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# Comparative assessment of external and internal insulation for intermittent air-conditioned bedrooms in Shanghai

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**Abstract**

A comparative assessment of external and internal insulation for an intermittent air-conditioned bedroom was performed numerically. A bedroom in Shanghai was used for the numerical calculations and two operation modes were assumed. The energy for the on-periods and the thermal comfort index during the off-periods were used to evaluate the exterior walls insulation configurations. The study shows that, the energy used for heating was significantly reduced by adding insulation layers on the surfaces of the exterior walls. The energy used for cooling was also decreased with the increasing insulation layers even though the exterior walls insulation seems have little impact on the amount of energy decreased. The external insulation configuration gave better thermal performance compared to internal insulation configuration, when measured by both the annual cooling and heating energy requirements. Using the thermal comfort index as criterion, for a given total thickness of insulation layer, the better performance was obtained when placing the insulation layers at the outdoor surface.


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*Keywords:* internal insulation, external insulation, intermittent air-conditioned, energy consumed, thermal comfort

**Nomenclature**

| | |
|---|---|
| $\lambda$ | thermal conductivity, W/(m$^2$·K) |
| $\rho$ | density, kg/m$^3$ |
| $c$ | specific heat, J/(kg·K) |
| $T$ | temperature, ℃ |
| $E$ | energy consumed per unit area and per year, kWh/(m$^2$ • year) |

## 1. Introduction

The climate in hot summer and cold winter zone of China is severe. It is very hot in summer and cold in winter. According to relevant data, the energy consumed to maintain indoor thermal comfort in residential building in this area is higher than those in cold zones [1]. It has been shown that energy consumption for air conditioning bedrooms took up more than 60% of the total residential energy consumption for air conditioning in 2014[2]. For the bedrooms, the major part of energy consumed for heating and cooling is due to heat transmission trough the exterior walls. Therefore, improving the thermal performance of the exterior walls is the key to energy conservation.

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A lot of research has focused to comparatively assess the two main configurations installation of the thermal insulation on either the external or the internal side of the wall. For intermittent air-conditioned buildings, the situation is further complicated. Then Bojic. M [3] investigated three different positions of the thermal insulation layer in the exterior walls in a high-rise residential building in Hong Kong. The result shows that the highest decrease in the yearly cooling load is obtained when the thermal insulation layer faces the inside of the residential flat. G. Barrios et al. [4] investigated the performance of wall/ roofs configurations in an intermittent air-conditioned room. The result showed that, for intermittent air-conditioned room, using energy for cooling as criterion, the order of configuration, from best to worst, is: placing the insulation layer on the exterior side, in the middle of the concrete and on the interior side. Recent studies have shown that placing the insulation layer on the interior side can effectively decrease both heating and cooling energy consumption based on the intermittent air-conditioned room in hot summer and cold winter zone in China [5]. In the regions where the total energy demands were predominantly for cooling, it was found that there are instances where adding wall insulation directly increases cooling energy demand for applications with intermittently operating [3, 5-9]. Therefore, there is still much deeper research to find the relationship between the energy consumed for heating and cooling and the exterior walls configurations in intermittent air-conditioned buildings in hot summer and cold winter zone.

In this study, a bedroom model was used to analyze the thermal performance of different insulation configurations of the exterior walls. The parameters used to evaluate the thermal performance of exterior walls insulation configurations were energy consumed for heating and cooling and the indoor thermal comfort during the off-periods.

## 2. NUMERICAL SOLUTIONS

The apartment has a total floor area of 71.28m$^2$. The height of the apartment is 2.7 m. It comprises 1 living room, 1 bathroom and 2 bedrooms (Fig.1). The apartment is on an intermediate floor of the building. It was assumed that the air-conditioned area included bedroom A and bedroom B. The other area was non-air-conditioned area. The two bedrooms were occupied during 22:00~6:00 every day. The thermal parameters of the building elements are presented in Table 1. Two operation modes for air conditioning are considered and shown in table 2.

In this paper, moisture transfer was disregarded because the interest is focused on different thermal properties caused by different configurations of exterior wall. The commercial software COMSOL Multiphysics was used for calculation. Typical meteorological year (TMY) data, which was based on measured weather data of year1971-2003[10] was used for the numerical calculations. The cooling season in shanghai was from 15th June to 15th September and the heating season in shanghai was from 1st December to 20th March.

Table. 1 The thermal parameters of the building envelope

| Part | Material | Thickness δ/[mm] | λ/ [W/(m$^2$·K)] | ρ / [kg/m$^3$] | c / [J/(kg·K)] |
|---|---|---|---|---|---|
| Exterior base wall | Reinforced concrete | 200 | 1.74 | 2500 | 920 |
| Thermal insulation | XPS | ------ | 0.03 | 25 | 2376.2 |
| Interior wall | Steamed lime sand brick | 200 | 0.62 | 1600 | 1051.6 |
| Floor and Roof | Reinforced concrete | 200 | 1.74 | 2500 | 920 |
| windows | Total U-value (W/m$^2$·K)： 1.8 | | | | |

Table. 2 Operation mode for air conditioning

| Operation mode number | Operation time | design temperature in cooling season | design temperature in heating season |
|---|---|---|---|
| 1 | 22：00-24:00 | 26℃ | 20℃ |
| 2 | 22：:00-2:00 | 26℃ | 20℃ |