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GEOFORM TRENCH WALL METHOD FOR REDUCING GROUND VIBRATION

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SYNOPSIS
Effects of two ground trench walls, composed of an expanded polystyrene block and a cast-in-place rigid polyurethane, on the reduction of public nuisance of the propagated ground vibration were investigated in field tests. These geofoam wall methods had been applied for the first time in the world to the vibration reducing purpose. The reduction effects of frequency, depth of open trench, two types of geofoam were observed in detail using full-scale experiments. The results indicated these ground wall methods could reduce a marked improvement of polluted vibration level.

Key Word
ground vibration, vibration pollution, trench wall, geofoam, EPS, polyurethane

1 INTRODUCTION

A propagated ground vibration problem caused by moving vehicle, factory machine, construction machine and others is recently paid considerable attention as one of the public pollutions. In fact the current overcrowded urbanization damages very severe vibration shock and noise to inhabitants nearby heavily trafficked roads and railways, and industrial and residential areas under development especially in the countries retaining insufficient available land. Moreover only limited legal regulations or voluntary controls have been imposed on diminishing the vibrations up to the present.

A propagation of ground vibration is affected complicatedly by soil condition, soil profile, vibration intensity, wave distribution properties, and natural frequency of structures. There are two methods in order to reduce a vibration of building structures on he propagation route. One is to coincide with both natural frequencies at the receiving spot and dominant frequency of seismic source. Another is to reduce a acceleration of vibration by means of a frictional resistance or a cut-off using an aseismic isolation foundation or a trench.

Development of effective prevention methods and systems against the ground vibration is demanded technically and politically. It is known since early times that an open trench wall can cut or reduce markedly its ground vibration. However the top and sidewall surfaces are needed to be covered and to be protected against safety and long-term stability. Filling materials in the trench wall, which have been taken into consideration until now, are cement concrete, expanded and extruded polystyrene blocks which are abbreviated as EPS and XPS respectively, polyurethane, and others. It is recognized from the past experiences that lower density of the filling material, higher effects of vibration-proof. In this study two types of geofoam employed were a precast expanded polystyrene block and a cast-in-place rigid polyurethane. These geofoams are applied firstly in the world to vibration isolation purpose. It is also proved that geometric sizes such as depth, length and width of a trench, and ground conditions affects significantly to the propagated vibration properties.

In this study field tests were carried out to investigate a damping characteristics of ground vibration and effects of the depth of trench walls, vibration frequency were considered. The input frequencies selected for tests were between 5 to 30 Hz, because the traffic and small building vibration demonstrates a prominent behavior at almost between 10 to 30 Hz, and 5 to 30 Hz, respectively.

2 EPS TRENCH WALL

2.1 Ground conditions

EPS trench walls of 6 m length and 30 cm in width was excavated with different depth in a volcanic cohesive soil ground, so called *Kantoh* loam, in Chiba prefecture in Japan. The soil profile was as shown in Fig.1. The water table could not be seen within this investigated range of depth. The apparent density of the soil is 1.15 g/cm^3, natural moisture content is 110 %. The standard penetration test value N converted by the measured Swedish penetration test values are N = 4 at 1 m depth, N = 3 at 2 m depth, N = 2 at 3 m depth and $N \geqq 15$ at more than 5 m depth.

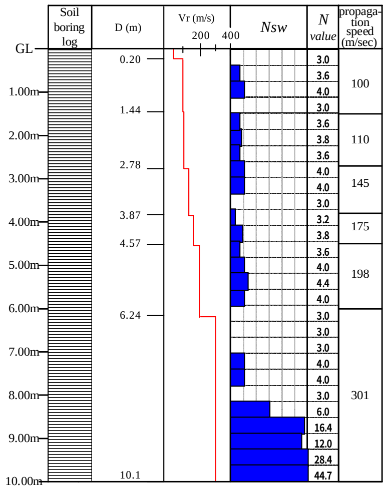

Fig. 1 Soil profile (converted *Nsw* value and wave velocity)

2.2 Procedures of the investigation

Four levels of vibration frequencies of 5, 10, 20 and 30 Hz are applied to the ground using a vibrator of 500 gal and its weight of 981 N. Vibration acceleration levels of ground are measured at several ground surface points and their wave profile are recorded by an oscillator.

