Reduction of sound immission in buildings by sound insulation using active facades

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Introduction

Today, low sound immissions into rooms have become more and more important for the construction of large buildings such as hotels, hospitals, or conference centres. Particularly near airports, major roads, and railway lines, the acoustic shielding of ambient noise is, in many cases, difficult to handle with classic passive methods. The reasons lie mainly in the physical and financial limitations of the construction. In modern architecture, facades serve as the outer skin of a building and so have to fulfil the demand of static strength. However, if facades are planned in a suitable way, they can also act as a barrier for incident sound fields.
On one hand, they should be constructed to be as light as possible. This helps to reduce the weight and reduces the cost. On the other hand, heavy and stiff elements can provide better acoustic shielding. However, if active noise control techniques are used, relatively light elements could be used whilst still providing good sound insulation.

The Project

The investigation of the possibilities for a reduction of structure borne sound using active techniques is the object of a research project initiated by the German Ministry of Education and Research (BMBF). The project partners are the Department for System Reliability in Mechanical Engineering as well as the Department of Mechatronics and Machine Acoustics, both of Darmstadt University of Technology, and the SCHUECO International KG, builder of aluminium shop fronts and façade units.

The acoustic shielding provided by the façade elements of buildings is mainly dependent to their individual design, like the balustrades, frames and their connection to the inner and outer walls of the building.
In addition to the different window sizes of the façade, the systems for sealing and opening have to be the subject for research too, and will be important for any active system.
Equally important is the noise transmission sideways, along the elements themselves.

Status in March 2004

One of the central questions so far addressed by the project is the investigation and detection of the lower natural frequencies and eigenmodes on a façade composed of several frame elements.
Therefore, a reference façade was designed and measured in 2003, (see Figure 1). The façade is built out of standard components including nine glass and aluminium panels in four different sizes. The dimension is 2,8 by 3,0 meters which is one quarter of a classical element usually shielding 2 floors.

The measuring equipment necessary for the project had been partly designed and tested in the first quarter of 2003. For the measurement of structure borne noise, a laser scanning vibrometer was used. To measure the sound fields, a low cost microphone array had to be designed. It consists of 64 silicon microphones mounted in small circular plastic tubes to allow calibration with standard microphone calibrators. Silicon microphones are temperature and shock resistant and, due to their small mass, very insensitive to structure borne noise. Eight microphones are mounted on each of eight thin vertical aluminium rods in a square frame. The horizontal spacing is fully variable whereas the vertical spacing can be changed from 0.2m to 0.1m. (For details, please refer to the presentation "Design and Application of a Low-Cost Microphone Array for Nearfield Acoustical Holography" by Joachim Bös and Lothar Kurtze in the "silicon and other microphones" - session. [1])

Figure 1: Reference façade at the test facility of Schueco in Bielefeld with the microphone array in the rear (right lower side).

As the receiving room of the test facility at the Schueco International KG has only little absorption, an additional "box" had to be designed to allow measurements of the airborne noise. Except one open side, the interior includes different layers of absorbing material. The "box" can be rolled in front of the façade with the microphone array mounted in its interior. It is shown in Figure 1 behind the façade element.

The measurements of structure borne noise made in August 2003, as measured with a scanning vibrometer, show clearly that the lowest natural frequencies are between 12 and 35 Hz, depending to the element.

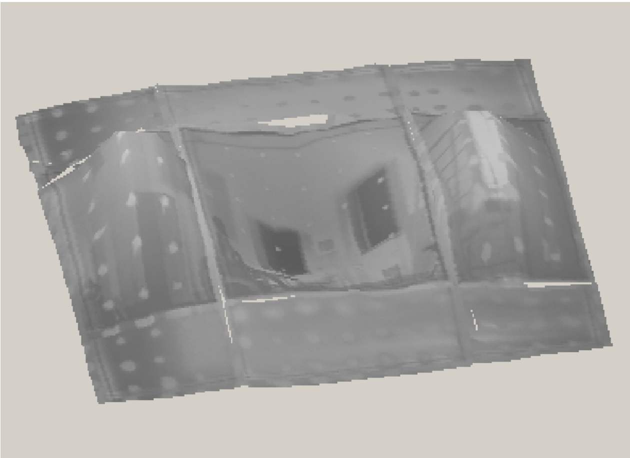

Figure 2: 3D-Print of the reference façade with the measured eigenforms at 22 Hz.

The mode shapes were then compared with the results of numerical FEM calculation. The difference between the calculation and measurement of these frequencies differs less than 2 Hz.

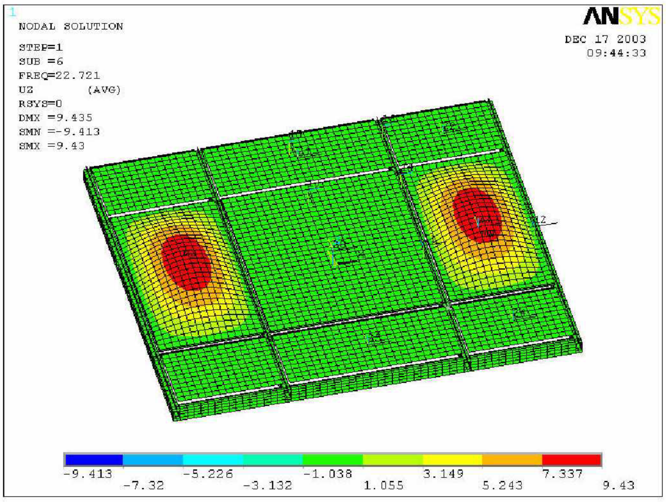

Figure 3: FEM-Model of the reference façade for 23 Hz

The next step in the research is to find an actuator design for generating anti-vibrations and calculations relating to suitable systems are in progress. One option under consideration uses 16 piezoelectric stacks per element. Another option could utilise 4 or more active panels placed at random across the facade element.

The calculations of both options were based on the use of the actuator type PIC 151, permitting a high piezoelectric coupling factor and dielectric constant. Thanks to the cooperation with the Fraunhofer Institute in Darmstadt-Kranichstein, new types of actuators, currently under development, will be subject of research as well.
The actuators will be tested with a smaller, simplified demonstrator element which will be available for measurements at Darmstadt University from April 2004.
After that, suitable positions for the actuators must be determined and an appropriate control system designed.

Possible solutions with adaptronic systems:

With adaptronic systems, there is the option to generate “intelligent structures”. The plan is to create an autonomous system with the help of self-regulated algorithms adapting to different operation conditions. Therefore, it is highly important to get an optimal conjunction between the sensors and the actuators. The actuator design will be dependent on the latest developments such as piezoelectric fibres or foils with adaptive controllers. Thus, the new structure systems may react in a self-optimized way to avoid disturbing effects like airborne noise caused by the deformation of the structure.

Conclusion

During the measurements, the fundamental data for the FEM-Modelling work will have been collected. The data provides the basic information on which the design and number of the actuators is based; this work being currently in progress. Meanwhile, a simplified façade element for detailed studies at Darmstadt University of Technology is under construction. In addition, there are continuing studies about structural intensity. Software development in the area of acoustic nearfield holography may also become helpful in the project.

References

[1] Bös / Kurtze: Design and Application of a Low-Cost Microphone Array for Nearfield Acoustical Holography, DAGA 2004