Study on Numerical Simulation of Wind Resistance Effect on the Opening Holes Plate Chimney

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ABSTRACT

The structural shape of almost all the enclosure structures and some decorative structures are platy as its simple construction method. In order to avoid their collapse under bad weather conditions and enhance the wind resistance of the plate structures, we investigated the plate chimneys in Tile Factories which are widely distributed in Shandong of China. The effects of different openings holes of plate chimney on the wind resistance are studied and simulated by ANSYS, and the data of results are processed by MATLAB. After comparing and analyzing, it can be found the higher of the holes, the larger effect to wind resistance, increase the holes size and the number of holes can also increase the resistance of wind, however, the opening position, the size of the holes and the number of holes must be within a certain range to avoid the increase of the vibration amplitude and the weaken of the resistance capacity of structures themselves.

I. INTRODUCTION

The wind-induced vibration problem of plate type structure is a problem that necessary and urgent to solve which often encountered in many engineering fields, the traditional tile factory wet chimney is a typical example. If the wind speed exceeds a certain critical value, the amplitude of the plate structure will be more and more larger, that is to generate flutter; when vibration disappeared, there will leave a large static deformation behind, that is divergent instability, make the structure cannot work properly or fatigue damage finally (Ginger 2010). Limit cycle vibration, bifurcation, chaos and so nonlinear dynamic behaviors are also possible if the structure has a strong nonlinearity (Li 2010; Li 2013). The small tile factory used the traditional production technology, has a labor-intensive operation mode. As an important production facility in tile factory, the wet
chimney adopts a type of plate multi-tube structure (Zhang 2013). The plate wet exhaust chimney used the traditional method of design and construction (Yang 2011), currently widely distributed in Zibo, Shandong Province, China. The wet tile production line and wet drying workshop are under the chimney which is staff-intensive areas (Shen 2015). So it is necessary to investigate and analyze for the existing plate chimney and other plate structure, then put forward the strengthening measures to prevent the occurrence of collapse accident, resulting in unnecessary casualties. To obtain the sample data of wind load is the first step for the analysis of the wind load of the structure. Traditional wind tunnel test and field test are more reliable methods for obtaining samples, with the rapid development of computer technology and the further study of numerical analysis method, the random input of artificial computer to simulation load is widely used. The field, the wind spectrum characteristics, the characteristics of the building and other conditions can be considered in computer simulation, so that the simulate load is close to the actual wind on structure (Biao 2010).

Wind tunnel experimental data (including wind speed, wind pressure and response) become the basis for studying the mechanism of wind vibration, establishing the model of complex calculation and verifying calculation method (Zhou 2012; Xu 2013). Generally speaking, when people carry out computer simulation of fluctuating wind speed, it can be roughly divided into stationary Gauss random process simulation method, non-stationary Gauss random process simulation method and non-Gauss random process simulation method (Ye 2012). If the serious non-stationary area in the initial stage of the record is ignored, the pulse of the wind speed process can be regarded as a stationary Gauss random process. Spanos and Zeldin have outlined the Carlo Monte method, which is based for the theory of stochastic process simulation of stationary Gauss (Li 2014).

The external wind pressure is very different for the shape of the structure and the influence of the flow, therefore, the external wind load to the construction structure is often the focus of wind engineering research (Zhou 2012). The wind load action to the plate structure is often not paid enough attention, And the current domestic and international architectural structure load code for the structural pressure value is very rough, the pressure value of structures with different holes is not more detailed provisions. However, when the wall, doors and windows of buildings, or other enclosure structure occur damage (tearing, set off) in wind load, will lead to the sudden increase in building structural pressure and the change of distribution of wind pressure in the adjacent area, which may cause structural continuous damage (Huang 2011; Ginger. 2008).

For studying the transient response of the sudden opening of the building in the wind, Stathopoulos and Luchian (Stathopoulos 1989) used a new experimental technique, such as the rapid melting technology of membrane and the camera shutter technology, in the boundary layer wind tunnel test study, obtained a better test results. Combined with other relevant research scholars, such as Sharma and Richards, Beste
and Cermak, and so on (Beste 1997; Sharma 2005; Sharma 2003; Xu 2013), their focus points are on the internal and external pressure distribution of buildings, for the plate structure, the effect of opening holes are seldom involved. The lack of the research on the problem has caused lacking uniform standard in engineering design, this is also the main cause of the major casualties occurred again and again.

