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Research on the wind-induced aero-elastic response of closed-type saddle-shaped tensioned membrane models

Key words: membrane structures, wind-induced response, aero-elastic instability, aero-elastic model, vortex-induced vibration

1. RESEARCH BACKGROUND

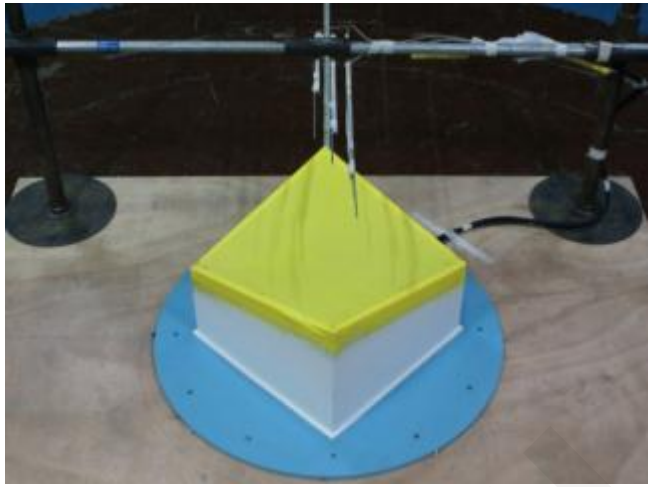




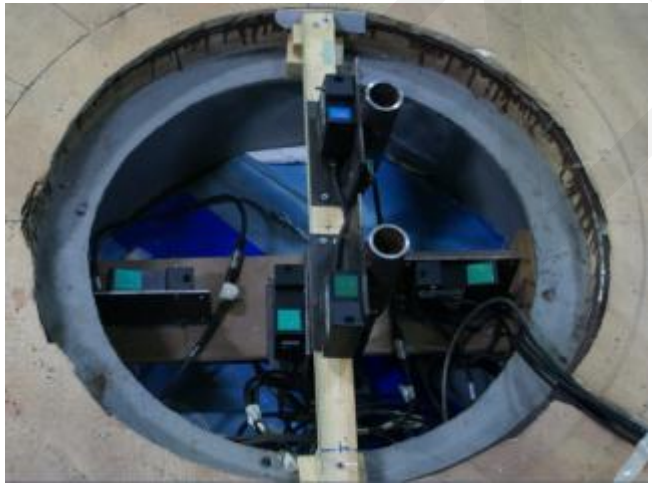
Membrane may absorbs energy from wind and result in the large amplitude vibration or even damage of the membrane structures.

The wind-induced aero-elastic response of membranes can help designers to make clear the aero-elastic instability mechanism of membrane structures.

