Abstract

In this research, the authors have carried out the research to investigate the characteristics of building energy standards of the residential building in China. Efforts have also been made to promote a better understanding of the energy policy and relevant standard for architects and building designers to achieve optimal energy efficient building design in China. The results can mainly summarized as follows:(1) As for the thermal environment design, the climate of China has been classified five zones.(2) The sunlight, lighting, ventilation environment of residential building have been specified in the new standards.(3) Prescribed the building design elements, such as layout, orientation, shape, color, plan and the type of window. In particular, the thermal insulation measures for heating system has been added in hot summer and cold winter region, which was not described in old standard.(4) It is admitted that there is still a difference compared with the standard of many foreign countries, and the improvement in the further heat insulation performance and positive execution of the standard continue to be expected.

Keywords: China; residential building; energy conservation; environmental design; standard

1. Introduction

In recent years, China has had significant development on construction sector. Particularly the residential house has been constructing. In 1996, the constructed amount of residence is 2 1,221,880,000m² in the whole country. Moreover, the target of residence construction is that the habitation area of a three-person household arrived 81m² in 2010 with 3,300 million m² in urban and 5 billion m² (500 million m² per year increased) in rural, this area is the 1.5 times than now.

However, many of the residential building have poor insulation and indoor thermal environment. The remarkable increasing of air-conditioner usage will cause large energy consumption and urban heat island phenomenon in city. In the face of these problems, China has revised the residential building energy code and standard for the energy efficiency design of building envelope and space heating for new construction and expansion of residential building. In this research, the authors have carried out the research to investigate the characteristics of building energy standards of the residential building in China. Efforts have also been made to promote a better understanding of the energy policy and relevant standard for architects and building designers to achieve optimal energy efficient building design, and also for assuming the building energy consumption, assessment of the thermal environment in China.

2. Outline of standard of energy conservation in China

In this paper, the research has been done by mainly using [Code of Design for Residential Building], [Thermal Design Code for Civil Building], [Technical Code for Renovation of Existing Heating Residential Buildings], and [Design Standard For Energy Efficiency Of Residential Building In Hot Summer And Cold Winter Zone] [1-3]. Moreover, in order to have a comparison, the Japanese standard for rationalization of energy consumption in residential houses has also been presented in Table one.

In China, the three types of civil building can be classified as following: (1) the buildings with a long-time use, such as residential building, nursery, kindergarten, medical-treatment institute, hospital; (2) the buildings with an intermittent use, such as: office,
school. (3) the buildings with an intermittent use which has lower heat demand than (1) type and (2) type, such as hall, dining-room, gymnasium, theater and airport. Moreover, the residential building includes residence, lodgings, hotel and so on.

There are four standards for energy conservation and thermal environment improvement on national level in China, as are shown in Table 1. Those standard mainly described the indoor thermal environment, measurement to decrease of heating load and the energy conservation in severe cold region, cold region and hot summer, and cold winter region. There is no standard for hot summer and warm winter region or warm region. However, there are some non-national standards. Some province and cities have specified the standard suitable for special climate and economic level. Among these standards, “energy conservation design standard for residential building in Shanghai” (DG/TJ08-205-2000) has been used as the standard for high economic area in hot summer and cold winter region.

3. The climate classification in the thermal environmental design of building

China is a large country with a range of climates varying from tropical to cold temperate; it has been classified into five zones shown in Figure one and Table two in the thermal environmental design of building. The zoning was based on the two indexes, main index and auxiliary index. Main index was defined as a monthly average air temperature in the coldest month or hottest month. Auxiliary index was defined as a day number in which daily air temperature was higher than 25°C or lower than 5°C. For example, cold zone II is an area that the monthly average temperature ranges between 0~10°C in the coldest month with about 90~145 days in which the daily average temperature is lower than the 5°C. Severe cold zone I and cold zone II have been called heating region conventionally which mainly includes the northeast China, north China, and southwest China. And those zones account for 70% area of the whole country. However, many residential building in those zones have not satisfied with the demand of energy conservation design standard for civil building. Although the 13 billion m² residence floor area has been built from 1979 to 1996 in the whole country, only 40 million m² is energy-saving building.

