# APPLICATION OF RENEWABLE MATERIALS IN ENERGY SAVING OF NEW BUILDING SOLAR GREENHOUSE

by

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*This paper studies the application of renewable materials in the energy saving of new building solar greenhouse, and analyzes the influence of different building materials on the energy saving of solar greenhouse, it can adjust the angle of the sunlight greenhouse roof manually to improve the solar radiation into the room and adjust the fan system manually to increase the heat storage of the back wall. The test greenhouse located in a modern production base of a city was measured, and the test data under different weather conditions in winter of 2020 were selected to analyze the characteristics of temperature and light data indexes in the renewable material solar greenhouse and common material solar greenhouse, and the active lighting mechanism and active heat storage mechanism of the renewable material new building solar greenhouse were theoretically studied. The results show that the average light transmittance and indoor illumination of the solar greenhouse with recycled materials are increased compared with that of ordinary materials under different weather conditions in winter. In winter solstice, cloudy days and sunny days, the light transmittance of active daylighting and heat storage solar greenhouse was 61.17%, 58.26%, and 70.81%, respectively, which was 7.87%, 5.88%, and 11.45% higher than that of ordinary energy-saving solar greenhouse, and the corresponding indoor illumination was 15.42%, 11.73%, and 21.28% higher than that of ordinary energy-saving solar greenhouse. In terms of temperature, under different weather conditions in winter, the indoor temperature and ground temperature of the solar greenhouse with active daylighting and heat storage are significantly higher than those of the control material energy-saving solar greenhouse. The temperature difference between indoor and outdoor is above 27 ℃.*

Key words: *tilting roof technology, active heat storage technology, mechanism of active daylighting, roof angle*

## Introduction

In modern society, the consumption of natural resources by traditional materials, the destruction of ecological environment and the pollution of air have become the issues of widespread concern. The concept of *green building materials* was put forward in the 1st International Symposium on Materials Science. The research on *green building materials* has attracted the attention of governments all over the world. In the high-tech development plans of various countries, green building materials are an important topic [1].

In China, as the country has decided to take the road of sustainable development, I have successively issued a series of policies and regulations and carried out a series of publicity

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activities. Greenhouse building is an important agricultural production facility for producing off-season fruits, vegetables and flowers in northern China. In greenhouse production, the problems of high fuel cost of heating greenhouse in winter and poor self-insulation performance of non-heating greenhouse, unable to ensure normal production, have been the bottleneck problems affecting the production efficiency of facility agriculture [2]. Therefore, the heat storage and energy conservation technology of greenhouse, especially the research of economic energy conservation technology, is very important for the efficient production of agricultural facilities. The PCM can store the surplus heat in the greenhouse during the day, and release the heat at night when the heat is insufficient. When they are used in greenhouse construction, they can maintain the daily heat self-balance in the greenhouse in winter [3]. At present, the research and development of PCM for residential building energy saving has entered the application stage, while the research on phase change heat storage suitable for greenhouse production is rare [4]. Due to the poor thermal insulation performance of solar greenhouse, indoor temperature is greatly affected by outdoor climate change, large temperature fluctuation, and crop growth have specific requirements for temperature range, so it is of great practical significance to research and develop phase change heat storage materials suitable for solar greenhouse buildings and systematically study the relevant basic theory of its application in today's increasingly fierce energy crisis [5]. Due to the lack of systematic research on the selection and performance of PCM suitable for greenhouse environment, it is still a long way to go to apply PCM to greenhouse production. Therefore, this paper studies the application of renewable materials in the energy saving of new building solar greenhouse.

## Application of renewable materials in energy saving of solar greenhouse

At present, the high consumption of resources and high pollution of the environment have aroused widespread concern and attention of the international community. People realize the importance of recycling renewable materials [6]. In various fields, the use of renewable materials has been deeply studied and elaborated, and there are a large number of related books for everyone to learn and reference. Most of the researches on the application of renewable materials in landscape architecture appear in the ecological restoration of urban wasteland and the construction of conservation which oriented landscape architecture [7].

