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Analysis on the Influencing Factors and Definition of Typical Model of Commercial Buildings in the Pearl River Delta

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Abstract. As a rapid developed area in China, the Pearl River Delta (PRD) has its own building features. Analysis on its characteristic can serve as a reference for future application of energy-saving technologies in this region. As a key factor for energy consumption simulation, a typical building model can be used to evaluate the energy-saving potential of green building materials, designs as well as device. It is of great significance for building energy research, policy formulation, and market orientation. In this paper, a statistic involving over 200 construction drawings is adopted to analyze the correlation among window-to-wall ratio (WWR), building area, building height, building age and floor number after 2000 in the PRD. Finally, based on the analysis of the design parameters of the influencing factors, a typical commercial building model of the PRD is defined.

1. Introduction

To the year 2016, China's public building area achieved approximately 11.73 billion m² of which commercial buildings accounts for 59.6%. It is believed that China's public building area will reach 18 billion m² in the year 2035, and the commercial buildings ratio will be 49.8% then. From 2006 to 2016, the total energy consumption of public buildings increased nearly three times, accounting for 31% of the total energy consumption of buildings^[1]. Considering the rapid growing in the number and size of large-scale commercial buildings in metropolises such as Guangzhou, Shenzhen, Dongguan and Foshan in the PRD in recent years, the building energy conservation in the PRD is the key topic for building energy conservation in Guangdong Province^[2].

Due to the diversity of different buildings, certain technology would perform different effects in different buildings. In order to quantifying the performance of different energy-efficient technologies, the require for a typical building model has been put forward. A typical building model is a hypothetical building that only represents a specific construction category. Application of a typical building model during simulation can be applied to eliminate the interference of design parameters on



the building performance. The result could serve as a solid reference for market-orienting and decision-making process. This paper conducted a statistics on actual building drawings collected. An analysis on the data was also carried out to provide relevant reference for the energy-related research of the PRD. A typical commercial building model of the PRD was also defined.

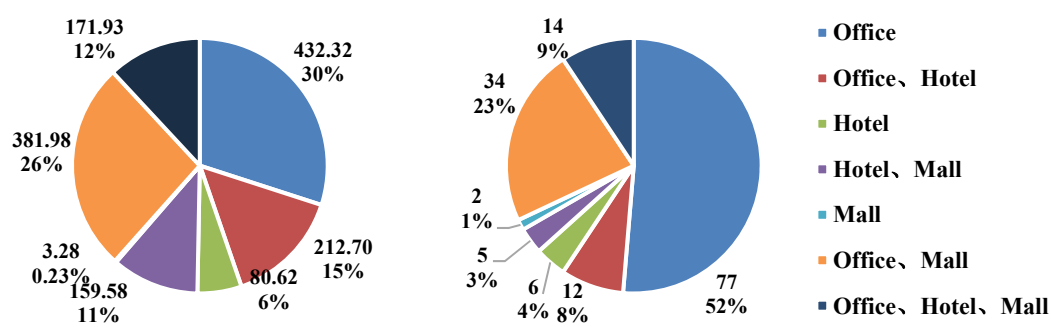
2. Research background

2.1. Status of research

In 1976, UK began to conduct energy consumption surveys for domestic commercial, office, entertainment and other public buildings^[3]. The US Energy Information Agency (EIA) conducted a CBECS survey and investigated the basic information of 5,215 commercial buildings in 2003. Statistical analysis of these basic information were conducted by The Department Of Energy(DOE) and the Renewable Energy National Laboratory (NREL), the Rolls-Royce Berkeley National Laboratory (LBNL), and the Northwest Pacific National Laboratory(PNNL) of United States. And 16 typical building models that represents more than 60 % of commercial buildings in the United States were jointly adopted in 2011. Due to the different years of building and the adoption of different design standards, the same model also has different versions^[4]. In 2015, the Design Standard for Energy Saving in Public Buildings(Standard) was issued in China. Based on the data provided by the National Bureau of Statistics, the distribution characteristics of various types of buildings were studied and determined. A typical public building model database representing public buildings was presented.

2.2. Sample Building Profile

Over 200 architectural design drawings were collected for the statistic conducted, including buildings from Guangzhou, Shenzhen, Dongguan, Huizhou, Zhuhai and Foshan. During the statistical process, incomplete or low credibility data were eliminated. Both single buildings and integrated commercial centers were considered. The proportion of different building types was presented in Figure 1.



