Comparative analysis of residential building 75% energy efficiency design standards of Shandong Province and Germany building energy efficiency standards

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Abstract. Efficiency design standard for residential building of Shandong Province should be improved by comparing current residential building 75% energy efficiency design standards of Shandong Province with Germany relevant standard. Taking certain multi-story residential building as an example, the paper calculates heating demand in 75% energy efficiency design standards of Shandong Province, Germany building design standards in 2002 and 2009 and passive house energy efficiency design standards. It discusses possible technical route diagrams for improving building energy efficiency design standards of Shandong Province, including countermeasures such as high performance building envelope thermal insulation materials, reducing proportion of energy consumption by fresh air and improving building overall air tightness.

Foreword

In order to carry out building energy efficiency work, our country increases the requirements of building energy efficiency design standards gradually. After Beijing took the leading to implement residential building 75% energy efficiency design standard in 2012, Shandong, Tianjin, Xinjiang, Hebei, etc issued the standards on energy efficiency 75%[1-4].

Developed countries that have similar climatic conditions as northern area of our country are leading in building energy efficiency aspect, so it is necessary to research the gap between 75% energy efficiency standards and those of developed countries so as to provide technical route diagrams of improving building energy efficiency.

The paper will, on the basis of comparing the differences between Germany building energy efficiency design standards and energy efficiency standards of Shandong Province, get clear understanding of the gap between building energy efficiency standards of Shandong Province and those of developed countries. Then taking certain multi-story residential building of Jinan area as example, it compares on the stipulations of current 75%residential building energy efficiency design standards of Shandong Province (referring to as residential building energy efficiency design standards hereinafter), Germany building energy efficiency design standards in 2002 and 2009 and passive house, and finds main bottleneck problems on further improving building energy efficiency rate according to development mode of building energy efficiency standards of our country; finally, while proposing the countermeasures, it gives out suggestions on technical routes for further improving residential building energy efficiency level of Shandong Province.

Comparison between residential building energy efficiency design standards of Shandong Province and Germany corresponding standards

Comparison of weather conditions

Germany is located in the middle of Europe, belongs to north temperate climate, and has similar latitude to that in the north of Harbin City in Northeast China. However, its climatic conditions are more similar to North China. When researching and designing building energy consumption and heating, climatic conditions of Wurzburg is normally used as average climatic conditions of Germany. Heating degree day of the city is 3,500 ℃·d (using 20℃ is reference temperature) [5].

heating degree day of 17 prefecture-level cities of Shandong Province (using 18℃ as reference temperature) is 2,165-2,604 ℃·d, wherein that of Jinan is 2,211 ℃·d. If using 20℃ as reference temperature, annual heating degree day of Jinan is 2,638 ℃·d. Heating degree day of Shandong Province is less than that of Germany, about 75% of that of Germany. Under same building thermal insulation conditions, Germany shall consume more energy when reaching same room temperature.
Development course of Germany building energy efficiency standards

Evolution of Germany building energy efficiency standards is shown in Table 1.

Table 1Evolution of Germany building energy efficiency standards

Year	Standard name	Main feature
1994	Regulations on Building Energy Efficiency Thermal Insulation	Propose annual heating terminal energy consumption limit value, and improve envelope K value
2002	"Regulations on Building Energy Efficiency" EnEV2002	Propose primary energy limit value. Decrease heating terminal energy consumption by 30% on the basis of that in 1994.
2004	EnEV2004	Add contents of energy certificate
2007	EnEV2007	Introduce public building energy consumption limit value
2009	EnEV2009	Further decrease annual heating and hot water terminal energy consumption by 30%.
2014	EnEV2014	Passive type technical requirements

In February 2002, Germany implemented new building energy efficiency norm EnEV2002. Core concept of the new building energy efficiency technical norm is to make system control on real energy consumption of building from controlling the lowest thermal insulation index of building envelope in certain aspect so as to make strict and effective energy consumption control. Maximum primary energy consumption of EnEV2002 is shown in Table 2.

Table 2 Maximum primary energy consumption of EnEV2002

Building shape coefficient	Annual basic energy consumption	
	Unit usable area energy consumption	Energy consumption of unit heating volume
	Normal residential building kWh/(m²·a)	Non-residential building kWh/(m²·a)
≤0.2	66.0+2,600/(100+An)	14.72
0.3	73.53+2,600/(100+An)	17.13
0.4	81.06+2,600/(100+An)	19.51
0.5	88.58+2,600/(100+An)	21.95
0.6	96.11+2,600/(100+An)	24.36
0.7	103.64+2,600/(100+An)	26.77
0.8	111.17+2,600/(100+An)	29.18
0.9	118.70+2,600/(100+An)	31.59
1.0	126.23+2,600/(100+An)	34.00
An building usable area		

Germany low energy consumption building is divided into three grades, i.e., low energy consumption building, 3L oil building and passive house. Unit usable area heat demand required by Germany low energy consumption building is 30-70 kWh/(m²·a). Heat demand stipulated by Germany EnEV2009 is 45 kWh/(m²·a), which is equal to low energy consumption building. Unit usable area heat demand of 3L oil building is 15-30kWh/(m²·a). Unit usable area heat demand of passive house shall be below 15kWh/(m²·a) [6].

Comparison of thermal parameters

Germany buildings are mainly low-rise and multi-story building [7]. In order to make building energy consumption of the two countries comparable, and residential building with 4-8 stories is selected as comparative object. Comparison results are shown in Table 3.