With the increasingly serious environmental problems, people have been aware that the contradiction between home consumption and saving is more prominent: how can we spend a lot of money to achieve distinctive space effect? How can we reduce the waste of time and materials in the decoration process? How can we use less energy in our future life and design a warm home? In the new architectural design, the use of waste materials is also paid attention by designers [8]. According to the *Economic Daily* recently reported that wood products such as doors, folding doors and kitchen cabinets for indoor performance building materials have to rely on logs. Using hierarchical processing technology, plastic raw materials can be combined with plywood or dense board to produce products with the same appearance and characteristics as logs [9]. After continuous improvement, the appearance of the plastic door body made of waste is exactly the same as that of the log, and the color is the same. There is no need for secondary processing or painting, which can save a lot of time and cost.

Therefore, the technical route of this paper is shown in fig. 1.

### *Structure design of active daylighting and heat storage*

In this study, an innovative active daylighting and heat storage solar greenhouse is designed. The roof of the greenhouse adopts the tilting roof structure independently developed

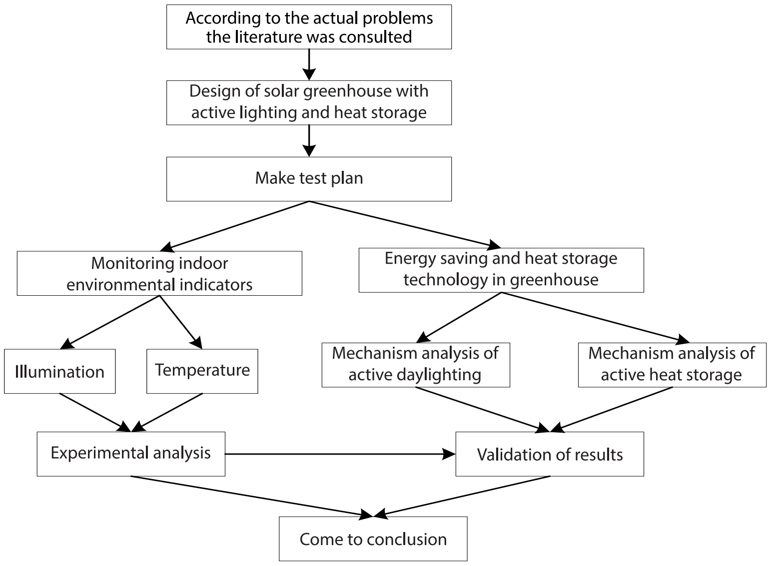


**Figure 1. Research technology route**

by Northwest A & F University. In the structural design, it is mainly divided into two parts. One part is the fixed roof skeleton, which is similar to the two folds daylighting roof skeleton. At the foot of the south slope, there is a skeleton with an inclination of 53° and a length of 1.2 m, which is covered with transparent plastic film. The upper part is a fixed roof skeleton with an inclination of 25° [10]. The other part is the movable roof skeleton, which is called the movable roof for short. The skeleton is covered with transparent plastic film. When the equipment is not opened, it is overlapped in the roof fixed skeleton with an inclination of 25°. The fixed roof is hinged with the movable roof at the corner by using the long rod axis, so that it can be opened to form a certain angle [11]. The motor is installed on the motor bracket near the ridge in the middle of the greenhouse and tightly connected with the transmission rod shaft. A serrated steel frame is installed on the transmission rod shaft every certain distance, and one end of the steel frame is connected with the roof movable framework [12]. When starting the equipment, the reduction motor rotates at a certain speed, and then drives the transmission shaft connected with it. With the rotation speed of the motor, the drive shaft drives the serrated steel frame to move outward, and then the serrated steel frame pushes the roof movable framework outward out of the roof fixed framework, forming an angle of 10-15° with it. That is, the daylighting roof changes its inclination angle through the opening of the equipment [13].

The back wall of active daylighting and heat storage solar greenhouse applies the active heat storage technology of axial flow fan system. Different from the back wall of other greenhouses, in the loess layer of the main heat storage layer, several pieces of active heat storage concrete prefabricated with two parallel layers are installed at a certain height from the ground, and the channels of the prefabricated concrete slab are used to form active heat storage channels [14]. In this study, the total length of the prefabricated duct floor with active heat storage is 75 m, which runs from the east of the back wall of the solar greenhouse to the west of the back wall. There are two floors with an interval of 1.5 m between the two floors. Four axial flow fans are installed 2.5 m away from the gable in the east and west. The design parameters of the fans are rated power 0.37 kw, total pressure/static pressure 230/160 Pa, rated speed 2800 rpm and air volume 3000 $m^3$ per hour. The ventilation method is to use the axial flow fan near the east gable wall of the solar greenhouse as the air inlet (air supply to the rear wall air duct), and the axial flow fan near the west gable wall of the solar greenhouse as the air outlet (air extraction from the rear wall air duct). The active heat storage concrete prefabricated duct floor is connected with the interior of the solar greenhouse through four axial flow fans installed at the air outlet of the inner surface of the rear wall [15].

