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LOW FREQUENCY ABSORPTION IN A REVERBERATION CHAMBER

L Feng

The Marcus Wallenberg Laboratory for Sound and Vibration Research, Royal Institute of Technology, Stockholm, S-100 44, Sweden

The MWL at the Royal Institute of Technology has recently built a new laboratory, which includes an anechoic room, a semi-anechoic room, a shock and vibration room, and a reverberation room. In the qualification measurement, it is found that the reverberation time of the reverberation room below 800 Hz is much shorter than required by the standard ISO 354 [1]. In order to make the room to fulfil the requirement, we have to find the mechanism of the high absorption.

DESCRIPTION OF THE PROBLEM

The room is of the dimension 7.86 x 6.21 x 5.05 meters and with the volume 246 m^3. There are three doors: one to the corridor, one to the anechoic room, and one to the shock and vibration room. The total area of the doors is about 16 m^2. On the floor and the ceiling, there are many "╨" shaped anchor-rails covered with hard plastic covers. Those anchor-rails are reserved for mounting and hanging machines and other structures. There is also a service channel on the floor which is covered with concrete bricks. On the wall to the corridor, there is an observation window with area of about 0.5 m^2. There is also a steel plate (3 mm thick and with the area of about 0.6 m^2) on the same wall. The plate is used to cover cable holes. By knocking the plate one may feel that the back of the plate is a big hole. Over the two doors to the anechoic room and to the shock and vibration room, there are two big Plexiglas screens. All of the factors mentioned above may cause problem of high absorption. Besides, the painting of the surface of the room is also not good enough. For this laboratory, there is even a special problem: the room is constructed by one company, and the doors are manufactured by another one. We have to distinguish responsibilities of the two different companies.

Direct measurements of the absorption coefficients *in situ* are almost impossible. This is because that the room is a reverberation room and the absorption coefficients of the elements are very low. Attempt has been made by using an impedance tube to direct against the wall or door. Intensity measurements have also been tried. Both methods are failed because of the high uncertainty level.

The elements mentioned above can be divided into two groups. The first one consists of the Plexiglas screens, the covers of the anchor-rails, and the covers of the service-channels. They can be removed without big difficulty. Their contributions to the sound absorption are evaluated by measuring the reverberation time of the room when they are in their places and when they are removed.

Another group consists of the window, doors, and the cable-holes cover. They can not be easily removed. One thing in common for them is that they are all with a panel exposed to the sound field and with a cavity behind it. In other words, they are all panel-resonator-like structures. The absorption coefficients of them are approximately in direct proportion to the sound induced vibration of the panel. By measuring sound induced vibration of the panels, and taken into account of their area, their relative importance sound absorption can be estimated.

ELIMINATION METHOD

The reverberation time of the room is measured according to standard ISO 354 before anything is removed from the room. After that, parts of elements are removed and the reverberation time is re-measured again, with the same microphone and the sound source positions. This process is repeated several times until all of interested elements are removed from the room. The results are shown in Fig. 1.

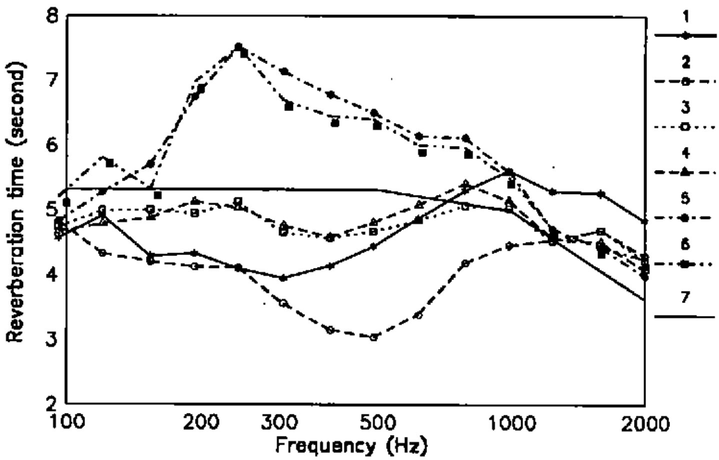

Figure 1 Measured reverberation time of the room

1: previous measurement; 2: results when nothing is removed; 3: covers of the anchor-rails on the floor removed; 4: besides 3, the two Plexiglas panel also removed; 4: besides 4, the covers of the anchor-rails on the ceiling also removed; 6: besides 5, the covers of the service-channels also removed; 7: required by ISO 354.

It is seen from the figure that of those elements, the covers of the anchor-rails are the most important for the absorption at the frequency region 160 - 800 Hz. When they are removed, the room fulfils the ISO requirements from 200 Hz and above. The present covers are also very easy to be damaged, since the reverberation time measured this time is much lower than what measured previously, when the covers were newly mounted.

The influence of the Plexiglas screens can be neglected, since the line 3 and 4 are basically the same. Similarly, line 6 and 7 are also roughly the same, indicating that the covers of the service-channels are not important for the sound absorption.