II. THE WET EXHAUST CHIMNEY OF HONGJIN TILE FACTORY

The Hongjin tile factory is located in Zibo Shandong of China, it built in hills Areas. Production workers of the tile factory mostly are migrant workers, who had low security awareness and low safety skills. The tile factory which adopts the traditional production technology is one of labor intensive operation mode factory. As the important production facility, the wet exhaust chimney adopted the structure of plate and tube, used traditional method design and construction. Table 1 laid the wet exhaust chimney parameters, Figure 2, Figure 3 displayed space layout of wet exhaust chimney.

Table 1. The wet exhaust chimney parameters of Hongjin tile factory

<table>
<thead>
<tr>
<th>project</th>
<th>size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper width</td>
<td>105 cm</td>
</tr>
<tr>
<td>Lower width</td>
<td>270 cm</td>
</tr>
<tr>
<td>length</td>
<td>1830 cm</td>
</tr>
<tr>
<td>Height</td>
<td>3200 cm</td>
</tr>
<tr>
<td>Structure</td>
<td>Materials: clay brick, Concrete mortar caulking; The following 20 m high chimney wall thickness is about 25 cm, 20 m above wall thickness about 12 cm Shape: Top thin bottom thick; Ladder structure;</td>
</tr>
</tbody>
</table>

III. NUMERICAL SIMULATION
A. Mechanics model establishment

Before opening holes the model height is 32 m, the upper and lower widths are consistent with 1830 cm. The chimney model is built and the meshing is shown in Figure 3 (Zhang 2010).

After opening holes the model height is 32 m which is not change, the upper and lower widths are consistent with 1830 cm. In this paper, we mainly study the effect of the different holes on structure, so according to the opening position, the number of holes, and the size of the holes, we simulated the influence of wind resistance of the chimney. The specific opening of the hole is shown in Table 2. The M3-11 model is established and the grid division shown in Figure 4.

![Figure 3. Plate type multi tube wet exhaust chimney mechanical model (before opening hole)](image1)

![Figure 4. Plate type multi tube wet exhaust chimney mechanical model (model M3-11)](image2)

