MITIGATION OF GROUND VIBRATION BY PILE-SUPPORTED BRIDGE DUE TO TRAIN TRAFFICS

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1. INTRODUCTION

One of the important problems in soft soil sites is the transmission of vibration due to traffic from elevated bridges to the surrounding soil. Since commonly the bridge is supported by piles, these piles also become the source location and at larges distances the vibrations can be significant when the deeper stiff soil layers conduct the vibrations easily[1)]. In this study, a railroad bridge supported by piles is analyzed to investigate the characteristics of wave propagation at near and far distances for homogeneous stratum.

2. MODELLING AND RESPONSE ANALYSIS

The numerical analysis is performed using the time domain FE-BE hybrid method[2),3)]. The central zone of finite element domain, which includes the structure and the homogeneous soil, is shown in **Fig. 1.** The countermeasure proposed by the authors for the reduction of the vibrations in near and far zone from the bridge is illustrated in **Fig. 2**. This includes a solid soil improvement below the footing and the honeycomb shaped WIB improvement at nearby soil. The considered improvement cases are shown in **Fig. 3**. The depth of soil improvement below the footing is determined by the pile active length $1/\beta$ from the pile top (G.L. –11 m). The soil-cement columns are defined as shear velocity of 1000 m/s, mass density of 2000 kg/m^3, Poisson's ratio of 0.4 and damping ratio of 0.05. Since the behavior of soil depends on the frequency characteristics of input loading, bridge and soil; the loading frequencies are chosen as 2, 2.5 and 3.3 Hz. These loadings correspond to one Ricker wavelet (Tp=0.4 s, Ts=1 s) and series of Ricker wavelets as shown in **Fig. 4**. The external loads are applied at pier top in x-direction for the in-plane analysis and in y-direction for the out-plane analysis, which are respectively as $P_1(t)$ and $P_2(t)$ in **Fig. 1**. First, the analysis is realized for the one Ricker wavelet because of its simple form permits the understanding of the wave propagation mechanisms that is vital to define the mitigation measure. **Fig. 5** shows the Fourier amplitudes of the in-plane horizontal responses at pier bottom, far surface and deeper soils. The Case A has predominant frequencies around 1.8 Hz and 3 Hz at pier bottom and deeper soils, which are near to frequencies of structure (1.8 Hz) and soil Airy phase (2.8 Hz). Therefore, the same frequency contents at near and far deeper soil confirms that the vibration propagates at this stiff layer. The propagation of vibrations from structure to deeper soil and subsequent propagation to surface at far distances from bridge also was noted for layered soil[1)]. Moreover, the effects of soil improvement below the footing (Case B) are appreciated with an amplitude reduction at 3 Hz for these 3 places. This can be due to following factors: constraining by soil improvement and impedance ratio. In the first, wave interaction effects take place between the source and the improved soil. In the second, the impedance ratio between the improvement and original soil is an important parameter for the reduction of vibration toward the deeper stiff soil. In the analyzed case, the impedance ratio is lower than 0.2 Hz, which in combination with constraining condition can be explaining the amplitudes reduction at 3 Hz. At far surface (x=226 m, z=0 m), the contents of frequencies change with respect to soils near the structure. Moreover, if the surface and depth responses at x=226 m are compared, the variation of frequencies is clearly noted. The predominant frequency at surface response is around 2 Hz, which can be associated with the up-down predominant frequency at site (1.7 Hz). Here, it is necessary to point out that this frequency and the Airy phase frequency are different concepts. **Fig. 6** shows the maximum acceleration at surface for Case A due to different loadings. For the 3.4 Hz multi-Ricker loading, local peaks at far distances are noted, which are not visible for the one Ricker loading. This difference between the response due to impulsive and harmonic loadings also was verified for not deep soils[4)]. The effectiveness of soil improvement for this periodical loading is investigated in **Fig. 7**. These computation results are depicted in normalized form, which is taken by dividing the maximum acceleration response by maximum horizontal loading. In the vertical response, the reduction effect by the improvement is appreciably noted at ground above the honeycomb WIB especially for the Case D. However, the Case C and Case D show that the response becomes large in the zone immediately behind the honeycomb WIB located area. It is due to the honeycomb WIB change the propagation characteristics of the waves and work for constraining the soil motions. Consequently, amplifications are expected just behind the honeycomb WIB located area. Therefore, the decreasing of the proper honeycomb vibrations is an important factor for reduction of vibrations behind the honeycomb WIB located zone. Away from the structure, the case D results in higher response reduction, which varies between 40 percent and 60 percent for distances larger than 200 m. In the in-plane horizontal response, the small response corresponds to Case D near to bridge and Case C and Case D far from the structure. The reduction is about 40 percent and 80 percent for distances larger than 200 m. As shown in the out-plane horizontal response, at far distances from structure, the Case D has the biggest reduction, which is around 40 percent and 70 percent for distances larger than 200 m. However, the maximum soil improvement length in this direction is limited by the distance between piers (30 m), which suggests a continuous improvement in the longitudinal direction of bridge. In this way, the natural frequencies of bridge-footing-pile-soil system change and if the fundamental frequency of structure is calculated assuming as fixed at the base, these frequencies become very high (larger than 5 Hz). In view of above results and according to the field evidences which indicate the main vibrational frequencies of bridges due to traffic are approximately between 2 Hz and 5 Hz[5)], it can be said that the improvement of soil has also an important role in the isolation of the structure.

