Study on Wind Induced Interference Effect of T Shaped Light Camping Housing Group

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Abstract. In order to study the wind induced interference effect of T shaped flat light camping house under regular arrangement, based on the theory of atmospheric boundary layer and the basic principle of computational fluid dynamics, the FLUENT software was used to keep the transverse distance $S_x = 2H$ unchanged by using the wind direction angle and the longitudinal distance as variable parameters. A total of 15 numerical values are simulated and the T shape is flat under the regular arrangement. The surface wind pressure distribution of the light camping house group is studied. The average wind pressure coefficient of the selected target house is compared with the single house data, and the interference factor is introduced to describe the interference effect of the group housing, and the area and the conditions of the target housing enlarging effect and shielding effect are obtained. The study shows that 0 degrees is the most unfavorable wind angle, and the most interference factor is 3.45, and the interference factor less influenced by the longitudinal distance, and most of the areas are sheltered effect. It can be seen that the wind induced interference effect of the camping house under the regular arrangement should not be ignored, and enough attention should be paid to the design.

1. Introduction
T shaped plane light camping house, as a kind of light mobile temporary structure, has been widely used in military and civilian fields. However, such structure is quite sensitive to wind load, and wind load often plays a controlling role in the design. The domestic and overseas scholars began to study such light housing later, and there has been no complete specification design method. The chapter on wind load of Code for the Load of Building Structures (GB50009-2012) just gives the shape coefficient other simple forms, rather than that of T shaped plane light camping house. In this paper, the related research was conducted based on the T plane light camping house with the structure size of $L*B*H = 6.6m*4.6m*4.6m$ and eaves height of 1.8m (see Figure 1) as an object.

Camping houses are usually arranged in groups in emergency shelters, which results in the inconsistency of their wind induced response with monomer buildings. Most studies on the wind induced interference effect of low-rise buildings at home and abroad focus on the cube buildings with simple shapes, while there are few researches on the wind induced interference effect of complex buildings. Literature [4] studies the cube group by taking parameters of building area density $C_A$, model distance $B$, upstream building distance $L_{fetch}$, different arrangement (including regular and staggered one), and the smooth or rough incoming flow surface. The study shows that the influence of surrounding building
roughness is within the range of \( L_{\text{fetch}}/B = 15 \). Literature [6] conducts numerical simulation of regularly-arranged camp groups and individual camps respectively by taking variable parameters of wind direction angle, arrangement mode and distance between camps, and obtains the shape coefficient suitable for wind resistance design of folded camp groups. Literature [7-8] study the static interference effect of grade glyph buildings and explore the variation law of interference factors with distance and wind angle. However, there has been no report on the wind induced interference effect of T shaped light camping houses under regular arrangement. In order to meet the requirements of group design and planning arrangement, it is necessary to discuss and analyze the wind induced interference effect of T shaped light camping houses under regular arrangement.

![Figure 1. The outline of T shape plane camping house](image)

2. Numerical Simulation Analysis of the Wind Induced Interference Effect of House

2.1. Basic Theory of CFD Numerical Simulation

In computational fluid dynamics, turbulent air flows around pure body, and fluid is assumed to be an incompressible fluid. Its core control equation is Navier-Stokes equation, which is also the basic control equation of numerical simulation, with its expression being as follows:

\[
\frac{\partial \mu_i}{\partial x_i} = 0
\]  

\[
\frac{\partial \mu_i}{\partial t} + \mu_j \frac{\partial \mu_i}{\partial x_j} = -\frac{1}{\rho} \frac{\partial p}{\partial x_i} + \nu \frac{\partial^2 \mu_i}{\partial x_i \partial x_j} - \frac{\partial \bar{\mu}_i}{\partial x_i} \frac{\partial \bar{\mu}_j}{\partial x_j} - \mu_i \mu_j
\]  

