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TRANSMISSION LOSS MEASUREMENTS IN A FULL SIZE MODEL OF TIMBER FRAME BUILDING

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INTRODUCTION

A full scale model of a timber frame building has been built at the University of Compiègne using standard construction techniques. The model consists of two identical rooms 3.07 m wide, 4.27 long situated one on top of the other. The ceiling height is 2.42 m in its present unfinished state without internal panelling. This model has been designed to study the transmission characteristics of timber frame construction and in particular the effects of flanking transmission (figure 1). In order to do this it has been built so that the walls, floor and ceiling can be modified to improve their acoustic characteristics relatively easily. It is intended to test in this way the improvements obtained using double wall construction, different panel materials and fixings, and several types of absorbant material in the cavities.
Initial results have been obtained using classical techniques for the measurement of transmission loss by assuming that a diffuse field exists in the source and the receiving room. At low frequencies this assumption is not justified of course because the rooms are relatively small, but since the aim of this research programme is to develop methods that can be used on site where room sizes will also be small it is necessary to pursue the investigation in conditions that are as close to the reality as possible. Other results have been obtained using measurements of acoustics intensity levels over the surfaces of the receiving room to calculate the transmitted sound energy.

CHOICE OF MEASUREMENT TECHNIQUES

In order to correctly identify the flanking transmission characteristics the energy transmitted by each surface of the room must be measured. Three methods are available to do this, the shielding technique, surface velocity measurements and, acoustic intensity measurements. In the case of heavy structures all three of these methods have been applied with relatively good results.
For light structures the first two methods have considerable disadvantages at low frequencies, in the first case because a shield does not significantly improve the low frequency transmission characteristics because of resonance effects with double and triple walls [1]. It is also a method that is difficult to carry out on site.
The use of velocity measurements to calculate the radiated energy is limited because the radiation coefficient is difficult to evaluate for complex structures below the critical frequency. In timber frame construction values for the critical frequency are typically between 1000 Hz and 4000 Hz, thus eliminating the low and mid frequencies which most affect the transmission rating. This leaves the technique of acoustic intensity measurement which has the additional advantage of not modifying the characteristics of the structure or the acoustic field in any way. Unfortunately the precision of the measurements is greatly affected by the accuracy of the calibration of the system, the averaging techniques used and the nature of the sound field measured. Most of the work that has been carried out so far has been aimed at testing the validity of this

method for a single floor configuration before changing the model to investigate different types of construction.

DEVELOPMENT OF THE MEASUREMENT SYSTEM

A two microphone acoustic intensity probe was constructed using the side-by-side arrangement with two 1/2" microphones. The use of these microphones is justified in preference to 1/4" because of their higher sensitivity and the errors at high frequencies caused by the limits imposed on the separation distance are less than 1 dB at 4000 Hz. For the low frequency range a separation distance of 60 mm was chosen for the range up to 800 Hz and the measures were repeated for the range 1000 Hz to 5000 Hz with the minimum separation distance of 13 mm. The microphone signals were processed using a dual-channel F.F.T. analyser to calculate the cross spectral density. The acoustic intensity was then calculated after transferring the datas to a PDP 11/23 mini-computer. The results were calculated from the imaginary part of the cross spectrum using the expression introduced by Fahy [2]. These were then treated to permit the presentation of the data in narrov band or third octave form. The accuracy of the system was tested in an anechoic room by comparing the sound pressure level and intensity level in the far field of a loudspeaker. The results of this test are presented in figure 2 and show the good agreement obtained between the two results.

MEASUREMENT ON THE MODEL SYSTEM

Measurement were first carried out to establish the transmission loss characteristics using the classical technique. Pressure and reverberation time measurements were taken at six points in the source and the receiving rooms and the average values were calculated in each. The results for the measured transmission loss are presented in figure 3. These are compared with the results of a calculation using the methods developed by Sharp [3] and Sewell [4]. The differences observed between these results are a possible indication of the effects of flanking transmission or acoustic leaks.
The technique of acoustic intensity measurements was then applied to each of the surfaces of the receiving room. The wall, ceiling and floor surfaces were subdivided into 24 rectangles and the intensity was measured at the center of each of these rectangles. The total sound power was then calculated for each type of surface and the results are presented in figure 4. These are compared with total power sound measured in the receiving room using the classical technique.
It can be seen that the results at low frequency are unsatisfactory because the sound power calculated for each of the surfaces exceeds the total sound power. Investigation of the results obtained for each measurement point showed that there was a very high variation in level from on point to another in the low frequencies range. In figure 5 results are presented for six adjacent measurement points of the floor.
The critical frequency for this configuration composed of 22 mm chipboard should be about 1040 Hz. It can be seen that the dispersion in intensity levels is very low above this frequency but considerable below it. This indicate that one of the problems associated with the use of intensity measurements on light structures, is the non homogeneity of the intensity levels below the critical frequency. In this frequency range there are numerous negative values of intensity caused by the recirculation of energy. The averaging process is

