Wind-induced Dynamic Analysis of the Arched Tensegrity Structures in Time Domain

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ABSTRACT

Tensegrity structures are sensitive to wind. Wind-induced dynamic analysis for arched tensegrity structure is performed with the nonlinear random simulation method in time domain in this paper. And several parameters such as wind speed, length-windth ratio, rise-span ratio and prestress of cable are considered. The arched tensegrity structure appears obviously peak resonance in the low-frequency part under wind load. Reducing the length-width ratio and increasing prestress can reduce wind-induced response of arched tensegrity structure effectively.

INTRODUCTION

Tensegrity structures have the characteristics of light weight, large flexibility and small damping, so they are sensitive to wind (K. Kebiche, 1999). One of the key factors for structure design is the wind-induced response, and thus the wind load will be the main one for roof structure design (M. Gu, 1999). Therefore, it is an important problem to solve how to analyze wind resistance and wind vibration effects for tensegrity structures accurately and efficiently. After the random vibration theory had been used to analyze wind-induced response by Davenport researchers mostly used time integration method analysis for wind-induced response of nonlinear structures (Minh.N.N, 1999). Applying the random simulation method in time domain, wind-induced response of the arched tensegrity structure has been analysed in this paper. Parameters such as wind speed, length-width ratio, rise-span ratio and prestress of cable are taken into account on effect of wind resistance for structures. Law of changes of wind-induced response in structures is gained.

THE RANDOM SIMULATION METHOD IN TIME DOMAIN

The random simulation method in time domain is a dynamic response analysis method for nonlinear structure under stochastic dynamic loading. It is suitable for any system and incentives in principle. The whole process of structural dynamic response can be gained. This is an effective approach in which the random simulation method in time domain is applied to analyze wind-induced response of flexible system. The main steps for analysis((Yong Guo, 2006, Bo Chen, 2003):

(1) According to the statistical characteristics of wind load, we start to calculation and simulation. The time-history of wind speed with a specific spectral density and spatial correlation is artificially generated and transformed into the time-history of the wind pressure which is acted on the structure.

(2) According to excitation sample applying Newmark step by step integration method to solve motion equations, and using Newton-Raphson iteration to consider the geometric nonlinear characteristics of structure. We may get the nodal displacement, velocity and acceleration of every time step.

(3) Make Statistical Analysis for the response samples to determine average, mean-square deviation and the corresponding spectral characteristics of the wind-induced response.

COMPUTATIONAL MODEL

The arched tensegrity structure is shown in Figure 1. The short side length of structural model is 20m. The length-width ratio is 1.5 and rise-span ratio is 0.2. Structure is supported by the 10m high rigidity base and the boundary constraints is the surrounding hinged. Material properties of cable member: elastic modulus is 1.85×10^{5}MPa, density is 7.85×10^{3}kg/m^{3}, tensile strength is 1860MPa, where design value may takes 40%, 744MPa. The ratio of height and length of unit is 0.631. Initial prestress value which is controlled by the strain of cable is 1.495×10^{-3} MPa. Cable member consists of seven steel wires and area of its cross-section is 7.939×10^{-3}m^{2}. Material properties of strut element: elastic modulus is 2.06×10^{5}MPa, density is 7.85×10^{3}kg/m^{3}, yield strength is 235MPa. Strut member selects the seamless steel pipe. Diameter of its cross-section is 83mm and thickness is 3mm. The basic wind speed 25m/s. In this paper weight of structure is 0.15kN/m^{2} and dead load is 0.15kN/m^{2}. Assuming the wind-induced response of structure to satisfy the quasi-steady theory, the shape factor of wind load is determined by ‘Load code for the design of building structures’ (GB 50009-2001).

PARAMETRIC ANALYSIS SCHEME

Parametric variations of arched tensegrity structure in the wind-induced vibration analysis are considered as follows:

(1) length-width ratio: 1.0, 1.25, <u>1.5</u>, 1.75

(2) rise-span ratio:1/3, 1/4, <u>1/5</u>, 1/6

(3) standard wind speed: 20m/s, 25 m/s, 30 m/s
(4) prestress values:1.0, 1.1, 1.2

Underlined parameters are the basic model parameters. We make parametric analysis to follow the principle that when considering the effect of certain parameter, other parameters remain the basic parameters of the model.

WIND-INDUCED DYNAMIC RESPONSE CHARACTERISTICS OF THE BASIC MODEL

The maximum displacement node 1 of the basic model is shown in Figure 1. The time-history curve and the power spectrum curve of displacement response for node 1 are shown in Figure 2 and Figure 3. We can draw a conclusion from the Figure 2. The arched tensegrity structure appears obviously peak resonance in the low-frequency part under wind load. The corresponding vibration mode of structure vibrates upward along geometric centre axisymmetry.