Where, \( \mu_i \) is velocity component; \( \rho \) is density; \( p \) is the pressure. For incompressible turbulent motion, the currently-widely used is the N-S equation based on Reynolds time average. It belongs to the system average method. Reynolds time-averaged N-S equation is shown in Equation (3):

\[
\frac{\partial \bar{\mu}_i}{\partial t} + \frac{\partial \bar{\mu}_i \mu_j}{\partial x_j} = -\frac{1}{\rho} \frac{\partial \bar{p}}{\partial x_i} + \nu \frac{\partial^2 \bar{\mu}_i}{\partial x_i \partial x_j} - \frac{\partial \bar{\mu}_i}{\partial x_i} \frac{\partial \bar{\mu}_j}{\partial x_j} - \mu_i \mu_j
\]  

Where, \( \bar{\mu}_i \) and \( \bar{\mu}_j \) are Reynolds average velocity component; \( \nu \) is velocity component; \( \bar{p} \) is average pressure; \( \bar{\mu}_i \) is additional stress term, namely, Reynolds stress. Because the equation itself is not
closed, it is necessary to conduct numerical calculation by introducing the assumption of turbulence model. According to the assumption of turbulence model, commonly used turbulence models include Reynolds stress model (RSM) and eddy viscosity model. There are many applications of the two equation models in the eddy viscosity model; in addition, there are the most representative standard model and the improved standard model (realizable \( k-\varepsilon \) model and RNG \( k-\varepsilon \) model). In this paper, the model of RNG \( k-\varepsilon \) was used to simulate and calculate the wind disturbance of T shaped camping houses.

2.2. Numerical Calculation and Analysis of Camping Housing Group

First of all, the modeling of monomer was established with the consideration of 0°, 45° and 90° wind direction Angle, as shown in Figure 2. The wind pressure value of the monomer was compared with the group. Next, the modeling of group camp complex was established. Considering different distance arrangement, and 0°, 45° and 90° Angle of wind direction, the numerical simulation of the wind was carried out. As for various factors, the architectural complex as shown in Figure 3 was selected as the research object.

A total of 15 kinds of conditions, namely, the direction Angle of 0°, 45° and 90°, model distance of 1H, 2H, 3H and 4H (H refers to housing average height), and three kinds of monomers were selected for numerical simulation. Besides, the actual size was selected to establish the model. The calculation domain was selected by referring to that in literature [2] and it met the requirement that the block rate was less than 3%. The building was located at 1/3 of the drainage basin. By using the partition method of hybrid grid, the unstructured tetrahedral grid cells were selected near the model, while the structured grid cells were selected for the peripheral space far from the model, thus greatly reducing the number of computational grids. Due to the complex shapes of the camping house, the structural surface was divided into 17 regions including A, B, C, D, E and H according to surface shape and function, as shown in Figure 2. Inflow plane adopted velocity-inlet boundary conditions. The rate of index was used to simulate the boundary layer wind velocity profile: \( u_z = u_0 \times (z/z_0)^\alpha \), where \( z_0 \) and \( u_0 \) respectively denote standard reference point height (10m) and average wind velocity of standard reference point height (20m/s); \( Z \) and \( UZ \) respectively represent the height of a certain point in the basin and the average wind velocity at the height; \( \alpha \) is the ground roughness index. It was the same as the wind tunnel experiment, and type A landform was selected, \( \alpha = 0.12 \). The gradient wind height was 300m. In the calculation, the turbulent parameters at the inflow plane such as turbulent kinetic energy \( k \) and dissipation rate \( \varepsilon \) were directly given.

\[
\begin{aligned}
    k &= 1.5 \left( \frac{\mu}{\rho} \right)^{2/3} \\
    \varepsilon &= 0.09 \alpha_{in} k^{1.5} / l
\end{aligned}
\]  \( (4) \)

