MODELING FLANKING TRANSMISSIONS IN LIGHTWEIGHT CONSTRUCTIONS

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ABSTRACT

Standard EN 12354, which predicts the acoustic performance of buildings from the performances of building elements must be modified when applied to estimate flanking transmissions in lightweight constructions ; the modifications presented in this paper introduce new quantities such as the radiation efficiencies, which seem to be a key parameter, a corrected Velocity Level Difference, which describes vibration transmission through junctions between building elements, and also take into account the non uniform vibration response of lightweight elements.

1 - INTRODUCTION

The theoretical approach used in European Standard EN 12354 to model and characterize flanking transmissions is based on a first order Statistical Energy Analysis (SEA) but also differs from classical SEA since it only uses Building Acoustics quantities for which laboratory measurement standards exist. When applied to lightweight constructions, the European model has to be modified and new quantities as well as new characterization methods have to be defined. In this paper some modifications are proposed and discussed ; others elements of discussion can also be found in [1]. The modified model is then applied to a laboratory full scale two story four room wood frame structure ; detailed experimental results will be presented at the conference.

2 - MODIFIED FLANKING TRANSMISSION EN 12354 MODEL

2.1 - Airborne excitation

In the EN12354 approach and in the case of airborne excitation, flanking transmissions correspond to the three following physical phenomena :

Airborne excitation of the emission plate : the plate velocity can be expressed in terms of the sound pressure in the emission room, the plate sound transmission factor τ_1 ($R = 10.\log(1/\tau)$) and a radiation efficiency σ_a according to

$$\tau_1 = \frac{\rho c.\sigma_{a1} < v_1^2 >}{\dfrac{< p_e^2 >}{4\rho c}} \qquad (1)$$

Note that σ_a is not the SEA radiation efficiency and corresponds to the radiation of both forced and resonant plate bending waves.

Vibration transmission at the plate junction : a velocity level difference $D'_{12} = 10.\log(1/d'_{12}) = 10.\log(< v_1^2 > / < v_2^2 >)$ between the emission and the receiving plates is then used. The symbol ' indicates that D'_{12} is different from the vibration level difference D_{12} measured with the emission plate mechanically excited since the emission plate vibration field consists here of a forced (index *f*) field and a resonant (index *r*) field :

$$< v_1^2 > = < v_1^2 >_f + < v_1^2 >_r \qquad (2)$$

It has been shown [2] that forced waves do not seem to significantly contribute to the vibration transmission through junctions between lightweight plates with stiffeners ; therefore d'_{12} can be easily estimated from d_{12} as :

$$d'_{12} = \frac{d_{12} < v_1^2 >_r}{< v_1^2 >_f + < v_1^2 >_r} = d_{12} / (1 + \frac{< v_1^2 >_f}{< v_1^2 >_r}) \qquad (3)$$

Radiation of the receiving plate : the power radiated can be expressed from the receiving plate vibration field using the SEA radiation efficiency σ_r (since the receiving plate is mechanically excited through the junction) as well as from the sound pressure in the receiving room (equivalent absorption area A) :

$$\Pi_{rad2} = \rho c S_2 \sigma_{r2} < v_2^2 > = \frac{< p_r^2 >}{4\rho c}.A \qquad (4)$$

Combining (1), (3) and (4) leads to an expression of the ratio τ_{12} between the power radiated by the receiving plate and the incident sound power in the emission room which completely defines the flanking path considered.

Figure 1 shows typical radiation efficiencies of lightweight wood frame elements under both acoustical and mechanical excitations and measured in the CSTB Phonoscopy Laboratory (based on Near field Acoustical Holography) ; σ_a and σ_r are very different and cannot be eliminated by calculating a direction averaged flanking path. Moreover, reference [2] shows that the ratio $< v_1^2 >_f / < v_1^2 >_r$ can be expressed in terms of the two radiation factors σ_a and σ_r ; typical values of this ratio are given figure 2 corresponding to a difference of about 2 dB between D'_{12} and D_{12} which is not very significant. However, if the emission plate considered is the inner leaf of a double wall, this difference can reach values up to 5 dB at frequencies close to the double wall resonance frequency. A solution consists in considering the inner leaf alone and putting the corresponding sound reduction index into equation (1) ; the dominant forced vibration field disappears (no more coupling through the cavity) and the absence of the outer leaf should not change much the total loss factor of the inner leaf, high in case of lightweight panels with stiffeners.