In the main daylight period of the day, when the indoor temperature exceeds a certain value (the experimental design is 20 °C), the back wall axial flow fan active heat storage system is turned on, and the hot air in the solar greenhouse is input into the reserved ventilation duct of the back wall. Because there is a certain temperature difference between the hot air in the duct and the duct wall, the heat exchange process will be actively carried out, In this way, the heat in the greenhouse is stored in the heat storage layer of the back wall, so that a large amount of solar radiation energy in the greenhouse can be collected before ventilation in the daytime, and this part of energy can be continuously stored in the main heat storage layer of the back wall of the greenhouse through the ventilation heat exchanger [16]. Based on the passive heat storage mode of the back wall of the traditional solar greenhouse, the purpose of active heat storage of the back wall of the solar greenhouse is realized, so that the solar radiation energy storage efficiency of the solar greenhouse in the daytime is improved, and the humidity and heat loss caused by ventilation in the solar greenhouse can be effectively reduced.

The two greenhouses are located in a new modern agricultural demonstration garden base in a city. The basic structure of the greenhouse is shown in tab. 1. Among them, the tilting roof technology is used in the active daylighting and heat storage solar greenhouse, which can adjust the angle of the daylighting roof artificially. Four axial fans are installed on the inner surface of the back wall of the greenhouse, and two parallel precast concrete floors are set on the heat storage layer of the back wall. The solar greenhouse in the test control is an ordinary energy-saving solar greenhouse, the daylighting roof is a fixed daylighting angle roof, and the back wall is an ordinary brick wall. The other structural parameters of the two greenhouses are the same. The two solar greenhouses are newly built, and the completion time is around October 20, 2019. The structural parameters of the greenhouse are shown in tab. 1.

**Table 1. Structural parameters of test greenhouse**

| Greenhouse type | Clear span [m] | Ridge height [m] | Back corner [°] | Length [m] | Main materials and dimensions of back wall [mm] | | |
|---|---|---|---|---|---|---|---|
| | | | | | Interior brick wall | Thermal insulation layer | External wall brick wall |
| Solar greenhouse with active lighting and heat storage | 9.0 | 4.7 | 40 | 80 | 370 | 500mm solidified soil +100 mm EPS | 370 |
| Common energy saving solar greenhouse | 9.0 | 4.7 | 36 | 80 | 370 | 500mm solidified soil +100mm EPS | 370 |

The effective time of data collection is from October 15, 2020 to February 28, 2014. In order to further study the performance difference of active daylighting and heat storage solar greenhouse compared with ordinary energy-saving solar greenhouse, this study is divided into two different data collection time stages. The first stage is from October 15, 2020 to January 6, 2021. In this stage, in order to ensure the control effect of the experimental study, in this stage, there is no cultivation and production activities in the two solar greenhouses, and there is no ventilation management. The second stage of data collection is from January 7, 2021 to February 28, 2021. The local production management personnel carry out normal production management. There are local vegetable crops planted in the greenhouse, and ventilation management is carried out when the indoor temperature reaches a certain value. In the whole process of data acquisition, the opening time of the quilt is from 10:00 a. m. to 16:00 p. m. In order to increase the indoor solar radiation energy and the heat storage capacity of the back wall of the solar greenhouse with active daylighting and heat storage, we manually turn on the tilting roof system during the period of opening the thermal insulation quilt, so that the daylighting roof angle changes from 25-40 ° and turn on the axial flow fan system.

### *Heat transfer analysis of back wall of solar greenhouse*

On this basis, the heat transfer differential equation of isotropic body is constructed, and the temperature and heat transfer coefficient of fluid medium are calculated. Heat transfer is a subject to study the law of heat transfer. The Second law of thermodynamics points out that as long as there is a temperature difference, the heat is always spontaneously transferred from the high temperature object to the low temperature object. Heat transfer refers to all kinds of heat transfer phenomena. According to the different heat transfer mechanism, heat conduction can be divided into conduction, convection and radiation.

