The Acoustic Design and Evaluation of Sound Insulation Room

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Abstract

According to the architectural acoustic principle, this paper describes the designing of modern prefabricated sound insulation room which is built by using the double sound insulation structure containing soundproof board for floating construction and sound insulation wall and taking sound transmission loss, absorption coefficient and reverberation time as main architectural acoustics index. The background noise of the flat let is evaluated from 9 choice points under 5 environments and the effect of the flat let comes up to the requirements for the study of phonetics. So the designing provides the reference for phonetics study in other domestic universities and research institutions.

Keywords

Architectural acoustics; sound-absorbing; sound isolation.

1. Introduction

At present, the professional anechoic chambers and soundproof rooms are used for industrial manufacturing, testing household appliances, studios, etc. at home and abroad [1]. Plenty of literatures have discussed all of the issues which need considering for the anechoic chambers and soundproof rooms based on architectural acoustics fields, for example, the amount of space, reverberation time, echo, sound focusing, reflected sound, ventilative noises, background noises, crash etc..

At abroad, each of the phonetics research institutions has a modern and professional soundproof room; however, at home, the phonetics research is still in early stages, only a few institutions have soundproof room. Generally, the soundproof room contains two parts which are sound insulation room and monitoring room, and the former is more important. According to the realities and actual requirements of phonetics research, the sound insulation room can be built simple or complicated [2]. In this paper, the amount of space and the acoustic characteristics are the keys to be focused on, the soundproof room is designed to be a fabricated soundproof room, which has reached the design goal of strong, economical and environmental characters with the result of indoor acoustic detection by the Construction Quality Surveillance and Inspection Center of the State.

2. The architectural design for soundproof room

The effect of sound isolation has close relations with the types of used deadening materials. It will be discussed by the following parts: overall physical layout, walls, the floor and the ceiling, doors, windows, etc...

2.1 The overall physical layout

An ordinary school classroom is chosen to be converted into our soundproof room, which is well equipped with vibration isolation facilities, ventilation facilities, lightings and fireproofing facilities. Soundproof room is made up of one sound insulation room and one monitoring room. The sound insulation room is used to collect speech signals, speech images, and speech videos and so on. The monitoring room is used to monitor the process of collecting signals.

The size of the ordinary classroom is 9490 (L)×6270 (W)×2900mm (H), and is divided into sound insulation room and monitoring room. The muffler is equipped outside of the sound insulation room in order to ensure that the height has reached the design goal. The size of the converted sound insulation room is 5600(L)×5100 (W)×2400mm (H) and the size of the converted monitoring room is 6270(L)×3390 (W)×2600mm (H).

2.2 The walls and the ceiling

The sound insulation-absorption metal board is used for walls and ceiling. During the actual constructing process, all the insulation-absorption metal boards are jointed by the special connectors and formed as a pentahedral whole, the pentahedral whole is a structural support, which needn't have any extra wood structure system. For the sound insulation-absorption metal board, its average absorption coefficient is greater than 0.85, thickness is 100mm, and its width is 1000mm; meanwhile it is also low noise, long life span and difficult to burn. The surface out of board is steel insulation plate, while the surface in of board is perforation galvanized steel absorption plate, meanwhile, the prerogative rate is greater than 20. Sound absorption and sound insulation materials have to be filled between the two plates.

2.3 The floating floor

The clearance area will be narrowed if we prefer spring vibration isolator for ground, so we adopt rubber isolators for ground, comparing to the whole soundproof room system the natural frequency of ground is 8Hz, and it has reducing effects when the frequency of vibration is higher than 15Hz.

2.4 The sound proof door

The sound proof property of door depends on the property of door's material and the crack of the door, although the heavier the door's weight is the better the door's sound proof property is, but it is not convenient to open and close the door, meanwhile it is easy to course a big crack at the hinges, which will affect the sound proof. The side hung steel door is adopted for our soundproof room and the thickness is 64mm.

2.5 The sound proof window

The sound proof window is an observation window which is between the sound insulation room and the monitoring room and has double layers. Such window's sound insulation is as same as the inside wall and its sound insulation property depends on three things: each window glass's thickness, the distance between both windows and the clearances of the window frame. The double layers toughened glass sound proof window is adopted for our soundproof room, and the width of it is over

1 meter, the distance between the two glasses window layers is 100mm. in order to avoid inner resonance, set the inner window on a 3-5 percent incline.

3. The acoustic design of soundproof room

The acoustic design of sound proof room is based on some parameters, such as capacity, sound insulation, reverberation time, background noise. Take a test on the soundproof room after the basic acoustic parameters have been set on it.

3.1 Volume

There are two points needing considered. For one thing is that the diffusive sound field must be even and without noise under suitable condition, as the size of space plays an important role on the quality of the sound. For the other thing is that we have to make sure that there is a comparative space for the experimenters at a reasonable cost. For our soundproof room, the interior space is 5600(L)×5100(W)×2600mm(H)(1.1:1:0.51).

3.2 Sound insulation

The effect of sound isolation is the key in building soundproof room. Formula 1 is about acoustic attenuation, Formula 2 is about the relationship between sound insulation (R) and acoustic transmission coefficient.

$$R= -42 + 20\lg f + 20\lg M. \quad (1)$$

$$R= -10\lg t. \quad (2)$$

R is the sound insulation, dB; f is the sound frequency, Hz; M is the weight of the per unit area of sound insulating material, Hz.

