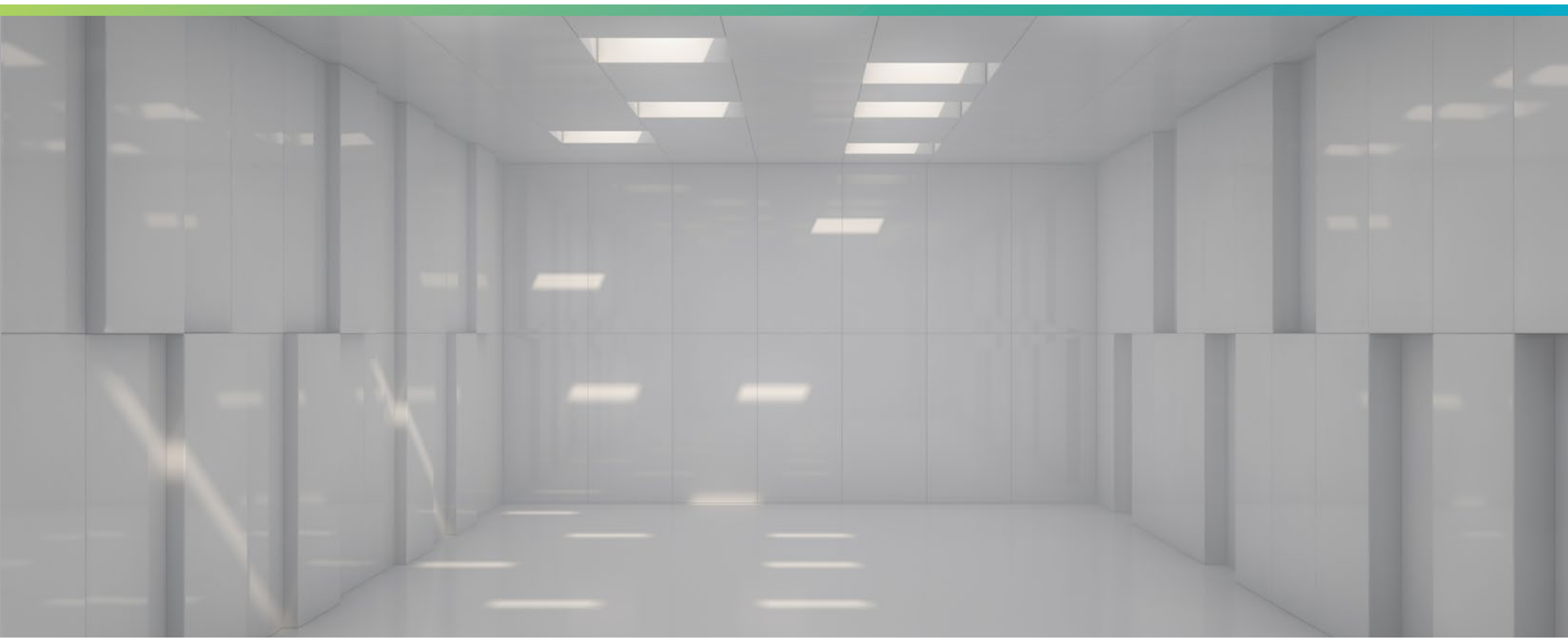
Belgian building research institute

Actran helps improve predictions for room to room vibration transmission



Introduction

The stringent acoustical requirements imposed by the Belgian standard for dwellings (NBN-S01-400-1 (2008)) present a major challenge for architects. In particular the standard defines strict requirements for the global sound insulation between rooms which is mainly determined by the direct transmission and flanking transmissions in which sound waves produced in one of the rooms excite the flanking structure and generate structural waves which are transmitted through the structure.

The flanking wall then radiates the sound in the adjoining room. There are four junctions between two adjoining rooms and three flanking transmissions at each junction which makes for a total of 12 flanking paths. The energy of these waves is attenuated as they pass through the junction is determined by the vibration reduction index Kij. Architects and acoustic consultants face the challenge of accurately estimating the vibration reduction index Kij for a particular building design.