Where, \( I \) is turbulence intensity; \( k \) is kinetic energy of turbulence; \( \varepsilon \) is dissipation rate; \( l \) is turbulence scale; the formula of average wind profile \( I, k \) and \( \varepsilon \) was also implemented using UDF programming and Fluent as interfaces. The outflow surfaces were closed by fully-developed outflow boundary conditions. Symmetry boundary conditions on both sides and top surface of the drainage basin were equivalent to free-sliding wall surface. The non-slip wall condition was adopted for the ground and building surface. RNG \( k-\varepsilon \) turbulence model was adopted and the second-order wind convection item format was used. Velocity pressure equilibrium adopted SIMPLEC algorithm, and wall surface adopted non-equilibrium wall function. The convergence standard of flow control equation was less than 10^{-4}. Numerical analysis was conducted based on a total of 15 kinds of working conditions (Like Literature [6], 2H of horizontal distance between camps \( S_{x} \), while 1H, 2H, 3H and 4H of longitudinal distance, and 0°, 45° and 90° of wind Angle value). The plane layout of camping house group is shown in Figure 3. As the structure was arranged in a single axisymmetric manner, the middle house in the second row was selected as the target object.
The interference factor of the camping housing group $IF_{\mu}$ was introduced into the analyze the mutual interference of camping housing groups. $IF_{\mu}$ was defined as follows:

$$IF_{\mu} = \frac{\mu_{sl}}{\mu_{sa}}$$

Where, $\mu_{sl}$ denotes the average wind pressure coefficient of the housing surface after interference; $\mu_{sa}$ is the average wind pressure coefficient of monomer house surface.

![Figure 2. Schematic diagram of wind direction and structure zoning](image)

![Figure 3. Schematic diagram of group layout of camping houses](image)

The numerical calculation results of the average wind pressure coefficient of monomer houses are shown in Figure 4, 5 and 6. When $IF_{\mu} = 0$, it suggests that the average wind pressure coefficient is the same before and after interference. When $IF_{\mu} > 1$, it indicates the amplification effect appears. The larger the value is, the more obvious the amplification effect is. When $0 < IF_{\mu} < 1$, occlusion effect appears. The smaller the value is, the more obvious occlusion effect is. When $IF_{\mu} = 1$, there is no interference effect. However, when $IF_{\mu} < 0$, the average wind pressure coefficient is reverse before and after interference.

2.2.1. Influence of Longitudinal distance on the Interference. In the analysis of wind induced interference effect, the distance between the interference building and the interfered building had quite obvious influence on the wind induced interference effect. The influence of the change of longitudinal distance on the interference effect is shown in Figure 5.

According to the analysis of Figure 4, the interference factor was considerably affected by longitudinal distance. To be specific, for the interference factor in most regions, amplification effect and occlusion effect were weakened with the increase of the longitudinal distance. When the wind direction Angle was $0^\circ$, due to the effect of upstream building slit, there was amplification effect in windward region C1, C2, C3 and H2; H1 had reverse interference, while the rest regions were characterized by
The interference factors of the windward region C1, C2, C3 and H2 decreased with the increase of the longitudinal distance, showing that the amplification effect was continuously weakened. The interference factors in other regions increased with the increase of longitudinal distance, suggesting that the occlusion effect was continuously decreased. The amplification effect and occlusion effect were strongest when the longitudinal distance was 1H (corresponding to the building area density of 27%); and the variation trend of disturbance factor tended to be stable when the longitudinal distance was increased to 3H. When the wind direction angle was 45°, under the influence of the upstream building block and inclined direction of the wind, wind flow direction between buildings was changing, and wind field change was relatively complex. With the increase of the longitudinal distance, region C1, C2, C3, D2 and H4 showed amplification effect; region H1 had reverse interference, while the rest areas had occlusion effect. When the longitudinal distance was 2H (corresponding building area density of 13%), the disturbance factor value tended to be relatively stable. With the increase of the longitudinal distance, the interference factors and the amplification effect in region C3, D2 and H4 increasingly increased. Because region C3, D2 and H4 covered smaller area, and were sensitive to wind load, when building distance was smaller, there was no enough distance for air flow to adhere to the target camp after separating from the upstream building. With the increase of distance, the airflow separating from the upstream building hit the target camp, and the amplification effect was produced. Region C3 was located in the wake flow area of buildings, and affected by the interference of adjacent buildings. The maximum interference factor 2.6 appeared in region C3 when the longitudinal distance was 4H (corresponding to the building area density of 27%). When the wind direction angle was 90°, because the target camps had direct building block, the interference factor was obviously affected by the change of the longitudinal distance; interference factors under four kinds of the longitudinal distance value changed considerably. Region D2, E2 and H4 showed amplification effects. To be specific, region E2 had obvious amplification effects after 2H; region D2 had amplification effects after 3H; region H4 had amplification effects after 4H. The maximum interference factor in region E2 was 1.68 when the longitudinal distance was 2H. As the wind direction blocking of the building changed, Region D1 and H3 had reverse interference.

