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BUILDING FOUNDATION LINING AGAINST GROUND BORNE VIBRATION FROM RAILWAYS

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ABSTRACT
The simple case of an infinite concrete plate in contact with a half-space ground and excited by an incoming ground borne wave is studied. Using the wave approach for multi-layered infinite systems (often referred to as the transfer matrix technique), the effect of inserting a soft layer between plate and ground is calculated in term of reduction of the plate velocity amplitude. Ground borne incident in-plane compressional waves as well as in-plane and out-of-plane shear waves are considered. Results are given for single or random (diffuse field) incident plane waves. It is found that inserting a relatively soft layer leads to a substantial reduction of the plate velocity amplitude in the usual frequency range of interest for ground borne vibration from railways.

1 - INTRODUCTION
Railways generate ground borne vibration which propagates and excites the foundations of buildings located nearby (the word "foundation" means any part of the building structure in contact with the surrounding ground). The structure borne vibration created propagates through the building structure and radiates the so-called ground borne noise from railways. The question asked in this paper is the following: if the building foundation considered is a plate (wall or floor), is it possible to insert a soft layer between ground and plate in order to decrease the vibration level generated in the plate (and therefore the ground borne noise radiated in the building)? The plate with soft lining is a multi-layered plane structure which can be studied using the wave approach. The wave approach [1] considers an infinite plane structure acoustically excited by a single or random (diffuse field) incident plane wave and greatly simplifies the calculation of sound transmission through multi-layered structures by means of the transfer matrix technique as developed by Munjal [2]. In the case of a soft layer covering a wall or floor excited by a single or random incident ground borne plane wave, the same approach can be used to theoretically estimate the efficiency of the resilient layer, the emission medium being then an half- space ground. The same model has already been used by the authors to study the vibrational interaction of a bare concrete plate and a half-space ground in terms of wave type [3].
This paper is divided into 2 parts: section 2 briefly describes the wave approach in the particular case of incident ground borne waves; section 3 gives numerical results, obtained for a typical half space homogeneous ground and different types of resilient layer, the effect of foundation lining being expressed in terms of reduction of the plate velocity amplitude.

2 - THE WAVE APPROACH
The configuration studied is shown in figs. 1 and 2: a concrete plate (thickness h) of infinite extent in the x and y direction lays on a half-space ground (figure 1); an incident ground borne wave propagates in a direction parallel to the (x,z) plane with time dependence $e^{j\omega t}$. Three types of incident waves must be considered: in-plane (x,z) compressional waves (P waves), in-plane shear waves (SV waves) and out-of-plane shear waves (SH waves with displacement perpendicular to the (x,z) plane), as also shown in figure 1.
A resilient layer (thickness e) is inserted between the concrete plate and the elastic half-space as shown in figure 2.

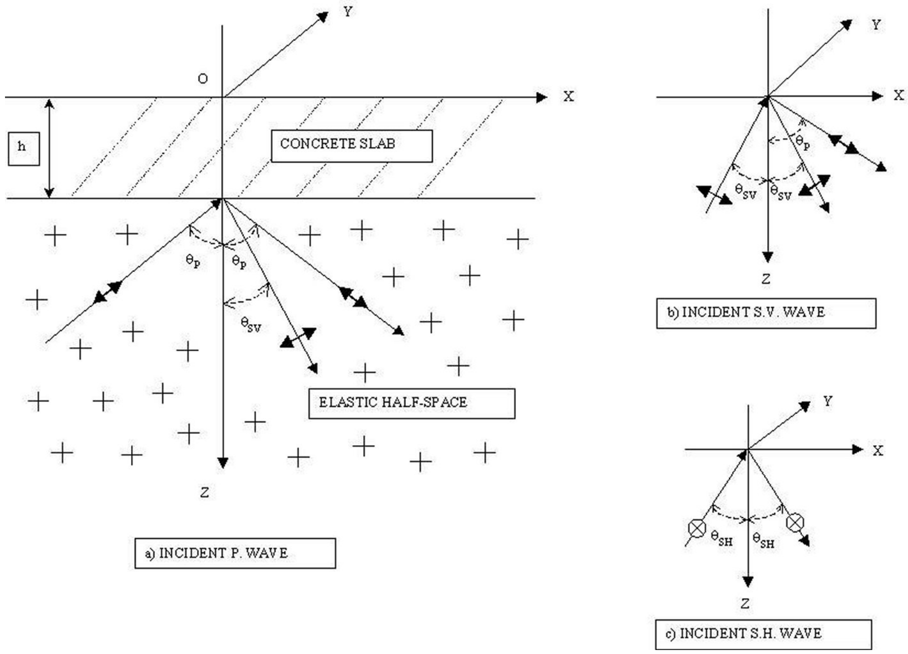

Figure 1: Configurations studied; bare concrete plate.

