Reduction of road traffic-induced vibration by layered soilbags (Donow)

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ABSTRACT: The effect of layered soilbags (“Donow” in Japanese) against ground vibration is studied experimentally and analytically for its development in practical use. Layered soilbags is a congeries of individual soilbags. Its discontinuous surface made by each soilbags has the effect to absorb the vibration energy, and also the flexibility in its shape makes the construction against ground vibration more efficient and effective. To verify the effect of layered soilbags, the vibration level was observed in two main experiments: the experiment at the epicenter, and the experiment at the propagation route, and also in the test construction on 2 roads. At the epicenter, the vibration in both vertical and horizontal directions was largely reduced. Also, the layered soilbags showed the effect to reduce the vibration at the propagation route as well. In the test construction at the epicenter on several roads, the vibration level was decreased about 10dB.

1. INTRODUCTION

Layered soilbag (it is called “Donow” in Japanese) has not only a characteristic to increase bearing capacity of buildings but also a characteristic to reduce vibration efficiently and effectively. The unique characteristics are caused by its individuality (it is a congeries of individual soilbags) and flexibility in its shape. In this study, the effect of layered soilbags against ground vibration is studied experimentally and analytically for its development in practical use. To verify the effect of layered soilbags, the vibration level was observed in two main experiments: the experiment at the epicenter, and the experiment at the propagation route, and also in the test construction on several roads. Experiments were conducted both inside of room and outside. In experiment inside, the mechanism of vibration reduction of layered soilbags was studied. Vibration reduction at propagation route was studied in experiment outside, and 2 test constructions were conducted based on the result of those experiments.

2. EXPERIMENTS AT EPICENTER

2.1 Vibration reduction of layered soilbags

A soilbag used in this experiment was 40cm in width and 8cm in height, and filled with gravel. To verify the effect of vibration reduction of layered soilbags, vertical vibration was observed using, the first, 5-layered soilbags, the second, cardboard box filled with the same gravel as soilbag, and the last, a heap of gravel, putting a oscillator on the top. To measure the vibration acceleration, four accelerometers which were strain gauge type were put between soilbags or every 8cm deep in the gravel (fig.1). Fig.1 (b) is a picture of this experiment using 5-layered soilbags. As shown in figure 1 (a), the vibration acceleration (gal) decreased to half every time passing through a soilbag (50% x 50% x 50% □ 13%). 87% of the vibration acceleration was decreased in total (the vibration acceleration decreased to 13%). When the cardboard box filled with gravel was used, shown in figure 1 (c), only 43% of the vibration acceleration decreased even passing through 24cm (8cm x 3). Also, when using a heap of gravel (fig.1 (d)), only 61% of the vibration acceleration decreased after passing through 24cm (8cm x 3). As a result of the examination, the reduction effect of layered soilbags was four times that of the cardboard box with gravel, and three times that of the heap of gravel. One of the reason of this result is considered that soilbags attenuate the vibration energy because soilbags change its shape (for instance, stretching or shrinking) when they receive vertical vibration. It is easier to understand that soilbags flexibility attenuate the energy, compared with the fact that the vibration energy increases when the oscillator is put on the concrete plate.
2.2 Reduction of horizontal vibration

In this experiment, effect of layered soilbags against horizontal vibration was studied (fig.2). The same soilbags of the previous experiment were used. Two Figure 2 (a) and (b) show the experiment that used a 60Hz oscillator, and (c) and (d) show the experiment that used a 6 Hz oscillator. Figure 2 (b) and (d) show that the vibration transmitted to the next soilbags even they were not touched each other. It means that the vibration propagated through a floor under the layered soilbags. The vibration acceleration was almost 0, when subtracting the horizontal vibration acceleration level of figure 2 (b) and (d) from that of figure 2 (a) and (c). (The acceleration levels were 10gal and -10gal in figure2 (a). It is considered that a tolerance of the accelerometer (±1%) of 1G (980gal).) As result of the experiments showed, the vibration barely propagated to the next soilbags, even if they were touched each other.

