A PRELIMINARY STUDY OF THE SPEECH CLARITY OF THE HIGH-SPEED RAILWAY WAITING HALL-AN EXAMPLE OF CHENG DU RAILWAY STATION

Haitao Sun, Peijie Liu
State Key Laboratory of Subtropical Building Science, South China Univ. of Tech., Guangzhou, China
email: htsun@scut.edu.cn

With the continuous development of high-speed train technology in China, many high-speed train lines have been incorporated into the national plan, and high-speed railway stations have gradually become the indispensable center of urban economic and cultural development. As the main part of high-speed railway station, waiting hall plays an important role in passenger diversion waiting. Because the high-speed railway station belongs to the super-large space in acoustics, there is little research data on its acoustical characteristics. At present, China has not formulated the acoustical design specifications for high-speed railway station, so there is no reference for the acoustic design parameters of waiting hall. For this kind of huge public space, how to hear public broadcasting clearly is the primary problem of acoustic design. In this paper, the main acoustic parameters (STI, STIPA and RT) related to speech intelligibility are selected to simulate and analyze the acoustic characteristics of the waiting hall of Chengdu Railway Station. The analysis results show that the reverberation time of the waiting hall with a volume of 1.2 million cubic meters can be shortened to 6.2seconds and the average speech transmission index of the waiting hall can reach 0.4 by using perforated aluminum panels with acoustic tissue applied on the back in the ceiling. Afterreasonable electroacoustic design, the average speech transmission index of public broadcasting in waiting area can be increased to 0.5 by using strong directional loudspeaker array with large horizontal coverage angle and small vertical coverage angle to cover passenger seats evenly. According to IEC 60268-16 standard, STIPA results are in the fair level (0.45-0.60).

Keywords: high-speed railwaywaiting hall;acoustic design; speech transmission index; speech transmission index for public address; reverberation time

1. Introduction

With the continuous development of high-speed train technology in China, many high-speed train lines have been incorporated into the national plan, and high-speed railway stations have gradually become the indispensable center of urban economic and cultural development. As the main part of high-speed railway station, waiting hall plays an important role in passenger diversion waiting. How to hear clearly the public broadcasting is the primary problem of acoustic design for this kind of large public space. It is not only related to the normal conversation of passengers, but also directly affects whether the public broadcasting system can convey the key information clearly and accurately to them.Especially in the case of safety accidents such as earthquakes and fires, the evacuation broadcast with higher speech Intelligibility will avoid huge losses of personnel and property. In this paper, the main acoustic parameters (STI, STIPA and RT) related to speech intelligibility are selected to simulate and analyze the acoustic characteristics of the waiting hall of Chengdu Railway Station.

2. Overview of Architecture

The construction scale of high-speed railway station can be divided into four types according to 'peak hour delivery volume': super-large, large, medium and small. The waiting hall of Chengdu High-speed Railway Stationwhose acoustic effective volume is 1000,000m^3 belongs to the large type referring to the investigation data of other high-speed railway stations[1][2].Due to building daylighting requirements, large area glass is applied to roof and wall structure in the hall. Glass has low acoustic scattering coefficient;the structure and form of glass should be considered in acoustic design to prevent acoustic defects.Considering the decorative and acoustic effects of the waiting hall, the aluminium ceiling is designed as a compositesound absorption structure which is consist of 3mm thick perforated aluminium sheet (pore size:3mm,pore distance:9mm,perforation rate:25%) and100mm thick glass wool (density:32kg/m^3).The main purpose of sound absorption ceiling is to reduce the overall reverberation time of the waiting hall and prevent the sound defect of long-time reflection sound.The irregular triangular structure of the daylighting glass forms angles with the ground of the waiting hall, which can prevent the sound defect caused by the flutter echo between the roof and the ground.The interior rendering, plan and cross section of the waiting hall are shown below.

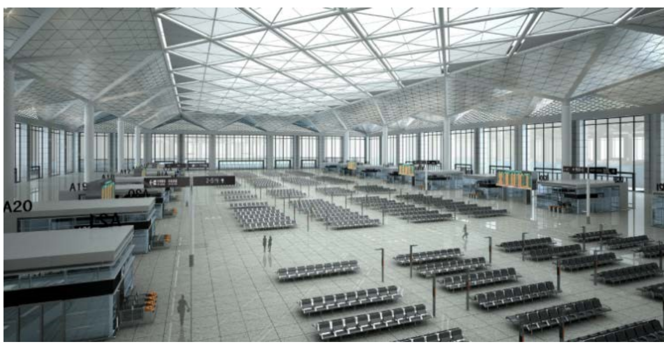

Figure 1:Interior rendering of the waiting hall.

