Preliminary Study on Natural Ventilation for Hospital Building in Hot and Humid Regions

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ABSTRACT

This essay proposes the necessity of natural ventilation of the hospital buildings in the hot and humid regions from the perspective of energy saving. It integrates the existing natural ventilation technologies from traditional houses and other types of buildings in such area to further investigate the natural ventilation design methods for the purposes of energy saving and requirements satisfaction, thus to provide useful data for the engineering design in the future.

KEY WORDS
Hot and Humid Regions, Hospital, Natural Ventilation, Passive Design

1. INTRODUCTION

In today’s world, the energy issues which are drawn more attentions worldwide are generally recognized as one of the four survival prerequisites we are facing. It is estimated that the population will come to 10 billions by the end of this century, resulting in more severe conditions of energy consumption.

The energy consumption of buildings has been taking a significant proportion in energy consumption of human life. According to the experiences from industrial developed countries, the building energy consumption took a ratio of 35% in total energy consumption. In China, the building energy consumption holds 1/3 of total energy consumption and is still increasing.

Being different from normal civil buildings, the hospital building is a fairly complicated form in public architectural design field involving a lot of specialties, as there are too many types of energy required for hospital operation. Based on relevant data, the hospital energy consumption is 1.6-2 times than normal public buildings. Nowadays, the hospital buildings in China in fact have faced with tremendous energy consumption pressure which drives us to focus on energy-saving researches. The energy-saving hospital is not only for reducing the operation cost of hospital, but also to lighten the burden of maintenance cost for medical services.

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2. NATURAL VENTILATION DESIGN FOR BUILDINGS IN HOT AND HUMID REGIONS

2.1. Climate features

The climate in the hot and humid regions features as high rainfall amount, high humidity and temperature, strong sunlight, and violent lightning. The humidity and temperature are stable all the year. The year-around temperature is about 27℃ with large amount of rainfall, while the humidity is 80%-90%, therefore, such regions are under hot and humid conditions all the year.

Such climate condition, existing in widely areas of China, is a combination of high temperature and high humidity. The energy consumption of the buildings under this kind of climate condition inevitably become a major issue to be solved if we aim to achieve absolute conformity and modernity of architecture.

2.2. Basic design principles of the buildings in hot and humid regions

Following factors must be taken into account for the buildings in hot and humid regions: heat protection, moisture proof and good ventilation in summer; but cold proof and heat preservation in winter are not necessary. Open design is preferred in overall planning, individual design and structure processing, making good use of natural wind; the building shall avoid a western exposure with sunshade; storm rain, flood, moisture and lightening proofs shall be seriously considered.

2.2.1. Heat protection

In hot and humid regions, the temperature in summer is very high and lasts so long that heat protection is the priority task for the buildings in this area. Amongst building shading is the most effective way to isolate the heat. Many shading methods are adopted for the hot and humid regions, from large cantilevered roof used in traditional houses, "Special shading method invented by Professor Xia Shichang" that is commonly used in Guangdong and Guangxi, to modern building shade. All are designed to reduce direct radiation from the sun onto the building, while using shading structure to improve ventilation performance for heat dissipation.

2.2.2. Moisture proof

Most hot and humid regions laid along the ocean or are located where rivers and lakes are spread over, so the relative humidity in such areas are greater than that in inlands. As a result, the adjustment of humidity in the building should be considered in addition to heat protection and temperature cooling. In particular at the end of spring and the beginning of summer, necessary measures shall be taken for moisture and mould proof of the building envelope, while reducing the effects of high temperature and humidity on human body and improving indoor comfort.

2.2.3. Ventilation

The climate characteristics of high temperature and high humidity in such area determine that the enclosing structure is not good enough to prevent solar radiation from into the room for the traditional buildings, ventilation shall be used for heat dissipation. Ventilation substantially is the flow of air, which is produced by pressure difference of air. The people living here learned a lot of experiences from their construction practices, so as to resist to those climate characteristics of high temperature, long duration, strong solar radiation and greater humidity.

