

Energy efficient design for residential buildings in China

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Abstract: This paper illustrates an integrated energy design model based on the energy balance of a single zone. The results of energy efficient residential building design for the different climate zones of China by implementing an integrated energy model have been presented. Optimum measures of building design for typical Chinese residential buildings are introduced, with the objective of minimizing annual energy consumption for those buildings and improving thermal comfort. One overriding conclusion is that significant energy savings and thermal comfort can be achieved through optimum design.

Keywords: energy efficiency; residential building; China, climate zones

1. Introduction

China's buildings sector currently accounts for 23% of China's total energy use and is projected to increase to one-third by 2010. The level of energy efficiency in the Chinese residential housing stock remains low. Energy efficient housing design can promote wider sustainable development aims and objectives because it produces environmental, social and macro-economic benefits in addition to a significant impact on household's ability to obtain adequate levels of affordable thermal comfort. Therefore increased energy efficiency in China is an important element of a strategy to achieve sustainable development. Whilst detailed simulation models have developed in their range of application and their accuracy, they carry the disadvantage that they require a detailed description of the building and its systems often unavailable at early design stage. It is increasingly recognised, however, that it is at the early, strategic stage of the design, that the ultimate performance of the building is largely determined. Therefore the simplified energy design tool for the architects evaluating energy use in buildings at the strategic design stage is necessary. It helps not only to optimize energy use in buildings but also to provide the designer with quantitative guidance on the likely best combination of building design parameters for different climate zones. not passed the review.

2. Methodology

The basic idea is to develop a simple tool of energy efficient design at the strategic design stage. This kind

of design tool should require minimum data input, give reliable indication of trends and sensitivities. The architect can then generate with little effort positive inputs to his/her design. The LT method [1][2] is a widely used energy design tool that enables users to evaluate the energy performance of a number of options and to make comparisons.

The performance criterion for the solver is its ability to distinguish accurately between realistic room response types – lightweight, medium and heavyweight, and that it is able to model the build-up of heat in the deep structure of the building in response to the occurrence of successive hot days. The solver also has to model the effect of night ventilation, requiring a ventilation conductance that is coupled to the internal surface of the room. The solver does not simulate the whole building. Instead it simulates a standard module with parameters (such as glazing ratio, fabric U-value, internal gains, lighting datum level, thermostat setting, occupancy profile) to replicate those chosen for the proposed design. The performance of the whole building is then assembled from an appropriate number of standard module performance data, corresponding to parameters such as orientation

The energy consumption for heating in summer and cooling in winter is based on the single zone energy balance. It can be illustrated as follow:

$$\Phi_{\text{heat/cool}} = (\Phi_{\text{cond}} + \Phi_{\text{vent}} + \Phi_{\text{solar}} + \Phi_{\text{sp}})\Delta t$$

where $\Phi_{\text{heat/cool}}$ is the energy for heating and cooling the room, Φ_{cond} is the conductive heat transfer through the building envelope (wall and window); Φ_{vent} is the ventilation heat transfer through the building, Φ_{solar} is

the solar gain, Φ_{sp} is the internal gain from electrical lighting, people and appliance, and Δt is the time step. The detailed simulation equation was illustrated in the reference paper[3]. This model was validated with popularly used simulation tool esp-r.

3. Climate

The climate in China is extremely diverse. For building thermal design, five climate zones have been presented by "Thermal Design Code" [4]. These five climate zones are categorized into Coldest Zone, Cold Zone, Hot Summer and Cold Winter Zone, Hot Summer and Warm Winter Zone and Mild Zone. Fig. 1 shows the climate zones for the building thermal design in China. Table 2. Shows the climatic characteristics of the representative city in each zone[4][5][6]. The

climate data for each city required for simulation was produced from Meteonorm software.