Table 3 Comparison of envelope thermal parameters

Envelope position	Heat transfer coefficient K limit value W/(m2·K)			
	75% standards	Energy efficiency norm EnEV2002	Low energy consumption building EnEV2009	Passive house
Roof	0.35	0.25	0.20	0.15
Exterior wall	0.40	0.35	0.24	0.15
Exterior window	2.00	1.50	1.30	0.80
Non-heating floor slab	0.50	0.40	0.35	0.15
Overall air tightness	/	$N_{50}=3.0$	$N_{50}=1.0$	$N_{50}=0.6$

By analyzing above table and considering gap between heating degree day of the two countries, it can be seen that envelope thermal performance of 75% residential building energy efficiency design standards of Shandong Province reaches the level of Germany energy efficiency norm EnEV2002. However, for building overall air tightness, Shandong Province hasn't corresponding control index. In Europe, even for residential building that uses natural ventilation, building overall air tightness control index is also controlled strictly. During calculation of energy efficiency of Shandong Province building, ventilation rate of 0.5 times/h is used during theoretical calculation value, and can't be used as the requirement on room overall air tightness really.

4 Comparison of residential heat demand

Residential building of Shandong Province and Germany residential building has large difference on boundary condition of heat demand calculation, and is summed up as following table.

Table 4 Comparison of calculation heat demand boundary condition

Item name	75% energy efficiency residential building	Germany low energy consumption building
Winter heating indoor temperature	18℃	20℃
Winter heating calculation ventilation rate	0.5/h	0.35/h or 30m^3/(h.person)
Building inside heat gain	3.8 W/m^2	2.1 W/ m^2
Calculation heating period days	92 days	Ensure indoor temperature, without fixed time limit
Area used by heat consumption index	Building area	Usable area
Heat consumption index	9.2 W/m^2	/
Heat demand	20.3 kWh/(m^2·a) (calculating according to heating period of 92 days)	45 kWh/(m^2·a) (low energy consumption building) 15 kWh/(m^2·a) (passive house)

Building heat consumption index of 3.8 W/m^2 adopts index value stipulated by "Energy Efficiency Design Standard on Civil Buildings (Heating Residential Building Part)" issued in 1986. Living way of current residential building people, average living population and energy use way have very large difference with those in 1980s, change of these factors causes change of building internal heat source, and more rational value way of building heat consumption index shall be prepared [8].

Ventilation rate of 0.5 times/hadopts the data stipulated by JGJ26-95 "Energy Efficiency Design Standard on Civil Buildings (Heating Residential Building Part)". The index is now that required according to the requirements of hygiene standard. Current residential building population has very large difference with that in 1990s, and the index shall be also correct.

Due to difference of boundary conditions, heat demand calculated by both of them isn't comparable. Same boundary conditions shall be used, i.e., Winter heating indoor temperature of 20℃, Winter heating calculation ventilation rate of 0.35 times/h, building inside heat gain of 2.1 W/m^2 and usable area are used for calculating heat consumption index (building area is converted into usable area by conversion factor of 0.8).

Low energy consumption house is often defined as annual heating heat demand of unit usable area in unit heating degree day. By considering Germany low energy consumption standards of 45 kWh/(m^2·a) and heating degree day of 3,500 ℃·d, according to heating degree day of 2,638 ℃·d in Shandong Province, low energy consumption building heat demand index of Shandong Province is converted.

Calculation results are shown in Table 5.

Table 5 Comparison of uniform calculation boundary condition heat demand

Item name	75% energy efficiency residential building	Low energy consumption residential building
Heat consumption index	13.5 W/m^2	/
Heat demand	29.9 kWh/(m^2·a) (calculating according to heating period of 92 days) 39.0 kWh/(m^2·a) (calculating according to heating period of 120 days) 44.9 kWh/(m^2·a) (ventilation rate of 0.5 times/h, heating period of 120 days)	33.9 kWh/(m^2·a)

Analysis is made by above table, if ventilation ventilation rate is same as the requirement in Germany standards, heat demand of 39.0 kWh/(m^2·a) is close to heat demand of 33.9 kWh/(m^2·a) in low energy consumption building standards, but if ventilation ventilation rate continues use original ventilation rate of 0.5 times/h, then heat demand can't meet the requirement of low energy consumption building.

Improvement routes of residential building energy efficiency design standards of Shandong Province

By comparing to Germany energy efficiency standards, improvement routes of residential building energy efficiency design standards of Shandong Province are summed as following.

Table 6 Improvement routes of residential building design standards of Shandong Province

Technical measure	Basic requirement
Better envelope thermal performance	Implement according to the requirements of Germany EnEV2002
Reduce heat bridge effect	Propose better requirement on heat bridge part treatment, besides meeting the requirement on non-condensation heat bridge part
Decrease air infiltration	Stipulate building overall air tightness index, for example, N$_{50}$=3.0
Have organic ventilation	Ventilation system without heat recovery
Suitable heating system	Heating system has automatic control device with high sensitivity
Other technical measure	Heat metering and charging

Conclusion

1. 75% energy efficiency design standards of Shandong Province reach the level of Germany EnEV2002 energy efficiency norm. However, it has certain gag with the level of Germany low energy consumption building.

2. Research on parameter value used by heat consumption index calculation shall be enhanced, for example, building internal heat gain and ventilation rate. Under the precondition that envelope thermal performance is improved continuously, influence of value of these index on heat demand index is increasingly bigger.

3. Residential building energy efficiency improvement level in the future shall be mainly made in various aspects such as reducing heat bridge effect, improving building overall air tightness and having organic ventilation.

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