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Why Heavy Seismic Damage has Centered at a Specific Area for The Sanyo Shinkansen Line Viaduct ?

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INTRODUCTION

Heavy damages caused by the Great Hanshin Earthquake (Jan. 17, 1995) were centered in certain area on the Sanyo Shinkansen Line while the residential houses in the neighborhood have less damages. This strongly suggests that the local site topography has a significant effect on the soil response that may cause resonance for the above ground structure's response. In this paper, the site investigations are performed in time domain. The hybrid technique is adopted for coupling FEM for the irregular near field and BEM for the far field, extending to infinity. The input excitation is composed of a series of Ricker wavelets. Detailed formulations can be found in the authors' previous work.

MODELING AND SITE RESPONSE ANALYSIS

One of the most damaged structures is the railway viaduct constructed for the bullet train along Sanyo Shinkansen Line at Osaka-Kobe Portion. Three spans of the viaduct are totally collapsed within a distance between Muko River and Rokko Mountain. According to the geological map of this area, the soil conditions consist of thin very soft surface layer (depth of 6 -10 m) with irregular subsurface underlain by stiff to very stiff soil or base rock. From the soil profile and the bore hole data at the collapsed bridge site, the shear wave velocity of the surface layer varies between 80 and 100 m/s while the stiff soil or the base rock has the shear wave velocity varies between 800 and 1000 m/s. Based on these data, the dimensions and the soil profile of the analyzed site are shown in Figure 1.

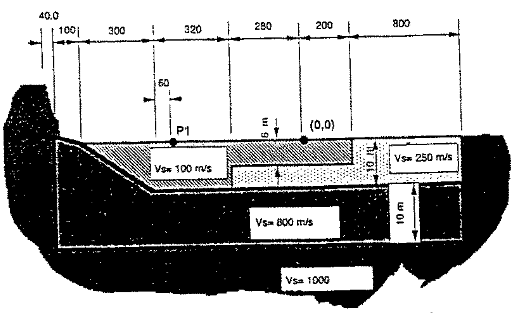

Fig. 1 Dimensions and Configurations

First, in order to investigate the soil behavior and the wave propagation pattern inside the soft soil the surface response due to SV single Ricker wavelet is considered. The fundamental frequency of the soft soil layer having a depth of 10 m is 2.5 Hz (period of 0.4 sec.). The comparison between the maximum acceleration response due to incident wavelet with predominant frequency of 1.5 Hz and 2.5 Hz is shown in Fig. 2. The maximum horizontal response values are highly amplified at the frequency of 2.5 Hz even for the portion having only 6 m depth soft soil and the distribution of the maximum response along the surface is drastically changed. Figure 3 displays the time history of horizontal acceleration for the second case. The resonance inside the 10 m depth soft soil portion and the long duration can be clearly observed. The horizontal propagation of the surface wave generated by the soft soil edges is also displayed.

Based on the above finding, the earthquake-like motion in the far field is represented by a consequent series of five Ricker wavelets with different predominant frequencies and time histories. As the earthquake plane waves always contains both P and SV waves, the response analysis is performed for both types simultaneously. The maximum amplitude is set to be 0.5 cm for input displacement and 180 gal for input acceleration in the far field. Figures 4 and 5 show the maximum response and time history of the surface displacement and the acceleration respectively. The strong amplification and the big phase difference for the horizontal response are concluded while the amplification of vertical response is not so high. As well as the extended structure is considered, the spatial variation of the surface response is of great importance. Both figures display the drastically spatial variation along the surface which cause the extended structure to be subjected to different excitations at different locations and consequently, very high internal stresses and strains at the weak viaduct columns. Another important factor is the frequency content of the surface response. Figure 6 shows the Fourier transform spectrum of the response at point P1 as defined in Fig. 1. The very high maximum amplitude occurred at period of 0.407 sec. which is the fundamental period of the soft soil layer. This period may coincide or very close to fundamental period of the bridge girder at this site leading to the high possibility of the structure response resonance. These findings can explain why the damages happened to the extended bridge while the other type of nearby structures have not suffered from such sever damages.

