Experimental Study of Multi-type Macromolecule Porosity Moisture-Conditioned Material

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Abstract In a whole building, there are integrated multiple theories regarding porosity moisture-conditioned material. In this experiment, we tested the humidity-controlling performance and evaporative cooling performance of the material separately. Through contrasting experiments, results indicate that the humidifying adjustment effect and evaporative cooling effect of the porosity moisture conditioned material is remarkable, and could effectively reduce the cooling load of buildings.

Keywords: Passive evaporative, Porosity moisture conditioned material, Energy efficiency in buildings, Passive technology, Solar energy

1. INTRODUCTION

Large numbers of Chinese existing housing. Urban construction area of china rapid increase from 1996 to date, end of 2003, total area amounted to 1.4091 billion square meters. At the same time, with increasing of Chinese urbanization level, building energy consumption had accounted for the proportion of total energy consumption already from about 10% in 1978 to 27.5% in 2001. Fig 1 shows the trends of energy efficiency in buildings. Therefore, generally considered that the building energy-saving is the directly effective way with the largest potentiality in various energy-conserving ways, is the most effective measures to solve the contradiction of socio-economic development and energy supply.[1]

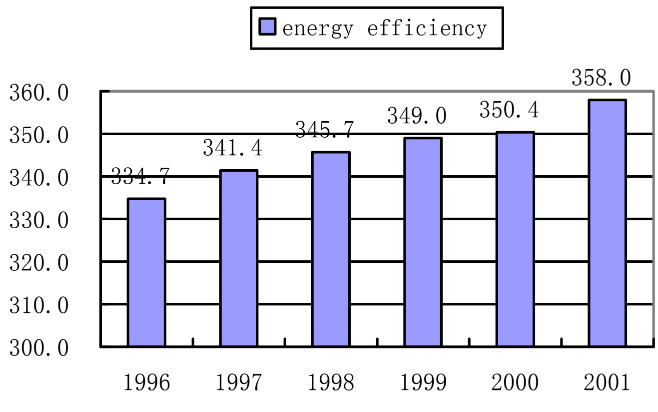

Fig.1 Trends of energy efficiency in buildings （Mtec）

In energy efficiency in buildings, air-conditioning energy consumption accounted for the main part, to create comfort environment of buildings, ancient architecture contains many passive features. After the energy crisis, people begin to become interested for building heating, cooling in utilizing the passive methods again. Passive solar technology uses natural sanitary energy (solar energy, wind, water etc) for cooling or heating buildings, avoiding Freon coolant damage to the ozone, compared with the mechanical system, the passive methods has the virtue of energy conservation, environmental protection. Practices show that on the basis of improving the insulation performance of the building envelope, integrate natural cooling technology and methods, is very effective for many areas.

There are many types of building energy-efficient technologies, passive technology aims at whole building, according to object, it could be divided into three: First, roof; Second, envelope ; Third, window, balcony, open space. Passive evaporative cooling technology combines characteristics of passive technology and evaporative cooling technology, use sanitary energy——water, solar to reduce the cooling load of building envelope.[2] With the continuous development of modern construction, in order to save land space, appeared great number of high-rise buildings. The emergence of high-rise buildings has greatly increased the proportion of the building envelope area, according to statistic, in the air-conditioned energy consumption, the ratio of building envelope energy consumption about 25～50%. Therefore, regard the envelope as main research object, it have great significance to research the refrigeration circulate for building energy-efficient which use porosity moisture conditioned material as a wall or the outside wall in hot summer.[3]

2. ENVIRONMENTAL CHARACTERISTICS OF CHINESE NORTHWEST REGION (WEATHER CONDITIONS)[4]

Chinese northwest region locate in Eurasia, vast territory with the complex and diverse topography, climate elements is asymmetric. Most areas belong to temperate zone continental semi-arid and arid climate, only the south-east fringe and the western hills of Sinkiang was influenced by the monsoon and the westerly wind circulation, precipitation slightly more, appeared temperate-humid temperate monsoon climate and mountainous humid climate. Northwest regional climate characteristics have significant impact to the natural ecological environment formation and human social economic development.

