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# EXPERIMENTAL AND NUMERICAL CHARACTERIZATION OF METALLIC STUDS

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## ABSTRACT

In this paper, the characterization of metallic studs used to mount lightweight double wall systems is studied both experimentally and numerically. The metallic studs are usually considered by introducing translational and rotational springs to couple the plasterboards composing the double wall. Therefore, the characterization involves determining these spring characteristics. The performance of this type of lightweight double wall in terms of sound transmission is presented in a companion paper. Different experimental setups have been investigated to determine the equivalent translational and rotational spring values. These experimental setups are described and involve the measurement of an input mobility. A finite element model of the laboratory tests has been developed. Shell and massive finite elements are employed in order to reproduce the experimental setups. A comparison of the measured and numerical results is shown. The FEM modelling is intended to help in developing new type of studs for double walls in order to obtain better sound transmission performance.

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## 1 INTRODUCTION

Lightweight double walls are a common solution employed in partition dwellings. They are typically constructed by means of two thin leaves (plasterboards, wood plates or similar) and some kind of absorbent material placed inside the air cavity to improve the acoustic isolation capacity of the system. In order to satisfy construction requirements and to give a minimum stiffness to the wall some kind of connection has to be employed. Wood beams or metallic studs are examples of actual solutions.

The existence of this kind of elements causes the actual acoustic response of the wall to be worse than those of an ideal double wall without connections between leaves. A new vibration transmission path (besides the airborne path) is possible due to the presence of mechanical connections. The decrease in the sound reduction index of the double walls highly depends on the mechanical properties (mainly stiffness) of the connecting element. An "ideal" one would be so flexible that does not transmit vibrations from one leave to another.

In this contribution, the attention is focussed on the study and characterisation of lightweight metallic studs. Their effect is very influenced by the cross section shape. Two direct applications can be mentioned. On the one hand, studs manufacturers are interested in knowing which stud is better from an acoustic (vibration transmission) point of view. On the other hand, wave approach [5] or statistical energy analysis models cannot reproduce the exact geometry of the stud and require some kind of parameter describing its mechanical response. Even when employing numerical methods, it is difficult to combine two scales of detail (walls or rooms and studs) without increasing too much the computational cost. The most frequently employed option is to reduce the studs to translational and rotational springs coupling the leaves of the double wall.

With the goal of finding these equivalent mechanical properties, several strategies have been employed. Firstly, laboratory tests of studs excited by a hammer shock in order to obtain the mobility in the excitation point have been carried out. These laboratory tests have been compared with a finite element model. The combination of these two points of view has been useful for understanding the behaviour of the metallic studs. With a calibrated finite element model, other aspects like eigenfrequencies, qualitative description of vibration shapes, outputs that are difficult to obtain in the laboratory... can be studied. Moreover, tests on non-existing (yet) cross sectional stud shapes can be performed. This part of the work will be presented in section 2. Secondly, a more simplified model has been employed in order to make parametric studies and obtain solid conclusions for steel industry and useful data for sound transmission models. This second approach will be presented in section 3.

## 2 LABORATORY TESTS AND FINITE ELEMENT MODELING

### 2.1 The experiments

Several laboratory tests have been carried out in order to obtain the frequency response of metallic studs. Two different setups have been employed (Fig. 1).

On the one hand, small pieces of studs (0.1-0.2 m length) have been tested alone. They have been excited by means of a point force in the middle of the upper flange. The studs have been supported over a nut (in the lower flange) which is a fix point. The point mobility

(*Y*=*v*/*F*, *v* and *F* are the velocity and force in the contact point), has been measured. On the other hand the metallic studs have also been placed between plasterboards in order to reproduce the actual degree of constrain (in double walls or floors). The point mobility has also been the measured output.

*Fig. 1. Two different setups for laboratory tests. On the right, isolated piece of stud excited in the upper flange (setup 1). On the left 0.65 m length stud placed between plasterboards (setup2).*

The relation between plate and studs is supposed to be punctual. This is an adequate hypothesis for an important number of lightweight double walls because a typical way to link leaves and metallic studs is by means of screws. Minimizing the contact flange/plate is important from an acoustic point of view.

## 2.2 The numerical model

The situations presented in the previous section have been reproduced using a finite element model [4][6][8][9]. The studs have been modelled by means of DKT shell elements and the laboratory devices with elastic tetrahedral. Some details of the employed meshes are shown in Fig. 2. The calculation is done directly in the frequency domain considering hysteretic damping. For this kind of problems the finite element method can be employed in the full frequency range. We are dealing with a mechanical problem (without acoustic coupling) and the dimensions of the solid are small enough when compared with the length of the vibration wave.

## 2.3 Comparison and description of response

In Fig. 2, we can see the typical vibration response of a stud. A first zone between 0 and 1500 Hz with a response very influenced by eigenfrequencies can be defined. For higher frequencies the mobility transfer function is smooth.

