Study on the Logical Facing Direction of Residential Building in Changchun City by Using the Passive Design Theory

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Abstract: In the paper, based on building energy efficiency, it is used as the foundation of the passive design theory, with considering climatic environment in Changchun, China, the corresponding parameters is determined, according to the energy efficiency principle of gain most heat in winter and avoid heat as little as possible in summer, and it is put forward that the logical range of residential building facing direction in Changchun city through theoretical analysis, which offers beneficial reference and experience how to design for energy efficiency in residential buildings in Changchun.

Keywords: the passive design theory, residential building, energy efficiency, the facing direction

Introduction

With the rapid development of society, energy problems has become a common concern in the world today, the inadequacy of energy resources has become an important factor affecting the economic development. According to the statistics of Building Energy Efficiency Special Commission of China Construction Industry Association, the amount of energy consuming of buildings in China has increase gradually these years, the proportion that energy consuming in buildings accounts for the total energy resources rises from the 10% in the late 1970s to 27.45% in recent years, and will rapid rise to more than 35%. Energy consuming in buildings in China is two or three times than developed countries with same climate conditions. At present, building energy efficiency in China is, over 80 percent of new buildings are high energy consuming buildings, over 95 percent of existing buildings are high energy consuming buildings. Therefore, to reduce building energy consumption and promote implementation of building energy efficiency not only is the needs of the
national energy strategy and sustainable development strategy, but also the needs of increasing the housing quality for urban residents, meeting the needs of people for high standard condition of living room, energy efficiency building will become mainstream in buildings.

The core of building energy efficiency is reducing the energy consuming in buildings, improving the energy efficiency rate for buildings. From the height of the sustainable development, the perspective of circular economy’s development to treat energy-saving residential buildings and the technology of saving energy which follows the whole life cycle of the residence to design construction. Energy efficiency residential buildings need high standards for scientific and reasonable planning, the best direction of the building should be selected correctly at first.

Based on the passive design theory of energy efficiency in residential buildings design of passive house of professor Long in Germany [1], whose basic principle is that no energy needs to get through the high-tech equipment, and to take advantage of natural conditions in architectural design.

According to design reasonable building size and facing direction in residential buildings design, and then to improve the effect of building energy efficiency. Therefore, the main elevation of residential buildings should face south, in combination with local geographical position, when buildings are restricted by some conditions, not exceeds a certain angle by east and west, avoid the buildings themselves or other buildings to keep out sunlight as little as possible. Through reasonable layout of direction and environment, and dealing with architectural materials, structural construction skillfully, it is made that buildings can collect, maintain and store solar energy in winter, which not only can solar energy be used naturally but also save the conventional energy.

**Study on Facing Direction of Energy Efficiency Design in Residential Buildings**

The selection of building direction deals with local climate condition, geographical environment, building land condition, and so on, which must be considered totally. In the residential building design, the main rooms should be toward south, south by east, south by west, which are always recognized reasonable design. In China, most of cold and severe cold region, in residential overall plan and single building design, to find the logical facing direction for the main space of residential buildings, and to satisfy the demands of the sunshine in winter, and to take advantage of natural energy, all of above, it is no doubted that these designs can improve residential indoor thermal environment essentially and be the most basic energy efficiency measures in the passive design theory as well.

In modern residential energy efficiency design, in order to select accurately the best direction (or interval) of residential energy efficiency under the different geographical environment and climate condition, and then it should be overall considered that the main factor including each direction walls, the available hours of sunshine and the sun illuminated area in the living-room, solar radiant heat that is conducive to local temperature peculiarity, the available amount of ultraviolet gained and relationship between residential facing direction and predominant wind direction, and through the
actual measurement statistics and analysis and calculation for relevant data, thus it will be get that the best facing direction and reasonable towards which can satisfy the energy efficiency demands of local residential buildings.

To Determine the Reasonable Range of the Residential Building Facing Directions in Changchun City

According to analysis of the relevant data, the best facing direction of residential buildings is usually about south by east 15° and south by west 15° in most cities in China. Based on different climate conditions and geographical positions, each area has various differences, in addition, the best facing direction of building should consider the needs of taking more solar radiation for heating in winter and preventing more in summer simultaneously, and avoiding cold winds in winter and be easy to ventilate in summer.