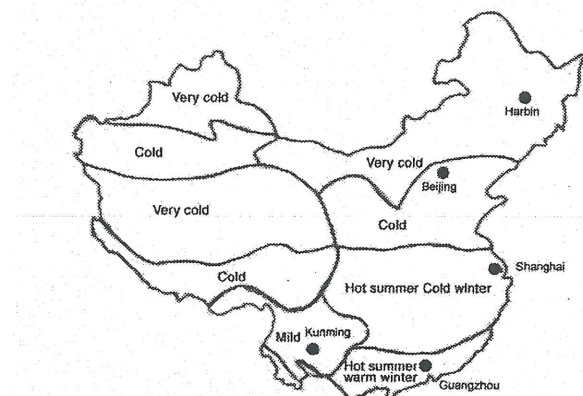


Fig. 1 Climate zone for building thermal design in china

Table 1. Climatic characteristics of the representative cities

Zone	City	Latitude	Heating season average outdoor air temperature °C	Heating degree day HDD18	Hottest month outdoor air temperature °C	Cooling degree day CDD26	Annual Sunshine hours /h
Very Cold	Harbin	44.46	-10.0	4928	22.8	---	2599
Cold	Beijing	39.56	-1.6	2450	26.5	---	2611
Hot summer Cold winter	Shanghai	31.00	3.7	1691	27.8	164	1914
Mild	Kunming	25.51	---	---	28.4	---	2068
Hot summer Warm winter	Guangzhou	25.01	---	---	19.8	---	1651

4. Energy efficient design and codes

Some factors of energy efficiency design have been taken into account since 1960s in China[7]. In response to the growing concerns about energy conservation and its implications for the environment, the government decided to introduce legislative control of building envelope design. The energy legal system in China is quite complicated, with many different types and format including national laws, provincial codes and departmental regulations. The building energy regulations are grouped into Residential and Hotel buildings. Table 2 lists the main regulations of building energy conservation[4][5][6].

Table 2 China's main building energeregulation

	Low bound		Middle bound		Upper bound	
	Harbin	Beijing	Harbin	Beijing	Harbin	Beijing
U-external wall	0.73	1.28	0.52	1.16	0.35	0.58
U-glazing	3.26	6.4	2.5	4.0	2.0	2.8
Infiltration	1	1	0.5	0.5	0.5	0.5

JGJ24-86 only recommended the minimum insulation requirement for the building envelop. JGJ26-86 is the start up regulation of building energy conservation in China. It proposed the target of 30%

energy saving. Actually the level of building envelope insulation was still very low. Further more it was not completely implicated in building design in north China. So far it was only implicated about 30 million squares meters in Beijing, Tianjing, Harbin, Xian, Lanzhou and Shengyang so called developed cities. JGJ26-95 proposed the target of 30% energy saving via building design comparison the building of 1980.

For the residential buildings in south China, indoor thermal comfort and energy efficiency are the most important issues which architects and engineers should work together to take into account, because these kinds of buildings are without central air conditioning in summer and heating in winter. Indoor thermal environment is not ideal in such kinds of building in summer and winter unless it is passively designed. Not all the families can afford room air conditioners and heat appliances.

5. Case studies

5.1 Input information

We take a standard module with size of $6 \times 6 \times 2.6$ in the middle of a multiple stories building as a research target. Occupied hour is 24 hours. The average internal gain is 4.3 W/m^2 . The required climate parameters are hourly solar normal beam, solar horizontal diffuse radiation and outdoor air temperature. The climate data for each representative city was produced by Meteonorm software. The room infiltration in winter is 1 air change per hour in winter and 3 in summer. The building is medium weight mass type. We set up three bounds of U value for analysis as low bound(code before 1996), middle bound(code of 1996) and upper bound(England Part L 2002 standard). The value for Harbin and Beijing is referenced to the Chinese building design code before 1996. These have been listed in the Table 3. There is no limitation for the other zones. Considering that the 240 mm brick wall is common in south China, we take the value of $2.05 \text{ W} \cdot \text{m}^{-2} \cdot ^\circ\text{C}^{-1}$ as the external wall U value. Window area is 5.4 m^2 as glazing ratio of 30%. The winter heating set point is 18°C and the summer cooling

setting point is 28°C .