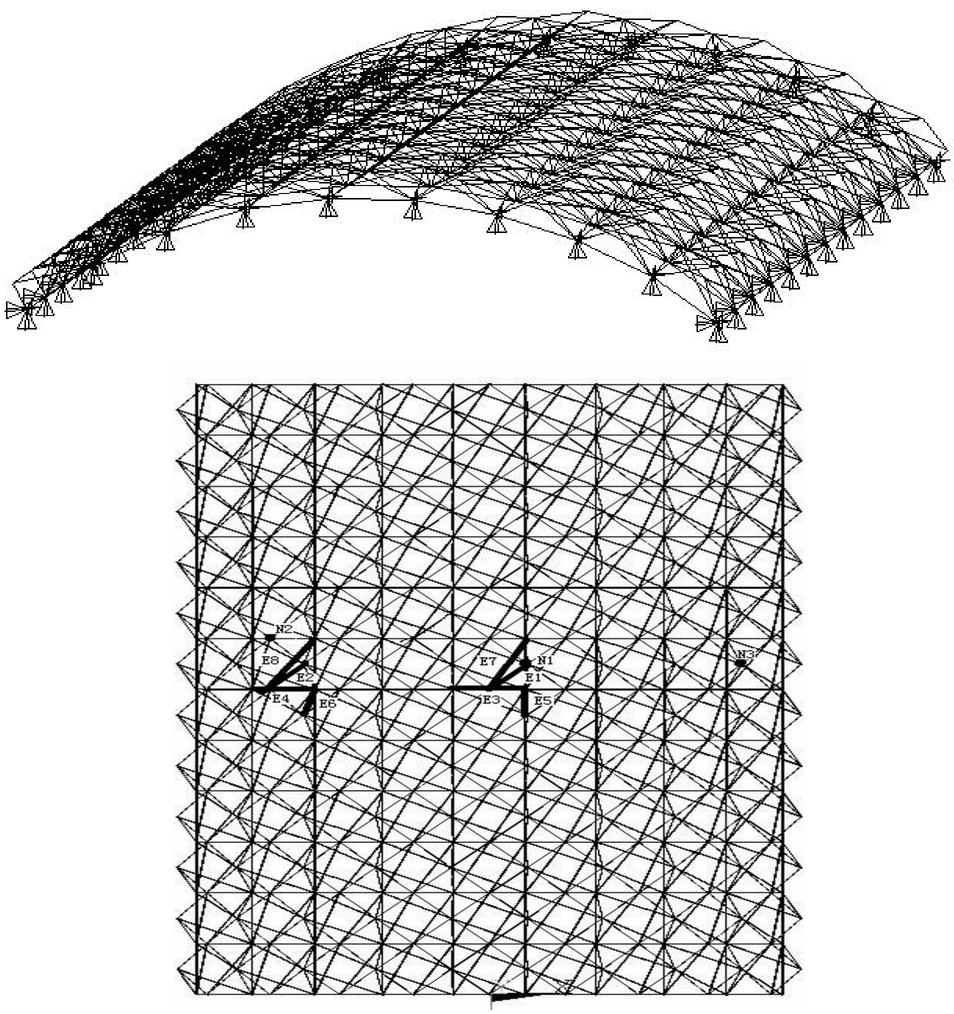


Figure 1. The arched tensegrity structure.

The calculated results of displacement responses for the observation points show that the displacement response of N1 is the maximum and N3 is the minimum. It is reason that is due to the boundary constraints. Responses of top cable, bottom cable, middle cable and strut show the same result. The internal force response of top cable is the maximum and strut is the minimum.

EFFECTION OF VARIOUS PARAMETERS FOR WIND-INDUCED RESPONSE

Effection of wind speed. The wind-induced response curve of corresponding node, the top cable, bottom cable, middle cable and strut with wind speed are shown in Figure 4, respectively.

