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Energy consumption prediction model of typical buildings in hot summer and cold winter zone of China

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Abstract: To overcome the shortcomings of the energy consumption prediction models in the application during the design stage, a quick prediction model for energy consumption is proposed based on the decoupling method. Taking typical residential and office buildings in hot summer and cold winter zones as research objects, the influence factors on building energy consumption are classified into intrinsic factors and operational factors on the basis of the heat transfer principle. Then, using the intrinsic factors as the fundamental variables and operational factors as the modified variables, the quick prediction model for the buildings in typical cold and hot zones is proposed based on the decoupling method and the accuracy of the proposed model is verified. The results show that compared to the simulation results of EnergyPlus, the relative error of the prediction model is less than 1.5%; compared with the real operating data of the building, the relative error is 13.14% in 2011 and 8.56% in 2012 due to the fact that the coincidence factor becomes larger than the design value about 16% in 2011 and 13% in 2012. The finding reveals that the proposed model has the advantages of rapid calculation compared with EnergyPlus and Design Builder when predicting building energy consumption in building designs. The energy consumption prediction model is of great practical value in optimal operation and building designs.

Key words: building energy consumption; energy conservation; load prediction; EnergyPlus

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Nowadays, with the increasing population, rapid urbanization and high thermal comfort requirement, building energy consumption increases sharply and it will catch up with and even exceed the industrial and transportation energy consumption. In the future, the building will be the most energy-consuming[1–3]. To realize an efficient energy management system, it is crucially important to establish a reliable and accurate prediction model for building energy consumption, which causes the construction of prediction models for building energy consumption to become an essential issue[4–5].

It is difficult to precisely predict the building energy consumption, since there are many factors influencing energy consumption, such as the change in weather conditions, structures of the building, geographic location, layout and the operation of internal facilities[6–8]. The prediction accuracy directly affects design, configuration and operation. During the past several decades, there have been various forecasting techniques that are applied to the building energy consumption calculation, such as engineering methods, statistical methods, artificial neural networks, support vector machines and grey model techniques, etc[9], to name only a few. Stephenson et al. [10–12] put forward the reaction coefficient to discuss the heat transfer and heat load. Spitler et al. [13] utilized periodic response factors to reduce the unnecessary computational quantity. The frequency-domain regression method was introduced by Wang et al. [14] to calculate transient heat flow. A report sponsored by the agency of the United States government proposed the key criteria that was used for precise heating and cooling load calculations[15]. Softwares Design Builder and EnergyPlus are usually adopted to calculate energy consumption, the accuracy of which has been validated by the American HVAC Engineering Association[16–17].

These methods mainly concentrate on reducing energy consumption and optimizing the building operation. However, there is little research on how to predict building energy consumption at the stage of building designs. The usage of new materials and new technology can reduce the building's energy consumption, and thus it is important to comprehensively calculate the building energy consumption in construction and operation[8, 18]. On the other hand, sometimes these methods present a hysteretic nature from the perspective of engineering application and require elaborate construction drawings and parameters, whose data is difficult to obtain in the stage of building designs. Nevertheless, designers cannot have the comprehensive understanding, for instance, when the government wants to convert a coal-fired power plant into a CCHP (combined cooling, heating with power) power plant. They should find some consumers to utilize the cooling and heating supply produced by the plant. Under this circumstance, designers hope to know the dynamic characteristics of building load and afterwards configure

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different types of buildings in a region, so that they can make the peak-valley difference as small as possible. Moreover, with the development of the economy, occupancy density, coincidence factor and schedule may change, which may be different from the design conditions[19–20]. Therefore, the influential factors of building should be grasped and the prediction model that satisfies accuracy requirements should be established.

This work develops an energy consumption prediction model for typical buildings based on the heat transfer principle. This work also analyzes and distinguishes the influential factors of building energy consumption to simplify the prediction model. Finally, the accuracy of the proposed model is verified.

1 Methodology

1.1 Heat transfer model

The building energy system is fairly complex; therefore, there are four assumptions when predicting the energy consumption. 1) The building consists of four parts: vertical walls, windows, ceilings, and floor. The heat storage of the building can be ignored when calculating building energy consumption[16]. 2) Only the internal heat generation of the building which includes electrical equipment (including computers, lighting, etc.) and body heat dissipation is taken into account. 3) The windows and doors are shut when air conditioning is running. 4) Indoor heat transfers promptly so that temperature distribution is uniform.

