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LETTER TO THE EDITOR

Optimal Design of Underground Building Space Considering Ventilation and Thermal Conductivity of Environment

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As a whole of urban space, underground space plays an increasingly important role in the process of urban development. Air environment is a difficult problem for underground building development. In order to improve the indoor air environment of underground buildings, mechanical ventilation is mostly adopted, which will greatly increase the energy consumption cost of the whole underground buildings. Nowadays, when sustainable development and ecological architecture are advocated, the ecological and green development of underground architecture has become an inevitable topic. This paper discusses the possibility of natural ventilation of underground buildings, and makes full use of the research results of ecological ventilation of ground buildings to put forward the corresponding solutions, and studies the possibility of forming a basic mode of ecological natural ventilation of underground buildings.

Underground buildings; Sustainable design methodology; Natural ventilation; Energy saving

I INTRODUCTION

With the accelerating of urbanization process, the development of underground space has become an important part of urban development, people more and more realized the underground space in improving the urban environment, improve the significance of land utilization, and underground structures from the original single function, necessary for the combat readiness to architectural form that has a variety of functions (Albertelli and Strano 2017, Mohsenzadeh et al. 2018). From commercial buildings, public buildings, transportation buildings to office buildings, sports buildings and even residential buildings, underground buildings are meeting more and more social functions (Guo et al 2016, Luo and Li 2017). With the increasing number of underground buildings and their increasingly complex functions, they are no longer attached to the ground buildings, but present themselves to people in a more independent manner. Many scholars have analyzed it and obtained some research results.

Rui Wang published an article in Ekoloji Issue 107, 2019. The title is “Livability Design of Residential Building Environment Space”. This article (Wang 2019) mentioned that with the improvement of people’s living quality, living environment requirements and spiritual pursuit level, life concept has changed from simple “survival needs” to “environmental needs”. Human beings’ living environment requires the return of ecology, and their demand for environment ecology and culture needs to create livable residential areas. The current methods of residential building environment space design have low accuracy in selecting the optimal path, planning the building area, and satisfaction with the design environment space. The design method of habitability of residential

building environment space is put forward. The road network and floor connections on each floor are treated as separate structures. According to the floor distribution of parking spots, the structural network model is used to analyze the path of the floor, and the optimal path through all parking spots in the multi-storey building space is obtained. Basic areas, Shared areas and individual building areas are calculated and planned on the basis of a hierarchical structure. Interior design of residential buildings through spatial shapes, lighting and colors. The outdoor environment space of the residential building is planned and designed by architectural style, road space and green space. The combination of interior design and outdoor design completes the livability design of residential building environment space. The experimental results show that this method has high accuracy in selecting the optimal path, building planning accuracy and residents' satisfaction with the design environment and space. Based on the above research, this paper proposes the optimal space design of underground building considering the environmental ventilation and thermal conductivity characteristics.

The air environment quality of underground buildings is not optimistic due to the closed environment, the inherent deficiency of poor ventilation, and the increasingly complex objective reality of underground building functions, which has become the main aspect affecting the comfort level of people in underground environmental activities. The pollutants in the air environment of underground buildings are mainly composed of the following parts:

Inhalable particulate matter refers to solid and liquid particulate matter with particle size less than 10m and carried by air. Because the underground building is relatively closed to the ground, the proportion of inhalable particles entering from the outdoor is small, which is mainly caused by people's indoor activities, such as walking dust, clothing dust and smoke, as well as dust caused by special environment, such as the high concentration of iron powder in subway stations.

Carbon monoxide and carbon dioxide. The main source of carbon dioxide in underground buildings is human beings. An adult in a quiet state exhales about 20 L of carbon dioxide a day and night. Under normal circumstances, carbon dioxide is non-toxic, but when the concentration reaches a certain level, people will feel uncomfortable. Due to the particularity of the underground environment, the recommended standard of carbon dioxide in the underground environment in China is 0.07%, 0.15%, and the highest is no more than 0.2%. The main source of carbon monoxide in underground buildings is smoking. Carbon monoxide emitted from a cigarette is 20 mg of mainstream smoke and 80 mg of secondary smoke. Kitchens and diesel generators are also a source of carbon monoxide. Due to the high concentration of carbon monoxide in automobile exhaust, the concentration of carbon monoxide in underground parking garage is relatively high. Japanese parking regulations stipulate that the concentration of carbon monoxide should not exceed 0.01%. Because the majority of underground buildings are used for commercial and public purposes, making a large number of indoor decoration is essential, so the air produced a lot of formaldehyde pollutants, its main impact on human health is smell odor, eye irritation and respiratory mucosa, allergic reaction, etc.

Volatile organic compounds (VOCS) refer to organic compounds with saturated vapor pressure greater than 70 Pa at room temperature and boiling point less than 260 at room pressure. They are mainly derived from decorative materials and coatings. Their health effects on human body are mainly stimulative, especially on eyes, nose, throat, face, head and neck skin (Yuan et al 2017).

