SCALE-MODEL INVESTIGATION OF THE EFFECT AND OPTIMAL DESIGN OF SOUND ABSORBERS IN AN OPEN-PLAN OFFICE

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1 Introduction

Porous sound-absorbing materials are frequently used in the ceiling areas of open-plan offices to reduce high reverberation times and improve speech-communication and speech-privacy conditions. The UBC Vancouver AERL building fourth-floor open-plan student area has a distinctive arrangement of porous sound absorbers. Tectum boards [www.tectum.com] are suspended from the ceiling in rows of 4 boards across the width of the space at two-metre intervals and also mounted flat against the ceiling at eight-metre intervals. It is not known how this configuration was chosen. Therefore, it was of interest to determine whether this existing configuration of the porous absorbers is the optimum one for acoustical performance. While a previous research study of Orlowski [1] investigated the effect of porous-absorber arrangements on acoustical performance experimentally in a 1:16-scale model from 1 to 64 kHz, it only investigated the effect of suspended baffles in a reverberation chamber (ie., in a diffuse sound field). The present work intends to investigate 15 different configurations of ceiling-mounted, suspended and sidewall baffles and their various combinations, including the current configuration, and find the optimum arrangement of the porous absorbers.

2 Methodology

2.1 Model construction

A 1:8-scale model of the selected zone of the AERL student space was used to investigate the performance of each proposed absorber configuration. The model was constructed as a rectangular box from sheets of 9-mm-thick plywood for simplicity of construction. To conserve materials, a concrete floor and concrete wall were considered as two of the surfaces of the space. 18 workstations of the selected zone were built on the roof of the model. The partitions of the workstations were made of cardboard covered with a single thickness of 3-mm-thick felt materials to add absorption similar to the existing AERL space. The top surface of the model is hinged to allow for convenience in placing the porous absorbers inside. The dimensions of the rectangular box and workstations are 2.45 × 1.4 × 0.46 m^3 and 0.25 × 0.25 × 0.25 m^3, respectively. Figure 1 shows a photograph of the model. Figure 2 shows its ceiling with the 18 workstations, and the source and absorbers on the floor.

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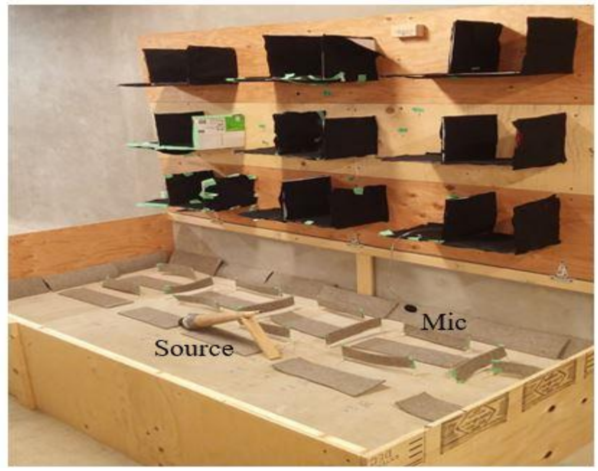

Figure 1. Photograph of the model (open roof) with work -stations showing source, receiver and sound absorbers.

2.2. Sound-absorbing material

The AERL student space has two sizes of tectum boards; size A (110 × 39 × 1.96 in^3) was used as the ceiling-mounted absorber and size B (78 × 21 × 1.96 in^3) as the suspended absorber. Hence, the baffles used in the test configurations were designed exactly as 1:8-scale versions of those boards using the 6-mm-thick felt material. Moreover, Size B absorbers were also used in a sidewall-mounted configuration with baffles on the floor inclined against the walls for convenience of arrangement.

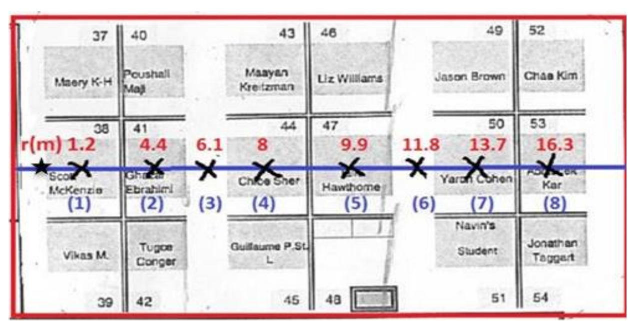

Figure 2. Photo of DL2 (★) source and (X) receiver positions in AERL floor plan.