There are many factors influencing the building energy consumption as shown in Fig. 1, including solar radiation, air circulation, internal heat generation and so on. As can be seen in Fig. 1, conductive heat transfer via the walls and ceiling, convective heat transfer with air circulation, radiation through the windows, and solar radiation absorption are the main heat transfer mechanisms in buildings. In this section, we concisely discuss the building model. The cooling and heating load of the building can be demonstrated in the following equation:

$$\left.\begin{aligned} q_c &= q_1 + q_2 + q_3 + q_4 \\ q_h &= -q_1 - q_2 - q_3 - q_4 \end{aligned}\right\} \tag{1}$$

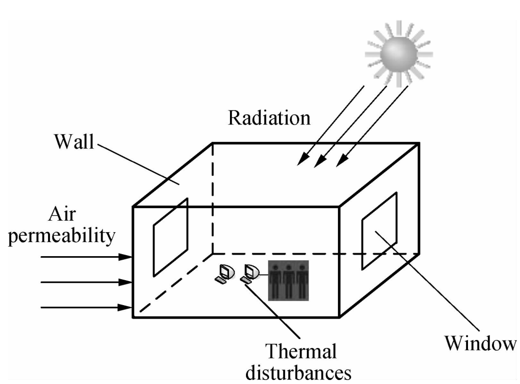

Fig. 1 Heat transfer model of a building

where q_c and q_h are the cooling load and the heating load; q_1, q_2 and q_3 are the heat flux between indoors and outdoors, which is triggered by temperature difference, the solar radiation and the air circulation, respectively; and the internal heat generation of the building is denoted by q_4. The total building energy consumption can be obtained from the time integration of q_c and q_h.

According to the Chinese National Standard (GB 50189—2005)[19] and the basic principle of heat transfer[20], q_1 is described by the following general equation:

$$q_1 = \frac{(T_o - T_i)\left(\dfrac{A_{wa}}{R_{wa}} + \dfrac{A_{wi}}{R_{wi}}\right) + k_g A_a (T_g - T_i)}{A_a} \tag{2}$$

where T_o, T_i and T_g are the ambient temperature, the indoor temperature and the ground temperature; A_{wa}, A_{wi} and A_a are the areas of wall, window and floor, respectively; $A_{wi}/(A_{wa}+A_{wi})$ is defined as the window-wall ratio r; R_{wa} and R_{wi} are the thermal resistances of the wall and the window between indoors and outdoors, respectively; and k_g is the heat transfer coefficient. The ambient temperature and the ground temperature are obtained by consulting meteorological data.

q_2 is calculated by the following equation:

$$q_2 = \frac{(T_o - T_i)\sum \varepsilon_{st} k_{st} A_{st} + \varepsilon_{ab} k_{an} A_a}{A_a} \tag{3}$$

where q_2 consists of the direct radiative heat flux density of architectural enclosure and the indoor radiative heat flux density; ε_{st} and ε_{ab} are the correction coefficients of the enclosure structure and solar radiation absorption; k_{st} and k_{an} are the heat transfer coefficients of the enclosure structure and solar radiation angle. The parameters ε_{st}, ε_{ab}, k_{st} and k_{an} are related to building orientation denoted by θ[19].

q_3 is calculated as

$$q_3 = \frac{(T_o - T_i) C_p \rho N V}{A_a} \tag{4}$$

where C_p is the average specific heat capacity at constant pressure; N and V denote the rate and volume of air exchange per unit time, respectively. N is closely affected by indoor heat distribution, proportional to q_4 below.

