Architectural Acoustic Application of Medical Space Roof Wall System Based on Prefabricated Interior Decoration Technology

Xiuyun Li
Department of Architectural Engineering, Guangzhou Nanyang Polytechnic College, City, Guangdong, 510925, China
Corresponding author’s e-mail: suone921@163.com

Abstract. The roof wall system building components carry the functions of sound absorption, fire prevention, decoration, environmental protection and comfort, which can well solve the problems of medical space efficiency, quality and benefit. Based on the development trend of the assembled interior technology, the green and precast glass fiber reinforced gypsum components and inorganic high-strength sound absorbing board are selected as the engineering practice decoration materials for the integrated ceiling and wall of multiple spaces in the hospital. The application status of boards in architectural acoustics is introduced, along with the application status of assembled type medical space roof system, which provides practical experience of the fabricated interior technology.

1. Introduction of medical space roof wall module board
The top wall system designer of medical space is the key point of interior design. The roof wall system building components carry the functions of sound absorption, fire prevention, decoration, environmental protection and comfort, which can well solve the problems of medical space efficiency, quality and benefit. Throughout the world building development trend, the interior decoration technology in developed countries has reached full assembly. In recent years, many different countries and regions have issued many different technical specifications that have practical guiding significance for the construction industry. Due to the differences in production process and equipment manufacturing, production efficiency, energy consumption and final product performance are different, which directly affects the homogeneity and environmental protection of building materials performance. At present, studies have shown that most of the ceiling materials and wall materials focus on the strength, mechanical properties, joint connection and other aspects of materials, and optimize the stability and safety of the top and wall through reasonable structural connections.

According to the requirements of the code, the operating room or surgery department, the delivery room, the intensive care unit, the valuable precision medical preparation room, the storage room, the laboratory, the film room, etc, and the medical attached building as nurseries, children's rooms in kindergarten, children's play halls and other children's activities places, and elderly care facilities, which fireproof walls with fire resistance limit is not less than 2.00h. The ceiling of which building’s the fire resistance rating belongs to Grade II and Grade III the entrance hall and aisle shall be made of non-combustible materials[1].

Considering the basic technical indexes such as apparent density, thermal conductivity, permeability coefficient, compressive and flexural resistance, and water absorption rate, compared
with the advantages and disadvantages and different application environments of expanded polystyrene board (EPS), extruded polystyrene board (XPS), and polyurethane composite board. Phenol insulation boards, rock wool and other materials in building materials market, it is worth noting that the material selection and thermodynamic indexes of the roof wall system, which is consistent with the high requirements of safety and environmental protection for medical space. Further considering the common requirements of fire prevention and tranquility in medical space, precast glass fiber reinforced gypsum and inorganic high-strength sound absorbing board are selected as the top and wall materials in public halls, consultation rooms and conference rooms of the medical space.

2. Test section

Medical space decoration has high requirements for the selection of plates, especially considering the construction materials that release toxic gases during the combustion process, which will affect the safety of life. However, hospital patients need better medical environment due to physical reasons, therefore, in the selection of decorative materials, combined with the "Code for Fire Protection Design of Building" GB 50016-2014 (2018 edition) to comply with the requirements of wall fire protection, and to test the board.

| Frequency(Hz) | 100 | 125 | 160 | 200 | 250 | 315 | 400 | 500 | 630 |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Acoustic absorptivity αs | 0.44 | 0.58 | 0.56 | 0.72 | 0.70 | 0.78 | 0.86 | 0.85 | 0.96 |

| Frequency(Hz) | 800 | 1000 | 1250 | 1600 | 2000 | 2500 | 3150 | 4000 | 5000 |
|--------------|-----|------|------|------|------|------|------|------|------|
| Acoustic absorptivity αs | 0.95 | 0.85 | 0.79 | 0.67 | 0.69 | 0.71 | 0.76 | 0.71 | 0.80 |

The raw material tested was a precast glass fiber reinforced gypsum component (GRG) with a plate thickness of 19 mm and an area of 4.2 m × 4.2 m totaling 10.08 m². Center for building environment test of Tsinghua University was commissioned to use RTA840 system to test the sound absorption coefficient and noise reduction coefficient of the board. According to GB/T 20247-2006 "Acoustics—Measurement of sound absorption in a reverberation room" and GB/T 16731-1997 "The graduation of sound absorption property for absorbent products", the sample serial number is A14-011, and the result of the report determines that the noise reduction coefficient of the test piece is...
NRC=0.80, and the sound absorption performance of the sound absorbing structure is grade I. (Table 1, Figure 1).

