EVALUATION OF THE ACOUSTIC PROPERTIES OF HOMOGENEOUS AND COMPOSITE ELEMENTS APPLIED TO PARTITION WALLS AND DOORS

ABSTRACT

Thin and flexible slab elements of higher square weights are suitably used in assembled envelopes forming partition walls and door leaves or as additional panels in composite dividing components. A detailed knowledge of the material and physical properties and the ability to use an optimised structural composition may result in a design demonstrating satisfactory sound insulation characteristics. The paper analyses selected results of laboratory measurements to appraise the outlined dependences within the narrow area of partition walls and doors.

1. FUNDAMENTAL CONDITIONS FOR AN INCREASE IN SOUND REDUCTION OF SINGLE-LEAF WALLS

Slab structures are simple lightweight elements with prevailing planar dimensions. They are constructed of homogeneous materials of $m \leq 20 \text{ kg.m}^{-2}$ surface density and $h \leq 20 \text{ mm}$ thickness and have acoustical properties indicative of those of single-leaf acoustically soft walls (ACUMIN, IZOMIN acoustical insulation boards, plasterboard, chipboard, plywood and flexible materials, e.g., sheet metal, etc.). For our purposes foils were defined as elements with a thickness of $h \leq 10 \text{ mm}$ and of a minimal rigidity of $B$, e.g., PVC, rubber foils, cardboard, alufoils, etc.

The essential properties characterising the acoustic quality of a wall are:

- Defined and proportionally increasing surface density $kg.m^{-2}$, areic mass $kg.m^{-3}$, high dynamic elasticity modulus value of slabs $E_d \text{ Pa}$, forming the envelope and low modulus of the insulating filler, sufficient attenuation of the slabs $B \text{ Pa.m}^{-1}$, low flexural rigidity and suitable material structure of the slab.

The following conditions for an increase in the sound reduction of a slab can be derived from:

- $f_{\text{crt}} < 100$ Hz (lightweight, stiff or very thin slabs) and $f_{\text{crt}} > 3150$ Hz (heavier slabs of a low rigidity)
- Exclusion of the critical frequency $f_{\text{crt}} = 500$ Hz from a significant band of frequencies
- Reduction of the slab radiation factor $s [-]$ by using dampening inserts, an anti-vibration surface treatment, using layered structures with suitable anchoring, etc.
2. ANALYSIS OF THE MEASURED RESULTS

Measurements of single-leaf and layered slab components were carried out in the first stage of work at the Acoustics Laboratory of the Faculty of Civil Engineering of STU Bratislava. The results, supplemented with those obtained at other workplaces, were analysed in considerable detail to arrive at conclusions of a relative and comparable nature, which may be applied to specific preliminary designs of acoustically satisfactory slab elements. The following elements were selected for the analysis:

- Envelopes: plasterboard, chipboard, sheet metals,
- Fillers: honeycombed paperboard, polyurethane, polystyrene, mineral fibre,
- Additional slab materials: plasterboard, IZOMIN acoustical insulation board, cardboard, wire mesh, PVC foil.

2.1 Evaluation of measurements with selected envelope materials

- Doubling of the slabs resulted in an increase on average in a 4 – 6 dB of sound reduction; higher values were obtained in heavier boards;
- The critical frequency was present in the significant frequency band in both the single-leaf and double-leaf slabs of the envelope, regardless of the material and affecting the single-leaf slabs more significantly;
- The frequency responses of both the single-leaf and double-leaf slabs were similar and mutually almost parallel, and were affected primarily by the slab’s surface density as compared to the thickness or type of material (Fig. 2);
- The doubling of the slabs was less favourable than supplementing the single-leaf slabs with additional materials (IZOMIN), which resulted in the elimination of the $f_{crit}$ from the significant frequency band (100 < $f_{crit}$ < 3150 Hz) and showed maximum effects in zones with a higher frequency;
- Additional, heavier, low-rigidity foils were more effective (e.g., a steel sheet increased the $R_w$ value by 8 – 15 dB); rubber foils failed to remove the $f_{crit}$;
- Wire mesh used as additional material on the internal side of the envelope only showed effects in single-leaf slabs and only in the midrange (200 < $f$ < 1600 Hz) frequency band (increases of 2 dB);
- Wire mesh placed between two slabs was ineffective and thus superfluous.

