

# Study on the Influence of Piloti Ratio on Residential Block's Wind Environment by Coupled Simulation Method

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**Abstract.** The environmental degradation results in not only the increase of energy consumption in cities but also healthy problem of people, and many researches regarding to outdoor environment and thermal comfort are carried out. Wind velocity is considered to be one of the thermal comfort influential factors, and there are few work studied the comprehensive influence of piloti on wind environment by coupled simulation method, which offers high precision CFD simulation results. This paper taking the city of Guangzhou, China, as an example, adopting coupled simulation method, studied the wind environment of residential blocks under various piloti ratio (0%, 40%, 60%, 80 and 100%). Both of the cumulative distribution and average wind velocity under piloti and out of piloti area are simulated and analysed. This work is expected to offer reference for architects and civil engineers in outdoor environment and thermal comfort design, and contribute to further study in sustainable and healthy building environment research field.

## 1 Introduction

The degradation of outdoor environment leads to not only energy consumption but also people's health problems. of Urban heat island is now regarded as one of the most serious environmental problems, and to optimize the outdoor thermal environment and thermal comfort, a lot of research were carried out [1]-[4], including plant, high reflective capability materials of building envelope, green building walls and roofs, improvement of city ventilation, use of sea wind and decrease of artificial heat, etc.

To get good outdoor ventilation and create shadow areas, piloti is commonly used in tropical and subtropical climate zones (Fig. 1), but there are few studies reveal the comprehensive influence of piloti on wind environment in residential blocks, and furthermore, a coupled simulation method, which offers high precision prediction result, is seldom taken into consideration in piloti research field. Xi et al. published field measurement results of various human built elements in Guangzhou [5]-[8], including piloti, but no systematic analysis by simulation was used in those research. The influence of piloti on mean radiant temperature simulated by 3-D unsteady state heat balance radiation calculation method was published by Xi, Hong Jin et al. but no wind environment was mentioned [9], [10]. Xi, Qiong Li et al. studied on the effects of semi-open space (100 percent ratio piloti) on the outdoor thermal environment of residential communities, by adopting coupled simulation method, but no different piloti ratio cases were compared [11].

This research takes residential blocks in Guangzhou, China as an example, aiming at study on the comprehensive influence of piloti ratio on the wind environment. A coupled simulation method, which combines the commercial STAR-cd software and homemade program (coded in Tokyo University) was adopted in this study, and this method is expected to get high precision prediction result.



Figure 1. Building piloti design in subtropical climate zones.

## 2 Methodology

### 2.1 Coupled simulation method

Firstly, non-isothermal CFD analysis is carried out by STAR-cd, using data from local meteorological bureau (wind velocity and prevailing wind direction, and air temperature) and observed data (ground and building surface temperature). In this step, the surface temperature is set to be mean value as traditional method, which cannot reflect the real surface situation and will cause buoyance calculation omit in the velocity simulation.

Secondly, ground and building surface temperatures are recalculated in step 2 by homemade program (coded in Tokyo University), which is based on unsteady state heat balance calculation including 3-dimensional radiation and 1-dimensional conduction calculations.

Based on outcomes in above 2 steps, CFD analysis is carried out one more time in STAR-cd and more accurate results will be obtained (Fig. 2).

### 2.2 Time selected in simulation

Based on TMY (typical meteorological year) data, 24-hour meteorological data are averaged per day to get mean daily data. Consequently, the whole summer mean data are obtained by averaging the cumulated mean daily data. Finally, analysis date is determined by choosing the day whose data are most close to the whole summer mean data. Therefore, 14th July in Guangzhou is selected as a typical day of summer. Analysis time is selected based on at the time when maximum temperature occurred during analysis date (15:00).

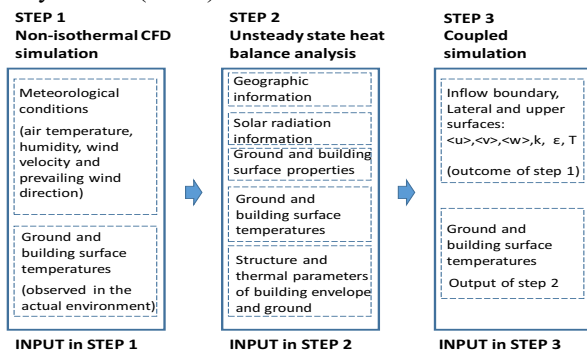


Figure 2. Coupled simulation chart flow.

### 2.3 Cases design

The domain size, wind direction and building orientation are shown in Fig. 3, the distance between buildings and inflow and wall boundary is set to be 5 times of building height, and the distance between buildings and outlet boundary is set to be 15 times of building height, both of which are set due to AIJ guidelines. The evaluated area is set in the middle of the community to avoid the lateral influence of CFD simulation. The piloti ratio of each case is set to be 0, 40, 60, 80 and 100 percent. To avoid the lateral influence, the standard area was chosen in the centre of simulated cases (Fig. 4).

