RESEARCH ON THE WIND DAMAGE OF WIND VULNERABLE STRUCTURES CONSIDERING LOCAL WIND FIELD

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Summary The damage of the wind vulnerable structures in modern cities will lead to heavy losses. On the other hand, the group of urban buildings will disturb the local wind environment and the enlarged local wind speed may be a potential causation of sever damage. In this paper, the urban street tree is regarded as a typical wind vulnerable structure and considering the spatial distribution and the local wind effect, the damage of the street trees in an urban regional area is investigated with a numerical simulation method.

INTRODUCTION

Along with the rapid urban development, destructive wind disaster such as typhoon frequently destroyed vulnerable structures other than urban buildings, such as outdoor advertising boards, power transmission lines and urban greening. Such wind-vulnerable structures would be the weakness if the strong wind came. Every year, severe typhoons would cause heavy losses in the southeast coastal region of China and especially damage the urban greening seriously. The No.8807 Typhoon which landed Hangzhou City of China in 1988, induced to 3498 shade trees falling over and 3021 shade trees heeling. The falling trees resulted in 80% electric transmission line destroyed severely and the downtown power cut area over 90%. Hangzhou City was under uncontrollable condition at one blow. At the same time, the irregular urban planning will significantly influence the distribution of the local wind field because of the complex group of buildings. One side, the group of urban buildings enlarge the ground roughness and reduce the local wind speed due to the trailing effect. On the other side, the high-rise buildings in the flow field will change the airflow movement direction. The group of urban buildings will disturb the local wind environment and the enlarged local wind speed may be a potential causation of sever damage. In this paper, the numerical simulation method will be involved to analyse the influence of the group of urban buildings to the low-ground wind field. The urban street tree will be studied as a typical wind vulnerable structure and the wind disaster loss analysis will be investigated considering the local wind effect.

THE NUMERICAL SIMULATION OF WIND FIELD

With the development of computer technology, CFD (Computational Fluid Dynamics) software has been extensive applied to simulating the local wind environment. In the paper, FLUENT is used to simulate the flow field of a buildings compact district. Fig. 1 is shown to be the group of buildings and A to D are the object points. The high of the buildings is 20 to 150m respectively. A non-structured mesh division method is adopted which means that the mesh will be sequentially larger from the edges of the buildings to the edges of the computational region as shown in Fig. 2

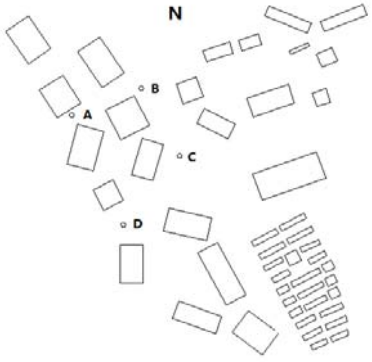

Fig. 1 Group of Buildings

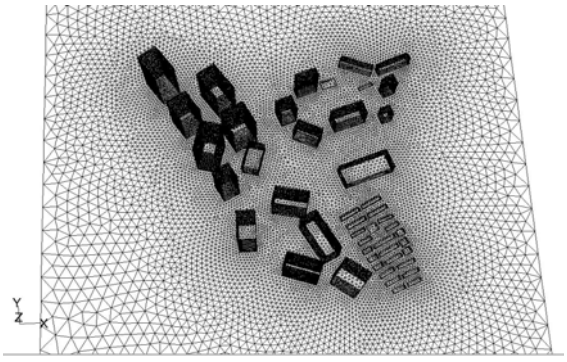

Fig. 2 Calculating Mesh

In the paper, the k- ε Mode is accepted as a turbulent mode. The inflow boundary condition is velocity-inlet and the wind direction is north and west respectively. The exponential wind profile is adopted with the wind speed at 10m as 30m/s, the terrain as Type D and the roughness parameter as 0.3. The outflow boundary condition is assumed to be free. The boundary condition of the buildings surface and the ground surface are assumed to be the wall without slippage. The simulation results of different wind directions are showed as Fig. 3 and Fig. 4 respectively, which are the wind speed section at 15m high. As is shown, because of the funnelling between the high rise buildings, the local wind field is significantly different and the partial wind speed may enlarge remarkable.