As a result the following unidirectional equation could be used, involving indexes R of single leaf elements, the corrected vibration level difference $D_{v12}^{'}$ and the radiation efficiencies σ_a and σ_r :

$$R_{12} = 10.\log(1/\tau_{12}) = R_1 + D_{v12}^{'} + 10\log(\sigma_{a1}/\sigma_{2r}) + 10\log(S_S/S_2) \quad (5)$$

2.2 - Impact sound (mechanical excitation)

The case of impact sound and mechanical excitation is much simpler since only resonant vibration fields are involved. Only the excitation of the emission plate is different ; its velocity is then expressed as a function of the direct impact sound pressure radiated according to the following equation :

$$< v_1^2 > \rho c.\sigma_{r1} S_1 = \frac{< p_d^2 >}{4\rho c}.10 \quad (6)$$

As a result, the following flanking impact sound level could be used, involving the direct impact sound level L_{nd}, the vibration level difference D_{v12} and radiation efficiencies σ_r :

$$L_{n2} = L_{nd} + 10\log(\sigma_{r2}/\sigma_{r1}) + 10\log(S_2/S_1) - D_{v12} \quad (7)$$

3 - VALIDITY OF FIRST ORDER SEA APPLIED TO LIGHTWEIGHT CONSTRUCTIONS

The quantities and characterization methods used in EN12354, which is based on a first order SEA cannot be directly used when applied to lightweight constructions. These limitations are mainly related to the non uniform vibration response of lightweight floors and wall, mainly in the case of mechanical excitation, which can partly be attributed to high damping ; as an example, the vibration level attenuation along a bare decking of a wood-framed floor in the direction perpendicular to the joists corresponds to an equivalent loss factor close to 10 %. What is the meaning of the vibration level difference D_{v12} used in section 2 for such highly damped elements then?

An exact analytical model of a junction has been used to evaluate the accuracy of SEA in the case of a L junction between two highly damped plate [3]. It is shown that SEA yields a correct velocity level difference (VLD) between the plates only in the case of multi point excitation uniformly distributed over the emission plate and in spite of the still inhomogeneous response of the receiving plate ; figures 3 and 4 compare some results obtained from the exact model and from classical SEA. With the condition mentioned above, the VLD method would therefore still be valid to characterize junctions between highly damped elements ; a vibration transmission index could then be calculated from the measured VLD and from the receiving plate total loss factor, which could be estimated from the measured spatially decaying vibration field of the plate. However, if the mechanical excitation is localized, [3] shows that classical SEA fails and that a modified energy approach, treating direct and reverberant fields separately can be used to correctly estimate the corresponding VLD.

4 - CONCLUDING REMARKS

Standard EN 12354 must be modified when applied to estimate flanking transmissions in lightweight constructions ; the modifications presented in this paper introduce new quantities such as the radiation efficiencies, which seem to be a key parameter, a corrected VLD and take into account the non uniform vibration response of lightweight elements. The modified model is being applied to a laboratory full scale two story four room wood frame structure under both acoustical and mechanical (impact) excitations ; direct and flanking transmissions are being estimated using the model presented and the different input quantities needed are being obtained from separate laboratory measurements on the different elements composing the two story structure. Detailed experimental results will be presented at the conference and the accuracy of the modified model discussed.

5 - ACKNOWLEDGEMENTS

This work was partly supported by the French Ministry of Agriculture ("Direction de l'Espace Rural et de la Forêt").

