Sound absorbing glass

transparent solution for poor acoustics of monumental spaces

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Abstract

Monumental buildings are demolished when they lose their traditional function. These historical monuments can be maintained by repurposing them for modern use, like lectures and musical events. This results in a demand for different acoustic conditions. However, monuments are subject to strict building intervention regulations; any intervention concerning changes to the original elements are often prohibited. This creates a demand for demountable and adaptable product design, repurposing monumental buildings by alleviating acoustical problems without distorting the view towards the monumental elements.

This research focused on developing sound absorption panels based on the micro-perforation principle: manufacturing these in thin glass panels, evaluating their influence on strength and transparency, optimizing sound absorption (perforation diameter and ratio) using a tailor-made computational model, and creating a pattern of perforations that optimizes strength.

Keywords

sound absorbing; glass panels; micro-perforation; sound absorption glass panel

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Sound absorbing glass provides a transparent solution for bad acoustics in spaces in which the aesthetics must not be visually affected.

To come to a product that can improve the acoustic surroundings in monumental buildings without affecting the beautiful sights, different aspects needed to be studied. The starting point became a microperforated (transparent/glass) panel (MPP) in front, backed by a closed air cavity and an unperforated transparent back panel. By manufacturing micro- perforations (≤ 1 mm diameter) in a thin transparent panel, sound absorption can be achieved due to viscous thermal dissipation inside these perforations, flow distortion effects at both sides of the panel and the acoustic resonances in the air cavity. During this study many of such panels with different perforation diameters, perforation ratios, cavity sizes, panel thicknesses and combinations of differently sized perforations were tested in an impedance tube. This measures the normal incidence sound absorption: the amount of sound that is being absorbed of a certain frequency (range). We discovered that by solely using a single perforation diameter only a small frequency range was absorbed. Even though sound absorption is nearly perfect in that small range, our goal is to broaden this range in order to create improved acoustic surroundings for multiple, very different, types of events with accordingly different ranges of sound.
To come up with transparent sound absorbing panels with the highest sound absorption coefficient and the broadest frequency range, a mathematical model was developed. This model requires the following input parameters: perforation diameter, perforation ratio, depth of air cavity and the thickness of the panel. The model was validated making use of the measurements done in the impedance tube showing good correspondence, even for combinations of different perforation diameters and ratios within one panel. Making use of the validated computational model, optimum values for the input parameters are obtained, which will be used in the production of specified panels for a specific location.
The production process of the panel had as a starting point: the use of glass, being the most transparent material available, and the thickness of the panel to be 2 mm, due to the limiting structural properties of float glass.

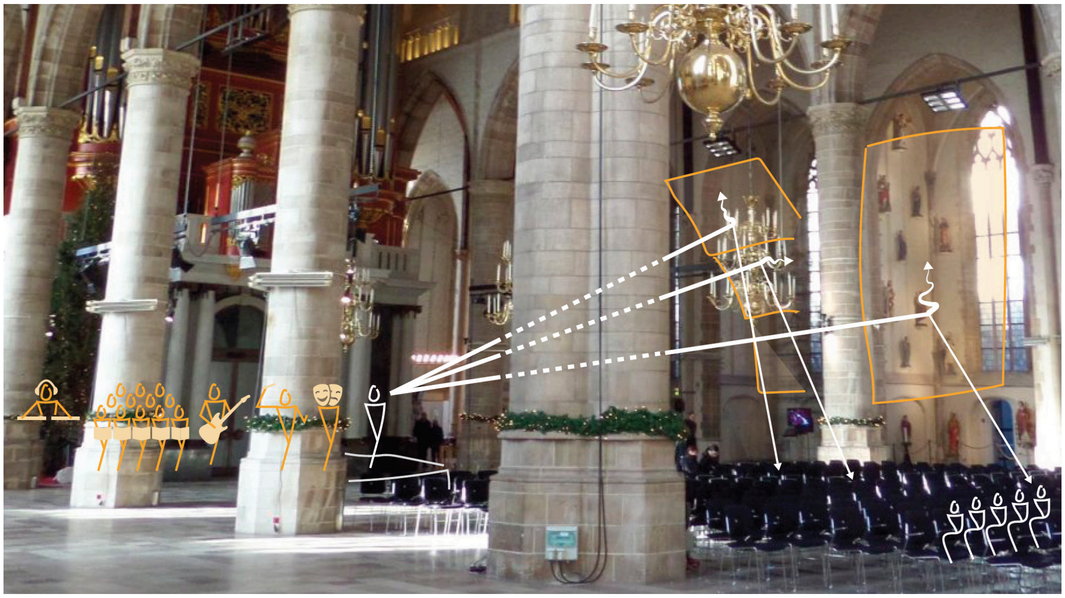

FIGURE 1

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We tried three techniques to make micro perforations in glass, but hydrogen fluoride etching led to uncontrollable perforation sizes and shapes. But, there are two feasible ways to manufacture micro-perforations (≤ 1 mm diameter) in a glass panel: drilling or using a high-end pulse laser-cutting technique. These techniques are both as precise as leaving only 150 μm chip size around the cut, but the cost differs about 4:1.

