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Effects of green roof on the wind field of a low-rise building

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Abstract

A three dimensional numerical wind tunnel based on the Navier-Stokes equations for viscous, incompressible fluid and LES method is established. Incoming wind field is generated based on the AIJ guidelines (2004). The numerical wind tunnel is validated against experimental results. A low-rise building with green roof is tested in the numerical wind tunnel. The results show that the green roof reduces the drag force of the building, cuts down the fluctuation near the roof, but has insignificant effect on the time-averaged velocity field.

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Keywords: green roof, low-rise building, LES method, porous media

1.INTRODUCTION

In nowadays, many people, especially retired people like to have plant works on their roofs. A roof with vegetation covered is known as green roof. Green roof has many advantages, like improving urban environmental condition, cooling down the roof, etc. Due to security reasons, green roof is more often seen on a low-rise building than on a high-rise building. The effects of green roof on the wind field are interested. There're several ways to study the wind field of a building, Yang Wei et al. [1] use a time steady, kappa-epsilon (κ-ε) turbulence model. Guo Dong-Peng et al. [2] compare the numerical simulation result between κ-ε turbulence model and Large-Eddy Simulation (LES) turbulence model, and that comparison show that LES model leads to better results.

In this paper, a three dimensional numerical wind tunnel based on the Navier-Stokes equations for viscous, incompressible fluid and LES method is established and is validated comparing with experimental results, which is provided by Tokyo Polytechnic University [3].

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Then the same building with green roof is tested in the numerical wind tunnel. The parameter of green roof is provided by Li Jian-Feng et al. [4].

2. NUMERICAL PROCEDURE

2.1 Model

The commercial CFD package FLUENT is used to build up the numerical wind tunnel. As shown in figure 1, the numerical wind tunnel is 2.2m wide by 1.8m high, according to the Boundary Layer Wind Tunnel in the Tokyo Polytechnic University, Japan. The tested building is flat-roofed, 160mm*160mm*160mm. The wind direction angle is 0. The numerical scheme is SIMPLE, the turbulence model is LES. The total cell number of the numerical wind tunnel is about 3000000.

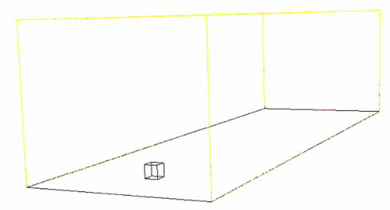


Fig. 1: The numerical wind tunnel

2.2. Inlet wind field

The inlet wind field is based on AIJ (2004) [5] with terrain category III. This category has a mean wind velocity profile exponent of 0.20. The turbulence density at a height of 10cm was about 0.25. The test wind velocity at this height was about 7.4m/s.

2.3. Near-wall treatment

The Werner-Wengle wall functions [6] is employed, which proposed an analytical integration of the power-law near-wall velocity distribution. With this treatment, the yplus limitation is extended.

2.4. Green roof treatment

The green roof is 10mm height. According to Li Jian-Feng et al. [4], the green roof is treated as a porous zone. Regardless of viscous resistance, the initial resistance is set to 1.095.

3. RESULTS AND COMPARISON

3.1 Mean wind pressure coefficients

Comparing Figs. 2 and 3 (1), the numerical results have a similar distribution to the experimental results, the maximum and minimum value are also the same. Therefore, this numerical wind tunnel is credible. Figure 3 shows that the green roof leads to a smaller pressure coefficient, which means a smaller lift force on the roof.

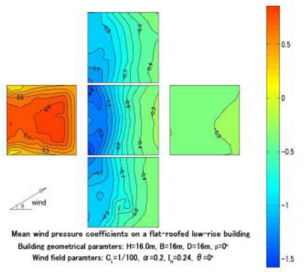
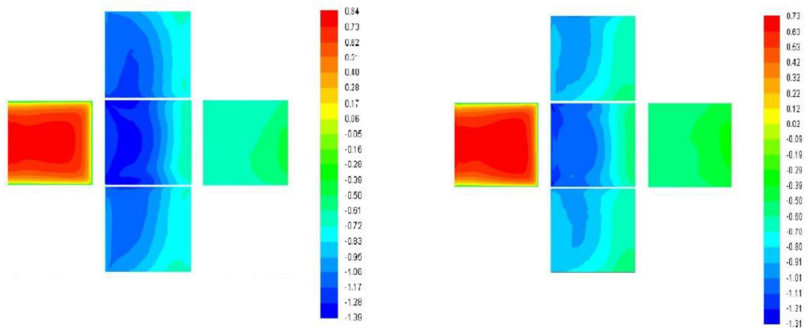


Fig.2: Experimental result [3]