The ambient temperature in Eqs. (2) to (4) is presented in Fig. 2, which is the hourly air temperature of Nanjing, a typical city in the hot summer and cold winter zone in China. The date of Fig. 2 can be obtained from Autodesk Ecotect Analysis.

q_4 is calculated as

$$q_4 = \frac{h}{3.6}(e_{el} + e_{bo} p_e) \tag{5}$$

where h is the height of a single-story and its value is 3.6 m. The internal heat generation of the building has a

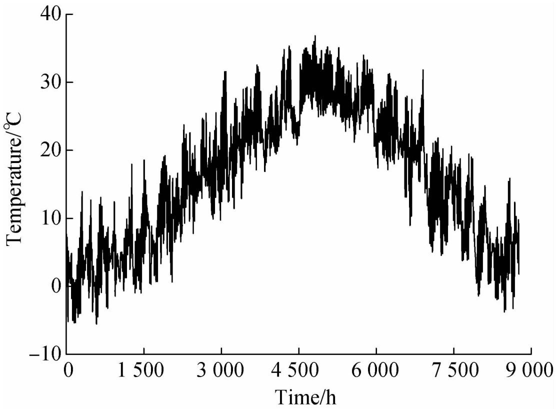

Fig. 2 Ambient temperature of Nanjing

great influence on q_c and q_h. In a typical building, the internal heat generation is caused by electrical equipment and body heat dissipation. e_{el} and e_{bo} are the electrical equipment density and body heat dissipation, $e_{bo}=50$. p_e is the occupancy density.

1.2 Calculation process

In the proposed model, the influential factors of the cooling and heating load can be divided into two categories: intrinsic and operational parameters. Their concrete explanations are as follows:

1) Intrinsic parameters contain orientation, thermal resistance of walls and windows, window-wall ratio, and so on. When the building has been built, these parameters will not transform basically.

2) Operational parameters include schedules, the staff and their behavior, the comfortable indoor temperature, electrical equipment, and so on. In an engineering application, these parameters will vary with users' requirements frequently.

The proposed model is a multi-input and multi-output system. In order to simplify the calculation, the multi-variable system is divided into several subsystems, and each subsystem has a function matrix, as shown in Fig. 3. The cooling and heating loads are the coupling consequence of multiple factors. The research strategy is demonstrated in Fig. 4.

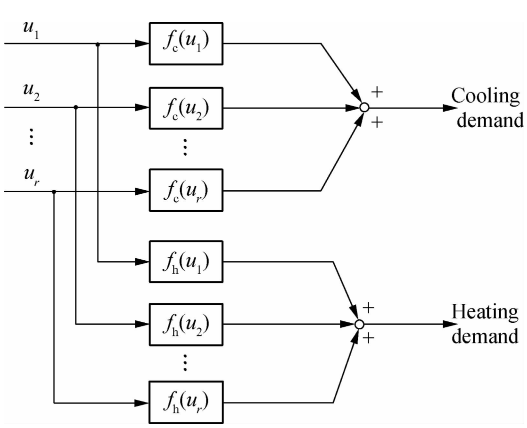

Fig. 3 Division of multivariable process

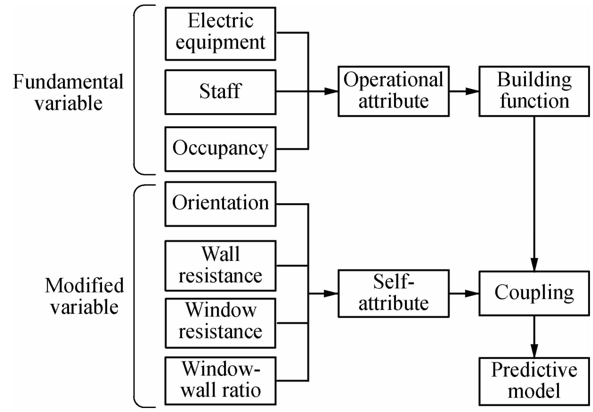

Fig. 4 Research strategy of the predictive model

In the model, the detailed procedure can be conducted as follows:

Step 1 Operational parameters are considered to be the most important factors in this prediction model, which directly determine the application of the building.

Step 2 When the application of the building has been determined, intrinsic parameters can be used to revise the load of building. Intrinsic parameters will produce an opposite effect on the load of building when the internal heat generation is greater than a certain value. Therefore, the coupling relationship between intrinsic and operational parameters is taken into account.

