PROTECTION OF BUILDINGS AGAINST RAILWAY VIBRATION BY FOUNDATION LINING. THEORY AND MEASUREMENT.

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Abstract

Reductions of vibrational levels and noise inside buildings due to surface trains can be achieved when inserting a resilient layer between the income ground waves and the foundations. Such solutions are first tested numerically, using 2D finite elements. Experimental validations are under way.

INTRODUCTION

The vibration generated by surface or underground transportation propagate in the ground and penetrate into buildings through their foundations or underground elements such as buried walls (parking places for instance). The purpose of this presentation is to report the results of a study carried for the French Government [1] concerning the use of isolating layers placed between the ground and the buried structures. A 2D-Boundary/Finite element program has been developed and used to simulate different configurations. Parameters such as the source position, the type and composition of ground, the type, size, thickness and location of isolating layers, the influence of the size of the superstructure, the type of buried structures, the type of source spectra have been considered. The determination of a pertinent indicator has also been addressed. The effect of the isolating layers has been best evaluated by computing sound pressure levels inside the buildings.
NUMERICAL ANALYSIS

The computer program MEFISSTO [2,3,4], developed at CSTB, has been used. It is based on a classical 2D Boundary/Finite element approach where the BEM part describes precisely the semi-infinite or layered ground medium. Any finite part or sub-domain can be either modelled by BEM or FEM. A complex Green function can be considered if one wishes to restrict the meshing only to finite boundaries. The 2D limitation implies that the excitation forces are in fact infinite coherent lines and that the buildings, also, are infinite on a line parallel to the excitation. As a first approximation, this will correspond to the case of a train running close and parallel to a long building, although a train can not be considered as coherent.

In [1], a very extensive study can be found, where the variation of many parameters is considered: type of ground, position of excitation, type of foundation, size of underground and surface structures, type and location of isolating layers. The analysis can be done directly on the velocity levels in different manners (local values or surface averaged), but due to the complexity of the problem and to the presence of different wave-types it has been finally chosen to assess the global efficiencies by computing the pressure levels in the upper volumes in an SEA-type manner: normal plate velocities are combined with plate radiation loss factors to give radiated powers which are then summed to lead to the pressure values assuming a diffuse pressure field.

Case 1: wall foundations

Figure 1 shows the configuration here considered. One or two storey buildings and simple wall foundations are modelled. The ground is an infinite half-space either made of Loess or of Sand and a vertical unit force \( F \) is applied 6 m before the treated foundation wall either on the surface or 10 m under the ground thus figuring a surface or an underground train. A 10 cm-thick elastified polystyrene (E=0.3 M Pa) is used as an isolating layer. It is positioned along the vertical side facing the source. Covering other parts of the foundations does not improve the results. The excitation force has the typical spectrum showed in Figure 2, showing a peak at 63 Hz. The dB(A) efficiencies computed as differences of the pressure levels without and with the treatment are mentioned on each graph relative to this spectrum. Figure 1 also reports the efficiency of the treatments on the pressure level in the upper volume for the two types of ground and the two source positions. It can be seen that better efficiencies can be found for a surface excitation than for a buried one. With loess, 3.3 dB(A) of attenuation is observed whereas with sand it goes up to 7.7 dB(A) (for a surface excitation). Figure 3 compares the reduction of sound pressure levels for loess and a surface excitation, with either one or two upper levels, showing little difference which suggests that the results obtained for a building of limited height are representative of what can be expected for higher buildings.
Case 2: building with a basement

The most frequent situation, in France, corresponds to a building with a basement. Figure 4 represents such a building with two basement levels. Three types of treatment are considered, where type A covers only one underground level, type B the two levels and type C further covers the lowest slab. Figure 4 also reports the same type of results as in Figure 1. Reductions of more than 7 dB(A) are obtained for Loess and for Sand even if only one underground level is treated (A treatment). Treating the underside (C treatment) is not necessary but increasing the vertical treatment down to two levels (B treatment) further increases the efficiency. For the underground excitation, the isolating layers are significantly efficient only for a sandy ground. When the source is on the ground surface, Rayleigh waves are mostly generated. They are rapidly attenuated with depth so that most of the energy impinging on the foundations is cut off by the polystyrene, which explains why the addition of a bottom lining is not necessary. On the other hand, when the source is buried, body waves are generated; they will excite all the underground structures. Even the fullest C-treatment may be insufficient, since the soles, which can not be treated for stability reasons are then significantly excited.