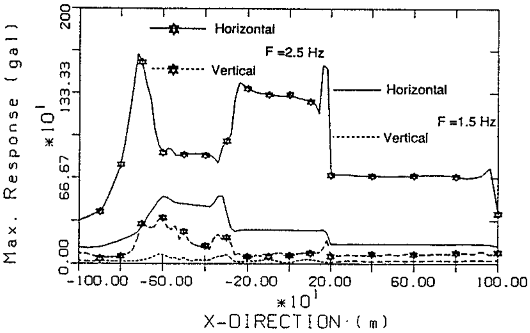

Fig. 2 Acceleration Response Comparison

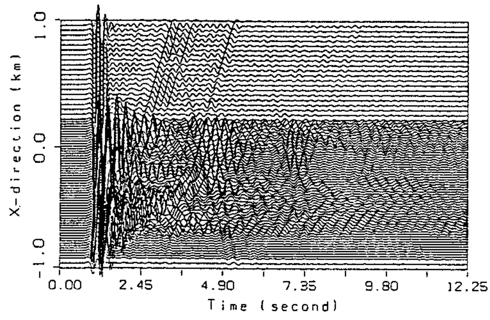

Fig. 3 Acceleration Time History (f=2.5 Hz)

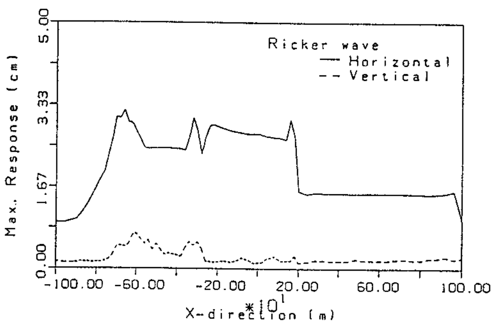

Fig. 4.a Max. Surface Displacement

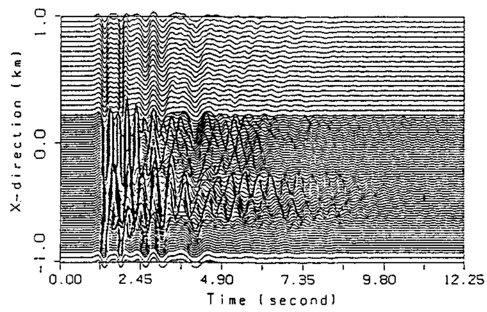

Fig. 4.b Hl. Displacement Time History

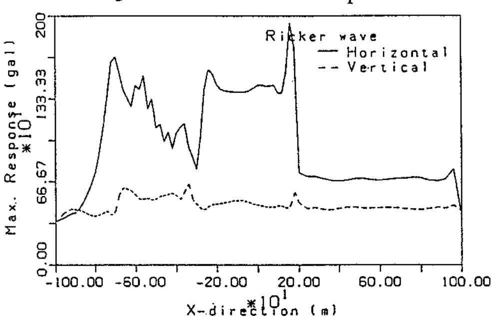

Fig. 5.a Max. Surface Acceleration

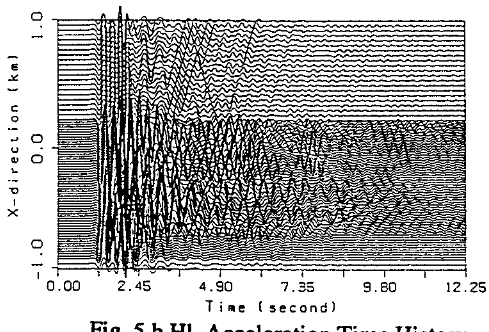

Fig. 5.b Hl. Acceleration Time History

CONCLUSIONS

The soft soil strongly amplified the surface response and modified its critical period during the Great Hanshin Earthquake. Resonance of soft soil and structure reposes was the crucial factor for the heavy damages at Sanyo Shinkansen Line viaduct. The site conditions and the soil-structure interaction must be considered in the practical analysis and design of extended structure.

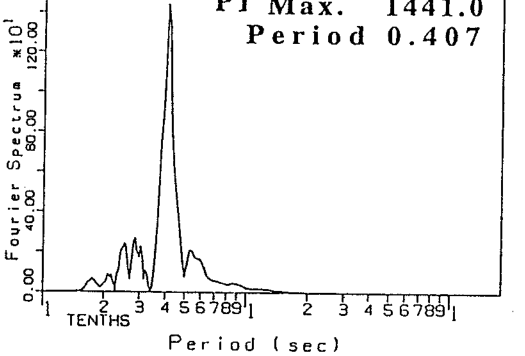

Fig. 6 Frequency Content at Point P1

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