On the other hand, since hot summer and cold winter region III was defined a non-heating area by government, the shelter thermal property of building was poor and air conditioning equipment was not installed. However, summer is very hot and winter is very cold in this region. In recent years with the economy development, air-condition in summer and heating in winter has become general. Moreover, this region includes the Yangtze River valley and circumference area of this valley, such as Shanghai, Chongqing, added up to 16 provinces and

| Region          | Standard of China | Japan |
|-----------------|-------------------|-------|
| I: Severe cold zone | Outdoor average air temperature ≤ 5°C | ≥ 3500 |
| II: Cold zone    | Outdoor average air temperature 5°C~15°C | 3000~3500 |
| III: Hot summer and cold winter zone | Average temperature of coldest month is 0°C~15°C and average temperature of hottest month ≤ 25°C~30°C | 2500~3000 |
| IV: Hot summer and warm winter zone | Average temperature of coldest month ≤ 10°C and average temperature of hottest month ≤ 25°C~28°C | 1500~2600 |
| V: Warm zone     | Average temperature of coldest month is 0°C~13°C and average temperature of hottest month is 18°C~28°C | 500~1500 |

| Region          | Standard of China | Japan |
|-----------------|-------------------|-------|
| I: Severe cold zone | Days of daily average temperature ≤ 0°C is ≥ 1456 | ≥ 3500 |
| II: Cold zone    | Days of day average temperature ≤ 5°C is 30~1456 | 3000~3500 |
| III: Hot summer and cold winter zone | Days of day average temperature ≤ 5°C is 0~90° | 2500~3000 |
| IV: Hot summer and warm winter zone | Days of day average temperature ≤ 25°C is 40° | 1500~2600 |
| V: Warm zone     | Days of day average temperature ≤ 5°C is 0~90° | 500~1500 |

Table 1. Standard of energy conservation for residential building

Table 2. The classification in the thermal environmental design of building
autonomous. In this region, it is about 1,800,000 square kilometers with 550 millions populations and also its GDP occupied 48% of the whole country. Crowded population and developed economy are the characteristics of this region. The energy conservation design and the low environment load in construction is an urgent subject, and the standard need to be revised greatly.

4. Design standard in residential building

In the new standard, it has been described as elements such as sunshine, lighting, and the ventilation environment. First about the sunshine standard, it follows the residence sunshine standard of present national standard [standard design for residence community in city] (GB50180). As about the lighting standard has been shown in Table.3. Furthermore, in order to guarantee the ventilation of room, the vent area was shown in Table.4. And also, in the severe cold region and only one orientation residence, the ventilation equipment should be installed in bedroom and living room; the natural ventilation way should be installed in kitchen and bathroom.

5. Energy conservation standard

5.1 Standard for construction

**Layout and orientations:** Buildings are suitable to be designed in south-north orientations or close to that. It will be located in sunlight and avoid prevailing wind direction, and the ventilation property should be good. About the windows in the side of face to sun, especially the west and east sides, some sunshade measures should be adopted, such as, exterior corridors, veranda, and eave. Main rooms should avoid an east and west orientation. In cold zone II, hot summer and cold winter zone III and hot summer and warm winter zone IV, the west orientation windows of a room must to take sunshade measures, and the insulation measures must be taken in the roof and west exterior wall.

**Shape:** It should reduce building external surface area, and the main building should avoid too much concave-convex part. The shape coefficient of the building has been shown in Table.5. The shape coefficient of building is that ratio of exterior surface area of building exposing to the air to the volume enclosed by it.

**Plan:** Residential building should avoid the open staircases and outside corridor; it is also necessary to make windows area as small as possible, to reduce crevice length of windows, and to raise air tightness in the severe cold zone and cold zone. The various heat transfer coefficient of window about different orientation and ratio of windows to wall have been shown in Table.5. Moreover, the double sliding window is suitable for building with high stories, and it needs to install a movable type sunshade for window.

**Color:** Building should take the building material with shallow color. If possible, especially a flat roof needs to take heat insulation measures, such as roof planting in hot summer and cold winter region.

**Windows:** In the case of conventional glass, the ratio of windows to wall should be below 0.3 and in the pair-glass, the ratio should not exceed 0.4. The side faced to sun, especially the west and east orientation windows must take sunshade measures, such as heat reflected glass, movable bride, and windows can be made to partial opening and closing.

