Design of Air Conditioning and Ventilation System for Emergency Fever Clinic of a Hospital in Longyan

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Abstract. This paper focuses on the system form, air handling and airflow organization of the air conditioning and ventilation system for emergency fever clinics. In order to ensure that the technical parameters such as regional pressure difference between functional rooms meet the usage requirements and technical standards, the ventilation volume of each area is calculated in this paper based on the principle of air pressure balance, and the applied method can provide an important reference for similar projects.

Keywords: Component · Respiratory Infectious Diseases · Fever Clinic · Air Handling · Differential pressure control · Airflow organization

1 Introduction

Respiratory infections are characterized by rapid transmission, high transmission capacity, high viral load, atypical symptoms, and long treatment time. According to the "light cases can be centralized isolation management and equipped with appropriate medical personnel. The relevant centralized isolation site cannot be isolated at the same time the inbound personnel, close contacts and other people. During isolation management, symptomatic treatment and disease detection should be done, and if the disease worsens, it should be transferred to a designated hospital for treatment" [1]. The treatment plan, the regional governments in China set up emergency fever clinics temporary buildings to deal with such sudden infectious diseases. Based on the design requirements of the prevention and control for emergency cabin hospitals, this paper proposes the design process and design points for the air conditioning and ventilation system of a hospital in Longyan by controlling and calculating the room pressure difference as well as the air supply and exhaust air volume of the emergency fever clinic, which will have significant reference value for the design of such projects later.

2 Project Overview

Emergency fever clinic is a separate building, generally set in a separate area of the medical institution, clearly marked, and the entrance and exit should be independent.

S. H. B. D. M. Zailani et al. (Eds.): ICMSEM 2023, 259, pp. 1650–1661, 2024.
https://doi.org/10.2991/978-94-6463-256-9_168

The project has a total construction area of 1119 m^2 and a height of 4.3 m, with 13 beds, and is a temporary building for a new emergency fever clinic for respiratory class infectious diseases. The distance between the exterior wall of the building and the surrounding buildings or activity places is not less than 20 m.

The emergency fever clinic is equipped with "three zones and two channels" and a spacious treatment space. The hardware facilities of the fever clinic meet the requirements of prevention and control of respiratory infectious diseases, and it should be set up with other functional areas such as general outpatient area (including non-infectious emergency area) and inpatient area in the hospital building with strict hard isolation facilities, in which the flow of people, goods and air should be physically isolated, and the channels should not allow the chance of cross-infection.

3 Air Conditioning and Ventilation System

3.1 Air Conditioning and Ventilation Systems

The comfortable temperature is conducive to the normal work of the medical staff wearing protective clothing and is also more conducive to the health of patients. At the same time, in order to ensure the amount of ventilation and air exchange in the room, as well as to ensure the pressure gradient in the room, combined with the respiratory infectious disease hospital building and other relevant codes, the main room indoor environmental control parameters of the project are shown in Table 1.

3.2 Project Overview

Reasonable In order to avoid cross-infection and to form a reasonable pressure gradient and airflow direction in the room, the ventilation system inside the emergency fever clinic should be designed with reference to the Building Design Code for Infectious Disease Hospitals (GB50849-2014) and Requirements Of Environmental Control For Hospital Negative Pressure Isolation Ward(GB/T 35428-2017). Each area should ensure a certain pressure gradient, for example, the clean area and outdoor relative to the semi-polluted area, the polluted area should maintain a positive pressure. The flow direction of the air flow organization should ensure the direction of flow from the clean area → semi-polluted area → polluted area. Semi-polluted area, polluted area and clean area of the air supply and exhaust system should be set up separately. Building through the polluted area, semi-polluted area exhaust ducts should not cross the clean area again [2].

All functional areas of the project use air-cooled heat pump type split air conditioning and fresh air system, cooling in summer, heating in winter, split air conditioning are with auxiliary electric heating. Fresh air is provided by the direct expansion air conditioning unit. The fresh air and exhaust system are set up independently according to the functional partition.

