Sound insulation and noise reduction technology for modular housing used in airport environments

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Abstract. The purpose of this study is to provide a modular building of steel structure to meet the requirements of internal construction and acoustics of the airport, improve the living environment and rest conditions of tower staff, relieve the daily work pressure of staff and improve work efficiency. The research of this subject has practical application value for the construction of staff dormitory of airport tower.

1. Introduction

As the air traffic control facilities in the airport, the airport tower is used to supervise and control the take-off and landing of aircraft, which plays an important role in the operation and maintenance security of the airport. Over the years, poor accommodation and simple living facilities for tower controllers have seriously affected the physical and mental health. In addition, due to the special of nature work and working hours, traditional buildings can not be built quickly and efficiently during airport operation\cite{1}. As a new building system, the modular building has a high prefabrication rate, which has significant advantages in improving project quality, shortening construction period, saving manpower and material resources, protecting environment and other aspects. It meet the construction conditions and the acoustic requirements of airport environment. The research of this subject has practical application value for the construction of staff dormitory of airport tower.

2. The impact of noise on human physiology

The physiological effects of noise include the damage to the auditory system, the cardiovascular system, digestive system, nervous system and other organs. Long-term exposure to noise can cause a variety of chronic diseases, including heart disease, hypertension and gastric ulcer\cite{2}.

Near the airport control tower, the harm of noise on people is mainly interference with sleep. It has been accepted that the effect of noise disturbance on sleep will lead to physical and psychological damage\cite{3}.

3. Acoustic environment test

In order to understand the airport aircraft noise pollution, the acoustic environment test was carried out near the airport tower at 10 a.m., including take-off from the east runway, taxi from the south runway, taxi from the north runway, taxi from the north runway and take-off from the west runway, taxi from the east runway, taxi from the north runway and take-off from the west runway, taxi from the west runway, taxi from the east runway respectively. The results are shown in table 1.

Instrument used: B&K 2230 sound level meter calibrated by China institute of metrology.
Test environment: wind level 1, the temperature of 12 degrees.

Table 1 A sound level calculation results

| test status                        | Octave Band (Hz) | Weighting |
|-----------------------------------|------------------|-----------|
|                                   | 31.5             | 63        | 125      | 250      | 500 | 1K | 2K | 4K | 8K | A   |
| take-off from the east runway     | 62.1             | 61.7      | 59.2     | 55.2     | 53.6 | 53.5 | 54.1 | 50.7 | 49.5 | 59.8 |
| taxi from the south runway        | 54.9             | 54.9      | 58       | 62       | 57.1 | 40.8 | 43   | 41.8 | 35.6 | 57.3 |
| Taxi from the north runway        | 56.0             | 58.7      | 59.9     | 55.0     | 53.7 | 49.7 | 41.2 | 36.5 | 32.9 | 54.7 |
| taxi from the north runway and take-off from the west runway | 65.8 | 58.7 | 64.0 | 63.1 | 69.0 | 58.7 | 51.0 | 53.1 | 32.9 | 67.2 |
| taxi from the east runway         | 59.6             | 63.7      | 63.6     | 57.5     | 59.5 | 54.8 | 52.5 | 45.3 | 34.3 | 60.6 |
| taxi from the north runway and take-off from the west runway | 70.1 | 71.6 | 68.6 | 67.0 | 61.6 | 58.6 | 55.8 | 51.4 | 43.6 | 64.8 |
| taxi from the west runway         | 69.9             | 71.5      | 69.1     | 65.9     | 60.9 | 58.3 | 54.1 | 48.9 | 41.0 | 63.9 |
| taxi from the east runway         | 72.0             | 73.7      | 71.6     | 66.8     | 63.1 | 60.2 | 55.1 | 47.6 | 38.9 | 65.6 |

According to the curve of aircraft noise frequency measured in the field and calculated, the maximum a-level noise near the airport tower is 67.2dB, and it is mainly low-frequency noise.

