ISSN (ONLINE): 2349-7084
GLOBAL IMPACT FACTOR 0.238
I2OR PIF 2.125

INTERNATIONAL JOURNAL OF COMPUTER ENGINEERING IN RESEARCH TRENDS
VOLUME 2, ISSUE 10, OCTOBER 2015, PP 683-686

Rain - Wind Induced Vibrations of Stay Cables

[1]J. Chinna Rama Swamy, [2]P. Ravindra Nagu, [3]K. Laliteswar

Abstract: Rain - Wind Induced Vibrations of a cable is a concomitant issue in cable - stayed bridges which it will threats the durability and safety of the structures. A deep understanding the phenomenal of the Fundamental physics was important to understand for improving the effective remedies to resolve. This Concept was firstly observed several decades ago. It found the attention of investigators when Shiraishi and Hikami observed that, at the time of construction of the Meikonishi Bridge in Japan, under the excitation from the wind during rain, these stay cables often exhibited large-amplitude vibrations. Rain – Wind induced vibrations was identify by an oscillation frequency and also the large amplitude that is much lower than the comparable Strouhal frequency for a classical Karman – vortex induced vibrations, which it have been regularly observed on many cable - stayed bridges and stated as Rain – Wind - Induced vibrations. By the last three decades, Rain - Wind induced vibrations of Stay cable bridges have been subjected to extensive study for two reasons. Firstly this type of vibrations occurred at large amplitude and potentially threatens the serviceability and safety of cable-stayed bridges. There have been records in the literature of both cable failure and damage to the Cable Deck connection because of Rain – Wind induced vibrations. Also secondly, the mechanism of Rain – Wind induced vibrations, as it will be examined in this following section.

Index Terms - Rain-Wind, Strouhal frequency, Cable - stayed Bridge, Cable Deck.

---

1 Introduction

Cable - Stayed Bridges are relatively a new structural form that made likely with sequence of construction technology, advances in manufacturing of materials, and also analytical capabilities which that took place heavily with in the last few decades. The first modern Cable - Stayed Bridge is the Stromsund Bridge which is built in 1950's at Sweden. It has only two cables which on each side of tower and also on the anchored to steel **'I'** edge girders. An early Engineering approach to the stay cables was hybridized and essentially derived from the already established Engineering experience with suspension cables and post-tensioning technology. Today, Cable - stayed Bridges has firmly established their un-rivaled positions as it most efficient and also cost effective structural form. The cost efficiency and the general satisfaction with their aesthetic aspects had propelled span range of either direction, with both increasingly longer and increasingly shorter spans being designed and constructed at the present time. The Stay Cables are flanking adjustable structural divisions with very low 'Fundamental persistence'. Due to the range of different cable lengths, collection of the Stay Cables on the Cable - Stayed Bridge has practically a continuum of fundamental and also greater mode frequencies. So, any stimulation mechanism with any arbitrary frequency is likely to be finding one or more cables with either a fundamental or to the excitation. Cables also have very little inherent damping and also clumsy to dissipate the excitation energy. For this reason, the stay cables can be somewhat lively by the nature and has been known to be a susceptible to excitations especially, during the construction of Rain - Wind and also the wind conditions. One of the effective methods available for satisfying was to raise the natural frequency of the cables over the use of a cable Cross – Ties which the external dampers that increase cable damping and also through deflect of the deep spread recognition of stay cable issues. However, those incorporating external dampers have generally performed well.

- *Chinna Rama Swamy Jetty is currently pursuing Master of Technology in Structural Enginering from M V R College of Engineering & Technology, India, PH-8125002588. E-mail:chinnaramaswamy345@gmail.com*
- *Ravindra Nagu Penugurthi, Bacheolor of Technology in Civil Engineering from M V R College of Engineering & Technology, India, PH-9000330877. E-mail:pravindra5797@gmail.com*
- *Laliteswar Katragadda, Bacheolor of Technology in Civil Engineering from M V R College of Engineering & Technology, India, PH-9966023123. E-mail: katragaddalaliteswar@gmail.com*

2. RAIN – WIND INDUCED VIBRATIONS

The combination of moderate wind speeds and rain can cause huge amplitude cable vibrations at low frequencies. This type of phenomenon had observed so many on cable-stayed bridges and has been researched in detail.