![Figure 4. 0 degree wind direction](image1)

![Figure 5. 45 degree wind direction](image2)
2.2.2. Influence of Wind Angle on Interference. As the structure had symmetrical layout, interference effect on housing group only in the standard direction Angle 0°, 45° and 90° was analyzed. From the analysis of Figure 7, 8 and 9, at 0°, 45° and 90° Angle of wind direction, some interference factors were positive and some were negative, showing that average wind pressure coefficient changed before and after the disturbance. When the wind Angle was 0°, 45° and 90°, most of the regions showed occlusion effect; when wind direction Angle of 0° was the most unfavorable wind direction. At the time of 1H, the maximum interference factor of 3.45 appeared in region H2. As can be obtained from the interference pattern of the same longitudinal distance and different wind direction Angles, when the wind direction Angle was 0°, region C1, C2, C3 and H2 were featured by amplification effect, and the rest region were characterized by occlusion effect mainly because the occlusion effect of the upstream building made the wind speed in windward area target structure increase. Therefore, the interference factor was basically not affected by the change of the longitudinal distance, and interference factors under different distance value were basic similar. When wind direction Angle was 45°, region H1 had reverse interference, and the longitudinal distance was 1H (corresponding to construction area density of 27%), region H1 appeared the maximum interference factor, reaching 1.24; the region was greatly affected by wind load. Thus, corresponding aerodynamic measures should be made in the design so as to prevent structural damage caused by the large local wind load. When the wind direction Angle was 90°, except the region 1H, other regions had amplification effect, mainly because the target structure was under the dual influence of upstream building occlusion and downstream building air flow. With the increase of distance, it tended to be 1, showing the interference effect weakened.

3. Conclusion

1) The wind pressure on the surface of T shaped camping houses is considerably influenced by the longitudinal space between buildings. With the increase of longitudinal space, the interference factor increases while the amplification effect and occlusion effect weaken.

2) When wind direction Angle is 0°, interference factors is slightly affected by the longitudinal distance; after the longitudinal distance reached 3H, the interference factor tended to be stable. When the wind direction Angle is 45°, the wind field changes are relatively complex, and interference factors obviously fluctuate with the change of the longitudinal distance; When the wind direction Angle is 90°, most of the regions show occlusion effect and interference factors are obviously affected by the change of the longitudinal distance, and weakened with the increase of the distance. When the longitudinal distance reached 3H, interference factors change tends to be steady.

3) As for housing group under the regular arrangement, most of regions show occlusion effect when the wind Angle is 0°, 45° and 90°, 0° of direction Angle is the most unfavorable wind direction Angle.
Interference factors under different distance values are basically similar, being less than 1 and only region C1, C2, C3 and H2 are characterized by amplification effect. When the longitudinal distance is 1H, region H2 has the maximum interference factor of 3.45, which should be noticed in design.

![Figure 7. 1H longitudinal distance](image1)

![Figure 8. 2H longitudinal distance](image2)

![Figure 9. 3H longitudinal distance](image3)

![Figure 10. 4H longitudinal distance](image4)

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