3.3 Air Treatment Measures

The new air unit of this project should be a direct expansion type combined air conditioning unit. All the fresh air systems in the emergency fever clinic area, the semi-polluted

Table 1. MAIN ROOM INDOOR ENVIRONMENTAL CONTROL PARAMETERS OF KEY PROJECT

Room Name	**Summer**		**Winter**	**Minimum Fresh Air Volume**	**Allowable Noise Level**
	***Temperature* (°C)**	***Relative Humidity* (%)**	***Temperature* (°C)**	***Times per hour***	**dB(A)**
Observation Room	26	60	22	6	≦45
Treatment Room	26	60	20	6	≦45
Nurse Station	26	60	20	6	≦45
Laboratory	26	60	20	6	≦45
Emergency Room	26	60	22	6	≦45
CT/DR Room	26	60	22	6	≦45
Consulting Room	26	60	20	6	≦45
Medical Hallway	27	60	18	6	≦45
Changing And Resting Area	26	60	22	6	≦45

area and the exhaust air units in the polluted area should have three-stage filters (such as coarse-effect (G4), medium-effect (F7) and sub-high-effect filters (H11)) at the entrance, and the air outlet of the fresh air system should be higher than 2.5 m above the outdoor ground. The exhaust air unit should be box fan and set at the end of the negative pressure side of the exhaust air pipeline, set at the outdoor [3].

3.4 Air Flow Organization Design

The most critical thing in the design of airflow organization is the relationship between the location of the air supply and exhaust air outlets, such design specifications and related standards require: "The air supply outlet should be set in the upper part of the room; the exhaust air outlet of wards, consultation rooms and other polluted areas should be set in the lower part of the room, and the bottom of the room exhaust air outlet should not be less than 100 mm from the ground" [3], indoor airflow in polluted areas The organization should be conducive to the control of pollutants and their discharge as soon as possible. The vent in the ward is mainly arranged in the lower part of the bed and the top of the bathroom, where the position of the lower vent should ensure that it is not less than 100 mm from the ground, and the wind speed should not be greater than 1.5 m/s to

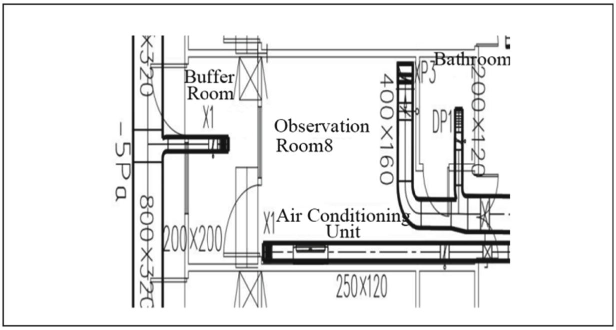

Fig. 1. Air Conditioning and Ventilation Plan of the Ward. Note: X1 is the fresh air inlet; XP3 and DP1 are the exhaust outlets

ensure that the vent can inhale the droplets and aerosols produced by the patient with the shortest range. In rooms such as consultation rooms, outpatient medical and technical rooms, treatment rooms and disposal rooms, in order to ensure that fresh airflow reaches the working area of medical and nursing staff as a priority and that polluted airflow can be discharged in a timely manner, all air vents should be set in the lower part of the room and air supply vents in the upper part of the room. See Fig. 1 for the air conditioning and ventilation plan of the ward.

3.5 Safe Distance Between Outdoor Air Inlets and Outlets and the Arrangement of Roofing Equipment

When dealing with such respiratory infectious diseases, the air supply inlet and exhaust outlet should be set reasonably. Meteorological conditions, surrounding buildings, structural loads, building elevations, air inlet locations and other factors are the main influencing factors. The south-west direction is the most windy direction in Longyan, so it is advantageous to place the exhaust air inlet centrally on the east side of the roof of the building, and downwind of the air inlet, while the exhaust air unit should be far away from the densely populated area and should take corresponding protective measures. Fresh air should be introduced from outside and the inlet should be located in a clean outdoor area.

Exhaust air should be discharged overhead, and the horizontal distance between the exhaust air outlet and the new air inlet should not be less than 20 m, or not less than 6 m above the new air inlet; other pollution sources and the new air inlet should not be set on the same side of the building, and the above safety distance should be maintained. For the air ducts that are 6 m high beyond the roof, steel brackets should be set up to support them, and the structural expertise should be mentioned, and the air outlet should be set up with a conical air cap for high altitude discharge.

3.6 Condensate and Equipment Reliability

Condensate and Equipment Reliability.