In the wave approach, the vibration field of each layer is decomposed into compressional and shear plane waves, having the same wave number component k_x as the incident ground-borne wave.
In the case of in-plane excitation, a state vector $\left\{\tilde{U}(z)\right\}$ can be defined at each z plane as:

$$\left\{\tilde{U}(z)\right\} = \left[\tilde{\sigma}_z(z), \tilde{\tau}_{xz}(z), \tilde{V}_x(z), \tilde{V}_z(z)\right]^T \tag{1}$$

where $\tilde{\sigma}_z$, $\tilde{\tau}_{xz}$ represent the compressional and shear stresses, $\tilde{V}_x$, $\tilde{V}_z$ the tangential and normal particle velocities, T denotes a matrix transposition and $\sim$ denotes quantities in the k_x space. Using the transfer matrix technique [2], a relationship between the state vector at the top surface of the concrete plate (z=0) and the bottom surface of the resilient layer (z=h+e) can be found, the later state vector being expressed in terms of the incident and reflected ground borne plane waves indicated in figure 1. The four equations obtained can be used to determine the four following unknowns: the velocities $\tilde{V}_x(0)$ and $\tilde{V}_z(0)$ at the top surface of the concrete plate and the complex coefficients of the two reflected P and SV waves in the half-space ground ($\tilde{\sigma}_z(0)$ and $\tilde{\tau}_{xz}(0)$ at the free top surface of the concrete plate are known and equal to zero).
In the case of out-of-plane excitation, the state vector $\left\{\tilde{U}(z)\right\}$ reduces to

$$\left\{\tilde{U}(z)\right\} = \left[\tilde{\tau}_{yz}(z), \tilde{V}_y(z)\right]^T \tag{2}$$

leading to only two equations to determine the two following unknowns: the velocity $\tilde{V}_y(0)$ at the top surface of the concrete plate and the complex coefficient of the single reflected SH wave.

3 - NUMERICAL RESULTS

In this section, a 0.3 m thick concrete plate laying on a typical soil (loess type) is lined by a 10 cm thick resilient layer made of materials of the different Young moduli given in table 2; table 1 contains the material properties of the concrete plate and soil. The vibrational behavior of the plate is analyzed in a [5-200 Hz] frequency band, which is the usual band of interest for ground borne vibration from railways.

	CONCRETE	LOESS
Young modulus E (M Pa)	25.10^3	269
Density ρ (kg/m^3)	2500	1550
Poisson ratio ν	0.15	0.26
Loss factor η	$\eta(f)$	0.01

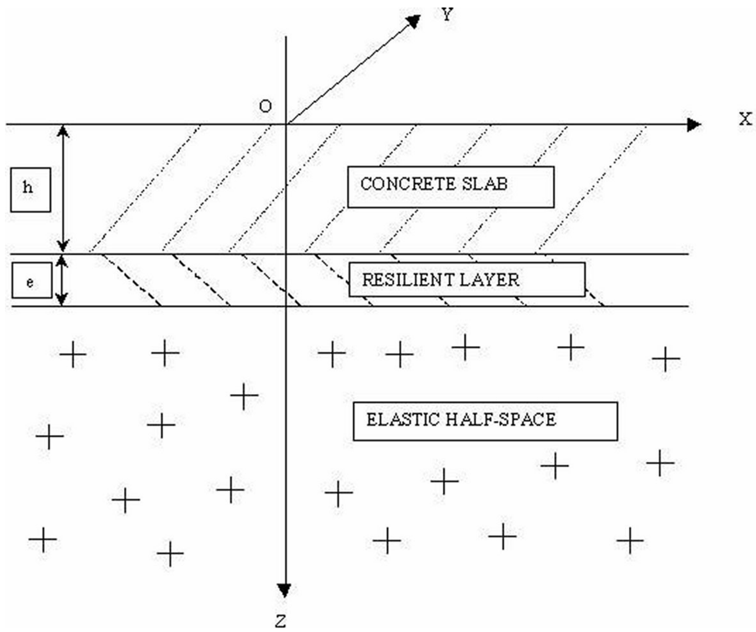

Figure 2: Configurations studied; concrete plate with resilient layer.

