On the use of trenches and walls on the control of ground transmitted railway vibrations

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ABSTRACT

An actual case of an underground railway in the neighbourghood of habitation buildings has been analyzed.

The study has been based on a twodimensional BEM model including a tunnel and a typical building.

The soil properties were obtained using geophysical techniques. After a sensitivity study, the model has been simplyfied and validated by comparison with "in situ" measurements. Using this simplyfied model, a parametric study has been done including trenches and walls of different materials and different depths at two different distances from the tunnel. The reductions obtained with the different solutions can then be compared.

1. PROBLEM DESCRIPTION

An increasing number of litigation between building owners and railway companies is been registered recently due on the one hand to the city developments and the consequent use of land in the vicinity of railway lines and, on the other, to the growing exigences on life quality for urban population.

In Spain, the Direccion General de Infraestructuras del Transporte of the Spanish Ministry of Public Works has launched an effort to understand the behaviour and solutions that can be applied to this problem.

A variety of methods to control the induced vibration can be used nowadays including:

a) Reduction of the emitted vibration level either at the vehicle, track or platform settings
b) Placement of a screen between the focus of vibration (track) and the receptor (building)
c) Installment of isolation devices under the building or instruments to be controlled.

The use of trenches and/or walls as a screen between the track and the building is an atractive "a posteriori" solution. Different authors (ref 1,2,3,4) present results about the effectivity of trenches and walls of moderated depth when the important point is the interception of Rayleigh waves. In the above mentioned problem the situation is different: the energy is not confined in a surface layer but propagates in the whole body of the halspace. This is probably the reason why the first meters of the wall or screen, especially when placed by the tunnel, seem to be not useful for wave screening.

In the case studied, the tunnel had not invert so the generation of wave is a mixture of those produced by the displacements of the lateral tunnel walls and those transmitted through the ballast.

The actual situation is a shallow tunnel of about 5 Km lenght that was produced to suppress the large number of crossings with the city streets.

The cross section is a double track one, 9m width and 6.45m height over the rail level. The geometric shape is a circular vault 0.70m thick on vertical walls of 0.90m. In addition there are fottings 1.80 x 0.90 under the walls to transmit the loads to the natural soil. The track is a classical one: wood sleepers on ballast.

The natural soil is a mixture of sandstone, and claystone which mechanical properties have been determined by reflection seismic propecting. The layering can be approximated by a structure of a shallow layer 2m thick, a 5m intermediate one and a deep basement.

Due to the lenght of the most usual trains (~ 80 m) and the distance to the buildings (~ 15 m) it is possible to assume a plane strain situation and try to model the geometry described in figure 1.

The surface level is 1.60m over the crest and a 9 flats building 13m width is the wave receptor.

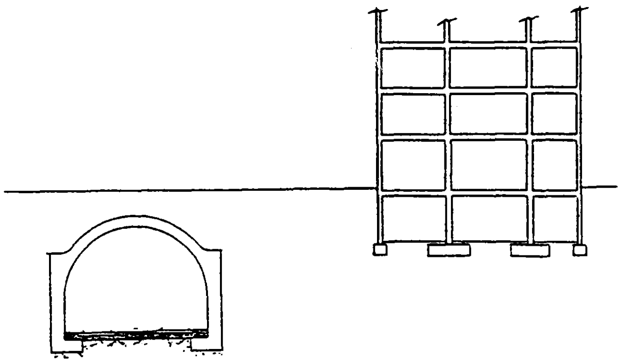

Figure 1

The excitation is produced by a harmonic load in the frequency domain applied over the ballast by two rigid areas 0.90m width to simulate the sleeper effect. The most interesting frequency band is bounded by the 30 and 70 Hz but the study has adopted the band 0-100 Hz.

2. SENSITIVITY ANALYSIS

A careful study of the influence of the different parts of the model has been conducted in order to develop criteria for building the simplest model able to represent faithfully the situation without increasing the computational effort of the parametric study beyond a reasonable level. In addition, from every model a comprehension of the phenomena can be obtained.

Table I summarizes the results obtained from the different studies. The detail variations are related to three main models. Model I is a simple symmetric model including the tunnel and a layer 30 m thick on a stiffer halfspace. The idea is to provoke a wave reflection at the interface magnifying the differences to be studied on this.

Then a halfspace with varying number of layers has been studied in order to see the influence of varying the wave celerities in depth.

The so called Model II is also a symmetric model in which the influence of a shallow infilled layer is being studied.