Contact or possible contact with respiratory infections, contaminants (blood, body fluids, secretions, vomit and excreta, etc.) and their contaminated objects or environmental surfaces will cause the spread of viruses. In order to block the transmission of viruses more effectively, the condensate system of the air-conditioner in this project is discharged in zones (i.e. contaminated zone, semi-polluted zone and clean zone) and discharged to the medical wastewater in each zone in the form of indirect discharge The condensate from the air-conditioning system will be discharged to the medical wastewater system of each zone in an indirect way, and will eventually be concentrated into the disinfection tank for unified treatment [4].

Reliability of the Equipment.

In order to prevent contaminants from escaping from the wards, to prevent cross-infection, to ensure the relative pressure of the wards and other infectious rooms, to ensure the stable operation of the air supply and exhaust systems, the fresh air conditioning units should be equipped with standby fans and the exhaust equipment should be equipped with standby units, and each redundant The equipment can be switched over quickly and automatically in the event of a fault.

4 Room Pressure Control and Ventilation Rate Calculation

4.1 Pressure Difference Control Principle

The main feature of this type of infectious disease medical building is effective isolation and protection, so the primary task of designing this type of project is not to ensure the pressure difference between the functional areas and prevent cross-infection. The pathways of cross-infection are divided into two main categories: one is infection between patients and patients; the other is infection between health care workers and patients. As the patients admitted to this type of emergency fever clinic belong to the same type of group, priority should be given to preventing cross-infection between doctors and patients, and then to preventing cross-infection between patients through a careful division of patient areas. In summary, the pressure gradient of this type of project exists in the following relationship: so that the airflow is organized along the clean zone → semi-polluted zone → polluted zone single flow; the pressure difference between adjacent and connected rooms of different pollution levels is not less than 5Pa.

4.2 Design Static Pressure of Each Functional Room

The plan layout and static pressure of the emergency fever clinic hall in this project are shown in Fig. 2, the laboratory room is −15 Pa, the consultation room is −10 Pa, the clinic hall is −5 Pa, the pharmacy, the charge office is 0Pa.

The layout and static pressure of each room in the ward area is shown in Fig. 3, the ward bathroom is −20 Pa, the ward is −15 Pa, the buffer/patient corridor is −10 Pa, the medical corridor is −5 Pa.

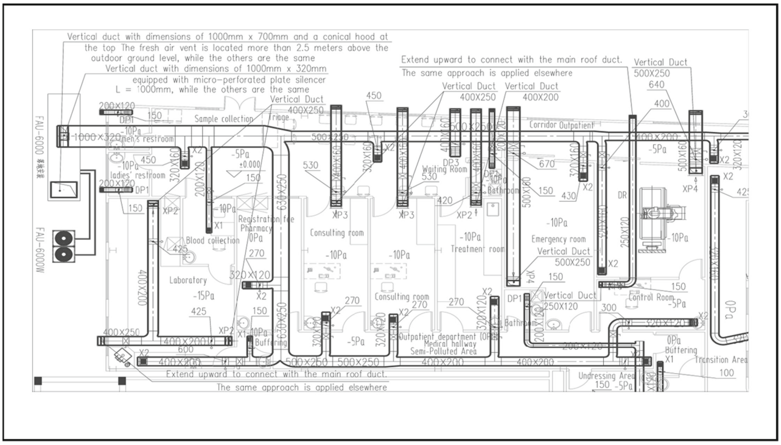

Fig. 2. The plan layout and static pressure of the emergency fever clinic hall in this project

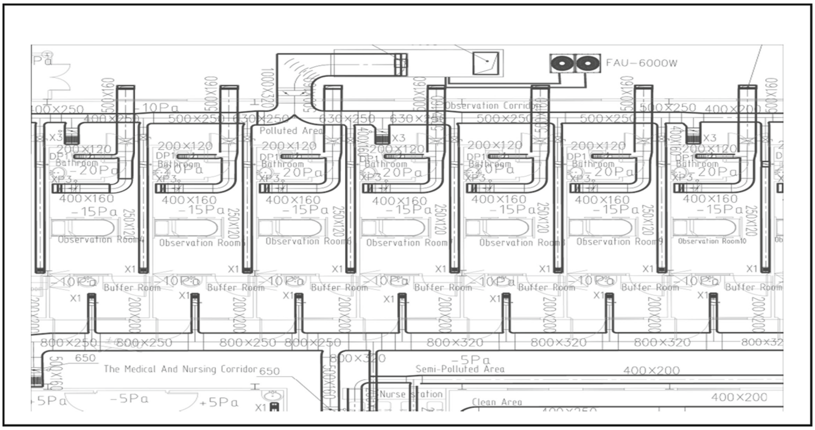

Fig. 3. The layout and static pressure of each room in the ward area

The static pressure of each room in the clean area in the fever clinic is shown in Fig. 4, with −5 Pa in the bathroom, 5 Pa in the medical and nursing aisles, and 10 Pa in the duty room and lounge.

