PREDICTION OF TRAFFIC-INDUCED VIBRATION AND INFULUENCE OF BRIDGE STUCTURAL PROPERTIES ON RESPONSE

University of Tokyo Student Member Sakda CHAIWORAWITKUL
University of Tokyo Member Piotr OMENZETTER
University of Tokyo Fellow Yozo FUJINO

1. INTRODUCTION

New tendency in bridge structure is to use 2 girders and rubber bearings, but these trends can cause the obtained structure to be more prone to vibration due to traffic load. This study is devoted to analytical prediction of traffic-induced vibration. Experimental results are compared to simulations. Consideration on influence of bridge structural characteristics, i.e. bearing and slab stiffness, on response is also conducted.

2. VEHICLE-BRIDGE SYSTEM EQUATION OF MOTION

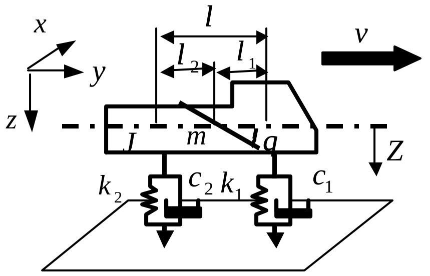

Figure 1 Vehicle bridge system

Let us consider a 3-dimension vehicle-bridge system as shown in Figure 1. Displacement $\mathbf{u} = \{u_x \quad u_y \quad u_z\}^T$ at any arbitrary point $\mathbf{x} = \{x \quad y \quad z\}^T$ in 3 dimensional space can be written in modal form:

$$\mathbf{u}(\mathbf{x},t) = \sum_n f_n(\mathbf{x}) q_n(t) \tag{1}$$

Where $f_n = \{f_n^x \quad f_n^y \quad f_n^z\}^T$ and q_n denote the n-th mode shape and the corresponding generalized coordinate respectively. By assuming proportional damping, the equation of motion of the bridge in generalized coordinates is:

$$\ddot{q}_n(t) + 2x_n w_n \dot{q}_n(t) + w_n^2 q_n(t) = \frac{1}{m_n}\left\{f_n^z(\mathbf{x}_1)P_1(t) + f_n^z(\mathbf{x}_2)P_2(t)\right\} \tag{2}$$

Where m_n, x_n and w_n represent n-th modal mass, damping ratio and frequency respectively. $P_i(t)$ denotes the vertical force exerted at point $\mathbf{x}_i$ $(i = 1, 2)$ on the bridge. The equation of motion of vehicle is

$$m\ddot{Z} + \sum_{i=1}^{2} V_i = 0, \qquad J\ddot{q} - \sum_{i=1}^{2} (-1)^i l_i V_i = 0 \tag{3a, 3b}$$

$$V_i = k_i\left\{Z - (-1)^i l_i q - u_z(\mathbf{x}_i)\right\} + c_i\left\{\dot{Z} - (-1)^i l_i \dot{q} - \dot{u}_z(\mathbf{x}_i)\right\} \tag{4}$$

$P_i(t)$ in equation (2) is defined by

$$P_i(t) = mg(l - l_i)/l - V_i \tag{5}$$

Equations (2), (3) and (4) form "vehicle-bridge interaction (VBI) equation", which is time dependent, coupled system of equations.

3. EXPERIMENT VS. SIMULATION

The experiment was conducted on Hibakaridaira bridge[1)] which is 2-girder, 4-span bridge with length of 192.8m. (47.4m+48.5m+48.5m+47.4m). Vehicle passage test was conducted. 3 passage courses (C1, C2, C3) as well as measurement points (1-8) on the bridge are shown in Figure 2.

For numerical simulation, modal properties were found by FEM analysis. Dynamic properties of vehicle model are given as : m = 37240 kg, J = 150900 kg m^2, k_1 = k_2 = 7.39 kN/m, c_1 = c_2 = 1.352 kN/ms, λ_1 = λ_2 = 2.41 m. Figure 3 shows the comparison of acceleration responses at point 1 of passage course C1, whereas Figure 4 illustrates their Fourier spectrum.

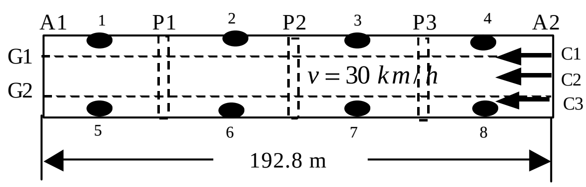

Figure 2 Passage courses and measurement points

Key words : traffic-induced vibration, 3 dimensional bridge model, modal analysis
Address : Hongo 7-3-1, Bunkyo-ku, Tokyo 113-8656, Japan, Tel: 03-5841-6099, Fax: 03-5841-7454

