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MEASUREMENT OF DYNAMIC STIFFNESS OF RESILIENT STUDS USED FOR MULTILAYER CONSTRUCTIONS

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Abstract

Sound insulation of mechanically coupled multilayered constructions, such as lightweight floors and walls, depends on the resiliency of line connections (a.k.a. studs or bars) which are mechanically connecting the rigid layers (boards). Typical examples are vertical or horizontal wall studs and floor or ceiling joists. The transmission of mechanical vibration reduces when the dynamic stiffness, *K'*, of the studs reduces. There is no standardized method of measuring *K'* of resilient studs. Our purpose is to present a method for that purpose. The measurement apparatus contains a vibration exciter, two planar load masses hanging from ceiling, force and vibration transducers, and a two-channel real-time analyzer. The stud samples are mounted between the load masses. Thirty geometrically different resilient studs were measured. The profile width of studs varied from 17 to 125 mm. The resulting database includes the *K'* and loss factor values of many typical stud profiles available in the market. The measured range of *K'* was 0.08–6.91 MN/m², and range of loss factor was 0.01–0.03. The most significant properties that were different between individual studs were the profile geometry, thickness of the material, and the cut openings in the studs. The method is complete and it could also be considered in standardization committees. Full paper is available in Ref. [1].

Keywords: *material properties, measurement, building structures*

1. Introduction

Coupled double layer constructions are very usual, e.g., two-pane windows, drywalls, double walls in partitions and façades, and multilayered intermediate floor constructions. If the coupling between boards is made using rigid studs, sound insulation is significantly weaker compared to a situation without stud connections. This adverse effect can be mitigated by using resilient studs, e.g., profiled steel studs (Fig. 1), which can elevate sound insulation more than 10 dB at certain frequencies.

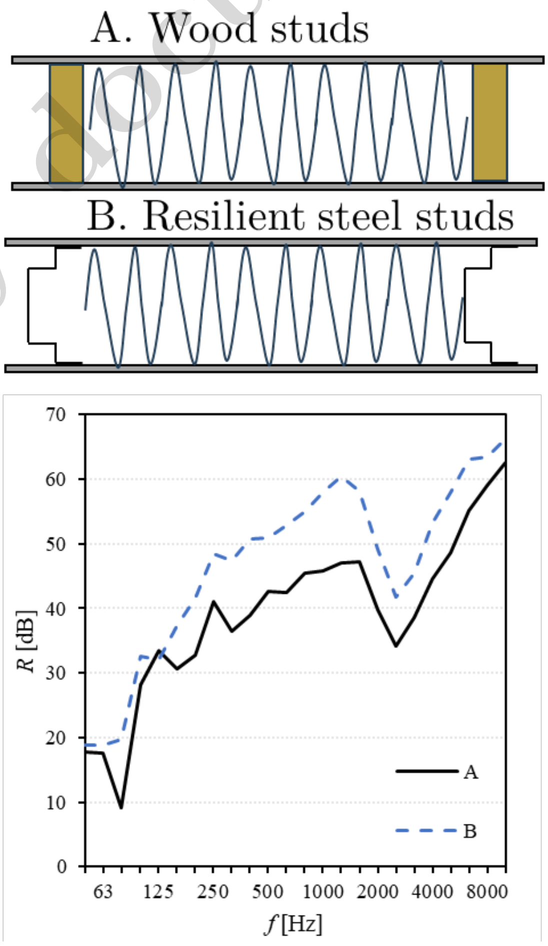

Figure 1. Measured sound reduction index, *R*, as a function of frequency, *f*, for two coupled double walls differing in stud resiliency. In cases A and B, cavity thickness was 175 mm, cavity was filled with mineral wool, and both boards were identical (13 mm thick gypsum).

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Sound insulation of double layer constructions containing resilient studs can be calculated with reasonable accuracy when the surface masses of the boards, the properties of the cavity (size and absorption), and the dynamic stiffness (per unit length), *K'* [N/m^2], and loss factor, η, of the studs are known [1-3]. However, reliable determination of *K'* requires experimental measurement. The measurement must be dynamic in nature, i.e., it must be based on exciting the studs into vibration because the studs are not ideal springs. The dynamic stiffness is not the same as the spring constant which can be measured using static mass loads.
Although resilient studs are very broadly applied, there is no standardized method for measuring dynamic stiffness.
The purpose of our study is to present a robust method for measuring *K'* and η in laboratory conditions. The full version of our study is available in Ref. [1].

2. Materials

We measured 30 geometrically different resilient studs (Table 1). The studs were designed for partition walls, façade walls, or suspended ceilings. The stud profiles are presented in Fig. 3.
All studs were made of steel profile having material thickness within 0.46-1.20 mm (t in Table 1). Profile width (i.e., the thickness of the cavity formed by the studs) of the studs varied from 17 to 125 mm (W in Table 1). Typical profile shapes were variations of C-shape or Σ-shape. Individual profile shape could contain different geometrical details and material thicknesses. A photograph of one typical stud is shown in Fig. 2. Section details of the studs are visualized in Ref. [1].