Most of northwest region are belonged to arid, semi-arid climate. Air temperature changes by a large range at daytime. The average temperature is most above 20 in July. Large evaporating capacity in five provinces of northwestern, evaporating capacity is the largest in summer (June to August), evaporating capacity of most areas in 400～2000mm.

In order to analyze the climate situation in the northwest, we have introduced a dry index DI. Formula (1) is:

$$DI = \frac{kT_s}{P_s} \qquad (1)$$

Ts —— the average temperature of three months in summer (June, July, August) ( );

Ps ——total precipitation of the three-month summer (mm);

K——factor.

Calculate the Northwest dry index by formula(1). Northern Shaanxi, most of Ningxia, northern Gansu, eastern Qinghai, and Tianshan mountain foothills, dry index is 1.5～5, less precipitation; dry index of North-western Gansu, northwest Qinghai, southern Sinkiang most area greater than 5, dry index of north-east talimu basin more than 20, belong to semi-desert or even desert, the climate is extremely dry.

It can be seen from the climate environmental features of the northwest that in most parts of the northwest climate is torridity, dry, low relative humidity, is propitious to the freedom of moisture evaporation, and there is a natural wet potential energy. Natural wet potential mean the presence of a natural humidity potential, the potential energy exists to make this water do not need any additional energy for evaporation, great natural wet energy, the more obvious effects of evaporation, cooling effect better. Thus it can be seen that the north-west climatic conditions conducive to the promotion of the use of evaporative cooling technology.

3. POROSITY MOISTURE CONDITIONED MATERIAL

Air humidity is closely related to the production and life. Appropriate relative humidity is propitious to people's physical and mental health, improve work efficiency. Large energy efficiency of traditional air-conditioning to dehumidify greatly increased the energy efficiency of air-conditioning. Thus, the emergence of a new-style building material—— moisture conditioned plate, the moisture conditioned plate impose the humidity controlling performance to adjust indoor humidity, no energy efficiency. Japan is the first country to study of the moisture conditioned plate, have developed variety products, and use to museums, art galleries etc [5]. In China, southern area is rainy humid, northern is dry climate, and the wet transfer capabilities of existing wall is poor, thus, to improve the building humidity environment, the research of moisture conditioned materials is necessary.

Combination the various characteristics of moisture conditioned materials and porous materials, forms multi-type porosity moisture conditioned material, it can be used in external of the building envelope. The porosity moisture conditioned material has automatic ability in humidity absorbing and releasing, and preferable capability in moisture storage and evaporation. Moisture transmission shows in Fig2. It can be seen from figure that humidity relocation process of the porous moisture conditioned materials similar to the principles of humidity absorbing and releasing performance, when outside water vapour pressure less than sub-surface water vapour hours material pressure, the release of material outward water, and bring a humidity removal because of capillarity in porous layer, porous layer absorb moisture from the wet floor, evaporation continuing (Fig2a). When outside water vapour pressure greater than sub-surface material, materials begin to absorb moisture from the air, makes the water vapour pressure greater than sub-porous material layer, the porous material layer play it's capillarity, absorb moisture from the humidity-conditioned layer (Fig2b). This process does not require any additional energy. Using porous humidity-conditioned material in building envelope, the water supplement and management issues can be resolved, at the same time, it's significantly to reduce air-conditioning system load.