*Heat conduction*: heat conduction can be defined as the exchange of internal energy caused by temperature gradient between two objects in complete contact or between different parts of an object. Heat conduction follows Fourier's law:

$$q = -\lambda \frac{\mathrm{d}T}{\mathrm{d}x} \tag{1}$$

where $q$ [Wm$^{-2}$] is the heat flux and $\lambda$ [Wm$^{-1}$K$^{-1}$] – the thermal conductivity.

Thermal convection refers to the heat exchange between the solid surface and the fluid around it due to the existence of temperature difference. Thermal convection can be divided into two types: natural-convection and forced convection. In engineering, the flowing fluid and the solid wall with different temperatures contact to exchange heat. This heat transfer process is called convective heat transfer, which can be described by Newton's cooling equation:

$$Q = \alpha F \left(t_w - t_f\right) \tag{2}$$

where $\alpha$ [Wm$^{-2}$K$^{-1}$] is the convective heat transfer coefficient (or membrane heat transfer coefficient, heat transfer coefficient, membrane coefficient*, etc.*), which represents the heat transfer ability between the fluid and the solid surface, that is, the temperature difference between the object surface and the nearby air is 1 K, and the heat exchanged with the nearby air through convection in unit time, $F$ [m$^2$] – the area of the object participating in the heat transfer, $t_w$, $t_f$ [K] are the temperature of solid surface and surrounding fluid medium, respectively.

Thermal radiation refers to the process of heat exchange in which electromagnetic energy is emitted and absorbed by other objects. The higher the temperature of the object is, the more heat is radiated per unit time. In engineering, the mutual radiation between two or more objects is usually considered. In the system, each object radiates and absorbs heat at the same time. The heat transfer between objects is calculated by the Stephen-Boltzmann equation:

$$q = \varepsilon \sigma \mathrm{A}_1 F_{12} \left(T_1^4 - T_2^4\right) \tag{3}$$

where $q$ is the heat flux, $\varepsilon$ – the emissivity (blackness) of the object, the numerical range is (0-1), $\sigma$ – the Stefan-Boltzmann constant, generally $5.67 \cdot 10^{-8}$ W/(m$^2$K$^4$), $A_1$ – is the area of radiation

Surface 1, $F_{12}$ – the shape coefficient from radiation Surface 1 to radiation Surface 2, $T_1$ – the absolute temperature of radiation Surface 1, and $T_2$ – the absolute temperature of radiation Surface 2. The heat transfer differential equation of orthotropic body in the body is:

$$\frac{\partial}{\partial x}\left(\lambda_x \frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial x}\left(\lambda_y \frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial x}\left(\lambda_z \frac{\partial T}{\partial z}\right)+q_v=\rho c\frac{\partial T}{\partial t} \tag{4}$$

The heat transfer differential equation of isotropic body in the body, (assuming that there is no heat source in the body):

$$\frac{\partial T}{\partial t}=\frac{\lambda}{\rho c}\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)\partial^2 \tag{5}$$

where $T$ [K] is the instantaneous temperature in the body, $t$ [s] – the time, $\lambda_x$, $\lambda_y$, $\lambda_z$ [Wm$^{-1}$K$^{-1}$] are the thermal conductivity of the three principal axis directions of the object, $\rho$ [Kgm$^{-3}$] – the density of the object, $c$ [KJkg$^{-1}$K$^{-1}$] – the specific heat capacity of the object, and $q_v$ – the heat source in the body.

In order to make the differential equation have a unique solution, it is necessary to take certain heat transfer boundary conditions and initial conditions. There are three kinds of boundary conditions:

– The first kind of boundary condition: the temperature function on the object boundary is known, which can be expressed:

$$T\left|r=f\left(x,y,z,t\right)\right. \tag{6}$$

– The second kind of boundary conditions: the heat flux [Wm$^{-2}$] on the boundary of an object can be expressed:

$$-k\frac{\partial T}{\partial n}\left|r=g\left(x,y,z,t\right)\right. \tag{7}$$

– The third kind of boundary conditions: the temperature and heat transfer coefficient of the fluid medium in contact with the object are known:

$$-k\frac{\partial T}{\partial n}\left|r=\alpha\left(T-T_f\right)\right|r \tag{8}$$

where $T_f$ is the temperature of the fluid medium and $\alpha$ – the heat transfer coefficient. The initial condition is that the temperature of the object in the whole region at the beginning of the heat transfer process is taken as the known condition determine the solution of the differential equation.