3. Example of board acoustics application of roof wall module

3.1. Design case of ceiling and wall in medical space

In order to create a quiet and comfortable medical space, various methods are used in the interior design of hospital buildings to solve the problem of noise pollution. It is generally controlled from the noise source, or controlled in the path of noise propagation, or uses a variety of labor insurance equipment to protect against noise. In many functional areas of the hospital, considering the frequent medical and nursing activities, the key measure in the noise reduction process is to control the transmission path of noise.

The assembled integrated roof system is one of the important components of the assembled interior technology. The tested panels have good sound absorption and noise reduction characteristics and have been recognized by the market. In the process of designing modular in the ceiling and wall of medical multiple spaces, the board selected by the case can effectively suppress the disadvantages compared with the unfavorable factors such as easy deformation and mildew of ordinary ones. For common problems such as exposed beams and columns of ceiling, cross-collision of lines and so on, a variety of software technologies are adopted, put the design in advanced and coordinate the layout so as to meet the individualized requirements of medical space. Meanwhile, on the basis of satisfying the functional requirements, the pursuit of roof-wall integration, seamless connection, and diversified aesthetic modeling.

Case 1 is the precast glass fiber reinforced gypsum component of the integrated ceiling of a stem cell engineering technology research center (Fig. 2). In the design stage, considering the comfort of the light source from the lamp trough, the method of visible light invisible lamp is adopted. In order to cater to the theme of stem cells, the related cell and blood module boards are designed, and the reserved holes, embedded parts and structure nodes are also integrated into the design scheme. The boards are prefabricated in the factory in a customized way so as to facilitate the later civilized construction, save the opening time, control the miscellaneous gap caused by the improper opening which affect the aesthetic perception, and control the sound leakage. The ceiling module precast glass fiber reinforced gypsum component of this case contains uniform small holes, considering the influence factors of the reflection and reverberation of the medical hall, and then using the perforation rate of the board to assist in noise reduction. There are many arc-shaped modules in this design, and the board exhibits excellent performance, which perfectly deduces a variety of dynamic shapes.

Case 2 is the design of the assembly module of the video conference room top wall system of a hospital (Fig. 3). Under the guidance of the overall style, convenient installation and environmental protection concept, the integrated ceiling products rapidly extend to the wall, forming a more integrated, more economical and green roof-wall integrated products[2]. The hospital video conference room utilizes these two kinds of tested pieces as the main components of the ceiling module and the wall module, making a combined effect of the sound absorption and noise reduction by boards, leading the indoor space comfortable and quiet, which provides a good indoor environment for the use of the video. The inorganic high-strength sound absorbing board of the ceiling module is located above, and it is easy to absorb high-frequency sound absorption by using its own sound absorbing structure and appropriate perforation rate. This can be used as a background to suppress the reflected sound. In addition, the sound has a certain reverberation on the transmission path so that the sound retains the stereo sense.
Figure 2. View of GRG ceiling module of the medical hall.

Figure 3. Assembled wall image of inorganic high-strength sound absorbing board in hospital video conference room.

For the precast glass fiber reinforced gypsum of wall module, it also has a sound absorbing structure, which plays the role of sound insulation and sound diffusion of the wall. The treatment of sound absorption and noise reduction in hospital video conference rooms is not always a single measure. Indoor soft fabrics and sofa chairs also work in effective roles. From the perspective of the acoustic treatment program of the case, on the one hand, the requirements of the contract clause are met, and on the other hand, the board characteristics of the roof wall system show a good sound absorption effect, so the user is satisfied.