6 - REFERENCES

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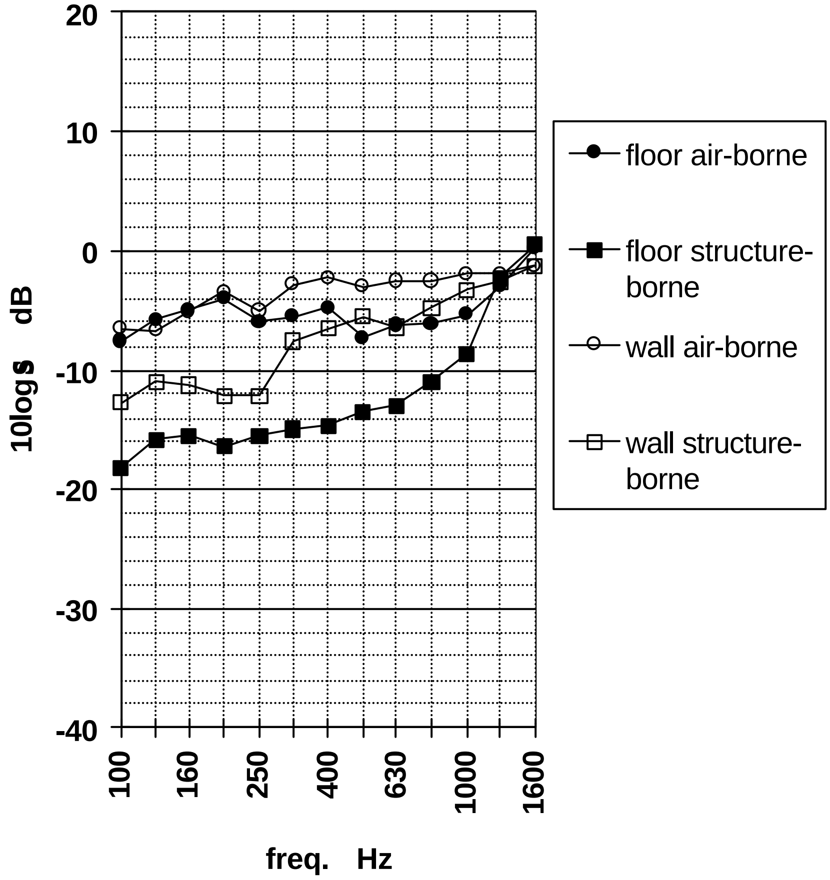

Fig 1 - Typical radiation efficiencies, under both acoustical and mechanical excitation, of a bare wooden floor and a lightweight wall made of gypsum boards on a wood stud frame

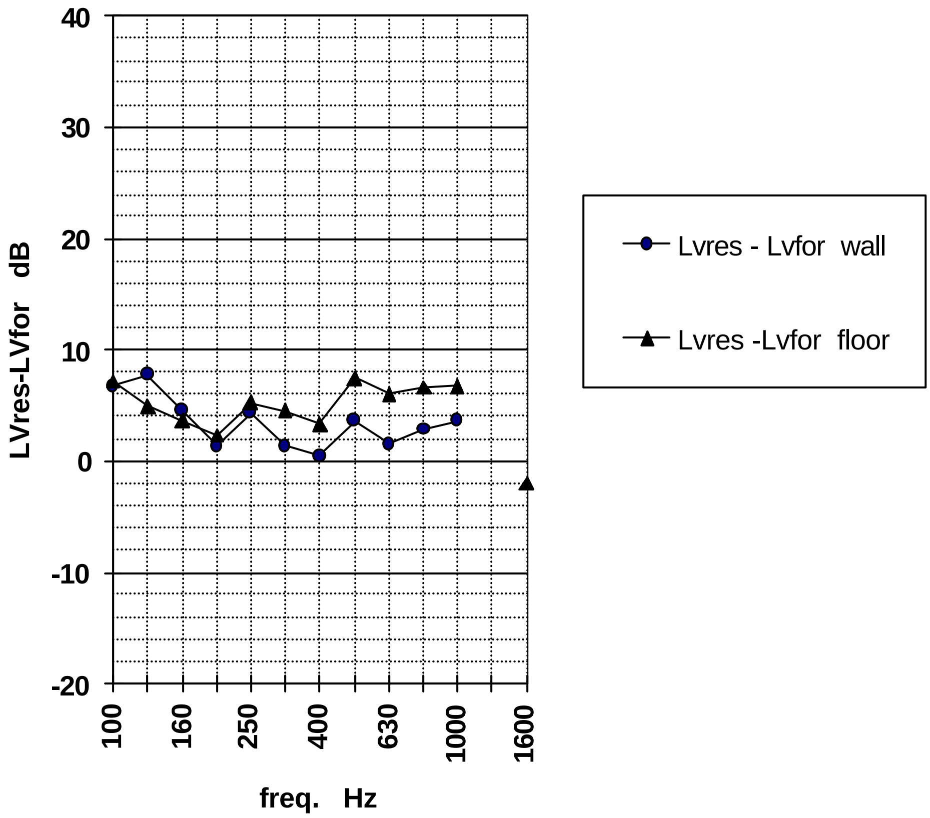

Fig 2 - Ratio between resonant and forced vibration levels for the lightweight elements given in figure 1.