3. CONCLUSIONS

In this paper wave propagation problems have been dealt with a bridge at soft site focusing on the ground vibration reduction by soil improvement-pile foundation system and honeycomb shaped WIBs. From the previously presented results, the mitigation of the vibrations

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due to loading at bridge-pile system can be divided into two zones: near and far from the structure. If the target is in the zone near to structure; a sufficiently large honeycomb WIB is recommend, giving almost an effective response reduction above the honeycomb WIB. On the other hand, if the target is in the zone far from the structure, since the response is mainly due to up-down wave propagation from deep stiff soils, a measurement to impede the propagation from superstructure to stiff depth soil is recommended. The improvement of soil below the footing, in addition to constraining the waves propagation, originates a low impedance ratio and consequently the wave propagation toward the deep soil is impeded. More parametric studies are needed involving a variety of properties of the soil, honeycomb WIB length and improvement ratio, in order to establish detailed design guidelines covering all possible cases.

4. REFERENCES

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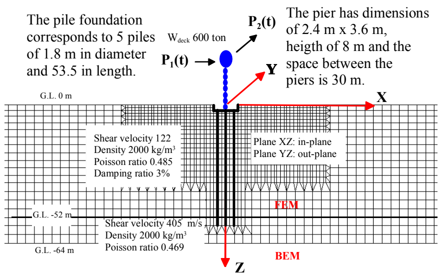

Fig. 1 Model of analysis

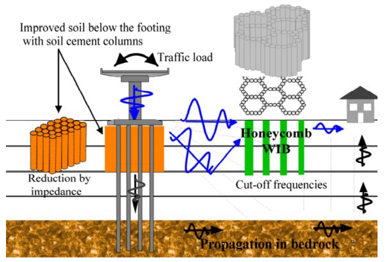

Fig. 2 Wave propagation mechanism and mitigation procedure

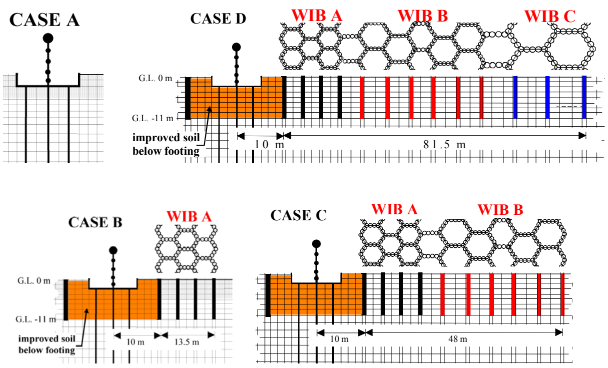

Fig. 3 Cases for the analysis

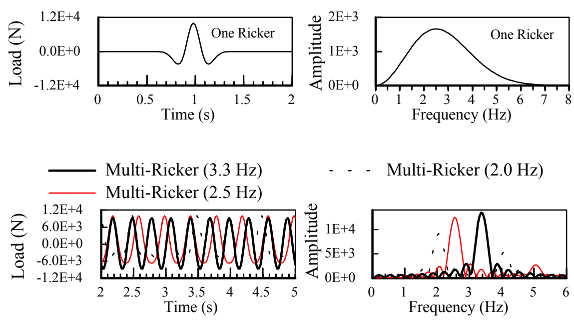

Fig. 4 Loading functions

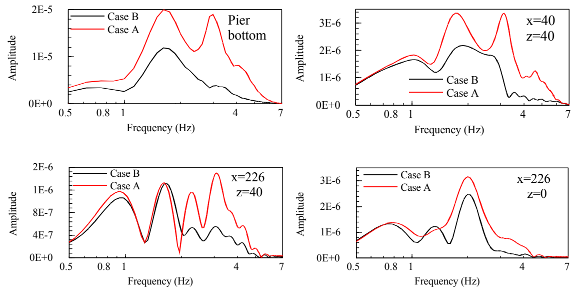

Fig. 5 Fourier amplitudes for Case A for one Ricker wavelet

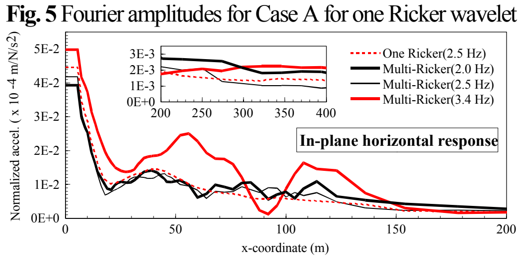

Fig. 6 Maximum acceleration at surface for Case A

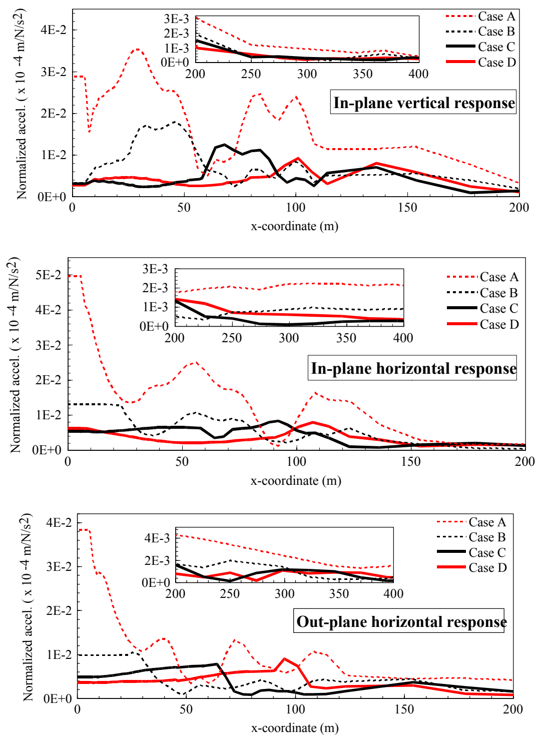

Fig. 7 Maximum acceleration at surface for 3.4 Hz loading