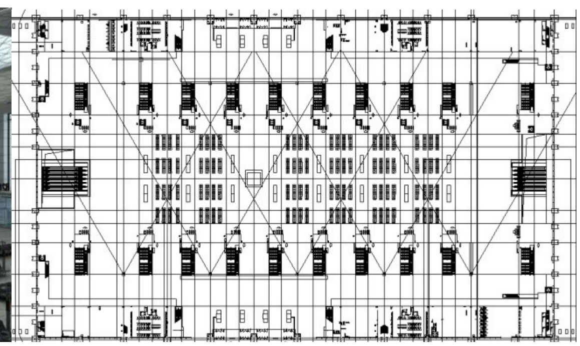

Figure 2:Plan of the waiting hall.

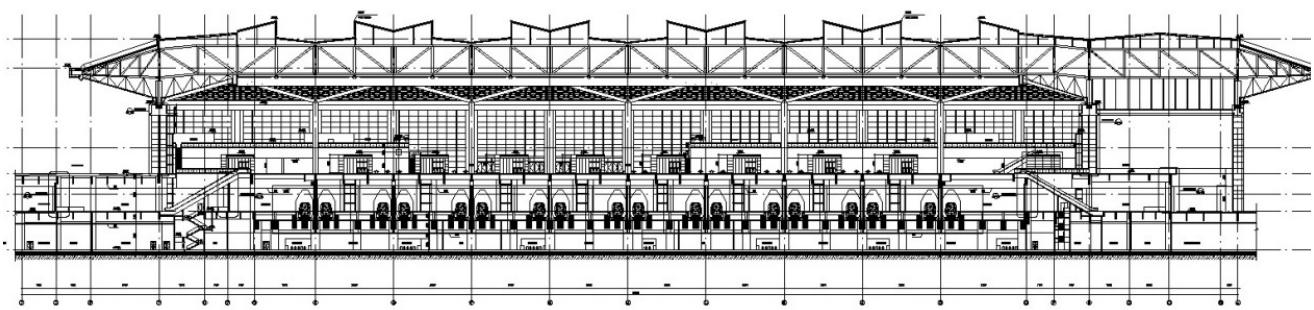

Figure 3:Cross section of the waiting hall.

3. Computer simulation of architectural acoustics

In order to get the acoustic parameters of the waiting hall of Chengdu High-speed Railway Station, ODEON software is used to simulate and analyse in this paper.The sound field of the waiting hall is predicted by the sound absorption coefficient of the designed material. The acoustic parameters such as reverberation time T_{20}, early decay time EDT and speech intelligibility STI are mainly analyzed.

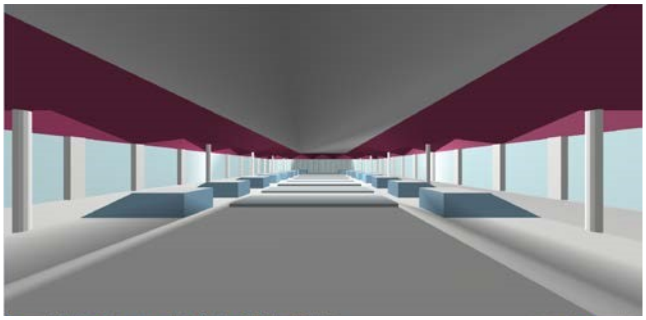

Figure 4:Perspective drawing in Odeon.

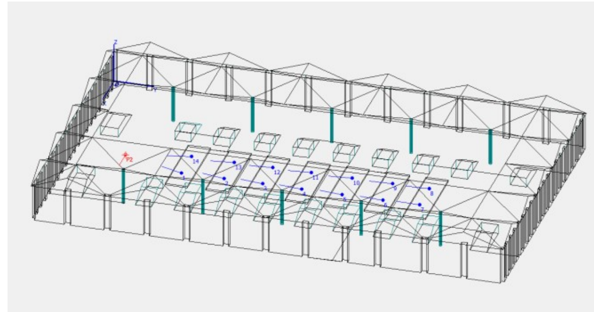

Figure 5:Sound source and receive point arrangement.