Step 3 The temperature difference between indoors and outdoors and the radiative heat flux absorbed by the building change with time. Therefore, a temperature difference coefficient matrix (TDCM) and radiation coefficient matrix (RCM) are employed when building the mathematical models.

2 Results and Discussion

2.1 Influence analysis of operational attribute parameters

When studying the impact of operational parameters, a group of intrinsic parameters are assumed unchanged: site = Nanjing, $\theta=0$, $R_{wa}=2$ (m^2 · K)/W, $R_{wi}=0.5$ (m^2 · K)/W, $r=0.5$.

It is assumed that the indoor comfortable temperature is 26 ℃ in summer and 20 ℃ in winter. Figs. 5 to 7 show the change of cooling load in the typical day (July 15th) and cooling months, and the relationship between cooling load and q_4 in cooling months.

Fig. 5 displays that the cooling load in the typical day in summer has a certain proportional relationship with q_4. The coefficient of cooling load a_c and the coefficient of heating load a_h of each duration when $q_4=25$ W/m^2 are shown in Tab. 1. Figs. 6 and 7 indicate that the cooling load of different months or typical days has a similar proportional relationship with q_4. Based on the above-mentioned analysis, we introduce baseline values, proportional

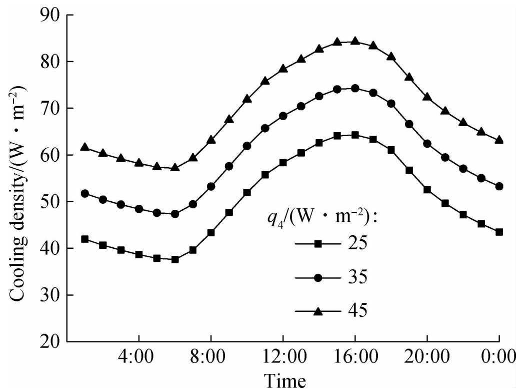

Fig. 5 Influence of time and q_4 on cooling density

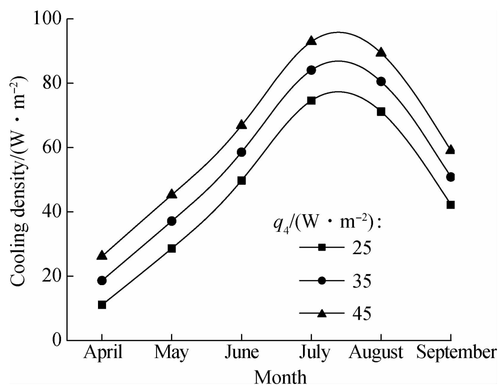

Fig. 6 Influence of month and q_4 on cooling density

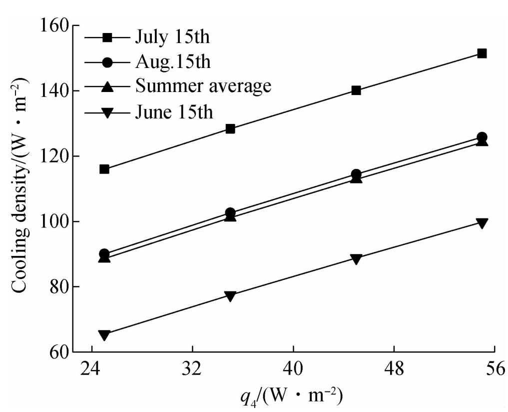

Fig. 7 Influence of q_4 on cooling density in typical day

coefficients, and correction coefficients to express forming energy consumption. Baseline values can be determined by q_4 using the following equation:

$$B_c = f_1(q_4), \ B_h = f_2(B_c) \tag{6}$$

where B_c and B_h are the average value of the daily cooling and heating load from June to August, and the calculation period is from December to February. B_c and B_h can be solved by the polynomial function. The coefficients of the polynomial are listed in Tab. 2, where B_c^1 represents the coefficient of one degree term of B_c and the rest can be deduced by analogy.

