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STUDY ON BUILDING LAYOUT ON PEDESTRIAN WIND ENVIRONMENT

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ABSTRACT

Building layout is one of the most important factors of residential outdoor wind environment. Existing researches on the impact of building layout mainly focus on a certain layout or an actual case, which lacks comparisons and analysis of different typical models. Three typical residential models with different layouts are established in this paper. Based on the meteorological data in Shanghai, the influences of different layouts in different seasons are analyzed through the numerical simulation. The study helps to provide a reference for architecture design.

Keywords: building layout, wind environment, CFD

NONMENCLATURE

Abbreviations	
CFD	Computational fluid dynamics
SE	Southeast
N	North
NNW	North-northwest
Symbols	
α	Ground surface roughness index
V	Wind velocity at a height of Z, m/s
V_0	wind velocity at the height of Z_0,m/s
Z	Height, m
Z_0	Reference height of 10.0m

1. INTRODUCTION

Wind environment and thermal environment is important for residence and blocks. The quality of outdoor wind environment will directly affect outdoor thermal environment. Good outdoor wind environment can not only ensures the outdoor activity space of comfort and security, but also helps to the spread of pollutants, and can use the different wind pressure of the building to provide favorable conditions for natural ventilation, which reduces the energy consumption of the air conditioning system. Therefore, how to design a good outdoor wind environment in block areas need to be considered by the designers.

In recent years, many experts have carried out relevant studies on the impact of building layout on wind environment. For example, Lin et al. carried out a numerical simulation of the wind environment of the residence, especially for the different forms of quadrangles[1]. Liu et al. studied the influence of different building layout with existing enclosed sites on outdoor wind environment by a project in Tianjing as an example[2]. Gong et al. studied the influence of four kinds of building layout, alignment, stagger, diagonal and hybrid on the wind environment of the residence[3]. Zhang et al. optimized a high-rise residential building layout in Shenyang to study the influence of layout[4]. The above researches all proved the influence of building layout on wind environment, but the object of study is relatively single, most of them study only a specific type

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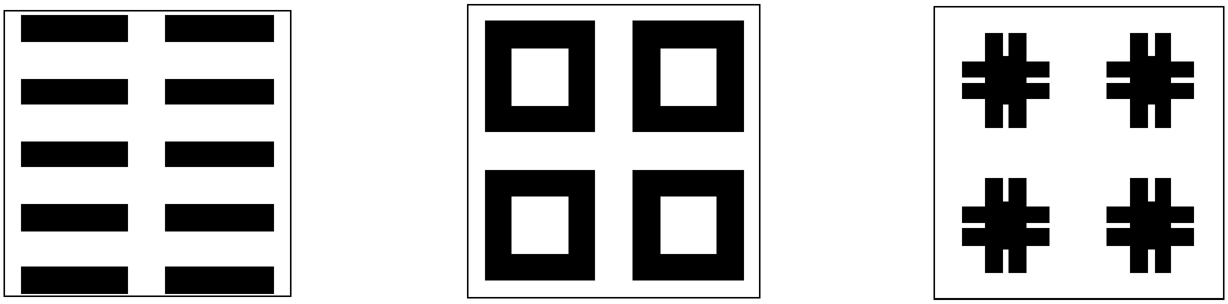


(a)aligned (b)enclosed (c)dotted

Fig 1 Geometric model

of building layout, or often only for a certain project instance. It is difficult to show the comparison of different types of layout.

In this paper, in accordance with the relevant specification of the design of the residence and in the form of common residential, three different layout form model of a typical block were set up based on the meteorological data in Shanghai, and Windperfect software was used for numerical simulation to obtain the influence of different layout forms on wind environment in each season. The wind field distribution uniformity and the proportion of wind velocity comfort area of outdoor pedestrian area are adopted as the evaluation indexes of outdoor wind environment.

2. BUILDING LAYOUT MODEL

2.1 *Physical Model*

The relevant specifications of the design of the residence [5-8] have made a specific provision for sunshine spacing and fire prevention spacing. But with certain plot ratio, different building layout forms will have different influence on the outdoor wind field around buildings. Therefore, considering the control requirements of sunshine spacing, fire prevention spacing, plot ratio and other parameters, the aligned, enclosed, dotted layout form models for a typical block is setup and used to analyze the influence of layout on outdoor wind environment. These three models are shown in Fig 1. The block size is 150m×150m, the plot ratio is 2.0, and other parameters are listed in Table 1.