Biological pollutants are one of the three major indoor pollutants. Due to the poor air mobility, strong airtightness and humid environment of underground buildings, infectious diseases can spread. With the outbreak of SARS epidemic in 2003, China has attached greater importance and requirements to this aspect. Radon is an inert gas derived from the decay of radium, which mainly exists in rocks and soil, and is also a prominent air

pollutant in the underground environment. Generally speaking, radon is mainly emitted from the soil within 3 m, among which the proportion within 1 m accounts for about 50%. Radon is one of the main causes of lung cancer. The standard maximum value of radon and its daughter content in the United States is 0.03 WL, and 0.01 WL for schools and houses. Experiments have proved that the combination of underground buildings and ventilation can effectively reduce the concentration of radon. Generally speaking, doubling the ventilation volume can roughly reduce the concentration of radon by 50% and reduce the concentration of radon daughter by 75%.

II IDEA DESCRIPTION

People in the closed, poor air environment of the building will appear in discomfort, allergy and other symptoms, usually we call sick building syndrome (SBS), will produce such symptoms of the building is called sick building, it has been proved that sick building is mainly caused by indoor air pollution. Ventilation is closely associated with air quality, according to a 1987 study by the national institute of occupational safety and health. In order to dilute the air pollutants, maintain indoor air clean, make the mechanical ventilation system of underground building must spend a lot of energy to maintain the necessary ventilation, due to objective reasons relative to ground buildings, underground structures spend on ventilation and lighting energy is much big, underground construction in the past for civil air defense engineering and warehouse under the condition of this disadvantage is not obvious, but as more and more people to the underground construction activity, it is increasingly prominent. In today's sustainable development, how to save energy through natural ventilation in underground buildings is an urgent issue to be studied. According to the experiment, it is feasible to realize natural ventilation of underground building at night and in some seasons. In addition, good energy saving effect can be achieved through the combination of mechanical ventilation and scientifically designed controllable natural ventilation system. At present, about 15% of China's electric energy is consumed by air conditioners, among which fresh air accounts for 25% and 38%. This proportion is even higher in underground buildings. For example, a two-storey civil air defense project of more than 6000 m^2, of which the power of the ventilation and dehumidification machine is about 148kw if it is used in the first floor. The high cost of use limits the use of underground buildings. Therefore, it is urgent to study the energy conservation of underground buildings by means of natural ventilation (Cheng et al 2016, Zhao 2016).

Natural ventilation, as a major way of energy saving in sustainable buildings, has become a synonym for it. A large number of studies and practices on natural ventilation have been made in the researches on sustainable buildings abroad. Although most of them are ground buildings, there are many experiences and methods worth learning from.

Natural ventilation refers to the movement of air under the action of wind pressure and thermal pressure, which is embodied in the air flow through the gaps and Windows of the wall. According to the formation principle of natural ventilation, we need to consider the orientation, orientation, permeability and the opening degree of doors and Windows of the building, and promote and control the natural ventilation inside the building by setting atrium (patio) that reaches to the top, special air inlet and exhaust ducts, and well-designed air paths. We can draw lessons from these studies and practical buildings, especially large commercial and public buildings' natural ventilation design experience. In addition, some special forms of underground architecture (caves, houses covered with earth, etc.) also have successful experience in utilizing natural ventilation.

For a large depth floor of 50 m × 50 m square, the natural ventilation design was carried out, and the experiment simulated by the designer confirmed that the traditional draught design from one side of the building to the other side was not feasible (most underground commercial complexes are of such a large depth, and the

draught-style building form cannot be realized). Designers put the building (coventry university library) is divided into four parts and respectively set up four ventilation raise their air supply, exhaust gas through the atrium and set up in the exhaust chimneys around the building, it is a driven by thermal displacement ventilation design, by reducing the distance between the air inlet and air outlet, and good ventilation and the details of the design (e.g., in order to prevent the top may appear the airflow stagnation phenomenon and plus four exhaust chimneys) to achieve sustainability ventilation design without mechanical ventilation.

By introducing underground ducts to ground air to achieve the aim of natural ventilation, for the small size, buried depth of underground engineering have certain effect, but in what is now the embedded depth of underground construction is generally larger, more realistic conditions only to depend on wind pressure to solve the problem doesn't work, so some dominated by hot pressing problem solving measures are put forward. According to the actual measurement, the natural ventilation of underground building changes with the change of internal and external thermal pressure.

It is well known that in addition to the necessary entrances, vents and lighting patios, underground buildings are basically an airtight body with a very thick rock and soil layer as its surrounding structure, which has good thermal stability. According to the actual measurement, the indoor temperature of underground building is lower than the outdoor temperature in summer, but higher than the outdoor temperature in winter. The temperature difference between them promotes the internal and external thermal pressure of underground building to form natural ventilation, which is an incomparable advantage of ground building. According to the experimental data, we can clearly see the rule of using thermal pressure ventilation in underground buildings, and prove the possibility and regularity of natural ventilation in buildings under specific conditions. In the design of our underground buildings, we can draw lessons from the natural ventilation design method of modern sustainable buildings mentioned above, and achieve our goal of energy saving by carrying out effective and controllable natural ventilation design.

