

Elastic properties of shaped porous materials : experiments and modelling

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EXTENDED ABSTRACT

Under certain conditions, porous materials used for noise abatement need to be shaped to satisfy architecture constrains as for corrugated sheets. Moreover, it may be used to increase the material performance.

For instance, wedge shape is used to increase the sound absorption properties at low frequencies. It was earlier demonstrated that the performances of this type of materials could be reproduced by representing the wedge as a series of perforated layers, each of them being modelled using the double porosity theory [1] (see Figure 1).

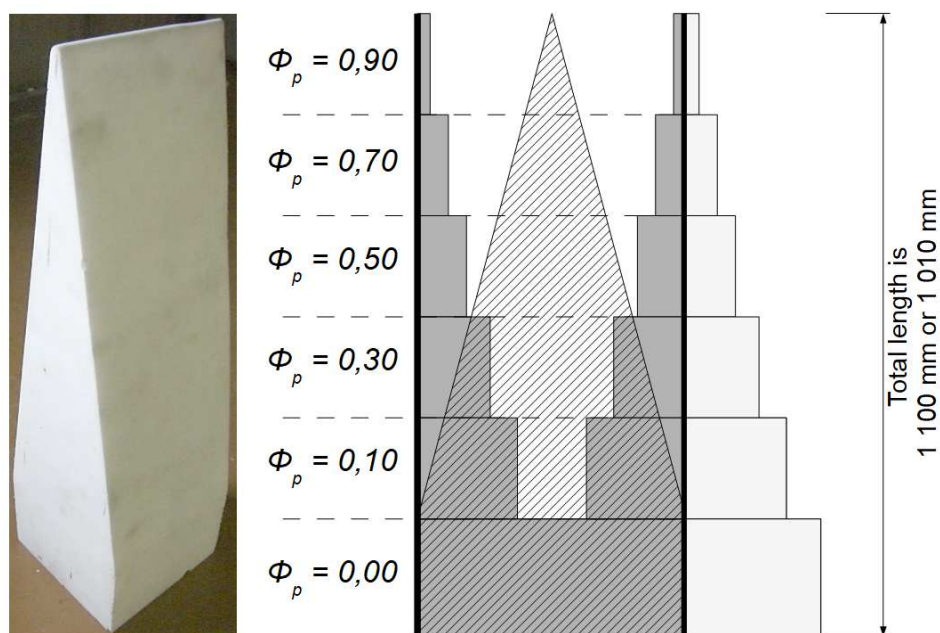


Figure 1 : Model of an anechoic wedge by a series of perforated layers [1].

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This analytical model was proved to be numerically efficient compared to purely numerical approaches (e.g. finite elements), allowing for fast and reliable predictions [1,2] (see Figure 2). It was also proved that this model could be coupled to an image source model to predict the sound field inside an anechoic room to detect possible discrepancies from the free field assumption [2].

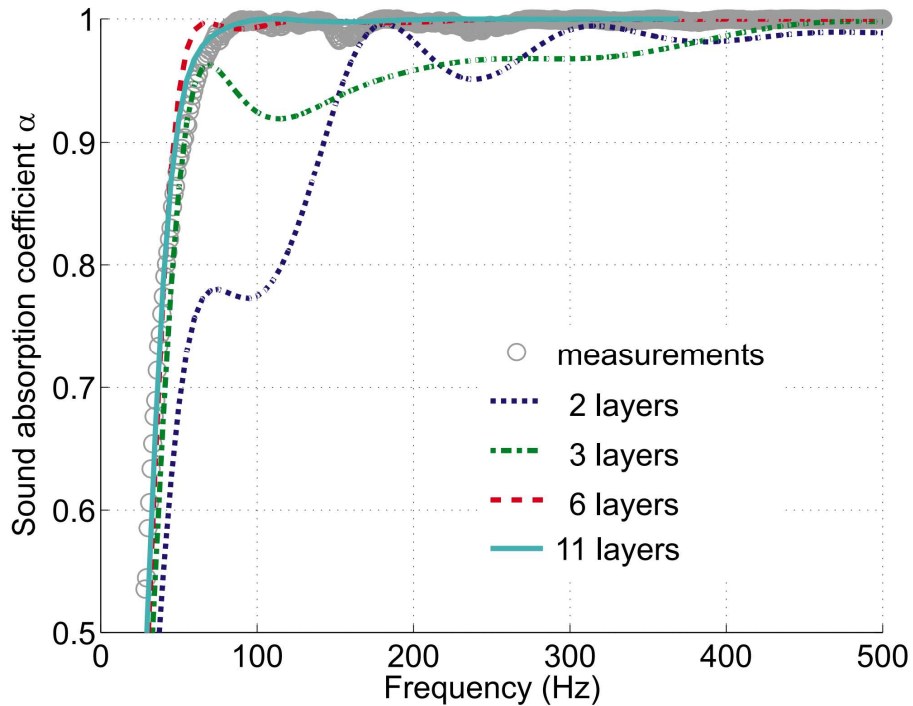


Figure 2 : Results of the analytical simulation of the sound absorption under plane wave at normal incidence for an anechoic wedge [1].

