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Wind-induced Vibration Response Analysis Of FRP Bracket-line Coupling System

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Abstract. According to the basic properties of fluctuating wind, Simiu spectrum and linear autoregressive filter method, a program of Simiu spectrum-time curve has been compiled in the MATLAB. The time history of fluctuating wind velocity for a few points has been simulation based on Simiu spectrum. The results show that the method is feasible. Taking the FRP bracket-line coupling system as an example, the wind-induced vibration response of the structure at different angles of wind and wind speeds is analyzed by using the finite element software ANSYS. The results show that the wind in the 90 degree direction is the most unfavorable wind direction for the whole structure according to the three kinds of angle wind calculated at present and when the 0 degree wind acts on the structure, wires have a certain damping effect in the bracket-line coupling system. By comparing and analyzing the influence of different wind speeds and wind attack angles, it is found that in the bracket-line coupling system, the bracket structure is more sensitive to the increase of wind speed while the conductors are more sensitive to the change of wind attack angle.

1. Introduction

The previous structure mainly focused on the reinforced concrete structure, and the reinforced concrete structure did have many advantages with long-term exploration. However, as time goes by, the corrosion degradation problems of the reinforced concrete, especially the corrosion problem of steel bars, not only affect the normal use and service life of the building structure, even lead to engineering accidents in severe case.

In order to construct engineering structure with high durability and long life cycle, it is necessary to apply new materials to engineering practice. FRP composite material has the advantages of fatigue resistance, corrosion resistance, electromagnetic shielding and long service life, which is one of the most using the prospect of new civil engineering materials[1].

In this paper, the response of FRP Bracket-line coupling system under wind-induced vibration is analyzed in detail by using finite element analysis software. When the disconnection of wire occurs in FRP bracket-line coupling system under the condition of extreme wind load, the dynamic response characteristics of the structure are explored, which can provide reference for the application of FRP composite in civil engineering.

In this paper, the finite element analysis software is used to analyze the response of the FRP bracket-line coupling system under wind-induced vibration and the dynamic response characteristics dynamic force of the structure when the FRP bracket-line coupling system breaks under the extreme wind load.



The response characteristics were explored to provide a reference for the application of FRP composite in civil engineering.

2. Finite element model of FRP bracket-line coupling system

Firstly, the finite element model of FRP bracket-line coupling system is established by finite element analysis software ANSYS. The total length of the structural system is 198m, the maximum span is 61.8m, the height is 30.8m, and the BEAM189 element and LINK10 element are selected for the bracket system and the wire system respectively to simulate. The material of the bracket beam is Q345 steel tube and the bracket column is made of FRP composite. The finite element model is shown in Figure 1.

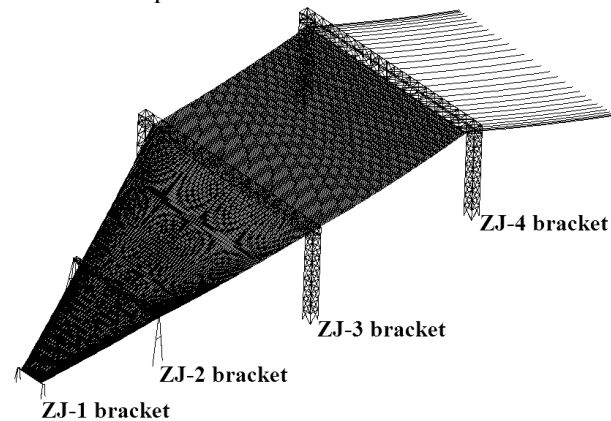


Figure 1. Finite element model of FRP bracket-line coupling system

3. Numerical simulation of wind field

The wind is formed by the unequal air pressure in different places and the flow of air. According to a large number of observations, it is found that the wind has two different components: one has a longer period, and its value is usually more than 10 minutes, which is much larger than the natural vibration period of the general structure. Its effect on the structure is similar to the static load, called average wind; the other period is shorter, and its action time is usually only a few seconds or so. It is closer to the natural vibration period of the structure and easy to cause structural vibration, called fluctuating wind. Therefore, the wind speed at any height and time can be expressed as the sum of the average wind speed and the fluctuating wind speed:

$$v(z,t) = \bar{v}(z) + v_f(z,t) \quad (1)$$

Where $\bar{v}(z)$ = the average wind speed at a height of z ; $v_f(z,t)$ = fluctuating wind speed.

A program of Simiu spectrum-time curve has been compiled in the MATLAB and the fluctuating wind speed at different heights has been obtained. In this paper, the fitting curves of the simulated spectrum and the target spectrum at two different heights are given.

It can be seen from Figure 2 that the simulated wind spectrum of each layer agrees well with the target spectrum, and the simulated wind can be used to analyze the wind-induced response.