Step-1: Receiving propagated vibrations of the non-excavated ground are measured at the ground surface of every 1 m apart from the seismic source as shown in Fig.2.

Step-2: An open trench of 6 m in long, 75 cm in width and 1 m in depth, the distance of which is 2 m from the seismic source, is excavated. The same measurements to Step-1 mentioned above are carried out on the point of 1, 3, 5, 10 and 20 m from the seismic source.

Step-3: The open trench used in Step-2 is excavated to 2 m in depth and the same measurement to Step-1 is done.

Step-4: The open trench excavated to 3 m in depth and the same measurement to Step-1 is conducted as shown in Fig.3.

Step-5: The trench of 3 m in depth is finally filled with EPS blocks and the same measurement to Step-1 is made as shown in Fig.4.

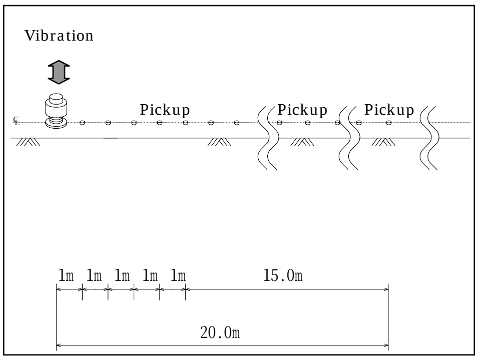

Fig. 2 Step-1 (Natural ground)

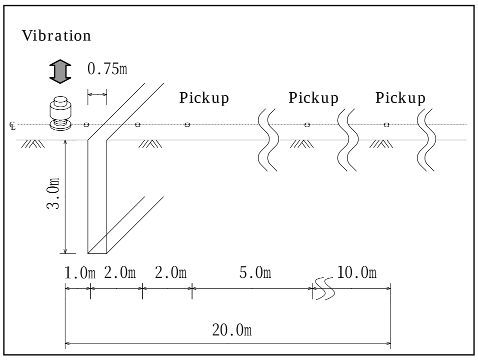

Fig. 3 Step-4 (Open trench of 3m)

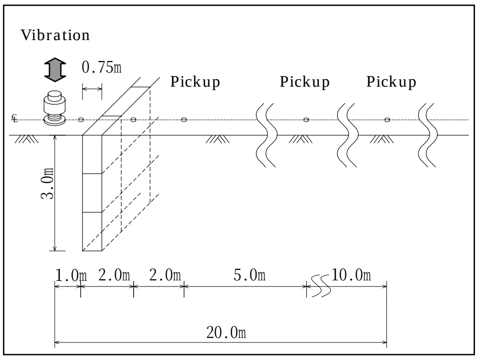

Fig. 4 Step-5 (EPS trench wall of 3m)

2.3 Results of the field test

2.3.1 Effects of frequency on acceleration of vibration

Figures 5 to 7 show the relationships between the distance from seismic source and the reduction of vibration acceleration level in vertical direction, concerning non-excavated natural ground (Step-1), open trench of 3 m in depth (Step-4) and EPS wall of 3 m in depth, respectively. It can be seen from these figures that higher frequency of vibration wave, larger reduction of acceleration level. Contrary to a theoretical presumption, the reduction rate at the highest frequency of 30 Hz was not sufficiently large. Its reasons may be due to interactive effects among ground profile, soil texture, wall properties and structure and others.

It was also found that the range of reduction effects by the open trench and the EPS wall were recognized about 10 m from the seismic source. The reduction of vibration acceleration shows some fluctuation; however the rate of reduction increases with the increase in the depth of trench. It is interesting that the reduction effect of EPS wall of 3m in depth equals roughly to that of the open trench of 1m in depth. It should be noted that the lowest frequency of 5 Hz did not show the clear reduction of acceleration. Therefore in order to cut lower frequency vibration, a deeper, longer and wider trench or EPS ground wall may be required.

