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Acoustic Environment of Large Terminal Airside Concourse in China

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Abstract. This study uses the model of the airside concourse of a certain terminal building in China, which is under construction, and compares the indoor reverberation time with six different indoor heights and different situation of unoccupied and occupied indoor field. The results of the study show that due to the narrow design of the airside concourse and the large number of glass curtain walls, the insufficient indoor sound absorption will result in - in the case of unoccupied field - the reverberation time of the 500Hz at 20m height terminal lasts as long as 7.2 seconds. With each 1m lower in height, the reverberation time increases by 0.16 seconds. The conclusion of this study is that, in the case that the indoor sound absorption cannot be increased and the number of indoor people is fixed, reducing the height of the terminal building helps to reduce the indoor reverberation time.
Keywords: terminal airside concourse, indoor acoustic environment, reverberation time

1. Introduction

In recent years, China's economy has grown rapidly, and economic growth has been closely integrated with transportation development [1]. In 2015, China proposed an initiative focusing on the development of the "Belt and Road" [2]. In this context, China's aviation industry has grown from 142 civilian airports, 284.41 million passengers per year in 2005 [3], to 229 civilian airports, 117.478 million passengers per year in 2017 [4], which annual growth rate has been more than 10%. At the same time, China's "13th Five-Year Plan" (2016-2020) clearly states that by the end of 2020, China's general aviation airports will reach 500, including 260 civil airports [5], an increase of 31 from 2017. Under the circumstances of such rapid growth, in addition to the development of the Green Terminal Standard [6], we need to do more research on passenger comfort.

In 2014, the team conducted a survey of passenger comfort for seven major terminals in five different cities across the country. The questionnaire includes seven items: indoor thermal environment, light environment, acoustic environment, air quality, space satisfaction, space layout and facility convenience, and comprehensive evaluation. In the 3,489 valid questionnaires within a year, the passengers have the lowest satisfaction with the acoustic environment. In the subsequent feedback of the acoustic environment, the indoor uncomfortable echo and the conversation are the main sources of indoors noise. In the terminal building, the longest place for passengers to stay is the waiting area, and most of the waiting areas are designed in the airside concourse [7]. At present, most of the international researches on passenger comfort in the terminal are concentrated on indoor thermal comfort [8][9], and there is little terminal indoor acoustic environment evaluation. Therefore, this study is aimed at the simulation on the acoustical properties of one Chinese terminal building which is under construction.

2. Acoustics study on terminal building

The existing research on the acoustics of the terminal is mainly about the noise generated by the aircraft. The focus is on the exterior area of the terminal building, even the residential area outside the airport [10][11]. Internationally, the Airport Development Reference Manual published by IATA and the Civil Airport Project Construction Standard published in China all use sound insulation as the main requirement of the acoustic design for the terminal building, which indicates that the past experience has all considered the noise of the terminal is mainly from the aircraft. While the results of the passenger comfort survey show that the passenger's dissatisfaction mainly comes from the indoor noise.

At present, there are few studies on the indoor acoustics of the terminal building directly, but the indoor acoustic environment of large space building can be used for reference to analyze the indoor acoustics of the terminal building. In 1984, T H Lewers et al. [12] studied the acoustical properties, especially the relation between reverberation time and speech intelligibility of St. Paul's Cathedral. In 1992, Xiang Ruiqi et al. [13] improved the indoor reverberation time of the Beijing Olympic Stadium and swimming pool through the sound absorption structure of the roof and side walls. In 2018, Chao Wang et al. [14] examined the sound fields in extra-large spaces and found that in such spaces inhomogeneous reverberant energy caused by uneven early reflections with increasing volume has a significant effect on sound fields. In addition, same with the terminal building, the tunnel buildings also need to ensure the clarity of the broadcast, such as what Sander J van Wijngaarden et al. [15] studied. It is found from the above literatures that the indoor reverberation time will gradually increase when the internal volume exceeds 100,000 m3, so it is necessary to pay attention to the indoor acoustic environment effect of large space, which is also the research purpose of this paper.

3. Research approach

In order to understand what factors will affect the quality of indoor acoustic environment, the research methods of this paper are questionnaire survey and its analysis, acoustic simulation of the airside concourse of large international airports taken by the acoustic software CATT, as well as the analysis of the simulation results.