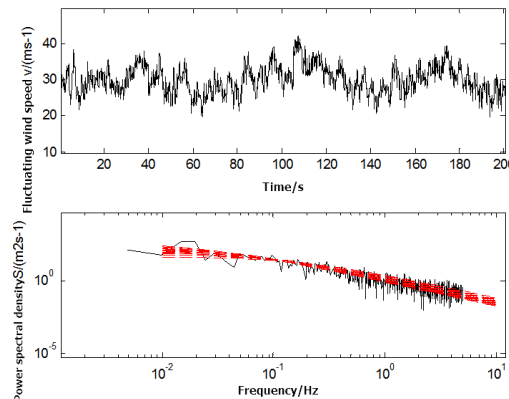


Figure 2. Fluctuating wind speed-time curve and comparison of simulated spectrum and target spectrum

4. Wind-induced response analysis of bracket-line coupling system

4.1. Time response curve under wind load excitation

Considering the damping ratio (0.03), the wind-induced vibration response of the structure is analysed. Figure 3 is the displacement-time curve of the top of No.ZJ-3 bracket, Figure 4 is Displacement-time curve of third span conductors along vertical direction of the wire, Figure 5 is the Vertical displacement-time curve of third span conductors and Figure 6 is the axial force-time curve of third span conductors.

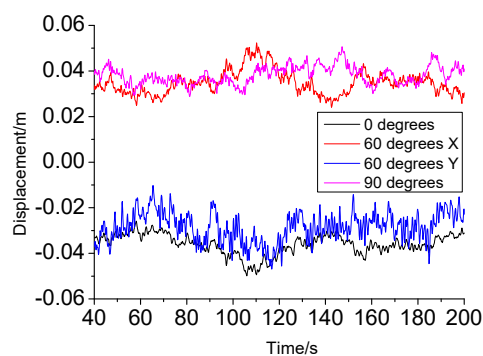


Figure 3. Displacement-time curve of the top of No.ZJ-3 bracket

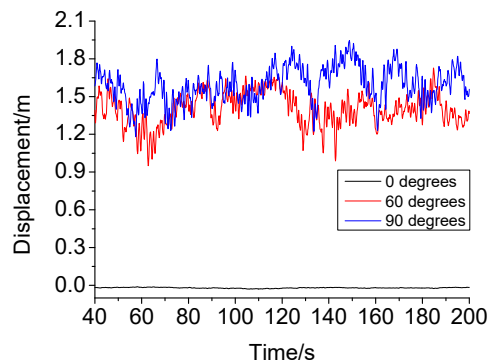


Figure 4. Displacement-time curve of third span conductors along vertical direction of the wire

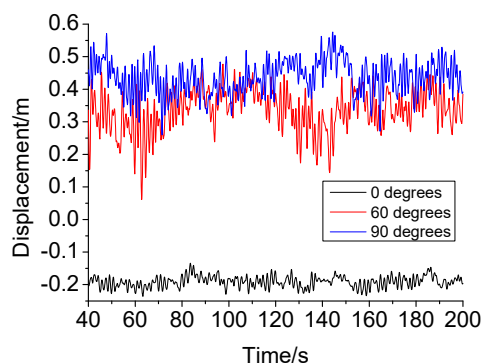


Figure 5. Vertical displacement-time curve of third span conductors

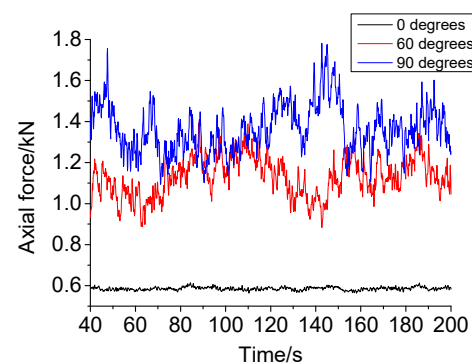


Figure 6. Axial force-time curve of third span wires

It is not difficult to see from the diagram that the effect of wind at different angles on the structure is different. When the 90 degree wind acts, the brackets have the largest displacement response, while

the 0 degree wind has the least influence on the brackets. This is mainly because: In the bracket-line coupling system, When the 0 degree wind acts on the structure, Wind-shield area of the wire is small, as a result, it is less affected by wind load. What's more, the wire itself has a certain weight, therefore, wires have a certain damping effect in the whole structure.

4.2. Dynamic analysis of FRP bracket-line coupling system with disconnection of wire

When the FRP bracket-line coupling system is subjected to extreme wind load or severe icing on the wire, the line structure in the FRP bracket-line coupling system is highly prone to disconnection. When a wire of a certain span is disconnected, a large unbalanced tension will be generated between adjacent spans. When the unbalanced tension is applied to the bracket, it may make the displacement response and internal force response of the bracket increase, so that the stress distribution is unevenly increased, posing a great threat to the safety of the overall structure, and even cause the collapse of the bracket. In order to understand the impact of the disconnected wire on the structure in more detail and more clearly, this paper will analyze the set working conditions and observe the displacement and tension of the wire, as well as the displacement and stress changes of the bracket.

