SEISMIC VULNERABILITY STUDY OF GUILLEMARD RAILWAY BRIDGE

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For my beloved family

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ABSTRACT

Malaysia is surrounded by countries that had experienced many great earthquakes. Records have shown that we do sometimes experience some off-set tremors originating from the Indonesian zone. Therefore it would be unwise to totally ignore the effects of earthquakes on structures. The purpose of this study is to present the results of the case study of the earthquake response on the Guillemard Railway Bridge. The bridge had been remodeled using SAP 2000. The behavior of Guillemard Railway Bridge under the earthquake loading can be obtained by analyzing the Free Vibration Analysis, Time History Analysis and Response Spectrum Analysis with different levels of ground acceleration (0.074g, 0.15g, 0.25g and 0.35g), in different directions (x, y, z). Moment and shear force capacities for each element are calculated to enable comparison to be made between element capacity and element loading. The purpose is to check to what extend Guillemard Railway Bridge could survive under different ground acceleration and to identify the critical part of the bridge under earthquake loading. From the results, it is noticed that the column failure could occur even in low intensity earthquake acceleration. Deck failure is caused by its inability to hold the design ultimate resistance moment of earthquake loading. Earthquake which happens in horizontal transverse direction has very little effect to the seismic performance of the bridge deck. The bridge deck may fail when earthquake happens in vertical direction, under all various earthquake intensities. For horizontal longitudinal earthquake direction, the bridge deck is safe up to 0.15g earthquake intensity. The most earthquake-vulnerable part of Guillemard Railway Bridge is the fourth span and the fourth pier. Moreover, the top chords at the highest point of the truss and the connection between the spans also most likely to be vulnerable if earthquake occur.

ABSTRAK

Malaysia dikelilingi oleh negara-negara yang kerap mengalami gempa bumi. Rekod telah menunjukkan kesan gempa bumi dari kawasan gempa bumi Indonesia kadang kala dirasai juga. Maka, pengabaian kesan gempa bumi ke atas struktur adalah perbuatan yang kurang bijak. Tujuan kajian ini adalah untuk mempersembahkan keputusan respon Guillemard Railway Bridge terhadap gempa bumi. Jambatan ini telah dimodelkan semula dengan menggunakan SAP2000. Kelakuan Guillemard Railway Bridge di bawah pembebanan gempa bumi boleh diperolehi dengan menjalankan analisis Free Vibration, analisis Time History dan analisis Response Spectra, dengan mengenakan pelbagai keamatan gempa bumi (0.074g, 0.15g, 0.25g dan 0.35g) pada arah yang berlainan (x, y, z). Kapasiti momen dan kapasiti daya ricih untuk setiap elemen telah dikira supaya perbandingan dapat dibuat antara kapasiti elemen dengan pembebanan elemen. Tujuannya untuk menyemak kepada tahap manakah Guillemard Railway Bridge sanggup bertahan di bawah pelbagai keamatan gempa bumi dan juga untuk mengenalpastikan bahagian jambatan yang paling kritikal di bawah pembebanan gempa bumi. Daripada keputusan yang diperolehi, didapati bahawa kegagalan tiang berlaku walaupun untuk gempa bumi berkeamatan rendah. Kegagalan papak pula disebabkan ketidakmampuan untuk menampung momen rintangan muktamad daripada pembebanan gempa bumi. Gempa bumi yang berlaku pada arah datar-melintang meninggalkan kesan yang sangat kecil kepada papak jambatan. Papak jambatan mungkin akan gagal apabila gempa bumi berlaku pada arah menegak, di bawah pelbagai keamatan gempa bumi. Untuk gempa bumi yang verlaku pada arah datar-membujur, papak jambatan adalah selamat sehingga 0.15g keamatan gempa bumi. Bahagian jambatan yang paling lemah ketika dikenakan gempa bumi ialai rentang keempat dan tiang keempat. Tambahan pula, bahagian atas pada titik tertinggi yang terletak pada kerangka jambatan dan sambungan antara rentang juga berkemungkinan besar gagal jika berlakunya gempa bumi.

