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ANALYSIS OF ENERGY-SAVING DESIGN OF BUILDING ENVELOPE

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Abstract
The research work of this article to some extent reduces the life cycle investment cost, reduces the investment cost of energy-saving buildings for enterprises, and is conducive to improving the continuous expansion and promotion of energy-saving buildings, and strengthening the sustainability and practicality of energy-saving buildings.
Keywords: orthogonal experimental design (OED), energy efficiency, building envelope, multicriteria assessment.

Introduction

Currently, the energy issue is one of the most concerning issues in the world. In all countries around the world, whether in Europe or Asia, the proportion of energy consumption is relatively high, especially in building energy consumption, which covers heating and air conditioning, construction and domestic energy consumption, accounting for over 30%. The value of this experiment lies in its ability to bring benefits to countries from economic and social perspectives, so it has certain application value and practical value.[1]First of all, applying the life cycle to energy-saving buildings is conducive to strengthening people's understanding and understanding of energy-saving buildings, and further promoting the increasing scale of energy-saving buildings.[2-3] Secondly, considering the economic aspects and based on the actual situation of the local construction industry, explore personalized solutions[4-5].

This article discusses in detail the primary and secondary order of the influence of window types, floor heat transfer coefficient, exterior wall heat transfer coefficient, and roof heat transfer coefficient on the following aspects through the orthogonal test method[6-7].

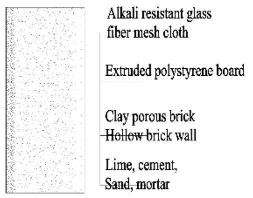
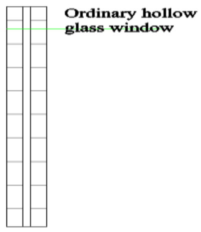
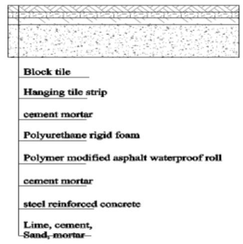
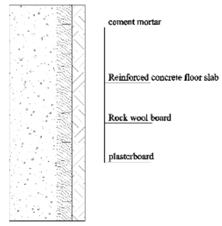
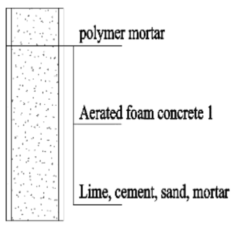
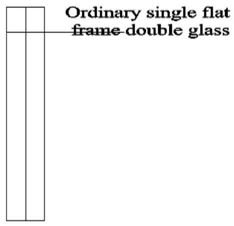
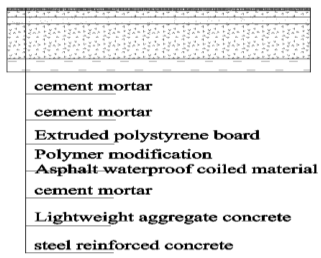
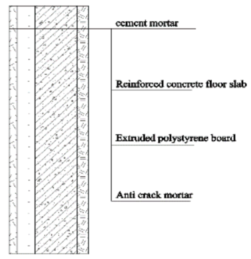
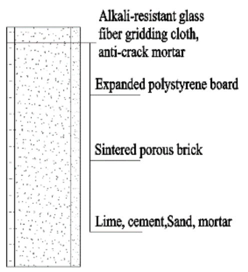
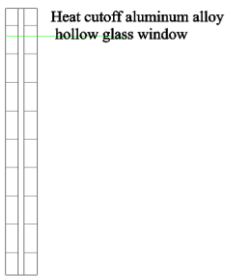
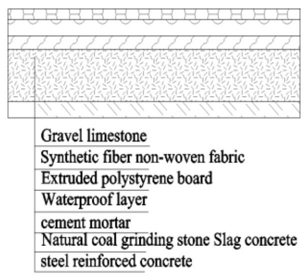
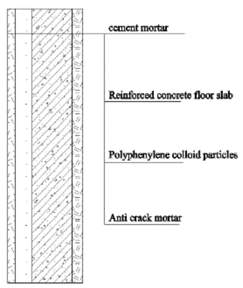
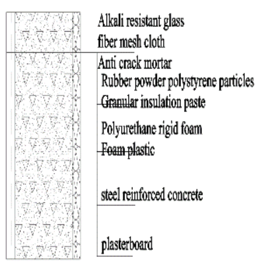
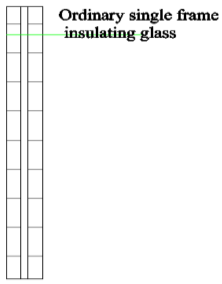
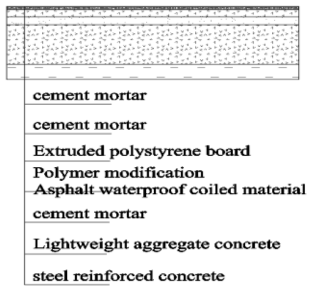
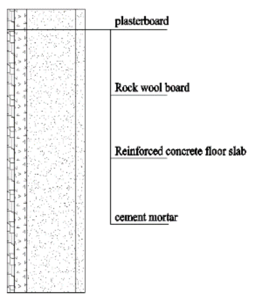
Research results