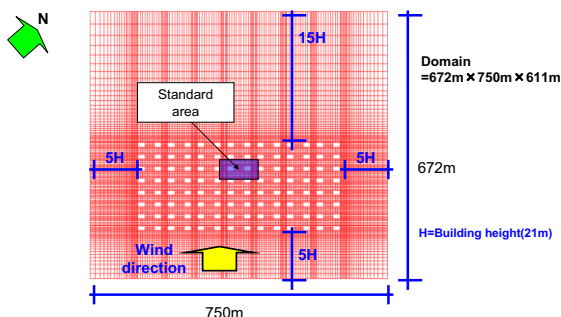


Figure 3. Domain description of simulation.

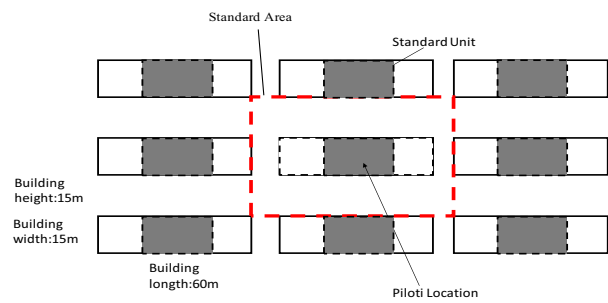


Figure 4. Standard unit and standard area.

## 3 Results and analysis

### 3.1 Wind environment of non-piloti area

The cumulative distribution of wind velocity of those non-piloti areas is shown in Fig. 6. It shows that when piloti ratio is lower than 40 percent, the average wind velocity is clearly divided into 2 levels, and the blank interval is vanished when piloti ratio reaches 60 percent, which should be because the non-piloti area includes wind channel area and space before and after buildings. When piloti ratio is 100 percent, no low wind velocity exists anymore, and the lowest wind velocity is over 0.9m/s.

The average wind velocity of non-piloti area is plotted in Fig. 5, and it shows that 40 percent piloti ratio cannot optimize the wind environment efficiently, and the slop becomes shaper when piloti ratio increases from 60 to 80 percent, which seemed to be the inflection point of non-piloti space wind velocity.

### 3.2 Wind environment of piloti area

The cumulative distribution of wind velocity of piloti areas is shown in Fig. 7, and the average wind velocity of non-piloti area is plotted in Fig. 8. When piloti ratio equals to 40%, the wind velocity is very low, and no velocity is beyond 0.3m/s. Each 20 percent piloti ratio increase can highly improve the wind velocity, and both of the lowest and highest wind velocity value keeps increasing along with the piloti ratio's change from 40% to 100%. 80 percent and 100 percent piloti ratio can highly optimize the wind environment under piloti area, leaving blank in low velocity intervals (Fig.7). The increase slop changed at the 80% piloti ratio, and before that the increasing trend seemed to be constant.

