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Experimental Investigation of a New Cables in Cable Stayed Bridges to Reduce Rain-Wind Induced Vibration

H. Baghi[1], A. Golsoorat Pahlaviani[1]*, M. H. Rramesht[1], J. Asgari Marnani[1], A. Mirabdolah Lavasani[2]

[1] Department of Civil Engineering, Faculty of Civil and Earth Resources Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran.

[2] Department of Mechanical Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran.

ABSTRACT: In this present, two pairs of cable models were designed and tested to reproduce the induced vibration of stay cables in a wind tunnel. Cable of cable-stat stayed bridges are flexible structural members that have very low natural frequency and low intrinsic attenuation, Therefore, they are able to various vibrations such as wind vibration, wind-rain-induced vibration (RWIV), and earthquakes. Wind-rain-induced vibration has become one of the major concerns of bridge engineering. One of the ways to reduce the effects of wind and rain on cable bridges has been examined is cable aerodynamic specification and also one of the factors affecting the aerodynamics of the cable is the formation of rainwater flow on the surface of the cable. Therefore, spiral grooves were installed on the surface of the cable to direct this flow of water to the bottom of the cable. By testing two cable models (without grooves and with grooves) in the wind tunnel with artificial rain flow, the effect of different wind speeds, and also different yaw angles, it was concluded that by creating spiral grooves to The cable circumference can reduce the induced vibration caused by wind and rain, and the presence of these spiral grooves around the cable eliminates low-frequency currents and thus reduces the amplitude of the induced vibration.

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1- Introduction

One of the types of bridges with large spans is cable-stayed bridges, the difference between this category of bridges and other existing bridges is in the load-bearing structural element, i.e. their cables. The advantage of cable-stayed bridges over other bridges is the large span of these bridges, which reach up to 750 meters. This issue requires precision in the design of the cable system for the optimal transfer of loads from the deck to the pylons [1]. Truss bridges are a system with a high degree of uncertainty due to the large number of cables. The remarkable thing about these structures is the unknown shape of the lines of influence of the cable in advanced and multi-cable modes. These lines are significantly affected by secondary effects, which can be a combination of wind and rain on the cables.

Wind at moderate speeds may lead to high-amplitude vibration at low frequencies. This phenomenon has been observed in many cable-stayed bridges and has been studied in detail. The vibration caused by wind and rain was observed for the first time by Hikami and Shirishi on Meikonishi cable-stayed bridge [2]. Then this vibration was observed in other parts of the world. Many studies have been carried out to reveal the construction and operation and conditions of induced vibration of wind and rain in cable-stayed bridges. In the article that Hikami et al presented in 1998, according to their observations of the Meikonishi Bridge, they concluded that the cable vibration in this bridge was caused by the combination of wind and rain. Vibration is characterized by a lower frequency than induced oscillation and with a larger amplitude. The effect of rain originates from the flow of rainwater along the upper part of the inflatable surface of the cable, and with the flow on top of the cable, the appearance of the cable along the length of the piece becomes aerodynamically unstable [3-18].

2- Methodology

The flow of water on the cable causes the effective shape of the cable to change and move along with the oscillation of the cable and creates periodic changes in the aerodynamic force, which ultimately converts the energy caused by the wind into oscillation. According to past observations and research, the vibration of cables occurs when the rain along with the wind hits the cable at an average speed (8-15 m/s) in a direction with an angle of 20 to 60 degrees relative to the cable plane. It should also be kept in mind that the downward slope of the cable should also be in the direction of the wind. The frequencies of the cables are generally low, but the maximum range is very high and in the range of 0.25 to 1 meter, accompanied by rapid movements, which in some cases have even led to strong collisions of adjacent cables

*Corresponding author's email: Ali.golsoorat_pahlaviani@iauctb.ac.ir

[19].

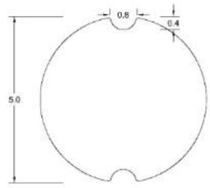
The one-degree-of-freedom model is based on a state analysis that describes the aerodynamic fluctuations along with the flow and the cable. Linearization of the presented model and explicit evaluation of aerodynamic damping forces and excitation forces provide simple formulas for estimating the amplitude of cable vibrations caused by wind and rain [20].

3- Results and Discussion

The cables of cable-stayed bridges usually have a diameter between 100 mm and 180 mm, but according to the dimensions of the wind tunnel, a cable with a diameter of 50 mm was selected. According to the dimensions of the tested sample and the dimensions of the test chamber, two cable samples were tested at angles of 45° and 60° relative to the plane perpendicular to the wind and 25° angle relative to the horizon. The wind tunnel has a test chamber with dimensions of 1000 mm width and 800 mm height and a speed of 0 to 100 m/s. The tested cables were designed as follows:

1- The first sample of cable sheath with a length of 1000 mm and a diameter of 50 mm made of PVC

2- The second sample of the cable sheath is similar to the first sample, with the difference that two grooves with a diameter of 8 mm and a height of 4 mm are installed on it. The grooves have an angle of 45° (Figure 1-a).



