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Acoustic environment research of railway station in China

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Abstract

One characteristic of railway stations in China is that the entrance hall, ticket office, integrated waiting hall and auxiliary space are all concentrated in a large span of space, forming a unified whole space. However, the multi-function fusion in such a large space results in a series of acoustic problems, such as long reverberation time, high environmental noise and poor language articulation. Therefore, it is necessary to study the acoustic environment of railway stations in China. In this study, the sound field characteristics of the typical railway station are studied to reveal its law of sound propagation. Next, subjective evaluation and objective experiments are carried out to study the acoustic environment and comfort in the waiting hall. Finally, based on the comparative analysis of various influential factors, such as sound source and sound field, this paper advances some suggestions for the acoustical design of high-speed railway stations.

Keywords: Acoustic comfort; sound field; auditory guidance; crowd noise; acoustic design.

1. Introduction

With the continued development of China's economy, the construction of a large number of high-speed railway stations has gradually become more comprehensive and complicated [1]. The waiting hall of many railway stations is a huge space with a long reverberation time (RT), high environmental noise, and poor language articulation. The

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indoor material basically does not absorb sound. At the same time, the complexity of the types of sound sources is the main factor of the acoustic environment, which leads to a variety of emotional responses from users, and acoustic comfort in the waiting hall has yet to be studied. Acoustics research in waiting halls is more focused on environmental noise. Liu [2] discussed the influence of materials on the acoustic environment, Yin [3] tested the RT in the waiting hall, and Gu [4] proposed the demand of the acoustic environment. The study of the sound field characteristics of large spaces is insufficient, and the acoustic comfort factor is not considered. Taking architectural acoustics as a basic starting point, this study first examines the sound field characteristic of the waiting halls of China's typical high-speed railway stations; then, it employs a subjective evaluation and objective experimental research methods of the acoustic environment and acoustic comfort inside the waiting hall; studies the influence of the crowd noise on the sound field; and finally, based on the comparison and analysis of sound sources, the sound field and other influential factors, an acoustic design of a high-speed railway station is advanced.

2. Sound field characteristics

2.1. Sound filed test

When a space is too large, the RT is not uniform in spatial distribution, the Sabine formula cannot be used to calculate the RT, and the sound field is no longer diffuse. The kinds of non-diffuse sound fields include long spaces [5], flat spaces [6], and coupling spaces [7]. With the increased depth of research, the acoustic characteristics of large spaces are also gradually gaining attention [8]. China's high-speed waiting area is a typical large space, and in order to understand the sound field characteristics of the waiting hall, the most direct approach is to conduct on-site tests of the railway station's waiting hall. The test subject is the waiting hall of a high-speed railway station, the type of plane is rectangular, the size is 240m x 65m, and the volume is 15600m^3. The roof of the waiting hall is a steel structure roof, with a height of 7.5m, and a two-layer commercial interlayer on the north and south sides, with a height of 4.6 m-6.5 m. The highest point of the roof is 47.5 m, and the lowest point is 37.5 m. The sound absorption coefficients at all frequencies of the material used in the waiting hall are shown in Table 1.

Table 1 Interface material table of the waiting hall of the high-speed railway station.

Number	Interface parts	Material	125Hz	250 Hz	500 Hz	1kHz	2kHz	4kHz
1	Roof (vault)	Gypsum board	0.15	0.2	0.1	0.1	0.1	0.1
2	Roof (ceiling)	Gypsum board	0.15	0.2	0.1	0.1	0.1	0.1
3	Wall surface	Marble	0.01	0.02	0.02	0.03	0.03	0.04
4	Ground	Marble	0.01	0.02	0.02	0.03	0.03	0.04
5	Shop wall	Glass	0.18	0.06	0.04	0.03	0.02	0.02
6	Population	Cloth	0.1	0.21	0.41	0.65	0.75	0.71