Based on the previous research, we conducted a more detailed questionnaire survey of 142 passengers in one of the terminals, as shown in Figure 1 and Figure 2. The research uses auditorium acoustics simulation software CATT, which can analyze acoustic parameters for various types of buildings. The specific method is: use drawing software SketchUp or AutoCAD to import the building to be simulated into the software, set the materials in the building and the corresponding sound absorption parameters, calculate on various acoustic actions in the room through virtual sound sources and acoustical line tracking of the software, and then simulate the acoustic parameters in the building through simulation calculation, such as the sound pressure level distribution, reverberation time, speech intelligibility, etc. In this study, the impacts of different heights of the terminal on indoor reverberation time are especially compared to analyze the relation between the height of the terminal building and the acoustic environment.


Airport Environmental Quality Questionnaire

Disclaimer: This questionnaire is for academic research data collection, we will strictly keep your personal information confidential!

I Personal basic information

1. Gender: □male □female
2. From: □mainland China □Hong Kong, Macau, Taiwan □Europe and America □Other
3. Age: □< 25 □25~30 □30~35 □35~40 □40~50 □> 50
4. Flight frequency: □<5 /year □5~10 /year □11~20 /year □>20/year

IV. Light environment assessment

5. You feel the lighting inside the terminal:
Too dark moderate too bright

6. Your satisfaction with the light environment of the terminal is:
Very dissatisfied dissatisfied a little dissatisfied a little satisfied satisfied very satisfied

V. Acoustic environment assessment

7. You feel the broadcasting sound inside the terminal:
□cannot hear clearly □can hear, but hard □ clear

8. Where is the main source of the noise you are feeling now (multiple choices):
□conversation □phone call □aircraft □broadcast □indoor uncomfortable echo
□airconditioner □vehicles □none above □other

9. Your overall satisfaction with the acoustic environment of the terminal is:
Very dissatisfied dissatisfied a little dissatisfied a little satisfied satisfied very satisfied

Figure 1. Figure with questionnaire sample

Figure 2. Figure with questionnaire survey on site.

4. Analysis on questionnaire results

In the broadcast clarity study, only 44% of passengers felt that they could hear clearly (see Figure 3). From the analysis of on-spot passenger survey results, the reason for poor indoor acoustic environment may be people's conversation and indoor echo (see Figure 4). The reason for the poor performance of the broadcasting system is that under a certain space, the reflection caused by the excessive indoor reverberation time is too strong. Therefore, the design of the acoustic environment should be added to the new airport construction, and the acoustic simulation should be involved at an early stage to improve the indoor acoustic environment.

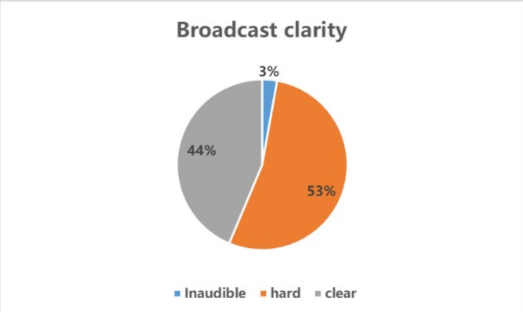


Figure 3. Broadcast clarity felt by passengers.

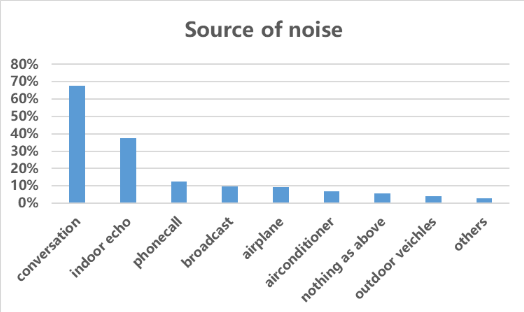


Figure 4. Source of noise considered by passengers.

5. Acoustical simulation

The research object of this study is a large international airport terminal building under construction, which has a total area of 700,000 square meters. The specific location of this study is the waiting area of the airside concourse, with an area of about 24,000 square meters. The software used is CATT, and the modelling of the airside concourse is shown in Figure 5, in which the sound source is from 2.5m heights, and the sound receiving point is shown in the same figure.

