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Room Acoustics

Homework 1
Classroom without Sound Reinforcement

Group 1

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Task

In this assignment, we will focus on the requirements that a 40-seat classroom (10 m x 6 m x 3m) without sound reinforcement should satisfy.

Expected sources of sound

A classroom needs to be planned for a "communication intensive use distributed to several simultaneous speakers" (DIN Deutsches Institut für Normung e. V, n.d., 11). Regarding expected sources, human speech is of course a source of sound. It can be expected through the teacher, who is presenting his course, and the students, who can ask questions to the teacher or chat with their classmates. Other sources of sound might come from outside (course in neighboring classes, human activities outside, etc) but also from inside noises such as ventilation or light fixtures.

With an normal speaking voice, the speaker emits an A-rated sound pressure level of $L_{WA} = 68\,dB$ (DIN Deutsches Institut für Normung e. V, n.d., 27) between $125\,Hz$ and $4\,kHz$ (Masovic, 2021, 15). The coverage Angle is between $300°$ at $125\,Hz$ and $90°$ at $4\,kHz$ (Masovic, 2021, 16).

Relevant objective/subjective criteria of the listeners

Once the expected sources of sound have been identified, we are now looking for criteria, both objectives and subjectives, for the listeners that have to be fulfilled in a classroom.

These requirements are focused around two cornerstones: the appropriate loudness and the intelligibility of speech.

Indeed, the speech has to be clearly heard and understood by everyone meaning a minimum dynamic range has to be verified. On the other hand, the loudness is an essential criteria for the listeners because every student should be able to hear what is being said from everywhere in the classroom and the speech has to cover indoor and outdoor noise .

Requirements according to ANSI Standard S12.60 for Classroom Acoustics

The main purpose of this standard is to ensure a good speech intelligibility. Therefore, we are interested in the reverberation time and the background noise level, which both play an important role in the speech intelligibility.

The aim of ANSI (American National Standards Institute) Standard S12.60 for Classroom Acoustics is to set maximum permissible levels for these quantities such that: "Under the new standard, the maximum reverberation time in an unoccupied, furnished classroom with a volume under 10,000 cubic feet is 0.6 seconds, and 0.7 seconds for a classroom between 10,000 and 20,000 cubic feet. The maximum level of background noise allowed in the same classrooms is 35 decibels (dBA)". (Quiet in the Classroom ANSI Standard S12.60 and Classroom Acoustics, Armstrong Ceiling Solutions, 2002, page 4)

The volume of the classroom is: V = 10 (m) x 6 (m) x 3 (m) = 180 m^3 ~ 6,500 ft^3 < 10,000 ft^3

Thus, the requirements for the considered classroom are a reverberation time under 0.6 seconds and a maximum level of background noise of 35 decibels to ensure a Signal-to-Noise Ratio (SNR) greater than +15 decibels (recommended by the American Speech-Language-Hearing Association).

Requirements according to DIN 18041 for Classroom Acoustics

The DIN 18041 is a German standard that gives specifications and instructions for the room acoustic design of small and medium-sized rooms. Referring to the above mentioned ANSI Standard, both Standards share the same objective: speech intelligibility.

Two applications are distinguished in this Standard: speech intelligibility over a medium and long distance (Rooms of group A) and speech intelligibility over a short distance (Rooms of group B). A classroom belongs to group A for which the direct sound shall be as great as possible and the first reflections shall arrive no more than 50 ms after the direct sound arrived at the receiver.

Different categories are defined in DIN 18041. Category A3 (lecture/communication and language/presentation inclusive) and Category A4 (lecture/communication inclusive) are the ones in which classrooms are a representative.

The reverberation time is one of the indicators that need to be analyzed by a room acoustical simulation during the planning phase and eventually a room acoustic experiment (applying the German Standard DIN EN ISO 3382 part 1 and 2) when the room is ready to be used. For the Categories A3 and A4, the following equations for the required reverberation time are regulated:

- Category A3:

$$T_{req,A3} = \left(0{,}32\lg\left(\frac{V}{m^3}\right) - 0{,}17\right) \text{ s} \qquad\qquad \text{for } 30 \text{ m}^3 \leq V < 5\,000 \text{ m}^3$$

For a classroom of Category A3 with a volume of 180 m³ the required reverberation time $T_{req,A3}$ equals 0,55s.