Table 3 U value of wall and glazing for different bounds

Year	Title	Code
1986	Code of thermal design for residential buildings	JGJ24-86
1986	Energy conservation design code for heating residential buildings	JGJ26-86
1987	Design code for heating ventilation and air conditioning	GBJ19-87
1993	Code of thermal design for residential buildings	GB50176-93
1993	Energy conservation design standard on building envelope and air conditioning for tourist hotels	GB50189-93
1995	Energy conservation design standard for new heating residential buildings	JGJ26-95
2001	Design standard for energy efficiency of residential buildings in hot summer and cold winter	JGJ134-2001 J116-2001

Computer simulation for the annual energy consumption was performed for each base case in five representative cities. In order to analyse the energy efficient design strategy, additional cases of optimum sets were simulated for each zone. For the convenient of analysis, we category very cold zone and cold zone as Heating Zone; hot summer and mild zone as Cooling Zone; and hot summer and cold winter as Transient Zone.

5.2 Heating zone

The energy efficient design for this zone must focus on the heating energy consumption. The optimum solution therefore will focus on insulation for the envelop, limit infiltration and maximum use of solar gain in winter etc. Reducing the thermal transmittance of the building envelope by adding insulation can help reducing heating demand and result in lower heating energy consumption. Table 4 lists the results of different solutions. Optimum orientation is also essential. Fig.2 shows the effect of orientation. The south orientated sun-space balcony can save heating energy significantly however it will also increase summer cooling energy if it was implicated improperly. The proper way of implicated with a sun-space balcony is to implicate external blinds in summer. Fig.3 shows the example of internal air temperature for the rooms

with and without sun-space balcony which is operated with external blinds in summer.

Table 4 Energy saving in heating zone

Measures	Beijing			Harbin		
	Heating	Cooling	Total	Heating	Cooling	Total
	%	%	%	%	%	%
Insulation	Low bound (base)	-	-	-	-	-
	Mid bound	25	-10	15	10	-10
	Upper bound	36	-14	22	17	-10

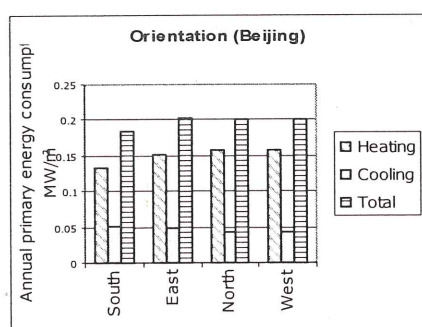


Fig. 2 The effect of orientation Beijing

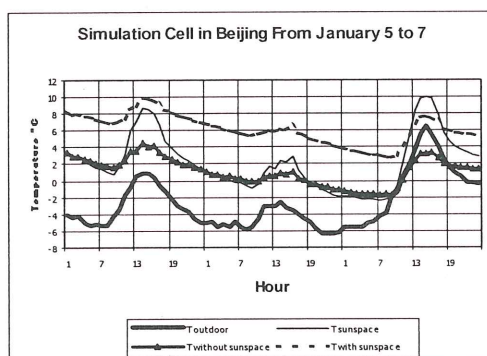


Fig. 3 Air temperatures with/without south orientated sun-space balcony in Beijing in winter