Table 1: Material properties of the and the soil.

	LAYER #1	LAYER #2
Young modulus E (M Pa)	3.10^5	3.10^6
Density ρ (kg/m^3)	10	10
Poisson ratio ν	0.0	0.0
Loss factor η	0.05	0.05

Table 2: Material properties of the resilient layers.

Figure 3 presents, for the three types of ground borne incident waves, the diffuse field plate velocity amplitude obtained with no resilient layer (curve (0)), a layer made of styrene foam type material (layer #2) and a layer 10 times more elastic (layer #1); note that Figure 3 shows the velocity component V_z normal to the plate in the case of in-plane excitation and the component V_y in the case of out-of-plane excitation. It can be clearly seen that the system plate/layer/soil exhibits a resonance frequency depending on the stiffness of the layer. Of course the more elastic the layer the lower the resonance frequency. It should be noted that for a given resilient layer, the resonance frequency obtained is the same for incident P or SV wave and a little lower for incident SH wave with a much less pronounced effect on the plate velocity.

4 - CONCLUDING REMARKS

The case of a soft layer inserted between a concrete plate and the surrounding ground when the plate is excited by an incoming ground borne plane wave, has been theoretically studied using the wave approach. The efficiency of the soft layer to decrease the vibration level of the plate has been estimated; it is found that inserting a relatively soft layer leads to a substantial reduction of the plate velocity amplitude in the usual frequency range of interest for ground borne vibration from railways. This type of treatment seems particularly well adapted to the case of tracks at the ground surface exciting vertical basement walls. In this case, the soft layer is vertical and the static load is greatly reduced; the wall is then excited by incoming surface waves, combining mainly horizontal in-plane compressional waves and vertical out-of plane shear waves, the plane considered being the ground surface.

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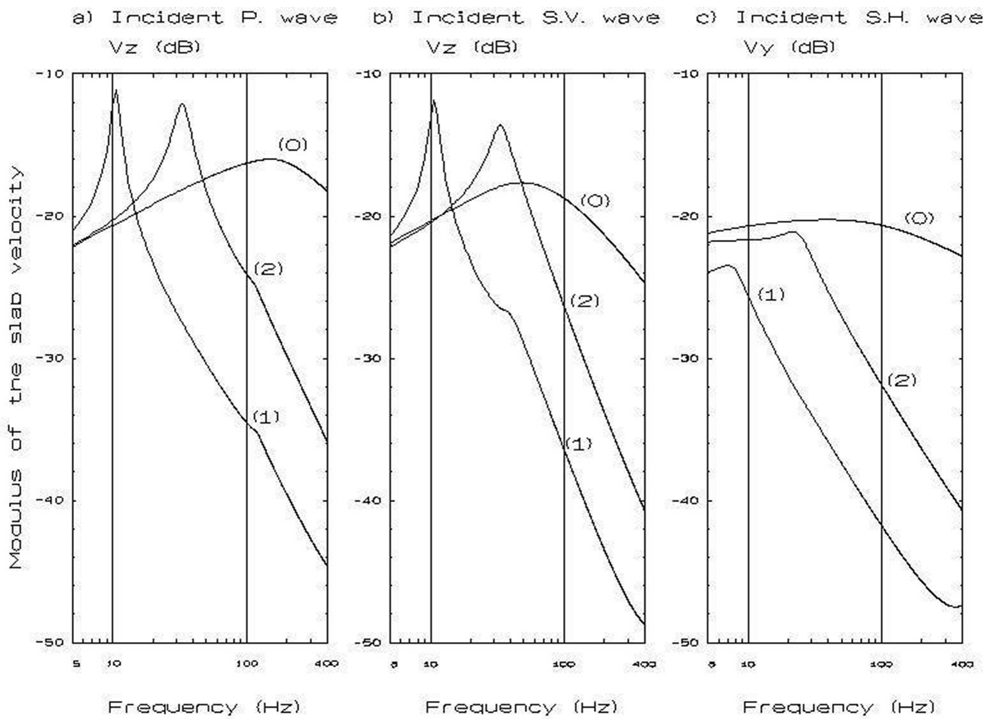

Figure 3: Amplitude of the plate velocity − case of a concrete plate on soil #2 without any treatment (0), with soft layer #1 (1) and with soft layer #2 (2).

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