The static pressure and layout of each room in the sanitary passages in the ward area and as shown in Fig. 4, the medical and nursing aisle in the clean area is 5 Pa, the dressing area is 5 Pa, the buffer area is 0 Pa, the undressing area is −5 Pa, the transition area is 0 Pa, and the nursing corridor is −5 Pa.

4.3 Differential Pressure Control Strategy

In order to ensure a reasonable pressure difference between each functional room and its surrounding area, the design process should be based on the static pressure of each

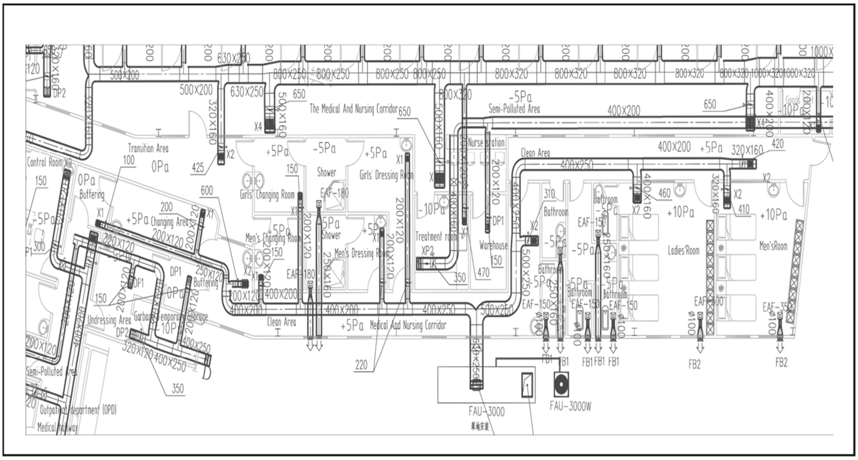

Fig. 4. The static pressure of each room in the clean area in the fever clinic. The static pressure and layout of each room in the sanitary passages in the ward area

functional room to calculate the air supply and exhaust volume of each functional room and each area, and reasonably select the air supply and exhaust system units, in order to facilitate the adjustment of the air supply and exhaust volume of each room, constant air flow valves should be set at the air supply and exhaust branch pipes of each room. As the airtightness of doors, windows and other envelope structures in the rooms seriously affects the control of differential pressure, special attention should also be paid to the cooperation with the architectural profession, and in the construction process, attention should be paid to the sealing and blocking of various ducts through the floor and wall openings [3].

As the air volume in each air supply and exhaust system is changing, and the actual system conditions in the air ducts are also adjusted in real time, in order to better adapt to the rapid pressure difference commissioning after construction, and also to ensure that the changes in pressure loss due to changes in filter resistance in the operation of individual systems, each air supply and exhaust fan is recommended to use variable frequency fans. At the same time, a micro differential pressure display device should be set up within visual range of the personnel to facilitate timely monitoring and control of the differential pressure in the room [3].

The control of differential pressure is an important measure for static isolation, which can only be achieved with the doors closed. Considering the personnel access, door opening and closing, the temperature difference between adjacent rooms will produce the reverse flow of airflow, so between the areas (contaminated area, semi-polluted area, clean area) and between the functional rooms with strict pressure gradient requirements, it is necessary to achieve dynamic isolation through the sanitary passage area and buffer zone. Isolation in the true sense of the word requires good static and dynamic isolation in order to achieve, in order to make the airflow organization from the clean area to the semi-contaminated area to the contaminated area of the one-way flow of air.