(a) Building area ratio ($\times 10^4 \text{ m}^2$) (b) The proportion of building types number

Figure 1. Information of building type

3. Analysis of key building design factors

The relevant intuitive parameters are statistically summarized as shown in Table 1, and the basic data is combined with the relevant national building design specifications for the typical model of the PRD building.

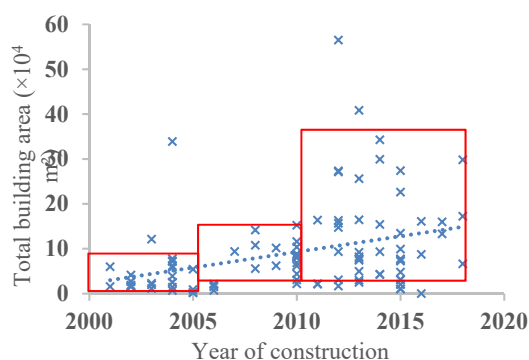
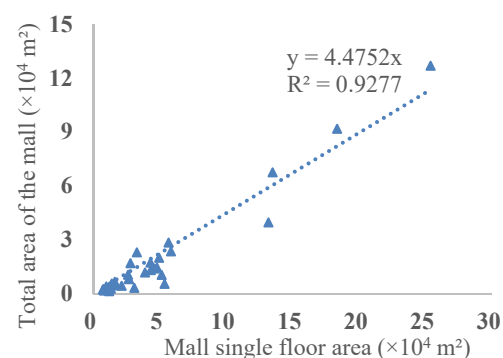
Table 1. Statistics of building information

Classifications	Basic information	Graphic design	Facade design	Section design
	Year	Building area	WWR	Building height
Factors	Function	Floor area	U-values of wall	Layer height
	Location	Orientation	U-values of window	U-values of roof

3.1. Building area

Statistics on the commercial buildings area of the PRD in the past two decades are shown in Figure 2. From 2000 to 2005, 80 % of the samples have a building area of 0~60 ,000 m²; From 2005 to 2010, 80 % of the samples have a building area of 3~15 million m²; From 2010 to 2018, 80 % of the samples have a building area of 3~34 million m². It can be concluded that with the increase of people's demand for building and the continuous development in construction technology, the number of large-scale buildings has gradually increased. It is calculated from the samples that the average commercial buildings area of the PRD is 104,844 m². The average area of single office, hotel and mall is 62,700 m², 10,700 m² and 16,400 m² respectively. The average area of the OFFICE + HOTEL building is 146,900 m², and the average area of the OFFICE + HOTEL + MALL building is 105,100 m².

When presenting the typical commercial building type composition, the standard floor with three different functions is statistically defined as a carrier of typical buildings. Different standard floor has different areas, partitions, heights, and WWR. The slope of the line fitted by linear regression is used as the area of the standard floor by the "slope method" (as shown in Figure 3). In the process of rounding the typical value, it is found that the area of the standard office floor and standard hotel floor is about 1870 m² and 1840 m². The two values were very close, and it can be concluded that in the small-scale buildings such as office and hotels in the PRD, this standard floor area is traceable. In order to simplify the model, the area of the standard office floor is set to be equivalent to the hotel.

**Figure 2.** Trends in total building area**Figure 3.** Slope method to find typical values

3.2. Window-to-wall ratio

The window-to-wall ratio refers to the ratio of the area of the external window to the area of the external wall. In the design of modern architecture, large-area glass curtain walls are quite popular among the architects to pursue the modernity of the building, which increases the beauty of the

building while also contributes to the day lighting of the building. The WWR has always been an important research object that affects the energy consumption of buildings.