3. NECESSITY OF VENTILATION FOR HOSPITAL BUILDING

Hospital building is high-energy consuming building and energy is used mainly for air condition and illumination. As a case study in Guangdong, electricity consumption of air condition is obviously seasonal, identical to the monthly electricity consumption of the hospital and the average temperature of Guangdong area. Its peak is from May to September, which is the hottest period, accounting for 50% of the total monthly electricity consumption. (Fig.1-3) In addition, the electricity consumption of air condition has a close relationship with the number of month using it. Hospitals with good natural ventilation can reduce or even cancel the use of air condition in transition season so that their annual electricity consumptions are lower, while hospitals with bad natural ventilation have to use air condition all year long which leads to a higher annual electricity consumption. (Fig.4) Electricity consumption of
illumination remains the same without seasonal difference. Its difference is caused by the hospital size and the area using natural lighting only.

In summary, speaking of energy-saving of the hospital building, the energy consumption by air conditioner is the very first thing we need to discuss. If we adopt natural ventilation to reduce the burden of air conditioners, the operation costs of the hospital may be reduced as well as of the medical and health services, moreover, it provides high quality indoor air that is comfortable for the patients.

4. STUDY ON NATURAL VENTILATION DESIGN FOR HOSPITAL BUILDINGS IN HOT AND HUMID REGIONS

4.1. Natural ventilation by wind pressure

The wind pressure may be used as the main measure for implementation of natural ventilation in good wind environment. This kind of wind for ventilation by wind pressure is “Through Flow”. According to the wind tunnel test: when the wind flows to the building, the positive pressure only will be generated on windward side of the building by blockage of the building. And, the negative pressure will be generated on appropriate places when the flow bypasses each side and the back of the building. The ventilation by wind pressure refers to such ventilation implemented by the pressure difference between the windward side and the leeward side of the building. The value of pressure difference is related to the form of building, the included angle of the building and the wind, and the ambient environment. When the wind flows to the front elevation in vertical way, the positive pressure at the center of windward side reaches to the maximum value, and the maximum negative pressure appears at the corner and ridge. (Fig. 5)
Another effect caused by wind pressure is the Venturi Effect. When the air flows, the flow rate will be accelerated because of shrinkage of space, thus the shrink section forms a negative pressure zone.

The layout suitable for such climate conditions in this area is that all rooms will be directly ventilated with good sunlight and the balconies or veranda shall be provided around the building. However, such space design is difficult for most of functional spaces in the hospital building. Therefore, all rooms in different position at each floor shall have ventilated air, and the through flow is required for plane design.

According to authors’ experiences, there are two common strategies for hospital building design: 1. The air inlet of each functional area, as reasonable as possible, shall be placed in the dominant wind direction in summer time, without wind-shield wall, and the air outlet is placed on the other side. The inlet and outlet shall be aligned or displaced, so as to guide the air to flow into and circulate in the open plane from one side of the building. 2. Consecutive consulting rooms or wards in rows block the flowing air and shades the corridor space, therefore, the consulting room and ward shall not be arranged consecutively along the side of the building. It is recommended that some rest rooms or waiting rooms are designed in the middle of the corridor to leave the ventilation opening, so as to form through flow by wind pressure, thus to improve the ventilation performance of consulting room, ward and waiting space. (Fig. 6)

The waiting space and consulting room may be designed with courtyard concept, so that the wind can be flown into the room from the windows or holes on the building. When the courtyard window opens, the air may flow into the building for ventilation. (Fig. 7)

Secondly, take an example of bottom overhead method, which has seen more often in traditional building. The hospital building is designed to elevate the ground floor so as to improve slow flow on the ground floor and generate faster free-air speed in where is helpful for directing air flow. In addition, the air into the first floor will be in the building shadow by such overhead design, thus to reduce the air temperature and improve indoor thermal comfort. Except for some public rooms and necessary inspection rooms, the overhead design shall be available to the ground floor of hospital building as practicable as possible so that the internal building will have a better natural ventilation effect in the summer time and transitional seasons as well as a smoother process of thermal pressure ventilation. (Fig. 8)