5 Calculation of Ventilation Volume

5.1 Calculation Method

Accurate calculation of supply and exhaust air volume is an important link to control the pressure difference and ensure the pressure gradient. According to the principle of air balance, combined with the requirements of the relevant codes, the exhaust air volume of the functional room should take into account the various air volumes into and out of the functional room (i.e. local exhaust air volume, infiltration air volume, fresh air volume, etc.), where the fresh air volume of the functional room can be clarified according to the requirements of the relevant codes, such as the Code for the Design of Infectious Disease Hospital Buildings (GB50849-2014), etc. Figure 6 shows the principle diagram of room air balance.

As shown in Fig. 5, the exhaust air volume of the functional room = Σ infiltration air volume + room fresh air volume - (Σ infiltration air volume + local exhaust air volume). According to the relevant provisions of the Code for the Design of Infectious Disease Hospital Buildings (GB50849-2014), "the exhaust air volume of each room in the contaminated area shall be greater than the fresh air volume of 150 m^3/h" [5]. From the formula for calculating the exhaust air volume in functional rooms, it can be concluded that this provision is only for the situation where only infiltration air volume and supply air volume are available in functional rooms (the difference in air volume of 150 m^3/h is the minimum air volume, which refers to the air volume infiltrated through the doorway in functional rooms at a minimum pressure difference of 2.5 Pa), while for rooms in certain contaminated areas (e.g. medical and nursing corridors, patient passages, buffer rooms, etc.), the following two air volumes are to be considered: The air volume infiltrated in the clean area and the air volume infiltrated by the buffer room of the ward. The calculated exhaust air volume may be very small or may not even be required.

In the design process, for the cleaning aisle in the cleaning area, it is often found that the exhaust air volume obtained according to the above formula for calculating the exhaust air volume in the functional rooms is negative, which means that the area does

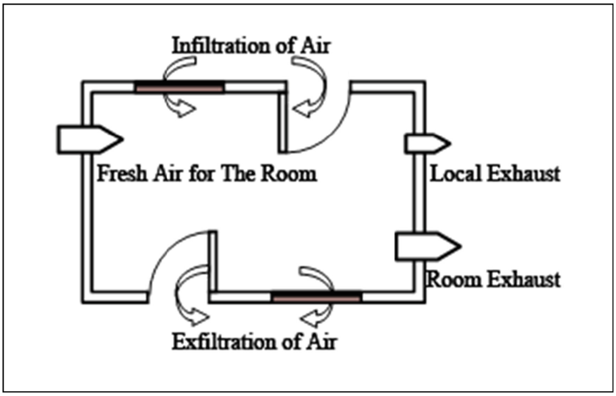

Fig. 5. Room air balance schematic diagram

Table 2. THE CALCULATION RESULTS OF THE INFILTRATION ON AIR VOLUMES OF TYPICAL DOORS AND WINDOWS

Pressure Difference (Pa)	**Single Door (Width × Height) (m)**		**Double Door (Width × Height) (m)**		**Pass-through Window (Width × Height) (m)**	**Exterior Window (Width × Height) (m)**
	0.9 x 2.2	**1.1 x 2.2**	**1.1 x 2.2**	**1.5 x 2.2**	**0.6 x 0.6**	**0.6 x 1.7**
5	120	135	180	196	10	19
10	179	190	254	277		24
15	223	238	317	346		35

not need to be set up with an exhaust air system, but instead the fresh air volume needs to be increased to ensure the balance of the area and the accuracy of the pressure gradient in the area. The reason for this is that the local exhaust air volume of the adjacent rooms in the clean walkway (e.g. bathroom, changing room, store room, etc.) is larger, and the air volume infiltrated into the adjacent semi-polluted area is also quite a lot, plus the design process in many cases the new air volume is only considered according to the specification requirements of 6h-1, so there is a negative value of the calculated exhaust air volume of the clean walkway.

The infiltration air volume Q is calculated according to the gap calculation method in the Clean Plant Design Code (GB50073-2013) as follows [6]:

$$Q = a \sum (qL) \tag{1}$$

where a is the safety system, determined in accordance with the airtightness of the enclosure, usually taken as 1.1 ~ 1.2; q is the air leakage volume per unit length of the gap under the conditions of this enclosure, $m^3/(m.h)$, when the clean room is a certain determined pressure difference value, according to the Clean Plant Design Code (GB50073-2013), Article 6.2.3, Table 7 of the article description; L is the gap of the enclosure length, m. The calculation results of the infiltration air volume of typical doors and windows are shown in Table 2 [6].

