Prediction and Mitigation of Ground Vibrations from Viaduct Traffic

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INTRODUCTION

This paper focuses on the environmental vibration problem caused by road-traffic on a continuous multi-span viaduct. First, analysis on vibration measurement data is conducted both at the structure and the nearby ground. Second, by using the measurement results, the authors propose a procedure to predict the ground responses based on an axisymmetric 3 dimensional (A3D) FEM model. Finally, the vibration mitigation by the honeycomb-cell wave impeding barrier (Honeycomb-WIB) is investigated by installing it around the foundations. A satisfactory vibration reduction is proved with it.

FIELD MEASUREMENT

Herein, the vibration related to a highway viaduct at soft site is investigated. The viaduct in this study has a 3-span continuous curved girder. See Figure 1and 2 for the illustration. The pier, “P4” is a movable joint and other piers are free to move along the viaduct axis. The site condition is also described in Figure 1. The vibrations of viaduct due to the traffic emit vibrations from its foundations that are then transmitted through ground to the nearby build-up zone. It is significant along the soft stretched out zone in Figure 1. The low predominant vibration frequencies are of our concern since they may cause resonances with those residential houses or gives disturbance to residents at least. Temporarily, bent frames (indicated by B in Figure 1) are used at several sections of the viaduct for shifting the natural frequency of the structures to the higher range.

A field test has been conducted by using a single 20t truck on the viaduct. The measurement has been made for it, besides for the normal traffic. The acceleration sensors were placed at the piers as well as the nearby ground surface specifically in the zone perpendicular to the viaduct (see Figure 1). Figure 3 shows the Fourier spectra for the ground responses at the indicated positions in Figure 1 for the test run. The vibrations at the piers distribute over a wide range of frequencies although the major portion is in the low range below 5Hz, the ground responses are noted mainly concentrating in the low range especially around 3.5 Hz. Since the viaduct has a curvature of 1/800, the substantial transversal motions with respect to the viaduct axis are noted around viaduct foundations.

GROUND RESPONSE PREDICTION

Research attention is placed on the ground vibration prediction in the neighboring area along the viaduct. We substitute the traffic loading from the girders by the driving forces at respective foundations. In view of the relatively higher rigidity of the piers and footings, as well as the small deformation of the concrete pier structures, they are regarded as rigid bodies during present motions.

Displacements at footing top $U_O(\omega)$ can be derived from measured data at the pier body. The impedance function $K(\omega)$ at the footing top can be obtained by the A3D FEM program. Then the driving force at the footing top is then

$$P_O e^{i\omega t} = K(\omega) U_O e^{i\omega t} \quad (1)$$

By using the compliance function $F(\omega)$ of the foundation-soil system, which is available from the soil-foundation interaction analysis, we can predict the ground responses by

$$U_g e^{i\omega t} = F(\omega) P_O e^{i\omega t} \quad (2)$$

Figure 4 depicts the predicted ground responses representatively at the indicated positions G4 and G8, by taking account of the contributions from the vibration emission of the pier P4 and P6. The simulation results compare well with the measured data in Figure 3, which verifies the program and the proposed procedure.

RESPONSE MITIGATION BY WIB

Now, we are going to pursue the vibration reduction by installing the honeycomb-WIB measure. For the present situation, since P4 has the predominant effects on the neighborhood area of the bridge, the WIB is considered around this caisson foundation only. Herein, a ring type WIB is considered instead for the convenience of the computer code used (see Figure 5).

The present ring WIB has 1m thickness for the wall and 15m depth and positioned from 6m through 20m by three cells. The mitigation effect by this approximate model is studied by different parameters for the WIB zones. The fill-in material is considered as a certain high damping, say 20% for the critical value for the material comprising tire-shreds of asphalt emulsion included. A significant reduction is gained in the horizontal responses by 4 walls (denoted by WIB4) and satisfactory reduction is obtained even by 2 walls (denoted by WIB2) over the WIB zone and even substantial distances beyond it (see Figure 6). For the vertical response, although the reduction ratio is not as effective as those in horizontal directions, it is not necessary to pay more attention to improve it because of the much smaller quantity.

CONCLUSIONS

A hybrid procedure has been developed in this paper to predict the ground vibration due to traffic from viaduct traffic. It has been validated by the measured data by test runs of a truck and normal traffic flow. The honeycomb-WIB, aiming at the vibration reduction in low frequency region, is proposed for the mitigation of the excessive vibration in the neighborhood. Significant reduction can be expected especially for the horizontal response.

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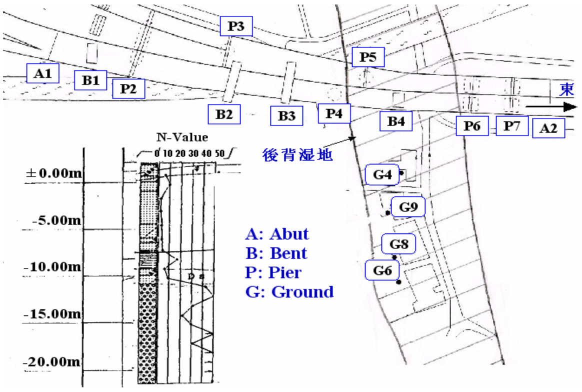