## Experimental analysis

### *Test instrument*

In the experiment of this study, in order to understand the basic characteristics of the indoor environment of the two solar greenhouses, we need to test and compare the indoor temperature, light, humidity and other environmental indicators of the solar greenhouse. The instruments used are:

– The Pde-r4 four channel temperature data recorder: there are four temperature probes in total. The temperature measurement range of the instrument is –30 ~ 70 °C. The manufacturer is Harbin Wuge Electronic Technology Co., Ltd.
– The Pde-ki long term data recorder, pde-ki, fig. 2(b): there are three probes, namely temperature and humidity probe, ground temperature probe and light probe. The measurement range of temperature is 30 ~ 70 °C. The humidity range is 0 ~ 99% RH. The measurement

range of solar irradiance is 0 ~ 200000 lux. The manufacturer is Harbin Wuge Electronic Technology Co., Ltd.
- Temperature and heat flux tester, jtr01, fig. 2(c): the measuring range of heat flux is 0-1800 W/m$^2$, manufactured by Beijing Century Jiantong Environmental Technology Co., Ltd.
- The A3F portable wind speed measuring instrument: range: 0-30 m/s; accuracy: ± 3.0%. It is produced by Beijing selsese Instrument Technology Co., Ltd.

In the whole process of data acquisition, except for the temperature and heat flux tester and anemometer, the other instruments are set to the automatic data acquisition mode, and the time interval is 10 minutes.


**Figure 2. Physical diagram of the instrument; (a) Pde-ki long term data recorder (b) Pde-r4 four channel temperature data recorders, (c) temperature and heat flux measuring instrument, and (d) portable anemometer**

### *Method of monitoring point distribution*

– *Temperature distribution*

In order to measure the indoor and outdoor temperature of solar greenhouse in the experimental stage, several representative sections were selected as the main measurement sections, fig. 3. Because the solar greenhouse uses a folding arm type mobile device as the system of opening and closing the heat preservation quilt, there is a heat preservation quilt strip with a width of about 2 m on the half-length section of the solar greenhouse. Therefore, 1/4 and 3/4 length sections of greenhouse are the main measurement sections for temperature distribution; Six temperature probes were arranged in each of the two greenhouses, with a total of 12 probes: the 1/4 and 3/4 length sections of the greenhouses were the main measurement sections. One temperature measuring point shall be set at each main measuring section which is 0 m away from the back wall (the surface of the back wall), 3 m away from the back wall, 6 m away from the back wall, and 1.5 m above the ground. A temperature measuring point is arranged at the height of 1.5 m outside the greenhouse and 2 m away from the greenhouse.

There are two ground temperature probes for measuring soil temperature in two greenhouses, four in total. The arrangement of each greenhouse is in the horizontal direction, select the intersection of 1/2 span section of greenhouse and 1/3 and 2/3 section of greenhouse length direction, and arrange one ground temperature measuring point, respectively. In the vertical direction, the measuring point is located at the soil depth of 15 cm below the ground. The outdoor measuring point of soil temperature is arranged 2 m away from the greenhouse, and one measuring point is arranged at the soil depth of 15 cm below the ground.

– *Humidity distribution*

There are two probes for measuring indoor humidity in the two greenhouses, and a total of four probes: in the horizontal direction, one humidity measuring point is arranged at the intersection of the 1/2 span section of the greenhouse and the 1/3 and 2/3 sections of the greenhouse length direction in the span direction of the greenhouse, and in the vertical direction, it is 1.5 m above the ground. Outside the greenhouse, 2 m away from the greenhouse, and 1.5 m above the ground in the vertical direction.

– *Light distribution*

In order to measure the indoor and outdoor light of the greenhouse in the experimental stage, several representative sections are selected as the main measurement sections of the measuring points. Because the solar greenhouse adopts the folding arm type heat preservation quilt opening and closing system, there is always a heat preservation quilt strip about 2 m wide on the half-length section of the solar greenhouse. Therefore, the lay-out of each greenhouse is in the horizontal direction, the intersection of 1/2 span section of greenhouse and 1/3 and 2/3 section of greenhouse length direction is selected in the greenhouse span direction, and a light measuring point is arranged, respectively, and in the vertical direction, it is 1.5 m above the ground. The outdoor light measuring points are arranged 2 m away from the greenhouse and 1.5 m above the ground in the vertical direction.