**Table 2.** The design parameters of plate chimney opening holes

<table>
<thead>
<tr>
<th>Serial number</th>
<th>code</th>
<th>Opening position</th>
<th>Number of holes</th>
<th>Hole size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M1-11</td>
<td>average distribution along the direction at 18 meters, 21 meters, 24 meters, and 27 meters height</td>
<td>each height 1 holes</td>
<td>Round hole of 60 cm diameter</td>
</tr>
<tr>
<td>2</td>
<td>M1-12</td>
<td>average distribution along the direction at 15 meters, 18 meters, 21 meters, and 24 meters height</td>
<td>each height 1 holes</td>
<td>Round hole of 60 cm diameter</td>
</tr>
<tr>
<td>3</td>
<td>M1-13</td>
<td>average distribution along the direction at 12 meters, 15 meters, 18 meters, and 21 meters height</td>
<td>each height 1 holes</td>
<td>Round hole of 60 cm diameter</td>
</tr>
<tr>
<td>4</td>
<td>M1-21</td>
<td>average distribution along the direction at 18 meters, 21 meters, 24 meters, and 27 meters height</td>
<td>each height 2 holes</td>
<td>Round hole of 60 cm diameter</td>
</tr>
<tr>
<td>5</td>
<td>M1-22</td>
<td>average distribution along the direction at 15 meters, 18 meters, 21 meters, and 24 meters height</td>
<td>each height 2 holes</td>
<td>Round hole of 60 cm diameter</td>
</tr>
<tr>
<td>Number</td>
<td>Code</td>
<td>Average Distribution</td>
<td>Height Distribution</td>
<td>Holes</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>-------</td>
</tr>
<tr>
<td>6</td>
<td>M1-23</td>
<td>At 12 meters, 15 meters, 18 meters, and 21 meters height</td>
<td>Each height 2 holes</td>
<td>60 cm</td>
</tr>
<tr>
<td>7</td>
<td>M1-31</td>
<td>At 18 meters, 21 meters, 24 meters, and 27 meters height</td>
<td>Each height 3 holes</td>
<td>60 cm</td>
</tr>
<tr>
<td>8</td>
<td>M1-32</td>
<td>At 15 meters, 18 meters, 21 meters, and 24 meters height</td>
<td>Each height 3 holes</td>
<td>60 cm</td>
</tr>
<tr>
<td>9</td>
<td>M1-33</td>
<td>At 12 meters, 15 meters, 18 meters, and 21 meters height</td>
<td>Each height 3 holes</td>
<td>60 cm</td>
</tr>
<tr>
<td>10</td>
<td>M2-11</td>
<td>At 18 meters, 21 meters, 24 meters, and 27 meters height</td>
<td>Each height 1 hole</td>
<td>90 cm</td>
</tr>
<tr>
<td>11</td>
<td>M2-12</td>
<td>At 15 meters, 18 meters, 21 meters, and 24 meters height</td>
<td>Each height 1 hole</td>
<td>90 cm</td>
</tr>
<tr>
<td>12</td>
<td>M2-13</td>
<td>At 12 meters, 15 meters, 18 meters, and 21 meters height</td>
<td>Each height 1 hole</td>
<td>90 cm</td>
</tr>
<tr>
<td>13</td>
<td>M2-21</td>
<td>At 18 meters, 21 meters, 24 meters, and 27 meters height</td>
<td>Each height 2 holes</td>
<td>90 cm</td>
</tr>
<tr>
<td>14</td>
<td>M2-22</td>
<td>At 15 meters, 18 meters, 21 meters, and 24 meters height</td>
<td>Each height 2 holes</td>
<td>90 cm</td>
</tr>
<tr>
<td>15</td>
<td>M2-23</td>
<td>At 12 meters, 15 meters, 18 meters, and 21 meters height</td>
<td>Each height 2 holes</td>
<td>90 cm</td>
</tr>
<tr>
<td>16</td>
<td>M2-31</td>
<td>At 18 meters, 21 meters, 24 meters, and 27 meters height</td>
<td>Each height 3 holes</td>
<td>90 cm</td>
</tr>
<tr>
<td>17</td>
<td>M2-32</td>
<td>At 15 meters, 18 meters, 21 meters, and 24 meters height</td>
<td>Each height 3 holes</td>
<td>90 cm</td>
</tr>
<tr>
<td>18</td>
<td>M2-33</td>
<td>At 12 meters, 15 meters, 18 meters, and 21 meters height</td>
<td>Each height 3 holes</td>
<td>90 cm</td>
</tr>
<tr>
<td>19</td>
<td>M3-11</td>
<td>At 18 meters, 21 meters, 24 meters, and 27 meters height</td>
<td>Each height 1 hole</td>
<td>120 cm</td>
</tr>
<tr>
<td>20</td>
<td>M3-12</td>
<td>At 15 meters, 18 meters, 21 meters, and 24 meters height</td>
<td>Each height 1 hole</td>
<td>120 cm</td>
</tr>
<tr>
<td>21</td>
<td>M3-13</td>
<td>At 12 meters, 15 meters, 18 meters, and 21 meters height</td>
<td>Each height 1 hole</td>
<td>120 cm</td>
</tr>
</tbody>
</table>
21 meters height
average distribution along the direction at 18 meters, 21 meters, 24 meters, and 27 meters height

22 M3-21
average distribution along the direction at 18 meters, 21 meters, 24 meters, and 27 meters height
each height 2 holes
Round hole of 120 cm diameter

23 M3-22
average distribution along the direction at 15 meters, 18 meters, 21 meters, and 24 meters height
each height 2 holes
Round hole of 120 cm diameter

24 M3-23
average distribution along the direction at 12 meters, 15 meters, 18 meters, and 21 meters height
each height 2 holes
Round hole of 120 cm diameter

25 M3-31
average distribution along the direction at 18 meters, 21 meters, 24 meters, and 27 meters height
each height 3 holes
Round hole of 120 cm diameter

26 M3-32
average distribution along the direction at 15 meters, 18 meters, 21 meters, and 24 meters height
each height 3 holes
Round hole of 120 cm diameter

27 M3-33
average distribution along the direction at 12 meters, 15 meters, 18 meters, and 21 meters height
each height 3 holes
Round hole of 120 cm diameter

The hole size of chimney meet the requirements of structure strength and easy to construction; Ventilation hole is rolled and welded with thick steel plate, convenient for construction.