2.2 Evaluation of the effects of sheet metals:

- Single sheets of steel or galvanised steel ($h$ = 0.8 to 1mm), indicated a very low sound reduction index ($R_w$ = 10 – 15 dB) at low frequencies;
- In contrast to other materials, steel sheets indicated no decreasing attenuation properties in the presence of $f_{crit}$;
- Doubling of the sheets was only effective at $f$ < 800 Hz;
- Inserts of paperboard between two sheets had little effect; increasing attenuation was shown in lighter, low $R_w$ slabs.

2.3 Evaluation of the effects of selected sound-absorbing filler materials placed between two slabs in a layered structure (Fig. 1):

- Heavier types of low rigidity and low elasticity acoustical insulation materials inserted between two planar slabs improved attenuation by up to 20 dB on average, compared to lightweight and rigid inserts (boards from mineral fibres were more suitable than honeycombed paper inserts; lightweight rigid polystyrene foam slabs demonstrated the least favourable properties when compared to soft and heavy materials);
- Lightweight rigid filler required thin, heavier and low rigid slabs of an envelope;
- Insertion of a light and rigid filler between two sheets of metal deteriorated the sound reduction in comparison with a double-sheeted slab; conversely, heavier and softer inserts successfully eliminated the $f_{crit}$ from the significant frequency band and considerably increased the sound attenuation.

2.4 Application of the analytical conclusions with respect to selected slab element frequency responses in the construction of dividing walls and doors (Antalová, L.)

- Doubling should only be used in heavier slabs.
- Optimal results are obtained by connecting two slabs of different surface densities and material structures.
- Heavy and flexible metal sheets are most suitable for jacketing dividing walls and doors from the viewpoint of acoustics ($\Delta R \geq 10 – 15$ dB).
- Use of additional foils between sheets is less effective than expected, showing an advantage ($\Delta R \leq 2$ dB) only in combination with lightweight sheets.
- In comparison with other materials, heavy and flexible metal sheets have the highest frequency response curves, showing no reduction in the critical frequency $f_{crit}$;
- Acoustical insulation fillers in the airgap between jackets are most effective when made from acoustically soft, heavier slabs (e.g., mineral fibre boards).
- Sound reduction of layered envelope constructions is improved by additional foils on the internal side. Soft lightweight foils are less favourable than heavy and flexible foils, with the latter...
Fig. 1 Frequency curve of the air sound reduction factor of flexurally soft layered slabs from metals and dampening materials (Zajac, J.)
The results of the measurements were compared with reference values according to EN ISO 717 - 1.

A Lead foil 1 x 1 mm, $R_W = 34$ dB, plywood 1 x 13 mm
B Steel sheet 1 x 3 mm, $R_W = 39$ dB, asbestos cement board 2 x 6 mm
C Steel sheet 2 x 2 mm, $R_W = 38$ dB, foam glass 1 x 38 mm
D Steel sheet 2 x 2 mm, $R_W = 43$ dB, mineral wool slab 1 x 40 mm
E Steel sheet 2 x 1 mm, $R_W = 22$ dB, rigid polystyrene foam 1 x 603 mm
F Aluminium sheet 2 x 0.8 mm, $R_W = 18$ dB, rigid polyurethane 1 x 50 mm

Fig. 2 Frequency curve of the air sound reduction factor of single-leaf flexurally soft layered slabs (foils), used as additional material to increase the attenuation properties of walls and doors (Zajac, J.)
The results of the measurements were compared with reference values according to EN ISO 717 - 1.

A Rubber foil, $h = 5.0$ mm, $m = 4$ kg.m$^{-2}$, $R_W = 21$ dB
B PVC foil, $h = 3.5$ mm, $m = 3$ kg.m$^{-2}$, $R_W = 18$ dB
C Plywood, $h = 4.0$ mm, $m = 3$ kg.m$^{-2}$, $R_W = 20$ dB
D Aluminium plate, $h = 3.8$ mm, $m = 6$ kg.m$^{-2}$, $R_W = 27$ dB
E Steel sheet, $h = 3.5$ mm, $m = 28$ kg.m$^{-2}$, $R_W = 36$ dB
F Plasterboard, $h = 7.0$ mm, $m = 7$ kg.m$^{-2}$, $R_W = 26$ dB
effectively increasing attenuation of medium and high frequencies and eliminating the adverse effects of $f_{cr}$. These conclusions are not the only preconditions for increased sound reduction in single and composite constructions, the methods of their mutual connection being of similar importance. Less effective are planar glued or densely spot-joined connections, because they increase rigidity and decrease sound attenuation. Small slabs may be joined and anchored circumferentially. The insertion of flexible support pads in broken patterns between two rigid slabs is considered an advantage. The sealing of joints of layered constructions into a wall or into a door frame, remains an important method for sealing and anchoring.

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