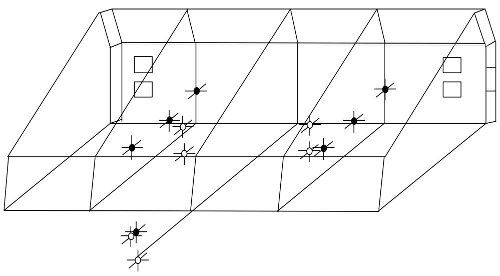

**Figure 3. Main lay-out;** *note: the positions of light, humidity and ground temperature measurement points of hollow points are the positions of temperature measurement points of black solid points.*

### *Results study*

The total amount of solar radiation entering the solar greenhouse through the daylighting roof is closely related to the indoor temperature environment and night insulation performance of the solar greenhouse, and in production practice, the solar radiation entering the solar greenhouse also determines the yield and quality of indoor crops.

In this study, I measured and collected the light data of renewable materials new building solar greenhouse and common material building solar greenhouse from October 15, 2020 to February 28, 2020. The light data of the main daylighting period (10:00 a. m. – 15:00 p.m.) in solar greenhouse on sunny day (2021-01-04) were compared and analyzed. The experimental results are shown in tabs 2-4.

According to tab. 2, the outdoor temperature will reach the maximum at 13:30 on December 21, 2020, and the maximum temperature is 7 °C. At 13:30, the temperature of the new type building solar greenhouse with recycled materials is 32 °C, and that of the ordinary building solar greenhouse is 20 °C. At 10:00 a. m., the outdoor temperature is –2 °C, the temperature of the new building solar greenhouse with recycled materials is 11 °C, and the temperature of the common building solar greenhouse is 6 °C. At 15:00 in the morning, the outdoor temperature is 2 °C, the temperature of the new building solar greenhouse with recycled materials is 20 °C, and the temperature of the common building solar greenhouse is 8 °C. The new building solar greenhouse designed by recycled materials has higher temperature, which shows that the solar greenhouse designed in this paper has better warming effect in winter solstice.

**Table 2. Sunlight data of solar greenhouse on winter solstice (sunny to cloudy on December 21, 2020)**

| Time | Temperature [°C] | | |
|---|---|---|---|
| | Outdoor | New building solar greenhouse with recycled materials | Building solar greenhouse with common materials |
| 10:00 | –2 | 11 | 6 |
| 10:30 | 0 | 13 | 8 |
| 11:00 | 1 | 15 | 11 |
| 11:30 | 2 | 17 | 13 |
| 12:00 | 3 | 20 | 15 |
| 12:30 | 4 | 26 | 17 |
| 13:00 | 6 | 28 | 21 |
| 13:30 | 7 | 32 | 20 |
| 14:00 | 5 | 30 | 14 |
| 14:30 | 4 | 27 | 12 |
| 15:00 | 2 | 20 | 8 |

According to tab. 3, on cloudy days, the maximum outdoor temperature can reach 6 °C. The maximum temperature of solar greenhouse constructed with recycled materials is 29 °C and that of ordinary materials is 18 °C. At 10:00 in the morning, the outdoor temperature is –4 °C, the temperature of the new building solar greenhouse with recycled materials is 8 °C, and the temperature of the common building solar greenhouse is 3 °C. At 15:00 in the morning, the outdoor temperature is 0 °C, the temperature of the new building solar greenhouse with recycled materials is 16 °C, and the temperature of the common building solar greenhouse is 10 °C. The new building solar greenhouse designed by recycled materials has higher temperature, which shows that the solar greenhouse designed in this paper has better warming effect in cloudy days.

**Table 3. Light data of solar greenhouse on cloudy day (December 23, 2020)**

| Time | Temperature [°C] | | |
|---|---|---|---|
| | Outdoor | New building solar greenhouse with recycled materials | Building solar greenhouse with common materials |
| 10:00 | –4 | 8 | 3 |
| 10:30 | –2 | 10 | 5 |
| 11:00 | 0 | 12 | 6 |
| 11:30 | 1 | 13 | 8 |
| 12:00 | 2 | 15 | 10 |
| 12:30 | 3 | 19 | 12 |
| 13:00 | 3 | 26 | 15 |
| 13:30 | 6 | 29 | 18 |
| 14:00 | 4 | 27 | 17 |
| 14:30 | 3 | 25 | 15 |
| 15:00 | 0 | 16 | 10 |

According to tab. 4, on cloudy days, the maximum outdoor temperature can reach 13 °C. The maximum temperature of solar greenhouse constructed with recycled materials is 37 °C and that of ordinary materials is 23 °C. At 10:00 in the morning, the outdoor temperature is 2 °C, the temperature of the new building solar greenhouse with recycled materials is 15 °C, and the temperature of the common building solar greenhouse is 8 °C. At 15:00 in the morning, the outdoor temperature is 5 °C, the temperature of the new building solar greenhouse with recycled materials is 30 °C, and the temperature of the common building solar greenhouse is 15 °C. The new building solar greenhouse designed by recycled materials has higher temperature, which shows that the solar greenhouse designed in this paper has better warming effect in sunny days.