B. Load simulation
The current wind resistance calculation is mainly divided into the calculation in the frequency domain and the time domain. The frequency domain analysis is a common method of wind vibration analysis. But in the frequency domain, it can only be linear analysis to structure; it is assumed that the relationship between the instantaneous wind pressure and the wind force is linear, the characteristics of the structure are also assumed to be linear. Under the action of strong wind, the large span structure often produces geometric or material nonlinear changes, so the frequency domain analysis sometimes cannot reflect the real characteristic of the structure (Fu 2015). To carry out a more precise analysis, the method can only be analyzed in time domain. Time domain method can directly understand the features of the structure, derive the change law of force and displacement with time and maximum value. Although the time domain method is complex and time consuming, but with the development of computer, the problem can well be solved. Moreover, the time domain method is necessary for the experiment and scientific research.

In this paper, the wind speed is simulated by linear filter method (Li 2008), which also named white noise filtration method, the random process is abstracted to meet certain conditions of white noise, and then through a certain hypothetical system making the proper transformation fitting the time domain of the process (Chen 2012; Peng 2010; Yuan 2007).

The main parameters of the simulation are shown in Table 3.
Table 3. The main parameters of the simulation

<table>
<thead>
<tr>
<th>parameter</th>
<th>Value</th>
<th>parameter</th>
<th>Value</th>
<th>parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total height (m)</td>
<td>32</td>
<td>Simulate spacing (m)</td>
<td>2</td>
<td>Computational order</td>
<td>4</td>
</tr>
<tr>
<td>Ground roughness</td>
<td>0.003</td>
<td>Initial frequency (HZ)</td>
<td>0.01</td>
<td>Initial time</td>
<td>0.1</td>
</tr>
<tr>
<td>Average wind speed at 10 m (m/s)</td>
<td>20.515</td>
<td>Cutoff frequency (HZ)</td>
<td>10</td>
<td>Total time points</td>
<td>2048</td>
</tr>
<tr>
<td>Simulate points</td>
<td>15</td>
<td>Frequency increment (HZ)</td>
<td>0.01</td>
<td>Time increment (s)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

The time variation of the wind speed of each point is calculated by MATLAB programming which are based on existing formula (Yuan 2007). We change the wind speed with Bernoulli equation into the wind pressure variation. Figure 5; figure 6, respectively, are the 18 m, 29 m height pressure time history chart.

\[ P = \frac{1}{2} \rho V^2 \]  

(1)

Where, \( P \) is Pressure; \( \rho \) is Air density; \( V \) is Fluctuating wind speed.

![Figure 5. Wind pressure time history chart of 18 m height simulation point](image1)

![Figure 6. Wind pressure time history chart of 29 m height simulation point](image2)

The changeable wind pressure at each height is imported into the ANSYS, and the pressure load is applied to the model. Then the extract each model results in different height of 30 nodes shear stress and the compressive stress will be imported into the
MATLAB (Wang 2013), to make the time history diagram, last make the overall process analysis.

IV. RESULTS CONTRAST AND ANALYSIS

A. The comparison of model results with different open holes position.

![Figure 7. Comparison chart of compressive stress of representative node on the bottom of the model](image1)

![Figure 8. Comparison results chart of compressive stress of representative nodes in 24 m of each model](image2)

Compare bottom compressive stress of representative node of model M3-31, M3-32, M3-33 and no holes results (figure 7), combine with other 8 comparison results chart which are as same as above shown only hole positions are different while other conditions are same, indicate that the change of hole position has little effect on the compressive stress of the bottom, compared with the bottom compressive stress before opening, after opening, the compressive stress of the hole is increased, but the increase in the range of less than 5%, which can be neglected.

Compare 24 m height node compressive stress of model M2-21, M2-22, M2-23, which only hole positions are different while other conditions are same (figure 8), In the case of no holes, the cross section in height 24 m the nodes produce tensile stress and the maximum value reached 0.41 MPa, and in the whole stress change process, it frequently excess the design tensile stress value 0.23 MPa (Load code for the design of building structures 2012). After opening, at the same height, the model M2-21, its maximum tensile stress is 0.17 MPa, the model M2-22 whose maximum tensile stress is 0.26 MPa, the model M2-23 whose maximum tensile stress is 0.34 MPa. Combined with the other 8 comparison results chart which only holes positions are different while other conditions are same, the results show that the change of hole position has a great influence on the weakening of the tension stress in the 24 m which are dangerous cross
section of no holes model. When the other conditions are the same, as the higher of opening holes the greater affect to weak the tensile stress.

