MATEC Web of Conferences 47, 02011 (2016)
DOI: 10.1051/matecconf/20164702011

Identification of Dynamic Characteristics of Bridge Crossing Sungai Simpang Kiri Using Free Vibration Analysis

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Abstract. This paper presents a free vibration analysis (FVA) of a reinforced concrete bridge crossing Sungai Simpang Kiri, located at Batu Pahat. The bridge consists of three simple spans with a total length of 70meter (20 m + 30 m + 20 m). The concrete deck of the bridge is supported by concrete tensioned pre-stressed T-beam. The girders are sitting on two abutments at both ends and two piers as internal supports. The base of the piers is considered as fixed base and the abutments were free to move. The structural dynamic characteristics of the bridge in terms of fundamental frequency and mode shapes were obtained analytically using SAP2000 three-dimensional finite element modeling software. It is very important to evaluate the dynamic characteristics of reinforced concrete bridges that can lead to the detection of stiffness reduction or damage of the structure. From the analysis, the fundamental frequency of the bridge was 1.94 Hz with fundamental mode shape is critical in transverse bending mode.

1 Introduction

Bridges are important elements in a transportation system which span over aquatic obstacles, valleys and gorges. Bridges also act as a key elements in the lifeline of a country and play a fundamental role economically, politically and militarily [1]. Indeed they have always occupied a special place in the attentions of structural designers because their structural form tends to be a simple expression of their functional requirement [2]. These bridge designs which comply with current codes may satisfy safety and strength requirements; however, they may not have the capacity to withstand undesirable dynamic responds in the form of large displacements and consequently increased stress, which may affect the long-term performance of the bridge.

Therefore, there is a need to incorporate dynamic characteristics of modal parameter as an important parameter for the design. The measured fundamental frequency is useful information as they relate closely to the stiffness of the bridges [3].

This paper discussed the dynamic characteristics in terms of fundamental frequency and fundamental mode shape of the non-seismically designed bridges bridge crossing Sungai Simpang Kiri located at Batu Pahat by free vibration analysis (FVA) to make a start toward the seismic evaluation or retrofit of the bridge. These dynamic characteristics used as a basis for the finite element model updating, structural control, damage detection, condition assessment and long-term health monitoring of the structure [3].

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2 Description of the Bridge Crossing Sungai Simpang Kiri

The bridge crossing Sungai Simpang Kiri is a two carriageway, three-span structure with a total length of 70 meter (20 m + 30 m + 20 m). The deck was supported on two piers. The pier end is considered as fixed base whereby soil- structure interaction is ignored. The abutments of the bridge were free ends on both sides. The real view of the bridge is shown in Figure 1.

Figure 1. The bridge crossing Sungai Simpang Kiri.

3 Bridge Modelling

The bridge crossing Sungai Simpang Kiri was modeled using SAP2000 software in 3- dimensional finite element model (FEM) as shown in Figure 2 and the geometrical details of the bridge are as tabulated in Table 1.

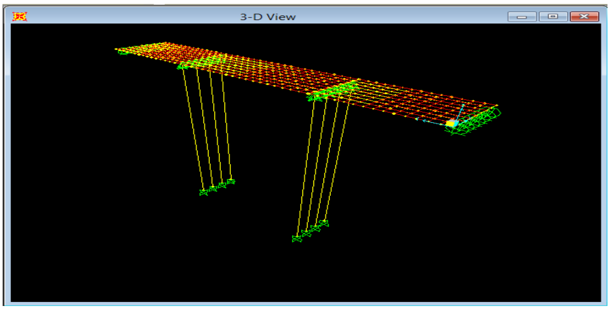

Figure 2. 3D model of the bridge.

Table 1. Geometrical details of the bridge.

Type of bridge	Concrete tensioned pre-stressed T-beam
Material	Reinforced concrete
No of span(s)	3
Support condition	Fixed at pier, roller at abutment
Length	70m (20m+30m+20m)
Deck width	12m
Slab thickness	200mm
No of intermediate piers	4

4 Free Vibration Analysis (FVA) Methodology

The bridge model was analyzed using free vibration analysis (FVA) or the so called Eigen value analysis without excitation of external load. The importance of the analysis is to identify the dynamic characteristics which include fundamental frequency and fundamental mode shapes. This method of analysis has been choosing as mentioned in [4] dynamic test can be classified according to the three types which are Forced Vibration Test, Ambient Vibration Test and Free Vibration Test.

5 Results and Discussion

5.1 Fundamental frequency

During the analysis, the fundamental frequency or first frequency was considered without diaphragm effect and excitation of external forces. The frequencies for the six modes shapes selected were tabulated in Table 2.

Table 2. Frequencies of the bridge crossing Sungai Simpang Kiri.

Mode	Frequency (Hz)
1	1.94
2	2.24
3	3.39
4	6.36
5	6.52
6	6.60

The measured fundamental frequency is useful information as they relate closely to the stiffness of the bridges [5]. The fundamental frequency of bridges is in general rather low and depends of course strongly on the span length and there type of bridge construction [5]. For Highway Bridge, the fundamental frequency may be simply estimates as:

$$f = \frac{100}{L(m)} \tag{1}$$

where L= span length in meter.

