UNIVERSITI PUTRA MALAYSIA

STRUCTURAL ASSESSMENT OF DISTRESSED BRIDGES AS AN AID TO DEVELOPMENT OF AN EXPERT SYSTEM

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The aim of this project is to develop a knowledge-base system to provide the rating system in analysing the effect of the various distresses on the structural behaviour of the deteriorated reinforced concrete beams bridge. This knowledge-base system is prepared for the " Structural Assessment " part and use in an overall Comprehensive Expert System for bridge conditional assessment and evaluate the residual life of the bridge. In addition, the knowledge-base system can also help the experts in making decision/rating during the early Condition Assessment stage.

In this investigation, the structural response of reinforced concrete beams bridge subjected to loss of concrete under JKR-SV loading is presented. The JKR-SV loading is adopted in this analysis because it provides the most critical load effect on the overall performance of the bridge. The problem most commonly found in bridges that are subjected to high chemical environment or overloaded i.e. cracking, crushing of concrete and spalling of the cover to the reinforcement has been simulated by loss of concrete. The study in this project focuses on the

effect of the location, length of losses and depth of the concrete loss on the structural behaviour of reinforced concrete beam. The effect of the bridge span, dimension of the beams and the amount of tension steel to the structural performance of the reinforced concrete beam under JKR-SV loading were also been taken into consideration.

Non-linear analysis using finite element method (FEM) had been carrying out to take care about the material non-linearity. In the analysis, 2 fields of consideration had been made: i) Yielding stresses of the bottom reinforcement at the location of maximum moment. ii) Vertical displacement, Dy at the mid-span of the beam. The yielding load has been adopted as a failure criteria and deflection at JKR-SV load were compared with a control beam having no defect.

Based on the results obtained from the finite element analysis, a new rating scheme had been proposed considering the serviceability and strength requirement of the beam. By using Visual basic, a knowledge-base system had been developed to expert opinions on the structural behaviour for the deteriorated reinforced concrete beam bridges. Finally, this user-friendly system is used to assist an engineer in analysing the effect of the variation distress on the load carrying capacity of the bridges.

Abstrak thesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

PENILAIAN STRUKTUR KEATAS JAMBATAN YANG MENGALAMI KEROSAKAN DENGAN TUJUAN MEMBANGUNKAN SATU SISTEM PAKAR

Oleh

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Tujuan projek ini ialah untuk membangunkan satu sistem "knowledge-base". Sistem ini menyediakan satu sistem kadar tersendiri dan ia digunakan untuk menganalisis kesan dari pelbagai kerosakan terhadap tabiat struktur yang dialami oleh jambatan jenis rasuk konkrit. Sistem "knowledge-base" ini disediakan untuk bahagian "penilaian komponen struktur" sahaja, "penilaian komponent struktur" ini merupakan sebahagian daripada keseluruhan "Expert System" yang disediakan untuk penilaian jambatan dan juga penaksiran baki hayat jambatan. Sebagai tambahan, system ini juga boleh membantu pakar-pakar dalam membuat penentuan terhadap penilaian keadaan janbatan pada peringkat awal.

Dalam penyelidakan ini, kesan tindakbalas tabiat struktur dalam jambatan jenis rasuk bertetulang terhadap kehilangan konkrit dibawah beban SV dikemukakan. Beban JKR-SV dipilih dalam analisis ini kerana ia memberi kesan beban yang paling kritikal terhadap keupayaan keseluruhan sesebuah jambatan. Masalah yang paling umum ditemui pada jambatan yang didedahkan kepada persekitaran

yang bersifat kimia tinggi atau lebihan beban ialah seperti keretakan, letusan dan hancuran konkrit telah disimulasi sebagai kehilangan konkrit. Kajian dalam projek ini ditumpukan kepada kesan dari kedudukan, panjang dan kedalaman bagi kehilangan konkrit keatas tabiat struktur dalam rasuk bertetulang. Kesan yang disebabkan oleh panjang jambatan, dimensi rasuk dan juga jumlah besi tegangan yang digunakan keatas tabiat struktur rasuk dibawah beban SV juga diberi perhatian.

Analisis tak-linear telah dijalankan dengan bantuan "Finite Element method" untuk mengambil berat tentang sifat ketidak-linearan bahan. Di dalam analisis ini, dua bidang telah diberi pertimbangan: i) ketegangan dalam besi tegang di lokasi mana lenturan maksimum. ii) perubahan kedudukan secara menegak, D_y di kedudukan tengah rasuk. Beban ketegangan di pilih sebagai kriteria kegagalan dan perubahan kedudukan semasa beban SV telah dibandingkan dengan rasuk kawalan yang tidak mengalami sebarang kerosakan.