From model M3-31, M3-32 and M3-33 compressive stress changes chart at different heights (figure 9), we get, for model M3-31, the tension stress is generated at the section near 28 m, the maximum tensile stress is 0.12 MPa; model M3-32 whose tension stress is generated at the section near 25 m, its maximum tensile stress is 0.22 MPa; model M3-33 near 24 m nodes have the maximum tensile stress 0.23 MPa. Combined with other 8 grope graphics which as same as above shows whose only different condition is the holes position, The results show that as the position higher of opening holes the dangerous cross section will be correspondingly upward shift, and at same height the stress is also reduced.

Figure 9. The change chart of compressive stress of representative nodes of different Model at different height

Figure 10. Comparison chart of representative nodes shear stress at the bottom of each model
Figure 11. The change chart of representative nodes shear stress at different height in each model

Figure 12. Comparison chart of bottom compressive stress of representative nodes of each model

Compare the model M3-32, M3-31, M3-33 and no holes bottom shear stress results (figure10), combine with other 8 graphics which as same as above shows whose only different condition is the holes position, we can see that opening holes can be greatly affected the variation of the shear stress at the bottom, The more higher the hole position, the greater the shear stress can be weak. From the graph, we also see that as the more higher the hole position, the smaller the magnitude of the change, which is contribute to the stability of structures under fluctuating loads.

From model M2-21, M2-22, M2-23 (figure 11), the distribution of the stress in different height, it shows that model M2-21 in the stress variation process, the maximum shear stress of representative node at 2 m height is 0.12 MPa, the probability of excess 0.11 MPa (Design value of shear resistance) in the process is very small, that is near 2 m height it can be able to meet the basic requirements of shear resistance; but model M2-22 whose node shear stress at 2 m is frequently beyond the design value of shear resistance, that is under the action of fluctuating load, it is likely to be shear failure till 2 m height; the shear stress of model M2-23 till 4 m height is likely excess the shear
resistance. Compare the other 8 groups of the same type figures, the results show that the change of the hole position has a great influence on the shear stress, the higher of the hole position, the faster the shear stress reduction, and the smaller the shear stress at the same height.

B. The comparison of model results with different open holes size.

Compare bottom compressive stress of representative node of model M1-21, M2-21, M3-21 and no holes results (figure 12), combine with other 8 comparison results chart which are as same as above shown only hole sizes are different while other conditions are same, indicate that the change of hole size has little effect on the compressive stress of the bottom, compared with the bottom compressive stress before opening holes, after opening, the compressive stress of the hole is increased, but the increase in the range of less than 5%, which can be neglected.

Figure 13. Comparison results chart of compressive stress of representative nodes in 24 m of each model

Compare 24 m height node compressive stress of model M1-21, M2-21, M3-21 which only hole sizes are different while other conditions are same (figure 13), In the case of no holes, the cross section in height 24 m the nodes produce tensile stress and the maximum value reached 0.41 MPa, After the opening, at the same height, for the model M1-21, its maximum tensile stress is 0.26 MPa, the model M2-21 whose maximum tensile stress is 0.17 MPa, the model M3-21 whose maximum tensile stress is 0.05 MPa. Combined with the other 8 comparison results chart which only holes sizes are different while other conditions are same, the results show that the change of hole size has a great influence on the weakening of the tension stress in the 24 meters which are dangerous cross section of no holes model. When the other conditions are the same, as the larger the aperture the greater affects to weak the tensile stress. But for the model M3-21 and M3-31 whose holes size is 120 cm, in the course of its stress, the range of stress is significantly higher than other models. This has great damage to the
stability of structure.

From model M1-21, M2-21 and M3-21 compressive stress changes chart at different heights (figure 14), we get, for model M1-21, the tension stress is generated at the section near 24 m, the maximum tensile stress is 0.26 MPa; model M2-21 whose maximum tensile stress is 0.17 MPa at the section near 24 m; model M3-21 near 26 m nodes have the maximum tensile stress 0.09 MPa. Combined with other 8 grope graphics which as same as above shows whose only different condition is the holes size, The results show that as the greater size of opening holes the dangerous cross section will be correspondingly upward shift, and at same level the stress is also reduced.