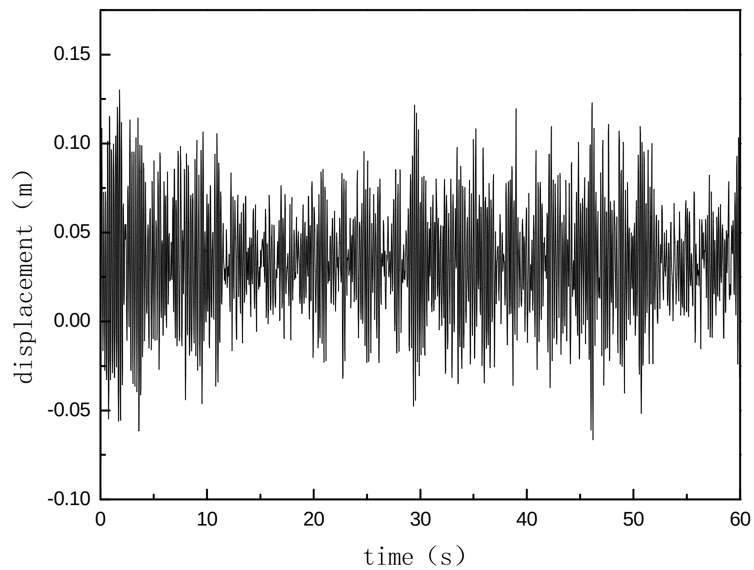


Figure 2. Time History Curve of displacement for N1.

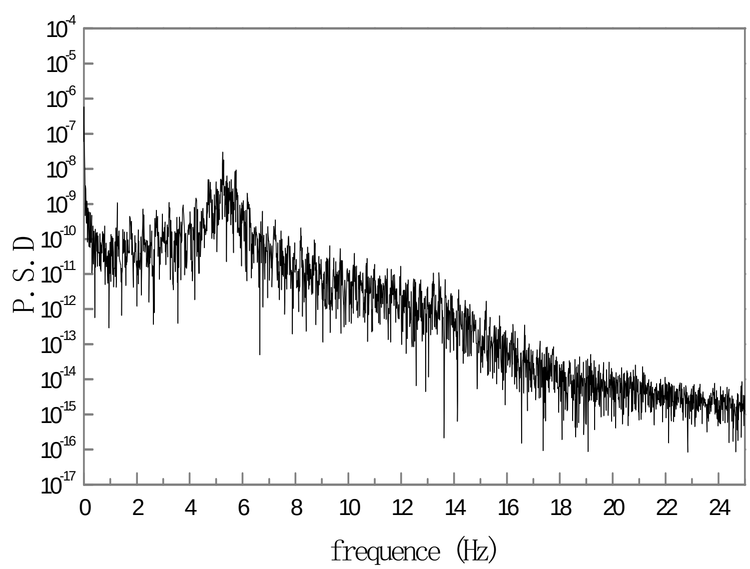


Figure 3. Power spectrum curve of displacement response for N1.

Figure 4 shows that wind-induced vibration force of the node increases with the increase of wind speed. Thereby displacement of the nodes and stress of members increase.

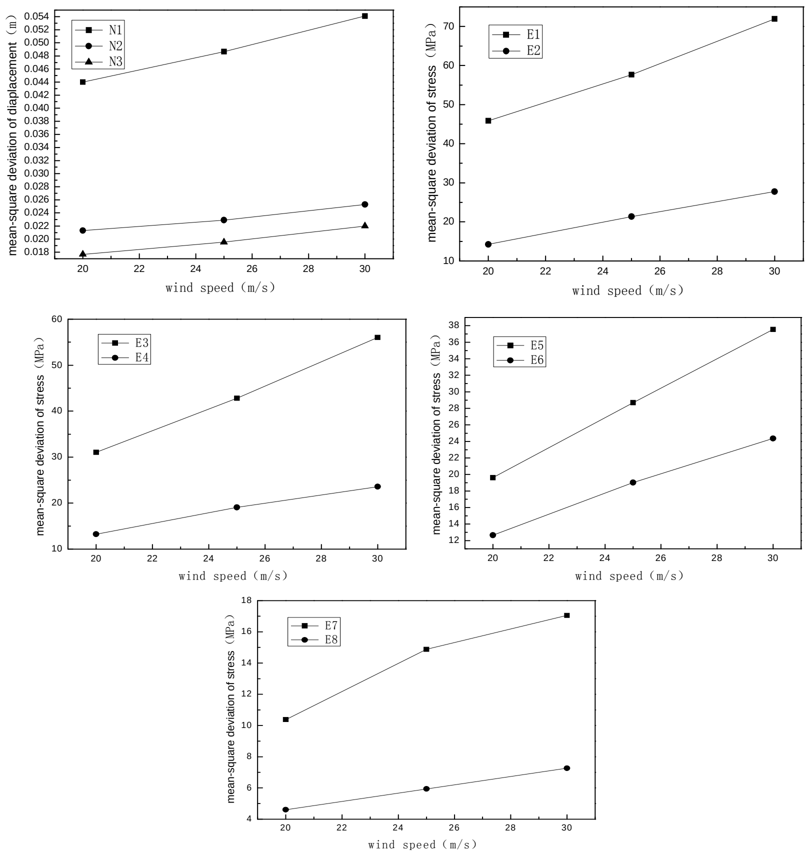
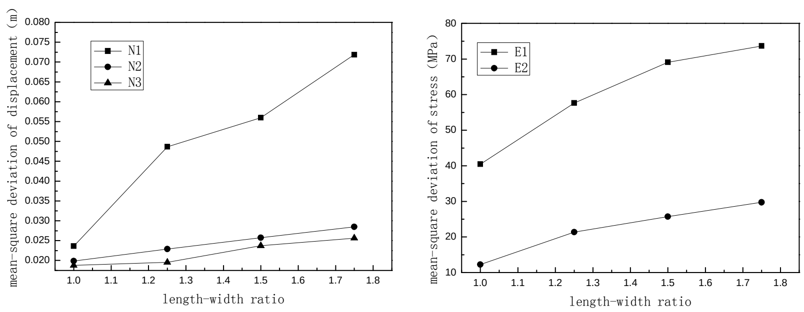