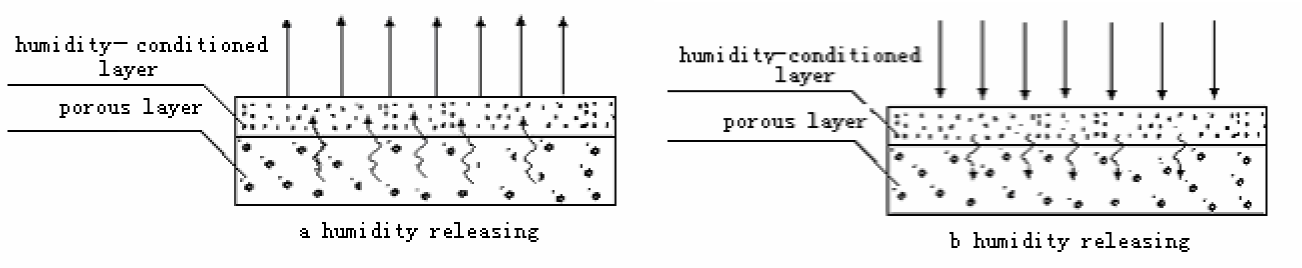

Fig.2 Moisture transmission of layers

Combined with the climate characteristics of the northwest and passive evaporative cooling technology performance, imposed the characteristics of moisture conditioned material and porosity material, the energy-saving potential of using a suitable porous cooling medium in the construction of is now worth considering tasks. The experiment mainly study to performance of multi-type porosity moisture conditioned material.

4. EXPERIMENTAL MATERIALS AND EXPERIMENTAL DEVICES

4.1 The Experimental Materials

(1) Porous materials: Concrete blocks, weight for 550Kg/m^3, pore rate of 73%, saturated humidity rate of 45%, dimensions of 300×600×80mm.

(2) Combined with the moisture conditioned paint and porous materials.

1) Moisture conditioned paint: Mix a suitable additive with absorbent resin, including coating material, paint, solvents, surface active agent, stabilizer and decentralized agent. Moisture conditioned paint can be daubed on buildings or wallpaper to adjust humidity.

2) Concrete blocks: 300×600×80mm.

(3) Combined with the moisture conditioned plate and porous materials

1) Moisture conditioned plate: Absorbent resin adsorption salt solution, forms a Gel, mixed the Gel

into coal ash, vesicant punch, and produced plate materials, material size: 300×600×20mm.

2) Concrete blocks: 300×600×80mm.

4.2 Experiments Testing Device

In experimental process, the experimental system to simulate outdoor wind speed by fan, through the Plexiglas box, the light transmission simulated solar radiation, and materials directly contact to the air without any disposal, and changes with the environment. Test pipeline as Fig3, the practical of experimental test as Fig4.

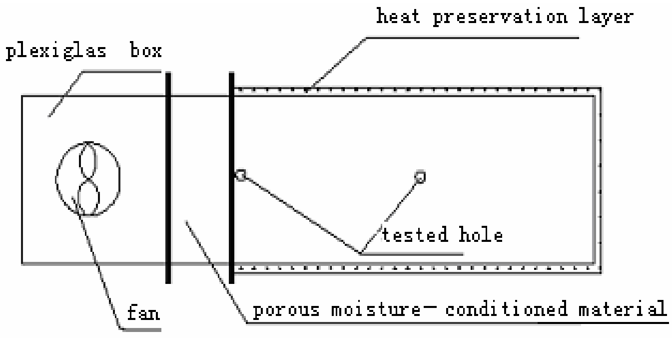

Fig.3 Test pipeline

Fig.4 Practical of experimental test

Experimental test pipeline is divided into three parts:

The former department of test pipeline is Plexiglas box; it was associated with air-compressors soft for simulating outdoor wind speed and solar radiation traveling sunlight;

Porous moisture conditioned material locate at the central, adopt live-link, may require replacement, at the same time, materials with supplement and drainage hole, to ensure water supply and excess water emissions;

Back of test pipeline is the airtight space, plus a heat preservation layer, through the test temperature changes in the airtight space to describe indirect evaporative cooling performance of the material. In addition, space and materials which could be used as test-enclosed cubicles for the moisture conditioned performance.

5. EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Evaporation Cooling Performance of Concrete Block Test

Evaporation cooling performance of humidity concrete block test: Fig5 is the trend curve, it can be seen from the chart that the difference temperature of humidity concrete block increased with dry-bulb temperature of environment rise, the max can reach 5.86 , and we can see that the evaporation cooling performance of humidity concrete block is better.