![Figure 14](image1.png)

**Figure 14.** The change chart of compressive stress of representative nodes of different Model at different height

![Figure 15](image2.png)

**Figure 15.** Comparison chart of representative nodes shear stress at the bottom of each mode

Compare the model M1-21, M2-21, M3-21 and no holes bottom shear stress results (figure 15), combine with other 8 graphics which as same as above shows whose only different condition is the holes size, we can see that opening holes can be greatly affected the variation of the shear stress at the bottom, the greater size of opening holes the greater the shear stress can be weak. From the graph, we also see that as the greater size the holes position, the smaller the range of the change, which is contribute
to the stability of structures under fluctuating loads.

From model M1-21, M2-21, M3-21, the distribution of the stress in different height of the group can be seen (figure 16), model M1-21 in the stress variation process, the maximum shear stress of representative node near 2 m height is 0.14 MPa, the probability of excess 0.11 MPa (Design value of shear resistance) in the process is great, that is near 2 m height it cannot be able to meet the basic requirements of shear resistance; but model M2-21 whose node shear stress at 2 m have little probability to exceed the design value of shear resistance; the shear stress of model M3-21 have been weaken to the range of Shear resistance. Compare the other 8 groups of the same type graphics, The results show that the change of the hole size has a great influence on the shear stress, The greater of the hole size, The faster the shear stress reduction, and the smaller the shear stress at the same height.

![Figure 16](image1.png)  
![Figure 17](image2.png)

**Figure 16.** The change chart of representative nodes shear stress at different height in each model

**Figure 17.** Comparison chart of bottom compressive stress of representative nodes of each model

C. The comparison of model results with different number of holes

Compare bottom compressive stress of representative node of model M3-11,
M3-21, M3-31 and no holes results (figure 17), combine with other 8 comparison results chart which are as same as above shown only the number of holes are different while other conditions are same, indicate that the change of holes number has little effect on the compressive stress of the bottom, compared with the bottom compressive stress before opening holes, after opening, the compressive stress of the hole is increased, but the increase in the range of less than 5%, which can be neglected. However as the more number of holes in the process of fluctuating, in the process of fluctuating load, the greater of stress range in change process at the bottom, which is disadvantageous for structure.

![Figure 18](image1.png)  
![Figure 18](image2.png)

**Figure 18.** Comparison results chart of compressive stress of representative nodes in 24 m of each model

Compare 24 m height node compressive stress of model M2-11, M2-21, M2-31 which only the number of holes is different while other conditions are same (figure 18). At the same height, for the model M2-11, its maximum tensile stress is 0.35 MPa, the model M2-21 whose maximum tensile stress is 0.17 MPa, the model M2-31 whose maximum tensile stress is 0.05 MPa. Combined with the other 8 comparison results chart which only the number of holes are different while other conditions are same, the results show that when the other conditions are the same, as the more the number of holes the greater effect to weak the tensile stress. But for the model M2-31 and M3-31 whose number of holes is 12, in the course of its stress change, the range of stress is significantly higher than other models. This has great damage to the stability of structure.

From model M2-11, M2-21 and M2-31 compressive stress changes chart at different heights (figure 19), for model M2-11, the tension stress is generated at the section near 24 m, the maximum tensile stress is 0.35 MPa; model M2-21 whose maximum tensile stress is 0.17 MPa at the section near 24 m; model M2-31 near 27 m nodes have the maximum tensile stress 0.07 MPa. Combined with other 8 grope graphics which as same as above shows whose only different condition is the number of holes, The results show that as the more holes in the structure, the dangerous cross
section will be correspondingly upward shift, and at same level the stress is also reduced.

Compare the model M2-11, M2-21, M2-31 and no holes bottom shear stress results (figure 20), combine with other 7 graphics which as same as above shows whose only different condition is the number of holes, it indicates that opening holes can be greatly affected the variation of the shear stress at the bottom, the more holes in the structure the greater shear stress can be weak. From the chart, it also indicate that as the more holes, the smaller the range of the change, which is contribute to the stability of structures under fluctuating loads.