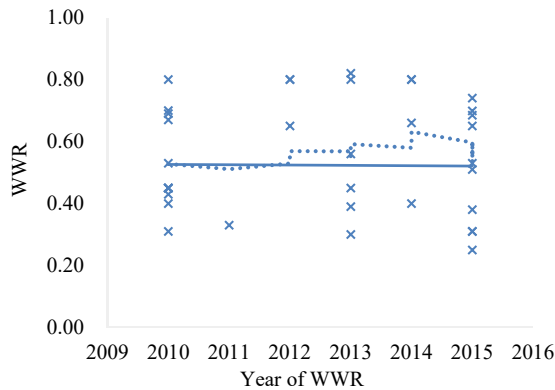


Figure 4. WWR range and trend direction

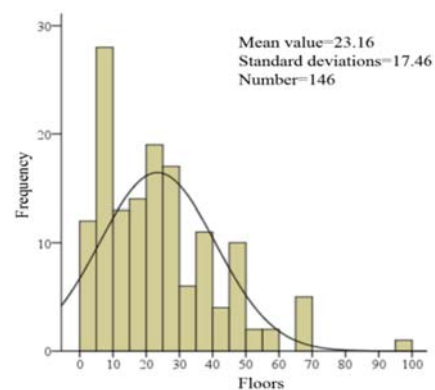


Figure 5. Floors setting for typical buildings

According to the statistics, there is no obvious relationship between WWR and building area, height, window walls or envelope heat transfer coefficient. It can only be claimed that the WWR is between 0.5 and 0.7, while the average value is 0.62. The trend is shown by the moving average trend line with a period of 12, and the WWR increases first and then decreases with the age of the building, but it does not indicate that the area of glass curtain walls used in buildings in the PRD has decreased. The WWR is based on the definition of the entire building, even if one façade was designed into glass screen wall, the total WWR could still be kept under 0.7. It is clear that some buildings have WWR greater than 0.7 from Figure 4, which indicates that extra energy-saving measures will be applied on external window, to minimize the solar radiation heat gain through window area.

3.3. Number and height of floors

The normal distribution function is used by SPSS software to analyze the number of floors as shown in Figure 5. It is concluded that the total number of floors is basically between 16 and 30, and The composition of typical Commercial buildings in the Pearl River Delta as shown in Table 2.

Table 2. The composition of typical Commercial buildings in the Pearl River Delta

	Mall	Office	Hotel
	3 floors in total	28 floors in total	
Mall	[3 floors of mall] (N=1)	[3 floors of mall, 16 floors of office, 9 floors of hotel] (N=8)	
	33 floors in total	27 floors in total	28 floors in total
Office	[5 floors of mall, 28 floors of office] (N=28)	[27 floors of office] (N=45)	[18 floors of office, 10 floors of hotel] (N=10)

	Mall	Office	Hotel
	26 floors in total	28 floors in total	20 floors in total
Hotel	[6 floors of mall, 20 floors of hotel] (N=4)	[10 floors of hotel, 18 floors of office] (N=10)	[20 floors of hotel] (N=4)

Note: "N" is the number of samples, the total number of samples is 100.

The floor height will change significantly with the number of floor. The floor height is affected significantly by the function. The linear regression fitting is taken by "slope method" as the height of the standard floor, and the standard floor height for office, hotel and mall is 4.1m, 3.6m, and 4.9m respectively.

3.4. Construction

The envelope construction of the building is mainly divided into walls, roofs, floor, windows, as well as internal construction such as internal partitions. The external gate is only located on the first floor of the building, and its area is almost negligible compared with the outer enclosure structure area. To simplify the model, the external gate of the typical building model is treated as the external wall.

During the definition of typical commercial building model, only a small portion of sample gave the detailed structure of each envelope construction. It is difficult to define a typical set of materials from limited data. Therefore, this paper can only put forward a group of typical commercial building model U-value (as shown in Table 3).

Table 3. Typical commercial building models - Building construction information

External Wall	U-value: 0.52 W/m ² ·K Gypsum Plasterboard: 4mm, Expanded Polystyrene: 20mm, Air Gap Concrete: 190mm, Mortar: 25mm
Roof	U-value: 0.54 W/m ² ·K Mortar: 20 mm, Concrete waterproof layer: 40mm, Expanded Polystyrene: 50mm, Cement ceramsite: 80mm, Concrete: 100mm
Internal Floor	U-value: 1.13 W/m ² ·K Plasterboard: 9mm, Concrete: 150mm, Plastic Tile: 3mm
Internal partition	U-value: 2.43 W/m ² ·K Mortar: 10 mm, Concrete: 80mm, Mortar: 10mm
Window	U-value: 1.80 W/m ² ·K Low-E Double-Glazing (6mm–12mm–6mm); SHGC: 0.5; VT: 0.62

Note: layers are listed from outside to inside.