3.2. Assembled construction

The use of various new materials and technologies has obviously improved the effects of energy saving, heat preservation, heat insulation and sound insulation, and made the living environment of residents more comfortable, therefore the modular design and modular construction are complementary[3]. The implementation of the assembled interior decoration system must connect the design technology and the construction process[4]. According to the principle of architectural acoustics, the boards should be constructed with a damping system to form an excellent sound absorbing structure to achieve sound absorption and noise reduction. The long-term accumulation of construction experience also proves that the sound-absorbing board filled with sound-absorbing cotton can effectively reduce noise[5]. The specific installation method of the case is as follows: the selected precast glass fiber reinforced gypsum (GRG) component with a surface density of about 23kg/m² and a square hole of 20mm×20mm (Fig. 4) with uniform arrangement with a perforation rate of about 25%, is installed indoors with C50 light steel keel. The boards has a 381mm thick back cavity, which is filled with a thickness of 50mm and a weight of 48kg/m³ centrifugal glass wool, and a maintenance structure of 40mm thick reinforced concrete slab is added to the periphery. (Fig. 5). This type of installation has good sound absorption and is also suitable for sound insulation in rooms of five-star hotels. In the process of assembly construction, it is necessary to carefully follow the concept of "labor saving, time saving, energy saving, environmental protection, sustainable development" to guide the construction, and strictly implement the standard construction process to enhance a perfect design[6].
The selection of the interior decoration of the assembly should be carried out simultaneously with the interior decoration design. The ceiling module and the wall module of the medical space should clearly define the key technical parameters such as sound insulation and sound absorption. In the process of installation of ceiling components, considering various holes in the ceiling of different spaces, such as light trough, air conditioning vent, smoke sensing hole, early warning vent and so on (Fig. 6), the movable module board components are appropriately installed to facilitate opening (Fig. 7). At the same time, in order to avoid excessive gaps to absorb medium and low frequency sound, special powder of the same material should be used to fill the gaps so as to obtain good sound absorption and noise reduction effect. On the other hand, the fire protection technical parameters of the material itself need to be paid on focus, giving priority to the selection of recyclable and environmentally-friendly parts. For the management of electrical fires, more attention should be placed on preventive measures[7]. Based on the precast glass fiber reinforced gypsum and inorganic high-strength sound absorbing board selected in the case, the raw material contains crystal water, which can evaporate when heated, absorb heat, and decompose the internal crystalline water to reduce the temperature and reach the level of fireproof grade I. At the same time, the material shows light weight and high strength in mechanical properties, durability is the same as that of the building, and can be recycled (Fig. 8). It is a green environmentally friendly new technology building material, which is very suitable for use in multiple medical spaces (Fig. 9).

Figure 4. Perforation plan of the tested piece GRG.

Figure 5. Installation diagram of the tested piece.

Figure 6. Reserved hole setting for top board.

Figure 7. Single active module component.
Figure 8. The ceiling module of the hospital ward.

Figure 9. Reality images of the top wall module in the hospital doctor's office.

4. Construction

(1) The boards used in the assembled ceiling module and wall module have good sound absorption and noise reduction characteristics. The structural cavity design in the board can purify the sound quality and create a quiet living environment while meeting the contract standard.

(2) The medical space can utilize the characteristics of the board and the principles of architectural acoustics, pay attention to and select the appropriate perforation rate of the board, and assist a variety of soft facilities for sound insulation and sound absorption;

(3) The installation of the assembled ceiling module and the wall module needs to consider the leakage phenomenon of each opening gap. Therefore, the opening of the same type of movable module is needed to adjust the sound environment and facilitate later maintenance, achieving the artistic aesthetic of the roof-wall integration.

5. Prospect

Assembled interior decoration is an innovative way of interior design and decoration. The essence of assembled interior decoration is to solve the quality problem of traditional decoration in a building components way. The core goal is to improve the quality and efficiency of building space and achieve social and economic benefits. Assembled interior is an important part of prefabricated buildings, an important driving force to promote the transformation and upgrading of the construction industry, and an important path to achieve high-quality development and sustainable development of the construction industry\(^8\). With the policy support, the concept of vigorously promoting the healthy development of assembly decoration industry will be deepened step by step. Exploring advanced assembly decoration technology and high-quality development path will be supported by more and more users at all levels. The assembly-type integrated ceiling has the advantages of optimizing and transforming the traditional ceiling decoration and construction mode, and is also an important part of the interior decoration of the fabricated architectural products\(^9\). The demonstration project and promotion example of the top wall system in medical space of many cities is a strong support for the interior decoration technology. It is believed that the assembled interior will be greatly developed.

Acknowledgments

The paper is based on College's scientific research project of Guangzhou Nanyang Polytechnic College, "Exploration and Application of Upgrading Medical Space Roof Wall System Based on Prefabricated Interior Decoration Technology" (NY-2019KYYR-31).
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