Research on Air Purification Wall Based on Heat Exchange Principle

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Abstract. With the acceleration of urban modernization, the use of prefabricated buildings on construction sites is increasing year by year. However, the following problems arise: the environmental quality of construction sites in our country is poor, the living comfort of prefabricated buildings is low, the recycling rate is low, and the indoor air is dirty, affecting the health and comfort of indoor personnel. Therefore, it is of great significance to complete the new wall for indoor air purification. Through the design of the three-layer interlayer, the heat exchange between the inside and outside air and the purification of the indoor air are realized, and a new type of movable plank house wall with low price and simple and ingenious structure is designed, which not only can improve the living comfort inside the plank house, but also can ensure the maximum embodiment of the energy-saving benefits of materials. The experimental results show that the indoor air quality of the air purification wall based on the heat exchange principle is improved by 21.6%, and the indoor temperature change in the air purification process can be effectively avoided.

1. Introduction

In the "13th Five-Year Plan" for the Development of Construction Industry in 2017, it is clearly proposed to promote building energy-saving technologies, organize research and development of renewable energy, new wall materials and external wall insulation, and efficient energy-saving doors and windows [1]. At present, our country is in a period of rapid economic development. The progress of urbanization is accelerating. The construction site area in the city is increasing gradually. As a temporary building, the movable plank house is characterized by easy disassembly, transportation and movement, and its demand is also increasing. However, the traditional movable plank house adopts the color steel plate sandwich wall as the enclosure structure, which has small thermal resistance and thermal inertia and poor thermal insulation performance. Moreover, due to its structural defects, the damage to the wall increases during disassembly and assembly, and the recycling rate is low. In addition, outdoor particulate pollution is serious in our country, and the existing method is to use closed doors and windows to block the entrance of air outside the construction site.

Based on the above background, this paper designs a new type of movable plank house wall with low price and simple and ingenious structure, which will effectively solve the above problems, not only can improve the air quality inside the plank house, but also can ensure the recycling rate of materials and the maximization of energy-saving benefits.
2. Global Design
In this project, the wall is mainly divided into two structures, the integral exhaust and seepage wall and the breathing energy-saving panel wall placed at one corner of the movable panel room. The breathing wall is divided into three mechanism modules, negative ion air purification module, Venturi tube heat recovery heat exchange module and top air cap flow aid module. The principle of heat exchange is applied to realize constant temperature ventilation, and the temperature difference produced by the heat absorbing solar panel and the wind pressure difference produced by the wind cap structure are used as driving forces for indoor and outdoor air circulation, thus effectively reducing the energy consumption of the air conditioner.

The main work flow is as follows: fresh air enters the outer interlayer through a micro louver fan, particles such as PM2.5 are removed through a purification module, and indoor and outdoor air heat exchange is realized through a Venturi tube heat recovery device. Fresh air flows into the room by adjusting the wind direction through the indoor adjustable louver fan to carry out convection heat exchange process, and indoor return air is driven by the temperature difference and the wind pressure difference of the hood module to flow to the outside through the hood.

![Figure 1. Overall device diagram](image)

3. Module Design

3.1. Plate-wall connection mechanism
The connecting mechanism is four "L" shaped rigid plastic material plates with the same size and shape, and two connected module plates are extended at the L-shaped short joint. There are screw hole connections for the fixed connection and disassembly of the two movable plate walls, and two rectangular cavities are left at the L-shaped extension for the insert link modular plate.

The wall board connecting structure with exquisite design structure is easy to assemble and disassemble, can be recycled for many times, and improves the recycling rate.

3.2. Thermal insulation seepage three-layer wall module
According to the principle of exhaust air seepage, when indoor and outdoor air passes through the seepage layer for gas exchange, the heat exchange is reduced, i.e. the increase of indoor temperature in summer ventilation and the decrease of indoor temperature in winter are reduced, and the heat flow is reduced, thus achieving the effect of heat preservation and heat insulation (cold). By searching for the best material of exhaust air seepage layer and estimating and simulating its optimal thickness to improve the thermal performance of the wall panel, the 40mm thickness superimposed reticulated glass fiber is finally adopted as the seepage layer of the wall, which can reduce the air conditioning load and improve the thermal comfort index of the panel room.
The design of the double-layer cavity structure not only facilitates the heat exchange of the gas inside and outside the breathing wall part, but also can achieve the effect of sound insulation and noise reduction and ensure the indoor comfortable living environment.

