Isolation Effect of PC wall-piles on Wave Propagation through the ground

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1. Introduction

The recent advent of larger and heavier vehicles capable of carrying heavier loads at faster speed has resulted not only in land transportation systems with a greater complexity but in a higher level of vibration bringing about a more severe environmental hazard to their neighborhoods. These sources generate relatively long wave lengths, and barriers are not effective unless they are installed to a relatively great depths. A new ground vibration isolation method is described, which uses PC wall-piles. PC wall-piles offer an advantage in that vibration barriers are easier to build to a greater depth. Because of this advantage, barriers made of PC wall-piles appear to provied a great potential to tame ground vibration in future applications. This paper presents the results of a series of experiments conducted on a PC wall- piles barrier 1). That barrier was built along side a road passing through some sensitive sites, to assess its effectiveness in isolating vibration caused by running trains and dropping a weight. Then, the effectiveness of PC wall-piles for controlling ground viblations is discussed.

Key Words: Damping, Ground Vibration, Isoration Method, PC pile, Site Investigation, Wave Propagation

2. Results and analysis

2.1 Effect on vibration from a free falling weight

Data acquired from a free falling weight were plotted in Fig.1 to shown how the vibration level decreases with distance at Test Site 1 by the presence of the barrier as compared to that observed without barrier. Similar experiments were subsequently conducted at Test Site 2 with the hollows of the piles filled-in and the data taken are shown in Fig.2.

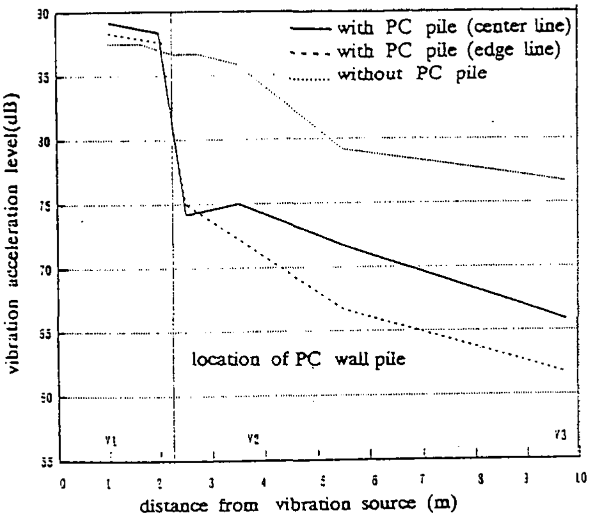

Fig.1 Comparison of vibration value with distance

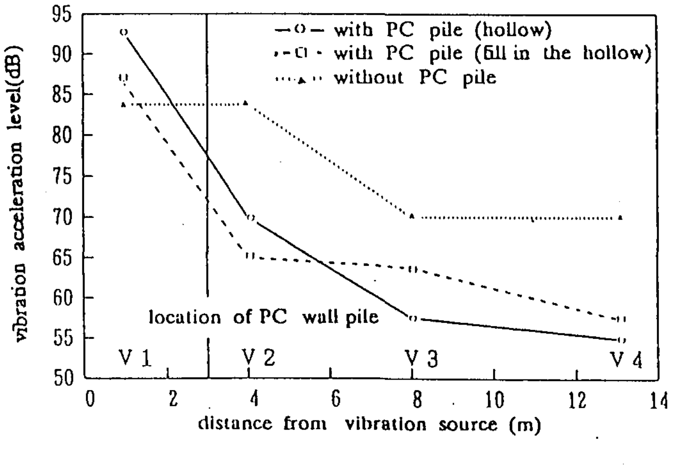

Fig.2 Comparison of vibration value with distance

Observing the data taken at Test Site 1, the vibration level along tne line normal to the barrier at its middle point is seen to have reduced by 7.5 to 13 dB over a distance from just behind the barrier to a point 4 m away from it. Along the line perpendicular to the barrier at its one edge, the decrease was about 11 to 16 dB over the same interval. It is interesting to note that the reduction in vibration level by the barrier was greater along the latter line than along the former. As this phenomenon is contrary to what might be expected, one must take into account the diffraction of the vibration wave. It can also be seen that the level was further reduced by about 4 to 7 dB over the same distance by filling the hollow of the piles though this can not simply be generalised as the magnitude of such reduction varied with distance from the barrier. The additional effectiveness of the barrier can be accounted for by a decrease in its void ratio by the filling in the hollows of the piles.