Figure1 Viaduct site

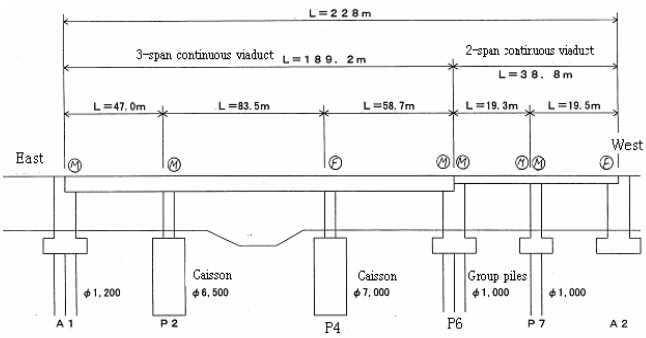
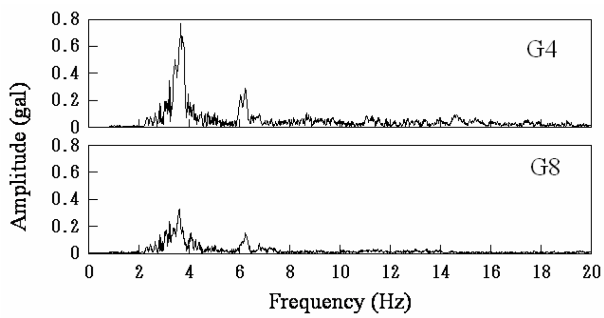
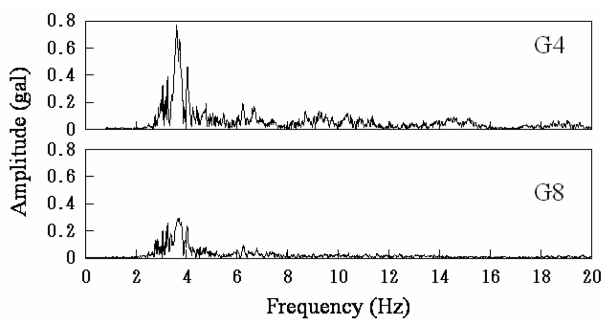


Figure2 3-span continuous viaduct for traffic

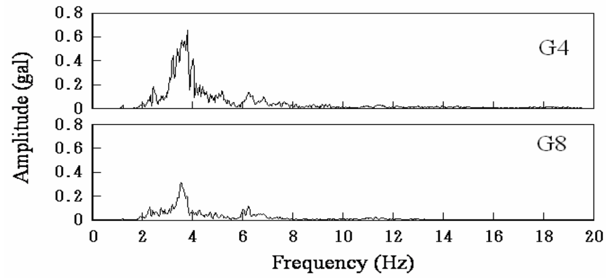


(a) Perpendicular to viaduct axis direction

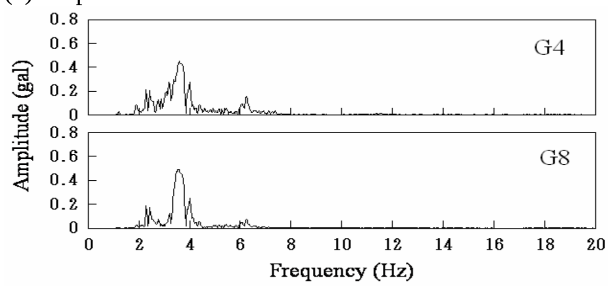


(b) Along viaduct axis direction

Figure 3 Response Fourier spectra for westbound test run by a heavy truck



(a) Perpendicular to viaduct axis direction



(b) Along viaduct axis direction

Figure 4 Simulation results for ground acceleration Fourier spectra

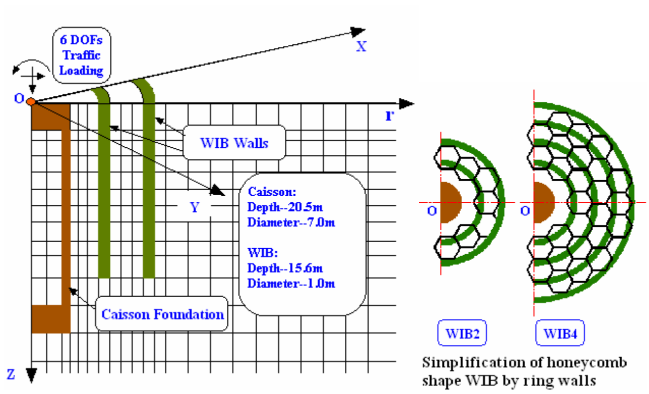


Figure 5 Foundation-ground FEM model

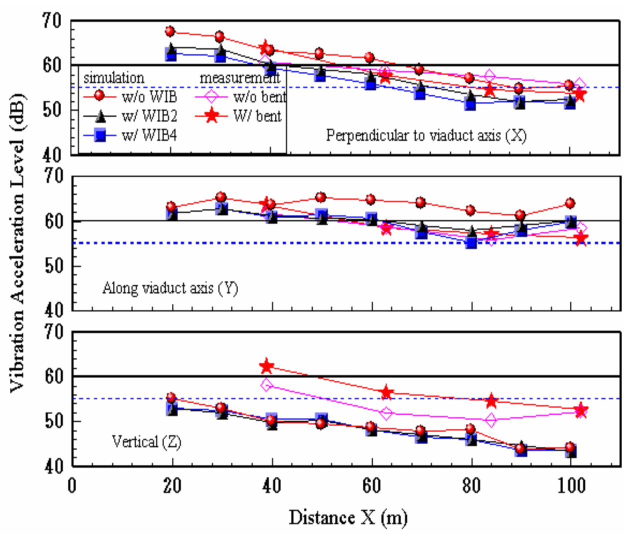


Figure 6 Maximum acceleration vs. distance for normal traffic