2.3.2 Effects of frequency on damping

It can be seen from Fig.6 that the input acceleration in the front side of the wall shows high level in the case of high frequency, because the acceleration of seismic source is kept constant in this study, and moreover that higher frequency of vibration, higher distance-reduction. From this tendency it is found that the stress-strain relation is independent on the acceleration. Therefore it is understood that the energy loss is equal during a cycle, and a high frequency containing many waves during a certain definite time may easy to loose much energy.

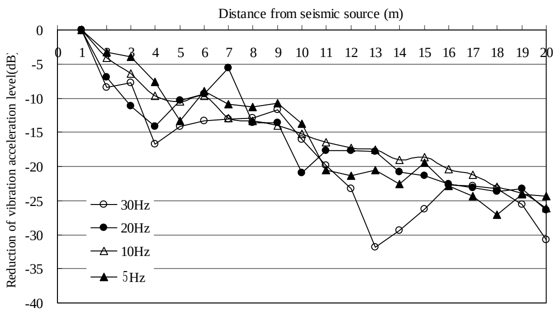

Fig. 5 Step-1 (Relation between distance and reduction)

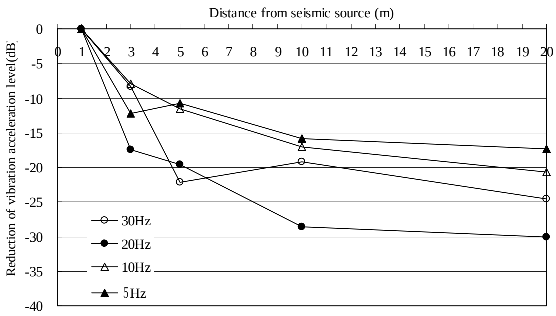

Fig. 6 Step-4(Relation between distance and reduction)

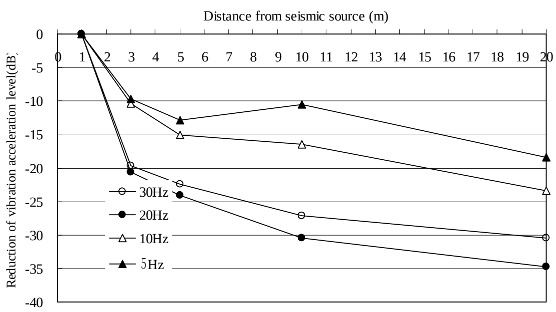

Fig. 7 Step-5(Relation between distance and reduction)

3 POLYURETHANE TRENCH WALL

3.1 Traffic vibration conditions

A full-scale polyurethane ground wall was constructed along the national route No.2 trunk road in Hiroshima City. The main source of vibration pollution in this area is very heavy trucks. The observed vibration level, L5, due to the moving vehicles at the road side did not vary much during 24 hours and the range of variation were 49 to 54 dB.

3.2 Ground conditions

The soil profile and converted SPT values based on Swedish sounding test in this area is shown in Fig. 8. Almost uniformly deposited sandy layer of 8 m in thickness indicates $N = 3$, and the lower layer shows high bearing capacity. The water table is observed about 1 m in depth under the ground surface.

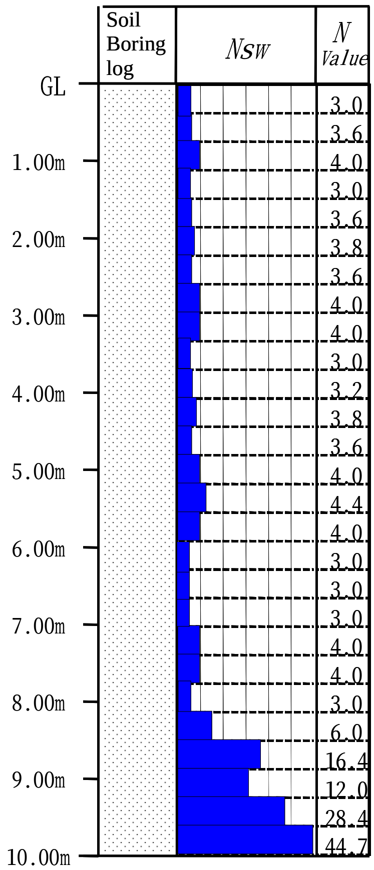

Fig. 8 Soil profile (converted *Nsw* value)