Table 1 Model parameter for a typical block

Type	Aligned	Enclosed	Dotted
Plot ratio (-)	2.0	2.0	2.0
Building density	34.70%	40.00%	15.50%
Building story	6	5	13
Floor height(m)	3	3	3
Sunshine interval (m)	20	20	45
Fire prevention interval (m)	6	6	13

2.2 *Model setting*

The standard k-e turbulent flow model is used for numerical simulation and the calculation area and partitioned calculation grids refer to the calculation condition and partitioned calculation grids of AIJ guidelines [9], which is shown in Fig 2 and Table 2.

Table 2 Calculation area and number of grids

Type	Number of grids	Minimum grid size(m)	Calculation area(X×Y×Z)
Aligned	8469160	0.2	1000m×1000m×106m
Enclosed	6932156	0.2	1400m×1400m×86m
Dotted	7903467	0.2	1200m×1200m×238m

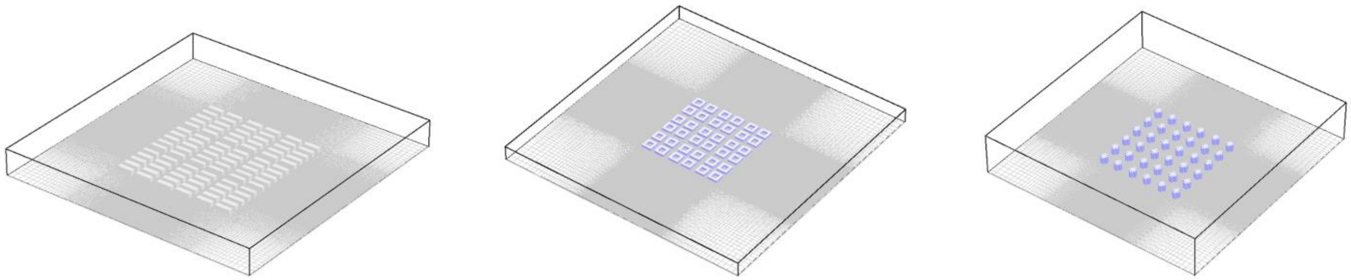
For the external wind conditions, the wind speed gradient distribution conforms to the law of power exponent distribution as follows. The ground surface roughness index is set as 0.3 for central urban area.

$$\frac{V}{V_0} = \left(\frac{Z}{Z_0}\right)^{\alpha} \quad (1)$$

Dominant wind directions and speeds of each season are listed in Table 3.

Table 3 Dominant wind parameter in Shanghai [10]

Season	Direction	Frequency	Velocity(m/s)
Summer	SE	14%	3.8
Transition season	N	16%	4.6
Winter	NNW	13%	5.3



(a)aligned (b)enclosed (c)dotted

Fig 2 Calculation model

3. SIMULATION RESULTS AND DISCUSSION

3.1 *Transitional season*

The pedestrian wind velocity field and distribution at the height of 1.5m for three typical building layouts in transition seasons is shown in Fig 3 and Fig 4. It can be seen that, when the wind flow hits the windward side of the building, a detention area will be formed at the front of the windward side. Due to the aligned and enclosed layout have bigger windward area, they also have a bigger detention area. Influenced by the detention area, the longitudinal roads of the aligned layout are the main channels for wind, and the wind velocity can be up to 5.68m/s. The lowest proportion of the wind velocity comfort area (between 2.0m/s -5.0m/s) for aligned layout is 54.4%. The longitudinal roads of the enclosed layout are also the main channels for wind, and the maximum wind velocity is 5.89m/s. The proportion of the wind velocity comfort area for aligned layout is the lowest, about 50.8%. The dotted layout forms a bigger wind velocity comfort area to 68.7%. When the wind enters the dotted layout against the front buildings, the wind retention area is smaller because of the small windward wall area of the buildings, and its influence on outdoor wind environment is also smaller.

