Experimental Study on the Thermal Performance of Ventilation Wall with Cladding Panels in Hot and Humid Area

Zhihua Zhu\(^a\)*, Xue Li Jin\(^b\), Qiong Li\(^a\), Qinglin Meng\(^a\)

\(^a\)South China University of Technology, Guangzhou 510641, China
\(^b\)Guangzhou Panyu Polytechnic, Guangzhou 511483, China

Abstract

In this paper, we discussed the principle of thermal pressure ventilation, tested the ventilation wall in hot and humid region and obtained the hourly temperature on the outer wall surface and the calcium silicate board surface. The results showed that, on sunny days, plug-calcium silicate board surface temperature can be up to 37 °C, while the exterior wall surface temperature can be up to 31 °C, the surface temperature difference between the two walls is about 6 °C. But on cloudy day, the difference is about 2.3 °C. And during the night, it is about 1.5 °C. Lower temperatures are found for the plug-calcium silicate board surface compared with exterior wall surface temperature. The delay and attenuation effect on outdoor temperature wave by ventilation wall is conspicuous.

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Keywords: Ventilation wall; Cladding panels; Thermal performance

1. INTRODUCTION

Thermal performance improvement of the wall so as to meet the requirement of indoor thermal comfort has long been an important part of building energy-saving technologies. The ventilation wall formed by hanging calcium
silicate boards on the outer wall surface is a new energy-saving wall construction. It will greatly reduce or even eliminate the building cooling load in summer by removing the environmental heat on the envelope structure with the influx of outdoor air. Then, it has a climate adaption to the hot and humid region.

F Stazi et al. make an experimental research on ventilated walls with an external clay cladding in a temperate Mediterranean climate and concludes that, on sunny days, the external surface temperatures are considerably higher, while during the night time lower temperatures are found for the various layers of the wall [1]. P Seferis et al investigate the thermal performance of a ventilated wall without cladding panels and find that the heat convection resulting from the buoyancy induced flow is a critical aspect of the ventilated wall’s behaviour [2]. While the experimental study on the thermal performance of ventilation walls with cladding panels in hot and humid areas are vacant.

### Nomenclature

| Symbol | Description                  |
|--------|------------------------------|
| T1     | Indoor air temperature       |
| T2     | Outdoor air temperature      |
| T3     | Surface temperature of Plug-calcium silicate board |
| T4     | Surface temperature of exterior wall |
| V1     | Air velocity of inlet        |
| V2     | Air velocity of outlet       |

### 2. METHODS

The main material of this experiment is high density fiber reinforced calcium silicate board provided by NEW ELEMENT BUILDING MATERIAL CO. LTD. The plug-in board for the materials is installed by the keel of a test room in the west wall of Guangzhou area. There is a cavity between the board and the external wall, which can be used for ventilation. The width, thickness and height of the wall are 6000mm, 200mm and 3000mm, and the size of the whole board is 2300mmx110mmx2860mm. The test room is airtight without air conditioning.

There are 6 layers of temperature sensor placements in the central region of the outer wall with the consideration of temperature stratification on the wall surface and marginal effect of cladding boards, and there are 18 temperature sensor placements in total with 3 temperature sensor placements distributed on each layer. Encapsulation Digital Temperature Sensor is affixed to the surface of the outer wall to measure the temperature. There are 6 temperature sensor placements totally with 2 temperature sensor placements distributed on each layer. The distribution method of sensor placements on cladding boards is the same as those on the outer wall.

JTNT-A Multi Channel Temperature and Heat Flux Tester is used to collect temperature signal in the experiment, and it also automatically records as well as conserves the signal in the computer once every minute, while the temperature is measured by HOBO Temperature and Humidity Recorder once every minute. For the inlet and outlet wind speeds as well as the temperatures on the back cavity of cladding calcium silicate boards, HD32.3 Thermal Environment Analyzer is applied for the measurement once every hour. What is more, DAVIS Vantage Pro2 Miniature Electronic Meteorological Station is used to measure and record the outdoor meteorological parameters including air temperature, relative humidity, solar radiation, wind speed and wind direction once every minute.