Furthermore, the two ends of medical spaces shall not be closed, such as clinic and medical technology section, and open design is developed to generate positive and negative pressure difference at the opening of two ends of the building. Such opening is connected to the corridor, resulting in gathering and guidance of the outside air flow because of continuity of corridor, thus to improve indoor ventilation effect. The veranda assists wind guidance, also creates a comfortable zone with cool air due to shading effect, to some extent that the indoor comfort level will be increased.
Figure 6  Schematic diagram of wind pressure ventilation in the hospital (source: capstone project by Zhong Haimin, directed by Zhang Chunyang)

Figure 7  Schematic diagram of wind pressure ventilation in hospital courtyard (source: capstone project by Su Yanjie, directed by Zhang Chunyang)

Figure 8  Schematic diagram of bottom overhead design for guidance of natural ventilation (source: capstone project by Zhong Haimin, directed by Zhang Chunyang)

From figure 9 to 12 are measuring analysis of ENT secondary waiting area of Panyu Central Hospital without air-conditioning, outdoor maximum temperature is 35℃ and minimum temperature is 27℃ in that day. It can be known from the data in figure, in waiting area there almost has lasting natural winds, whose speed is in the range of 0.1-1.0m/s. Since the outdoor temperature is too high, the erature and humidity in waiting area are not effectively reduced too much. Moreover, as the activities of patients, the humidity in middle of waiting area is higher than the other two test points. However, according to the interview, patients in waiting area do not feel discomfortable when they are in high temperature and humidity; on the contrary, the indoor environment with lasting natural winds make them feel more comfortable.

Figure 9  Measuring selected points of ENT waiting area in Panyu Central Hospital

Figure 10  Wind-speed comparison of ENT waiting area in Panyu Central Hospital

Figure 11  Temperature comparison of ENT waiting area of Panyu Central Hospital

Figure 12  Humidity comparison of ENT waiting area of Panyu Central Hospital
Lastly, the ventilation by wind pressure also can be achieved by design of detail structures, in order to optimize the air quality in the room and improve thermal comfort degree.

**Leading wind by sunvisor:**

The sunvisor is widely used in the hot and humid regions. The building sunvisor is not only able to effectively resist solar radiation, but also to change the indoor ventilation performance by adjusting the form of sunvisor and the position in the enclosing structure to improve the indoor comfort, taking the position of wind entering into the room and airflow pattern into account. For example, the louvers may change the air flow upwards or downwards when the wind enters into the room; the horizontal sunvisor on the window may direct the air flow upwards; the gap between the horizontal sunvisor and the wall may direct the air flow downwards; when the louvers are fully opened, the wind in wider area may be flown into the room. (Fig. 13)

![Figure 13](source: Allan Konya, Design primer for hot climates)

**Options for window opening:**

Normally, these windows with greater opening and ventilation areas are selected for the hospital building. Opening out by casement window is commonly adopted because of good ventilation and greater opening areas. In case of a higher numbers of opening windows and narrow average width of opening window, the vertical hung window can be fully opened and reaches the maximum ventilation rate with air leading effect, so it is recommend as well. The doctor offices, as auxiliary function of the hospital, are always located in west-east direction, the louver (i.e. vertical hung window) is preferred to meet the requirement of wider ventilation area and direct air flow in the summer time and transitional seasons for the purposes of sun-shading and air leading effect.

In order to improve indoor ventilation performance, it is suggested that the upper ventilation window shall be set up on the partition in the corridor and ventilation louver is provided on the doorstop to reduce hot air circulation.

**4.2. Natural ventilation by thermal pressure**

Another principle for natural ventilation is the thermal pressure difference generated by the air inside the building, which is so called “Chimney Effect”. The thermal pressure difference in the building, namely, “Chimney Effect”, can be used to achieve natural ventilation for the buildings which are affected by the layout of surrounding buildings and tall plants. According to the principle of rise of hot air, the dirty hot air is vented out from the upper air outlet, and the outside fresh cold air is sucked from the building bottom, in order to implement natural ventilation. In building design, the vertical chambers, like stair well and atrium shall be designed to meet the elevation difference of air inlet and outlet. The higher the temperature difference of inside and outside temperatures and elevation difference of air inlet and outlet, the more obvious the thermal pressure effect. Being different from natural ventilation by wind pressure, the ventilation by thermal pressure is more suitable to the ever-changing and adversely outside wind environment.