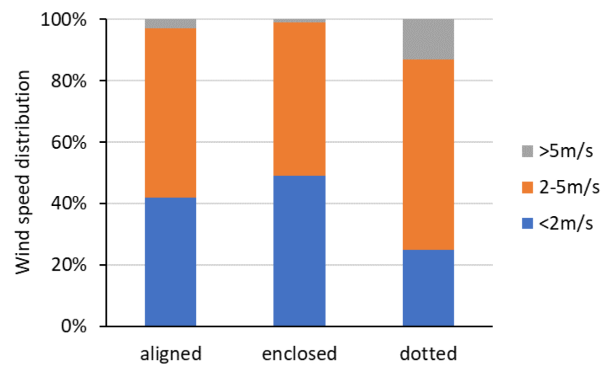
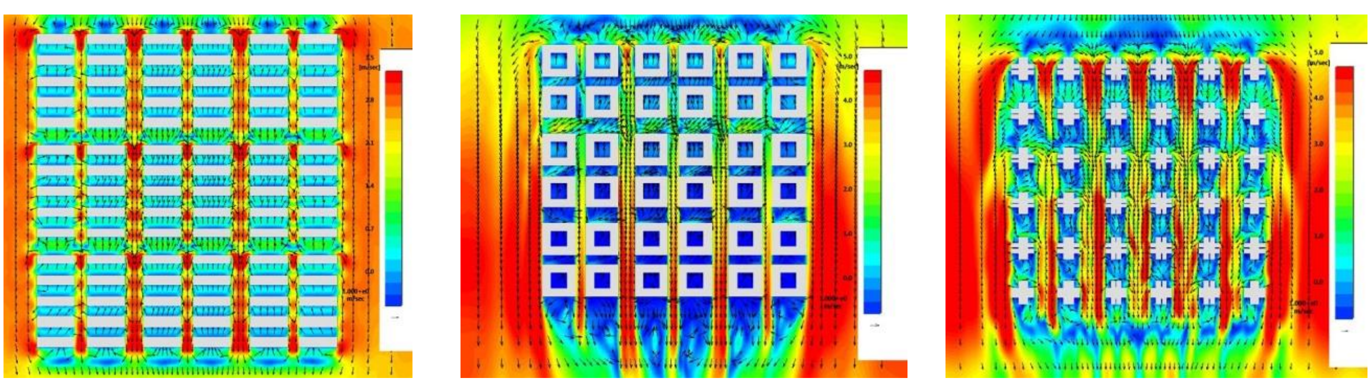


Fig 4 Wind speed distribution at the height of 1.5m for outdoor pedestrian area in transition seasons

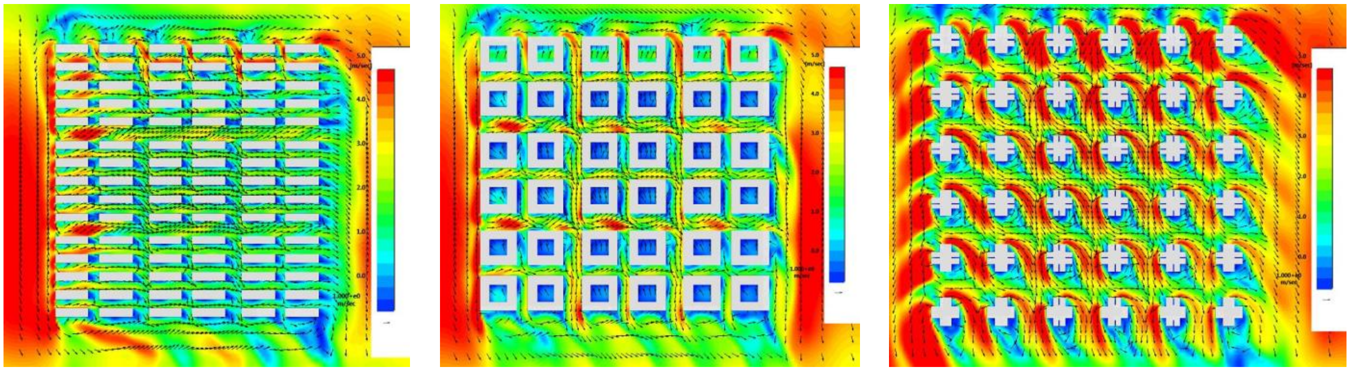
3.2 *Winter*

The pedestrian wind velocity field and distribution at the height of 1.5m for three typical building layouts in winter is shown in Fig 5 and Fig 6. Due to the wind direction in winter is at a certain deflection angle with the buildings, the shielding effect of the front buildings in the three layouts is greatly reduced, and the



(a) aligned (b) enclosed (c) dotted

Fig 3 Wind speed field at a height of 1.5m for outdoor pedestrian area in transition season



a) aligned (b) enclosed (c) dotted

Fig 5 Wind speed field at a height of 1.5m for outdoor pedestrian area in winter

ventilation performance of the three blocks is improved a lot. Among them, the windward area of buildings with aligned layout is smaller than that in transition season, and its wind shadow area is smaller. The highest proportion of wind velocity comfort area is 84.9%, and the wind velocity distribution is uniform. The ventilation performance of the lateral passage of enclosed layout is also improved comparing to that in transition season, but the windward area is still larger, and the proportion of wind speed comfort area is still the lowest, at 70.34%. The dotted layout has a small windward area, and the ventilation performance is the best among the three forms. However, the maximum wind velocity at local areas reaches 7.4m/s, which may affect the comfort and safety of pedestrians, and the wind comfort area accounts for 80.8%.