Tab. 1 Cooling (heating) load ratio, radiation coefficient and temperature difference coefficient

Duration/h	θ_c	θ_h	t_c	t_h	a_c	a_h
0-1	0	0	0.019 4	0.045 6	0.035 3	0.045 2
1-2	0	0	0.016 1	0.046 1	0.034 2	0.046 0
2-3	0	0	0.013 8	0.046 5	0.033 2	0.046 6
3-4	0	0	0.011 7	0.046 9	0.032 4	0.047 1
4-5	0	0	0.010 0	0.047 2	0.031 7	0.047 5
5-6	0.046 2	0	0.010 4	0.047 1	0.0312	0.047 7
6-7	0.047 5	0.093 0	0.013 9	0.046 5	0.032 1	0.047 4
7-8	0.051 4	0.090 7	0.023 1	0.044 9	0.034 8	0.046 2
8-9	0.056 5	0.086 5	0.035 8	0.042 7	0.038 2	0.044 1
9-10	0.061 9	0.082 0	0.048 1	0.040 5	0.041 9	0.041 8
10-11	0.066 8	0.077 8	0.059 0	0.038 6	0.045 2	0.039 6
11-12	0.070 6	0.074 3	0.067 2	0.037 2	0.047 8	0.037 9
12-13	0.073 3	0.071 8	0.073 3	0.036 1	0.049 6	0.036 6
13-14	0.075 9	0.069 8	0.077 5	0.035 4	0.051 3	0.035 6
14-15	0.078 1	0.068 7	0.078 8	0.035 3	0.052 9	0.035 0
15-16	0.079 0	0.068 8	0.076 2	0.035 6	0.053 4	0.035 1
16-17	0.078 4	0.070 1	0.071 2	0.036 5	0.053 0	0.035 7
17-18	0.076 2	0.072 0	0.064 8	0.037 6	0.051 6	0.036 7
18-19	0.071 8	0.074 7	0.055 7	0.039 2	0.048 6	0.038 0
19-20	0.066 3	0	0.047 0	0.040 7	0.044 8	0.039 7
20-21	0	0	0.040 3	0.041 9	0.042 1	0.041 0
21-22	0	0	0.034 0	0.043 0	0.040 0	0.042 2
22-23	0	0	0.028 7	0.043 9	0.038 2	0.043 3
23-24	0	0	0.023 8	0.044 8	0.036 7	0.044 3

Tab. 2 Polynomial function coefficient of baseline value

Coefficient	B_c^1	B_c^0	B_h^6	B_h^5	B_h^4	B_h^3	B_h^2	B_h^1	B_h^0
Value	1.185	5.814×10^{1}	-1.511×10^{-11}	1.822×10^{-8}	-8.758×10^{-6}	2.134×10^{-3}	-2.761×10^{-1}	1.837×10^{1}	-4.390×10^{2}

2.2 Influence analysis of intrinsic parameters

Intrinsic parameters directly affect q_1, q_2 and q_3. The results obtained from partial derivatives of q_c and q_h, respectively, with respect to θ, r, R_{wa}, and R_{wi}, can be expressed in the following terms:

$$\left.\begin{aligned} G_c(\theta) = f_3(\theta), \ G_h(\theta) = f_4(\theta) \\ G_c(r) = f_5(r), \ G_h(r) = f_6(r) \\ G_c(R_{wa}) = f_7(R_{wa}), \ G_h(R_{wa}) = f_8(R_{wa}) \\ G_c(R_{wi}) = f_9(R_{wi}), \ G_h(R_{wi}) = f_{10}(R_{wi}) \end{aligned}\right\} \tag{7}$$

The polynomial coefficients of the above-mentioned equations are presented in Tab. 3, where θ_c^2 represents the quadratic coefficient of $G_c(\theta)$; $R_{c,wa}^2$ represents the quadratic coefficient of $G_c(R_{wa})$; other terms can be obtained similarly.

2.3 Influence analysis of coupling factors

The coupling relationship between intrinsic and operational parameters includes three aspects: coupling terms of q_4, TDCM, and RCM.

1) Coupling terms of q_4. When q_4 is very small, the cooling and heating load of the building will become smaller when the wall or window resistance becomes larger.