Figure 4. Response versus reference wind speed.

Effection of length-width ratio. The wind-induced response curve of corresponding node, top cable, bottom cable, middle cable and strut with length-width ratio are shown in Figure 5, respectively. Figure 5 shows that the vertical stiffness of the structure reduces with increase of length-width ratio. Thereby displacement of the nodes and stress of members increase.



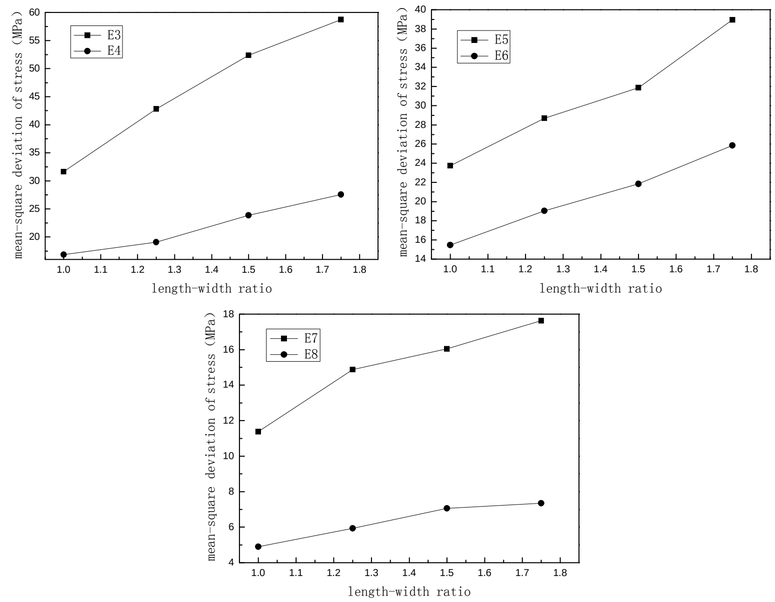
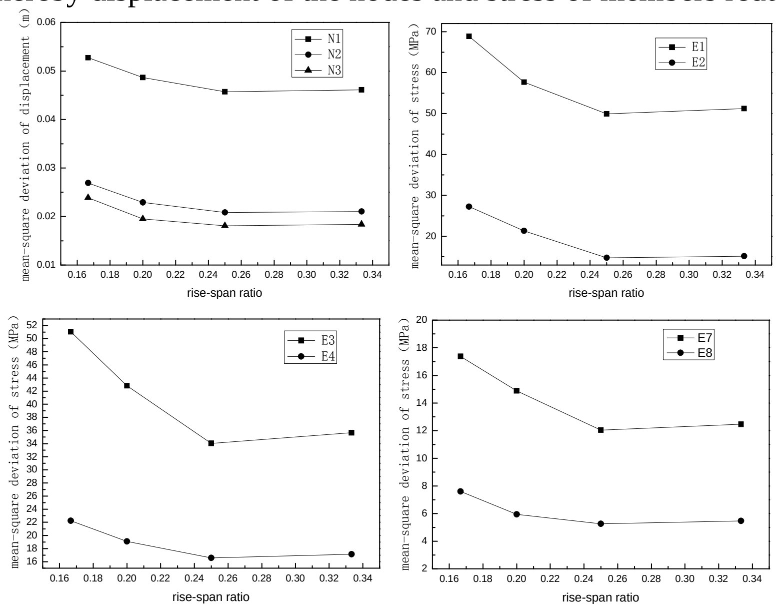


