REVERBERATION CHAMBER MEASUREMENT OF THEATRE CHAIR ABSORPTION

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1. Introduction

In most auditoria, theatre chairs and their occupants are the major source of sound-absorbing material. Knowledge of their sound-absorbing properties is critical to the acoustical design of an auditorium. Although the effects of the chairs and their occupants were first predicted in terms of the total absorption per chair, Beranek has suggested that it is better to describe the effects in terms of the absorption coefficients of the audience seating areas.

The results of reverberation chamber tests on small samples are used to estimate the sound absorbing-properties of materials in rooms. Such tests have been found to overestimate the effects of standard porous absorbing materials due to both edge absorption and diffraction effects. For these simple materials, the measured absorption coefficients have been found to relate approximately linearly to the ratio of perimeter/area, P/A, of the samples, as indicated by equation (1).

$$\alpha = \beta \bullet P/A + \alpha_{\infty} \tag{1}$$

where:

α = sound absorption coefficient of a finite sample
β = regression constant
P/A = perimeter/area of the sample, m^{-1}
α_{∞} = absorption coefficient of an infinite sample

The intent of this work was to verify that more accurate predictions of chair absorption in auditoria could be made by measuring absorption coefficients as a function of P/A in a reverberation chamber and then extrapolating to larger sample sizes using equation (1). In addition, other more approximate approaches are also compared.

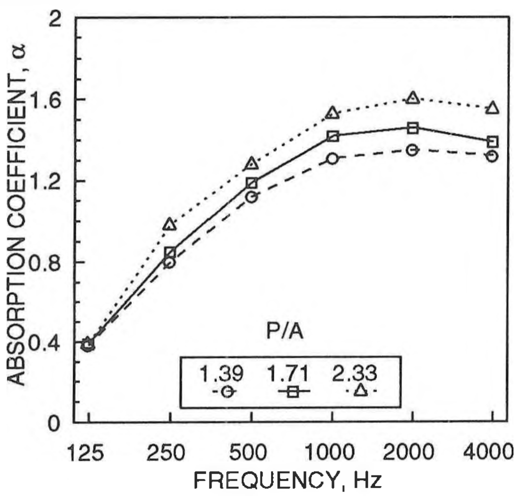

Figure 1. Measured sound absorption coefficients of unoccupied type E chairs for three different P/A values. Chair edges exposed.

2. Reverberation Chamber Measurements

The absorption coefficients of various groups of up to 18 upholstered theatre chairs were measured in a large reverberation chamber. Figure 1 gives examples of measured absorption coefficients versus frequency for three different P/A values. Smaller samples with higher P/A values have higher absorption coefficients, and the effect is strongest at higher frequencies.

In Figure 2, the measured absorption coefficients are plotted versus sample P/A value. The slope β of the regression lines tends to increase with frequency. By extrapolating to a P/A value of 0, the infinite area absorption coefficients α_{∞} are obtained. These results clearly demonstrate that the absorption coefficients of samples of upholstered theatre chairs vary considerably with sample size. Thus, measurements of a small sample (e.g. two rows of four chairs, P/A = 2.0) would not accurately predict the expected effect of the larger blocks of chairs found in most auditoria.

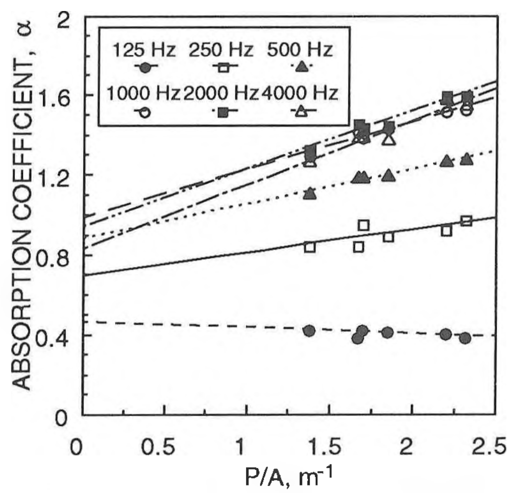

Figure 2. Measured absorption coefficients versus sample P/A for unoccupied type E chairs. Chair edges exposed.

3. Validation in Auditoria

The results of the previous section suggest that one could best predict the absorption of large blocks of chairs from extrapolations from measurements of samples of varied P/A. This concept was tested in halls that were undergoing renovations that included removing the chairs. The absorbing properties of four different sets of chairs were tested both in the reverberation chamber and in the auditorium. The effect of each type of chairs in each auditorium was predicted from the reverberation chamber measurements using data similar to that shown in Figure 2 and regression equations of the form of equation (1). These predictions were then compared with the absorption coefficients of the chairs obtained from reverberation time measurements in the auditorium with and without the chairs in place.