Tab. 3 Polynomial function coefficients of self-attribute parameters

Coefficient	Value	Coefficient	Value	Coefficient	Value	Coefficient	Value
θ_c^4	4.563×10^{-9}	θ_h^4	6.864×10^{-10}	$R_{c,wa}^3$	1.480×10^{-3}	$R_{h,wa}^3$	-4.983×10^{-3}
θ_c^3	-1.062×10^{-6}	θ_h^3	-2.034×10^{-7}	$R_{c,wa}^2$	-6.902×10^{-3}	$R_{h,wa}^2$	4.692×10^{-2}
θ_c^2	7.369×10^{-5}	θ_h^2	2.240×10^{-5}	$R_{c,wa}^1$	8.912×10^{-4}	$R_{h,wa}^1$	-1.653×10^{-1}
θ_c^1	-6.544×10^{-4}	θ_h^1	-5.529×10^{-4}	$R_{c,wa}^0$	1.270×10^{-2}	$R_{h,wa}^0$	1.771×10^{-1}
θ_c^0	3.636×10^{-5}	θ_h^0	7.158×10^{-5}	$R_{c,wi}^2$	-9.988×10^{-2}	$R_{h,wi}^2$	4.749×10^{-1}
r_c^1	4.676×10^{-1}	r_h^1	-7.373×10^{-2}	$R_{c,wi}^1$	1.696×10^{-1}	$R_{h,wi}^1$	-7.405×10^{-1}
r_c^0	-2.059×10^{-1}	r_h^0	3.266×10^{-2}	$R_{c,wi}^0$	-5.303×10^{-2}	$R_{h,wi}^0$	2.249×10^{-1}

However, when q_4 is greater than a certain value, an opposite effect may occur.

2) The calculation of TDCM is carried out on the basis of the temperature difference between indoors and outdoors of a building in Nanjing.

3) In order to obtain RCM, software Autodesk Ecotect Analysis is introduced to simulate sunshine, shadow, and lighting of a building in Nanjing, and the results are demonstrated in Figs. 8(a) to (d). Figs. 8(a) and (b) display the light and shadow of the identical building (θ is 0°) at 8:00 and 17:00 on July 15th. Fig. 8(c) indicates the light and shadow of a building (θ is 40° south by east, other parameters are the same as those shown in Figs. 8(a) and (b)) at 8:00. Fig. 8(d) represents natural lighting and lamp illumination inside the building. θ_c and θ_h are the radiation coefficients. t_c and t_h are the temperature difference coefficients. The values of these coefficients at different moments are given in Tab. 1.

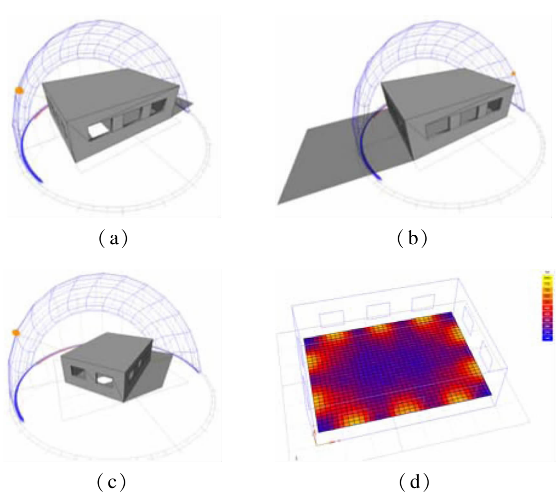

Fig. 8 Analysis on RCM. (a) 8:00 on July 15th ($\theta=0$); (b) 5:00 on July 15th ($\theta=0°$); (c) 8:00 on July 15th ($\theta=40°$); (d) Indoor natural lighting

2.4 Mathematical expression of the prediction model

Based on the above analysis, the following equation is used to calculate the average cooling and heating load of the prediction model:

$$\begin{bmatrix} q_c \\ q_h \end{bmatrix} = \begin{bmatrix} B_c\hat{\alpha}_c \\ B_h\hat{\alpha}_h \end{bmatrix}\left(1+\left(\begin{bmatrix} G_c(\theta) \\ G_h(\theta) \end{bmatrix}\times\begin{bmatrix} S_c(\theta) \\ S_h(\theta) \end{bmatrix}\right)\cdot\right.$$