5.3 Transient zone

The past and existing building design in hot summer and cold winter zone did not consider heating and cooling demand. The U value of building envelope is usually high. The traditional construction of the building envelope are 240mm brick wall, simple suspended air roof and single glazing with metal frame. The U value are 2.05, 1.66 and 6.6 $\text{W}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$ respectively for wall, roof and glazing. The internal thermal condition in summer and winter is severe. Room air conditioner and electricity appliances are the common measures for domestic thermal comfort. Passive design can reduce heating and cooling load for

affordable family and improve internal thermal condition for low income family. The major passive measures should be focused on reducing solar gain in summer by implying external shading device and night ventilation; and reducing heating load by increasing external wall and glazing insulation and making maximum use of solar gain in winter. Increasing ventilation at night can help remove the heat that is stored in the building structure during the daytime to avoid higher summer temperature. Ventilation helps to limit the temperature rise in a space. Cooling by ventilation in summer is a common method of improving indoor thermal climate for residential buildings. Most families still use ceiling or punkah table fans for cooling themselves. External shading device is the most effective measures for summer overheating.

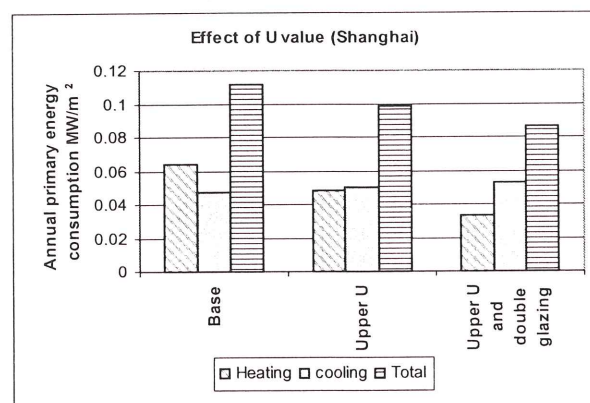


Fig. 4 Effect of u value in Shanghai

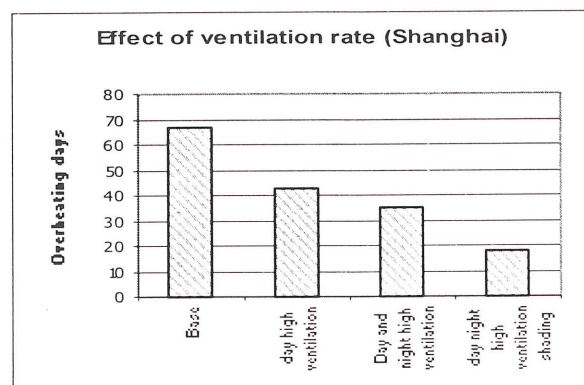


Fig. 5 Impact of passive measures on overheating risk

5.4 Cooling zone

The "Mild" and "Hot summer and Warmer Winter" zones can be considered as cooling zone. It locates in the southern China. Preventing overheating risk in summer is the major criteria for building design. The passive measures can be focused on night ventilation and shading device.

6. Conclusions

There exists great potential to achieve stable and sustainable housing development via energy efficiency design at the strategy stage in China. Good passive building design measures can improve indoor thermal comfort and saving energy. The simplified strategic energy design tool can assist the architects to evaluate the energy consequence. The simulation results for the five cities in China provide some advises.

The design strategy in the heating zone ("Cold" and "Very Cold" zones) should focused on building insulation technique. Upper bound U value of wall and double glazing can significantly reduce heating load. South orientated sun-space balcony is the most effective measure to reducing heating load. The internal temperature can be raised by up to 6 °C.

The thermal condition in transient zone (Hot Summer and Cold Winter zone) is the worse case because there is no heating and cooling policy for building design in history. Solar radiation is the major factor of causing thermal discomfort in summer. External shading device and night ventilation are the most effective method for improving thermal comfort in summer. South faced sun-space balcony can improve internal thermal comfort in winter but shading device and open-able function should be considered in summer. The building insulation and double glazing should be considered in building to reduce the heat loss in winter for this zone.

The thermal design for the Cooling Zone ("Mild" and "Hot Summer and Warmer Winter") should focused on

avoiding soar radiation. Therefore external shading device is important for this zone. Night ventilation is always the effective way to release the heat stored in building fabric.

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