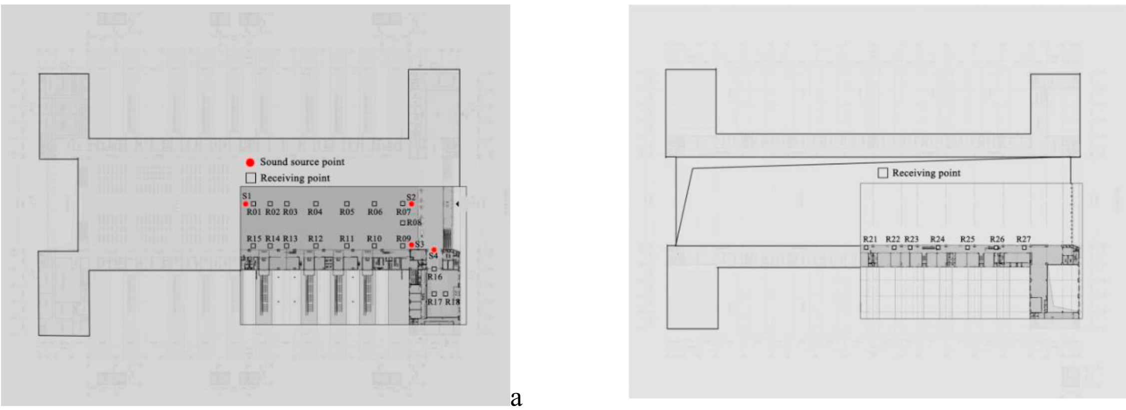

Fig. 1. (a) first floor; (b) second floor.

Due to the large plane size of the waiting hall, the space form and the material of various circles being approximately symmetrical along the east-west axis and north-south axis, the measurement is carried out in one-fourth of the waiting area. The measurement area, sound source point (S) and receiving point (R) of the waiting hall are shown in Fig. 1. There are 3 sound source points and 22 receiving points.

The overall trend is shown in Fig. 2. The sound pressure level decreases with the increase in distance of the sound source point. When the sound source point is in the middle of the hall, because it is far away from the walls, sound intensity is small when it is absorbed and reflected by the wall because this is an attenuation situation that is close to a semi-free sound field, with only one individual receiving point on the second floor having a small fluctuation. S2 and S3 sound is absorbed and reflected by glass windows and absorbent wall material, and the attenuation curve of the sound pressure level of these two source points is not completely consistent with the attenuation curve of a semi-free sound field.

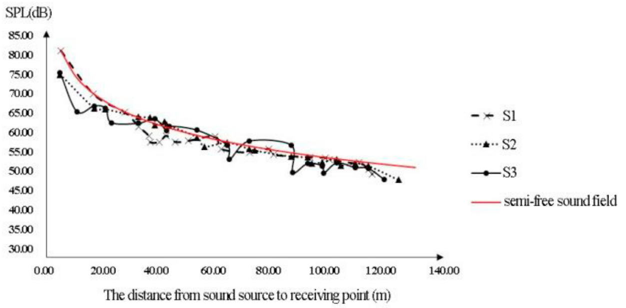

Fig. 2. Attenuation curve of sound pressure level with distance

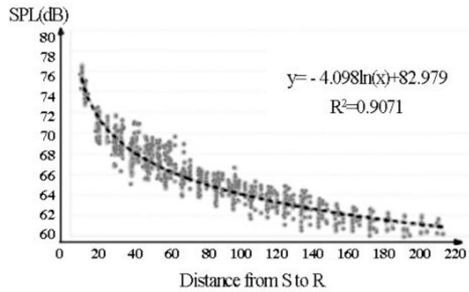

Fig. 3. Attenuation curve of sound pressure level with distance

2.2. Sound filed simulation

Odeon 9.0 acoustic simulation software was used to establish the acoustic model of the waiting hall. The study object is the same as the test object in 1.1. The acoustic attenuation characteristics of the whole space can be represented by the average value of eight sound source points evenly distributed in the space. Ten meters within the space are filled with testing points. In order to understand the attenuation of sound pressure levels within the whole space, the total number of testing points is 120, and the height from the ground is 1.5 m, approximately the height of a human ear from the ground. After the simulation, 120 testing points' sound pressure levels are put forward, the distance between each testing point and the sound source and acoustic pressure level figures were calculated and summarized, a scatter diagram of the test results of the sound pressure level's attenuation with distance was created, and a logarithm regression was performed, as shown in Fig. 3. In Figure 3, y is the sound pressure level, and x is the distance from the sound source. This is similar to the attenuation of a semi-free sound field. The result of RT in this simulation is very different from that of Sabine's formula. The architectural acoustics environment is bad because of the long RT and cannot satisfy diffusion field conditions. The intermediate frequency of RT is very long, and the low and high frequencies are short because the low frequency sound is absorbed by a large area of glass windows and roof metal plates, and the high frequency sound is absorbed by the air. In low frequencies large glass windows and metal roof plates have higher absorption, while, in terms of high frequency, sound absorption occupies the main part.

3. Acoustic comfort

3.1. Main sound sources analysis

According to different scales of the railway station, the scale and form of the waiting area of a railway station are also varied. Table 2 shows the sound source in six spaces of railway station.

Table 2 Interface material table of the waiting hall of the high-speed railway station.