Figure 2. Horizontal vibration level between soilbags

3. EXPERIMENT AT PROPAGATION ROUTE

Layered soilbags was built in a pit which was built by excavating the ground and putting river sand and roller compacting (fig.3). The pit was 960cm in length, 440cm in width, and 98cm in depth. The size of one soilbag was 40cm x 40cm x 7cm (height), and pit sand (grain size was 0.074mm-8mm) was used to stuff soilbags. An electric plate compactor (30kg in weight, 60Hz frequency) was used as the source of vibration. 4 layers of soilbags were built (28cm in height, 2columns in the first layer, 3 in the second layer, and 4 in the third and forth layer). The epicenter was moved to five points ( shown in fig.3(a). The vibration level was observed by the vibration level sensor. The vibration was regarded as steady oscillation and was observed by moving the sensor every 40cm along the siding. In the next, as shown in fig.3 (c), 10 layers were added in the direction of depth, and the vibration was observed in the same way.

Figure 3. Ground plan and cross section of the experiment

Figure 4 shows the results of the tests. Solid line indicates the decay by distance of the vibration level which was measured in the experimental pit without the layered soilbags. Compared with vibration level before and after building the layered soilbags, it can be seen that the vibration level was largely reduced right after passing through the layered soilbags. About 15dB was decreased when electric plate compactor was used, and about 10dB was decreased when motor plate compactor was used (fig.4 a, b).

Figure 4. (a) Vibration level before and after building the layered soilbags (Epicenter: electric plate compactor)
Fig. 4 (c) shows the result of the same experiment with 3-layered soilbags. The vibration level was decreased about 5dB even passing through only 3-layered soilbags. An accelerometer was set in the layered soilbags, and observed the transmission coefficient of the vibration. As shown in Fig. 5, the transmission coefficient was lower (the reduction of the vibration was greater) as the epicenter was close to the layered soilbags. The result coincides with the result of previous test which showed that the vibration was reduced as the epicenter was close to the layered soilbags.

4. TEST CONSTRUCTION

4.1 Test construction at Akatsuka intersection, Nagoya

The construction site shown in Fig. 6 is Akatsuka intersection in Higashi-Ku, Nagoya (the intersection was paved by asphalt). The width of one side of the road was about 10m, and the construction site was near the intersection. The volume of traffic was very large, and the surface of the road was uneven because of the friction which occurred when a car stopped at the intersection. In addition to that, the foundation ground was very soft. Residents in the neighbor often complain about the ground vibration from traffic.
4.2 Summary of construction
Fig.7 shows a summary of the construction. 3 layers of soilbags (20cm in height) was built in the subbase course, which was under the 40cm thick base, and also 2 layers of soilbags was constructed in the area where adjoined the concrete ditch of the side walk. The length of the construction area was 22m, and about 5,000 soilbags were used for the construction. As an important notice, the barrier of soilbags cannot be built in the asphalt pavement because soilbags would be melted by the heat when asphalt was paved. The vibration level was measured at 4 points (P1~P4). 3 of them (P1-P3) was placed on the road, and one of them (P4) was on the third floor of the steel framed house along the road.

4.3 Result of measurement
Table.1 has shown the result of measurement. All values in table was the largest number of the vibration levels in which were observed for 10minutes before and after the construction at the same time. The vibration levels observed at each point fell below the request limit which was the strictest standard of the vibration level from traffic.

<table>
<thead>
<tr>
<th>Measurement point</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Construction</td>
<td>67dB</td>
<td>66dB</td>
<td>57dB</td>
<td>65dB</td>
</tr>
<tr>
<td>After construction</td>
<td>55dB</td>
<td>54dB</td>
<td>46dB</td>
<td>50dB</td>
</tr>
</tbody>
</table>

The neighbor of the construction area was the place where residents often complain about the vibration from traffic. In this time there was no complaint after the construction. The vibration level was observed right after the construction and the road surface was newly paved. This study is going to continue to measure the vibration level to see if this situation was preserved.