clearly inadequate using so few points therefore the effects of using a finer network of measurement was examined. The number of points was multiplied by sixteen and the results were compared with these obtained by sweeping the probe over the surface to average the overall intensity levels. The repeatability of the results proved to be satisfactory for the sweep method and compared favourably with the multiple point method, with the advantage of being much easier and quicker to apply (see figure 6).
Futher investigations of the effects of the number of measurement points and implementation of the sweep method are now being carried out.
The situation is also rendered more difficult by the fact that there are no inside panels so the intensity measurements are affected by the presence of the timber frame studs which may be one of the causes of measurement error. The only panel which has a smooth measurement surface is the floor which seems to give reasonably consistent results using the intensity method. In figure 7 a comparison of the transmission loss of the floor calculated from the intensity measurements is compared with the theoretical value presented before in figure 1. It can be seen that there is a much closer agreement which would indicate that the difference observed in figure 1 is indeed due to flanking transmission rather than acoustic leaks in the floor.

CONCLUSIONS

The results obtained so far indicate the difficulties that can be encountered in the measurements of transmissions characteristics of light structures.
The intensity measurements can be improved by closer attention to averaging procedures with the use of sweep techniques.
The effects of non homogeneity of the surfaces and the radiation field will be investigated more thoroughly. Results at high frequencies seem to be relatively satisfactory as one would expect. Further work is also required to establish the errors caused by the assumption of a diffuse field in the source room. Selective intensity method [5] will be implemented on the full size model and various configurations will be tested.

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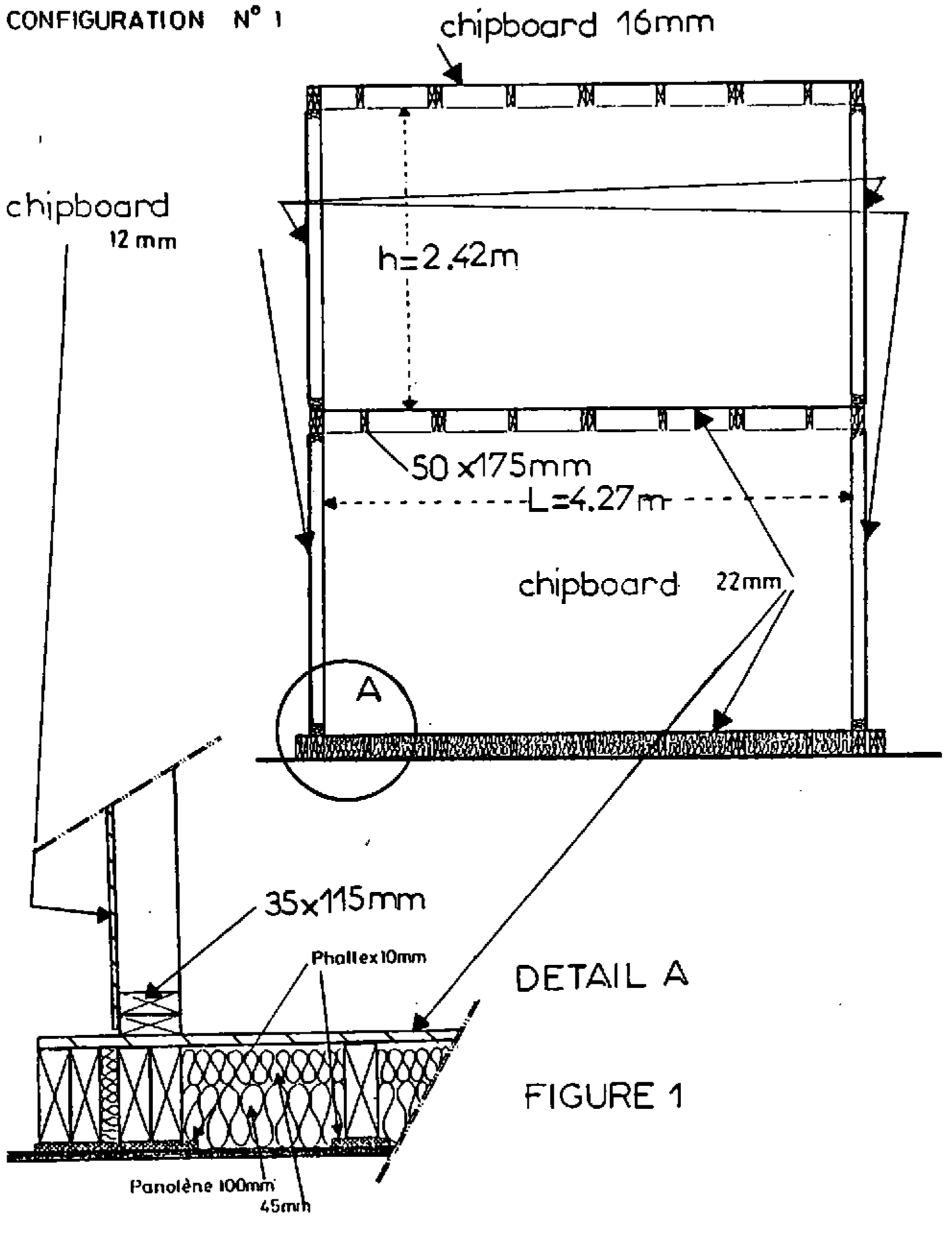
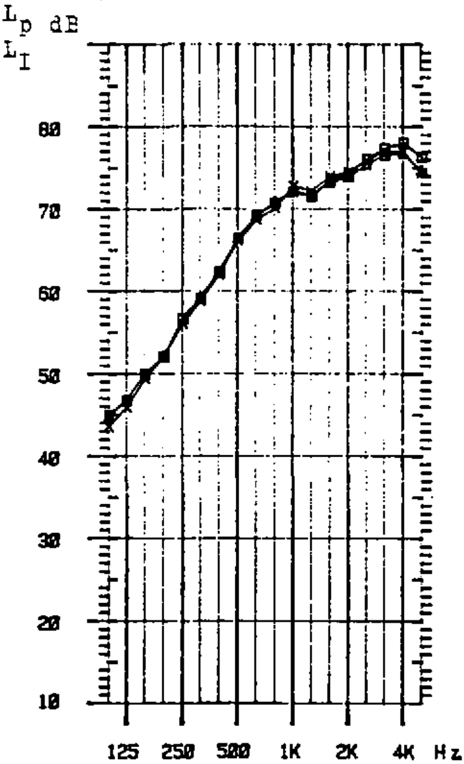