Finally, model III is a three layer soil structure with the following properties

shallow layer : 2m thick ; G = 1'65 E 8 N/m^2
Intermediate layer : 5'25m thick ; G = 5'05 E 8 N/m^2
Halfspace G = 9'51 E 8 N/m^2

TABLE I. SUMMARY OF SENSITIVITY ANALYSIS

MODEL	PURPOSE OF THE STUDY	CONCLUSSIONS REACHED
TYPE I with and without concrete footing	Possibility of suppressing the footing in the final model	Only affect frequencies over 60 Hz
TYPE I with different ballast depths	Influence of the ballast on response reduction	The increas of ballast depth increases the energy transmission through the tunnel walls in the range 60-70 Hz
TYPE I with concrete invert	Possible reduction of response by using an invert	Reduction only for frequencies in the range 50-80 Hz
Layered halfspace	Influence of number of layers when trying to simulate properties varying with depth	It is possible to reduce the number of layers when frequencies are comprised in the range 25-100 Hz
TYPE II with and without shallow layer	Influence of infills	Only important to represent local displacement in the space between the tunnel and the building
TYPES II & III with building	Influence of building properties and symmetric conditions	How to select the building best representing the measured results
TYPES II & III with building and screen	Influence of a 20 m depth concrete wall by the tunnel	No reduction except when there is no connection (trench) between the wall and the tunnel
	Ditto using hard or soft material by the building	The soft material produces better results for high frequencies

3. SIMPLIFIED MODEL

The conclusions obtained after the sensitivity study allow the establishment of a simplified model that will be used as a basis for the parametric study. As it is intended to analize the response level at the building basement and in a relected frequency range all the details that influence only local responses can be suppressed. This has allowed for instance the use of a homogeneous halfspace to model the soil medium and only three different regions i.e.: the soil, the tunnel and the building are taken into account (fig 2). The comparisons with the measurements taken "in situ" validate those assumptions.

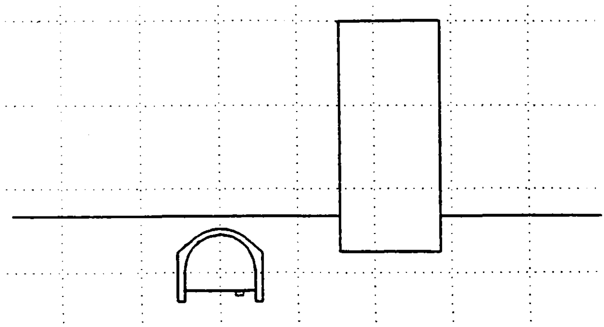

Figure 2

4. PARAMETRIC STUDY

To the basic model described in the previous sections a new element has been added,

a) a trench
b) a concrete wall
c) a clay wall

that has been placed either by the tunnel or by the building with different depths (10, 20, 30 & 40 m).

Table II contains a summary of the study. The discretization for one of the cases can be seen in figure 3 while figure 4 presents displacements of the model for one of the frequencies.

As an exemple and in order to compare the reductions obtained with a trench and with a concrete wall, figure 5 collects the results in thirds of octave band dB.

For the concrete walls it is seen that the reduction levels are very low (2 dB) and even negative around 50 Hz, while the trenches produce resuls one order

TABLE II. SUMMARY OF THE PARAMETRIC STUDY

Model series number	Objective	Conclussions
1	Influence of trenches by the buildings (depth 10, 20 30 and 40 m)	Similar effectivity. Grows from 10 m on, being neccessary to rearch a depth of the order of 20 m to obtain acceptable levels of reduction in the band 25-60 Hz
2	Ditto by the tunnel	
3	Influence of concrete walls by the building (depth 10, 20, 30, 40 m)	Reductions of interest are obtained only for frequencies higher than 70 Hz independently of the wall depth. They are not useful for that kind of soil
4	Ditto by the tunnel	
5	Influence of clay-filled trenches by the building (depth 10,20,30,40m)	Worst situation than cases 3 & 4 due to resonances of eigenshapes of the walls
6	Ditto by the tunnel	