About the large-scale underground structures of multilayer we met many problems in the design of natural ventilation, first, because its size is larger, buried depth is bigger also, so rely on with a hood vents ventilation can't meet the need of underground structures, so we should use the underground construction general design elements and advanced concept to design, especially the formation of the wind road. How to introduce fresh air into underground buildings and discharge indoor air is the key and difficult point of wind road design.

First we need to make full use of the role of the patio (atrium) in underground buildings. The underground building atrium has become a more common design method, which can improve the indoor environment of underground buildings. However, in the design of the atrium, we not only need to improve the visual environment, but also add natural ventilation factors, use the characteristics of the up and down and connected with the outdoor environment to form a chimney effect, and promote the natural ventilation efficiency of the building. However, in the design, we should pay attention to the atrium as the exhaust system in the whole air path design, because the atrium as the air inlet is not conducive to the evolution of air, in addition, because the atrium of the underground building is also used as the natural light, the atrium has high temperature due to the greenhouse effect, which is not conducive to the introduction of fresh air. Therefore, it is generally used as a vent.

Necessary devices should be installed at the top of the atrium, namely the air vent, to prevent air backflow. Therefore, air preheating devices (using waste heat of recovery equipment or absorbing solar energy) and adjustable skylights can be designed on the top of the atrium to promote and control the air flow according to different situations. And need to pass the wind tunnel test outlet to go through the wind tunnel test to prevent the wind on its formation of stagnation effect, if necessary, can use mechanical auxiliary equipment.

The air inlet chimney is installed. Since the atrium of most underground buildings is located in the center, we set the air inlet around the building. However, we should pay attention to the following aspects in the design:

(1) As some of the intake chimneys are located above the ground, the influence on the ground environment must be considered in the design to achieve harmony with the ground environment.

(2) To avoid as far as possible in the air pollution places (streets, factories downwind). Due to the limited height of the air intake of underground buildings, their fresh air is generally polluted by the city. Therefore, air purification equipment must be set in the air inlet to purify the incoming fresh air and avoid the pollution to the underground environment.

(3) The detailed design of air inlet must be based on wind tunnel test to prevent air turbulence and facilitate air entry. Cooling devices are installed inside the building (cooling the air by introducing underground water) to cause the air to sink, and they are combined with the atrium as the exhaust air passage to form the natural ventilation system of the underground building. When there are fewer air inlets and other conditions that are not conducive to the introduction of fresh air, we can adopt the method of progressive layers, that is, more cooling devices are set at different elevations of the air inlet to enhance the air entry.

(4) In the absence of atrium or atrium can not be used as a vent, the exhaust chimney must be set. Its key points are the same as the exhaust points of the atrium, but it is better to combine with the air inlet in design to reduce the impact on the ground environment. A heat exchanger is arranged between the two to improve their working efficiency on the basis of energy saving.

Establish a controllable and efficient ventilation system and get rid of the misconception that natural ventilation is spontaneous ventilation without control. Modern underground buildings need better sealing and thermal stability. Spontaneous and chaotic natural ventilation can only increase the energy consumption of buildings. In addition, natural ventilation cannot completely replace mechanical ventilation.

Use energy efficiently and improve comfort. For example, during the day when people are crowded, we can combine the two methods to better control mechanical ventilation, so that the ventilation volume can be increased without damaging the comfort level of underground buildings. At night, we can completely rely on natural ventilation to cool down the underground buildings and purify the air.

Indoor need to use advanced ventilation forms, improve ventilation efficiency. We want to mention here is that the displacement ventilation, as a form of reasonable ventilation has been applied in the domestic and international numerous sustainable architecture, which makes use of the density difference of air, through the air inlet and air vents on the ground and ceiling set separately, fresh air from near the ground slowly into the wind inlets, and at the same time will waste air is being exhausted from outlet near the ceiling, promote the air circulation, and make the pollutant discharge quickly. This requires us to increase the floor height in the design of the underground building, to promote the air flow inside.

However, for the shallower floors with lower burial depth, the inlets and exhaust vents that take advantage of the effect of wind pressure can be appropriately set when the thermal pressure effect is not obvious. In terms of design, we should turn the direction of the air inlet towards the dominant wind in summer and away from the dominant wind in winter. The details of the hood design will not be repeated here. However, we can still improve the air flow by setting preheating or precooling devices.

III CONCLUSION

With the rapid development of science and technology and the deterioration of the environment, it seems to be a pair of twins with the progress of human beings. While we are concerned about people’s quality of life, we

need to consider the natural environment on which we depend. Improving and protecting the environment has become a global common topic, and sustainable development has become the main theme of today's world development. As architects, we have the responsibility and obligation to pay more attention to the environment and promote sustainable buildings and sustainable building design methods in an industry that accounts for one third of the world's total energy consumption.

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