5.2 Calculation of Typical Room and Area Ventilation

The results of the typical room ventilation calculation for each emergency fever clinic area are shown in Table 3.

6 System Control

In the face of the prevalence of respiratory infectious diseases, ventilation and air conditioning system control is a guarantee of the normal operation of emergency fever clinics. In terms of system setting, regulation and operation, the following points still need to be noted:

Table 3. THE RESULTS OF THE TYPICAL ROOM VENTILATION CALCULATION FOR EACH EMERGENCY FEVER CLINIC AREA

Functional Room	**Room Static Pressure (Pa)**	**Room Fresh Air Volume (m^3/h)**	**Infiltration Air Volume (m^3/h)**	**Exfiltration Air Volume (m^3/h)**	**Local Exhaust Air Volume (m^3/h)**	**Room Ventilation (m^3/h)**
Waiting Area	−5	887	313.4	817	0	383.4
Diagnosis Room	−10	270	258.9	0	0	528.9
Observation Patient Pathway	−10	1469	691	2675.2	0	−515.2
Nurse Corridor	−5	2550	297	2534.8	0	312.2
Buffer Room (Nurse Corridor to Observation Room)	−10	150	150	300	0	0
Observation Room	−15	260	329.6	0	120	496.6

6.1. Reasonable control of the air supply and exhaust system. The start-stop control strategy for the supply and exhaust system is as follows: for polluted areas: ensure that the supply fan is turned on only after the exhaust fan is turned on; when it is turned off, the opposite is true, i.e., ensure that the supply fan is turned off before the exhaust fan. For clean areas: when opening, the supply fan should be started before the exhaust fan; when stopping, the supply fan is closed after the exhaust fan. The air supply system and the exhaust fan of the air supply system should adopt variable frequency and manual adjustment measures.

6.2. In order to ensure the reliable operation of the unit within the supply and exhaust system, it is necessary to monitor the differential pressure of the filters within the unit and provide timely feedback on the signal that the equipment requires maintenance through the alarm device on the differential pressure sensor.

6.3. The split air conditioner is controlled by remote control. The remote control is managed by the medical staff in a unified manner.

6.4. The electric heater comes with its own control device, which can be adjusted in three levels: high, medium and low, according to the change in outdoor temperature at the project site.

7 Conclusions

The key to winning the battle against such respiratory diseases is the early isolation and treatment of patients with suspected respiratory infectious diseases, and the emergency fever clinic plays an important role as a place used only to admit and treat patients with suspected respiratory infectious diseases. Because of the potential for aerosol transmission in the emergency fever clinic area, the pressure gradient distribution in the emergency fever clinic area, the number of air changes in each functional room, the dynamic isolation control of each area, and the rationality of airflow organization are all particularly important, and these are closely related to the design of the ventilation and air conditioning system of the project. During the operation of the ventilation and air conditioning system, the difference between the fresh air volume and the exhaust air volume is monitored and fed back in real time by making full use of the automatic control system to ensure the stability and orderly gradient of the differential pressure throughout the emergency fever clinic. To provide a better recovery environment for patients and to ensure the safety of health care workers exposed to this highly concentrated aerosol confined environment for a long time, the emergency fever clinic reduces the aerosol concentration in the room as much as possible through a reasonable ventilation and air conditioning system to reduce the risk of cross-infection. The following summary of the design is provided for subsequent reference by the designers:

7.1. For emergency fever clinics or similar places, choosing appropriate air handling measures to prevent cross-infection requires the reasonable arrangement of airflow organization and selection of appropriate HVAC system form, such as separating fresh air vents from exhaust air vents and utilizing high-efficiency filters.
7.2. To maintain good air flow dynamics and isolation control in emergency fever clinics, it is necessary to reasonably determine the pressure gradient of each region and functional room and calculate parameters such as the exhaust air and fresh air volumes based on principles of airflow balance. Technical measures such as setting fixed air volume valves and airtight valves in branch pipes can ensure the rooms reach a reasonable pressure differential control, thus preventing cross-infection.
7.3. In the design of temporary emergency fever clinics, in addition to meeting basic design specifications and requirements, it is also necessary to consider factors such as completeness, rationality, feasibility, cost control, and rapid implementation. The design should respect principles of building environment, safety, and sustainable development to achieve reliable safety, economic rationality, environmental protection and energy conservation, high efficiency, and rapid implementation.

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