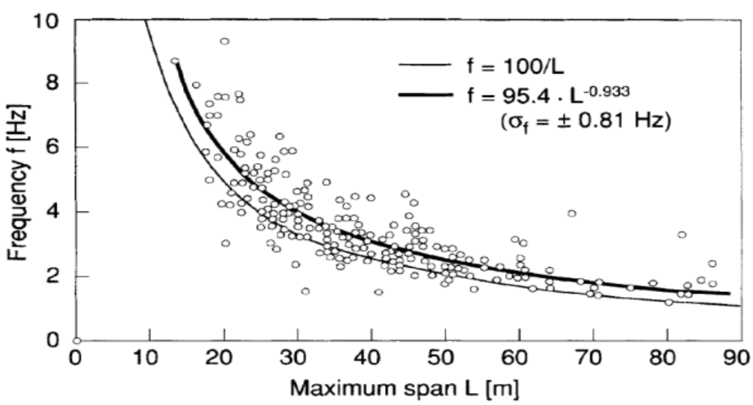

Figure 3. Frequency, f as a function of the maximum span L, derived from 224 bridges [6].

From Figure 3, many of bridge lie within range 2 to 4 Hz. The fundamental frequency of bridge depends on the span length and type of bridge construction [6]. Based on Figure 3, the longer the maximum span length produced lower frequency value. The maximum span length for RC bridge crossing Sungai Simpang Kiri is 30 meter. Estimated frequency value is 3.3 Hz. The fundamental frequency obtained from free vibration analysis is slightly different when compared to the empirical equations. It is due to the fundamental frequency of bridge depending on the span length and the type of bridge construction [7]. Furthermore, empirical relationships exist in codes to estimate elastic fundamental frequency but they miss experimental data to validate them accounting for national feature of building design [8].

5.2 Mode shapes

Fundamental mode shape is the mode having the lowest fundamental frequency [9]. Figure 4 illustrates the corresponding mode shapes of or bending mode of the bridge crossing Sungai Simpang Kiri. The first six modes were selected to limit the mode of vibration since only the dominant mode of fundamental frequency will be considered that relate closely to the stiffness of the bridge. Moreover, mode 6 shows changes in bending mode from vertical to transverse which reverse back to the dominant mode. From the illustration by software, the first, second and sixth modes are identified as transverse bending mode whiles the others in vertical bending mode.

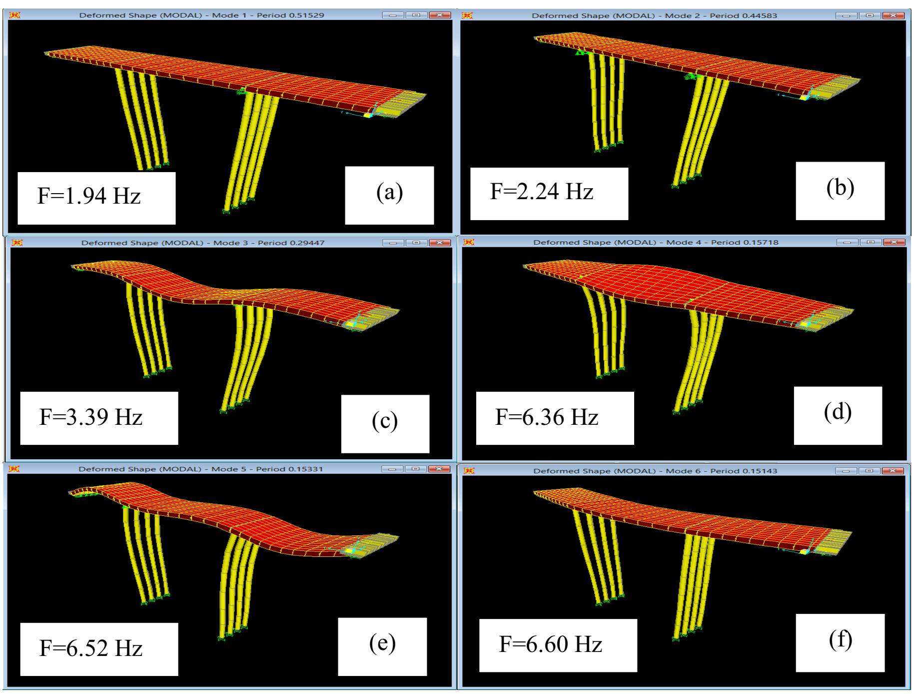

Figure 4. Mode shapes direction of the bridge crossing Sungai Simpang Kiri by FVA (a) Mode 1(Transverse) (b) Mode 2(Transverse) (c) Mode 3(Vertical) (d) Mode 4(Vertical) (e) Mode 5(Vertical) (f) Mode 6 (Transverse).

6 Conclusion

This paper aimed to determines the dynamic characteristics using FVA by SAP200 software. Based on the results obtained from the analysis, the following conclusions can be made: (i) The fundamental frequency is 1.94 Hz bending in transverse fundamental mode, (ii) This method of analysis was the fastest and inexpensive method to evaluate and localize damage using the change in dynamic parameters, and (iii) If the external load or dynamic load excited on the same direction of the dominant mode, the frequency of the bridge will be amplified and causing damage.

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