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A Parametric Study on the Community Form and Its Influences on Energy Consumption of Office Buildings in Shanghai

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Abstract

This paper aims to study the impact of community form on building energy consumption of commercial district. Building typology and FAR (floor area ratio) are two important morphology factors in district energy efficiency design. To explore how they influence building energy consumption, two major questions are concerning: (1) how a given FAR generates alternative building typologies that have different effects on energy consumption? (2) how increasing FAR affects building energy consumption generally? In this paper, a group of representative hypothetical models are built based on the form of actual office buildings in Shanghai. The energy consumption of three building typologies (the pavilion, the slab and the courtyard) are examined using DesignBuilder and EnergyPlus. The results suggest that, with the same building density, office building energy consumptions have a positive relationship with FAR, and different building typologies can lead to variations in energy consumption as well as energy-FAR relationship.

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Keywords: Community form, Energy consumption, Building typology, FAR, Office building;

1. Introduction

In a rapidly urbanizing world, the number of urban dwellers exceeds half of the world's population, and the proportion is on the rise [1]. China has an urban population growth of more than 500 million people over the past 35 years [2], accompanied by sharp increase of energy use. According to IEA [3], urban areas account for two thirds of the global primary energy demand, which urgently calls for significant reductions in urban energy use and emissions.

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Buildings contribute a lot to the total energy consumption in cities with a rate of 32% on average and 20%-40% in developed countries [4,5]. In principle, building energy consumption mainly depends upon three type of factors: building design, systems efficiency and occupant behavior. Among them, building design has the most remarkable effect by leading 2.5 times variation in energy use [6]. It is also argued that urban context play equally important roles as these three factors in energy consumption, while the contribution of the urban form is not quantified on account of regional differences and variable interactions [7].

Efforts have been made to explore the impact of urban form by using parametric study to examine the effect of morphology factors within community scale. Building typology and FAR are two important morphological parameters identifying community form by specifying the surrounding environment, building compactness and spatial characteristics. The floor area ratio reflects the total building capacity on a piece of land, which is usually used to measure land development intensity. The formula (1) shows the definition of FAR. It is also explained as formula (2), where building density equals to floor area/planning area.

$$\mathrm{FAR} = \frac{\text{Total Building Area}}{\text{Floor Area}} \tag{1}$$

$$\mathrm{FAR} = \text{building density} \times \text{floor numbers} \tag{2}$$

Quantities of researches have been conducted focus on these two morphological parameters. Steemers [8] assessed the energy trend and implications of varying FAR by applying the lighting and thermal (LT) method. Salat [9] investigated the influences of building typology on energy efficiency using statistical analysis based on a large case study in Paris. Rode et al. [10] used digital elevation model (DEM) simulation to study the effect of morphological parameters on heating energy demand of residential buildings. The energy-FAR relations of offices with different building typologies have been examined by conducting a series of parametric simulation experiments in Quan et al.'s research [11]. Detailed simulations were carried out on geometrically simplified models to calculate the impact of building typology on total energy demand in Tereci et al.'s research [12]. However, these researches reveal significantly different findings about the relationship between community form and building energy use.

This paper tries to explore how community form influences building energy consumption concerning two main questions: (1) how building typology affects energy consumption with a given FAR, (2) how increasing FAR influences building energy use. With the help of dynamic simulation software DesignBuilder and EnergyPlus, a group of representative hypothetical models are built based on the form of actual office buildings in Shanghai. The energy consumptions of three basic building typologies are examined: the pavilion, the slab and the courtyard [13]. The energy-FAR relationships with different building typologies are also studied.

2. Methods

The methodological framework of this study can be generalized as the following steps:

1) Select a representative actual office building as the experimental basis and determine the morphological parameters to be examined, including building typologies and the range of FAR that will generate an array of cases.

2) Specify the thermophysical, occupant related and operational characteristics of the building following the relevant standards.

3) Conduct energy simulations of a series of experimental models using dynamic simulation software DesignBuilder4.7 and EnergyPlus8.4. Calculate annual energy use intensity (EUI) for cooling and heating of each model.

2.1. Morphological parameter settings

Based on the form of actual office buildings in Shanghai, a group of representative hypothetical models are built within an area of 150m×150m. The practical building groups are located in the west of Shanghai Hongqiao Central Business District (Fig.1).