ACOUSTIC PERFORMANCE OF STUDY ROOMS - A CASE STUDY

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1 Introduction

A new building at an academic institution was built for the purpose of providing students with needed space for individual and group study. The building had quickly turned into a preferred space and is often heavily occupied. The study rooms are equipped with televisions and the walls are coated with a whiteboard layer, so that group discussion can be undertaken in addition to silent study. There have been numerous complaints from users of the study rooms about disturbances from the TVs and those speaking in adjacent rooms. Students noticed that conversations were easily audible, even when speaking at normal levels.

Two pairs of unoccupied study rooms were used to conduct tests and evaluate their acoustical performance. The Apparent Sound Transmission Class (ASTC) and Articulation Index (AI) ratings were calculated to determine if the study rooms are acceptable for students requiring a quiet workspace, while having their conversations kept private. The results of the study are presented in this paper.

2 Method

2.1 Inspection

Upon examination of the rooms, it was clear that the major flanking sound paths were gaps along the edges in the dividing walls, cut-outs behind the wall mounts for the TV's cables, and possibly, exposed return air grilles. The return air grilles led to an open plenum space, which was shared with other study areas and in close proximity to adjacent study rooms' exposed grilles. A plan view of all four rooms is shown in Figure 1. Room "A and B" were on a different floor than "C and B".

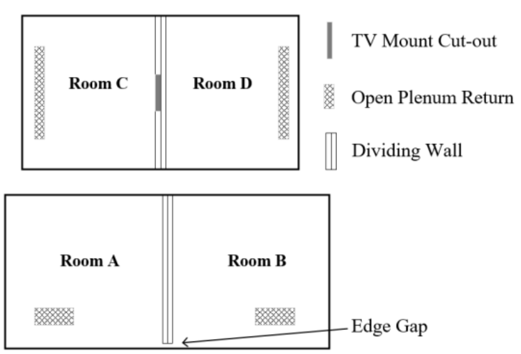

Figure 1: Plan view of tested rooms

The cut-out behind wall mounts were also placed on a dividing wall depending on the room, shown in Figure 2.

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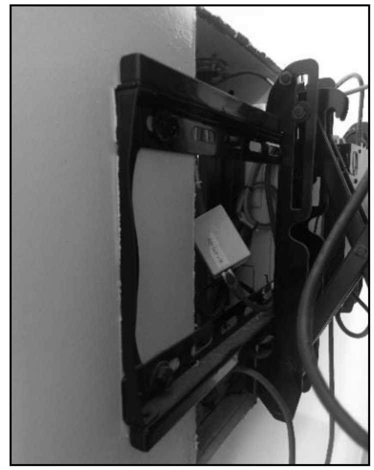

Figure 2: Wall extraction behind TV mount

2.2 Testing methodology

Four rooms in total were evaluated for the purpose of this study. The first pair, Room A and B, shared a dividing wall with an edge gap. The next pair, Room C and D, was on a different floor and shared a dividing wall with the TV mount shown in Figure 2, without an edge gap. This allowed for an individual analysis on both types of major flanking paths between the rooms. Testing to assess the open plenum return was done between Room A and B alone.

A pink noise generator was connected to a Brüel & Kjær omnidirectional speaker to produce sound in the room, and a Larson Davis integrating sound level meter was used to record 2-3 measurements in each room.

To calculate the reverberation time in each room, a full spectrum, logarithmic sine sweep was used to generate an impulse response within Odeon.

3 Results

3.1 Room conditions

Background noise levels were measured in each room and NC ratings were initially calculated to evaluate their conditions. These are presented in Table 1, along with the average reverberation times (T_{30}) across frequencies of 500 – 2000Hz, the most important range for speech [1]. Although Chapter 48, "Noise and Vibration Control" of the ASHRAE Handbook does not have any criteria specifically pertaining to study rooms, their indoor sound criteria for classrooms can be related as similar activities are undertaken in study rooms. Their design guidelines recommend a maximum of NC-30 for classrooms [2], and the study rooms had a suitable, low NC rating of 22-24. The T_{30} times ranged from 0.4s – 0.7s; a reverberation time of 0.5s – 0.7s is desirable for speech and is not expected to cause any issues [3]. Though Room B has the sole T_{30} out of this range, it was deemed acceptable for this study as it was marginally below 0.5s, and still under 1s. Speech intelligibility within a single room was therefore not a concern.