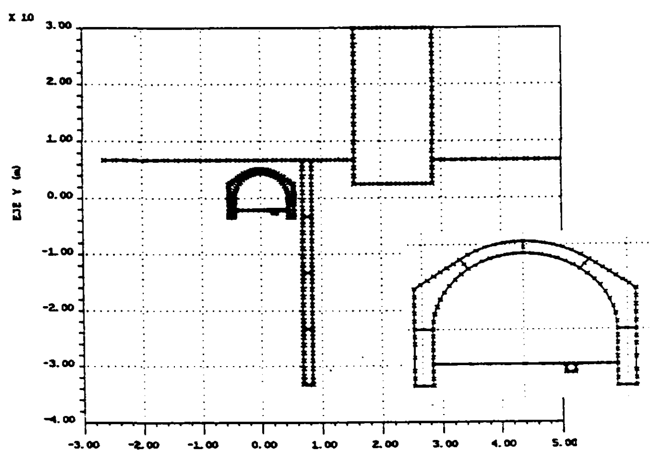

Figure 3

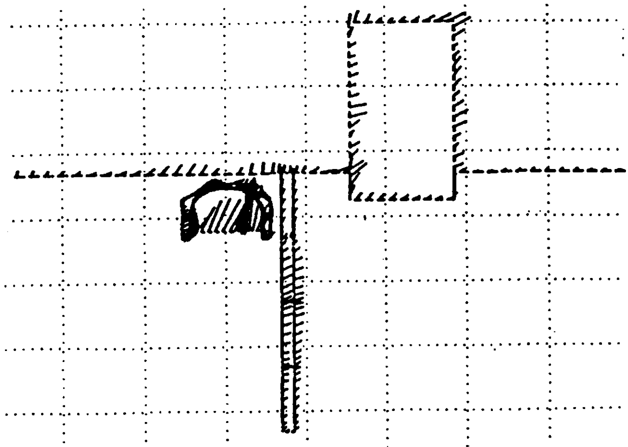

Figure 4

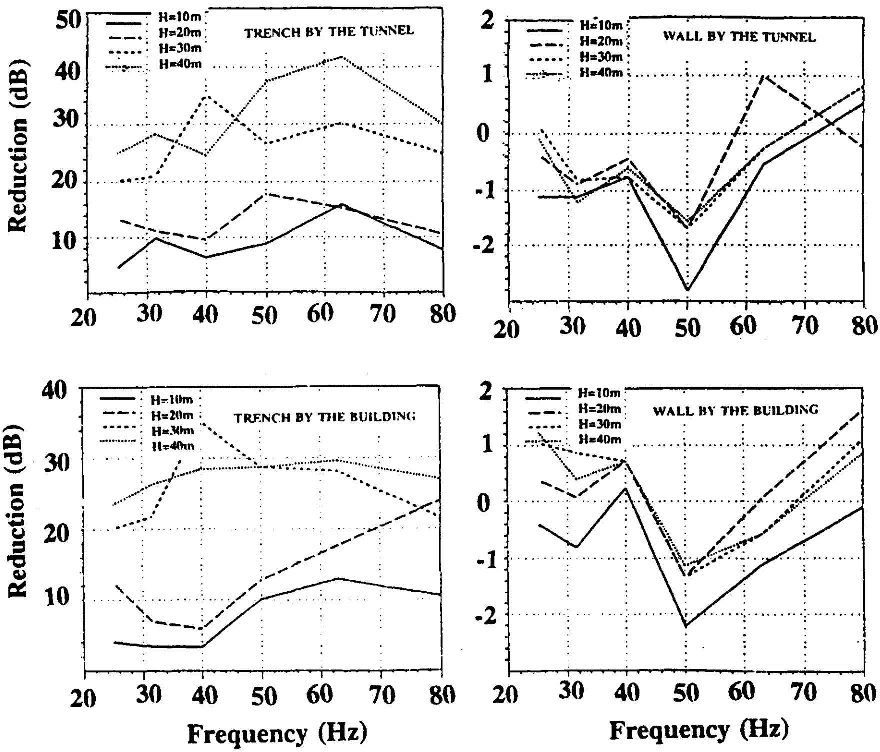

Figure 5

of magnitud better. The curve corresponding to a low depth trench by the tunnel is specially atractive.

For 31.5 Hz a reduction of 9.8 dB is obtained and 6.3 dB for 40 Hz.

5. CONCLUSSIONS

Inside the limits imposed by the hypothesis used in the cases that have been studied (soil properties, building characteristics, load depth, etc) the following conclussion can be summarized:

- Trenches produce better results than walls
- Trench effectivity increases with depth with a limit of 20 to 30 m around which the levels of reduction are practically constant.
- Concrete walls in that hard soil (G = 9'51 E 8 N/m^2) are very limited. They are effective at heigh frequencies independently of the depth.
- Clay infilled trenches amplify the response for a series of frequencies related to the modal shapes.

6. ACKNOWLEDGMENTS

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