The thermal parameters of the envelope construction meet the requirements of local Standard. The indoor heat source including equipment, lighting, and the occupant were set with reference to the Standard (as shown in Table 4).

Table 4. Typical commercial building model - Interior design parameters

	Personnel activity density (m ² /P)	Lighting power (W/m ²)	Equipment power (W/m ²)
Mall	3	12	13
Office	10	11	15
Hotel	15	15	15

3.5. Spatial distribution

According to the samples collected, the standard floors of typical commercial buildings are defined as the mall floor, hotel floor and office floor. The standard floor representing each floor function is selected by weight method, and the rooms are classified to different degrees according to the area size (as shown in Table 5).

Table 5. Typical commercial building model - Spatial distribution information

Classification	Number	Size (m ²)	Vertical traffic area (m)	Horizontal traffic area (m)	Corridor width (m)
Mall	[A]Big store	2	700		
	[B]Medium store	4	250	480	710
	[C]Small store	11	110		4.2
Office	[D]Office	14	13		
	[E]Multiplayer Office	5	90		
	[F]Open office	2	280	150	190
	[G]Meeting room	3	30		2.3
	[H]Conference room	2	110		
Hotel	[I] Rest room	30	43	220	330
					2.4

The standard floor can be divided into: regular shape (rectangle and near-rectangle), curve shape (ellipse, circle and arc) and irregular shape (L shape, H shape, triangle and other). The rectangle takes the largest proportion in the standard floor plan(as shown in Table6). Therefore, the standard floor of the prototype is set to be rectangle. Due to the influence of the building site, the aspect ratio of the building standard floor is not obvious. After normal distribution analysis, the aspect ratio of the hotel

and the office are set as 1.15, that of the mall is set as 1.33. In addition, the standard layer layout has two types: bilateral and single-sided. The bilateral layout takes the majority. This paper adopts the bilateral layout: the elevator, the stairwell and the toilet are arranged in the center, while the main functional space is arranged on both sides along the central axis.

Table. 6 Typical commercial building model - standard floor flat form classification

	Regular shape		Curve shape				Irregular shape		
	[Quantity/Proportion]		[Quantity/Proportion]				[Quantity/Proportion]		
	Rectangle	Near-rectangle	Ellipse	Circle	Arc	L shape	H shape	Triangle	Other
Mall	26/65%	2/5%	1/3%	1/3%	1/3%	8/20%	0/0%	1/3%	0/0%
Office	107/70%	6/4%	9/6%	0/0%	5/3%	17/11%	4/3%	2/1%	3/2%
Hotel	40/77%	4/8%	3/6%	0/0%	0/0%	5/10%	0/0%	0/0%	0/0%

From the above discussion, the three type standard floor as shown in Figure 6 and the corresponding typical commercial building model is established(as shown in Figure 7).