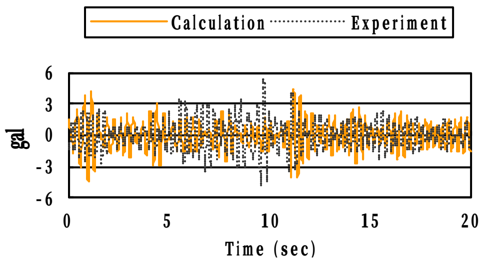

Figure 3 Acceleration at position 1, C1

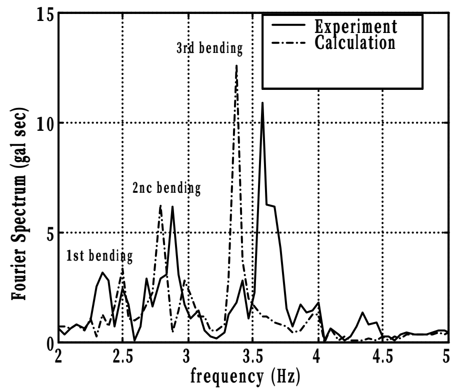

Figure 4 Fourier spectrum of acceleration response at position 1, C1

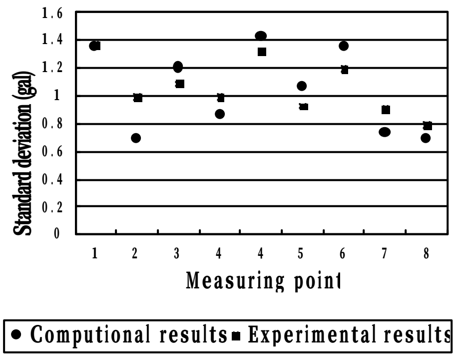

Figure 5 Comparison of measurement and simulation at various points, C1

There are some differences in peak frequency in Fourier spectrum, however the modes excited in experiment and those in simulation are corresponding to each other. Also the magnitudes of the spectrum are close. Figure 5 represents comparison of standard deviation of experimental and numerical results of acceleration at each point in case of passage course C1. Good agreement can be observed.

4. INFLUENCE OF BRIDGE STRUCTURAL PROPERTIES ON RESPONSE

Parametric study is conducted in 4 different cases as follows: 1) 2-girder bridge with rubber bearing (reference model) 2) 2-girder bridge with fixed bearing 3) 2-girder bridge with rubber bearing 5 times stiffer 4) 2-girder bridge with rubber bearing, 80% slab thickness. Acceleration responses at point 1 of passage course C1 are calculated for each case and are plotted in Figure 6. By finding the value of standard deviation of response in each model, it is found that

$$s_2 = 0.6 s_1, \quad s_3 = 0.8 s_1, \quad s_4 = 1.2 s_1 \qquad (6a-c)$$

It can be seen that stiffening the structure by increasing stiffness of bearing causes the response to be smaller. On the other hand, making the structure to be more flexible by decreasing slab thickness yields larger response.

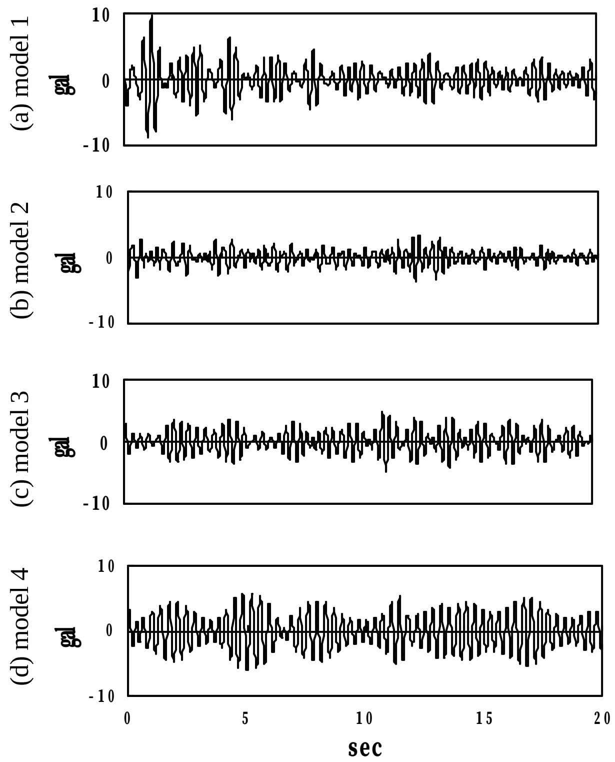

Figure 6 Vertical acceleration response of each bridge model at position 1, C1

5. CONCLUSIONS

The first part of this study is devoted to prediction of traffic-induced vibration in composite 2-girder bridge. Experimental results are compared to simulation results and good agreement is found.

In the second part of this study, the parametric study of the influence of structural parameters on traffic-induced vibration response was conducted. It was found that by increasing stiffness of the bearings by 5 times can cause the response to be smaller by approximately 20 %, whereas using fixed bearing reduces the response by approximately 40%. On the other hand, by decreasing the slab thickness to 80%, the obtained response increases about 20%.

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