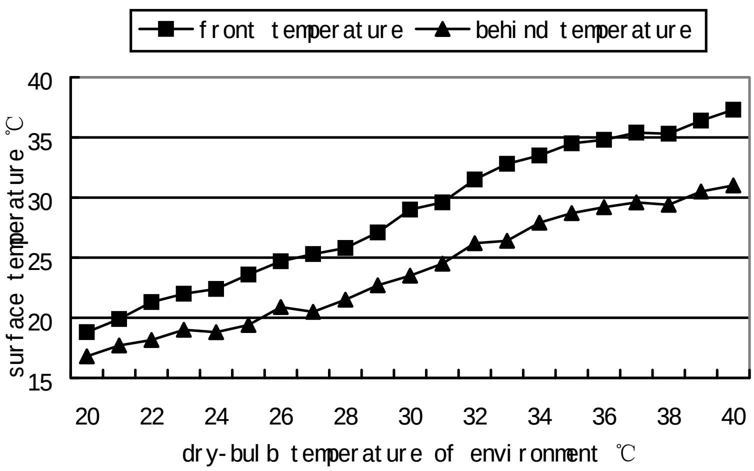

Fig.5 Evaporation cooling performance trend curve

5.2 Porous Moisture conditioned Material Combined with Porous Material and Moisture conditioned Paint

(1) Moisture conditioned performance test results: Under the same situation, we conducted airtight space humidity changes of moisture conditioned paint and no-moisture conditioned paint in ten hours, the corresponding curve trend Fig6, it can be seen that moisture conditioned material transfer capabilities appear the first turning point when relative humidity is 73%, when the relative humidity of the environment is above 73%, the moisture conditioned capability become better. When no moisture conditioned materials, environment relative humidity in airtight space only reduces 7% in ten hours, relative humidity from 92% down to 85%. When transferred to the moisture conditioned material into airtight space, after sixty minutes, the relative humidity of airtight space reduces 12.3%, relative humidity from 91.3% to 79%, in 10 hours on the relative humidity lower 24.1%, from 91.3% to 67.2%, Moreover, due to the capillarity of porous material, water will be gradually transferred from the moisture conditioned material part to the porous material, it will transfer the moisture conditioned material internal pressure of vapour continuing to fall, the moisture absorption role of moisture conditioned material will be continued, but its moisture absorption capacity is relatively weak; the trend curve tends to show that this transfer of water absorbability moisture conditioned materials can still more obvious.

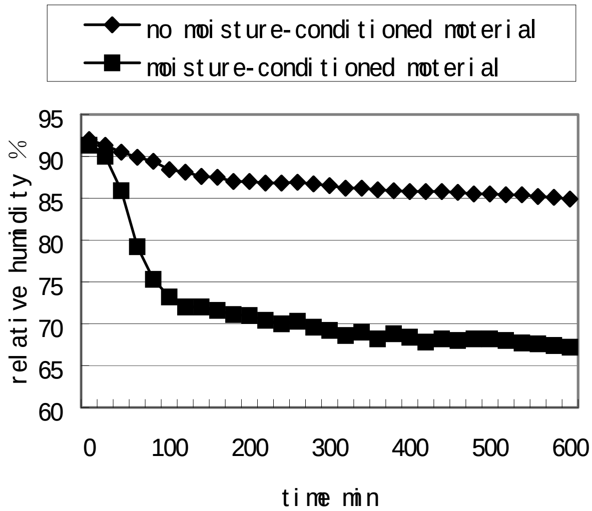

Fig.6 Relative humidity corresponding curve trend

(2) Analysis of evaporation cooling performance: Fig7 is comparison charts of temperature for porous moisture conditioned materials transferred outside temperature in different situations; materials maintain adequate water supplies at the testing process. From this chart can be seen that because of spray and surface wind speed, temperature of the former materials is lower than the dry-bulb temperature slightly, the temperature difference of front and behind surface is change with dry - bulb temperature environment and front temperature, when the environment temperature is 40 , the difference in temperature can reach 6.8 , so evaporation cooling effect of material is significantly.