$$\left(1.04-\frac{q_4}{205}\right)+\begin{bmatrix} 1.78-\dfrac{65-q_4}{214.5} \\ 2.32-\dfrac{65-q_4}{214.5} \end{bmatrix}\times\begin{bmatrix} S_c(t) \\ S_h(t) \end{bmatrix}\times$$

$$\left.\left(\begin{bmatrix} G_c(r) \\ G_h(r) \end{bmatrix}+\begin{bmatrix} G_c(R_{wa}) \\ G_h(R_{wa}) \end{bmatrix}+\begin{bmatrix} G_c(R_{wi}) \\ G_h(R_{wi}) \end{bmatrix}\right)\right) \quad (8)$$

where $\hat{\alpha}_c$ and $\hat{\alpha}_h$ are the sum of the factor of cooling and heating capacity during the working period, respectively; $S_c(\theta)$ and $S_h(\theta)$ are the sum of the radiation coefficient in cooling and heating time, respectively; $S_c(t)$ and $S_h(t)$ are the sum of the temperature coefficient in cooling and heating time, respectively.

2.5 Accuracy verification of the model by software

Software EnergyPlus can be used to simulate and analyze building energy consumption comprehensively[21], which is chosen to verify the accuracy of the prediction model proposed in this paper. Two types of typical buildings (Buildings No. 1 and No. 2) are established and simulated. Figs. 9(a), (b), (c) and (d) show the overall appearance and floor plan of the two buildings in turn.

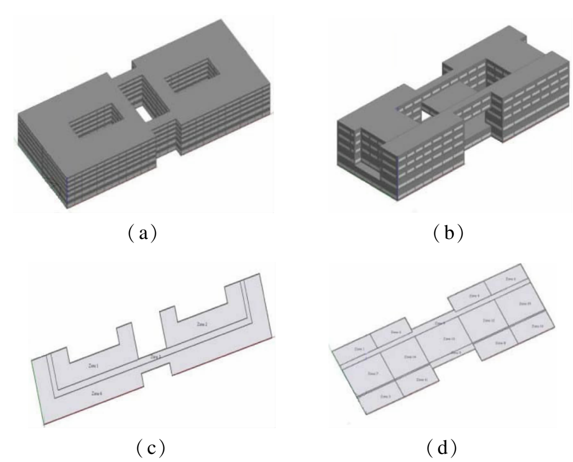

Fig. 9 Overall appearances and floor plans of the two buildings. (a) Appearance of Building No. 1; (b) Appearance of Building No. 2; (c) Floor plan of Building No. 1; (d) Floor plan of Building No. 2

The main parameters are given in Tab. 4. In order to investigate the performance of the prediction model, EnergyPlus is also used for performance comparisons and the results are shown in Tab. 5. It can be seen from the above investigation that the prediction model generally achieves similar accuracy compared with EnergyPlus and the relative error is permissible.

Tab. 4 Key parameters of the two buildings

Parameter	Building No. 1	Building No. 2
$\theta/°$	32.2	0
A_a/m^2	40 306	7 180.11
$R_{wa}/(m^2 \cdot K \cdot W^{-1})$	1.85	2.52
$R_{wi}/(m^2 \cdot K \cdot W^{-1})$	0.435	0.427
r	0.54	0.57
N/s^{-1}	4.9	7
Working period	All day	6:00-9:00, 11:00-13:00, 17:00-19:00
$p_e/(\text{person} \cdot m^{-2})$	0.08	0.26
$e_{el}/(W \cdot m^{-2})$	67	89
$q_4/(W \cdot m^{-2})$	58	92

Tab. 5 Comparison of calculation results

Parameter		Building No. 1	Building No. 2
q_c	$q_{c,a}/(W \cdot m^{-2})$	140.0	176.1
	$q_{c,b}/(W \cdot m^{-2})$	141.3	177.0
Relative error/%		0.92	0.46
q_h	$q_{h,a}/(W \cdot m^{-2})$	65.6	91.5
	$q_{h,b}/(W \cdot m^{-2})$	67.3	87.0
Relative error/%		2.52	−5.17

Notes: $q_{x,a}$ are the results calculated by software EnergyPlus; $q_{x,b}$ are the results calculated by the predictive model in this paper.