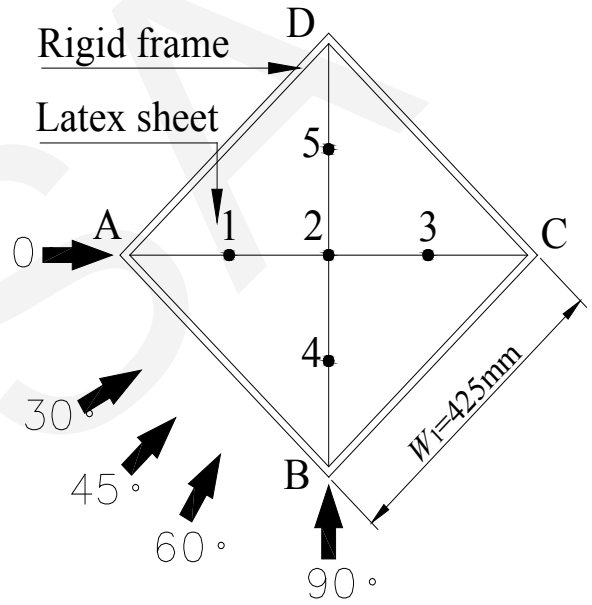
2. DESIGN OF AERO-ELASTIC MODELS



Hot wire and model

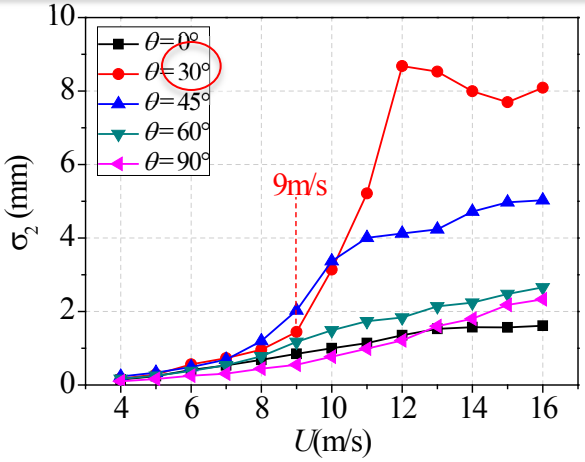


Laser displacement sensors

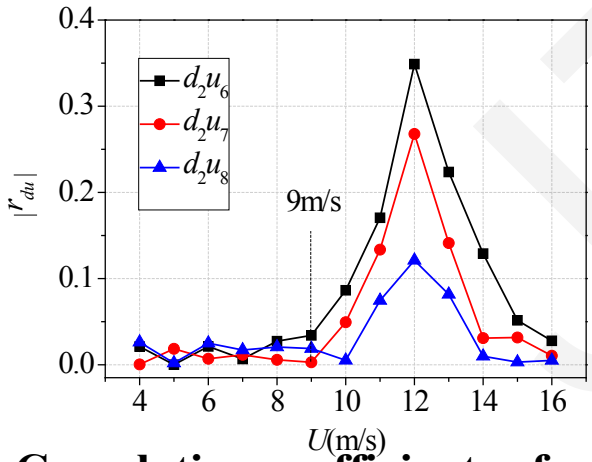


Schematic diagram of the test model

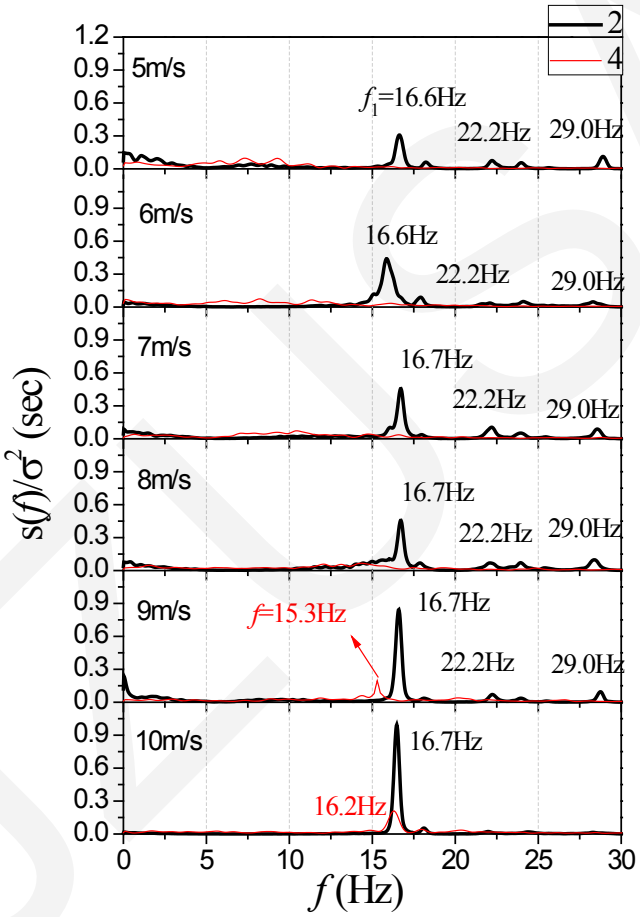
3. TEST RESULTS



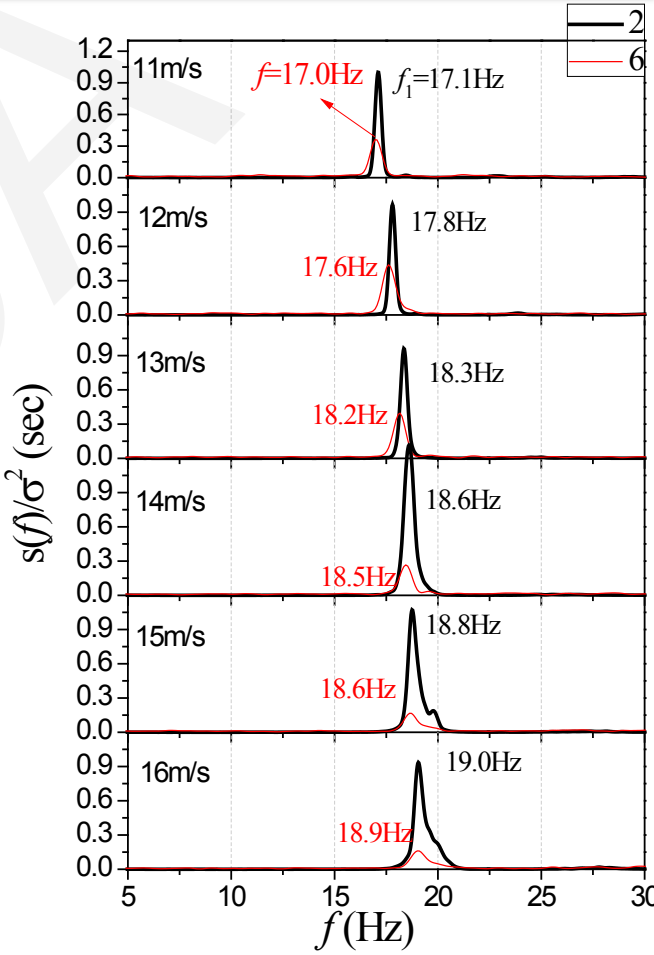
Amplitudes of the roof for Point 2 at 0~90° directions



Correlation coefficients of displacement and wind velocity for 30° direction



PSD of displacements and wind velocities for 30° direction at 5~10m/s



PSD of displacements and wind velocities for 30° direction at 11~16m/s

4. CONCLUSIONS

The aero-elastic instability mechanisms of membrane structures were studied. Some preliminary conclusions have been drawn, which are:

- Membrane structures deform to an equilibrium position and vibrate around it with certain amplitudes under the action of the wind.
- For most wind directions, several vibration modes are excited; the amplitude and damping ratio of the roof increase uniformly with the on-coming flow velocity.
- For some particular wind directions, only one vibration mode is excited; the amplitude and damping ratio of the vibration mode increase slowly with the on-coming flow velocity at first. Then, on exceeding a certain on-coming flow velocity, an aero-elastic instability caused by vortex-induced resonance occurs. The amplitude of the roof vibration begins to increase sharply and the damping ratio of the vibration mode begins to decrease quickly, to near zero, with the increasing on-coming flow velocity; the frequency of the vortex above the