FIGURE 1

TRANSMISSION LOSS MEASUREMENTS IN A FULL SIZE MODEL OF TIMBER FRAME BUILDING

Comparison between the sound pressure level L_p and intensity level L_I in the far field of a loudspeaker in an anechoic room



x x x L_I ($I_o = 10^{-12} W/m^2$)

□ □ □ L_{pA} ($p_o = 2\times10^{-5}$ Pa)

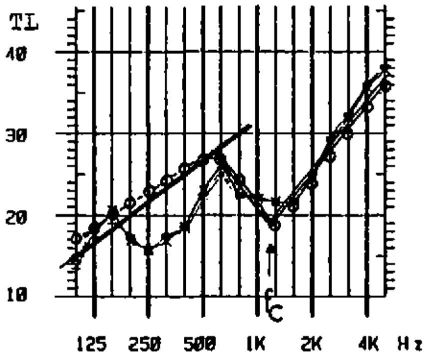
Δ Δ Δ L_{pB}

100Hz to 800Hz : h=60mm

1000Hz to 5000Hz : h=13mm

Figure 2

Transmission Loss caracteristics using the classical technique (first configuration)



. x x x ⎫
. □ □ □ ⎬ TL (laboratory)
. Δ Δ Δ ⎭
.———— TL (calculation [3])
. o o o TL (calculation [4])

(calculation does not take in account orthotropic behavior of the floor)