These vibrations were occupied during rain and moderate wind speeds i.e. 18-34 mph and 8-15 m/s in the oversight of 20° - 60° to cable in the direction of wind. A frequency was very low which it is very less than 3 Hz. The peak amplitude is very high, in the range of 10-in to 3-ft (0.25-m to 1.0-m), with forcible move appear in the opposite adjacent cables recognized in many cases.

Wind tunnel tests has presented that rivulets of water moving down the lower and upper surfaces of the cable in rainy weather were the important aspect of this 'Elastic instability'. The water creek changed the effective shape of the cable and it moved as cable oscillated which is causing cyclical changes in the aerodynamic forces which led to the wind feeding energy into vibrations.

The wind direction results the stimulation was approximately

45° to the cable planes. The particular range of the wind velocities, which caused oscillations, that appears to be maintained the upper rivulet within a critical zone on the upper surface of the cable.

It is not worthy that some of the rain or wind vibrations that have been identified on the Cable - stayed bridges has acquired during construction when both the damping and mass of the cable system are likely to possess lower to finished state, thus it will be resulted at low Scruton number. The grouting of the cables adds both damping and mass, and also often sleeves of visco elastic material are added to the cable end regions which further increase in damping. The obtainable evidence shows that the rain or wind type of vibration primarily arises as outcome of some cables which has particularly low damping as 0.001 ranges.

3. PROBLEM OF RAIN - WIND INDUCED VIBRATIONS

Large-amplitude stay cable vibrations are often associated with rainfall; therefore the current study has been primarily focused on the problem of rain-wind-induced vibrations. This Research was originated by full scale assessment on disparate bridges around the world, from which some characteristics of the vibrations i.e. amplitude vibration and frequency as well as their dependence on wind and rain have been reported. Observations from various investigations, these full-scale measurements, however, are not comprehensive and do not necessarily reveal the complete picture of wind- and rain-wind-induced stay cable vibrations. In fact, many observations reported in various literatures are contradictory.

While early reports of various papers suggested that only the stays declining in control of the wind is influenced to Rain - Wind excitation subsequent observations indicated that stays with opposite disposition is moved together. Previous reports also indicated that Rain – Wind induced vibrations were restricted to a wind speed range of 6 - 17 m/s, which is in the sub-critical range of the corresponding Reynolds number. Later observations, however, have reported vibrations occurring at a wind speed as high as 40 m/s. Further, the role of rainfall in the stimulation components has debated. At the same time maximum inspection suggested that large amplitude vibrations occur only with rainfall and that it is the water rivulet forming on the cable surface that renders the cable cross-section aerodynamically unstable, other observations however, have reported stay cables vibrating at large amplitude without precipitation.

To study the problem in a controlled manner, wind tunnel tests have been conducted in an attempt to replicate the vibrations observed in the field. Many tests were designed expressly to study the perceived important role of rain. Very different observations and, consequently, different hypotheses on the mechanism of the vibrations. However, resulted from these tests depending on the manner in which rainfall was simulated. It was subsequently proposed based on these wind tunnel tests that the actual motion of the water rivulets plays a negligible role in the excitation mechanism, and that it is the average position of the water rivulet that is important in changing the cross-section of the cable and rendering it susceptible to wind excitation.

While most of these wind tunnel tests have been successful in reproducing large amplitude vibrations and illustrating specific aspects of stay cable vibrations, such as the sensitivity of the cables to the excitation of wind or wind and rain and the dependence of the vibrations on wind speed and direction, they all have their respective drawbacks or limitations, both in the setup of the tests and the interpretation of the results, and may not adequately or faithfully reveal the true mechanisms of the phenomena of interest.