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Table 3. Standard of lighting for residential building

| Room          | Limitation of | Area ratio of |
|---------------|---------------|--------------|
| bedroom       | 1             | 1/7          |
| living room   |               |              |
| kitchen       |               |              |
| staircases    | 0.5           | 1/12         |

Table 4. Standard of ventilation area

| Room          | Ventilation area |
|---------------|------------------|
| bedroom       | ≥1/20 of floor area |
| living room   |                  |
| bathroom      |                  |
| kitchen       | ≥1/10 of floor area and ≥0.6m² |

Table 5. Shape coefficient of building of different zone

| Zone                      | Shape | Shape coefficient of building |
|---------------------------|-------|------------------------------|
| hot summer and cold winter region IV | line type | below 0.35 |
| hot summer and cold winter region III | point type | below 0.40 |
| hot summer and cold winter region I, II | below 0.30 |

Table 6. Heat transfer coefficient of window

| Orientation of window | Area ratio | 0.25 < area ratio | 0.30 < area ratio | 0.35 < area ratio | 0.45 < area ratio |
|-----------------------|------------|-------------------|-------------------|-------------------|-------------------|
| North                 | cold outdoor average air temperature in winter +5°C | 4.7 | 4.7 | 3.2 | 2.5 |
| West and East         | cold outdoor average air temperature in winter ≤5°C  | 4.7 | 3.2 | 3.2 | 2.5 |
| South                 | no sunshade measure | 4.7 | 3.2 | 3.2 | 2.5 |
|                       | with sunshade measure | 4.7 | 3.2 | 3.2 | 2.5 |

Table 7. Heat transfer coefficient and heat resistant index of shelter

| Exterior wall | Window glass (including balcony door) | Partition wall and floor | Floor with under ventilation | Door |
|---------------|---------------------------------------|--------------------------|-----------------------------|------|
| KS15 D ≥ 30  | follow the standard                    | K=2.0                    | K=1.5                       | K=3.0 |
| KS10 D ≥ 25  |                                       |                          |                             |      |

Notes:
1. Since the heat transfer coefficient of exterior wall is influenced with the heat bridge of structure, the value in this table is averaged value of exterior wall.
2. If the exterior wall and roof satisfy the heat transfer coefficient value and not satisfy heat resistant index value, it should to verify the requirement for thermal insulation design according to prescription 5.1.1 of [Specification for thermal design of civil building] (GB50176-93).
3. D is the heat resistant index that is the shelter resistant to heat transfer and temperature. The value of D is the integral of multiplication of heat resistant coefficient R and thermal storage integration for various materials. D= ∑ R·S; unit: W/m²·K.
5.2 Standard for insulation

Thermal property: Heat-protection calculation should be carried for the exterior wall, roof, the slab exposed to out air and staircases without heating and so on, and also the heat resistance of these parts should be satisfied the standards for different region. Thermal insulation measures should be taken for the locations of building envelope with heat bridge according to calculation. In the severe cold region, the building periphery of the first floor should adopted the heat protection measures, and the inside temperature of roof, east wall and west wall must satisfy the requirements for thermal insulation design in summer.

Table 6 and Table 7 have shown the thermal property of different building part. On this standards, each province and municipality have also enacted the standard for various regions. The heat transfer coefficient limitation values of different region for renovation of existing heating residential buildings have been shown in Table 8. Furthermore, this standard is also suitable for new residential building.

Table 9 is the heat transfer coefficient values of building shelter in different countries. As this
Table 10. Heat property of floor for heating residential building

| Zone | $B$ value (W/(m$^2\cdot$K)) | Attribute of building |
|------|-----------------------------|----------------------|
| I    | <17                         | senior residential building, nursery, kindergarten, Medical-treatment institution |
| II   | 17~23                       | general residential building, office, school |
| III  | >23                         | air temperature is larger than 23°C and Short-time stay room |

Notes: $B$ is calculated according to the position of material influencing on the heat absorption of floor.