Bedasar kepada keputusan yang diperolehi daripada analisis berdasarkan teori, kadar baru telah dicadang menimbangkan perkhidmatan and juga kekuatan yang diperlukan dalam rasuk. Dengan menggunakan "Visual basic", satu "knowledge-base" system telah dibangunkan untuk membekal ulasan dari segi tabiat struktur kepada jambatan jenis rasuk yang mengalami kerosakan dengan berdasarkan tahap kerosakan mereka. Akhirnya, system mesra pengguna ini akan digunakan oleh para jurutera untuk menganalisa kesan terhadap variasi kerosakan keatas keupayaan menanggung beban oleh jambatan.

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CHAPTER 1

INTRODUCTION

1.1 General

Evaluation of deterioration, assessment of load carrying capacity and lifetime estimates of reinforced concrete bridges and the selection of counter measures for repairing damaged bridge are very important for the bridge authorities, as well as public. The assessment and repair works have been carried out by the bridge authorities by using their own inspection codes and based on their experiences.

Assessment of distress to a structure from any disturbance, natural or man made is a difficult process that requires significant human judgement. This process is complicated by the fact that the information needed to make a distress assessment with high confidence is incomplete and involves uncertainty.

Although there is objective information available to the expert in the form of test data, the question of damage assessment is strongly tied to expert judgement. Thus the quality of the assessment process is highly dependent on an expert's knowledge of the actual situation under study. With development of an expert system, information and its associated uncertainty can be used in an expert system, which attempts to reach conclusions and recommendations in regard to the conditional assessment about damaged bridge.

Currently, much research effort is being focused on the deterioration of reinforced concrete, particularly in the area of decay processes and repair

technology. This problem is most commonly found in bridges and parking garages that are subjected to high chemical environment. In attack of the chloride ion (Cl^-) and reduction of the alkalinity of the concrete, this will allows oxidation of the reinforcement steel to take place. The oxidation process will leads to cracking of concrete and spalling of the cover to the reinforcement.

The loss of cover will also cause the steel corrosion due to chemical, climate and temperature attack. Debonding of reinforcing steel from its surrounding concrete is an immediate structural consequence of the corrosion of the embedded metal, subsequently leads to changing of flexural response of reinforced concrete elements.

Concrete and steel can only develop their full potentiality with respect to strength and stiffness when bond between them if perfect. The magnitude of steel tensile stress is increased in the region of bond loss, and it cannot be redistributed through bond stress. Therefore, all of the tensile stress is instantaneously directly into reinforcing steel, which results in stress concentration that demonstrated by premature yielding of the reinforcing steel.

The residual strength of the bridge will depend on the amount and location of the concrete loss from the beams and/or the slab. The problem is further aggravated in case of pre-stressed bridges where the losses of concrete affect the stresses in the pre-stressing wires.

1.2 Scope and Objectives

a) To investigate theoretically the structural behaviour and performance of a distressed reinforced concrete beam subjected to the JKR-SV loading (bridge live load).

b) To determine the effect of the location, length and depth of the concrete loss on the structural performance of reinforced concrete beam bridges having different amounts of tension reinforcement steel.

c) To propose two different rating systems considering the serviceability (deflection) and yield status of the beam (yield load).

d) To develop a knowledge-base system to analyse the effect of the concrete loss (spalling) on the structural capacity of the beam bridges.

To achieve the stated objectives, finite element method (FEM) has been used to analyse a number of reinforced concrete rectangular beams subjected to the JKR-SV loading. The analysis considers the non-linear characteristics of concrete and steel reinforcement with their failure mechanism. The structural response of the different beam models has been found in terms of the maximum deflection and yield load.

1.3 Structure of The Thesis

The thesis is divided into five chapters. A brief description of the content of these chapters is presented below:

The importance and the definition of the problem chosen for the present investigation have been highlighted in chapter 1 along with the scope of the study.

A literature survey of references in various areas relevant to this research is presented in chapter 2.The survey started with the deterioration of reinforced concrete elements in bridges, which explained the structural effect of the loss of concrete and exposure of the reinforcement to the reinforced concrete elements in bridges. The literature on methodology for evaluating the bridge capacity and the estimation of residual strength of the bridge are also presented. The survey also covered the modelling of distresses using finite element method and finally the application of expert system in safety assessment of existing structure also been included in this chapter of literature.

In chapter 3, the theoretical consideration in analytical models of concrete in 2 dimensional problems and the LUSAS finite Element System have been presented.

The methodology of theoretical analysis using LUSAS Finite Element System is discussed in chapter 4. It consists of selection of bridge live loads according to JKR Specification and modelling of the distressed reinforced concrete beams.