(1) normal (2) green roof

Fig. 3 Numerical results

3.2 Drag coefficient (C_d) and lift coefficient (C_l)

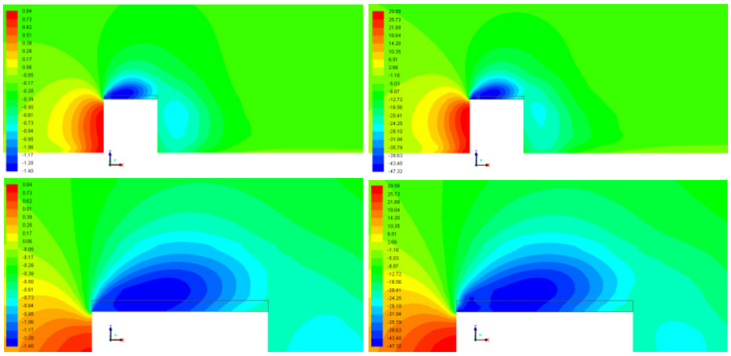
Table 1: Drag force coefficient and lift force coefficient

	Normal	Green roof	Reduction
Averaged C_d of the building on wind direction	1.141839150	1.041825707	8.8%
Averaged C_l of the building's roof	1.040294430	0.946057698	9.1%

Table 1 shows the averaged drag force coefficient of the building on wind direction and the averaged lift force coefficient of the building's roof. Comparing with the normal state, green roof could provide about 8.8% reduction to the building's drag force and 9.1% reduction to the roof's lift force. It's clearly that major contributor of the reduction of drag force is the roof, which is covered by vegetation.

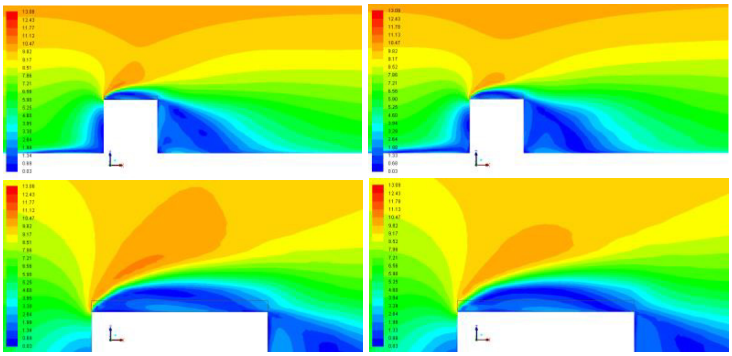
3.3. Distribution on the middle cross section

As shown in Figs. 4-6, the wind field with green roof is not much difference compared with the normal wind field. This phenomenon is easily explained. Firstly, the height of green roof is short compared with normal buildings; secondly, the building's roof is in the low wind speed and low pressure region. Yet the green roof still has some effect on the roof. As shown in the roof's detailed graphs, the green roof cuts down the RMS velocity inside the green roof region, it makes the max fluctuation appears higher than the normal state. Figure 7 shows that the transient pathlines of particles released from two lines in front of the building, different color means different particle. Those graphs give a visualized wind field distribution. The fluctuation of the normal state is more complicated than the green roof state.



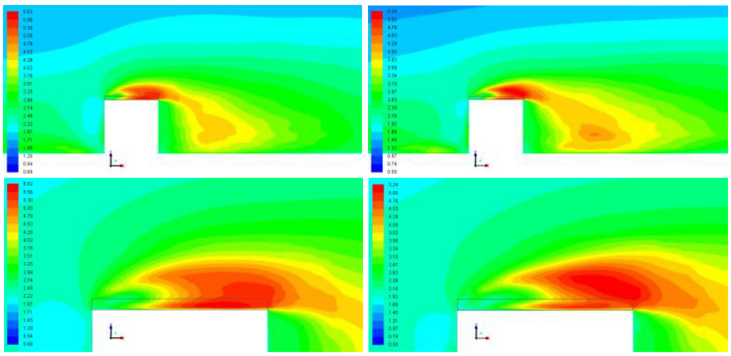
(1) normal (2) green roof

Fig. 4: Mean static pressure distribution on the middle cross section



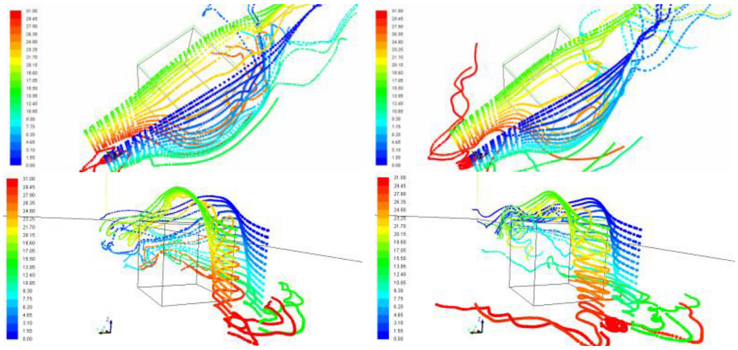
(1) normal (2) green roof

Fig. 5: Mean velocity magnitude distribution on the middle cross section



(1) normal (2) green roof

Fig. 6: RMS velocity magnitude distribution on the middle cross section



(1) normal (2) green roof

Fig. 7: Pathlines in different views, colored by particle ID

4. CONCLUSION

The three dimensional numerical wind tunnel works fine and gives a satisfied simulation result. The comparison between a building with/without green roof shows that the green roof could reduce the drag force of the building to a certain extent, but it could not have remarkable effect on the time-averaged wind field over the building. The major influence of the green roof is to cut off the fluctuation near the roof.

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