Table 1:Acoustic parameters of architectural acoustic simulation

Frequency（Hz）	125	250	500	1000	2000	4000
T_{20}（s）	10.70	6.98	6.30	6.12	5.59	3.55
EDT（s）	11.77	7.41	6.16	6.41	5.19	3.02
D_{50}	0.10	0.19	0.19	0.16	0.18	0.25
STI	0.40					

According to the calculation results of acoustic parameters such as reverberation time and early decay time of typical receive points in passenger waiting areas, it can be seen that the average of reverberation time is 6.20s in mid-frequency, the early decay time is 6.30s, the speech transmission index STI is 0.40.The acoustic parameters such as the sound pressure level and speech transmission index are unevenly distributed in the calculated area because of the omni source used in the acoustic simulation. And the calculated results of these parameters tend to decrease with the increase of the distance between the sound source and the receiving point, especially out of reverberation radius.According to IEC 60268-16 Sound system equipment-Part 16: Objective rating of speech intelligibility by speech transmission index, the hearing of normal listeners is divided into five grades according to 'bad~poor~fair~good~excellent'. The corresponding STI thresholds are 0.30, 0.45, 0.60 and 0.75[3].The average simulation result of STI in the waiting area of Chengdu High-speed Railway Station is 0.40, which belongs to the range of 0.30-0.45 and is in the poor level. On this basis, reasonable electroacoustic design of public broadcasting is expected to improve STI to more than 0.45.

4. Computer simulation of electroacoustic system

The plan shape of the waiting hall of Chengdu High-speed Railway Station is long and narrow. So, loudspeakers with large horizontal coverage angle, small vertical coverage angle and strong directivity are selected to cover the waiting area in electroacousticsystem design.A linear array loudspeaker named Driveline DRL12 (Compact line array 12x 3.5 inch) whose horizontal and vertical coverage angle of 6dB at 1000Hz are 186 degrees and 28 degrees is used in the computer simulation, and the weight of each group of loudspeakers is 12kg, the maximum power is 240W [4].The specific coverage angle parameters are shown below.

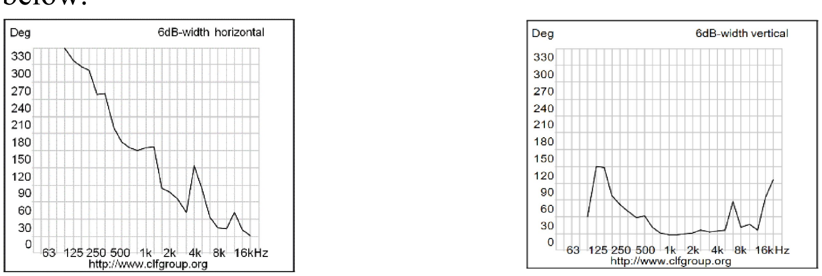

Figure 6:Horizontal and vertical coverage angle of 6dB frequency characteristic curve.

A set of loudspeakers with 12m vertical height off the ground is installed at each column position. A total of 10 groups of loudspeakers in 5 rows are set up on the left and right columns symmetrically. The main axis of the loudspeaker points to the middle of the waiting area. The vertical angle of the main axis of the loudspeaker is -20 degrees. The design principle of electro-acoustic is that the - 6dB vertical angle of the loudspeaker covers the waiting area on the side, and the horizontal - 6dB coverage angle is as large as possible. In public broadcasting mode, all loudspeakers simultaneously work, covering the whole waiting area. The layout of loudspeakers is shown in the figure below.

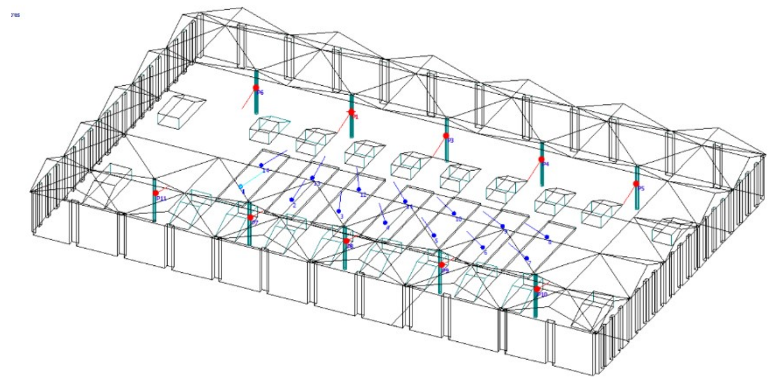

Figure **7**:Layout of loudspeakers (red dots represent loudspeakers).