A. Present understanding

Observed large-amplitude stay cable vibrations are often associated with rainfall, therefore the current study has been primarily focused on the problem of rain-wind-induce vibrations. The investigation was initiated with full-scale measurements on several bridges around the world, from which some characteristics of the vibrations, such as the vibration amplitude and the frequency, as well as their dependence on wind and rain have been reported. Observations from these full-scale measurements, however, are not comprehensive and do not necessarily reveal the complete picture of wind- and rain-wind-induced stay cable vibrations. In fact, many observations reported in the literature are contradictory. While early reports suggested that only the stays declining in the direction of wind were susceptible to rain-wind excitation, subsequent observations indicated that stays with opposite inclination can be excited simultaneously. Early reports also indicated that rain wind induced vibrations were restricted to a wind speed range of 6 to 17 m/s, which is in the sub-critical range.

Based on various research papers the observations from both the field and the wind tunnel tests, analytical formulations have also been pursued in attempt to explain and predict the problematic vibrations under specific wind and rain conditions.

4. STUDY OF MITIGATION METHODS

Development of recommended design approaches was based on previous and current research focusing on cable dampers. Theories on the behaviour of linear and nonlinear dampers systems was developed and compared to field measurements on 'The Leonard P. Zakim Bunker Hill Bridge', 'Fred Hartman Bridge', 'Veterans Memorial Bridge' and 'Sunshine Skyway Bridge'.

A. Linear and non-Linear Dampers

To suppress the problematic vibrations of the stay cables 'Dampers' are added to stays near the anchorages (Because of the practical limitations of an installation). Even though the mechanisms, which that induced observed vibrations will still not completely understood. Dampers will have relatively wide spread use and also their effectiveness had been determined. Though the criteria for the damper design are not established. The Current recommendations for required damping levels to

ISSN (ONLINE): 2349-7084
INTERNATIONAL JOURNAL OF COMPUTER ENGINEERING IN RESEARCH TRENDS
VOLUME 2, ISSUE 10, OCTOBER 2015, PP 683-686

suppress rain/wind vibrations were developed using relatively simplified wind-tunnel models, and it is not clear whether these guidelines are adequate or appropriate for vibration suppression in the field. In addition, it is important to note that vibrations can occur in more than one mode of a cable and little have been done to the address of the question which required damping levels to an each mode. An anticipated wide spread application of the dampers for a cable vibration suppression justifies further research aimed at better understanding the resulting dynamic system and refinement of 'Design Guide lines'. The example for a damper that provided to a cable anchorage is shown in the Figure 1.

B. Linear dampers

Free vibrations of a taut cable with an attached linear viscous damper were investigated in detail. In designing a damper for the cable vibration suppression it was necessary for determination of the levels of supplemental damping provided in the first several modes of vibration for different values of the damper coefficient and different damper locations. In the previous investigation of the linear dampers will have focused on vibrations in the first few modes for damper locations near the end of cable. Damper performance in higher modes is particular interest as; full-scale measurements were indicating that vibrations of moderate amplitude can occur over a wide range of cable modes. Now, this study will investigate the dynamics of taut cable -damper system in higher modes and without restriction on the damper location.

It is important to note that because the mode number is incorporated in the non-dimensional damping parameter. The optimal damping ratio can be achieved in only one mode of a vibration and this will a potential limitation for the linear dampers. Because it was currently un clear how to specify a priori that the mode in which highly optimal performance will be achieved for effective suppression of stay cable vibration and also designing the damper for an optimal performance in a particular mode may potentially leave the cable susceptible to vibrations in other modes.

C. Non-linear Dampers

The dynamic behavior of a taut cable with a passive, Power Law Damper and nonlinear attached at an intermediate point was investigated. Recent investigations indicated that a nonlinear damper may potentially overcome the limitation in performance of a linear damper whereby optimal damping performance can only be achieved in one mode of vibration.

The exact formulation of the complex Eigen value problem for a taut cable with a linear damper was extended to develop a single-mode approximation for the amplitude of a dependent effective damping ratio for the power law damper, in which an asymptotic approximate solution was revealed a non - dimensional grouping of parameters κ that was used to extend the universal estimation curve for the linear damper to the case of a nonlinear damper.