The dramatic increase of reverberation time when the anchor-rails-covers are removed also indicates that there may exist a resonance mechanism, since the absorption coefficient of the covers calculated from the measurements is greater than 1, sometimes even greater than 1.5, at lots of frequencies. The rails store sound energy when sound source is on, and feed it back when the source is turned off. It can be expected that the reverberation time at frequency region 200 - 800 Hz might be somewhat decreased when the rails are filled with some other materials.

When the anchor-rail-covers are fixed, the problem goes to the three lowest frequency bands: 100, 125, and 160 Hz, where the requirements are still not fulfilled.

RELATIVE IMPORTANCE OF THE PANEL-RESONATOR-LIKE ELEMENTS

In this measurement, we try to find the relative importance of the elements by measuring sound-induced vibration. The sound field is produced by a loudspeaker system and is kept constant for all of measurements. The sound-induced vibration is measured via an accelerometer attached to the element. A reference signal of the sound pressure is measured by a microphone located about two centimetres away from the accelerometer. Transfer functions between the vibrations and the sound pressures are measured and used as the basis of the comparison. The measurements are performed in narrow band by using a frequency analyser. Results are then averaged over third-octave band to reduce the fluctuation. The accelerometer used (B&K type 4396) has a very low acoustic sensitivity (0.002 m/s² at 154 SPL), hence the disturbance from acoustic signal to the measured vibration can be neglected.

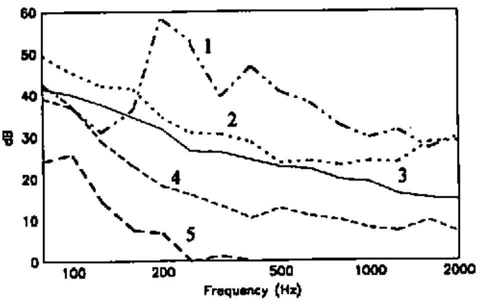

Figure 2. Sound induced vibration
1: cable-hole cover; 2: observation window; 3: doors;
4: service-channel cover; 5: wall.

The sound-induced vibrations, expressed in relative velocity levels, are shown in Fig. 2. The curve for doors is the average of seven measurement points and for the covers of the service-channels is the average of two measurement points. As a comparison, sound-induced vibration of the wall has also been measured.

It is clearly seen from the figure that the cover of the cable holes has the highest vibration under the same sound excitation, especially in the frequency region 200 - 1000 Hz. This is due to the resonance of the panel, which is backed by a hole and is not thick enough to avoid high resonance. In order to reduce the resonant absorption of the panel, the back of the plate should be filled with solid material.

The observation window and the doors are of the same order of the sound induced vibration. Except at 100 Hz, the vibration of the covers of the service-channels is about 10 - 15 dB lower than that of the doors and window.

The influences of the covers of the service-channels have also been investigated in the elimination method (line 6 in Fig. 1), where we see that the covers may have some influence at the 100 and 125 Hz frequency bands, but the influence is not big enough to make the room to fulfil the requirements. From Fig. 2 we see that the sound induced vibrations of the observation window and the doors are bigger than that of the covers of the service-channels. Taking into account of the area of those elements (about 5 square meters for the service-channel-covers, 0.5 square meter for the window, and about 16 square meters for the doors), we may conclude that the modification of the doors is more important and will make the room fulfil the requirements at 100 Hz - 160 Hz frequency bands.

DISCUSSIONS

The covers of the anchor-rails are the most important contributors of the sound absorption in the frequency region 200 Hz - 800 Hz. They should be replaced by new designed ones, preferably some solid fillings, to reduce the resonance. When this is done, the room will hopefully fulfil the requirements from 200 Hz and above.

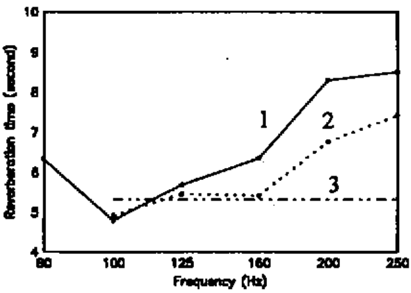

Figure 3 Results when back of the cable-hole-cover is stuffed. 1: after; 2: before; 3: ISO requirement

The Plexiglas screens have basically no influence on the sound absorption. The influences of the covers of the service-channels can also be neglected compared to the sound absorption of other elements.

Figure 3 shows the results when the back of the cable-hole-cover is stuffed with solid material. For the purpose of investigation, the reverberation time of 80 Hz is also shown in the figure, although this room is not qualified for the 80 Hz band. It is seen that from 160 Hz and above the room is now fulfil the requirement. The 125 Hz band fulfils the requirement marginally. For the 100 Hz band, there is basically no change. This result can be expected from the results in Figure 2. For those two lowest frequency bands, one possibility is to modify the doors. From Figure 3 we can see that the reverberation time of 80 Hz band is about 30% higher longer than that of 100 Hz band. This indicates that there might be some resonance at the 100 Hz band. Since the big area of the doors (about 16 square meters), and the low value of the averaged sound absorption coefficient of the room (about 0.035), any small resonance of the doors may change the results a lot. At the moment of writing the paper, the modification has not yet been carried out. The final result of the qualification measurement of the room will be present at the conference.

REFERENCE

[1] ISO 354-1985, Acoustics — Measurement of sound absorption in a reverberation room.