Study on Complex Wind Field Characteristics of Mountainous City Bridge Site

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Abstract. This paper takes chaotianmen yangtze grand bridge as the engineering background, With the help of computational fluid dynamics commercial software fluent, the complex wind field in the bridge site area of mountain city is simulated and analyzed, By comparing the results of wind tunnel test data and theoretical calculation, the characteristics of near surface fluid movement in complex terrain and bridge site are revealed. The relationship between fluctuating wind speed and power spectrum of bridge site simulated by superposition of harmonic method and AR linear filtering method. Research shows that the numerical simulation of the average wind speed in complex mountainous cities has a high precision, Compared with the application of superposition of harmonic method, AR linear filtering method is more suitable for engineering application.

Introduction

In most parts of western China, There are complex mountainous terrain and many rivers. The spatial distribution of wind speed in the bridge site is complex and shows significant three-dimensional characteristics. The analysis of the wind field characteristics based on the relevant standards, without considering the specific characteristics of the bridge site, will lead to great errors between the design and the actual situation. In this paper, the wind field characteristics of mountainous cities in Chongqing, chaotianmen yangtze grand bridge is taken as the background and the author makes researches on complex wind field characteristics of mountainous city bridge site by means of numerical simulation.

Computational Fluid Dynamics Numerical Model

The following describes the modeling approach based on the computational fluid dynamics software fluent. The elevation data extracted by google earth constructs the geometry of regional land surface in gambit, The boundary model is set up and meshed. After choosing the appropriate turbulence model, the model is solved in fluent.

Model Establishment

Geographically, Chongqing is located in ridge and valley province of chuandong. The more than 30 mountains are east to north and parallel to the river. The terrain is high in the north and low in the south, while the west is high and the east is low. there are nanshan in the east of Chongqing and zhongliangshan in the west, But the northern and southern directions have less topographic changes. The range of mountains on both sides is included in the model, which can take into account the influence of mountains on the characteristics of wind fields in bridge site. Selection of west-east length about 33km, north-south length about 8.4km. Figure 1 shows the areal map.

In order to reflect the features of mountain terrain well. Li Yongle [1]. and Xu Hongtao [2]. require more contour lines in the numerical simulation of mountain wind environment. Since the topography change of the main city of Chongqing is not obvious, the longitudinal length is 39.6m, and the transverse length is 35.4m. When google earth extracts elevation, the height interval 3s and height 2km are set up and the required height is automatically acquired by software, There are 197658
elevation points. As shown in figure 2, the extracted elevation is converted into the corresponding Cartesian coordinate and the 3D model is generated in gambit.

Mesh Generation and Selection of Object Type

Due to the large number of tetrahedral mesh, the discretization error in the boundary layer is large and the calculation is not easy to converge. Therefore, Hex mesh and type of map is selected in the model. As shown in figure 3, The east side of the terrain is equipped with a velocity inlet, and the west side is a free outflow area. The north and south sides are symmetrically fixed boundaries, The wind speed profile is implemented by user-defined function. The numerical simulation selects the gradient wind and gradient height defined by the class B and is simulated by UDF programming. The turbulence model of RNG and the non-equilibrium wall function are used to simulate the complex fluid motion near the ground [3].

Wind Tunnel Test

In order to compare with the numerical simulation results, This paper gives a brief description of the topographic wind tunnel experiment about the Ph.D Thesis of Cheng-qi Wang [4]. As shown in figure 4, The atmospheric boundary layer is modeled by means of minarets, baffles and roughness elements. The scale model is simulated by plastic foam, wood block and other materials. The wind tunnel experiment has determined that the roughness coefficient is close to that of class B and $\alpha=0.16$. It is advisable to calculate the surface of wind environment as class B.