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C	–	damping
K	–	stiffness
M	–	mass
N	–	total number of contributing nodes
u	–	displacement of the mass
$\dot{u}$	–	velocity of the mass
$\ddot{u}$	–	acceleration of the mass
$\ddot{u}_g$	–	ground motion acceleration
Z	–	maximum value of the some response quantity

CHAPTER 1

INTRODUCTION

1.1 Introduction

An earthquake is produced by the sudden rupture or slip of a geological fault. Faults occur at the intersection of two segments of the earth's crust. Peninsula Malaysia lies in the Eurasian Plate and also within the Indian-Australian Plate. Geologically, small faults also exist in East Malaysia. Records have shown that we do sometimes experiences some off-set tremors originating from the Indonesian zone. Thus there is a need for some seismic checking to be incorporated in the design process so that the structures would be resistant to earthquake.

Malaysia was affected by the Indian Ocean earthquake on 26 December 2004. The worst affected areas were the northern coastal areas and outlying islands like Penang and Langkawi. The number of deaths stands at 68. Houses in fishing villages along coastal area were damaged in Penang, Kedah and Langkawi. Therefore it would be unwise to totally ignore the effects of earthquake on structures.

The Guillemard Railway Bridge was built across the Kelantan River in Kursial near Tanah Merah. Construction of the railway began in 1920 and was completed in July 1924. This bridge consists of 2 spans of 200 feet and 2 spans of 250 feet. Today, the railway bridge is used only for trains and makes up part of the Jungle Railway line. The Jungle Railway is the railway line serving the East Coast states of Kelantan and Pahang in Malaysia. Guillemard Bridge also happens to be the longest railway bridge in Malaysia. However, the design of Guillemard Bridge excluded the seismic effect, thus in this project the seismic vulnerability of the bridge will be studied.

1.2 Problem Statement

In recent years, low intensity earthquakes have been occurred in least expected places, such as Malaysia. But most of the structure designs in Malaysia do not take earthquake into consideration. Therefore, the situation where there is complete ignorance and unawareness of earthquake should be avoided.

In bridge engineering, a large amount of bridges have experienced damages at region of low to high intensity earthquake. For example, the Loma Prieta earthquake which was a major earthquake that struck the San Francisco Bay Area of California on October 17, 1989. The earthquake measured 6.9 on the Richter magnitude scale which caused one 15-meter section of the San Francisco-Oakland Bay Bridge collapsed, causing two cars to fall to the deck below, leading to the single fatality on the bridge. There was little use of nonlinear analysis in the design of bridge. In order to correctly analyze bridge performance in a major earthquake of long duration, the use of nonlinear analysis technique is important.

1.3 Objective of the Study

The objectives of the study are:

(i) To determine the structural behaviour of Guillemard Railway Bridge under earthquake.

(ii) To identify to what extend Guillemard Railway Bridge could survive under ground acceleration.

(iii) To identify the critical part of the bridge under earthquake loading.

1.4 Scope of the Study

The scope of the study includes the following items:

(i) Study the architectural and structural drawings of Guillemard Railway Bridge.

(ii) The Guillemard Railway Bridge is modelled using SAP 2000 computer software.

(iii) The dynamic linear analysis using SAP 2000 is divided into free vibration analysis, time history analysis and response spectrum analysis.

(iv) The dynamic nonlinear analysis using SAP 2000 is divided into free vibration analysis and time history analysis.

(v) Different level of earthquake intensities: 0.074g, 0.15g (low intensity), 0.25g (moderate intensity) and 0.35g (high intensity) is applied to the bridge model respectively.

(vi) Each level of earthquake intensity is applied in x direction, y direction and z direction respectively.

(vii) Calculate the element capacity.

(viii) Comparison to be made between element capacity and element loading.