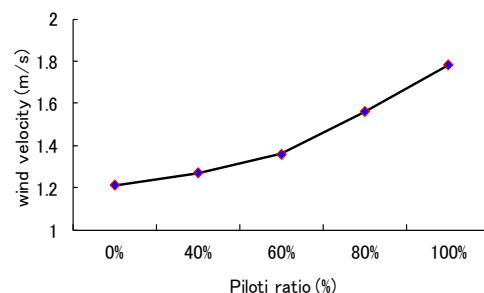
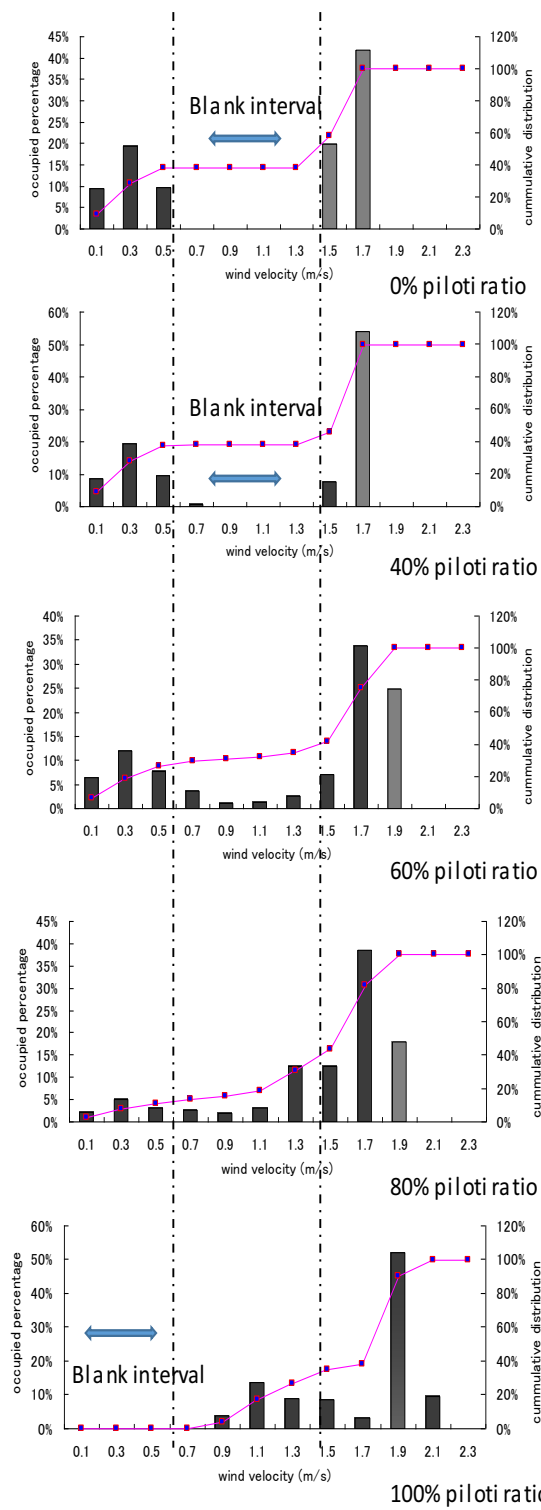
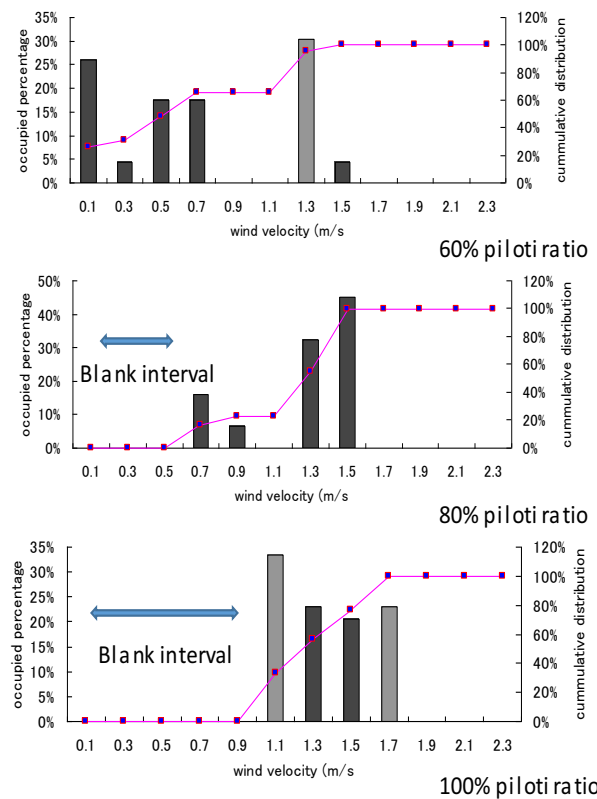
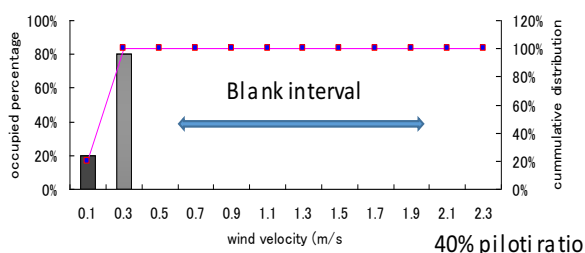


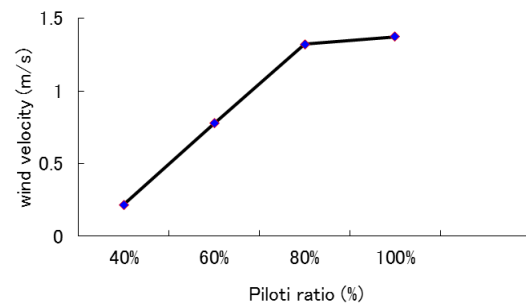
Figure 5. Average wind velocity of non-piloti area.



**Figure 6.** Wind velocity cumulative distribution of non-piloti area.



**Figure 7.** Wind velocity cumulative distribution of piloti area.



**Figure 8.** Average wind velocity of piloti area.

## 4 Conclusions

This work studied the influence of piloti ratio on residential block's wind environment by coupled simulation method, and to avoid the lateral influence, the standard area was chosen in the centre of simulated cases, which was divided into 2 parts to be analysed, the area under piloti and the space out of piloti.

For the non-piloti space, high wind velocity area (wind channel between buildings) and low wind area (before and after the buildings) are clear to be observed when piloti ratio is lower than 80 percent, and When piloti ratio is 100 percent, no low wind velocity exists anymore, and the lowest wind velocity is over 0.9m/s. For the average wind velocity, the slop becomes shaper when piloti ratio increases from 60 to 80 percent, which seemed to be the inflection point of non-piloti space wind velocity.

For area under piloti, the optimization on wind environment of 40 percent piloti ratio is very limited, and 80 and 100 percent piloti ratio is recommended in

subtropical climate cities, whose lowest wind velocity is 0.7m/s and 1.1m/s independently. The increase of velocity is constant before 80 percent, and only minus increase was observed when piloti ratio changed from 80 to 100 percent.

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