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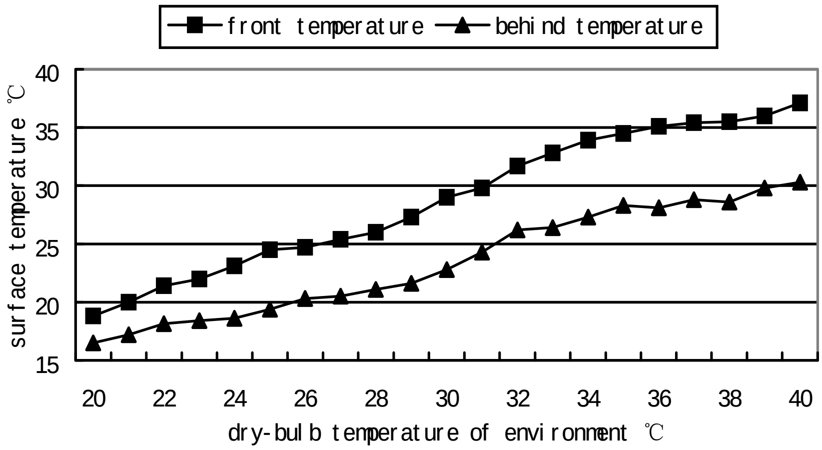

Fig.7 Porous moisture conditioned materials transferred outside temperature in different situations

Fig8, for temperature curve comparison chart of environment temperature and material surface temperature, it can be seen from Fig8 that the best time of the cooling effect appeared in 12:00～15:00, the value appears in 14:00, the difference in temperature between 7.9 . The average temperature is about 4.3 , because the wind speed in the process of testing has not been fully reflected the outdoor wind speed changes, the test data and the actual situation will have a certain gap.

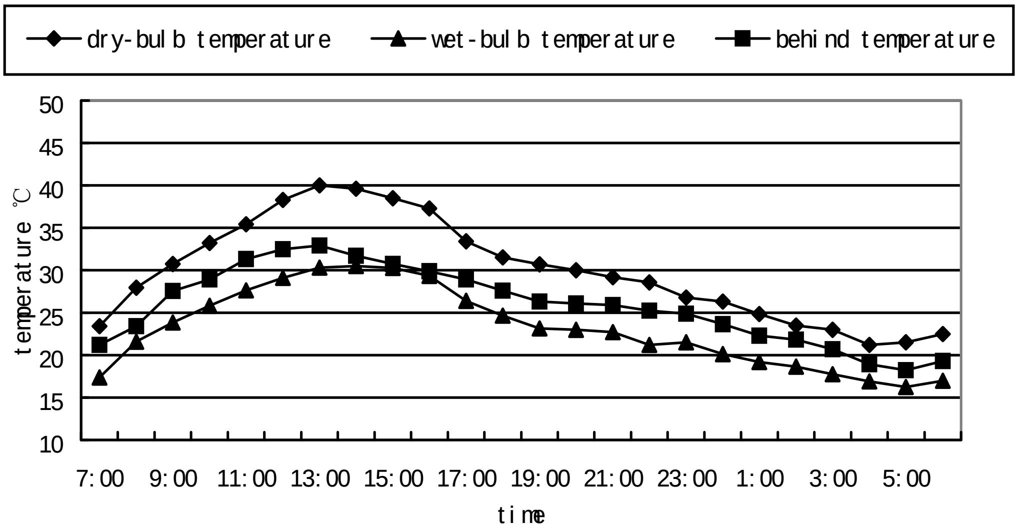

Fig.8 Temperature curve comparison chart of environment temperature and temperature of material surface in 24 hours

5.3 Porous Moisture conditioned Material Combined with the Moisture conditioned Plate and Porous Materials

(1) Moisture conditioned material transfer performance test results analysis: in the same circumstances, we analyze two cases of the moisture conditioned material and non- moisture conditioned material, the corresponding curve is shown in Fig9. It can be seen from the figure that the moisture conditioned material transfer capabilities appeared a turning point in a relative humidity of about 72%, when the relative humidity of the environment is above 72%, the moisture conditioned capability become stronger. and lower than this point the moisture conditioned capacity gradually weakened, curve slope gradually mild, and also should be noted that: since that moisture conditioned material have capillarity, porous material absorb a certain quantity water from the moisture conditioned material, which makes the moisture conditioned materials also have a certain moisture absorption capacity, wet curve will be downward trend, but this decline was small and

tended to level. It can be seen from the experiments that porous material could reinforce moisture conditioned performance of moisture conditioned material. When non-moisture conditioned materials, relative humidity of airtight space environment only reduced 7% in ten hours, relative humidity of airtight space from 92% to 85%, poor humidity controlling ability. When transferred to the moisture conditioned material into airtight space, after sixty minutes, relative humidity to reduce the 12%, relative humidity from 91.9% to 79.9%, in the ten hours to reduce the relative humidity of 26.1%, from 91.9% to 65.8%, the water absorbability of the humidity controlling materials are obvious.