- Category A4:

$$T_{req,A4} = \left(0{,}26\lg\left(\frac{V}{m^3}\right) - 0{,}14\right) \text{ s} \qquad\qquad \text{for } 30 \text{ m}^3 \leq V < 500 \text{ m}^3$$

For a classroom of Category A4 with a volume of 180 m³ the required reverberation time $T_{req,A4}$ equals 0,45s.
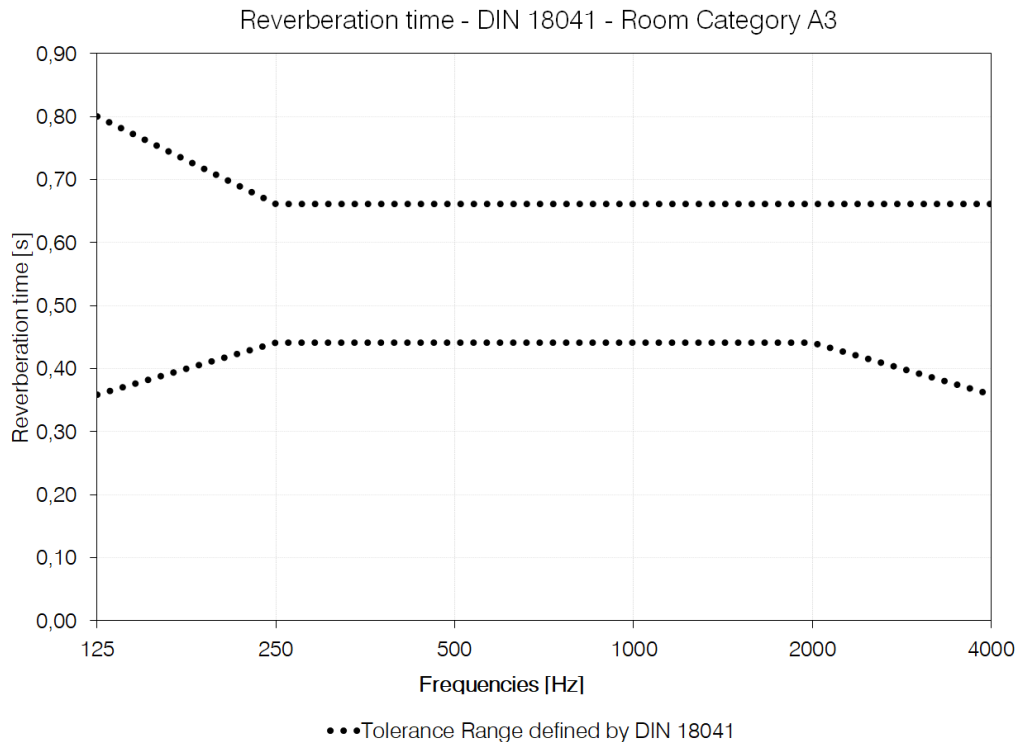
Figure 1: Reverberation time boundaries regarding to DIN 18041 for Rooms of Category A3 and a volume of 180m³

The requirements to the reverberation time is satisfied when the reverberation times in the octaves between 125 Hz and 4000 Hz are within the tolerance range defined by DIN 18041. An example for a tolerance range of a classroom that is categorized as Category A3 and has the above calculated volume of 180m³ is given in Figure 1.

The maximum level of background noise shall not be greater than 35 dB for Categories A2 to A4. Furthermore, a good audibility is achieved when the SNR is a minimum of 10 dB. The DIN 18041 recommends to keep the created noise of the audience at bay by installing a ground floor with a lower A-weighted structural-borne noise.

Discussion

First, it must be admitted that the German standard is much better documented than the American one. On one hand we are given thresholds not to be exceeded according to the size of the room only. On the other hand, there is a kind of optimization of these thresholds according to the size but also to their function.

With this in mind, we can finally notice that the conditions defined by these two standards are quite similar. Both give conditions on the reverberation time and on the background noise level with very similar values.