Comparative Analysis

The main structure of chaotianmen yangtze grand bridge is in the horizontal height from 60m to 140m. According to the formula (1) from wind-resistant design for highway bridges (JTG/T D60-01-2004), the theoretical average wind speed of 60m, 80m, 100m, 120m, 140m and 160m can be calculated in the horizontal height direction by using the basic wind speed of 27.5m/s in 100 years in the urban area of Chongqing. Wind tunnel experiment and numerical simulation are used to compare the simulated wind speed in complex mountainous area. Table 1 is used for comparative analysis.
\[ V_z = V_{10} \left( \frac{Z}{10} \right)^{0.16} \]  

(1)

where \( V_z \) = Required wind speed; \( V_{10} \) = Basic wind speed at 10m; \( Z \) = Height required.

<table>
<thead>
<tr>
<th>Horizontal height [m]</th>
<th>Wind tunnel Test [m/s]</th>
<th>Numerical Simulation [m/s]</th>
<th>Theoretical Calculation [m/s]</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>60</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>39.33</td>
<td>41.22</td>
<td>41.87</td>
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<tr>
<td></td>
<td>(-4.40%)</td>
<td>(-3.93%)</td>
<td>(-3.27%)</td>
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<tr>
<td></td>
<td>37.6</td>
<td>39.6</td>
<td>40.5</td>
</tr>
<tr>
<td></td>
<td>(-6.86%)</td>
<td>(-6.94%)</td>
<td>(-5.06%)</td>
</tr>
</tbody>
</table>

As can be seen from table 1, The numerical simulation of the average wind speed in complex mountainous cities has a high precision, The maximum error at the height of 60m is only -4.40%. The theoretical calculation value is smaller than the wind tunnel experiment data. Compared with the theoretical calculation, the numerical simulation data is more in line with the actual situation.

Simulation Study of Fluctuating Wind Load

Based on the power spectrum synthesis of fluctuating wind speed, a numerical simulation of fluctuating wind field is carried out. This paper selects the Davenport spectrum based on the superposition of harmonic method and AR linear filtering method two ways in matlab programming. The values of Davenport spectra are larger than those of other spectra, The range of spectral value is just where the frequency of the structure is similar to the frequency of wind speed., and it is easy to resonate with the structure. Therefore, The Davenport spectrum is used to make the structure safer. The superposition of harmonic method has high precision, while the AR linear filtering method can well simulate the randomness, temporal and spatial correlation of the fluctuating wind field [5]. Parameters of calculation are shown in table 2. As shown in figure 5 to figure 8, For limited space, The author analyzed the fluctuating wind speed by superposition of harmonic method and AR linear filter method for 80m and 120m.

| Table 2. Calculation parameters of simulated fluctuating wind speed time curve. |
|-----------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Sampling points                   | 500                             | Average wind speed at 10m       | 27.5[m/s]                      |
| Cutoff frequency                  | 8π                              | Inflow design wind speed        | 40[m/s]                        |
| Surface roughness coefficient     | 0.00215                         | Time interval                   | 0.001[s]                       |
| Attenuation coefficient           | 10                              | Simulation duration             | 200[s]                         |

(a) 80m
Compared with the superposition of harmonic method and the AR linear filtering method, it can be found that the fluctuating wind speed spectrum simulated by AR linear filtering method is relatively stable, and is closer to the target power spectrum.
Summary

Matlab program is used to synthesize fluctuating wind, and the numerical simulation is carried out by using fluent software. In this paper, the wind field of the bridge site of Chongqing, chaotianmen yangtze grand bridge, which has the characteristics of mountain city wind field, can be concluded as follows:

(1) Through wind tunnel experiments and ultimately determine the roughness coefficient with wind-resistant design for highway bridges (JTG/T D60-01-2004) in class B, which also verifies the gradient wind and gradient height of class B during the course of UDF.

(2) The average wind speed at 60m, 80m, 100m, 120m, 140m and 160m is simulated by using fluent. Compared with the theoretical calculation, the numerical simulation results are more close to the wind tunnel test results, and the numerical simulation has some reference value for the wind field characteristics.

(3) Comparing the application of superposition of harmonic method and AR linear filtering method in wind field characteristics, it is shown the latter is more stable than the former and wind power spectrum is closer to target power spectrum.

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References