Table 2:Acoustic parameters of electroacoustic simulation

Frequency（Hz）	125	250	500	1000	2000	4000
T_{20}（s）	10.91	7.65	7.04	7.31	6.31	3.62
EDT（s）	12.71	9.15	7.92	8.41	6.63	2.87
D_{50}	0.13	0.27	0.32	0.37	0.48	0.44
STI	0.50					

According to the calculation results of acoustic parameters ofelectroacoustic system such as reverberation time and early decay time of typical receive points in passenger waiting areas.It can be seen that the average of reverberation time is 7.10s in mid-frequency, the early decay time is 8.10s, the reverberation time of electroacoustic system is a litter longer than that of architectural acoustics.The average simulation result of speech transmission index for public address(STIPA) is 0.50.Compared with the simulation results of architectural acoustics, the simulation results of STIPA of electroacoustic system have been greatly improved, and it belongs to the range of 0.45-0.60 and is in thefair level. The National Standard "Technical code for public address system engineering" is applicable to the design, construction and acceptance of the electroacoustic system engineering of the newly-built, rebuilt and expanded public broadcasting system. Its core requirements are to ensure that the loudspeaker has sufficient sound pressure level and speech intelligibility (STIPA), which of the first, second and third-level broadcasting systems (business broadcasting and emergency broadcasting) shall meet the requirements of no less than 0.55,0.45,0.40 respectively [5].According to the simulation results of this design, STIPA under the electroacoustic system meets the requirements of the second level broadcasting system.

5. Conclusion

At present, China has not formulated the acoustical design specifications for high-speed railway station, so there is no reference for the acoustic design parameters of waiting hall. Because the high-speed railway station belongs to the super-large space in acoustics, the acoustic effective volume of the waiting hall which is six to seven times as large as that of the maximum reference gymnasium specified in JGJ/T 131-2012 "Specification form acoustical design and measurement of gymnasium and stadium"[6].

The sound field characteristics of the waiting hall in high-speed railway station are between the reverberation field and the free field.In this paper, the main acoustic parameters (STI, STIPA and RT) related to speech intelligibility are selected to simulate and analyze the acoustic characteristics of the waiting hall of Chengdu Railway Station.After reasonable architectural acoustic design, the average of reverberation time can be reduced to 6.20s in mid-frequency, and the speech transmission index STI can reach 0.40. On this basis, loudspeakers with large horizontal coverage angle, small vertical coverage angle and strong directivity are selected to cover the waiting area in electroacoustic system design,the average simulation result of speech transmission index for public address(STIPA)can reach 0.50, which can meet the requirements of the second level broadcasting system. Now, the acoustical theory research and design experience of super-large space is very little, further research is needed on the characteristics of architectural acoustic and electroacoustic acoustic field in this kind of space [7].

6. Acknowledge

This research was supported by the National Natural Science Foundation of China (51878281).

REFERENCES

1 GB 50226-2007, Code for design of railway passenger station buildings,Chinese National Standard, Beijing, (2011).

2 Peijie Liu., *Research on Sound Environment in Oversize Waiting Halls of High-speed Railway Elevated Stations*, Doctor of Technical Science Thesis, South University of Technology, (2015).

3 IEC 60268-16 4th ed. Sound system equipment-Part 16: objective rating of speech intelligibility by Speech Transmission Index. International Standard, Geneva, Switzerland, (2011).

4 [Online.] available: http://www.clfgroup.org/.

5 GB 50526-2010, Technical code for public address system engineering, Chinese National Standard, Beijing, (2010).

6 JGJ/T 131-2012,Specification form acoustical design and measurement of gymnasium and stadium, Chinese National Standard, Beijing, (2000).

7 WU, Shuoxian., ZHAO,Yuezhe., Recent research progress on the sciences of acoustic human settlements environment in the State Key Laboratory of Subtropical Building Science, *Applied Acoustics of China*, 32(05):331-335, (2013).