Place	Sound source	Personnel behavior	Effect of the room	Evaluation
Platform	Trains and broadcast	Arrive, leave ,wait, talk	Outdoor environment	--
Waiting hall	Trains and broadcast	Arrive, leave	Long RT	--
Passage	Luggage and machine	Walk, talk, up and down stairs	Echo, resonance	Noisy, rhythmic
Waiting room	Conversation	Talk, wait	Enclosed space, short RT	Quiet, comfortable
Ticket office	Conversation	Talk, wait	Enclosed space, short RT, isolated	Quiet, comfortable
Shop	Music and conversation	Talk	Long RT, echo	Pleasant

This study considers the facts that there is peak travel on holidays in China, that common rail and high-speed trains exist together, that most of the newly built railway stations are far from the central cities, that the mode of the waiting area can be expanded continually for a long time, and that the station hall, ticket office, comprehensive waiting area and affiliated space were focused on a long-span space to form a unified whole space.

3.2. Sound comfort evaluation

In this study, a questionnaire was used to evaluate sound comfort. The reliability of the questionnaire was 0.827, and the validity was 75.425%. A total of 120 questionnaires were issued, and 115 were effectively recovered. In the sample of the survey, the male-female ratio was basically flat. In terms of age distribution, the proportion of people aged 20 to 30 was 44.3%. In the distribution of education, the proportion of undergraduate students reached 62.6%.

The results of the evaluation of the hall's indoor sound environment showed that half of the respondents chose the option "moderate," 30.1% of people chose "quiet," 9.7% of people chose "noisy," and 4.2% and 3.1% of people chose "very quiet" and "very loud," respectively. It can be seen from figure 5 and figure 6 that the acoustic environment quality of the waiting hall is more critical for those over 60 years old, and those aged 40 to 60 are more inclined to give positive comments. During the duration of stay, the longer the stay is, the higher the evaluation of the acoustic environment quality of the waiting hall. Up to 67 percent of those who arrived at the station more than two hours early thought the waiting room was quiet. The shorter the stay time is, the more demanding it is; 31.4 percent of the respondents arriving at the station half an hour early thought the waiting room was relatively noisy.

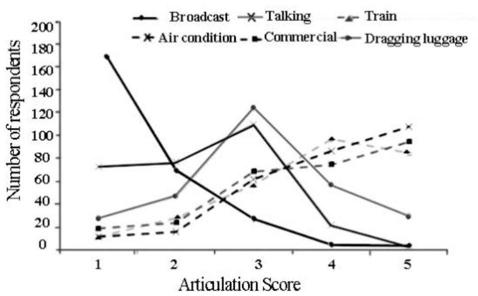

Fig. 4. The main sound source in the waiting hall

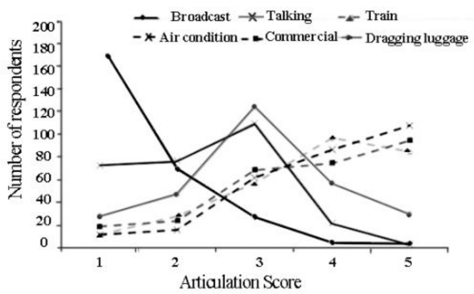

Fig. 5. The sound clarity in the waiting hall

While recording all kinds of voices heard by the interviewees, we marked the sequence of each voice heard, and the frequency of each voice is shown in Fig. 4. As the two main sound sources in the waiting hall, the broadcast voice and conversation sounds have an important influence on the evaluation of the acoustic environment of the waiting hall. The results are shown in Fig. 5. The sound of broadcasts, conversation and the sound of the store's advertisements were the sounds that most of the respondents could hear, while the sounds of trains, air conditioners and luggage were relatively weak and were not easily heard. Of the respondents, 87.2% thought that the sound of the radio was clear or relatively clear, but a small minority thought the radio was not clear enough. Regarding the articulation of the sound of conversation, 51.9% of respondents believed that it was relatively clear or very clear.