4. The design of sound insulation

This study is applied to the airport control tower, the sound insulation performance of the building is strictly required. It is very important for this design to solve the anti-noise ability. The external wall, roof, ground and windows are designed in this study, as follows:

4.1 The design of exterior wall and ground details

The exterior wall details of the box from the inside to the outside are 12mm size double fire gypsum board, 75mm size light steel keel (rock wool), 1.5mm size corrugated steel, 50mm size light steel keel, 12mm size double cement fiber board and wall painting. The design of exterior wall details is shown in figure 1. The details of ground from bottom to inside is 0.6mm size color steel plate, laminating films, 100mm size rock wool, 18mm size cement fiber board, 10mm size cement fiber board and composite wood floor. The 0.6mm color steel plate and the main structure are fully welded, as shown in fig. 2.

In the exterior wall design, the main factors for sound insulation are as follows:

(1) The surface of the building wallboard is a relatively hard and dense cement fiber board, which has a strong reflection on the sound wave incident on it and greatly reduces the transmitted sound wave.
It plays the role of sound insulation.

(2) Rock wool as porous materials, when the sound waves travel into the material through cracks and holes, the air movement will produce viscous and frictional effects. Sound energy is consumed by converting it into heat. At the same time, the 75mm rock wool thickness has a more significant effect on the low frequency sound absorption coefficient.

(3) A resonance system of air layer is formed between the cement fiber board and the keel. When the frequency of the incident sound wave is equal to the natural frequency of the sound absorption structure of the plate, the structure will resonate, and the plate consumes a lot of sound energy during resonance. It plays a role of sound absorption.

4.2 The design of roof and window details
The details of roof from outside to inside is 2mm size corrugated steel, the structure of purlin (embedded 100mm size rock wool, density 100kg/m³), 10mm size double cement fiber board, 100mm size cavity (embedded 100mm size rock wool, density 100kg/m³), 12mm size double fire gypsum board and wall painting. Corrugated roof board is fully welded with the main structure, and double cement fiber board is joined Staggered together, as shown in fig. 3.

The sound insulation of the window basically depends on the ply of glass, cavity size and the sealed degree of window frame and structure, the thicker the window, the better the sound insulation, the larger the spacing, the better the sound insulation. This design uses double bore windows. The outer window is made of broken bridge aluminum laminated hollow tempered glass with the specification of 6mm+1.52PVB (sound insulation film) +6mm+12A+6mm. The inner window is made of broken bridge aluminum laminated hollow tempered glass with the specification of 5mm+9A+5mm. See figure 4.

5. Sound insulation test

5.1 The test position
The north external wall, east external wall and south external wall of the sample box.

5.2 Testing equipment
Sound level meter B&K2230; 1/3～1/1 Octave filter B&K1625; Noise generator B&K1405; Sound
level calibrator B&K4230; Laser rangefinder; Steel tape.

5.3 The sample box
The test sample box and test position are shown in figure 5.

![Figure 5 The floor plan](image)

![Figure 6 Sample box appearance](image)

5.4 Test results
The test results are shown in the figure 7, figure 8 and figure 9.

![Figure 7 Sound insulation of the north wall](image)

![Figure 8 Sound insulation of the south wall](image)
The calculated results are as follows:

(1) The test result of sound insulation on the north external wall of the sample box (weight standardized level difference and traffic noise spectrum adaptation term) is 38dB, which meets the first-level sound insulation standard of the outer wall of hotel stipulated in chapter 7 of code for design of sound insulation of civil buildings GB50118-2010.

(2) The test result of sound insulation on the east external wall of the sample box (weight standardized level difference and traffic noise spectrum adaptation term) is 45dB, which meets the special sound insulation standard for the outer wall of hotel stipulated in chapter 7 of code for design of sound insulation of civil buildings GB50118-2010.

(3) The test result of sound insulation on the south external wall of the sample box (weight standardized level difference and traffic noise spectrum adaptation term) is 45dB, which meets the special sound insulation standard for the external wall of hotel stipulated in chapter 7 of code for design of sound insulation of civil buildings GB50118-2010.

6. Conclusion
The purpose of this study is to provide a modular building of steel structure to meet the requirements of internal construction and acoustics of the airport, improve the living environment and rest conditions of tower staff, relieve the daily work pressure of staff and improve work efficiency. The research of this subject has practical application value for the construction of staff dormitory of airport tower.

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