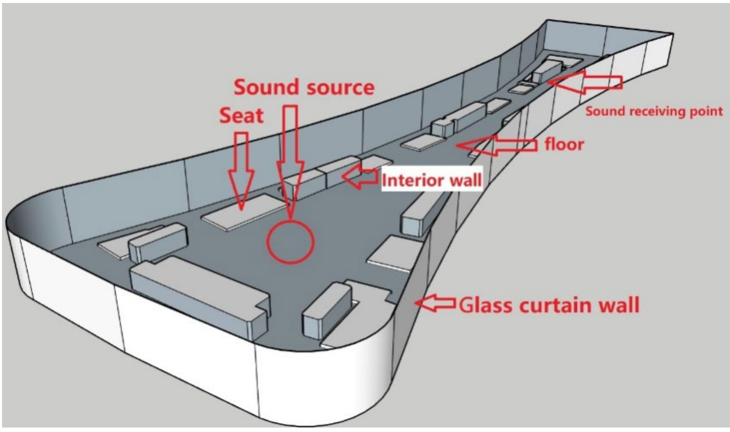


Figure 5. South-facing airside concourse model (20m height).

With the same indoor area, this study respectively simulates different storey heights of 5m, 8m, 11m, 14m, 17m and 20m, and divides two different cases of unoccupied field and occupied field. Case 1 is the simulation of unoccupied field. Because the sound absorption coefficient of the materials used indoor cannot be measured, the sound absorption coefficient of EASE is used in this study, see Table 1 [16]. Case 2 is the simulation of occupied field. The indoor situation is that the seat area is full of seated passengers, and standing passengers account for 8% of the whole indoor area. After that, against the two cases, this research compares the changes of indoor reverberation time (T30) under six different storey heights.

Table 1. Sound absorption coefficient of each material in Case 1.

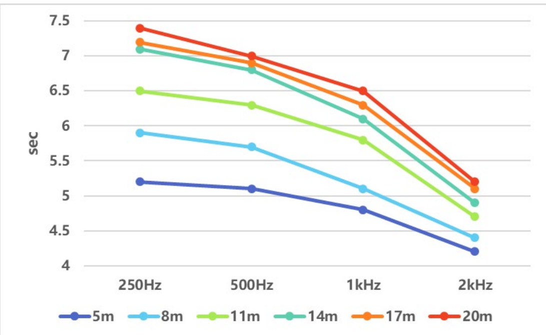
	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	Internal surface area ratio
ceiling	0.7	0.69	0.66	0.8	0.84	0.83	31%
glass 4mm	0.35	0.25	0.18	0.12	0.07	0.04	23%
floor	0.01	0.01	0.01	0.02	0.02	0.02	28%
Seat (artificial leather)	0.23	0.34	0.37	0.33	0.34	0.31	5%
Interior wall	0.01	0.01	0.02	0.02	0.02	0.03	13%

Table 2. Sound absorption coefficient of each material in Case 2.

	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	Internal surface area ratio
Seat (artificial leather) with seated people	0.2	0.2	0.33	0.36	0.38	0.39	5%
Person (standing)	0.13	0.33	0.44	0.42	0.46	0.37	8%

Figure 6 shows the indoor reverberation time of Case 1. Case 1 adds sound absorbing materials to the interior seats, floors, side walls and ceilings. In this state: when the storey height is 20 m, the indoor reverberation time of 500Hz is 7.2s; and when the storey height is 5m, the indoor reverberation time of 500Hz is 5.1s. Therefore, as the storey height decreases, the indoor reverberation time is gradually reduced, on the other hand, the indoor height of the building is increased by 1m on average, that the indoor reverberation time is increased by 0.16s.

Figure 7 shows the indoor reverberation time of Case 2. There is a big difference of tendency between the occupied field and the unoccupied field. It can be seen from the figure that the tendency of 5m, 8m, 11m heights are the same: the reverberation time of 250Hz is low, the reverberation time of 500Hz~1kHz is flat, and the reverberation time of 2kHz is increased. With the storey heights of 14m, 17m, and 20m, the reverberation time tendency is: the reverberation time of 250Hz to 500Hz is increased, and the reverberation time of 1kHz to 2kHz is decreased; in the 500Hz indoor reverberation time, the reverberation time of 5m storey height is 1.96s, which is the highest in Case 2; in the storey heights of 8m~20m, the indoor height increased by 1m on average, the indoor reverberation time increased by 0.0275s.