As per the elastic properties, “wavy” shaped materials are known to present interesting decoupling properties for undesired vibrational levels. For instance, concrete slab underlayers are known to enable higher compression performances compared to the same material having a flat surface (see Figure 3).



Figure 1 : Examples of a shaped porous materials used for vibration insulation.

While the analytical modelling of the acoustic properties is largely documented (see for instance above), the prediction of the elastic properties of this type of material is still an open question. Therefore, this paper proposes to investigate a numerical model based on a two-scale micro-macro approach.

The first stage consists in predicting the intrinsic elastic properties of the porous core. From a series of numerical tests for both compression and shear stress, the full elasticity matrix is retrieved, enabling to calculate the Young's modulus and the Poisson's ratio [3] (see Figure 4).

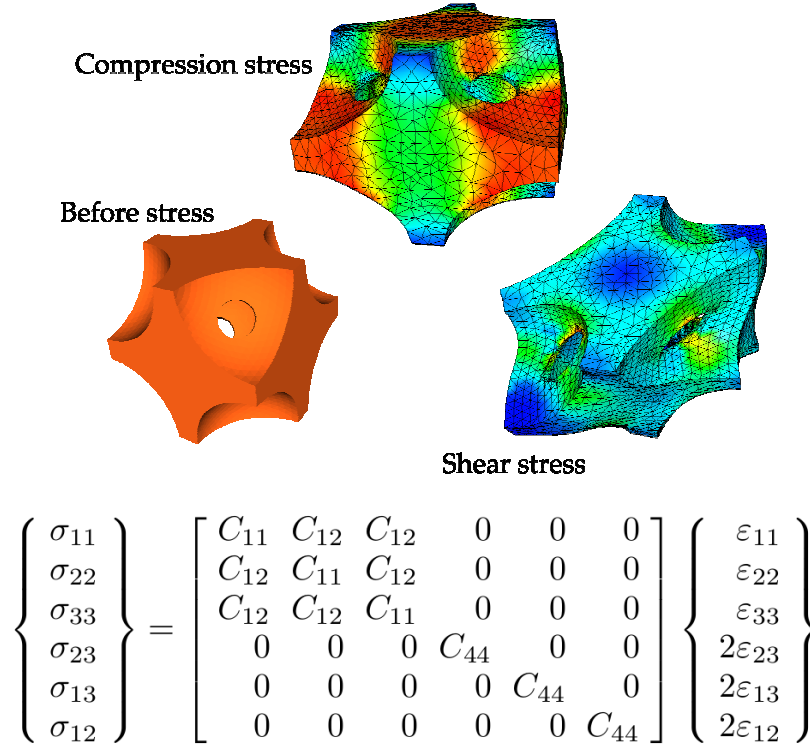


Figure 2 : Numerical compression and shear stresses (top) enabling to recover the full elasticity matrix (bottom). Illustrations extracted from the ScalingCell software (<http://scalingcell.matelys.com/>).

Once these intrinsic parameters retrieved, the second stage of the model consists in shaping numerically the porous materials and applying the stress under consideration using a similar approach as in the first stage. At the second stage however, the retrieved parameter is the stiffness of the shaped porous material. It should be highlighted that this is not an intrinsic property as it is associated with the prescribed material thickness and the value of the heel and of the tip of the “wave”.

The validation of this approach is carried out at the two considered stages. The predicted intrinsic properties are validated against measurement of the Young's modulus and Poisson's ratio carried out using a quasi-static compression method on the core (unshaped) material [4]. The stiffness of the shaped material is then evaluated both for compression and bending motion and compared to the numerical predicted values. Results are presented for various shape geometries and several nature of the porous substrate. In particular, the tested porous cores comprise fibrous and chipped materials as well as visco-elastic foams.

This work enables to prototype virtually the elastic properties of shaped porous materials as an alternative to less efficient trial and error tests.

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