Figure 3 illustrates the comparison of measured and predicted chair absorption coefficients for one of the sets of chairs. The other comparisons also gave good agreement between measured and predicted values. In some cases, differences were a little larger at some frequencies due to uncertainties in the effects of construction materials that were present during measurements and unknown changes in the auditoria. The results confirmed that extrapolations

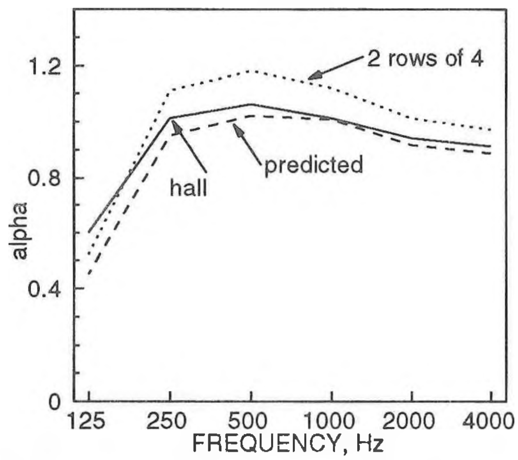

Figure 3. Comparison of sound absorption coefficients for type A chairs, measured in the hall and estimated from reverberation chamber tests for two rows of four chairs (P/A = 2.0) and for a hall sized sample (P/A = 0.8).

to smaller P/A values from reverberation chamber measurements led to better predictions than using the results of smaller samples directly.

4. Other Approaches

While the use of extrapolations from smaller samples is thought to be the most accurate method for predicting the absorption of theatre chairs in auditoria, other more approximate methods were also considered.

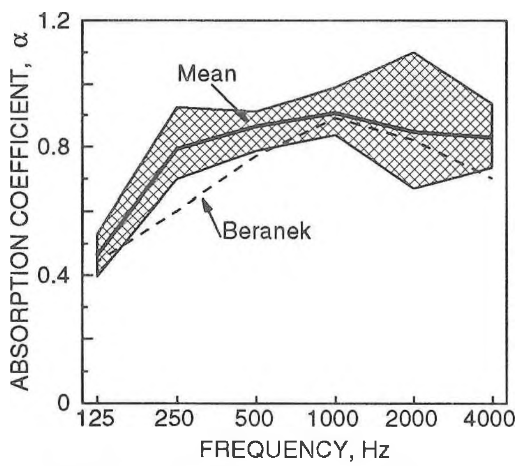

Figure 4. Comparison of the mean and range of values of the estimated infinite area sound absorption coefficients with Beranek's average upholstered chair absorption coefficients.

The simplest approach is to use one average absorption coefficient characteristic to represent all types of upholstered theatre chairs, as suggested by Beranek. The mean and range of absorption coefficients for infinite samples are compared to Beranek's data in Figure 4. The means of the five quite different types of chairs are similar to Beranek's values, but particular types of chairs can be considerably different. Thus, the use of a single set of average absorption coefficient values is a valid but approximate approach.

It has been suggested that in reverberation chamber absorption tests, the absorptive edges of chairs should be screened. This would be expected to reduce the edge absorption of the sample but not the diffraction effects. Figure 5 compares measured absorption coefficients versus P/A with and without the edges screened. The screening of the edges is seen to reduce the variation with P/A but does not eliminate it. The addition of the screens produces anomalous effects at low frequencies that lead to negative absorption coefficients.

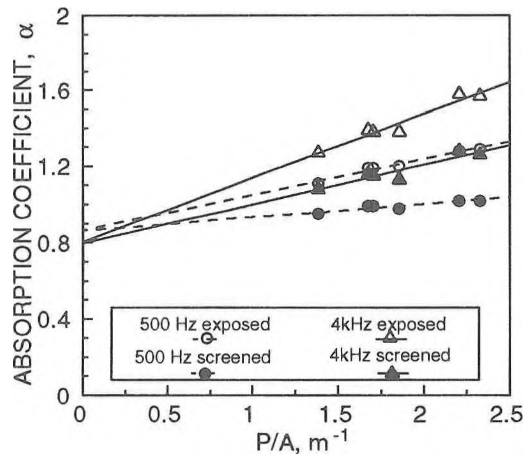

Figure 5. Comparison of measured sound absorption coefficients versus sample P/A for chairs with edges screened and exposed at 500 and 4000 Hz.

As a compromise approach, one could use average β values to extrapolate from a single measurement sample to the larger areas of chairs found in auditoria. The average β values could be based on measurements of chair samples with the edges either exposed or screened. The β values for the edges screened case are smaller and hence should lead to smaller prediction errors. Figure 6 compares β values versus frequency for occupied and unoccupied chairs with their edges screened. Also shown is Hegvold's data for simple model listeners and an average design curve.

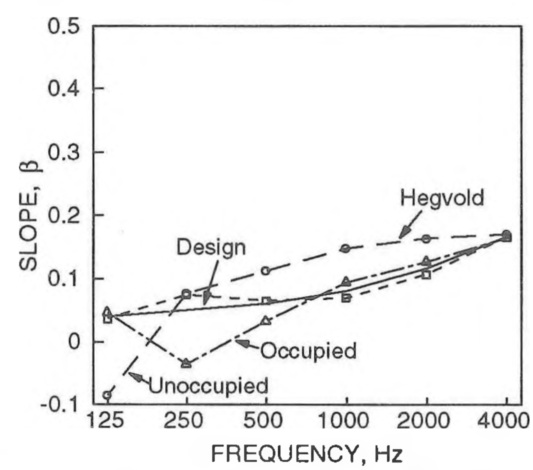

Figure 6. Calculated β values for upholstered theatre chairs with edges screened for occupied and unoccupied type E chairs. Also shown is a design curve approximating the calculated values and Hegvold's simple model audience results.

5. Conclusions

The results confirm that one can most accurately predict the absorption of upholstered theatre chairs in auditoria by extrapolating from measurements of samples of varied P/A. Other more approximate methods can be used to reduce the number of reverberation chamber sound absorption tests that are required, but with increased prediction errors.