The ground is usually more complex than a simple half-space, since it may be stratified. Adding a rigid surface, 10 m under the free surface will somewhat be the other extreme from the case already considered. The waves will be trapped between the surface and this rocky bottom, thus amplifying the excitation of the foundations. However in the previous case of surface excitation, and again due to the nature of the Raleigh waves, the efficiency of the proposed treatment was found to be little affected as can be seen in Figure 5 where a rigid substratum is added at 10 m of depth, for the surface excitation with loess and the B treatment (above 25 Hz the Rayleigh wavelength, in this case, is less than 10 m).

An other important point is the validity of this 2D approach. In practice, buildings are not infinite and the lateral underground walls (perpendicular to the line of excitation) will also be excited so that it may be necessary to also treat them. In order to access this effect the configuration represented in Figure 6 is considered. It is also a 2D situation but deep in the ground. The structure is an infinite rectangular duct, with 20 cm-thick walls, excited by a unit horizontal force directed towards the structure, 10 m away. The structure has a width of 5 m and a height of 10 m and is made of 20-cm thick concrete walls. A 10 cm-thick protection (elastified polystyrene) is placed either on the wall facing the source (thin lines) or also on the lateral sides (thick lines). This situation has some similarity with the 3D problem at stake. Note that in 3D a surface wave varies as the square root of distance and that 2D body waves vary in the same manner. In Figure 6, plain lines correspond to the front treatment and the lines with circles correspond to the side walls also treated. When the lateral walls are also treated, the velocity of the front wall is little affected and the side walls have a reduced velocity. Other computations have shown that when the source is aside, the velocity of the untreated lateral walls becomes more important. Experimental results should help assessing this effect.
Experimental validation

A full size facility has been built. It consists of an uncovered rectangular basement with dimensions showed in Figure 7. The basement will be excited by an artificial impact source (mass dropped on a small concrete slab laying on the ground surface). Several impact points located on two lines parallel to the basement and representing train tracks at two distances (3 or 6 m) will be chosen. The spatial average velocity levels of the buried walls will be measured for each impact point – the wall velocities corresponding to the uncorrelated infinite line source will be obtained by energetically adding the velocities obtained for each point. Measurements without and with protective layers will lead to the efficiency of the protection. Measurements are under way and some experimental results should be presented at the conference. In order to compare measured and calculated results, the ground has to be known – the Spectral Analysis of Surface Wave method SASW [5] will be used to experimentally estimate the mechanical characteristics of the upper ground layers.

CONCLUSION

It appears that the type of treatment proposed is most effective for surface excitations and it is clearly sensitive to the type of ground considered. Very promising efficiencies (more than 10 dB(A)) can be obtained for the frequent situation of buildings with basement with a vertical treatment facing the excitation and extending only down one or two levels. Measurements on a 1/1 scale test facility will be carried during the spring 2001 and results should be presented at the conference.

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REFERENCES

Figure 1. Sound pressure level in upper room.

Figure 2. input excitation (unit vertical force)
Figure 3. Effect of number of upper floors on protection efficiency.

Figure 4. Building with basement. Protection efficiency. Sound pressure level in upper room.
Figure 5. Effect of rigid substratum. Sound pressure level in upper room.

Figure 6. Effect of lateral protection. 30 cm elastified polystyrene.
Figure 7. Measurement configuration.