CHARACTERIZATION AND IMPROVEMENT OF SCATTERING AND ABSORPTION BY ARCHITECTURAL SURFACES WITHOUT THE USE OF SPECIALIZED FACILITIES

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1. INTRODUCTION

The Acoustics and Noise Research Group at the University of British Columbia is working with two companies that both manufacture a profiled wooden architectural wall panel. Currently these two surfaces are designed to be aesthetically pleasing and not intended to be used as an acoustic treatment. This work aims to first complete an acoustical characterization of the surfaces and secondly to modify them in such a way that they provide significant sound scattering and absorption, and can be marketed as an acoustical treatment. The two existing profiled wood surfaces and one flat wooden surface have been characterized in terms of their scattering and absorption coefficients. The two profiled surfaces have been modified for increased sound absorption and scattering, and re-characterized. The main challenge of this work has been to implement a method for measuring scattering on a limited budget and with limited facilities.

2. TEST SURFACES

Three original surfaces have been tested; throughout this paper they will be referred to as Surfaces 1, 2 and 3 respectively. Surfaces 2 and 3 have been modified for increased scattering and absorption. They are called 2S, 2A, 3S and 3A where S and A indicate designs altered to give increased scattering and absorption.

Surface 1 is largely flat and hard. It is composed of 5-mm-thick, 10-mm-wide softwood boards glued onto a 16-mm-thick plywood backing.

Surface 2 is made of 1- to 3-cm lengths of ‘2x4’ (50 mm x 100 mm), ‘2x6’ (50 mm x 150 mm) and ‘2x8’ (50 mm x 200 mm) boards glued to a 16-mm-thick plywood backing, so that the end grain of each block is visible. Adjacent blocks are separated by a 1-mm gap. Surface 2S was made by increasing the maximum block height from 3 cm to 15 cm and defining the height of each block by the quadratic residue sequence with a period of seven. This surface was prototyped using high density polystyrene. Surface 2A was created by raising surface 2 over a 7-cm-deep, glass-fibre filled, cavity. Some of the blocks were removed and the exposed plywood cut away creating holes into the cavity to form a Helmholtz resonator type absorber.

Surface 3 is a corrugated-plywood product. The plywood is 3-mm thick, its corrugations have a 10-mm amplitude and a 40-mm period. The corrugated-plywood sheet is suspended over a 50-mm cavity, surrounded by a wooden frame. Surface 3S was created by cutting the corrugated plywood into 45-cm-square sections, curving them slightly, and inserting them into 15-cm-tall cells. Various configurations were created by varying the height and inverting the curvature of the corrugated plywood sections in the cells. Surface 3A was created by filling the cavity with fibreglass and cutting 3 x 20 mm^2 holes in the surface of the corrugated plywood to create a Helmholtz resonator type absorber. Tests were made with a variety of hole concentrations.

3. MEASUREMENTS

Three methods were considered for measuring the scattering coefficient. Two of the methods use a free-field environment [1, 2] and the third method uses a diffuse field [2, 3]. The measurement method that involves the diffuse field (ISO 17497-1) was used because the available anechoic chamber is not large enough to make measurements in the far field at full scale. In place of a reverberation chamber, a fully enclosed, concrete-walled squash court was used to create an approximately diffuse-field environment. ISO 17497-1 includes, as part of the scattering coefficient calculation, calculation of the random incidence absorption coefficient.

3.1. Measurement Facility and Apparatus

For these tests, a standard reverberation room was not available. A squash court was used as a substitute. A turntable, 3.5 m in diameter, was built to rotate at 1 rpm. All of the samples tested were 8 ft x 8 ft (2.44 m x 2.44 m) in dimensions. Test samples were recessed into the turntable to reduce scattering by the edges. Impulse-response measurements were made using an MLS signal.

4. RESULTS

It is of interest to start by considering the accuracy of the measurements. Then the scattering- and absorption-coefficient results are presented and discussed.

4.1. Measurement Accuracy

Due to time and budget constraints, the measurements were subject to non-negligible uncertainties. The uncertainties come primarily from the low quality of the diffuse sound field, and the lack of control over the ventilation system in the squash court.

The diffuseness of the sound field was limited because the wooden floors and ceiling provide low-frequency absorption, and, as the walls were brick, an uneven absorption distribution. Furthermore, the room contained no diffusers, and its width and height were very similar, resulting in high modal densities and an uneven modal distribution.