Perforations in glass panels cause stresses to course around these perforations throughout the glass panel, making its failure behaviour unpredictable and therefore its possible application not so obvious. The final product will contain many perforations, but failure will occur at the weakest point. So, to see that effect, a singular weak point (hole) was tested through computational finite element method (FEM) and a strength-experiment. The experiment is still ongoing.

Another aspect of the finalised product is its transparency. This aspect entails two different scales: the smaller scale of the glass panel with the perforations and the larger scale, that of the entire composite panel and its support structure. The larger scale is dependent on the amount of 'edges' that obstruct the view behind the panel, i.e. frames, connections, cabling. Although the fixings and some connections could be made from the same transparent material as the panel, the structural components are inherently from different and opaque materials, so the less the better.

The smaller scale, that of the panel and the perforation itself and the pattern of the perforations, entails using a colourless glass or polymer with no light reflectance. Colourlessness can be influenced by the chemical composition of the material and the reflectance of the panel can be diminished by adding an AR-coating. Looking at the perforation itself any manufacturing technique 'scratches' the material and thereby leaves a white edge inside the perforation. However, those perforations can then be treated by flame polishing or acid etching. This would not only make the edges transparent again, but also alleviates the tension in the edges, giving back some strength to the panel itself.
Even though the edges of the holes can be transparent, light breaks differently inside the glass than inside the perforation. This entails that perforations do slightly affect view quality: having a negative impact on the amount of detail visible of the image behind the panel.

FIGURE 2

FIGURE 3

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By manufacturing micro-perforations in a thin transparent panel, sound absorption can be achieved.

The present study shows promising results to bring sound absorbing glass into the building industry. Research is ongoing to reach the optimum integral design of the panel taking into account the sound absorption, transparency, strength and production costs. Besides creating different acoustic surroundings for different types of events in beautiful monumental spaces, the possibilities for application in other types of buildings and building-objects are endless.

FIGURE 4

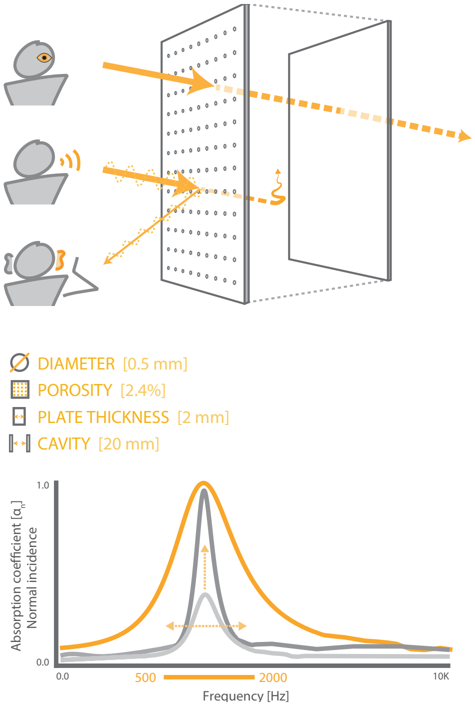

FIGURE 5

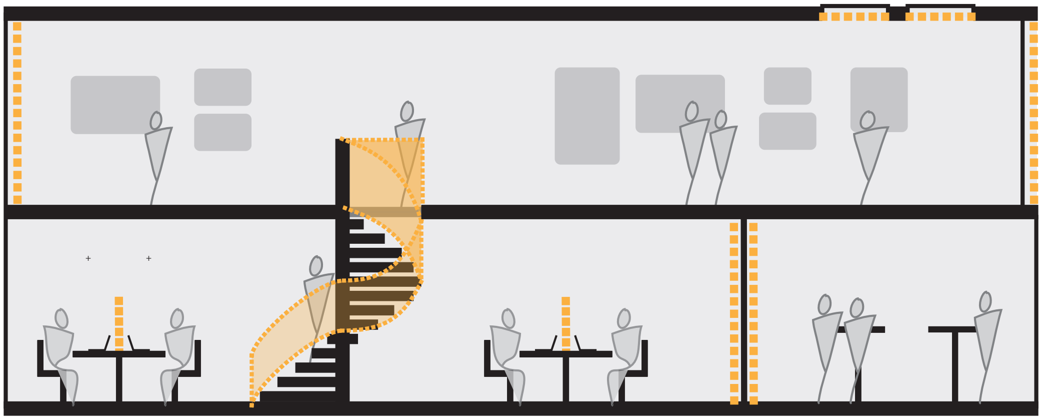

FIGURE 6

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