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EFFECT OF LOAD PLATE MASS ON DYNAMIC STIFFNESS DETERMINATION

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ABSTRACT

This study investigates the effect of load plate mass on the dynamic stiffness determination of resilient materials used in acoustic applications, specifically through the single mass method outlined in ISO 9052-1. The standard method, primarily designed for materials under floating floor conditions, may not be applicable for acoustic material stiffness determination in constructions used in cavity dampening solutions (e.g. wall linings) or heavy machinery foundations, due to differing load conditions. The study aims to assess how varying load plate masses influence the apparent dynamic stiffness of several resilient materials, including EPS, mineral wool, wood fibre, and foamed polyurethane elastomers. Experiments were conducted using load plates with total mass range from 0.868 kg to 7.665 kg . The results show a significant reduction in dynamic stiffness when the material is subjected to lower loads. Notably, for lighter load plates, nonlinearities and contact disruptions between the load plate and the material were observed, impacting the accuracy of dynamic stiffness measurements following the ISO 9052-1 measurement procedure. This study highlights the importance of considering load conditions when interpreting dynamic stiffness values in acoustic applications, especially in structures like double walls, where load and deformation conditions differ from those prescribed in ISO 9052-1.

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1. INTRODUCTION

The ISO 9052-1 standard [1] is frequently employed in building acoustics to determine the dynamic stiffness of resilient materials. Originally, this method was specifically designed for evaluating materials used beneath floating screeds, particularly those with smooth surfaces laid in a continuous layer. However, the applicability of this standard is limited to materials subjected to compressive loads between 0.4 kPa and 4 kPa. It is therefore unsuitable for materials experiencing lower loads, such as those found in wall cavities, or higher loads, such as in machinery foundations. Despite these specified limitations, dynamic stiffness values obtained using the ISO 9052-1 method are often referenced in studies analysing the sound insulation performance of lightweight wall systems to often used to predict the mass-spring-mass resonance frequency, even though the materials in such constructions are subjected to markedly different loading and boundary conditions. This inconsistency prompted us to investigate the extent to which variations in compressive loading influence the dynamic stiffness of resilient materials. Understanding this relationship is particularly relevant when examining how loose-form resilient materials contribute to a wall's acoustic behaviour. This need has been repeatedly emphasized in cases of studying the stiffness of loose form materials implemented in double [2–4] walls, but also in the case of research related to the stiffness of ETICS [5]. Building upon findings reported in previous studies [6, 7], we hypothesized that resilient materials exhibit reduced stiffness under lower loads. The mechanical behaviour of elastic, soft, and porous materials is often complex and subject to varying interpretations. Their apparent stiffness is influenced not only by the degree of compression or applied load [8], but also by the boundary conditions under which the material is installed [9, 10]. In particular, the material's response is affected by factors such as the sealing of contact surfaces, the geometric dimensions of the resilient layer, and the compliance or stiffness of the applied load mass. These variables can significantly alter the measured stiffness, complicating the evaluation of the material's performance in real-world applications. This study highlights the importance of considering load conditions when interpreting dynamic stiffness values in acoustic applications, especially in structures like sandwich panels, where load and deformation conditions differ from those prescribed in ISO 9052-1. The case study focusing on how the mass of the load plate affects the measured dynamic stiffness of commonly used resilient materials is presented in this paper.

2. CASE STUDY DESCRIPTION

2.1 Materials under test

A case study was conducted with the objective of comparing commonly utilized resilient materials frequently encountered in practical applications. The investigation accounted for the assumption that material stiffness would decrease under reduced loading conditions. The materials selected for evaluation were as follows:

Table 1. Thicknesses of individual resilient materials.

Material	thickness in m
EPS	0.04
XPS	0.04
Light MW	0.02
Heavy MW	0.01
Wood Fibre Board	0.01
PU Elastomer	0.025

All test samples had a lateral edge dimension of 0.20 m, except for the PU elastomer sample, which measured 0.10 m. Testing procedures were conducted in accordance with ISO 9052-1, with minor deviations: no plaster intermediary layer was applied between the steel plate and the material sample (goal was to simulate boundary conditions similar to conditions applied in dry building processes), and the interface between the test base and material was not sealed. These deviations are not expected to significantly influence the experimental outcome, as the primary aim was not the precise quantification of dynamic stiffness, but rather to examine the influence of varying load magnitudes on relative stiffness variation, particularly in the context of resonance response behaviour.

Figure 1. Example of a measurement setup - measurement of a sample marked Light MW.

2.2 Measurement setup and procedure

Three types of loading plates were employed in the testing. Two plates had dimensions of height × 0.20 m × 0.20 m and masses of m_{lp1}= 7.665 kg and m_{lp2}= 1.263 kg, respectively. The third plate had dimensions of height × 0.19 m × 0.19 m and a mass of m_{lp3}= 0.868 kg see (Fig. 1). The motivation behind this variation of unequal surface dimension case was to assess the effect of localized deflection in the damping material at the periphery of the load plate on the measured dynamic stiffness. A logarithmic frequency sweep signal was applied to excite the specimens using a shaker, and the resulting data were extrapolated to a zero-force amplitude condition. Excitation was provided by a TIRAvib 50018 shaker driven by a TIRA E60 analog power amplifier. The dynamic response was captured using a Dytran 3055B2 accelerometer and a Dytran 1051V1 force sensor, with data acquisition handled via NI 9234 hardware. Data analysis was performed using an automated routine developed in MATLAB.