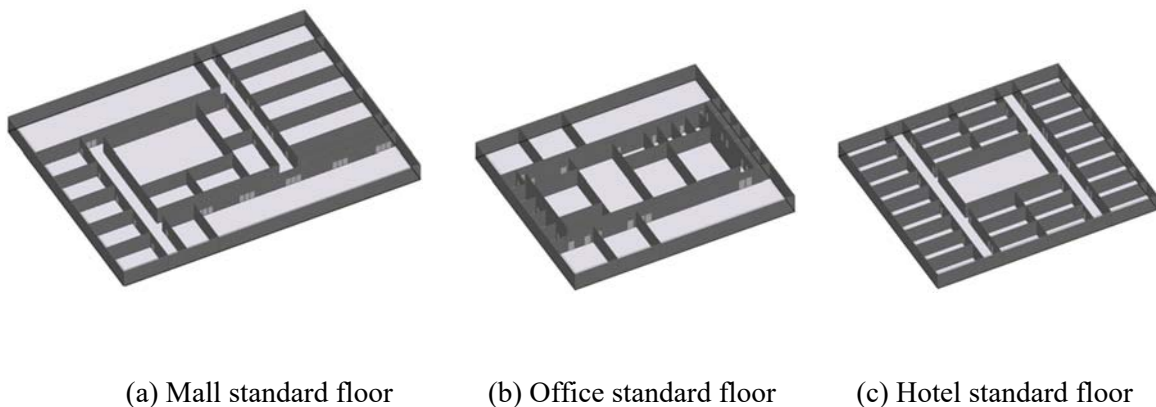


Figure 6. Schematic diagram of the layout of each standard floor

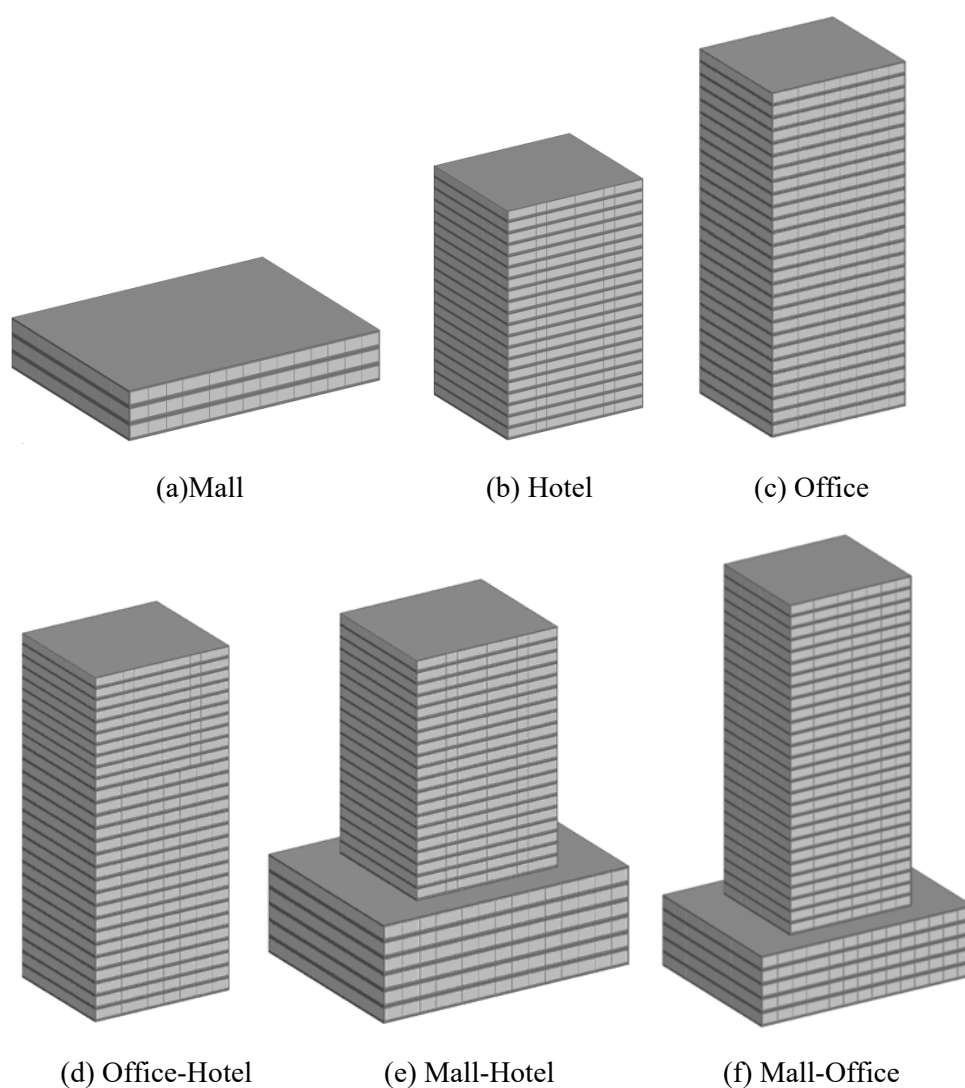


Figure 7. Combination of several typical Building models

4. Conclusion

(1) In recent years, the scale of commercial buildings in the PRD has been growing. Integrated business center is getting popular. The WWR is rising, while the number of floors gradually increased. The thermal performance was also developed.

(2) It can be concluded that the typical commercial buildings in the PRD can quantify the energy conservation effect of buildings, evaluate the performance of energy-efficient technologies, and provide a reliable carrier for the subsequent study of building design optimization.

Acknowledgements

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