTRA MALAYSIA

PREDICTION OF STRUCTURAL RESPONSE OF DISTRESSED BRIDGE USING FINITE ELEMENT METHOD

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Prediction of Structural Response of Distressed Bridge Using Finite Element Method

By

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A Project Report submitted in partial fulfillment of the requirements for the Degree of Master of Science in the Faculty of Engineering Universiti Putra Malaysia, Serdang, Selangor

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PROJECT APPROVAL SHEET

This project report attached hereby, entitled **"Prediction of Structural Response of Distressed Bridge Using Finite Element Method"** and submitted by **Shreeram Krishna** in partial fulfillment of the requirement for the degree of Master of Science (Structural Engineering & Construction) is hereby attached.

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ABSTRACT

Bridges must be evaluated to make sure they are capable of carrying the present load and most importantly the future load within the serviceability limit. The analysis of the loads consists of measuring the load distribution and the effect on the structural components. This can be done experimentally using the available field test instruments or also known Proof Load Test. The main objective of the field test is to measure the deflections, stresses and strains at the critical bridge components subjected to a predetermined load.. However, field test can be expensive in terms of cost and time. The development of a realistic analytical model seems to be an alternative to provide a supplementary load capacity assessment with lesser cost and time. This paper will provide a comprehensive review on the Finite Element Model prediction on the structural response of a distressed bridge with comparison made to the actual response obtained from the field load test results. Comparison reveals that the predicted model behaves similarly to the actual bridge response under live loading but it was also noted some variation or difference in term of the magnitude of responses. These differences are mainly attributed to the existence of field factors which were not included in the model.

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NOTATION

Z =safety margin

R = resistance of the component

D & L =dead and live load respectively

R = resistance margin for live load

L =can represented by five independent lognormal random variables according to Moses and Ghosn [1985]

A =constant relating truck gross weight to load effects.

W_{95} =characteristic weight representing the truck weight distribution

H =multiple truck presence on the bridge

M =variation in truck configuration.

G =load distribution factor

I =impact load factor

P_f =failure probability [Z<0]

P_s = survival probability [Z>0]

β =safety index

Ie =stiffness of equivalent beam element

ts =thickness of slab

tf =thickness of top flange of prestressed girder

Le =length of longitudinal element.

Ec = effective compressive modulus for bearing (AASHTO 1998)

Px =vertical force applied

x =vertical deflection corresponding to *Px*

kx =equivalent beam stiffness in vertical direction

E	=modulus of elasticity for bearing
h	=total height of bearing
Mtest-ex	=total applied external moment
Mtest-in	=total measured internal moment
MFEMin	=total predicted internal moment
Sj	=section modulus of composite section
Ec	=elastic modulus of concrete
εj	=strain
LDF	=load distribution factor
RF	=rating factor
Mu	= ultimate strength
Mn	=ultimate load demand
ε_m	=measured strain
ε_c	=calculated strain
I_{xx},	= moment of inertia at longitudinal direction
I_{yy}	= moment of inertia at transverse direction
C	=torsion constant

CHAPTER 1

INTRODUCTION

1.1 Problem Statement

Increase in vehicle loads, degradation and general corrosion of bridges often leads to a need to assess their load carrying capacity. Recent studies indicate that almost 40 percent of the national bridges in the country are defiant. The problem of an aging and rapidly decaying infrastructure is an issue facing many agencies charged with maintaining a fully functioning transportation system. Field testing is an increasing important topic in the effort to deal with the deteriorating infrastructure, in particular bridges and pavements. There is a need for accurate and inexpensive methods for diagnostic, verification of load distribution and determination of the actual load carrying capacity.

The deficient bridges are posted, repaired or even replaced. The disposition of bridges clearly involves clear economical and safety implications. To avoid high costs of replacement and repair, the evaluation must accurately reveal the present load carrying capacity of the structure and predict loads and any further changes in the capacity in applicable time span of the structure.

Accuracy of bridge evaluation can be improved by using the recent developments in bridge diagnostic, structural tests, material tests, structural analysis and probabilistic methods. These involved the proof loading concept or also known as Load Test to evaluate the capacity of a bridge in order for Load Rating. Load Testing can also be carried out on newly constructed bridges to provide data about the novel methods of design or construction and give assurance about the performance of the bridge. In the past, this was fairly common in the UK but has rarely been carried out in recent years. In contrast, new bridges are routinely load tested in some countries, for example in Switzerland (Hassan et al 1995).

In the UK the introduction of heavier lorries from Europe started a programme of assessment of all the bridges. This resulted in the production of Guidelines for Load Testing. The Guidelines define and distinguish the types of static load testing to be carried out on bridges. The proof loading method is the approach to determine the actual load carrying capacity of a bridge. The proof loading will give the realistic field measurement results in terms of deflection, strain, rotation and cracks at critical section by applying a load model distribution at the bridge deck. Sand bag, water bags, concrete blocks and real axial load are the common load model used for the assessment.