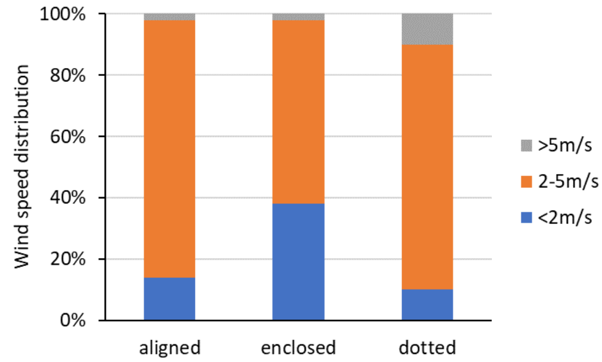
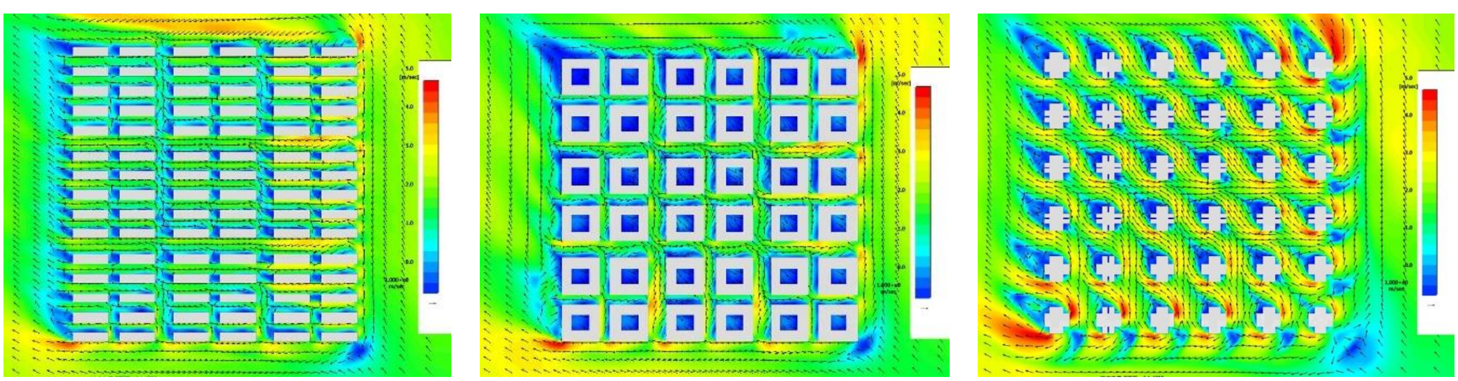


Fig 6 Wind speed distribution at a height of 1.5m for outdoor pedestrian area in winter

3.3 Summer

The pedestrian wind velocity field and distribution at the height of 1.5m for three typical building layouts in summer is shown in Fig 7 and Fig 8. The distribution of wind fields in the three layouts is relatively uniform. The lateral roads in the aligned layout are the main wind channels for good ventilation, and the area of wind velocity comfort area accounts for 82.6%. The enclosed



(a) aligned (b) enclosed (c) dotted

Fig 7 Wind speed field at a height of 1.5m for outdoor pedestrian area in summer layout has a larger windward area, with the minimum 65.1% wind velocity comfort area, but the ventilation performance of the transverse passage is improved compared to that in transitional season. The dotted layout has a small windward area, and the ventilation performance is the best with the highest proportion of wind velocity comfort area of 85.1%.

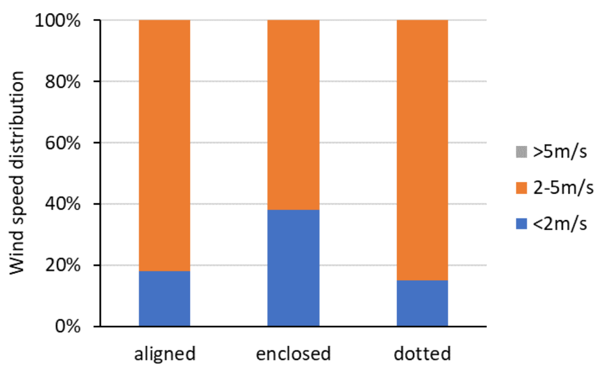


Fig 8 Wind speed distribution at a height of 1.5m for outdoor pedestrian area in summer

4. CONCLUSIONS

This paper three typical building layout models were setup to analyze the influence of layout form on outdoor wind environment in Shanghai, and the following conclusions can be obtained: the ventilation performance of three building layout during different seasons are almost the same. The ventilation performance of dotted layout is the best, followed by aligned, and the enclosed layout is the worst. However, from the view of the wind comfort area, the wind comfort in transitional season and summer accords with the above rules, but the wind velocity in some areas of dotted layout in winter is too large, which leads to its wind comfort lower than aligned. The incidence angle between the wind direction and the building can play a big role in the ventilation performance of different building layout.

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