The lack of control over the ventilation system causes uncertainty as sudden changes in temperature and humidity during the measurement are possible; this method is highly sensitive to both of these factors, especially at high frequencies. Furthermore, any airflow in the room will alter the paths of the sound waves causing the later part of successive impulse responses to be incoherent. The reverberation time calculated from the average of these impulse responses would then be reduced [4].

4.2. Scattering

A selection of scattering measurement results are shown in Figure 1. The third-octave data have been averaged into octave-band data to smooth the plots. Results are shown from 100 Hz to 4 kHz as required by ISO 17497-1.

The results show that the original surfaces do not scatter significantly, except for surface 2 at high frequencies. Surface 2S showed significant scattering above 500 Hz and high scattering above 1 kHz. Surface 3S showed scattering above 250 Hz and high scattering above 500 Hz.

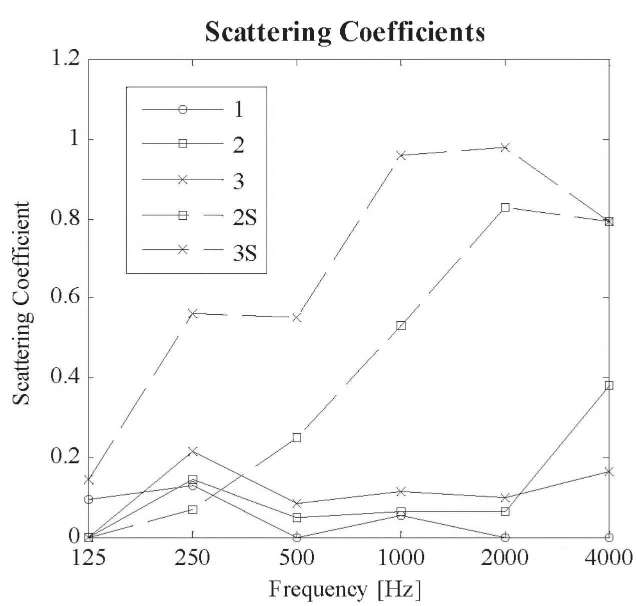

Fig. 1. Scattering results of select surfaces.

4.3. Absorption

A selection of absorption results are shown in Figure 2. As is expected for a flat, hard panel, Surface 1 has very low sound absorption at all frequencies. The absorption coefficient of Surface 2 is very low at low frequencies and slowly increases to nearly 0.4 at 4 kHz, possibly due to ¼ wave resonance in the gaps between the blocks. Surface 3 has a peak in absorption coefficient of nearly 0.4 in the 250-Hz octave band, which can be attributed to membrane absorption. Surfaces 2S and 3S both proved capable of being excellent low and mid frequency absorbers. This is typical of most Helmholtz resonator type absorbers.

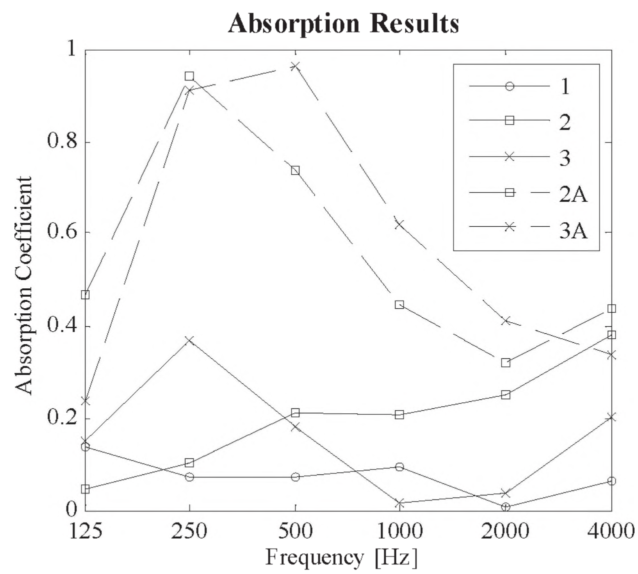

Fig. 2. Absorption results of select surfaces.

5. CONCLUSION

A method for measuring the random-incidence scattering and absorption coefficients has been implemented on a limited budget and without the use of specialized facilities. Test results from these methods, while not highly accurate, were sufficient to evaluate the general behaviour of the surfaces under study. The test method proved to be a useful tool for the development of absorptive and scattering surfaces for acoustic treatment.

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