2.2 Locus of ground movement

With a view to analyzing ground motion during vibration, movement was recorded at Test Site 1 at a point 3.7 m behind the barrier in all the three orthogonal directions: vertical (Z) as well as perpendicular (X) and parallel (Y) to the barrier. Fig.3 is the resulting plot showing the trajectory of the point on ZY plane during vibration.

The peak to peak amplitude of the vertical component is noted to be relatively small at this point as compared to that of horizontal component, indicating the effectiveness of the barrier to constrain the vibration. In this plot, no surfacewaves are seen to have been transmitted to the point at which the motion was recorded possibly because it was too close to the barrier. From this observation, it can be concluded that the barrier made of PC piles effectively prevented the body waves that might have originated from the vibration from being transmitted.

2.3 Summary of results

Summarised in Fig. 4 are the results from the experiments conducted at these Test Sites as well as data that had been reported elsewhere indication the reduction in the level of vibration with distance from a barrier made of PC piles. It can be noted that (i) the reduction in the level of vibration by a PC pile barrier from that registered without such barrier exponentially decreases with distance from it as represented by the empirical formula shown in the same figure. $VRVmax=29.4r^{-0.69}$ $VRVmin=19.3r^{-0.12}$ (1) (ii) At a point just behind the barrier the reduction as large as 10 dB can be achieved but it decreases to 5 dB at about 10 m away from it, and (iii) additional reduction in vibration level by the presence or otherwise of a filling in the hollow of a PC pile barrier has not clearly been identified enough data not being available at the moment.