3.3. Air purification module
A special breathing wall structure is designed in one corner of the board room. Negative ion dust collector, HEPA filter screen and heat recovery device are added. The indoor and outdoor temperature difference and wind pressure difference are used to passively drive air circulation for indoor and outdoor air breathing, thus reducing the air exchange power of the air conditioner. At the same time, it can effectively purify the air entering the room. Indoor fresh air controls the wind speed and direction by adjusting the louver fan to achieve the best human comfort angle.

3.4. Heat exchange module
The heat recovery device is placed in the middle of the corner breathing wall and is cylindrical. Outdoor air enters through the lower louver fan vent and enters the Venturi tube upward to increase the wind speed and create a pressure difference to further strengthen the outdoor air suction effect. And then lead to that room through the heat recovery device, and indoor air enters through an air vent at the low part of the inner wall body and upwards flows into a cold heat exchange pipe of the heat recovery device to exchange heat with outdoor air to the maximum extent.

Cold and heat exchange tubes are mainly made of aluminum foil, composite fiber or alloy steel as base materials, and are processed by adding heat absorbing agents such as lithium chloride, silica gel or molecular sieve and moisture absorbing agents. They have good heat exchange capability.

3.5. Air pressure difference module
The hood mechanism is designed at the top of the breathing wall. It uses the natural wind speed in nature to push the turbine of the fan to rotate and the principle of indoor and outdoor air convection to accelerate and convert the air flow in any parallel direction into vertical air flow from bottom to top to provide power for breathing.

A solar heat absorbing material is installed on the barrel wall of the air cap. One function of the solar heat absorbing material is to produce a temperature difference of heat in the barrel channel, and the temperature difference is utilized to improve the air carrying capacity of the air cap from bottom to top. The second is to supply the negative ion air purification device installed inside the wall with electric power to achieve the goal of no energy consumption.

The wind pressure difference generated by the wind cap and the temperature and pressure difference provided by the solar heat absorption plate are utilized——Passive air circulation is driven for indoor and outdoor air breathing to reduce the air exchange power of the air conditioner.
4. Experimental Verification

4.1. Air quality testing experiment

In order to verify the air exchange performance of the wall, an air exchange performance experiment was carried out. In the same sealed environment with a space size of 1 m×0.8m×1 m, a considerable amount of dust and other air pollutants were artificially produced, and the experiment was carried out by assembling the new and old two kinds of plates. Under exactly the same experimental conditions, the working conditions in winter and summer are simulated respectively. The thermometer is used as an indoor temperature acquisition device, and the air detector detects indoor air.

According to the experimental data, when simulating the winter environment, the indoor temperature of the wall of the new type of plank house decreased slightly by 1.2℃, but the air quality increased by 23.1%. When simulating the summer environment, the new type of plank house wall not only improves the indoor air quality, but also increases the indoor temperature by about 0.8℃ and the air quality by about 20.1%. Because the temperature difference between the inside and outside of the plate simulated under the experimental conditions is different from that under the simulated conditions, under reasonable conversion, the experimental results show that the air purification wall based on the heat exchange principle is obviously superior to the ordinary wall in air purification performance while maintaining the indoor temperature.

5. Benefit Analysis

A small negative ion air purifier is designed at the air inlet in the breathing wall, and clean air after haze removal and purification of outdoor air through the movable plate wall enters the room through the venturi tube heat exchange module for circulation, so that indoor air can ensure the health degree while circulating convection heat exchange. The premise of air purification by common indoor air purifier is to supply air to circulate indoor air through the purifier, and to complete purification when indoor air passes through the purifier, which leads to about 70% energy loss in generating indoor air circulation.