Figure 5. Response versus length-windth ratio

Effection of rise-span ratio. The wind-induced response curve of corresponding node, top cable, bottom cable, middle cable and strut with rise-span ratio are shown in Figure 6, respectively. Figure 6 shows that the vertical stiffness of the structure increases and the horizontal stiffness reduces with increase of rise-span ratio. Thereby displacement of the nodes and stress of members reduce. But in addition to vertical vibration, there is horizontal vibration in wind vibration, Figure 6 shows that the overall stiffness of the structure is better when the rise-span ratio is 0.25. So displacement of the nodes and stress of members is relatively smaller.

Effection of prestress. The wind-induced response curve of corresponding node, top cable, bottom cable, middle cable and strut with prestress are shown in Fig. 7, respectively. Fig. 7 shows that the stiffness of the structure increases with increase of prestress. Thereby displacement of the nodes and stress of members reduce.



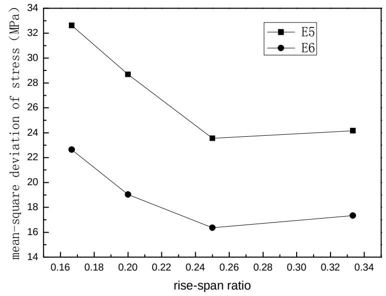


Figure 6. Response versus rise-span ratio.

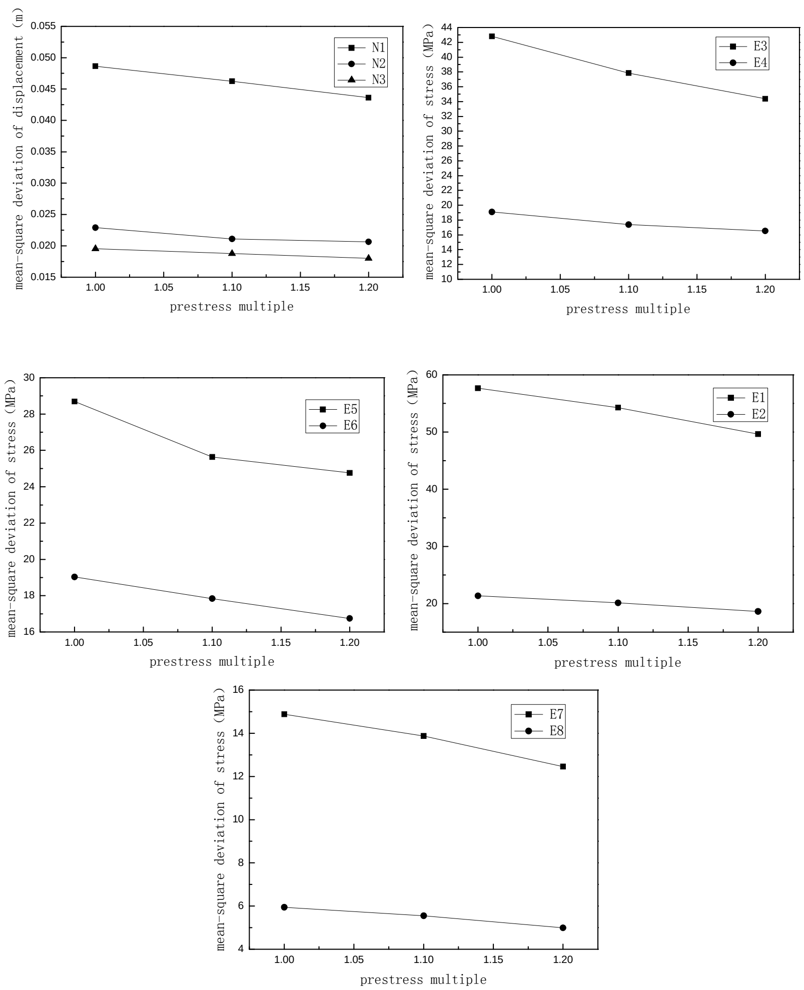


Figure 7. Response versus prestress of cable.

CONCLUSION

Applying the random simulation method in time domain, wind-induced response for the arched tensegrity structure is calculated and parametric analysis is performed in the paper. The arched tensegrity structure appears obviously peak resonance in the low-frequency part under wind load. Reducing the length-width ratio and increasing prestress can reduce wind-induced response of arched tensegrity structure effectively. The overall stiffness of the structure is better when the rise-span ratio is 0.25. So wind-induced vibration response of structure is smaller.

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