In this paper, a public building in Hexi, Jiangsu Province, China, is taken as an example for modeling experiment,Through modelling with Tianzheng Energy Efficiency Design Software , four aspects that have a significant impact on building energy consumption are selected for calculation, namely: floor heat transfer coefficient (D), roof heat transfer coefficient (C), window heat transfer coefficient (B), and exterior wall heat transfer coefficient (A). In the virtual experiment, there were considered four types of different construction for the exterior wall, the roof wall, the floor and the window type respectively. At the same time, four levels of these factors were selected to conduct orthogonal experiments.

Proposed envelope types and window types are given in Table 1.

This orthogonal experiment adopts a model of four factors and four levels. The table is established in $L10(4^4)$ mode, without considering the interaction of these factors, and an extra blank column is used to record the error data to measure this experiment. Each experimental scheme in the table corresponds to a row, which represents the horizontal combination of factors. The experimental scheme is sorted by numbers. At the same time, the blank column has no effect on the experimental content. For example, in Experiment 1, the schemes are A1B2C3D4. This scheme represents an experiment in which the selected materials are aerial floor with natural ventilation at the bottom (mineral wool, rock wool and glass wool board), aluminum alloy ordinary single-frame double glass 6~12mm (push and pull), flat roof (polyurethane rigid foam waterproof insulation layer) and sintered porous brick (expanded polystyrene board). The corresponding heat transfer coefficients are 1.470 W/m^2K for floor, 4.00 W/m^2K for window, 0.860 W/m^2K for roof and 0.960 W/m^2K for exterior wall. To sum up, this experiment needs 16 combined experiments, and finally the experimental results are filled in the table. The results are divided into: the total annual cumulative load and energy saving rate of the designed building, the cumulative heating load of the designed building, the cumulative cooling load of the air conditioner of the designed building, and so on.

Table 1 – Initial data for the energy performance design modelling

	A The exterior wall type	B The window type	C The roof type	D The floor type
1	 Clay porous brick and hollow brick wall 240 (molded polystyrene board)	 Plastic single-layer ordinary hollow glass window	 Slope roof (polyurethane rigid foam plastic)	 Cement mortar floor (rock wool, mineral wool)
2	 Aerated concrete block	 Aluminium alloy ordinary single flat frame double glass 6~12mm (push and pull)	 Roofing (extruded polystyrene foam plastic board)	 Overhead floor with natural ventilation at the bottom (extruded polystyrene board)
3	 Sintered porous brick (expanded (extruded expanded polystyrene board)	 Ordinary hollow glass window with heat-insulating aluminium alloy single roof frame	 Roofing (extruded polystyrene board)	 Overhead floor with natural ventilation at the bottom (polystyrene particle thermal insulation mortar)
4	 Reinforced concrete wall (polyurethane plastic)	 Aluminium alloy ordinary single-frame insulating glass 9~12mm (flat)	 Flat roof (polyurethane rigid foam waterproof overhead floor (rock wool, warm layer)	 Mineral wool with natural ventilation at the bottom, glass wool board)