2.3 Experimental setup and testing

The upper range of the available test equipment was limited to 20 kHz but, at 1:8 scale, it covers most of the dominant bands associated with human speech, which is the main source of sound in the AERL student space. Hence, the frequencies tested were from 1 to 16 kHz in octave bands corresponding to a range from 125 Hz to 2 kHz at full scale. To reduce the experiment set-up time, the floor of the model was considered as the roof of the student space. This allowed the sound-absorbing materials in the model to be placed on the floor as opposed to being hung from the roof of the model. The source sat on the floor and receiver microphones were inserted into the space through holes in the top of the model. The reverberation time of each configuration was calculated by averaging the values measured at six source-receiver positions near the centre of the model from 125 to 2000 Hz full scale, corresponding to the test 1:8-scale frequency bands from 1 to16 kHz. In this experiment Sound Level Decrease per Doubling of Distance (DL2) tests were done along a line along the length of the room in the centre of the model (to a maximum full-scale distance of 16.7 m – see Figure 2). Both the source and receiver were located at 15 cm from the ceiling of the model, corresponding to the approximately 1.2-m height of the listener's position above the floor in the workstations in a typical open-plan office area.

3 Results

Both the reverberation time, T_20, and DL2 of the 15 configurations of ceiling-mounted, suspended, current and sidewall configurations were compared with the values in the model with no absorber, and with the whole of the ceiling covered with absorbers.

3.1 Reverberation time

Results shown in Figure 3 show that the whole-ceiling configuration is the optimum configuration, while the combination of three absorbers is the second best and the no-absorber configuration is worst of all, as expected.

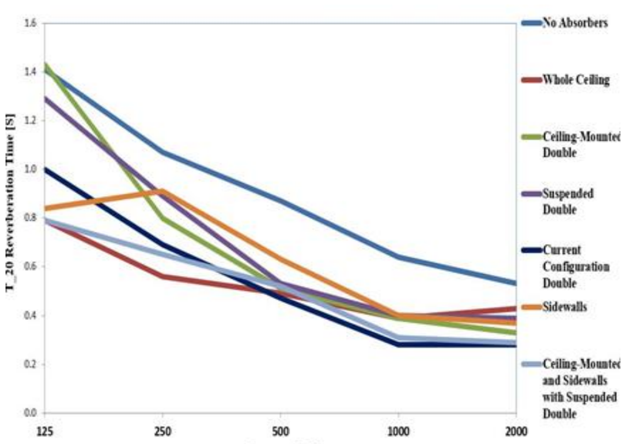

Figure 3. Overall comparison of reverberation time T_20 [s] for all absorber configurations.

3.2 Sound level decrease per distance doubling of (DL2)

As shown in Figure 4, the whole-ceiling configuration is the optimum of all absorber configurations, the current configuration doubled is the second best and the configuration with no absorbers is expectedly the worst of all configurations. It is very interesting to observe that DL2 for the current configuration double is better than the combination of three absorbers, which is the opposite trend of the T_20 results above.

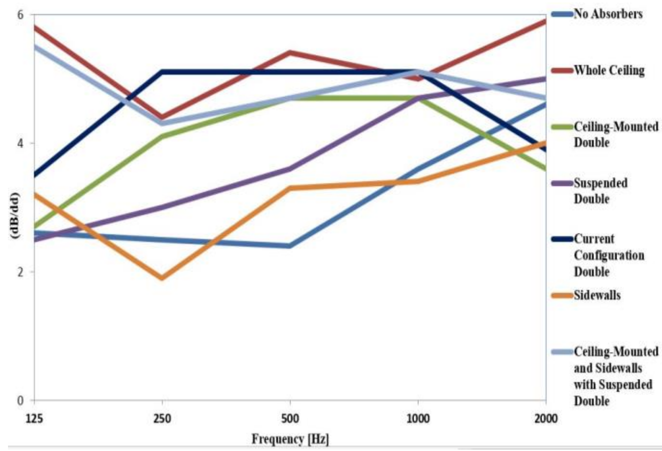

Figure 4. Overall comparison of sound level decrease per doubling of distance (DL2 in dB/dd) for all absorber configurations.

4 Conclusion

On the basis of both reverberation-time and sound level decrease per doubling of distance measurements, both the whole-ceiling configuration and the combination of all three types of absorbers perform much better than the current configuration of the AERL space. Doubling the absorber area in the current configuration seems to give a comparatively better DL2, but higher reverberation time, in contrast with the combination of all three absorbers. For both aspects, the double ceiling-mounted configuration performs the best among these three absorber types. Future work could investigate absorbers distributed over the sidewalls and determine the optimum absorber configuration for speech privacy between the workstations of the AERL open-plan area.

References

[1] Hodgson, M. R. and R. J. Orlowski. "Acoustic scale modelling of factories, Part I: principles, instrumentation and techniques." *Journal of Sound and Vibration*, 113(1): 29-46, 1987.

[2] Orlowski, R. J. "The arrangement of sound absorbers for noise reduction--results of model experiments at 1: 16 scale." *Noise Control Engineering Journal*, 22 (2): 54, 1984.