Figure 3

Comparison between total sound power and sound power for each type of surface

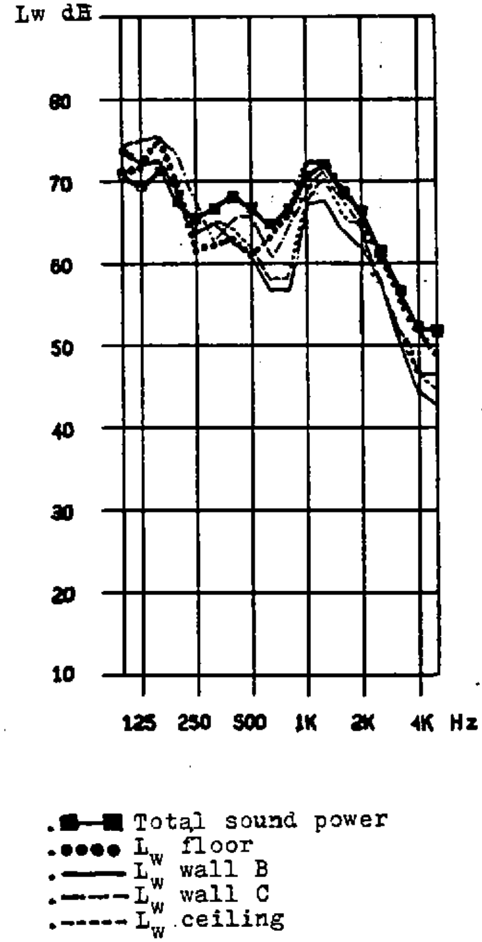


Figure 4

Intensity acoustic measurements for six adjacent points of the floor(floor surface was subdivided into 24 rectangles)

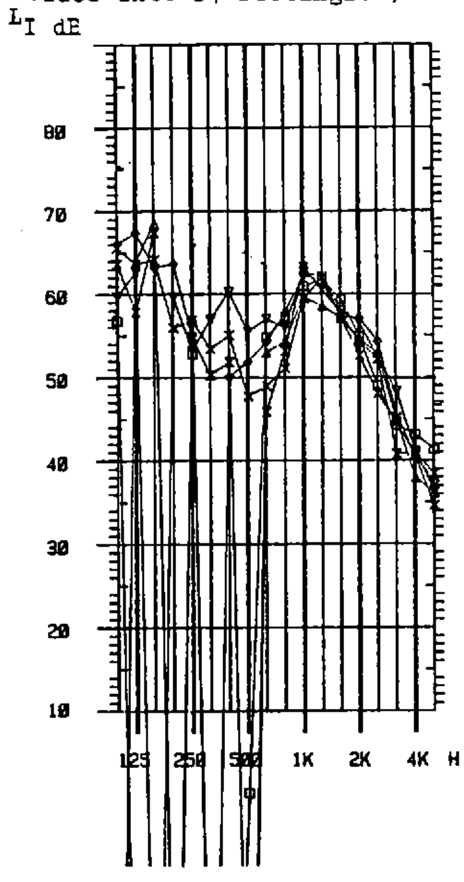
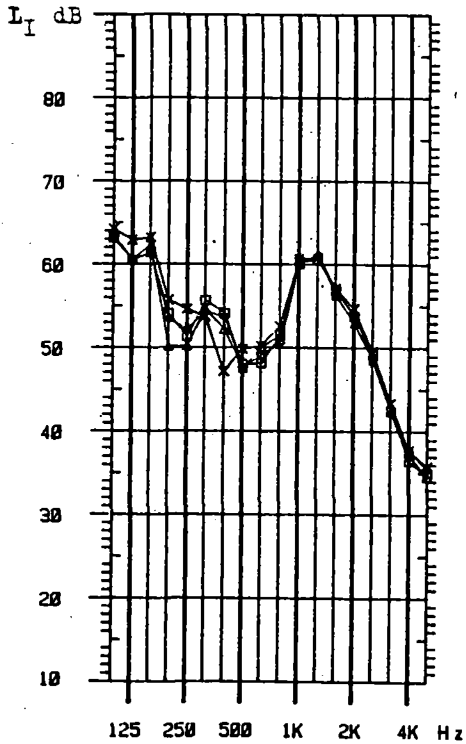


Figure 5

TRANSMISSION LOSS MEASUREMENTS IN A FULL SIZE MODEL OF TIMBER FRAME BUILDING

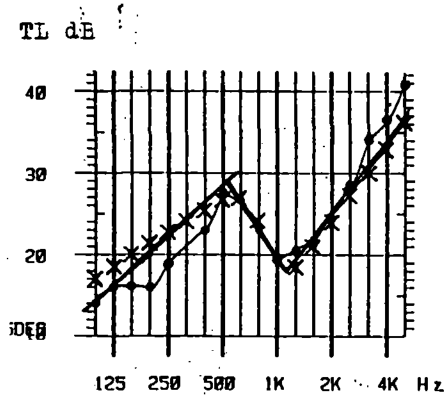
Comparison between the average intensity measured for sixteen adjacent points of the floor and intensity obtained by sweeping the probe over the same surface (floor surface was subdivided into 384 rectangles)



.x x x L_I (point measurement)
.□ □ □ }
.△ △ △ } L_I (sweeping measurement)
.◇ ◇ ◇ }

Figure 6

TL of the floor calculated from the intensity measurements



. ●-●-●-● TL(intensity measurement)
. ——— TL(calculation 3)
. x x x TL(calculation 4)

(calculation does not take in account orthotropic behavior of the floor)

Figure 7