The viability of the use of a physical load test on bridge structure are governed by the safe application of the load model and the economical advantage from the load test. BA 54/94 has included " Supplementary Load Test" in addition to physical load testing. Supplementary load testing, as the name implies, is carried out to supplement numerical calculations and most importantly, loads are sufficient to give measurable responses without causing permanent strain or damage. The instrumented physical load test have been used to calibrate analytical models in order to take advantage of the actual performance of the bridges without causing any damages.

Bridges in United Kingdoms designed before introduction of BD 37/88 loading are being assessed for live loads including 40 tonne vehicles. The assessment programme started in the mid-1980's to bring allowable gross vehicle weights in line with other European countries. A number of bridges have failed assessments mainly as a result of lower original design loads or because of strength deterioration. In concrete bridges strength reductions have mainly due to corrosion of reinforcement and prestressing tendons but in extreme cases poor concrete quality, coupled with defective waterproofing and bad detailing has permitted the ingress of water and de-icing salts and this has resulted in severe corrosion.

A considerable number of Malaysian bridges were constructed in 1970's and 1980's. Many of them showed signs of deterioration. In particular there is a severe corrosion on many steel and concrete structures. The increased of vehicle load spectra has been remarkable over the few decades and there is doubts on the reliability of the old bridges to withstand and perform to the present traffic load condition. By analytical methods, some of these bridges are not adequate to carry the normal highway traffic. However, the actual load carrying capacity is often higher than what can be determined by analysis, due to more favorable load sharing, effect of non-structural components such as parapets, railing , sidewalks and other difficult to quantify factors. Field testing, in particular proof loading can reveal the hidden strength reserve and thus verify the adequacy of the bridge. An important consideration in field testing is traffic control and safety of the bridge during the testing programme. The bridge need to be assessed in terms of load rating prior to the application of the real load effects and the monitoring of the bridge response have to be carefully and precisely evaluated under the elastic behavior when the loads are being applied. Failure in the correct assessment of the load rating will cause the bridge to response under over rated vehicle load model that leads to severe cracking and high possibility of collapse.

Full scale bridge tests provide very useful information about the global performance and the structural behavior of the bridge. However, field test does not reveal the localized effect of performance at the critical section of a bridge especially at the high shear and high moment area. There is a need for significantly more test data, covering various type of bridges but extensive field test programme are very costly and time consuming and cause traffic constraint. There is a need for testing methods which do not require closure of the bridge or even damaging the bridge. Therefore, a considerable effort should be directed towards evaluation and improvement of the current analytical methods on the basis of available test data.

1.2 Objective

In the previous chapter, the application of the field test to determine the structural performance of the bridge and the limitation has been discussed. A complete and efficient evaluation of bridge must incorporate both Field Testing and Analytical Methods. Analytical methods alone can be sufficient to make an accurate evaluation of a bridge. The designer has the option of using simple to more complex analysis such as Finite Element Method for the model. Also, FEM can be very accurate and help the engineer to predict the bridge behavior under certain conditions. If the bridge fails the analytical test then the engineer can decide whether to apply field test. The combination of both methods leads to an efficient evaluation and provide a supplementary solution because each takes into account what the other methods does not and helps the engineer to get a fuller perspective and understanding of the bridge system. In view of these facts, four prime objectives have been underlined in this paper to supplement the current field test application in Malaysian bridges to the development an analytical model to provide a check and balance evaluation and calibrate the model to represent the actual performance of the bride under field testing. The three objective of this paper will consist of the following:

i. A comprehensive review on the load test results on bridges

A comprehensive review will be carried out on numerous bridges to evaluate the measured parameters during the field test (e.g. stress, strain, deflection, rotation, cracks, load effect and others). The criteria for field test will also be reviewed focusing on the bridge deterioration and increased vehicle load

ii. One bridge will be selected for theoretical modeling using Finite Element Method

One bridge will be selected for theoretical evaluation and modeling using the Finite Element Method. In this paper, these method are used to predict the structural response of a distressed bridge based on the field measured parameters such stress, strain and deflection. The most important process in this section will involve the distress modeling of the structure if it's been assessed for deteriorated bridge and load effect model using the different method of analysis.

iii. Examine the difference between the predicted and the measured load test results.

The results obtained from the field load test results from the selected bridge will then compared to the theoretical model. The differences will be notified and the models will be calibrated to the actual results using certain assumption. These assumptions will be discussed thoroughly in order to understand the field factors that contribute to the differences between the actual response and the predicted using finite element method.

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