4. Acoustic design

4.1. Building acoustic design

Railway station buildings are used as public buildings for a long time. In order to facilitate the use of reflective materials, such as marble and glass, the RT is increased. In addition, for architectural modelling, the use of a curved roof and even round roof makes it easy to produce sound focusing of serious acoustic problems. Seating areas mainly rely on sound absorption and seat sound-absorbing material, and other small areas broken up with coaming or partition, which can have an effect similar to the reflecting plate of a concert hall, provide early sound reflection and strengthening and can also effectively improve language articulation. Because of fire protection requirements, the enclosure and the walls also have a certain sound absorption performance and sound insulation performance, which is conducive to improving the acoustic environment of the waiting hall. The roof of the waiting hall mostly comprises flat roofs and curved roofs with smaller radians, as well as larger curved roofs and round roofs. While using flat roofs, due to a length and width that is greater than the height, if the ground absorption coefficient is low, it is easy to produce multiple reflections between the ground and roof, and language articulation can be also influenced. This can be avoided by placing sound absorbing material on the ground or roof. While using a large curved roof, acoustic focusing should be avoided. In the low frequency band, the cavity can absorb more low-frequency sound energy due to the ground seat, side wall and ceiling glass and the ceiling of the structure. In the high frequency band, the air absorbs more sound energy. Therefore, EDT and T20 have the characteristics of low frequency and low high frequency. The absorption of the medium frequency band can reduce RT and improve the clarity of language, and the following measures can be taken: lay carpet on the floor, divide the space with a partition wall, divide commercial space from different spaces, and use empty cavity sound-absorbing material on the sound board. The roof increases the proportion of metal roof panels.

4.2. Electroacoustic design

The electroacoustic design of the railway station is mainly the design of the broadcasting system.

To summarize the requirements of a railway station broadcasting system, there are several characteristics: the main purpose of the waiting area radio is to provide notice to passengers and provide staff with instructions; it is unlike theatres, concert halls and other places that especially consider the quality of sound for listening; the requirements of broadcasting in railway stations is clarity. Based on the nature of the waiting area, the crowd is of greater liquidity, and the security check and brake machine area population density is larger, and the crowd noise value is high, while the seat and the channel areas are relatively quiet. Therefore, there is no requirement of unevenness of acoustic field, but there is a need to consider the partition layout of the amplification system. In the waiting hall, the traffic is heavy, the crowd is noisy during its peak, and the personnel density of the gate reaches to 2 people /m^2; therefore, the noise of the crowd will obviously interfere with the broadcast clarity. If there is an emergency, the background noise of the crowd will be greatly increased, and the broadcast will be drowned out. Therefore, in order to ensure the signal-to-noise ratio, it is necessary to request the loudest pressure level. Because the frequency band of the broadcast, business broadcast and emergency broadcast is mainly the language frequency band, the frequency transmission characteristic satisfies the language frequency band.

According to the above characteristics, the design objectives of the broadcast amplifying sound field of the large waiting hall are as follows:

(1) The loudest pressure level: 92dB; (2) frequency transmission characteristics: 125Hz~4 kHz; (3) language transmission index STIPA: not less than 0.40. The actual test results show that when the STIPA is greater than 0.34, the articulation of the sound amplification system is basically recognized. At more than 0.4, it is acceptable.

5. Conclusions

With the modernization of China's railway transportation, the construction of large railway stations serving many passengers is an important role of the city, but these have high background noise and complicated acoustic environments. In this study, the acoustic field of a large railway station in a cold region can be approximated to a semi-free sound field, which is not very uniform. The acoustic source in the waiting hall influences the perception of the comfort level by affecting the emotion of the staff, which has the greatest influence on the staff noise, while the increase of acoustic guidance can improve evacuation efficiency. The acoustic design in the waiting area, considering the sound source condition and acoustic field condition, needs to consider its rapidity and security to develop a design scheme for high-speed railway stations by combining building acoustics and expanding acoustics.

References

[1] Mu Wang, Chen Wu, and Li Wang. (2008) "The design and creation of the new Beijing south railway station." *World Building* 8 (2008): 38-49.
[2] Ju Liu. (2009) "Analysis and prediction of noise characteristics of railway passenger station." *Master's thesis of southwest jiaotong university*, Chengdu, China.
[3] Xiaoan Gu, and Lan Wang. (2012) "Study on the acoustical environment requirement of high speed railway elevated station." *China railway, science* 23 (2012): 55-78.
[4] Lijun Yin. (2013) "Test and analysis of reverberation time of large space in railway station." *Railway computer applications* 22 (2013): 37-43.
[5] Jian Kang. (1996) "Acoustics in long enclosures with multiple sources." *Journal of the Acoustical Society of America* 99.2 (1996): 985-989.
[6] Bin Yu, and Guorong Jiang. (2010) "Spatial distribution of reverberation time in flat space." *Proceedings of the international conference on building environmental science and technology*, 2010.
[7] Galaitsis, Anthony G., and W. N. Patterson. "Prediction of noise distribution in various enclosures from free-field measurements." *Journal of the Acoustical Society of America* 60.4(1976):848-856.
[8] Qin, Xin, J. Kang, and H. Jin. "Sound Environment of Waiting Areas in Large General Hospitals in China." *Acta Acustica United with Acustica* 98.5(2012):760-767(8).