(1) determine the primary and secondary order of factors

The experimental results are different because of the different combination of factors. Different experimental results will lead to different extreme ranges of various factors. The magnitude of extreme range values represents that the numerical values of factors will lead to changes in the experimental index values. The smaller the change, the smaller the influence of the level of proving factors on the experimental results. Conversely, the greater the change, the greater the proof influence. Therefore, the factor column with the largest range represents that the level of this factor has the greatest influence on the experimental results. Therefore, the cumulative heat load of heating in the whole year is influenced by the following factors: C roof heat transfer coefficient < D floor heat transfer coefficient < A exterior wall heat transfer coefficient < B window heat transfer coefficient. The order of cumulative cooling load factors of air conditioning is: d floor heat transfer coefficient < c roof heat transfer coefficient < an exterior wall heat transfer coefficient < b window heat transfer coefficient. For the cumulative total load of the whole year, the factors are arranged as follows: C roof heat transfer coefficient < D floor heat transfer coefficient <A exterior wall heat transfer coefficient < B window heat transfer coefficient.

Determination of the optimal scheme

In the experimental range, the best combination of various factors is the best scheme.

The best scheme of heating cumulative heat load is the overhead floor with natural ventilation at the bottom (polystyrene particle insulation mortar) + single-frame ordinary hollow glass window with heat insulation aluminum alloy + flat roof (extruded polystyrene foam plastic board) + clay perforated brick and hollow brick wall 240 (molded polystyrene board), which is A4B1C3D1 in the table.

The best scheme of air conditioning cumulative cooling load is cement mortar floor (rock wool, mineral wool) + plastic single-layer ordinary hollow glass window + flat roof (extruded polystyrene foam plastic board) + aerated concrete block, namely A2B4C2D4 in the table.

There are two best schemes for the cumulative total load in the whole year, namely, the overhead floor with natural ventilation at the bottom (polystyrene particle insulation mortar)+single-frame ordinary hollow glass window with heat insulation aluminum alloy + flat roof (extruded polystyrene foam plastic board)+clay porous brick, namely A4B1C3D1 in the table; And the overhead floor with natural ventilation at the bottom (polystyrene particle insulation mortar)+single-frame ordinary hollow glass window with heat-insulating aluminum alloy+hollow brick wall 240 (molded polystyrene board)+aerated concrete block, namely A4B1C3D4 in the table.

The example public building in this article covers an area of 5158.50 m^2, and the selected energy-saving standard reaches 50%. In the following tests, tests 1, 2, 3, 4, 10, 13, 14, 15, and 16 indicate that the elimination rate is within a half, and tests 5, 6, 7, 8, 9, 11, and 12 indicate that the energy saving rate is more than half. The validation basis of this experiment is to select the optimal scheme for this experiment based on orthogonal experimental design. This article analyzes and simulates optimization plan 1 and optimization plan 2, respectively, and completes them through Tianzheng Energy Saving Software. Carry out life cycle cost calculation and optimal scheme selection for Tests 5, 6, 7, 8, 9, 11, 12, Optimization Scheme 1 and Optimization Scheme 2.

Research period

The research period of architecture is mainly determined by two factors, one is the project construction period, and the other is the actual construction period. Each building has different characteristics, which determine the service period of the building. For example, the national reference period for office buildings is 50 years.

Discount rate

Discount rate = industry benchmark rate of return. At present, China has not yet formed a set of mature parameter standards for the discount rate, so it can only be calculated by using the combined model method, and the discount rate is obtained. In other words, the industry discount rate consists of the safe return rate If and the risk return rate β (I M I F), and the calculation formula is as follows

$$(1) Ic = If + \beta(Im - If) \tag{1}$$

When considering the time value of capital: taking the industry benchmark discount rate i=12%, the annual energy cost is A yuan/m^2, the service life of the building is 50 years, and the initial construction cost of the energy-saving scheme for maintaining the structure is p yuan/m^2, then the dynamic life cycle cost of the building is:

$$LCCPv = P + A\frac{(1+12\%)^{50}-1}{12\%\times(1+12\%)^{50}} \quad (2)$$

$$LCCFv = P(1+12\%)^{50} + A\frac{(1+12\%)^{50}-1}{12\%} \quad (3)$$

$$LCCAv = A + P\frac{12\%\times(1+12\%)^{50}}{(1+12\%)^{50}-1} \quad (4)$$

where

LCCPv-Present value of life cycle cost

LCCFv-Future value of the whole life cycle

LCCAv-Actual value of the whole life cycle

Initial construction cost of energy-saving scheme for maintenance structure

A-Annual energy cost

On the premise of ignoring the time value of funds, the static life cycle cost of buildings is calculated as: C=P+A×50.

Life Cycle Cost Calculation and Best Scheme Selection

In the Table 2 the calculation results of static life cycle cost (C) and dynamic life cycle cost (LCCpv, LCCFv, LCCAv) of envelope energy-saving scheme is presented.

Table 2 – Life Cycle Cost of Energy Saving Scheme for Envelope

Test number	A Type of exterior wall	B Window type	C Roof type	D Floor-type	Unit construction area cost (yuan/m²)	Annual energy cost (yuan/m²)	LCCpv (yuan/m²)	LCCFv (yuan/m²)	LCCAv (yuan/m²)	Static life cycle cost (c) (yuan/m²)
5	A3	B4	C3	D1	292.81	117.99	1272.66	367798.73	153.25	6192.31
6	A2	B3	C4	D3	339.42	117.96	1319.02	381197.12	158.83	6237.42
7	A4	B3	C3	D3	352.02	117.68	1329.29	384166.55	160.07	6236.02
8	A1	B4	C4	D3	291.58	117.72	1269.18	366792.37	152.83	6177.57
9	A3	B3	C1	D3	328.58	117.26	1302.37	376384.34	156.83	6191.58
11	A4	B4	C1	D3	329.96	118.01	1309.97	378583.16	157.74	6230.46
12	A1	B3	C4	D1	323	117.04	1294.96	374243.71	155.93	6175
Preferred scheme 1	A1	B3	C4	D3	324.21	116.40	1290.85	373057.40	155.44	6144.21
Preferred scheme 2	A1	B3	C4	D1	318.71	115.99	1281.95	370483.89	154.37	6118.21

The analysis of Table 2 has shown, that the energy saving rate required by the state should be kept above 50%, so taking this as the precondition, in the comparison of time value, Experiment 8 is the combination with the best energy saving effect in the enclosure structure scheme, that is, clay perforated brick hollow brick wall 240+ aluminium alloy ordinary single-frame insulating glass 9~12mm (flat open)+flat roof+overhead floor. The cost of scheme 7 is the highest in the whole life cycle cost, that is, the enclosure structure adopts reinforced concrete wall+insulating aluminium alloy single-frame ordinary hollow glass window+roof+overhead floor. Through the analysis and calculation of LCCAV, it is concluded that the lowest cost scheme of the selected building model costs 1,528,300 yuan per year, and the worst scheme costs 1,600,700 yuan per year, which can be reduced by 41,000 yuan.

From LCCAV, this index is analyzed in detail, and compared with the building area, the annual cost of the lowest cost scheme is 152.83 yuan, and the annual cost of the highest cost scheme is 160.07 yuan, which can be reduced by 37,347 yuan.

Ignoring the time value, Scheme 2 is the combination with the best energy-saving effect in the envelope scheme, that is, clay perforated brick+hollow brick wall 240 + insulating aluminium alloy single-frame ordinary hollow glass window+flat roof+cement mortar floor. Among them, the scheme with the most unsatisfactory effect is the single-frame ordinary hollow glass window with heat-insulating aluminium alloy+aerated concrete block + flat roof + overhead floor.

Conclusions

In this theses, the static life cycle cost is studied and analyzed, and it can be found that on the premise that the energy saving rate fully meets the national requirements exceeds 50%, in the whole life cycle cost of this model, the worst cost of using the scheme can be reduced by 614,900 yuan compared with the best cost of the scheme.

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