① steel sheet pile are driven

② excavation of 4 m

③ spraying polyurethane by a jet gun

④ curing of expanded polyurethane

Photo. 1 Procedures of polyurethane wall construction

3.3 Procedures of construction

According theoretical estimation the reduction effects of wall can be determined by the ratio of wave length to wall depth. When the amplitude is reduced to 1/2 by the wall, the depth of wall must be reduced at least to 1/4. From the conditions of a wave velocity of 200 m/s and a frequency of 15 Hz in this study, the depth of wall was determined as 4 m. In addition the position of the wall was 6 m from the building for avoiding any harmful influence of the foundation of building.

The brief construction procedures of cast-in-place polyurethane ground wall is shown in Phot.1 (① steel sheet piles are driven, ②excavation of 4 m, ③spraying polyurethane by a jet gun, ④curing of expanded polyurethane). The struts are assembled at every 1.5 m in vertical direction and the wall form are supported under construction and removed after splaying polyurethane. The sheet piles are buried.

3.4 Procedures of investigation

Before and after constructing the polyurethane ground wall, vibration level, oscilloscope wave, diffraction wave and other influence factors were observed at the roadside, house yard and the 3rd floor of steel framed reinforced concrete building, which is very close to the road, for 24 hours.

3.5 Results of field test

After constructing the polyurethane ground wall, about 1 to 3 dB of vibration level are reduced at the wall face as shown in Fig.9. These reduction levels of 1 to 3 dB are equivalent almost to 15 to 30 % of vibration acceleration levels. Therefore it can be seen that a marked energy is cut-off by the polyurethane wall.

Table 1 shows the vibration level, L5, at 3rd floor of the building in three directions. It can be seen that the vibration level in Y-direction (horizontal, perpendicular to the road) is larger than those of Z-direction (vertical) and X-direction (horizontal, normal to the seismic source and the wall). This reason may attribute to the mutual relation among the natural frequency of building and circumstance conditions. The reduction effects of the wall were obtained in the whole. The residents in the building stated that the vibration in the 3rd floor bedroom had been reduced.

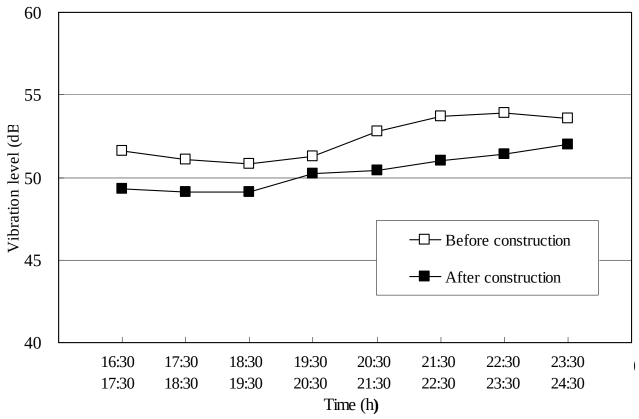

Fig. 9 Vibration level in Z-direction (L5)

Table 1 Vibration level on 3rd floor of building (L5) (dB)

Direction \ Vibration level	Before construction	After construction
X (horizontal)	47.3	46.2
Y (horizontal)	53.4	50.2
Z(vertical)	47.1	46.2

4 CONCLUSICE REMARKS

It was found from the results of actual field construction studies that the construction cost of geofoam trench wall methods were inexpensive than the other methods such as the improvement of traffic facilities, change of better factory machineries or foundation, aseismic base isolation structure of buildings.

From the field experimental works conducted in this study, the main results obtained are as follows;

1) Reduction effects of ground vibration are in proportion to frequency level of vibration.
2) It is preferable that a vibration-cut ground trench wall is installed at the seismic source as close as possible.
3) Reduction effects of the wall increase with the increase in length, depth and width of the wall.
4) Wave frequency does not vary through any ground vibration reduction walls.

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