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Achieving suitable thermal performance in residential buildings in different climatic regions of China

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ABSTRACT

The rapid economic expansion of China has been accompanied by environmental issues that have necessitated a national energy conservation strategy. It has become apparent that more resources must be made available for a national programme of developing sustainable buildings with an energy-saving capability.

This paper discusses how to achieve space heating and cooling as low as possible in the Chinese residual context, where three main issues need to be addressed: (1) climate variations – there are five different climatic regions partitioned by the Chinese authorities as severe cold region, cold region, moderate region, hot summer and cold winter region, and hot summer and mild winter region; (2) rigid building form – multi-storey building block is the most constructed during the construction boom last decade resulting from the application of the national building regulations; (3) favoured fenestration design due to viewing purpose.

This paper investigates the window size in relation to its corresponding annual space heating and cooling demand within the five different climatic regions. It quantifies the energy savings by energy-efficient measures in a step-by-step approach from the current representative scenario to the building regulative scenario and finally reaches the optimized scenario and concludes guidance for future energy-efficient residential building designs.

1. Introduction

Since the political and economic reforms of 1978, China has developed into the world's fastest growing economy with the result that great pressures have been placed on the country's physical environment. In particular, the energy consumption within the Chinese residential sector has soared over the last decade due to the quantity of construction taken place and the gradually growing living standards. China is already suffering the consequences i.e. weather extremes, air pollution due to coal burning culture for power generation and space heating, and temporary power shortages across the country especially in summer, where households and businesses having to experience planned power shortages on a regular basis when industrial production is combined with millions of cheaply available air conditioners that are almost constantly in use at this time. It is therefore crucial to identify a feasible solution to reduce energy consumption and thus combat the ever energy hungry nation. And the purpose of this paper is to demonstrate how to achieve suitable thermal performance within residential buildings that provides reasonable indoor comfort at low energy cost.

The Chinese residential sector has its unique context. Firstly, the country's territory ranges from 18° N to 53° N and covers five different climatic regions across the mainland: severe cold region, cold region, moderate region, hot summer and cold winter region, and hot summer and mild winter region. Climate-responsive building strategies need to be implemented that are appropriate for each region.

Another major concern is to house a 1.4 billion population. After the population boom of the 1970s, the situation facing China was that a large building programme was set in motion without any strategic forward planning. The main feature to note about this large-scale construction over short time period is its homogeneity. In order to accelerate building developments, the same production pattern was used continually across the country. This way of building was further encouraged when the government banned two different housing types in response to the acute shortage of habitable land resources: the detached house and the terraced house. They instead encouraged the construction of multi-storey linear shaped residential building blocks.

There are also historical barriers in the way: one of the most notorious issues is the current heating system, where heating has been distributed through a city network to reach end-users on a 24 h basis with a criterion of 18 °C. The heating bill is to

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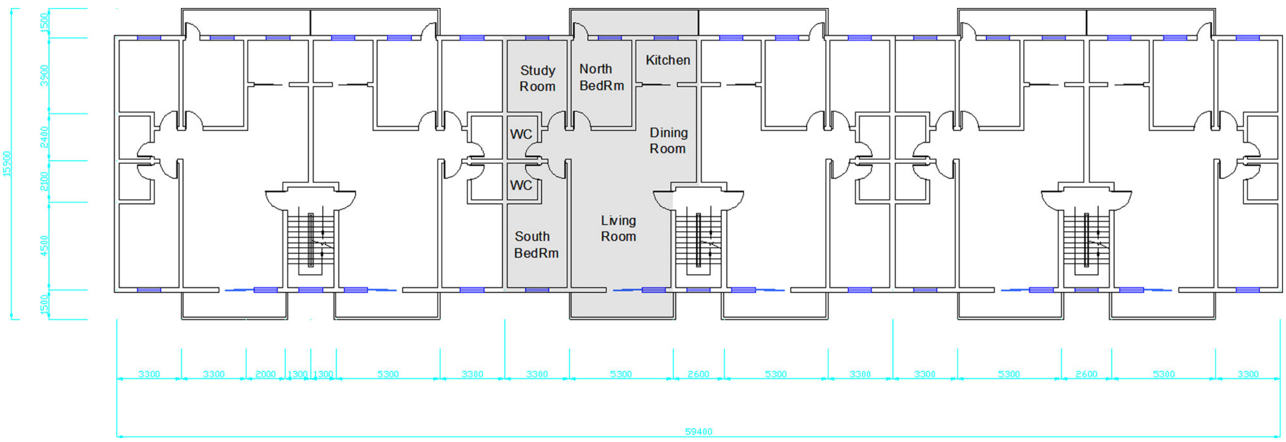