3. RESULTS

A series of dynamic stiffness measurements were performed for selected resilent materials that can be encountered in practice in horizontal and vertical building structures. The measurements were performed using three different load plates as explained in the previous chapter. Apparent dynamic stiffness was determined by extrapolation to zero excitation force in agreement to standard [1] (see Fig. 3). Individual resulting dynamic stiffness values are presented in Tab. 2.

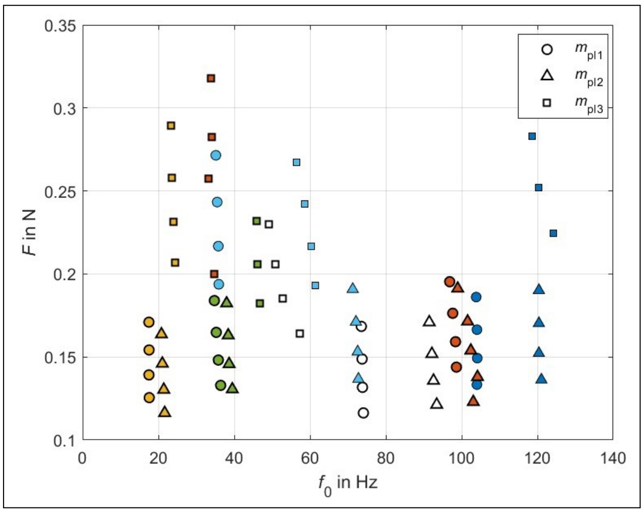

Figure 2. Measured resonance frequencies for three load plate variants and individual material types. Markers sequentially indicate the specific load plate used during the experiment: ○ - m_{lp1}; △ - m_{lp2}; □ - m_{lp3}. Materials are color coded - EPS (white); XPS (dark blue); Light MW (yellow); Heavy MW (green); Wood Fibre Board (red); PU Elastomer (light blue).

First of all, it should be noted that the use of a low-mass load plate can be associated with several problems. The first is the self-resonance of the load plate. The used load plates had their first natural resonance frequency in free boundary conditions (steel plates only) at frequencies $f_{0,\text{m,lp1}}$=1942 Hz, $f_{0,\text{m,lp2}}$=331 Hz and $f_{0,\text{m,lp3}}$=367 Hz. Therefore, it is important to have the assumed resonance of the measuring system under strict control when evaluating selected materials. As was shown in the experiments, the effect of reducing the load had such a significant effect on the reduction of stiffness that resonance phenomena always occurred in the region below 130Hz.

Here, a second important note was opened: the assumption is that individual materials will show significantly lower stiffness when loaded by a light plate. This is related to the compression of the tested samples due to the pull. Zhou has already addressed this issue [6].

The third complication is the bouncing of the plate with a low mass. Of course, applying a thin layer of plaster could have helped slightly here to achieve a better connection of the load plate and the individual layers. However, since the aim was to test the samples under conditions that can be encountered in dry construction processes as well as in applications in vertical structures (e.g. wall cavities, double walls), plaster was not additionally applied. The aforementioned bouncing of the load plate was already evident at low excitation values in the materials Wood fibre boards, EPS and XPS. This was of course also reflected in the results themselves. Table Tab. 2 presents a significant decrease in stiffness recorded in all samples by reducing the load mass. However, the unsystematic behaviour of the resonance response was evident precisely in the mentioned relatively stiffer materials

The PU Elastomer sample had smaller area dimensions than each of the load plates. In this case, the effect of the load on the resulting actual stiffness of the resilient material was clearly demonstrated. The dynamic stiffness, depending on the type of load plate, decreased from 43.56 MN/m^3 to 18.94 MN/m^3. The loading effect effect was of course also evident in the MW type fibrous materials. In this case, load plates 1 and 2 had the same area dimensions as the area of the damping pad. Here, the actual stiffness decreased from 2.37 to 0.71 MN/m^3 and from 12.5 to 2.29 MN/m^3, respectively. Since load plates 2 and 3 have the same mass per unit area (24 kg/m^2) but different contact areas, we could expect slight differences in the determined results of the actual dynamic stiffness in this case. In both cases, MWs showed a slight increase in stiffness by applying m_{lp3} (3 to 28 %). This can be explained by the effect of increased flow resistivity on the resulting actual stiffness