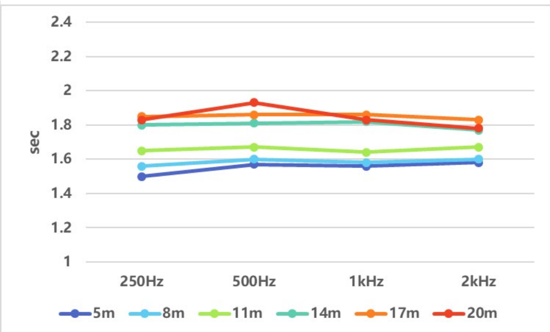


Figure 6. Reverberation time comparison, Case 1. **Figure 7.** Reverberation time comparison, Case 2.

Figure 8 shows the tendency of speech intelligibility. It can be seen from the figure that the tendency of the unoccupied field and the occupied field are the same: the STI is the highest at the height of 5m, and the STI is gradually decreased as the height is increased. Although the passengers themselves are good sound-absorbing materials, the STI of the occupied field is on the contrary lower than that of the occupied field. The reason is that too many passengers lead to crowded space, and the voice of conversation between people will also decrease STI.

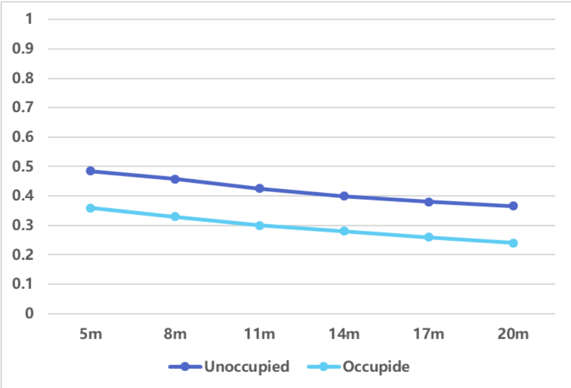


Figure 8. STI comparison of unoccupied field and occupied field.

6. Conclusion

In this study, it is learned from the passenger questionnaire survey that the passengers were dissatisfied with the acoustic environment, through the acoustic simulation analysis of the terminal airside concourse, the influence of the height of the terminal on the indoor reverberation time was compared, and the results of the comparison were discussed.

The specific conclusions are as follows:

- According to the analysis of the survey results, most passengers are not satisfied with the clarity of the broadcast; the passengers think that the first two sources of noise are people's conversation and indoor uncomfortable echo.
- From the simulation results, it can be found that the voice of people's conversation and the indoor uncomfortable echo become factors affecting the clarity of the broadcast, which are caused by the excessive indoor reverberation time.
- The simulation analysis found that, within a certain height, the indoor reverberation time is closely related to the height of terminal airside concourse: when the total storey height is less than 14m, the decrease of storey height will significantly decrease the indoor reverberation time. However, when the total storey height is more than 14m, the influence of the storey height on the indoor reverberation time is gradually reduced.
- Comparing the STI results, it is found that in both situation of unoccupied field and occupied field, the higher the height is, the smaller the STI will be. In the case of occupied field, the STI is worse than the unoccupied field due to the crowded space.

It can be seen from the above analysis that the STI is lower in the occupied field than in the unoccupied field, that is to say, the occupied field situation brings another problem, i.e. the conversation between people becomes another important factor affecting STI, which also corresponds to the results from the passenger questionnaire survey. Of course, we can increase the indoor sound absorption materials to improve the STI, but this will increase the cost, and the outer wall of this kind of large terminal building is mostly glass curtain type, which is more difficult to be changed into the sound absorption materials. Therefore, this study believes that reducing the height of the terminal building will be the most fruitful way in the pursuit of energy saving, material saving and passenger comfort.

In conclusion, this paper studies the acoustic environment of the large-scale terminal building in China, elaborates the relationship between the height of the space and the indoor reverberation time, and the different results of STI in the unoccupied field and the occupied field. It has certain guiding significance for the design of indoor acoustic environment of large-scale terminal buildings in the future. Not only that, the terminal building discussed in this paper is the representative of today's extra-large space buildings, and its height and space are more ambitious than the previous large space buildings. Therefore, this research on the acoustic environment of the airside concourse of this kind of terminal building is also meaningful for the design of acoustic environment of extra-large space buildings in the future.

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