Compare with the performance a former moisture conditioned paint, the humidity conditioned capacity of moisture conditioned plate was slightly better than the moisture conditioned paint, about 2% difference, but in a enclose space, the relative humidity adjust velocity of the moisture conditioned paint is more than that moisture conditioned plate.

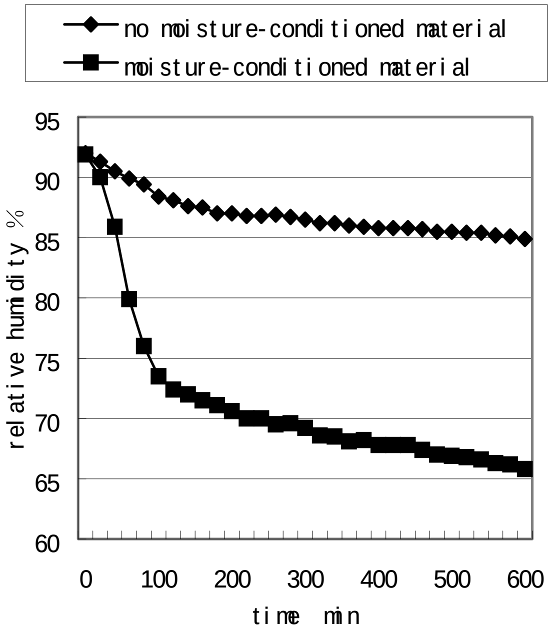

Fig.9 Corresponding curve of relative humidity in airtight space

(2) Evaporation cooling performance analysis of porous moisture conditioned material:

Fig10 is the contrast charts for moisture conditioned porous materials in different circumstances, in the experimental process, materials maintain water supply adequate. The former surface temperature of materials is lower than the ambient temperature; the difference in temperature could reach around 8 , thus cooling effect of evaporation materials is significantly.

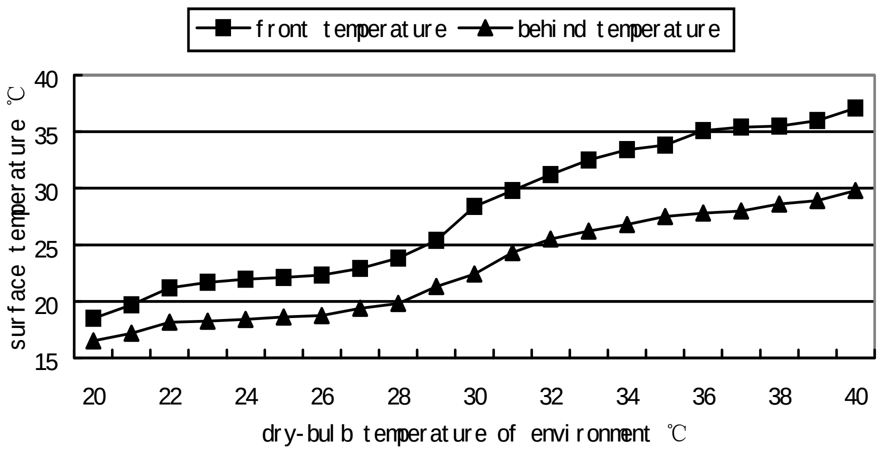

Fig.10 Moisture conditioned porous materials in different circumstances

Fig11 for temperature curve comparison chart of the outside temperature measurements and material surface, it can be seen from the chart that the environmental temperature in 12:00～15:00 is above 30 , the temperature difference relatively larger, it's the best time of cooling effect, the maximum appeared in 13:00, about 7.8 , minimum appeared in the early morning 5:00, about 2.8 , the average temperature is about 4.2 . The tested data and the actual situation will have a certain gap.