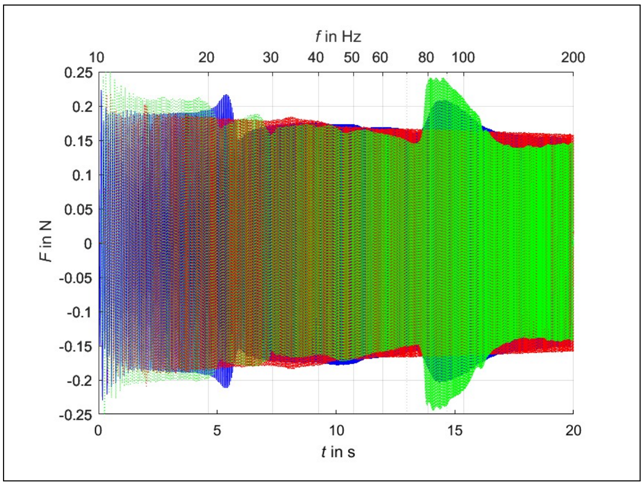

Figure 3. Example of a time record of force during logarithmic sweep excitation. Tested material XPS. Load plate type applied was color coded - m_{lp1} (red); m_{lp2} (blue); m_{lp3} (green);

of the sample as well as local overpressure of the sample at the edge of the light load plate. A similar effect can also be observed for the XPS sample. However, this result must be taken with a "grain of salt" since the XPS had a lattice texture on the surface.

Table 2. Determined dynamic stiffness depending on the load.

Material	s' in MN/m^3		
Load plate	m_{lp1}	m_{lp2}	m_{lp3}
EPS	42.78	11.95	5.52
XPS	82.81	18.63	19.82
Light MW	2.37	0.71	0.91
Heavy MW	12.5	2.29	2.36
Wood Fibre Board	81.61	14.84	1.21
PU Elastomer	43.56	29.35	18.94

4. CONCLUSIONS

This study investigated the effect of the weight of the load plate on the determination of the dynamic stiffness of soft materials used in acoustic applications, in particular according to the method defined by ISO 9052-1. The results showed that reducing the weight of the load plate leads to a significant decrease in the measured dynamic stiffness. This effect was particularly pronounced for materials with higher elasticity. However, this was due to the occurrence of nonlinearity associated with the interruption of contact between the plate and the material. This is very important, for example, for accurate prediction of $f_{\text{m-s-m}}$, which plays a role in evaluating the low-frequency performance of building elements.

Especially in vertical structures such as wall cladding or double walls, the materials are not exposed to the same load as in floor structures. Therefore, it is necessary to develop or recommend a measuring set-up that can accurately determine the actual stiffness of these materials. This set-up must: - eliminate the effect of the shaker pressure, which can affect the accuracy of the measurement, - ensure permanent contact between the load plate and the damping material even without the use of a gypsum layer.

The obtained results show that current measurement methods can distort dynamic stiffness values, especially under low load conditions, thus underlining the need to develop a more suitable variation of measurement techniques for soft structural elements loaded by low mass in various applications.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] "ISO 9052-1:1989. Acoustics — determination of dynamic stiffnesspart 1: Materials used under floating floors in dwellings," 1989.

[2] M. Neusser, F. Dolezal, M. Wurm, H. Müllner, and T. Bednar, "Evaluation of the acoustic and environmental performance of different wall structures with particular emphasis on straw," *Journal of Building Engineering*, vol. 66, p. 105922, 2023.

[3] M. Neusser, D. Urban, F. Dolezal, and H. Müllner, "The influence of different material properties of straw on the building acoustic performance of lightweight wall constructions," *Cellulose*, vol. 5, pp. 3–7, 2023.

[4] M. Neusser, D. Urban, and H. Müllner, "Acoustic performance and measurement challenges of loose blown-in insulation materials in wall constructions: A focus on straw," *Building Acoustics - Accepted for publication*, 2025.

[5] H. Bietz and V. Wittstock, "Investigations to determine the dynamic stiffness of elastic insulating materials," in *Proc., Euronoise*, 2018.

[6] J. Zhou, P. Zhao, and B. Z. Yang, "Apparent impact sound insulation performance of continuous floating concrete toppings on mass timber slab floors," *Journal of Architectural Engineering*, vol. 30, no. 4, p. 04024035, 2024.

[7] I. L. Ver, "Measurement of dynamic stiffness and loss factor of elastic mounts as a function of frequency and static load," *Noise Control Engineering*, vol. 3, no. 3, pp. 37–42, 1974.

[8] A. Schiavi, C. Guglielmone, and P. Miglietta, "Effect and importance of static-load on airflow resistivity determination and its consequences on dynamic stiffness," *Applied Acoustics*, vol. 72, no. 9, pp. 705–710, 2011.

[9] C. Crispin, C. Mertens, and J. Medved, "Measurement of the dynamic stiffness of porous materials taking into account their airflow resistivity," *Building Acoustics*, vol. 21, no. 3, pp. 221–233, 2014.

[10] M. Schmelzer, V. Wittstock, H. Bietz, and S. Brezas, "On the influence of the air flow resistivity on the measurement of the dynamic stiffness of underlays for floating floors," *Acta Acustica*, vol. 5, p. 13, 2021.