Two different kind of numerical models (for setup 1) have been employed. In the first one (M1), both the stud and the laboratory devices have been modelled. In the second one (M2). only the stud with a punctual force has been considered. As we can see, the model fitting better the experimental curve is the first one. It illustrates one of the more important aspects when characterising studs: it is very important to reproduce the actual degree of constrain that the stud have when placed inside the double wall, otherwise, the results will be very different. We must always define the conditions under which the stud is studied (i.e. free stud, stud placed between plates and linked by means of screws, studs glued to plates along all the flange surface...). In setup 2 this factor is better controlled (more similar to reality).

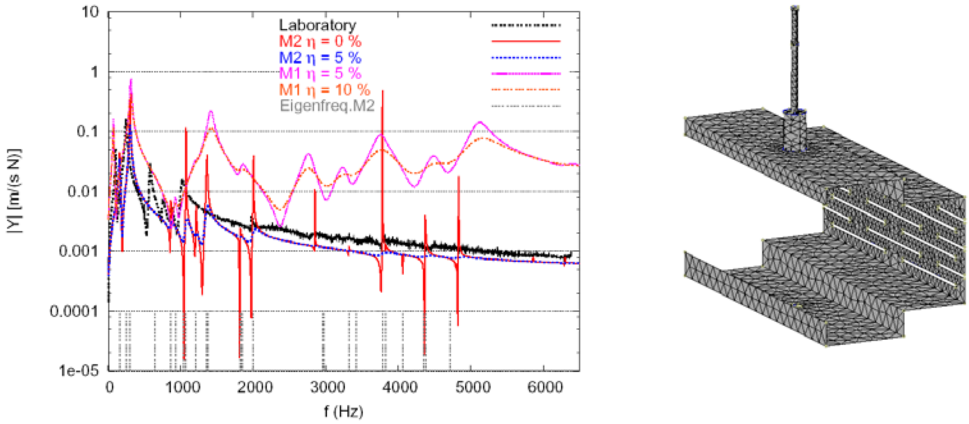


*Fig. 2. Calibration of the finite element model with a C-shaped section in setup 1. M1 = finite element model considering the additional stiffness provides by laboratory devices. M2 = finite element model where a vertical force has been applied (unconstrained for lateral displacements in the upper flange).Example of mesh employed for the finite element models(right)*

## 3 PARAMETRIC ANALYSIS

### 3.1 Description of the model

Making parametric studies with finite element calculations (especially for situations like the setup 2) can be computationally expensive. Laboratory experiments are also time and money consuming. If a big number of situations have to be analysed (variations of material and geometry parameters, frequencies in the full frequency range, influence of different types of boundary conditions,...) a more simplified model will have to be employed (keeping in mind the knowledge gained with the work presented in previous section). The models employed in this section are two-dimensional models. The situation presented in Fig. 3, will be considered. It is a cross section study of the full package (studs and leaves) modelled with spectral finite elements [7]. If this kind of finite elements with trigonometric shape functions is used, fast calculations can be done (without problems derived from the meshing requirements). At this time, only a punctual load (see Fig. 3) applied directly above the stud

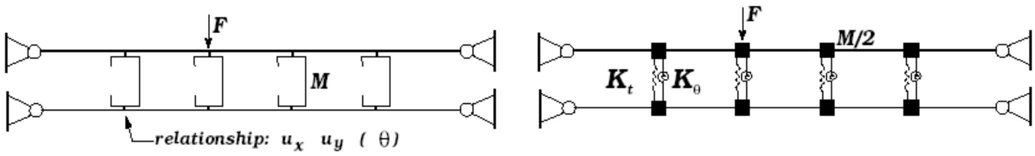


*Fig. 3. Models employed in parametric studies .On the left, reference case where the geometry of the stud is discretised. On the right, the studs have been replaced by rotation and translation springs.*

has been considered. More load locations will be considered in order to satisfy SEA hypotheses and use the presented models to obtain valid data for this technique. The leaves are 13 mm and 9 mm in thickness and has the physical characteristics corresponding to those of a gypsum board.

### 3.2 Comparison of several types of studs

Several section types for the studs (made of steel) have been analysed (data in Table 1; geometry and performance in Fig. 5). The performance can be studied comparing the vibration level difference between leaves for every stud type. This vibration level difference is given by

$$D_{ij} = 10\log_{10}\left(\left\langle \left|u_{upper}\right|^2 \right\rangle / \left\langle \left|u_{lower}\right|^2 \right\rangle\right) \quad (1)$$

where $<|u_{upper}|^2>$ and $<|u_{lower}|^2>$ are the mean square displacement of the upper and lower leave respectively. The highest the vibration level difference the better the performance of the studs in decoupling the two leaves. Differences can be important (at least for a wide range of frequencies), for some studs that are more flexible (LR125 and AWS 125). These are better from an acoustic point of view.