Consider heat gained for energy efficiency of residential building facing direction in winter.

Heat gained in winter is the main factor that needs to be determined facing direction of residential buildings, so it is get as follows:

$$\sinh_{so} = \frac{\ln p}{3} + \frac{3}{\sqrt{2}} - \frac{\sqrt{b}}{2} + \sqrt{\left(\frac{a}{3}\right)^3} + \frac{3}{\sqrt{2}} - \frac{\sqrt{b}}{2} + \sqrt{\left(\frac{a}{3}\right)^3}$$

$$a = \frac{(\ln p)^2}{3} \quad b = \ln p[1 - \frac{2}{27}(\ln p)^2]$$

Where, $h_{so}$ is the angle of sun height that gains the most heat, $p$ is coefficient of atmospheric transparency.

In Changchun area, $p = 0.75$, it can be calculated according to the most heat gained in winter solstice, so from the above formulas, it can be obtained as follows:

$$a = \frac{(\ln p)^2}{3} = 0.01 \quad b = \ln p[1 - \frac{2}{27}(\ln p)^2] = -0.18$$

$$\sinh_{so} = 0.71, \quad h_{so} = 44.84^0,$$

$$\sinh_{max} = \sin \phi \sin \delta + \cos \phi \cos \delta = \sin 43.88 \sin(-23.5) + \cos 43.88 \cos(-23.5)$$

$$h_{smax} = 23^0, \quad h_{smax} < h_{so}$$

Where, $h_{smax}$ is the angle of sun height at the noon of winter solstice, $\delta$ is declination angle (-23.5° in winter solstice), $\phi$ is geographic latitude (43.88° in Changchun area).

Due to $h_{smax} < h_{so}$, considering heat gained from winter, south is the best facing direction in residential buildings in Changchun area.

Consider heat insulation for energy efficiency residential building facing direction in summer. The direction which gains much heat under solar radiation in summer should be avoided, when Changchun areas gets the most heat in summer ($\delta$ is 23.5° at the day of summer solstice), the calculation of angle of sun height is as follows:
\[
\cos A_{so} = \frac{\sin \phi \sinh_{so} - \sin \delta}{\cos \phi \cosh_{so}} = 0.176
\]

To take \( p = 0.9 \), to calculate angle of sun height that gets heat: \( h_{s, \text{max}} = 66.8^\circ > h_{so} \)

The azimuth \( A_{so} \) that gets the most heat is

\( A_{so} = 79.86^\circ \) or \( A_{so} = 100.14^\circ \)

When azimuth is \( 90^\circ \pm 10.14^\circ \), heat get is the most.

**Analysis of energy efficiency facing direction.**

From the analysis above, in Changchun area, the building facing the south should be selected as the suitable facing direction of energy efficiency residential building that gets the most heat in winter. The direction which gets the most heat in summer is west by north 10.14° or east by north 10.14°, in order to reduce the sunshine in summer, gables of residential building should be toward west by north 10.14° or east by north 10.14°.

But when selecting the facing directions of buildings, it should be considered that the influence of predominant wind direction in winter and summer, and to avoid the predominant wind direction in winter as much as possible, and reduce air in buildings to permeate and dissipate heat capacity, in summer, buildings should be toward the predominant wind direction in order to the need of ventilation and facilitate to ventilate (as shown in Figure 1).

![Figure 1. The predominant wind direction picture and building facing direction analysis graphics in summer and winter in Changchun.](image)

**Conclusions**

Because of different kinds of limitation, building facing directions cannot be ensured to face south, under the guidance of the passive design theory, considering to take more solar radiation in winter and avoiding to take more solar radiation in summer, in Changchun area, the residential building facing directions should be selected between south to south by west 10.14° to south by east 10.14° to be a reasonable range in energy efficiency building design.

Of course, besides building facing directions studied by the passive design theory, there are many control factors which influence the effect of energy efficiency in the residential buildings, such as building proportion coefficient, planning energy...
efficiency design, wall energy efficiency design, window and door energy efficiency design, roof energy efficiency design, interior decoration energy efficiency design, etc., which need to be controlled in the design, and to ensure to get the best energy efficiency effect.

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References