It can be seen from formula (1) that the sound insulation R has relationship with the frequency of sound and the weight of material. We adopt multilayer metal sound absorbing board in order to get a better sound isolation effect and the walls are over heavy and thick.

3.3 The sound absorption coefficient

In order to control reverberation time and keep a lower the background noise for the soundproof room, we have to adopt good quality sound-absorbing materials for the inner walls. The sound absorption coefficient is the ratio of absorbing sound energy to incidence sound energy. As the sound absorption coefficients are different from each other for the sounds' different frequencies, typically, the frequency characteristic curve is used to describe the same material's sound absorbing performance for the different frequent sounds. According to the National Criteria and ISO system, the frequency range is 100-5KHz, and its average values are the sound absorption coefficient, which reflects the overall sound absorption properties of the material.

The formula (3) is about the average sound absorption coefficient a:

$$\bar{\alpha}=\frac{\sum \alpha_i S_i}{\sum S_i}=\frac{\alpha_1 S_1+\alpha_2 S_2+\cdots+\alpha_n S_n}{S}. \quad (3)$$

In the formula $\alpha_1,\cdots,\alpha_n$ and $S_1,\cdots,S_n$ are the sound absorption coefficient and its net area for the different materials [2].

There are two methods to measure the sound absorption coefficient, one is reverberation way and the other is standing wave method. As the sound's reflection is irregular, we use the reverberation way to measure the sound absorption coefficient. In the calculation, multiply the sound absorption coefficient by0.8 to make sure it is approach to the reality.

3.4 Reverberation time

Reverberation time is the time during which the sound has decayed for 60dB, after it is made and keeps stable in the inside. The reverberation time is represented by T60. The reverberation time is different from each other for the different frequency in the same room, it is called Frequency Characteristics of Reverberation Time. The frequency characteristics of reverberation time was first put up with by physicist W. C. Sabine, and later be improved by physicists Eyring and Knudsen. The Sabine formula describes T60 by the sound absorption characteristic, while the Eyring formula describes T60 by reflection characteristic. Although for the accurateness, Eyring formula is better than Sabine formula, neither of them consider the air medium's affection to the sound absorption. In 1932, Eyring formula has been further refined by V.O. Knudsen, which is as the following:

$$T60 \approx \frac{-0.161V}{S_a \ln(1-\bar{a})-4mv}. \quad (4)$$

T_{60} --- Reverberation Time (s);

V--- The Volume of Room, (m3);

S_α --- The Total Sound Absorption of Room (m^2);

m: the Decay Rate of The Air to The Sound(l/meter);when the room is small, the m=0.0014。

According to the above formulas, the reverberation time T60 is directly proportional to the volume, is inversely proportional to the indoor area, and is inversely proportional to the sound absorption coefficient. When the 'V' and 'S' are fixed, the T60 depends on $\bar{\alpha}$, that is, the Reverberation Time depends on the sound absorption materials. In China the Reverberation Time of

The phonetics soundproof room is 100-4000Hz, and the Frequency Characteristics of Reverberation Time is in an increasing order among 0.3-0.4 second or is straight-forward 0.4 second [3].

Table 1 The calculation of the soundproof room's Reverberation Time

item	area	250 Hz		1000 Hz		2000 Hz		4000 Hz	
	s	a	sa	a	sa	a	sa	a	sa
ceilling	28.56	0.95	27.1	0.84	23.9	0.82	23.4	0.82	23.4
wall (around the door)	10.2	0.95	9.7	0.84	8.6	0.82	8.4	0.82	8.4
wall (opposite the door)	13.26	0.95	12.6	0.84	11.1	0.82	10.9	0.82	10.9
Wall (the left and right two side)	29.12	0.95	27.7	0.84	24.5	0.82	23.9	0.82	23.9
Observation window	0.96	0.06	0.1	0.03	0.1	0.02	0.1	0.02	0.1
The sound proof door	2.1	0.25	0.5	0.07	0.2	0.10	0.2	0.11	0.2
floor	28.56	0.10	2.9	0.42	12.0	0.21	6.0	0.27	7.7
$\sum \overline{Sa}$			81		81		73		75
$\bar{a}$		0.7		0.7		0.6		0.6	
$\ln(1-\bar{a})$		1.2		1.2		0.9		0.9	
$S\ln(1-\bar{a})$			113		113		101		101
m				0.001		0.0025		0.006	
$4mV$				0.297		0.743		1.782	
$S\ln(1-\bar{a})-4mV$					112		112		99
$T60$			0.1s		0.1s		0.1s		0.12s

Note: the area of the wall around the door = the area of the wall- the area of the door- the area of the window

From the calculation of Table 1, it is known that Reverberation Time of the soundproof room is less than 0.2second, which will be a completely guarantee to the clarity and sample rate's accuracy of language. The Frequency Characteristics of Reverberation Time is straight-forward and the Frequency Characteristics of Reverberation Time for different frequencies are basically the same. According to the measuring method for the hall's sound reinforcement features, we detect the value of noise distribution in different environment by the Construction Quality Surveillance and Inspection Center of the State, the test result shows the background noise does not exceed 16 dB[4].

4. The Conclusion

In conclusion, the build of soundproof room is not only about a common decorate concept, but also involved in the skills of architecture, acoustics, physics and audiology et al.. Our soundproof room is rebuilt from a common classroom as the national standards by professional designers, and is constructed by a floating sound insulation nested room. Taking the capacity, sound insulation, reverberation time and others as the important indexes of architectural acoustics, the acoustic effect of the soundproof room has been tested, according the result, all can reach to the using requirement.

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