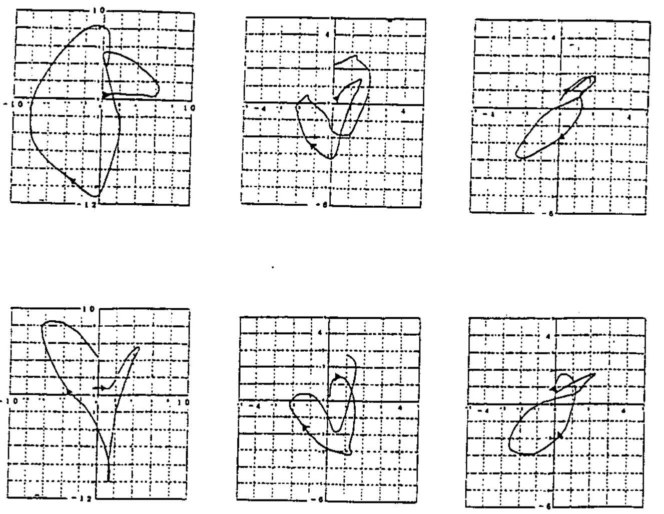

Fig.3 Locus of ground movement

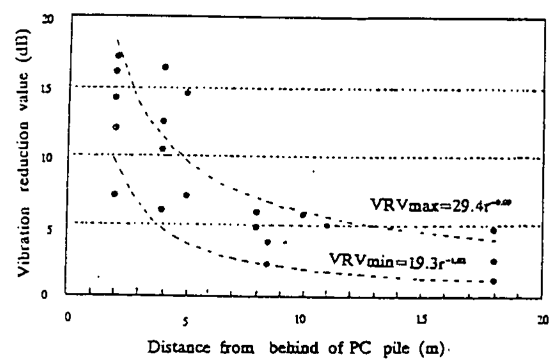

Fig.4 Vibration reduction value with the distance from behind of PC pile

2.4 Estimation of vibration reduction being based on wave penetration theory

The ratio between the amplitude of a vibration wave as registered on the on-side and that on off-side of an isolation barrier installed into the ground can be expressed by the formula according to the wave penetration theory 2). Shown in Fig. 5 is the reduction in vibration level as calculated according to the wave penetration theory by using data taken from the experiment conducted on the PC pile barrier installed at Test Site 2. In this calculation, combined reduction was then calculated by further using formula representing the vibration reduction factor $Ar=e^{-2.35H/\lambda r}$ where H=trench depth, λr=Rayleigh wave length as worked out through an experiment using a model assuming that the hollows in a PC pile barrier being an air trench 3). The continuous line in Fig.5 corresponds to the case where V_1 was taken to be 300 m/s while the broken line indicates the result as obtained by assuming V_1 to be 100 m/s. Data shown with symbol (·) are the reduction in vibration at a point 1 m away from the barrier as obtained from a frequency analysis conducted over 1/3 octave band on the results from the experiment by using an FFT analyser. It can be observed that the data from the latter analysis is in good agreement with the calculated results all over a range of frequency between 1 and 80 Hz, except at around 31 Hz.

2.5 Comparison with results of past works 4)

Having analised by using an FEM technique, the effect of such a rigid body as a concrete wall built into ground to isolate vibration. Haupt produced a graphical representation of the relationship between the vibration reduction factor achieved by such a body and its cross section $S=BT/\lambda r^2$ as normalised in terms of the Rayleigh wave length. Shown in Fig. 6 is this relationship along with the results obtained through this study, the latter data being plotted with symbol (·). The Rayleigh wave velocity herein referred to was determined by using the relationship between S wave velocity and the average N value over the interval from ground surface to a depth at which it had shown a sudden increase during a boring test,in the following manner; Vs=92N where Vs=S wave velocity (m/s), N =N value as obtained through a standard penetration test and Vr=0.92Vs Poisson s ratio was assumed to be 0.25. In Fig. 6 it can be observed that the reduction factor as achieved in this study by installing a barrier made of hollow PC piles is located below the curve representing the calculated result by Haupt indicating that the former offers a greater reduction factor than a rigid wave barrier. The better performance of PC pile barrier may be attributed to the combined effect of the piles themselves capable of partly isolating the vibration by acting as rigid bodies and the hollows in them which contributed to its further reduction. If this is the case, the difference between the curve showing the lower limit of the results as presented by Haupt and the data as measured in this study can be taken as representing the effect of the hollows in the piles composing the PC pile barrier herein dealt with.