The optimal damping performance was achieved in general at the different amplitudes of a vibration in every mode. An optimal value for the damper coefficient can be determined by specifying design amplitude of oscillation in a given mode at which the optimal performance is desired. Therefore a non-linear damper has the potential to allow optimal damping performance over a wider range of modes than for a linear damper.

Results before damper installation will show the patterns that are consistent with other field and wind tunnel observations:

- A high density of points is seen near the abscissa, which generally corresponds to vortex-induced vibration in a variety of modes and low-level buffeting response of the stay to random excitations.
- Multiple points over a wide range of wind speeds are of high amplitude (RMS acceleration is greater than 0.5g) which indicates the characteristic signature of rain/wind oscillation.
- One-minute mean wind speeds at deck level reached 34 mph (15 m/s) before the dampers were installed, and almost 40 mph (18 m/s) in the period after an installation. The latter value which corresponds to a one minute average wind speed of 60 mph (27 m/s) at the top of the tower which is recorded during a thunderstorm.
- The dependence on wind direction is also clear. With A16 showing its high responses between 90°and 160° , and A23 over a narrower range between 90° and 135°.

Results after the installation of dampers which suggest the following:

- Amplitudes are significantly reduced across all recorded wind speeds [up to 40 mph (18 m/s) at deck level] with maximum RMS acceleration amplitudes of around 0.5g.
- Dependence on the wind direction have been altered significantly, with the largest responses now nearer to a 90° angle of incidence.
- Depends on the measured forces in the dampers they are functioning and providing dissipative force to the stays as intended.

5. CONCLUSIONS

Stay-cables can be easily excited by the cooperation of wind and rain or only wind, if certain conditions would be satisfied and Periodical inspection of damping devices is definitely required. Stay cables are likely to vibrate under the combined effect of rain and wind. The combination of moderate wind speeds and rain will cause high or large amplitude cable vibrations with low frequencies. This type of phenomenon has been observed on various cable - stayed bridges and also it was discussed.

The rain or wind oscillations are because of the formation of rivulets on the cable surface. Then, it is probable that instability is very sensitive to the surface roughness. Several researchers have tried on the cable surface by using small protrusions to solve. "Flamand" had used on the cables of the Normandie Bridge by helical fillets 1/16 inches (1.5 mm) high. This method was proven successfully with the minimal increase in drag coefficient.

ISSN (ONLINE): 2349-7084

INTERNATIONAL JOURNAL OF COMPUTER ENGINEERING IN RESEARCH TRENDS
VOLUME 2, ISSUE 10, OCTOBER 2015, PP 683-686

REFERENCES

[1] A.RAEESI, S. A. (APRIL 2011). Some insight into the wind induced vibration of stay cables in the context of rigid static inclined circular cylinder. Journal of applied fluid mechanics.

[2] CORP, P. C. (2005). Wind induced vibration of stay cables.

[3] FELBER, N. P. (2006). Wind induced vibration of stay cables.

[4] PWRI.HRT, F. (2007). Wind induced cable vibrations.

[5] FHWA-HRT.HU, W. L. (2013). Influence of dynamic properties and position of rivulet on rain wind induced vibration of stay cables. American society of civil engineers.

[6] HUANG, L. (2011). Experimental studies on bridge stay cable vibration mitigation using external viscous damper. University of Windsor.

[7] JA MAIN AND NP JONES, H. Y. (2000). Characterization of rain wind induced stay cable vibrations from full scale measurements.

[8] JONES, D. Z. (2005). Stay cable vibration monitoring of Fred Hartman Bridge and veterans Memorial Bridge. Fhwa/tx.

[9] R.S PHELAN, K. M. (2006). Investigation of wind rain induced vibrations on cable stayed bridges. Texas Tech University.

[10] SCOTT, M. K. (2008). Performance and repair design of stay cables with rain/wind induced vibrations.

[11] SHIRAISHI, Y. H. (1998). Rain and wind induced vibrations of stay cabled bridges. Journal of wind engineering and industrial aerodynamics.

[12] SIRINGORINGO, D. (2013). Vibration mechanisms and controls of long span bridges. Structural Engineering international.