(a) (b)

Fig. 1. Cable sheath with grooves, a) Sample with spiral grooves, b) Grooves location

4- Conclusion

To better understand the construction and operation of vibrations with large amplitudes as well as the construction and operation of reducing these amplitudes, the fluctuations of the cable models were measured. Tests on cables with spiral grooves showed a significant reduction in the amplitude of vibrations. The presence of these spiral grooves around the cable eliminates low frequency currents and therefore the vibration amplitude is reduced.

References

[1] E. Sanaee, G. Fadavi, Investigate How to Analyze and Design Cable bridges, Iran University of Science and Technology (in Persian), (1996).

[2] Y. Hikami, N. Shiraishi, Rain-wind induced vibrations of cables stayed bridges, Journal of Wind Engineering and Industrial Aerodynamics, 29(1) (1988) 409-418.

[3] M. Matsumoto, Observed behavior of prototype cable vibration and its generation mechanism, Bridge Aerodynamics. Proceedings of the International Symposium on Advances in Bridge Aerodynamics, Copenhagen, Denmark, pp. 189–211 (1998).

[4] M. Matsumoto, T. Saitoh, M. Kitazawa, H. Shirato, T. Nishizaki, Response characteristics of rain-wind induced vibration of stay-cables of cable-stayed bridges, Journal of Wind Engineering and Industrial Aerodynamics, 57(2) (1995) 323-333.

[5] P. Warnitchai, Y. Fujino, T. Susumpow, A non-linear dynamic model for cables and its application to a cable-structure system, Journal of Sound and Vibration, 187(4) (1995) 695-712.

[6] S.H. Cheng, D.T. Lau, Modeling of cable vibration effects of cable-stayed bridges, Earthquake Engineering and Engineering Vibration, 1671-3664(01-0074-12) (2002).

[7] M. Gu, X. Du, Experimental investigation of rain–wind-induced vibration of cables in cable-stayed bridges and its mitigation, Journal of Wind Engineering and Industrial Aerodynamics, 93(1) (2005) 79-95.

[8] D. Zuo, N. Jones, Interpretation of field observations of wind- and rain-wind-induced stay cable vibrations, Journal of Wind Engineering and Industrial Aerodynamics, 98 (2010) 73-87.

[9] H. Yamaguchi, Y. Fujino, Stayed cable dynamics and its vibration control, in International Symposium on Advancesin Bridge Aerodynamics, Balkema, Rotterdam, Netherlands,, pp. 235–253 (1998).

[10] A. Pinto da Costa, J.A.C. Martins, F. Branco, J.L. Lilien, Oscillations of bridge stay cables induced by periodic motions of deck and/or towers, Journal of Engineering Mechanics, ASCE, 122(613–622) (1996).

[11] P. Warnitchai, Y. Fujino, B. M.Pacheco, R. Agretp, An experimental study on active tendon control of cable-stayed bridges, Earthquake Engineering and Structural Dynamics, 22, 93-111 (1993).

[12] K. Takahashi, Y. Konishi, Non-linear vibrations of cables in three dimensions, part II: Out-of-plane vibrations under in-plane sinusoidally time-varying load, Journal of Sound and Vibration, 118(1) (1987) 85-97.

[13] N. Daniotti, J.B. Jakobsen, J. Snæbjörnsson, E. Cheynet, J. Wang, Observations of bridge stay cable vibrations in dry and wet conditions: A case study, Journal of Sound and Vibration, 503 (2021) 116106.

[14] Y. Chang, L. Zhao, Y. Zou, Y. Ge, A revised Scruton number on rain-wind-induced vibration of stay cables, Journal of Wind Engineering and Industrial Aerodynamics, 230 (2022) 105166.

[15] Y. Ge, Y. Chang, L. Xu, L. Zhao, Experimental investigation on spatial attitudes, dynamic characteristics

and environmental conditions of rain–wind-induced vibration of stay cables with high-precision raining simulator, Journal of Fluids and Structures, 76 (2018) 60-83.

[16] H. Jing, Y. Xia, H. Li, Y. Xu, Y. Li, Excitation mechanism of rain–wind induced cable vibration in a wind tunnel, Journal of Fluids and Structures, 68, no. 32–47 (2017).

[17] FHWA, Wind-Induced Vibration of Stay Cables, Report of Federal Highway Administration, FHWA-HRT-05-083, (2007).

[18] P.A. Irwin, Wind vibrations of cables on cable-stayed bridges. Proceedings of Structural Congress XV, Portland, OR,pp. 383–387 (1997).

[19] P.G. Specification, Recommendations for Stay Cable Design, Testing and Installation, 4th edh, Post-Tensioning Institute Committee on Cable-Stayed, Bridges, (2001).

[20] H. Vo-Duy, C.H. Nguyen, Mitigating Large Vibrations of Stayed Cables in Wind and Rain Hazards, Shock and Vibration, 2020 (2020) 5845712.

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