Analysis of Thermal insulation performance of Aerated Concrete Block Wall in Solar Greenhouse

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Abstract. In recent years, the solid loam brick has gradually been forbidden. It made the construction of the solar greenhouse be confronted with a difficulty. In order to solve this problem, and satisfy the requests of the structural design and the heat preservation of solar greenhouse, aerated concrete, a new type of structural material, had been chosen to construct the north wall of solar greenhouse and replace the solid loam brick. The theoretical analysis and the actual tests all indicated that the aerated concrete brick was one of the appropriate structural materials for being used to construct the surrounding structure of the solar greenhouse. At the same time, economizing energy sources and protecting environment of this material would make it widely be used in the solar greenhouse.

1. Introduction
Solar greenhouse occupies a large proportion in China's agricultural production facilities [1]. Since 1990s, the rear wall of solar greenhouse has been built with clay solid brick (red brick), which consumes a huge amount of bricks, and consumes nearly 100,000 bricks in the 667m² solar greenhouse. The production of red bricks requires the consumption of large quantities of high quality clay and destroys the arable land. In 2000, the National Building Materials Bureau, the Ministry of Construction, the Ministry of Agriculture, and the Ministry of Land and Resources issued a document requesting the complete elimination of red bricks in most parts of the country and the promotion of the development and application of new building materials [2]. This makes the selection and construction of solar greenhouse facing urgent problems. This study proposes that one type of energy-saving and environmental-friendly new type building materials, such as aerated concrete blocks, is applied to the construction of solar greenhouse retaining structures. Both theoretical analysis and experiment prove that aerated concrete block is a new building material suitable for construction of solar greenhouse.

2. Materials and Methods
2.1. Material selection and analysis of advantages
The enclosure structure of solar greenhouse not only has good insulation performance to effectively prevent indoor heat transfer to outdoor, but also effectively absorbs and accumulates solar thermal energy in daytime. In the night, the accumulated solar heat can be released to the greenhouse to maintain a certain temperature of [3] in the room. In this study, we conducted a thorough investigation and theoretical analysis of the optional new building materials such as aerated concrete, ceramsite concrete, and fly ash bricks, and combined the structural characteristics of solar greenhouses and the
use of materials to determine the use of aerated concrete blocks. As a substitute for red bricks, it is used in solar greenhouses. Comparison of thermal and physical properties between aerated concrete and commonly used building materials in solar greenhouse is shown in Table 1.

Table 1 Main thermal physical performance contrast between aerated concrete and materials common used in greenhouse

| Material                  | Thermal conductivity / W·m⁻¹·℃⁻¹ | Specific heat capacity / KJ·kg⁻¹·℃⁻¹ | Density / kg·m⁻³ | Coefficient of thermal storage / W·m⁻²·℃⁻¹ |
|---------------------------|---------------------------------|-------------------------------------|------------------|------------------------------------------|
| Aerated concrete block    | 0.16                            | 1.05                                | 600              | 3.28                                     |
| Clay brick masonry        | 0.81                            | 1.05                                | 1800             | 10.53                                    |
| Concrete                  | 1.51                            | 0.92                                | 2300             | 15.36                                    |
| Cement mortar             | 0.93                            | 1.05                                | 1800             | 11.26                                    |
| Slag                      | 0.29                            | 0.92                                | 1000             | 4.40                                     |
| Polystyrene board         | 0.03                            | 1.34                                | 8                | 0.16                                     |

As can be seen from Table 1, the aerated concrete is only 2/3 of bulk density of red brick. The compressive strength of masonry is 4.0 to 5.0 MPa, which is superior to other lightweight materials. In addition, according to the energy-saving design standards, 300mm thick aerated concrete blocks can be used to meet the heat insulation requirements in cold regions of northern China, while the use of ordinary solid clay bricks requires 720mm thickness to meet the design requirements [4]. The aerated concrete block wall can meet the building requirements with smaller thickness, and can increase the effective area of the building while reducing the wall area.

2.2. Determination of the application parameters of materials

The performance parameters and specifications of aerated concrete block used in this study are shown in Table 2.

Table 2 The main specification and performance parameter and of aerated concrete brick

| Type | Length /mm | Breadth /mm | Height /mm | Density /kg·m⁻³ | Intensity /MPa | Dryness shrink /mm·m⁻¹ | Thermal conductivity /W·m⁻¹·℃⁻¹ |
|------|-------------|-------------|------------|------------------|----------------|------------------------|--------------------------------|
| 1    | 600         | 200         | 240        | 600              | 3.5            | 0.5                    | 0.16                           |
| 2    | 600         | 100         | 240        | 600              | 3.5            | 0.5                    | 0.16                           |

After testing and analyzing the structure and heat transfer characteristics of the rear wall of the solar greenhouse, many researchers think that the thermal resistance of the multi-layered composite wall is large, the heat storage, heat insulation and heat preservation are good, and the thickness is small and the material is saved. [5] The composite multiple wall has an attenuation multiple of 12.3 times that of the polystyrene wall and 9.5 times that of the pure brick wall. Based on the research and application conclusions of the heterogeneous composite wall structure of red brick masonry and polystyrene board, this study designed and built several new types of composite masonry structural walls in order to obtain aerated concrete through theoretical and experimental analysis. For solar greenhouse construction availability and appropriate thickness.