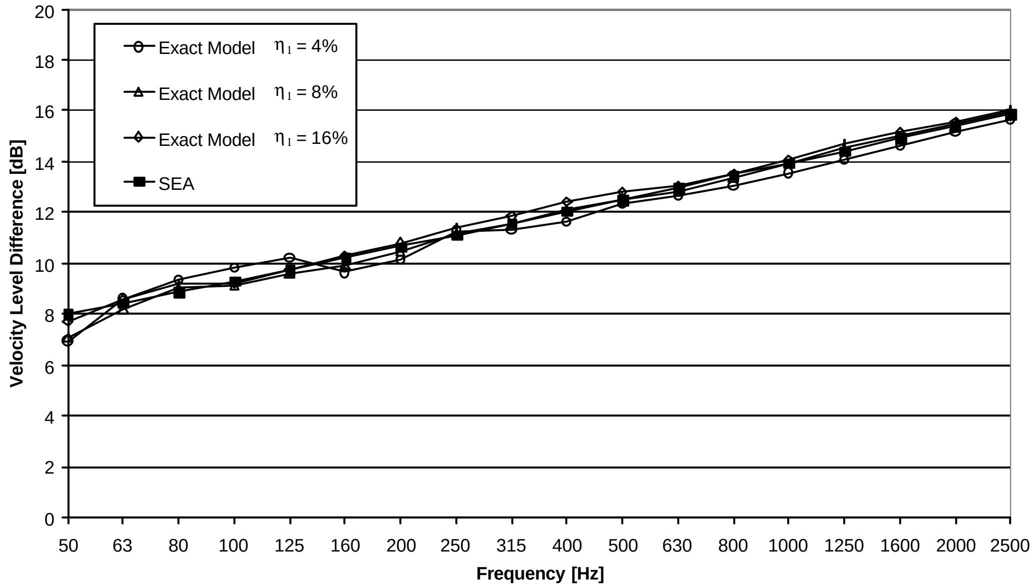

Fig 3 - VLD, calculated by an exact model and by SEA, for a L junction of two thin plates with multi point excitation uniformly distributed on the emission plate ; influence of emission plate internal damping

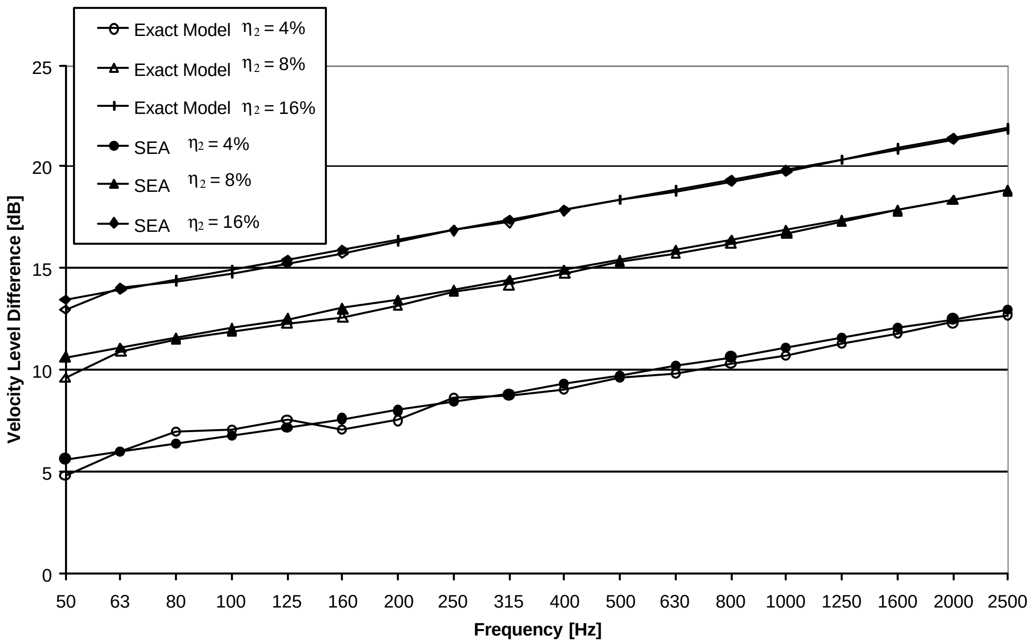

Fig 4 - VLD, calculated by an exact model and by SEA, for a L junction of two thin plates with multi point excitation uniformly distributed on the emission plate ; influence of receiving plate internal damping