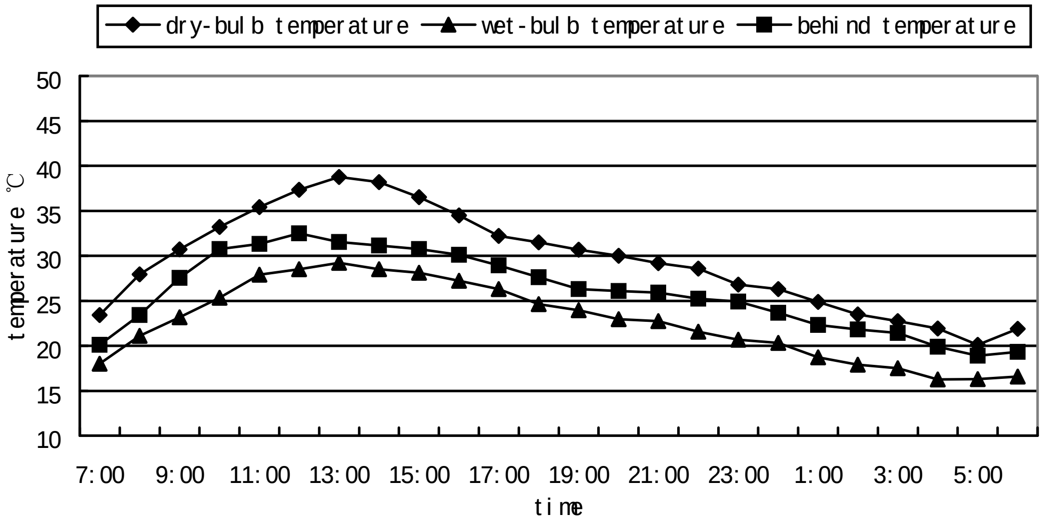

Fig.11 Temperature curve comparison chart of the outside temperature measurements and material surface in 24 hours

6. CONCLUSIONS

(1) Moisture conditioned materials have achieved significant effects, the relative humidity of airtight space is decreased about 24.1~26.1% in ten hours, moisture conditioned material capacity appeared a turn point at the environmental humidity of around 72%, because of the capillarity of porous materials, moisture conditioned material moisture absorption continues, the relative humidity of the surrounding environment continue to reduce, trends slowly. It can be seen from humidity change in the airtight space: the moisture c 6.8~8 , the average temperature is about 4.2~4.3 ; At the same time , with environmental temperature rise, evaporation cooling performance of onditioned performance of porous moisture conditioned materials clearly superior to conventional building materials.

(2) The passive evaporative cooling effect of porous moisture conditioned material is significantly, the temperature difference of material achieve maximum temperaturethe porous moisture conditioned materials is gradually increase, it plays a better role in lower building envelope cooling load.

(3) Compared to the performance of moisture conditioned paint, the moisture conditioned plate capacity slightly better than the moisture conditioned paint on the small enclosed rooms, the difference in relative humidity about 2%, the relative humidity adjust velocity of the moisture conditioned paint is better than the moisture conditioned plate. Due to the experimental process of moisture adequate materials, remain saturated condition, the evaporation cooling performance difference of porous moisture conditioned materials is little, it is impossible to measure the differences because of its saturation arising in evaporation of water efficiency differences. Compared with the cooling effect of the moisture concrete block, the porous moisture conditioned material evaporation temperature generally higher than wet concrete filling 1.2 , and moisture concrete block no apparent moisture conditioned function.

(4) The advantage of porous moisture conditioned materials in practical application

1) Porous moisture conditioned materials one (moisture conditioned paint): In a base-plate surface wipe moisture conditioned paint, such that the moisture conditioned paint has a fairly strong ability to paint color can change according to demand.

2) Porous moisture conditioned material two

(moisture conditioned plate) : a strong ability to transfer and scour-tolerant rain shower, quantity and composition of scour body drain limited, with an increase in the use of time-reversed moisture conditioned material capacity little impact.

(5) The experiments are tested under the weather conditions of Xi'an, because different areas and weather conditions in other parts, the test will be facing some differences to continue to study.

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