ISO 10848 defines a method for measuring Kij with physical testing however this is a long, tedious and expensive process. Full scale mock-up of a junction between two rooms is constructed. The wall of the first room is excited with a hammer and the vibration is measured simultaneously on the excited wall and on the reception wall in the other side of the junction given a velocity level difference. Then the process is reversed by exciting the wall of the other side.

The average of the velocity level differences in the two directions can be used to calculate Kij. Furthermore, in order to produce a building system that meets the acoustical requirements, manufacturers need to evaluate a number of different junctions for their products. The structure needs to be torn down and rebuilt for each of these junctions.

Challenge

Because of the high cost and time involved in physical measurements, architects and acoustic consultants normally use empirical formulas set out in the EN 12354 standard. These formulas estimate Kij as a function of the quantity M which is defined as:

$$M = lg \frac{m'_{\perp i}}{m'_i}$$

Where m'_i is the mass per unit area of the element i in the transmission path ij in kilograms per square meter and $m'_{\perp i}$ is the mass per unit area of the perpendicular element making up the junction in kilograms per square meter.

Researchers at the Belgian Building Research Institute (BBRI) laboratory measured K_{ij} for approximately 185 different junctions and compared the results to the prediction formulas. Discrepancy was found from this comparison. In particular, the measurements show a faster increase in K_{ij} as a function of the ratio of the surface mass than is predicted by the EN 12354 formula. BBRI researchers have proposed that the ratio of the characteristic moment-impedances A, instead of M, would provide better estimates of Kij as per the following formula ...

$$A = \sqrt[4]{\frac{m'_{\perp i} B^3_{\perp i}}{m'_i \, B^3_i}}$$

Where $m'_{\perp i}$ [kg/m²] and $B_{\perp i}$ [N.m] are respectively, the surface mass and the bending stiffness of the plate perpendicular to plate “i”

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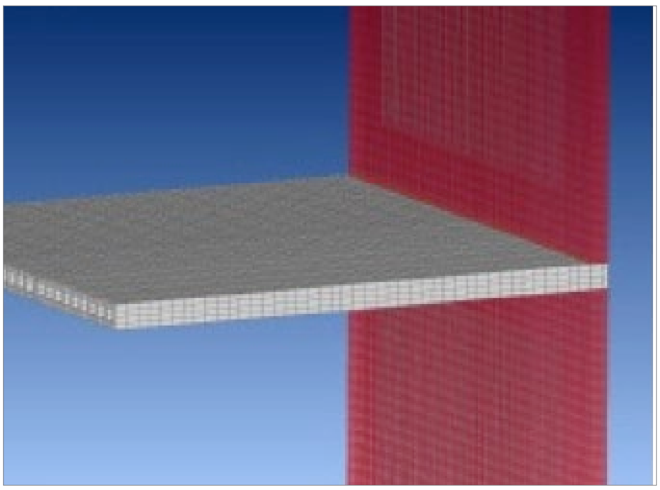
BBRI researchers needed to accurately simulate noise transmission over a wide range of wall properties in order to validate their proposed formula. Physical testing would have been far too expensive and time-consuming so the company needed a numerical simulation that could accurately predict Kij and cross-validate the new empirical formula.

Measurement according to ISO 10848

Solution/validation

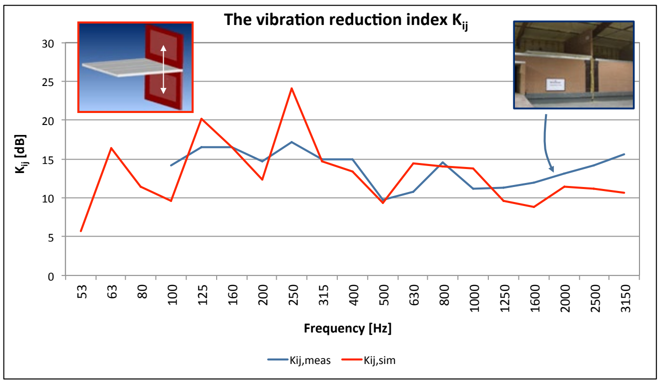
“We used Actran to simulate in-line and corner transmission because of Actran’s proven ability to provide accurate results over a broad application range and because it is so easy to use,” said Charlotte Crispin, head of laboratory for BBRI. BBRI researchers first validated the ability of Actran to predict a typical case. They built a test setup consisting of a rigid T-junction mounted between two acoustic cells. The vertical walls were made of brick and interrupted by perpendicular hollowcore slabs. Kij was measured in accordance with the 10848 standards.