5. TEST CONSTRUCTION 2
5.1 Test construction on National Route No.2, Hiroshima
The constructed section was about 150m where elevated road overlapped ground road, as shown in fig.8. The ground profile of the section was the soft layer 23m in thickness formed by sandy soil layer 10m thick (N=5~15) and cohesive soil layer 13m thick (N=1~3). The wavelength of ground vibration from road traffic was estimated over 10m. Due to secure traffic volume on National Route No.2, the constructed section was regulated 2m wide on the edge of the road, and 1m deep in part of the surface layer (fig.9). Observation points of the vibration were, as shown in fig.8, four points A–D which were placed on the 14m siding from the edge of the roadside to over the roadside.
5.2 Summary of survey
The survey was conducted focusing on five points shown in table 2, and examined effects of layered soilbags as compared between the results of survey before and after the construction. The survey focused especially on the number of occurrences of the vibration which maximum level was more than 50dB, and the amount of decrease in the vibration level of each frequency for examining the effect of soilbags. As an important notice, the result of traffic survey showed that volume of traffic per day was: about 75,000 vehicles before the construction and about 79,000 vehicles after the construction. The average speed of vehicles on the side of survey point was: average 56km/h before the construction and average 55km/h after the construction. Traffic conditions were almost the same before and after the construction.

Table 2 Items for vibration level survey

<table>
<thead>
<tr>
<th>Survey Items</th>
<th>Analyzed Points</th>
</tr>
</thead>
</table>
| 1. Ground vibration from road traffic (vibration level) | • Total amount of the vibration level \(L_{10}\)  
|                                                   | • Decay by distance of the vibration level  
|                                                   | • Analysis of maximum value of the vibration level          |
| 2. Ground vibration from road traffic (vibration acceleration) | • Decay by distance of the vibration level which is calculated from the vibration acceleration |
| 3. Ground dominant frequency                      | • Center frequency of 1/3 octave band                        |
| 4. Volume of traffic                               | • Traffic condition of each time section (day and night)     |
| 5. Average speed of vehicles                       |                                                               |

5.3 Results: Ground dominant frequency
The survey showed that ground dominant frequency was 16.5Hz when single large vehicle was running through the road. The value is a little bit larger than that of the average soft ground which dominant frequency is less than 15Hz. It is considered because of the rigidity of sandy soil layer that is distributed 10m deep in the surface layer.

5.4 Results: Statistics values and decay by distance
The results of comparison with vibration levels \(L_{10}\) Each value is the average of the value of day time (7:00-19:00) and night time (19:00-7:00) doesn’t show the large differences before and after the construction, as shown in fig.10. In the survey of decay by distance, the clear decay by distance was not observed because of the vibration which was made when vehicles pass on the gap nearby the 14m siding.

5.5 Results: Number of occurrences of the vibration level more than 50dB
The results of comparison with the frequency of vibration (50~70dB) occurrences are shown in fig.11. The number of occurrences was decreased 4~13% at each observation point. Especially, it was noticeable at point B which was behind the intercepting wall, and also at point D. The change by countermeasure is not seen in the statistic values of 2), but it is seen in fig.11, decrease in occurrences of the vibration level more than 50dB.

5.6 Results: Amount of attenuation of vibration level
(fig.8. before large vehicle passes by siding)
The vibration acceleration was observed at each survey points while a single large vehicle was running. To calculate the vibration level (the average vibration level of 12 large vehicles) at each point, the observed values were weighted with frequency of the vibration level by vertical method. The amount of attenuation of the vibration level before and after the construction is showed in fig.12. The maximum vibration level decreased about 1dB.

Figure 10. Vibration level before and after the construction

Figure 11. Number of occurrence of vibration more than 50dB

Figure 12. Amount of attenuation of vibration level

5.7 Results: Frequency characteristic near the maximum vibration level (fig. 8 after passing the gap on the pavement road)

Frequency characteristics near the maximum vibration level at survey points A and D, are shown in fig. 13 (lines indicated the mean of the analyzed result). After the construction, the vibration level more than 30 Hz decreased, but less than 20 Hz didn’t decrease. Also, the frequency characteristic reached the peak around the ground predominant period (16 Hz). The reason of the vibration level decreased in higher frequency is considered as the blockage effect of layered sand bags. It is considered that the layered soilbags were effective to higher frequency (shorter wave length) in connection with the depth of layered soilbags (1m).

6. CONCLUSION

From experiments and test constructions in this study, it is verified that layered soilbags is very effective to reduce traffic-induced vibration, especially, it shows more effect of vibration reduction when layered soilbags is used at epicenter. Since layered soilbags is flexible in its shape, it is expected that layered soilbags has more potential to reduce traffic-induced vibration when it is used at epicenter and propagation route appropriately.

7. REFERENCES