Figure 2. Photograph of resilient stud Nr. 13 of Table 1.

3. Methods

The measurement setup is presented in Fig. 4. The method is developed from ISO 9052-1 [4], which describes the determination of dynamic stiffness of resilient materials used under floor coverings. The method was first introduced in Ref. [5] but this work, and Ref. [1] complements that with better definition and larger experience.
The measurement principle is to determine the resonance frequency of a resilient stud in an isolated system. Two pieces of the same stud are installed between two equal load masses (rectangular concrete blocks) which are hanging from heavy concrete slab ceiling. Hopkins et al. [3] used similar method for measuring stiffness of wall ties used in brick walls.
The dynamic stiffness was determined experimentally by an action-response measurement. One of the load masses was exposed to a driving force. The response then was time-dependent acceleration of one of the load masses. The frequency behavior was examined using broadband vibration (white noise), followed by a frequency analysis. The white noise driving force was shaking one of the load masses and the response was the acceleration of the same load mass. The actual result of the measurement was the frequency transfer function between input (force) and output (acceleration) spectra:

$$H(f) = -\mathcal{F}\{a(t)\}/\mathcal{F}\{F(t)\} \qquad (1)$$

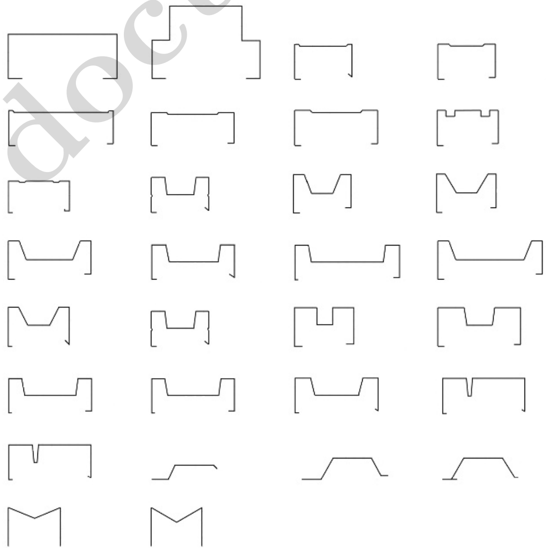

Figure 3. Stud profiles of the resilient studs 1-30 of our study. Dimensions are in scale. Western reading direction.

Resonance frequency, f_m [Hz], of the vibrating mass-spring-mass system appears as a peak in the transfer function. This frequency is in practice the same as the natural resonance frequency, f_0 [Hz], of the mass-spring-mass system. Thus, the dynamic stiffness per unit length was determined from

$$K' = \pi^2 f_0^2 m/L \qquad (2)$$

where L [m] was the length of the stud pieces (0.3 m in our setup), and m [kg] was the mass of the mass loads (10.2 kg in our setup).

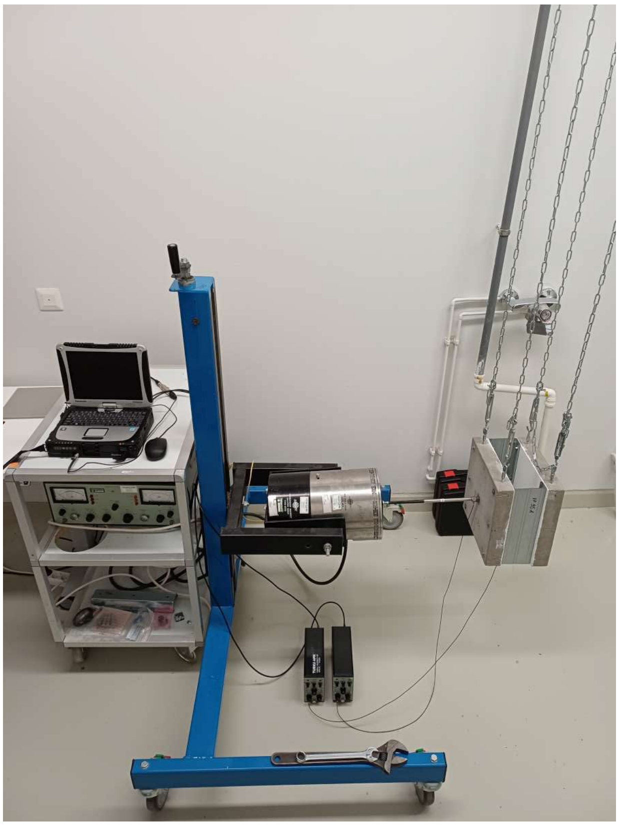

Figure 4. An example of measurement of a resilient C-shape stud. The stud samples are placed on the right between the load masses.

The loss factor was determined based on the half power bandwidth, Δf [Hz], i.e., the width of the resonance peak at the height of maximum value per square root of two and the natural resonance frequency by equation:

$$\eta = \Delta f / f_0 \tag{3}$$

Example of transfer function (magnitude and phase) and determination of K' and η is presented in Fig. 5.