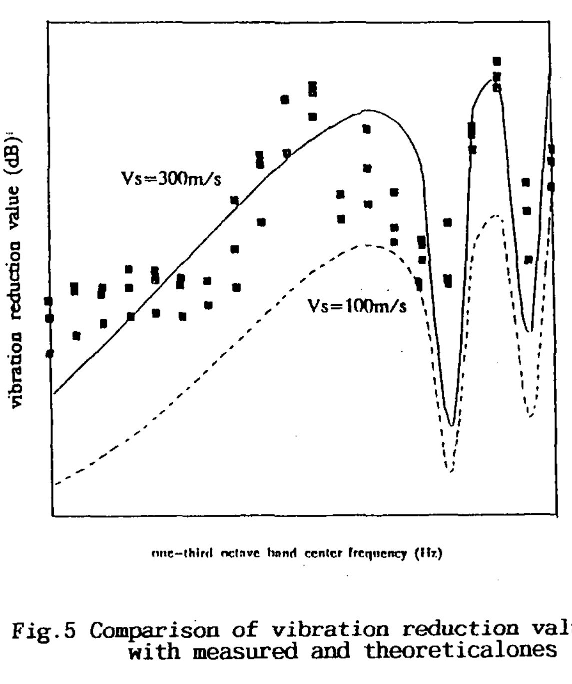

Fig.5 Comparison of vibration reduction values with measured and theoreticalones

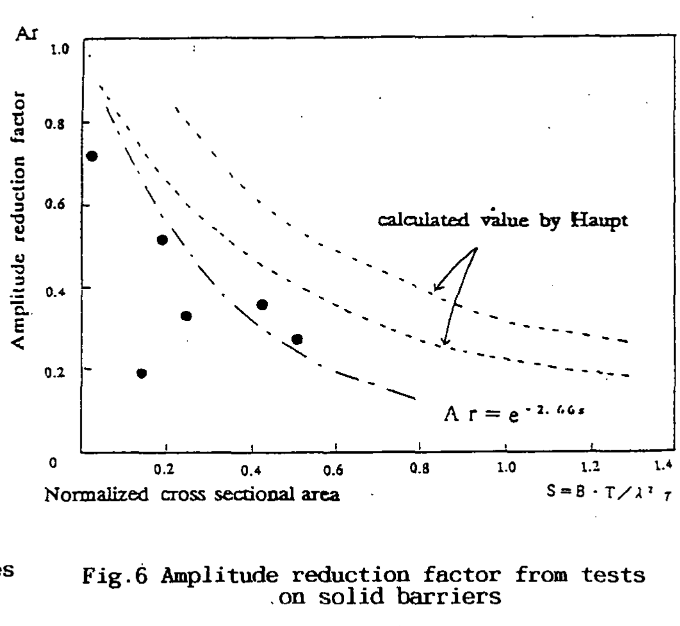

Fig.6 Amplitude reduction factor from tests on solid barriers

Ahmad et al. having analised the effect of such barriers as underground concrete wall and gas cushion, presented a relationship between their Ar values reduction factor and distance from such barriers as shown in Fig.7. Corresponding data as measured in the present work were plotted on the same diagram for comparison. It is natural enough that these data stand as can be noted, between the curve representing the reduction factor of the concrete wall and that of the gas cushion as presented by them. Through the former data are seen to be clustered at the extreme left in the diagram as they had been taken over relatively small distances from the barrier. This provides a further evidence to corroborate the view that a vibration barrier comprising hollow PC piles combines the effect of a rigid wall and hollows. From the above, and considering the ease with which it can be built, the safety and economy it provides, it can be concluded that a PC pile barrier may offer a highly effectiveness of isolating ground vibration.

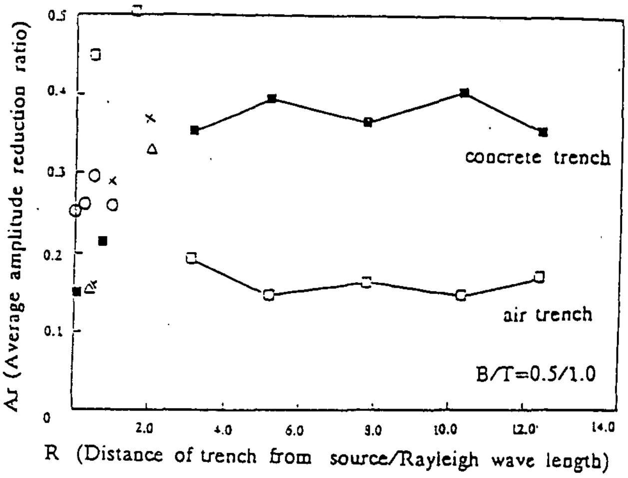

Fig.7 Amplitude redution factor depending on distance R

3.Conclusions

In this paper effect was addressed of a new type of barriers made of PC concrete piles to isolate ground vibration. Results were presented of the in-site experiments carried out on such PC pile barriers that had been built at five different localities. Reference was made of a method to calculate the reduction in vibration by a PC pile barrier in accordance with a wave penetration theory. Results from the present study were compared with those calcurated by using such method as reported elsewhere. From the study it was found that;

1. The PC pile barriers were found to be capable of reducing vibration level by 10 to 15 dB at a point just behind such a barrier and about 5 dB at 10 m away from it. The reduction being exponentially related with the distance from such barrier.
2. By using the above mentioned theory along with an empirical formula for open trenches, reduction in vibration by PC piles wave barrier can be calculated with a reasonable accuracy over a range of frequency between 1 and 80 Hz.
3. As verified through the present study, the effect of a barrier composed of hollow PC piles to isolate vibration is in between that of such a rigid barrier as concrete wall and that of such a gas cushion as an open trench, these latter effects being determined through a theoretical analysis as reported elsewhere.
4. From the finding as 4 above, the performance of the PC pile barriers can be attributed to the combined effect of the piles themselves composing a rigid body with that of the hollows in them acting as a gas cushion.

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