Table 1. Calculation conditions of disconnection

Condition	Disconnect situation
1	The third gear broke 10 lines at the middle span of the bracket

4.2.1. Response of line

In the process of disconnection, the bracket connected with the disconnection may be subjected to a larger impact, and the response of the adjacent span may also be larger. Figure 7 shows the mid-span vertical displacement time history of the gear adjacent to disconnection and the span with unbroken wire. It can be seen from Figure 7 that after the third span is disconnected, it will have an impact on the other spans, and the third span which is directly adjacent to the disconnected wire and the second span is relatively obvious. The vertical maximum displacements of the two during this process are 0.054m and 0.025m, respectively.

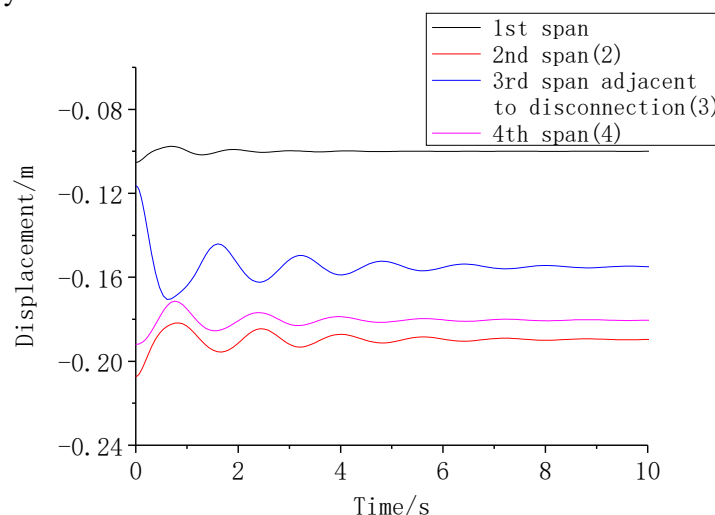


Figure 7. Vertical displacement of line's mid-span

4.2.2. The displacement response of bracket's top

The impact of the disconnected wire on the bracket is studied by extracting the displacement time history in the direction of the straight line in the top span of each bracket. Figure 8 shows the time history of displacement in the direction of the straight wire in the top span of each bracket.

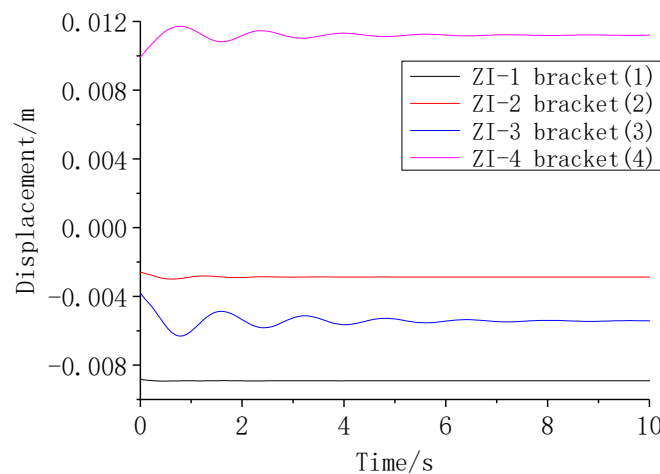


Figure 8. Mid-span displacement of each bracket's top along the straight line

It can be seen from Figure 8 that under this working condition, except for ZJ-3 and ZJ-4 brackets, the displacement of the other brackets in the direction of the straight wire is small and the vibration is very short. The time disappeared and then entered a steady state. For the ZJ-3 bracket, it has the maximum displacement along the direction of the straight line at 0.76s, the maximum displacement is 2.45mm, and it starts to enter a stable state about 6s after the disconnection, and finally shifts in the direction of the straight line. 1.58mm.

5. Conclusions

In this paper, the following conclusions are obtained by simulating the fluctuating wind speed time series and analyzing the wind-induced vibration response of the FRP bracket-line coupling system:

(1) In the bracket-line coupling system, when the 0 degree wind acts on the structure, wind-shield area of the wire is small, as a result, wires have a certain damping effect in the whole structure. So in the case of 30m/s wind, when the 90 degree wind acts, the brackets have the largest displacement response, while the 0 degree wind has the least influence on the brackets.

(2) Under the same wind speed, the influence of the 0 degree wind on the conductors is relatively small, and the displacement and tension response of the conductor is more obvious when the 90 degree wind acts.

(3) Considering the effects of wind on the brackets and the conductors at three different angles, we can see that in the case of 30m/s wind, the wind in the 90 degree direction is the most unfavorable wind direction for the whole structure according to the three kinds of angle wind calculated at present.

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