This project works will save this part of energy. The power of the air purifier placed in the wall is only 48W, and the air purifier with air supply function needs 200W. To achieve 50m2 indoor air purification, it takes about 600W anion air purifier to work for 3 hours. Assuming that the purifier works for a total of 6 hours in the morning and afternoon, based on this calculation, the purifier in the wall can save about 2448 W of electricity on average every day.

\[600W \times 6h - 48W \times 24h = 2448W\]  

(1)
According to statistics of Wuhan City in 2015, there will be a haze day for an average of 5 days, i.e. there will be about 73 days of heavily polluted weather in a year. Based on the 0.5 yuan per kilowatt hour, an indoor area of 50m2 can save 87.6 yuan of electricity charge per year.

\[
2.448kW \times 73 \times 0.5 = 87.6(Yuan) \tag{2}
\]

In addition, according to the conservation of energy, the power consumption of the air conditioner is equal to the heat exchanged between indoor and outdoor, and the hot (cold) air in summer (winter) is heat exchanged with the cold (hot) air of the air conditioner circulating outward indoors at the indoor and outdoor gas heat exchange device of the breathing wall part. To reduce (raise) the temperature of the air flowing into the room to the maximum extent and ensure the minimum variation difference of indoor temperature, so as to reduce the refrigeration (heat) power of the air conditioner and realize energy saving and emission reduction, the saved electric energy of this project can be calculated by the following formula.

\[
W_{\text{Section}} = \lambda \times S_1 \times \eta + S_2 \times r^2 \tag{3}
\]

Where:
- \( \lambda \) is the heat exchanger gain percentage;
- \( S_1 \) is the contact area of two gases of the heat exchanger;
- \( \eta \) is the average power required for normal work per hour;
- \( S_2 \) is the square meter of living room;

Here, the size \( S_1 \) of the heat exchanger is 42cm², the gain of the heat exchanger is 1.2 (°C \( \text{m}^2 \)/s with a temperature difference of 7°C or more per square meter, the size of \( S_2 \) room is 50m2, and \( \eta \) is 1.24 kw/h. According to theoretical calculation, the electricity can be saved by kW in one day. Take Wuhan as an example, the heating season is 50 days and the cooling season is 70 days.

By substituting the above data, it can be found that the board room can save 200kW of electricity in summer and 280 degree of electricity in winter. Based on the 0.5 yuan per degree of electricity, the 50m2 indoor breathing wall panel can save 240 yuan of electricity charge every year.

6. Innovative Design

The innovation of this scheme is mainly reflected in the following three aspects:

1) Technical innovation: passive breathing design, temperature difference made by heat absorption solar panel and wind pressure difference made by wind cap structure are used as driving forces for indoor and outdoor air circulation, thus reducing power consumption of air conditioner and realizing energy conservation.

2) Structural innovation: the new wallboard connection structure is easy to assemble and disassemble, can be used for many times, improves the circulation rate, and realizes high-efficiency heat preservation and sound insulation with a three-layer structure of exhaust and seepage.

3) Application innovation: the heat recovery machine installed inside the breathing wall uses the heat exchange principle to realize the heat exchange between indoor and outdoor air, realize constant temperature ventilation and reduce the air conditioning load.

7. Summary

At present, there is a huge amount of movable plank houses in our country, which are often used in workers’ dormitories, offices, canteens and warehouses, factory buildings, scenic spots, construction sites, disaster areas and many other places. People will use movable plank houses as space for activities. Cement prefabricated houses and prefab house are mostly used in prefabricated houses. Domestic prefabricated houses have numerous and complicated industries, but the market with the
greatest demand for prefabricated houses is still the construction industry and temporary buildings on urban construction sites.

However, compared with the two types of plank houses, the installation mode of the device is simple, the splicing is compact, the structure is firm, and the device can be recycled for many times, thus improving the use value of the device; According to the principle of ventilation and seepage, the indoor air can be kept warm in winter and cool in summer. Meanwhile, the double-layer design of the device has good sound insulation effect and indoor air evolution effect combined with breathing walls, which can bring good life and work experience to users.

In addition, the design of the energy-saving breathing wall not only effectively solves the problem of poor indoor air circulation in movable plank houses, but also greatly improves the indoor living comfort under heavy pollution weather such as smog. The breathing wall does not consume electric energy when circulating indoor and outdoor air, and realizes passive ventilation by relying on temperature difference and wind pressure difference. This work is cheap, beautiful and practical, with high energy saving and emission reduction benefits.

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