The courtyard may be designed for the hospital building in the hot and humid regions. The courtyard is one of well-known characteristics for Chinese residence. In the hot and humid regions, the traditional residences use such structure to create a good indoor ventilation condition. The courtyard design for the hospital building reflects the thermal pressure effect used by theses residences in the hot and humid regions, so as to improve the natural ventilation performance.
1. Light roof prolongs from the surface and open a window on the side of prolonged section as the air outlet, utilize and heat the accumulated air. Under heat pressure drive, the airflow is inhaled from the windows at each floor and then vent out after rise, thus to strengthen the chimney effect of the courtyard, and use the thermal pressure to provide side ventilation for the courtyard. (Fig. 14)

2. Set up exhaust chimney and increase height of air outlet, add the elevation difference of air inlet and outlet and the thermal difference of the air in the courtyard, and improve the natural ventilation by thermal pressure.

3. Combine the courtyard design to set up an integrated ventilation channel, use the courtyard space as the ecological exchange space, conduct overall design on building structure layer and courtyard space, and create an integrated ventilation channel to facilitate the natural ventilation of hospital building.

4. Set up pitched skylight to catch the wind on the windward side, and bring the outside natural wind into the courtyard to form natural ventilation; utilize the wind pressure difference of front and back of the pitched skylight on the leeside to draft the indoor air for coordination of courtyard ventilation.

4.3. Combination of wind pressure and thermal pressure for natural ventilation

Due to the building is subject to the weather conditions, geographic location, ambient environment and building layout, the natural ventilation design is normally combined by wind pressure and thermal pressure in practical application. The wind pressure and thermal pressure play different roles. In the less deep sections, the wind pressure is prevail for ventilation, while in the deeper sections, the ventilation by thermal pressure is adopted. (Fig. 15)

Taking the Shenzhen Binhai Hospital as an example. There are air vents provided at the front and back of the hospital street so that wind pressure ventilation will be achieved. In addition, the top of hospital street has an elevated roof to provide a good lighting condition without direct radiation from the sunlight. Therefore, the whole elevated roof forms the ventilation by thermal pressure and eliminates the hot air on the top as well. As mentioned above, the Shenzhen Binhai Hospital is able to implement the ideal natural ventilation by combining the wind pressure and thermal pressure, thus to significantly reduce the energy consumption. (Fig. 16)
4.4. Assisted mechanical ventilation

In some large-scale buildings, due to longer ventilation path and greater flow resistance, the natural ventilation hardly can be achieved only by wind pressure and thermal pressure. For those cities with serious air pollution and noise pollution, the direct natural ventilation will be harmful for human health when it brings the awful air and noise into the house. In this case, the assisted mechanical ventilation system is usually adopted. This system has a full set of air circulation channels, supplementing by some air treatment methods satisfying the ecological concepts (for example, soil pre-cool, pre-heat, heat exchange of deep well water, and it facilitates indoor ventilation by certain mechanical means. Comparing with fully natural ventilation, the mechanical plant with auxiliary power may consume a certain volume of energy, but this system is able to re-organize the air flow to achieve a better performance of natural ventilation.

The roof of hospital street of Guangdong Panyu Central Hospital is designed to a ventilated roof. The assisting mechanical ventilation plants, water curtains, are provided at the two sides of the roof, in order to reduce the temperature of hospital street and purify the air quality for natural ventilation. (Fig. 17)

5. CONCLUSION

The air conditioners used for hospital building in the hot and humid regions have enormous energy consumption. This essay discusses about the design strategies of hospital building in the hot and humid regions from the perspective of energy saving, and makes a contribution for constructing a energy-saving and adequate hospital building.

Figure 17 Roof view and water curtains in Guangdong Panyu Central Hospital (source: photographed by the author)

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