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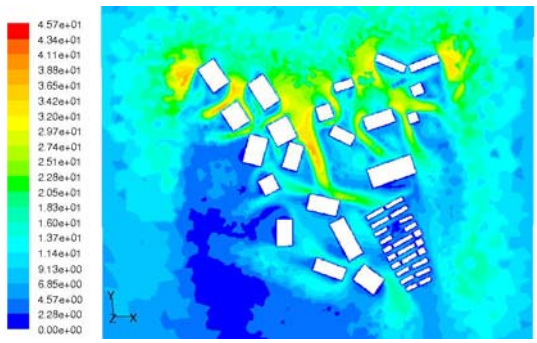

Fig. 3 Wind Speed Section (North Inflow)

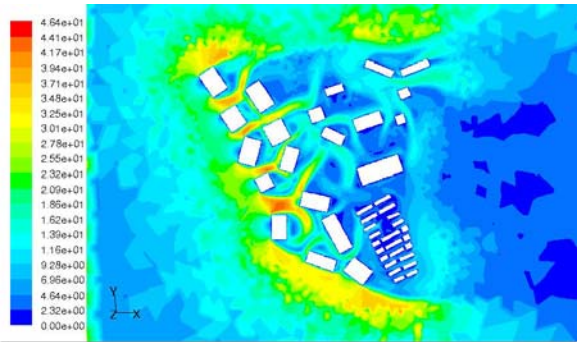

Fig. 4 Wind Speed Section (West Inflow)

WIND DISASTER LOSS OF THE URBAN SHADE TREES

For the wind resistance capability of urban street trees, the following would be the critical factors: physical characters (bending strength, air-dry density), geometrical features (crown extent, crown depth, crown type, crown density, trunk diameter) and root characters (deep-rooted or shallow-rooted). According to the configuration of street trees, the crown of a tree may be assumed as a revolving solid with the trunk as the centre. The tree may be regarded as a projecting beam and the wind pressure is centralized to the crown. The wind will lead to wind pressure moment through the tree wind centre. Under the wind loads, the stress of any part of the tree should less than the ultimate strength, or else the tree would break. If the wind pressure would be rather large with the maximum stress less than the ultimate strength, the tree would fall over. Based on the wind disaster survey and the macroscopical damage phenomenon, the wind damage of urban street trees may be classified to four Classes by different stress condition, which is figured as Tab.1.Thereinto, σ is the maximum stress of the trunk section, f is the bending strength of certain tree species.

Tab. 1 Wind Damage Classification

Damage Class		Damage Phenomenon	Strength Condition
I	Undamaged	Twig and leaf loss < 1/2	$\sigma \le 0.4f$
II	Slight damaged	Twig and leaf loss > 1/2	$0.4f \le \sigma < 0.7f$
III	Medium damaged	Trunk lean	$0.7f \le \sigma < f$
IV	Severe damaged	Trunk break	$\sigma \ge f$

For the camphor tree as an example, assuming the high of the tree as 8m, the crown extent as 9m, the crown depth as 6m and the trunk diameter as 25cm, the bending strength is adopted as 82.4MPa. For different inflow directions, the wind speed of different object points can be used to calculate the maximum stress of the trunk section and the damage class. The Result is presented in Tab.2.

Tab. 2 Wind Damage Assessment

Inflow Direction	Object Points	A	B	C	D
North	Wind Speed (m/s)	29.5	32.2	40.2	2.79
	Maximum Stress(MPa)	30.0	35.8	55.9	0.3
	Damage Class	I	II	II	I
West	Wind Speed (m/s)	40.3	31.2	15.6	44.2
	Maximum Stress(MPa)	56.1	33.6	8.4	67.5
	Damage Class	II	II	I	III

CONCLUSIONS

The result shows that because of the change of the urban local wind environment and the street trees distribution, the wind damage results would be differential. The local wind effect may induce to the wind speed enlarged remarkably and so much as exceed the designed value. The method presented can be used to evaluate the loss assessment of these wind vulnerable structures in an urban region. But in the paper, the root characters of the tress haven't been considered and the further investigation should be continued.

References

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