### 3. RESULTS AND DISCUSSION

The experiment lasts four days from October 31st to November 3rd in 2014, which can well represent the transition season in southern hot and humid areas. The foregoing two days are sunny while the posterior two days are cloudy. The ventilation of the wall is induced by heat pressure, which is closely related with the intensity of solar radiation. So the experimental data is respectively classified into three processes, which is sunny days, cloudy days and night.

1 The experiment results analysis on sunny day (November 1st 8:00-20:00)
As shown in Figure 1 the average indoor air temperature in the test room is 29°C with a maximum value of 29.9°C at 17:17 pm, the average temperature of outdoor air outside the test room is 30.7°C and its peak is 34.8°C at 13:11 pm, the average surface temperature of plug-calcium silicate board is 31.5°C and can reach 36.6°C maximally at 15:40 pm, the average and maximum exterior wall surface temperatures are 29.0°C and 30.7°C at 16:37pm. The average indoor air temperature is 1.7°C higher than the average outdoor air temperature and the difference of maximum indoor and outdoor temperatures is 4.9°C. There is a time lag of 4 hours and 6 minutes between the time of the maximum indoor air temperature and the maximum outdoor air temperature. Since the test room is airtight without air conditioning in the transition season, the heat in the room will rise up the indoor air temperature instead of scatter and disappear. Thus there is little difference between the average indoor air temperature and the average outdoor air temperature in the room. The difference between the average surface temperatures of plug-calcium silicate board and exterior wall is 2.4°C and the maximum difference is 5.9°C. There is also a time lag of 57 minutes between the plug-calcium silicate board surface temperature and the exterior wall surface temperature.

Fig. 1. The temperature-time curve on sunny day.

Then the comparison is between the air velocities of inlet and outlet of the ventilated wall, the transformation of the air velocities from 9:00 to 16:00 on November 1st has been shown in Figure 2. The average air velocity of inlet and that of outlet of the ventilated wall are 0.27m/s and 0.15m/s while the maximum velocities of them, which are both found to happen between 14:30pm and 15:30pm, are 0.33m/s and 0.24m/s respectively. The difference between the average air velocity of inlet and that of outlet is 0.12 m/s and the maximum difference is 0.09 m/s. There are two reasons for the occurrence that the air velocity of outlet is faster than that of inlet. On one hand, the discharge area of outlet is one third less than the discharge area of inlet. On the other hand, the rise in temperature of the cladding board exposed to solar radiation increases the temperature difference between the cladding board and the outer wall, air heated cavity expansion floating upward, forming ventilation.
The experiment results analysis on cloudy day (November 2nd 8:00-20:00)

The average indoor air temperature in the test room is 27.7°C with a maximum value of 28.1°C at 8:00 am, the average temperature of outdoor air outside the test room is 25.2°C and its peak is 28.3°C at 14:26 pm, the average surface temperature of plug-calcium silicate board is 26.9°C and can reach 27.7°C maximally at 15:04 pm, the average and maximum surface temperatures of exterior wall are 26.5°C and 29.93°C at 15:55 pm. The average indoor air temperature is 2.5°C higher than the average outdoor air temperature and the difference of maximum indoor and outdoor temperature is 0.2°C. Since the test room is airtight without air conditioning in the transition season, the heat in the room will rise up the indoor air temperature instead of scatter and disappear at night, the heat obtained on sunny day makes the maximum indoor temperature happen in mourning and the average indoor temperature higher than that of outdoor.

The difference between the average surface temperature of plug-calcium silicate board and the exterior wall is 0.3°C and the maximum difference is 2.3°C. In addition, the maximum temperature of the board surface and the maximum temperature of the exterior wall are achieved almost at the same time. The posterior two days of experiment were cloudy, the outdoor temperature drop, close to 12:00 ~ 16:00 this time period, the surface temperature of exterior wall rises, reaches the maximum at 15:00, the surface temperature of cladding panel rise in solar radiation, up to 30°C, time delay approximately 0.5 h. the surface temperature of exterior wall changes with the surface temperature of Exterior wall cladding panels slowly, and was stabilized at 27°C, the indoor temperature had a slight temperature drop at 8:00 ~ 12:00 am, but slowly rose after 12:00 am, finally it was stabilized at between 27 ~ 28°C.