Fig. 1. Building block plan.

multiply the floor area; unit price; and supplying days, and there is no thermal controls in the system. This inefficient system emerged continuously problems and disputes, and left the government with a difficult issue to address–heating reform, which still remains unsolved today. The UN has introduced a six-year heating reform project that has had a $100million budget since 2005. However, the 2010 annual report has concluded that it is 'likely' to achieve the objective of the project due to the 'commitment' made by the central government for 'continued energy efficiency improvements' and the progress so far had been 'slow' [1]. Apparently, there are politics, enforcement and administration issues involved, which are related to all sectors and parties in achieving China's energy-saving agenda.

Finally, fenestration deserves special attention mainly because of two reasons: the lack of a simple guidance for all climatic regions and the popular preference of large window areas in residential buildings for viewing purpose and there is a hidden danger of huge energy compensation if the fenestration is designed inappropriately.

The following content firstly establishes a typical representative based on the common features of the current scenario i.e. building form and internal conditions, and then assigns with regional building regulation to obtain the corresponding regional base case. The analysis looks at the annual space heating and cooling demand of these base cases under three different fenestration levels at first, and then it constructs and evaluates the energy-saving scenarios with the variety of fenestration in quantities from the base case to the lowest possible annual space heating and cooling case respectively. The finding not only helps us to quantify the energy saving potential that is hidden within our present residential sector, but it also demonstrates to what extent passive means can be utilized to gain the maximum efficiency in the thermal performance of the buildings.

2. Methodology and settings

The methodology used in this paper is the following:

(1) Based on the homogeneous features of the apartment building blocks, establishing a representative base case for all climatic regions, and the energy efficient level are considered to be the same as the level of the current regional energy conservation building regulation.
(2) Modelling studies of these five base cases undertaken by TAS software in sequence: quantifying the energy savings achieved by applied passive energy-saving strategies step-by-step, with the relation of various south fenestrations.
(3) Conclusion and discussion of the findings.

The demonstration apartment building block has been set up according to the commonly used features and the chosen apartment is a dual-aspect (north and south) apartment on the intermediate floor (Fig. 1). The representative apartment is a three bedroom dwelling with a floor area of 110 m^2; the living room and main bedroom are south facing, the kitchen and the other two rooms are facing north (Fig. 2 and Table 1). It is assumed to be occupied by a family of three (one couple plus a pre-school age child). The corresponding internal gains and daily schedules have been assigned as displayed within Table 2.

The apartment fenestration is considered to be the window to floor ratio, where north fenestration represents the ratio between the north window area and the floor area of the north facing rooms; the south fenestration is the ratio between the south window area and the floor area of the south facing rooms. The minimum fenestration rate is assumed as 12%; this is because the minimum allowance for the glazing area design in residential buildings is 10% of the floor area (Design Code for Residential Buildings, 1999). There is a 2% area assumed for the window frame areas. In this study, the north fenestration has been fixed as 12%, where the south fenestration varies from 12% to 35% and 50%. Details of the figures are given in Table 1. The background infiltration of the representative apartment is set as 0.2 ac/h, according to the same mentioned code and the mechanical ventilation is modeled at the rate of 0.3 ac/h (30 m^3/h of fresh air per person).

Based on the current regional energy conservation building regulations, this representative apartment has been assigned with different building envelope properties for these five regions (Table 3). The weather data considered are climate predictions

Table 1
Apartment details.

Floor area (m^2)	110
Net height (m)	2.7
Volume (m^3)	$110 \times 2.7 = 297\ m^3$
Study room	12 m^2
North bedroom	14 m^2
Kitchen + dining room	22 m^2
North facing rooms' floor area (m^2)	$12 + 14 + 22 = 48\ m^2$
North window area (m^2)	$1.4 + 1.7 + 2.6 = 5.7\ m^2$
North fenestration	5.7/48 = 12%
South window area (m^2)	
12% (south bedroom + living room)	$51 \times 12\% = 6.1\ m^2$
35% (south bedroom + living room)	$51 \times 35\% = 17.9\ m^2$
50% (south bedroom + living room)	$51 \times 50\% = 25.5\ m^2$