Table 1: NC and reverberation time of room A to D

Room	NC	T_{30} (s)
A	24	0.6
B	23	0.4
C	22	0.7
D	23	0.6

3.2 Articulation index

Although the primary purpose of the study rooms is not to host confidential conversations, the AI can be a useful metric when assessing scenarios where speech intrusion is unwanted. The AI for each pair of rooms was calculated, including the speaker and receiver room being exchanged at the end of each test. The values were computed by subtracting the averages of the noise and background levels from the signal levels, equalling the signal to noise ratio. One-third octave band weighting factors were then multiplied to the signal to noise ratios. Summing the weighted signal to noise ratios totalled the articulation index, presented in Table 2.

The ASTC was calculated in a simplified manner, incorporating Equation (1) below.

$$TL = NR + 10\log_{10}(A/S\overline{\alpha}) \tag{1}$$

The transmission loss across 125 – 4000 Hz was plotted against standard STC contours. Since flanking paths were known to be accounted for, this is effectively the ASTC. Values are shown in Table 2.

Table 2: Computed AI and ASTC results

Path	AI	ASTC
Room A to B	0.32	30
Room A to B*	0.32	30
Room B to A	0.17	30
Room C to D	0.35	27
Room D to C	0.46	35

*Open plenum return grille covered

4 Discussion

All of the results show that there is no privacy between the rooms [3], except for when Room A was the receiver and Room B was the source, there was marginal privacy. This is likely due to the fact that Room A had higher background levels, which resulted in negative signal to noise ratios (taken as zero when calculating partial AI). The test for Room A to B was repeated with the open plenum return grille covered, which showed no change in AI or ASTC. This suggests that it did not act as a major flanking path between rooms. However, the TL at 8000 Hz reduced by 5 dB with the grille covered. This could be as a result of the noise not entering the plenum area through the return as easily, and now having an additional reflection point within the room. The improvement in both AI and ASTC when using Room D as the source is due to the TV mount being on the other side of the wall, reducing the flanking path's effect.

Based on the calculated values, the acoustical performance of the study rooms suggests that they are not adequate for students requiring a private study space. Since they are equipped with TVs and can host group meetings, the speaker can be expected to have a raised voice. From this, the "none" degree of privacy suggests that a typical subjective response includes having a sense of community with numerous privacy complaints expected [4]. In consideration of students also wanting to use these rooms for quiet study, it is important to design and build for proper noise isolation. An approximate relationship by Weissenburger suggests that a minimum STC 52 partition should be used to have "normal" privacy, and speech not be distracting [4]. The American National Standards Institute (ANSI) similarly recommends a minimum STC of 50 when a wall assembly separates an "enclosed core learning space" from another such space [5]. These rooms are often booked for tutoring sessions, so they can be treated in a similar manner to spaces like classrooms.

5 Conclusion

In this scenario, it would be suggested to entirely fill the gap with a mass loaded filler designed for partitions, or similar. To conceal the television's cables, an enclosure that fits on the back of the TV, but not inside the wall is encouraged.

Glass partitions which separated part of the room to the open plan areas were dual pane, which suggests a focus on acoustic design. Therefore, the flanking paths noticed in these rooms were likely not part of the intended design. When following a rating such as the mentioned STC 50-52, testing is encouraged to make sure an assembly performs well. In the planning stage, it is recommended to follow some sort of acoustical guideline for educational institutes specifically, such as ANSI S12.60-2002, "Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools".

References

[1] J. Bradley, "Acoustical Design of Rooms for Speech," National Research Canada, Construction Technology Update No. 51, 2002.

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