Table 11. Air permeability grade values standard from Gb7107-86

| Grade | I | II | III | IV | V |
|-------|---|----|-----|----|---|
| Limitation value ($m^2\cdot m/h\cdot 10^3 Pa$) | 0.5 | 1.5 | 2.5 | 4 | 5.5 |

Table 12. Standard values according to the air permeability of window

| Condition | 1~6 stories | >7~30 stories |
|-----------|-------------|---------------|
| Outdoor wind velocity $>3.0 m/s$ | above III grade | above II grade |
| Outdoor wind velocity $<3.0 m/s$ | above IV grade | above III grade |

Table 13. Tolerance range of difference between indoor temperature and the surface temperature of shelter

| Type of building and roof | Exterior wall | Flat roof, inside of raked roof |
|---------------------------|--------------|---------------------------------|
| Residential building, hospital, kindergarten | 6 | 4 |
| Office building, school, Clinic | 6 | 4.5 |
| Hall, Dining-room, gymnasium | 7 | 5.5 |
| Building with high humidity | 7 | 6 |
| Inside of exterior wall and ceiling both are not allow to dew condensation | 6 | 5.8 |
| Only inside of ceiling are not allow dew condensation | 6 | 5.9 |

Notes: (1) The room with 13~14°C indoor temperature and above 75% relative humidity, and the room with above 24°C indoor temperature and above 60% relative humidity are defined as high humid room. (2) $R$ and $h$ respectively are indoor air temperature and dew point temperature. (3) When people are prolonged stay in the room, the tolerance temperature difference is 2.5°C of the slab opposed to the air and above slab of basement; otherwise, it is 5°C.

The $B$ value shown, the heat transfer coefficient value of Harbin, which located in the severe cold region of China, is about 0.5. It is still larger than that of advanced nation.

On the other hand, in Japan, the thermal insulation standard has been revised twice in order to raise the thermal insulation, and China should refer to the Japanese case for the standard draft from now on.

In addition, about the floor of heating residential building, the heat absorption index has been classified three grades shown in Table 10 according to attribute of building.

Airtight: according to outdoor air wind 3.0 m/s in winter, China has been classified into two regions; furthermore, building also has been specified by the number of stories. The air permeability grade values for windows were shown in Table 11. These values are specified in the current national standard [Air Permeability of outside Windows of Building] (GB7107). The standard value according to the air permeability of window was shown in Table 12.

Prevention of moisture: Table 13 has specified the tolerance range of temperature difference between indoor temperature and surface temperature of each part of building, considered the prevention of moisture respectively required about the building according to use. In addition, heat resistance measures should be adopted in the bottom of floor; and the moisture absorption materials is required for floor.

5.3 Standard of heating load in hot summer and cold winter region

The energy-saving synthetic index of building(Table 14) specified by calculating the heating and cooling load, and annual electricity used in the HVAC system. The dynamic method was used for the energy conservation calculation of residential building in hot summer and cold winter zone. The calculation conditions can be summarized as follows:

(1) indoor design air temperature: winter is 18°C, summer is 26°C. (2) As for outdoor calculation weather, the typical weather year data is utilized for calculation. (3) The ventilation is one time per hour of heating and air-conditioning system. (4) Coefficient of performance of heat pump air-conditioner is 2.3 and the heating resource is 1.9. (5) The heat generation from lighting is 0.0141 kWh/m$^2$, and other heat generations are specified as 4.3 W/m$^2$.

The annual electricity consumption for heating and air-conditioning system should not exceed the limitation value of Table 14.
6. Conclusion
In this research, the authors have carried out the research to investigate the characteristics of building energy standards of the residential building in China. Efforts have also been made to promote a better understanding of the energy policy and relevant standard for architects and building designers to achieve optimal energy efficient building design, and also for assuming the building energy consumption, assessment of the thermal environment in China. The results can mainly summarized as follows:

1) As for the thermal environment design, the climate of China has been classified five zones.

2) The sunlight, lighting, ventilation environment of residential building have been specified in the new standards.

3) Prescribed the building design elements, such as layout, orientation, shape, color, plan and the type of window. In particular, the thermal insulation measures for heating system has been added in hot summer and cold winter region, which was not described in old standard.

4) It is admitted that there is still a difference compared with the standard of many foreign countries, and the improvement in the further heat insulation performance and positive execution of the standard continue to be expected.

Reference
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