**Table 4. Sunshine data of sunlight greenhouse on sunny day (2021-01-04)**

| Time | Temperature [°C] | | |
|---|---|---|---|
| | Outdoor | New building solar greenhouse with recycled materials | Building solar greenhouse with common materials |
| 10:00 | 2 | 15 | 8 |
| 10:30 | 4 | 18 | 11 |
| 11:00 | 6 | 22 | 13 |
| 11:30 | 8 | 25 | 16 |
| 12:00 | 9 | 29 | 18 |
| 12:30 | 11 | 32 | 20 |
| 13:00 | 13 | 35 | 22 |
| 13:30 | 11 | 37 | 23 |
| 14:00 | 9 | 36 | 21 |
| 14:30 | 8 | 32 | 17 |
| 15:00 | 5 | 30 | 15 |

Based on the aforementioned data, it can be seen that under different weather conditions in winter, the indoor temperature of the new building solar greenhouse with recycled materials is significantly higher than that of the ordinary building solar greenhouse. Among them, the indoor and outdoor temperature difference of the new building solar greenhouse with recycled materials is more than 27 °C. This shows that the new building solar greenhouse designed by recycled materials can obtain higher temperature.

According to the previous data, the indoor and outdoor light conditions of the greenhouse were obtained, and the experimental results are shown in tab. 5.

Under different weather conditions in winter, the daily average humidity of the new building solar greenhouse with recycled materials is 30.8% and 31.2%, while that of the ordinary building solar greenhouse is 31.3% and 32.3%. The indoor relative humidity of the new building solar greenhouse with recycled materials is lower than that of the ordinary building solar greenhouse.

In conclusion, under different weather conditions in winter, the light transmittance and indoor illumination of the active daylighting and heat storage solar greenhouse are better than that of the control greenhouse.

**Table 5. Statistics of indoor and outdoor illumination of solar greenhouse**

| Weather conditions | Test greenhouse | Outdoor average illumination [lux] | Average indoor illumination [lux] | Transmittance [%] |
|---|---|---|---|---|
| Winter solstice (sunny to cloudy) | New building solar greenhouse with recycled materials | 41584 | 25436 | 61.17% |
| | Building solar greenhouse with common materials | | 22164 | 53.30% |
| Cloudy days | New building solar greenhouse with recycled materials | 42416 | 24710 | 58.26% |
| | Building solar greenhouse with common materials | | 22217 | 52.38% |
| Sunny day | New building solar greenhouse with recycled materials | 51041 | 36142 | 70.81% |
| | Building solar greenhouse with common materials | | 30296 | 59.36% |

## Conclusions

In this paper, the application of renewable materials in energy saving of new building solar greenhouse is studied, and the influence of different building materials on energy saving of solar greenhouse is analyzed. It can adjust the angle of the sunlight greenhouse roof manually to improve the solar radiation into the room and adjust the fan system manually to increase the heat storage of the back wall, are as follows.

- Under different weather conditions in winter, the average light transmittance and indoor illumination of the daylighting roof of the solar greenhouse with recycled materials are increased compared with that of the common materials.
- In winter solstice, cloudy days and sunny days, the light transmittance of active daylighting and heat storage solar greenhouse was 61.17%, 58.26%, and 70.81%, respectively, which was 7.87%, 5.88%, and 11.45% higher than that of ordinary energy-saving solar greenhouse, and the corresponding indoor illumination was 15.42%, 11.73%, and 21.28% higher than that of ordinary energy-saving solar greenhouse.
- Under different weather conditions in winter, the indoor air temperature and ground temperature of the solar greenhouse with active daylighting and heat storage are significantly higher than those of the control material energy-saving solar greenhouse. The temperature difference between indoor and outdoor is above 27 °C.

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