*Table 1. Dimensions of the studied sections (m).*

| Section | $d_1$ | $d_2$ | $d_3$ | $d_4$ | $d_5$ | Thickness (mm) |
|---|---|---|---|---|---|---|
| TC | 0.125 | 0.05 | 0.0155 | | | 1.16 |
| AWS | 0.125 | 0.05 | 0.0155 | 0.04 | 0.02 | 1.16 |
| LR | 0.125 | 0.05 | 0.0155 | 0.7 $d_2$ | 0.2 $d_1$ | 1.16 |
| S | 0.125 | 0.05 | 0.0155 | 0.2 $d_1$ | | 1.16 |
| O | 0.125 | 0.05 | | | | 1.16 |

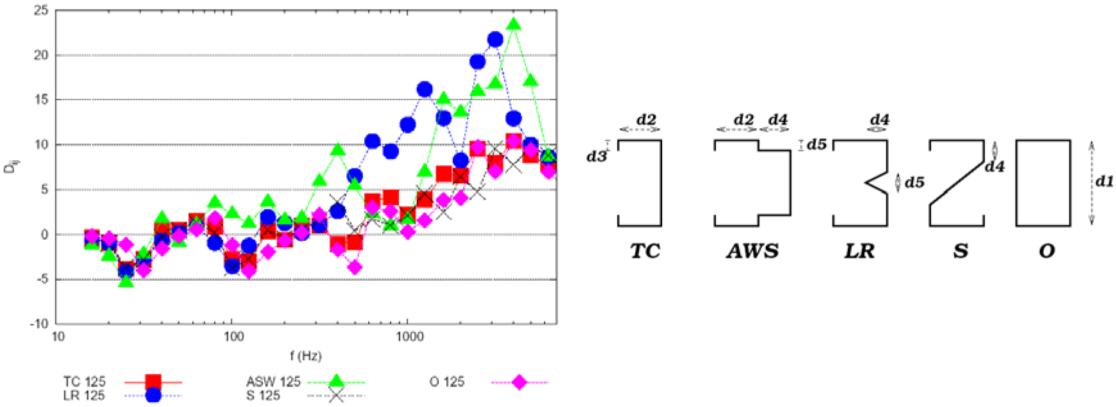


*Fig. 5.Comparison of the performance of several types of sections.*

### 3.3 Translational and rotational stiffness

Values of $K_t$ and $K_\theta$ can be deduced by comparing the vibration level difference between the leaves (see Eq. 1) obtained by the two different models shown in Fig. 3. The reference situation (Fig. 3, left) can be compared with the results obtained with the model with springs (Fig. 3, right). Calculations for a complete range of values of $K_t$ and $K_\theta$ are required before deducing the actual characteristics for a specific type of stud.

In Fig. 6, the influence of $K_t$ and $K_\theta$ is studied for the case of two leaves separated by 0.125 m. It can be observed that $K_t$ is important at low (< 1000 Hz) frequencies while $K_\theta$ is important at high frequencies (where the amplitude of vibration is smaller and the rotations are important).The values of stiffness obtained by comparison are bigger than the measured elastic ones.

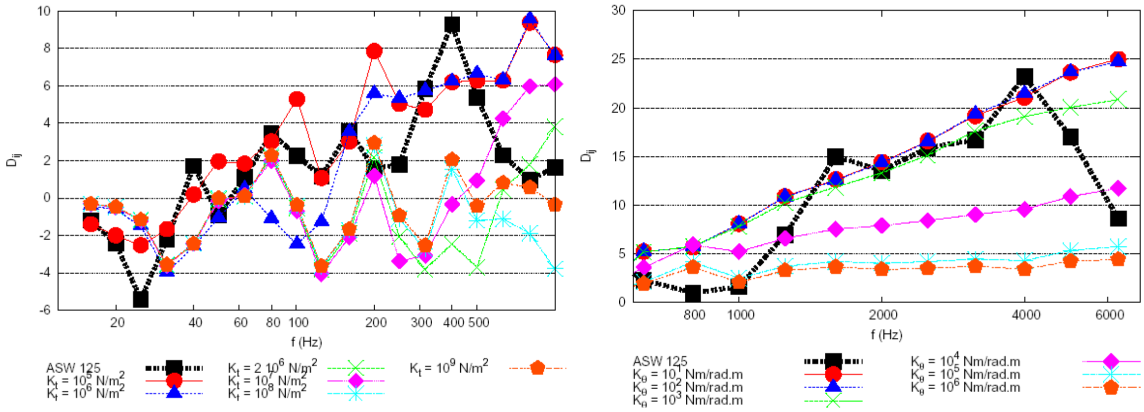


*Fig. 6.Influence of translational stiffness (left) and of rotational stiffness ( right).*

## 4 CONCLUSIONS

Characterisation of metallic studs has been done by means of experiments and several numerical models. The results depend a lot on the degree of constrain provided by the leaves. The studs can be characterised by means of translational and rotational stiffness but its value is frequency dependent. $K_t$ is important at low frequencies and $K_\theta$ at high frequencies. Considering measured elastic values of these stiffnesses underestimate the transmission of vibrations, especially for the case of rotational stiffness (at least for deterministic approaches).

The obtained results for the complete package will be checked with some three dimensional situation. However, the study of the problem at cross section level (simplified two-dimensional models of the entire package) seems to be a good approximation.

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