roof is locked in by the vibration within a certain wind velocity range. The amplitudes of the roof vibration at these wind directions reach 2~4 times the amplitudes for other wind directions. With an increase in on-coming flow velocity, the membrane can experience several aero-elastic instabilities.
- The reduced critical wind speeds for the first two modes are around 0.8~1.0.

5. PART OF OUR RECENT PUBLISHS ABOUT FLUID-STRUCTURE INTERACTION OF MEMBRANE STRUCTURES

[1] Wu Y., Sun X. Y., Shen S. Z. Computation of wind–structure interaction on tension structures[J]. ***Journal of Wind Engineering and Industrial Aerodynamics***, 2008, 96(10): 2019–2032.

[2] Chen Z. Q., Wu Y., Sun X. Y. Research on the added mass of open-type one-way tensioned membrane structure in uniform flow[J]. ***Journal of Wind Engineering and Industrial Aerodynamics***. 2015, 137: 69-77.

[3] 孙晓颖, 陈昭庆, 武岳. 单向张拉膜结构气弹模型试验研究[J]. **建筑结构学报**, 2013, 34(11): 63-69.(Sun X. Y., Chen Z. Q., Wu Y. Aeroelastic experiment of one-way tensioned membrane structure[J]. Journal of Building Structures, 2013, 34(11): 63-69. (in Chinese))

[4] 陈昭庆, 武岳, 孙晓颖. 封闭式单向张拉膜结构气弹失稳机理研究[J]. **建筑结构学报**, 2015, 36(3):12-19.(Chen Z.Q., Wu Y., Sun X.Y. Research on the aeroelastic instability of closed-type one-way tensioned membrane [J]. Journal of Building Structures, 2015, 36(3):12-19. (in Chinese))

[5] 孙晓颖, 武岳, 陈昭庆. 薄膜结构流固耦合的CFD数值模拟研究[J].**计算力学学报**, 2012, 29(6)：873-878.(Sun X.Y., Wu Y., Chen Z. Q. CFD numerical simulation on wind-structure interaction of membrane structures[J]. Chinese Journal of Computational Mechanics, 2012, 29(6)：873-878. (in Chinese))