2.6 Accuracy verification of the model by literature

In Ref. [22], the energy consumption of a teaching building in Donghua University was simulated by the software Design Builder and the actual building energy consumptions in the year of 2011 and 2012 were measured. The building is located in Shanghai, which also belongs to a hot summer and cold winter zone and the working time is from 7:00 to 18:00, May 20 to October 1 in summer and November 20 to March 20 in winter. The parameters of the building are listed in Tab. 6.

Tab. 6 Parameters of the teaching building

Parameter/constant	Value
$R_{wa}/(m^2 \cdot K \cdot W^{-1})$	0.609 7
$R_{wi}/(m^2 \cdot K \cdot W^{-1})$	0.171 9
r	0.513 4
A_a/m^2	15 989.06
$\theta/(°)$	0
N/s^{-1}	3
Coincidence factor/%	45
$p_e/(\text{person} \cdot m^{-2})$	0.08
$e_{el}/(W \cdot m^{-2})$	35
$q_4/(W \cdot m^{-2})$	35.4

According to the values listed in Tab. 6, the building load is calculated by the prediction model proposed in this paper. Comparisons of the results are detailed in Tab. 7.

It is surprising to find that the relative error between the data in Tab. 7 and the results calculated by the prediction model is merely 4.38%, which indicates that the results of the prediction model are close to the results of Design Builder. Nevertheless, there is a significant relative error when compared to the actual operating data. Ref. [22] showed that the coincidence factor becomes larger than the design value with the development of Donghua University, about 16% in 2011 and 13% in 2012, which results in a higher energy consumption.

Tab. 7 Comparisons of calculation results of the teaching building load

Parameter	Value
Cooling demand calculated by prediction model/(MW · h)	979.68
Heating demand calculated by prediction model/(MW · h)	585.73
Total demand calculated by prediction model/(MW · h)	1 565.41
Total demand calculated by Ref. [22]/(MW · h)	1 496.67
Actual consumption of 2011/(MW · h)	1 802.22
Actual consumption of 2012/(MW · h)	1 711.91
Relative error between prediction model and Ref. [22]/%	4.38
Relative error between prediction model and actual operating data in 2011/%	13.14
Relative error between prediction model and actual operating data in 2012/%	8.56

3 Conclusion

In this paper, the prediction model of typical buildings is proposed based on the heat transfer principle. First, the influential factors of the cooling and heating load can be divided into two categories: intrinsic and operational parameters. In order to simplify the calculation, the multivariable system is divided into several subsystems. Then, the influences of operational and intrinsic parameters and coupling factors on building energy consumption are analyzed, and the mathematical expression of the prediction model is presented. Finally, the high accuracy of the prediction model is verified by comparing the simulation results of EnergyPlus and Design Builder and the measured results of other literature. Furthermore, the results satisfy the requirements of engineering application.

Our findings demonstrate that the proposed model has the advantages of rapid calculation and high accuracy compared with other models when predicting building energy consumption for building designs. The prediction model can be used to guide building energy conservation design and provide the basis for the optimization of building operation, which has a high practical value in engineering applications.

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中国冬冷夏热地区典型建筑负荷预测模型

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摘要:为了克服建筑能耗预测模型在建筑设计阶段的应用不足,通过解耦方法建立了建筑能耗快速预测模型. 以中国冬冷夏热地区典型建筑为研究对象,依据传热学的基本原理,将影响建筑能耗的因素分为运行属性因素和自有属性因素两类,以运行属性参数为基准,自有属性参数为修正,依据主元解耦方法,建立了典型建筑冷热负荷计算快速预测模型,并验证了该数学模型的准确性. 研究结果表明:与软件 EnergyPlus 相比,该模型计算结果的相对误差在 1.5% 以下;与实际运行数据相比,该模型计算结果的相对误差在 2011 年为 13.14% ,2012 年为 8.56% ,其主要原因是建筑的同时率分别高于设计值 16% 和 13% ;与软件 EnergyPlus 和 Design Builder 相比,该模型计算快速、简捷且能够用于设计阶段. 该建筑能耗快速预测模型对建筑的设计和运行优化具有一定工程价值.

关键词:建筑能耗;能量守恒;负荷预测;EnergyPlus

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