4. Results

Summary of the measurement results are presented in Table 1. More details about the studs are given in Ref. [1].

5. Discussion

The strength of our study is that our database includes many typical stud profiles available on the market. The studied studs had large variation with respect to profile geometry, material thickness, and the cut openings in the studs. Because of that, the range of K' was broad, from 0.08 to 6.91 MN/m^2 which suggests that manufacturers are clearly aware how the resiliency can be controlled by the profile shape.

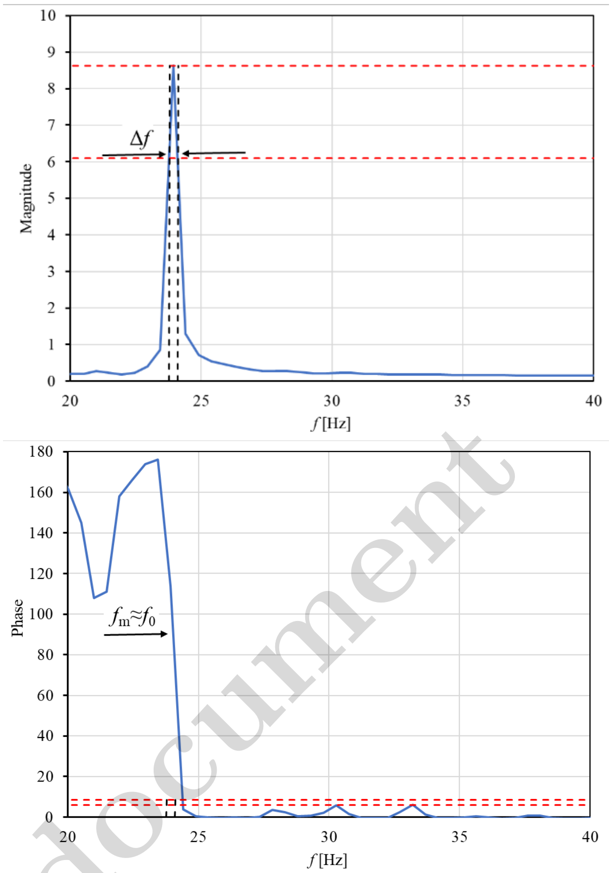

Figure 5. An example measurement result of a resilient stud (Nr. 13). Magnitude (top) and phase (bottom) of the transfer function as a function of frequency, f. K'=0.17 MN/m^2 and η=0.01.

The range of η was not so broad, within 0.01–0.03. The reason for that is probably the fact that all studied studs were similar, i.e., made of profiled steel.

Based on all this, we believe that our database has scientific novelty and the proposed measurement method is robust.

However, we also found some weak points in the method. The attachment of the studs to the load masses affects the results for stiffer studs. More flexible studs bend from the folds, and this dictates dynamic stiffness. The effect of attachment and tightness of screwing on results with stiffer studs deserve further research.

Further research should also determine between laboratories uncertainty of this test method.

Table 1. Dynamic stiffness per unit length, *K'*, loss factor, η, profile width, *W*, and thickness of steel, *t*, measured for 30 different studs. The results that could not be determined are presented with '-'.

Stud nr.	*K'* [MN/m^2]	η	*W* [mm]	*t* [mm]
1	3.10	0.01	125	1.20
2	0.08	0.01	125	1.00
3	1.06	0.01	66	0.46
4	1.47	0.01	66	0.50
5	1.17	0.01	120	0.53
6	1.61	-	95	0.54
7	1.64	0.02	95	0.57
8	0.68	0.02	70	0.46
9	6.91	0.02	70	0.52
10	0.23	0.01	66	0.46
11	0.21	0.01	66	0.46
12	0.10	0.02	68	0.46
13	0.17	0.01	95	0.46
14	0.15	-	95	0.46
15	0.14	0.03	120	0.46
16	0.13	0.02	120	0.46
17	0.32	-	70	0.50
18	0.24	0.01	66	0.50
19	0.13	0.01	68	0.50
20	0.18	0.01	95	0.50
21	0.16	0.02	95	0.50
22	0.15	-	95	0.50
23	0.28	0.01	95	0.56
24	0.25	0.01	95	0.56
25	0.17	0.01	95	0.56
26	0.53	0.02	17	0.52
27	0.24	-	25	0.53
28	0.32	0.01	25	0.56
29	0.90	-	60	0.56
30	0.82	0.01	58	0.56

6. Conclusions

We introduced a measurement method that can be used to test the dynamic stiffness and loss factor of resilient studs used in multilayered wall and floor constructions. The method seems robust enough and therefore it could be considered in standardization committees. If the method were standardized, the industry could more systematically develop their resilient studs and the industry could also declare their acoustic properties in a harmonized way, which helps business.

Our database is also useful in sound insulation predictions of coupled building constructions when measured value of *K'* is not available or measurements are not feasible.

7. Acknowledgments

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