Then the comparison is between the air velocities of inlet and outlet of the ventilated wall, the transformation of the air velocities on November 2nd has been shown in Figure 4 The average air velocity of inlet and that of outlet of the ventilated wall are 0.35m/s and 0.26m/s while the maximum velocities of them, which are both found to happen between 14:30 and 15:30, are 0.38m/s and 0.33m/s respectively. The difference between the average air velocity of inlet and that of outlet is 0.09 m/s and the maximum difference is 0.05 m/s. The reason for the occurrence that the air velocity of outlet is faster than the one of inlet is because the discharge area of outlet is two third of that of inlet. the wind speeds of outlet and inlet are higher than on sunny day, mainly due to higher wind speed outside that day, but the difference between the average wind speed of the outlet and inlet was sunny higher than cloudy, indicating the effect is more obvious in hot sunny day.

The experiment results analysis at night (November 1st 20:00-2nd 8:00)

The average indoor air temperature in the test room is 29.0°C with a maximum value of 29.8°C, the average temperature of outdoor air outside the test room is 25.7°C and its peak is 27.5°C, the average surface temperature of plug-calcium silicate board is 26.8°C and can reach 28.7°C maximally, the average and maximum surface temperatures of exterior wall are 28.4°C and 29.7°C. In addition, all of the maximum temperatures appear at 20:00 pm. The average indoor air temperature is 3.4°C higher than the average outdoor air temperature and the difference of maximum indoor and outdoor temperature is 2.3°C.
Since the test room is airtight without air conditioning in the transition season, the heat in the room will rise up the indoor air temperature instead of scatter and disappear at night, the heat obtained on sunny day makes the maximum indoor temperature happen in mourning and the average indoor temperature higher than that of outdoor, and there is no time lag for the appearance of the maximum temperatures. The reasons account for the occurrence of the above phenomenon can be listed as follows: above all, the solar radiation is strong on November 1st, daytime with a high air temperature. So the temperatures reach at its peak at 20:00, lower to the bottom at 3:00 a.m. and start to rise again. What is more, there is no possibility for the airtight test room to radiate heat outward through air conditioner, with the descend of outdoor air temperature, the indoor heat diffused outward through the wall and the temperature therefore start to drop gradually at 20:00. But the indoor temperature remains higher than the outdoor temperature the whole night. The average temperature of the exterior wall surface is 1.5°C higher than that of plug-calcium silicate board surface, and the difference of maximum temperature is 1°C.

4. CONCLUSION

Through field measurement, the article studies the problem of thermal pressure ventilation of ventilated wall in hot and humid area in the transition season. Comparative analysis has also been applied to the air temperature, the surface temperatures of the exterior wall and cladding board, and the air velocities of inlet and outlet through ventilated wall. It can be concluded that:

Compared with cloudy day and night, ventilated wall on sunny day has a notable attenuation and delay effect on the outdoor temperature wave. The maximum temperature of exterior wall surface is 5.9°C lower and 1 hour later than that of cladding board surface while the average temperature is also 2.4°C lower. This also lead to the occurrence that the maximum indoor air temperature is 4.9°C lower and 4 hour later than that of outdoor air while the average temperature is also 1.7°C lower. Thus it can be obtained that the ventilated wall play a good role in building energy-saving, especially in hot and humid area with rich sunshine.

The test room is airtight without air conditioner during the experiment and the experimental data is obtained continuously and respectively on sunny day, cloudy day and at night. The heat absorbed in sunny day cannot dissipate in cloudy day or in the evening which makes indoor air temperature higher than outdoor air temperature. This also implies that ventilated cavity is not helpful for the indoor heat release at night as it actually increases the thermal resistance of enclosure structure just like putting on a cotton-padded jacket on the building. Then, in the practical application, indoor natural ventilation system or even a draught fan in the ventilated wall are applied on cloudy day and at night, in order to dissipate indoor heat, mechanical ventilation should be used to draw air into the wall cavity so as to take away the heat on the wall from indoor thermal wave and help to dissipate indoor heat.

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