3. Results and Analysis

3.1. Analysis of Thermal Insulation Performance of New Material Composite Wall

The theoretical analysis is based on the general condition that the thermal insulation performance of the building is evaluated by the total thermal resistance R of the enclosure structure. [6].
The greater the total thermal resistance $R$, the smaller the heat transfer capacity; the $D$ value is the thermal inertia index of the enclosure structure, which characterizes the thermal stability of the structure, the $D$ value of the structure is large, and the temperature fluctuation in the room is small.

Based on the above theory, the new composite wall was analyzed for insulation properties. The results are shown in Table 3.

**Table 3** Thermal resistance $R$, thermal stability $D$ and diathermanous parameter of each composite wall in solar greenhouse

| Treatment | Wall structure (from inner to outer, mm) | Total thermal resistance/ m²·℃·W⁻¹ | Heat inertia index | Heat transfer coefficient/ W·m⁻²·℃⁻¹ |
|-----------|----------------------------------------|----------------------------------|--------------------|-------------------------------------|
| 1         | 200Aerated Concrete Block +100 Polystyrene Board +200Aerated Concrete Block | 5.558                           | 8.689              | 0.175                               |
| 2         | 150Aerated Concrete Block +100Polystyrene Board+200 Aerated Concrete Block | 5.246                           | 7.664              | 0.185                               |
| 3         | 150Aerated Concrete Block +110Polystyrene Board +240 Red Brick | 4.598                           | 6.733              | 0.210                               |
| 4         | 240Red Brick+100mm Polystyrene Board+240 Red Brick | 3.650                           | 6.729              | 0.262                               |

The national industry standard “Energy-saving Design Standards for Residential Buildings in Hot Summer and Cold Winter Regions” JGJ134-2001, taking $D$ or $(R+D)$ value as the evaluation index of the thermal insulation performance of building envelope structures, for external wall requirements $D \geq 3.0$ ($K \leq 1.5$ m²·℃·W⁻¹) For greenhouses, larger $R$ and $D$ should be used as much as possible. [7].

The comprehensive thermal resistance value of the enclosure wall and the rear roof of the solar greenhouse is given by the standard "structure of solar greenhouse" (JB/T10286-2001) of the People's Republic of China mechanical industry standard [8]. The low limit thermal resistance ($R_{min}$) is designed to be achieved. The outdoor design temperature of Beijing area in the standard is -12℃, so the thermal resistance value of the enclosure wall is higher than the low limit thermal resistance $R_{min}=1.4$ m²·℃·W⁻¹.

According to the results of thermal insulation analysis and the above theoretical analysis, the total thermal resistance value of the back wall constructed by aerated concrete far exceeds the design requirement; the thermal inertia index $D$ and the heat transfer coefficient $K$ all meet the requirements of civil buildings in cold regions in winter.

3.2. Test and verification of the thermal insulation performance of the new material composite wall

3.2.1. Test scheme. Comparing and testing the experimental greenhouses in Beijing Changping, Jinliuhuan Agriculture Park, planting the same crops in each room and adopting the same operation management, including the time of the coil insulation and the ventilation time; adopt the Tsinghua Tongfang RHLOG-TH intelligent temperature/humidity sensor, placed in the middle of the greenhouse, measured one meter above the ground, and read all data synchronously to ensure the complete comparability of data collected in each greenhouse (Figure 1). The test time is from December 8, 2015 to February 14, 2016, and the data read interval is 0.5h.
3.2.2. Result analysis. As can be seen from Fig.2, the four experimental greenhouses can maintain the indoor and outdoor temperature difference close to 20°C at the coldest time at night, verifying that the heavy solid material wall has a good delay effect on the change of the outdoor temperature and has the heat corresponding to the theoretical analysis. Inert and thermal insulation properties.

The night indoor temperature of 500mm thick aerated concrete wall greenhouse is higher than 580 thick red brick wall greenhouse, which proves that the aerated concrete block composite wall can replace the red brick wall.

The comprehensive test results also show that when the outdoor temperature is below -10°C, the temperature in the greenhouse is not much different at night, and it can be maintained at a better level. At the time when the temperature is low to -15°C, the greenhouse in the aerated concrete material wall remains higher than the indoor temperature in the other greenhouse. It can be explained that when the outdoor temperature is lower, the wall of the aerated concrete material can exert its advantages.

4. Conclusion
The high thermal insulation of the aerated concrete block makes the heterogeneous composite wall built with the polystyrene board have a relatively superior thermal characteristic than the red brick masonry, and the effect of the rear wall of the greenhouse is stronger to improve the temperature in the greenhouse. The aerated concrete block can keep the indoor temperature under the condition of reducing the wall thickness of 14%, which is not less than the back wall to double 240mm red brick greenhouse, which reduces the amount of material and improves the use rate of the interior of the
greenhouse. Theoretical analysis and experiments show that aerated concrete block is a new building material suitable for building in solar greenhouse.

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