Evaluation of an Indoor Open Space Acoustical Quality – A Case Study

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1 Introduction

The occupant's comfort in an indoor space depends on several factors including temperature, humidity, air quality, lighting, views, and acoustics. Of these factors, acoustical comfort is a key contributor to employees' performance and well-being in the workspace. Acoustical comfort is achieved when the workplace provides appropriate acoustical support for interaction, confidentiality and concentrative work [1].

As a result, the testing and evaluation of HVAC attributable background noise levels have been recognized by various organizations [2-5]. In addition, speech intelligibility is also an important factor for office environments [6, 7].

In this paper, an acoustic model was developed for an existing space. The acoustic model was first calibrated and then used to predict the benefits of applying suggested acoustical improvements in the space.

2 Acoustic Testing

To verify the modelling results, acoustic testing was conducted in a warehouse space, as shown in Figure 1.

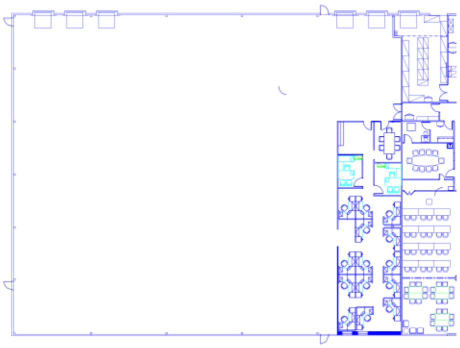

Figure 1: The Floor Plan of the Warehouse Space

A series of acoustic tests were conducted in the space. First, the HVAC attributable background noise was measured in the space. The average background noise levels without and with the unit heater operations were 44 dBA and 58 dBA, respectively.

Second, the sound pressure levels in the space were measured in the space. The measurements were used to calibrate the acoustic model. Third, impulse measurements were conducted in the space. From the impulse measurements, parameters like reverberation time and STI can be determined. The measured average reverberation time and STI were 2 s and 0.42 - 0.56, respectively.

The above measurements show that both the HVAC related background noise levels and reverberation times were significantly high for the use purposes of the space.

3 Acoustic Modelling of Existing Conditions

In this study, an acoustic model using CadnaR was built for part of the space within the warehouse, as shown in Figure 2.

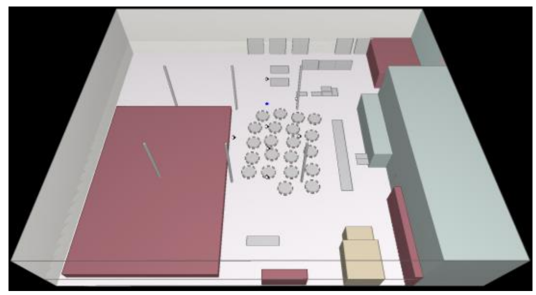

Figure 2: 3D View of the Warehouse Space

In the model, a point source representing the speaker was placed to the west side of the space. This was to simulate the sound pressure level testing. The receivers represent the microphone locations. The measured and predicted sound pressure levels are summarized in Table 1 below.

Table 1: Comparison of Measured and Predicted Levels

Testing Location	Measured Level, dBA	Predicted Level, dBA	Difference, dB
SPL-001	60.6	60.7	0.1
SPL-002	57.4	57.4	0.0
SPL-003	55.4	55.6	0.2
SPL-004	57.5	57.1	-0.4
SPL-005	60.1	59.6	-0.5
SPL-006	64.7	64.0	-0.7
SPL-007	67.9	67.2	-0.7
SPL-008	60.3	59.5	-0.8
SPL-009	57.1	57.6	0.5

Figure 3 shows the comparison between the measured and predicted reverberation time in the space. In general, both the measured and predicted results are in good agreement.

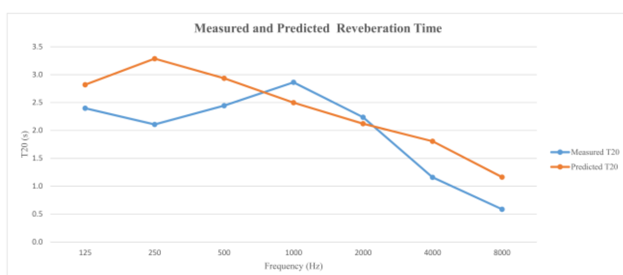

Figure 3: Comparison of Reverberation Time (T20)

4 Acoustical Improvements

A proposed treatment of absorptive materials placed around the space was incorporated into the acoustic model.

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Specifically, the absorptive materials considered included a carpet-type floor, 3.5 m high absorptive curtains around the space and absorptive baffles hanging at the top of the space. Figure 4 shows the 3D view of the proposed modifications to the space.

The model was used to assess the effectiveness of the proposed changes and showed that the predicted sound pressure level for receiver chains was reduced to 48 dBA, which meets the ISO 3382-3:2012 suggested value.

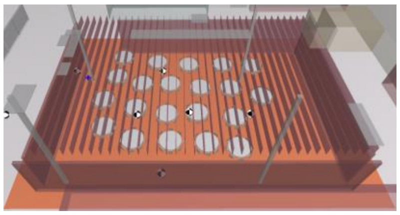

Figure 4: Warehouse Space with Proposed Treatments

The model also showed the average reverberation times were reduced to values of around 0.8 s, which are in line with the typical office uses. Most importantly, the predicted speech intelligibility for all receiver chains was increased to 0.8 - 1.0, which is a significant improvement.

5 Auralization Results

Auralization is a technique for creating audible files from numerical data. The auralization technique allows one to listen to the audio file created by the model, which would give an impression as to what it would sound like in the space. By playing and comparing the audio mixtures, it clearly shows that the treated space now has a much better speech intelligibility.

6 Conclusions and Discussions

In this study, selected acoustical parameters including sound pressure level, reverberation time, and speech transmission index were evaluated to understand the sound quality of an indoor space. The measured and predicted results showed that the untreated space had significant reflections, and rendered poor speech intelligibility.

To test the viability of acoustical improvements in the space, the calibrated acoustic model was revised and incorporated absorptive materials. The modelling results showed that the proposed acoustical treatments may be used in improving the acoustic quality of other spaces.

7 References

[1] US General Service Administration Public Building Service, Sound Matters: How to Achieve Acoustic Comfort in the Contemporary Office, December 2011.

[2] ASHRAE Handbook – HVAC Applications, Chapter 48. Noise and Vibration Control, 2011.

[3] BOMA Best Building Environmental Standards, Office Questionnaire, July 2018.

[4] International WELL Building Institute, The WELL Performance Verification Guidebook, 2018.

[5] US General Service Administration, Facilities Standards for the Public Buildings Service, March 2014.

[6] ISO 3382-3:2012, Acoustics - Measurement of room acoustic parameters -- Part 3: Open plan offices.

[7] IEC 60268-16:2011, Sound system equipment - Part 16: Objective rating of speech intelligibility by speech transmission index.