Figure 19. The change chart of compressive stress of representative nodes of different Model at different height
Figure 20. Comparison chart of representative nodes shear stress at the bottom of each model

Figure 21. The change chart of representative nodes shear stress at different height in each model

From model M2-11, M2-21, M2-31, the distribution of the shear stress in different height (figure 21), it can be seen, model M2-11 in the stress variation process, the maximum shear stress of representative node near 3 m height is 0.15 MPa, the probability of excess 0.11 MPa (Design value of shear resistance) in the process is also great, that is near 3 m height it cannot be able to meet the basic requirements of shear resistance; model M2-21 whose node shear stress at 2 m have little probability to excess the design value of shear resistance, basically meet the requirements of shear resistance; the shear stress of model M2-31 have been weaken to the range of Shear resistance within 1 m height. Compare the other 8 groups of the same type graphics, The results show that the change of the number of holes has a great influence on the shear stress, the more holes the faster the shear stress reduction, and the smaller of shear stress at the same height.
V. CONCLUSION

From the above analysis results can be seen, for plate structures, when subjected to fluctuating wind loads, opening holes can be greatly reduced the structural stress, ensure relative stability under strong wind. But the size, location, and number of holes should be analyzed according to the specific circumstances, to select the appropriate open holes states. Based on the investigation of the HongJin tile factory, then established the plate chimney model that have different size, location, and number of holes, after comparing and analyzing the results, found a suitable opening plan for the plate chimney. The wind resistant ability is effectively improved in theory, it provided the theoretical basis for the reinforcement of existing plate type chimney, and also provides a reference in the aspect opening holes of the high confining structure and other plate structures:

Through analysis and discussion there have some relatively general conclusions:

1) When the only different condition is the position, it indicates that the higher of the position of holes the higher of the section that generate tensile stress of the structure, and the smaller of the maximum tensile stress.

2) When the only different condition is the position, the higher the position of the opening holes is, the greater of cutting the shear stress at the bottom, with the height increasing, the higher the hole position The faster of the cutting speed of shear stress, and the smaller the shear stress at the same height.

3) When the only different condition is the size of holes, it indicates that the larger of holes area the higher of the section that generate tensile stress of the structure, at the same height, the stress is relatively smaller, and the maximum tensile stress value of section is smaller. But the larger of holes area, the stress range in change process under fluctuating load is greater; this is extremely unfavorable to the stability of the structure. However when the size of holes is too small its reduction effect for wind load is not obvious. So it needs the appropriate size of the aperture and the appropriate holes area.

4) When the only different condition is the size of holes, it indicates that the larger of holes area the faster the cutting speed of shear stress at the bottom, and the smaller the shear stress at the same height.

5) When the only different condition is the number of holes, the more holes the higher of the section that generate tensile stress of the structure, At the same height, the stress is relatively smaller, and the maximum tensile stress value of section is smaller. But the more holes, the stress range in change process under fluctuating load is greater; this is extremely unfavorable to the stability of the structure, so it needs to choose the appropriate number of holes.

6) When the only different condition is the number of holes, the more holes the faster the cutting speed of shear stress at the bottom, the more holes that is the larger area of holes ,and will be have the faster cutting speed to shear stress, then have the
smaller shear stress at the same height.

7) The compressive stress at the bottom of the structure is increased after opening holes, but the increase is so small which can be ignore. But as the more holes and the larger size of holes, the range of bottom stress change is increasing, this is likely to cause fatigue damage under the action of strong fluctuating wind load, so the number and the size of holes should be reasonably selected to ensure vibration amplitude in reasonable range.

If the choice of reinforcement measure is opening holes, it is recommended the opening number is 8 for plate chimney of HongJin tile factory, double symmetric arranged, hole size in the 90 cm-60 cm, to ensure the change range of structure stress is in a certain value, prevent fatigue damage and reduce the structure's ability to resist strong winds. At the same time, it plays a very good cut of the maximum value; The hole position is best in the middle and upper part, in the case that ensure the structure shear and tensile strength is not weakened, the opening holes can be moved up to the maximum weakening wind load. Of course, it is not satisfied the chimney structure resistance requirement just choose opening holes as the reinforcement measure, other aspects of reinforcement measures, such as the base reinforcement, the stay cable reinforcement, etc., are still to be further study to verify the reliability in the theory and the reality aspect.

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