BBRI researchers then modeled the test setup in Actran with the walls and the floor represented as isotropic solid materials. Five dynamic point loads were applied successively to the two walls and the floor. Actran computed the normal mean square velocity (NMSV) from 50 Hz to 3150 Hz. The direction averaged velocity level difference between the exciting and receiving surfaces were found to correlate well with physical measurements.



Actran model used for validation

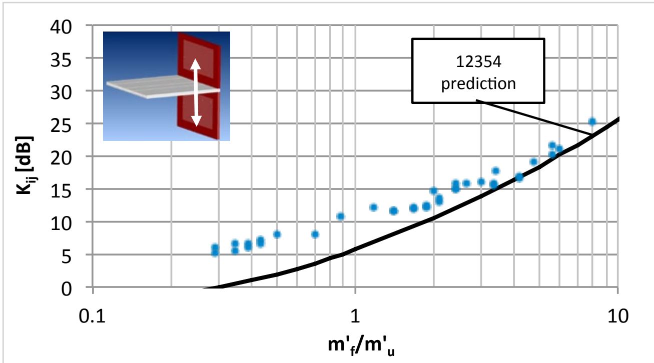
After proving the accuracy of Actran's results, BBRI researchers used the software for a parametric study of a T-Junction, X-junction and H-junction. Young Modulus was varied from 2e+9 N/m² to 2.6e+10 N/m² at 0.2e+10 N/m² increments. The density was varied from 400 kg/m³ to 2400 kg/m³ at 200 kg/m³ increments. The thickness was varied from 60 mm to 220 mm at 20 mm increments. Actran scripts were used to launch computations in a continuous sequence and compare the results. Three different model configurations were also tested: solid component with linear interpolation order, solid component with quadratic interpolation order and shell component with linear interpolation order. More than 900 computations were launched in this study.

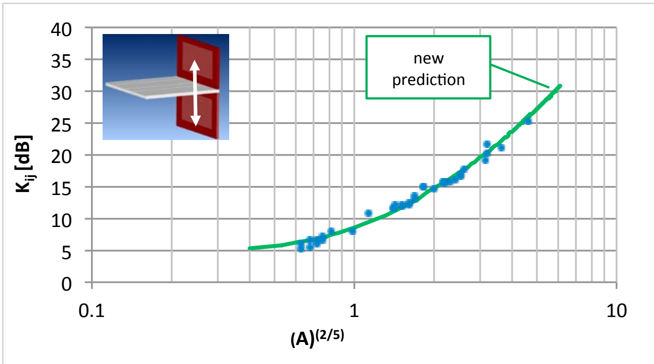


Measured and simulated results in validation study

Results

BBRI researchers evaluated the incumbent and new prediction formulas over a wide range of surface mass ratios in the case of the old formula, and ratio of characteristic moment impedances in the case of the new formula. The results showed that for in-line and corner transmission in T-junctions, X-junctions and H-junctions the new formula more accurately predicts Kij. This work shows that a best prediction of Kij can be obtained by using the ratio of the characteristic moment-impedances "A" instead of the ratio of surface masses. It seems logical that the attenuation of vibration depends on this new ratio since during a change of direction only moments and angular velocities can participate in energy transmission.





Kij estimates based on the new formula (top) provide closer match to simulation results than the old formula (bottom)

About Belgian building research institute

The BBRI is a private research institute founded in 1960 by the Federation of Belgian Building Contractors. Its mission is to perform scientific and technical research for the benefit of its members, supply technical information, assistance and consultancy to its members and to contribute in general to innovation and development in the construction sector. Research focuses are on the construction process, building materials and all aspects of sustainable construction. The BBRI has 230 employees and three locations in Belgium.

Key highlights:
Product: Actran
Industry: Building and construction
Benefits:
Accurate vibro-acoustic modeling of room to room vibration transmission
Reduce product development costs by avoiding expensive tests

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