AERODYNAMICS LABORATORY

Finite Element Simulation of Stay Cable Systems with Crossties and Dampers

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Outlines

- Significance of the Research
- Key Findings from the Research
- Current Status of the Research
- Recommendations for Further Research

Significance of the Research (1)

- Through the finite-element time-history analysis techniques, the research has provided information on the response of stay cable systems equipped with different types of mitigation measures under realistic wind profiles.

Significance of the Research (2)

- The analysis technique used is quite versatile to incorporate different types of mitigation measures within the framework of the general finite element procedure.
- Analysis conducted provides explicit time-history responses as well as modal characteristics of the system in frequency domain.

Significance of the Research (3)

- Literature survey indicates that the majority of studies on stay cable systems coupled with mitigation measures are either analytical, semi-analytical/semi-numerical, or mode-based numerical analysis
- Explicit, time-history analysis of cable systems subjected to realistic wind profiles is scarce

Significance of the Research (4)

- Effectiveness of diverse mitigation strategies involving crossties and dampers has been assessed and compared through these explicit, time-history analysis techniques.
- Sensitivity of the effectiveness of a particular mitigation measure to input wind profile is analyzed.

Key Findings (1)

- The performance of a cross-tied cable network is sensitive to the frequency content of the input wind profile
- Crossties are particularly effective in suppressing cable vibrations containing appreciable low-frequency components

Key Findings (2)

- Performance of cross-tied cable system is not necessarily proportional to the quantity (or the number of lines) of crossties. Excessive provision of crossties would render the system vulnerable to high-frequency wind profile

- Over-sized (or large-diameter) crossties make the system overly rigid, rendering the system vulnerable to high-frequency local vibration modes

Key Findings (3)

- Crosstie grounding increases the natural frequencies of the system's global modes of vibration, thus enhancing the mitigation effectiveness against low-frequency wind
- Performance of cross-tied cable network is insensitive to the pre-tension level of the crossties (as long as this pre-tension level is high enough to prevent the slack of crossties under design wind load)

Key Findings (4)

- The mitigation effectiveness of dampers depends sensitively on the spectral properties of the input wind profile
- Viscous dampers are particularly effective in controlling stay vibrations induced by highly turbulent wind rich in high-frequency components

Key Findings (5)

- Effect of a combined use of cable crossties and external dampers is not necessarily the sum of the effects of their independent uses, its efficacy depending on the layout of the crossties and dampers and on the spectral properties of input wind profiles

Key Findings (6)

- External dampers installed at crosstie connections to the deck appear to be very efficient in dissipating vibration energy of cross-tied cable systems, constituting a promising mitigation alternative

Current Status (1)

- The current phase of the research is near its completion.
- An interim report summarizing the research results compiled so far has been prepared and currently is in the process of review by the panel members and other individuals
- Manuscripts to be submitted to major professional journals are currently being prepared. Two or three papers in referred journals are being sought.

Current Status (2)

- Results from the current research have been presented at an International symposium and a workshop:

1. Bosch, H. R. and Park, S. W. (2005). Effectiveness of external dampers and cross-ties in mitigation of stay cable vibrations. 6th International Symposium on Cable Dynamics, Charleston, SC, September 19-22, pp.115-122.

2. Park, S. W. and Bosch, H. R. (2006). Influence of cross-tie geometry and details on mitigation of wind-induced cable vibrations, Wind Induced Vibration of Cable Stay Bridges Workshop, St. Louis, MO, April 25-27.

Current Status (3)

- A paper will be presented at another international conference:

  "Twelfth International Conference on Wind Engineering (12 ICWE)" , July 1-6 2007, in Australia.

Recommendations for Further Research (overview)

1. **Research on Combined Use of Crossties and Dampers**
2. **Research on Different Types of External Dampers**
3. **Research on Parametric Excitation of Stay Cables**
4. **Testing Mitigation Systems and Strategies under Larger Spectrum of Wind Profiles**

Recommendations for Further Research (1a)

1. Research on Combined Use of Crossties and Dampers

- Combined use of crossties and dampers has attracted increasing attention
- No in-depth studies have been conducted on this issue, and no design guidelines have been established

Recommendations for Further Research (1b)

- A combined use of the two systems has potential advantages over their independent uses.
- Crossties alone increase the overall stiffness of cable network but does not increase the network's energy dissipation capabilities.
- Dampers alone contribute to the increased energy dissipation capabilities of the system but does not increase the system's overall stiffness.

Recommendations for Further Research (1c)

- A preliminary analysis of stay cable system augmented with both crossties and dampers has indicated a good promise.
- In-depth studies are needed before the concept can be transformed into a mitigation measure that can be implemented.

Recommendations for Further Research (2a)

2. Research on Different Types of External Dampers

- External dampers have been accepted as a very effective means of controlling stay cable vibrations.
- Viscous (or hydraulic) dampers have been commonly specified as a type of external dampers.
- Despite their widespread use and inherent merits, viscous dampers have been reported to have weaknesses in terms of long-term durability and maintenance requirement.

Recommendations for Further Research (2b)

- Other types of dampers, such as friction dampers and viscoelastic dampers, are known to have certain strengths and advantages over viscous-type dampers
- These alternate type dampers have been successfully used in other areas of application including wind mitigation of high-rise buildings and seismic mitigation of highway bridges.

Recommendations for Further Research (2c)

- Friction dampers offer threshold vibration amplitudes below which dampers remain unengaged, resulting in elongated longevity of the dampers.
- Viscoelastic dampers are known to offer optimal damping for a broad range of frequencies (or vibration modes).
- Both friction dampers and viscoelastic dampers are generally viewed as less demanding in terms of maintenance requirement than viscous dampers.

Recommendations for Further Research (2d)

- Nonlinear viscous dampers with a fractional power have also been addressed by others. However, no particular finite element simulation of stay cable systems augmented with fractional-power viscous dampers has been reported in the literature.
- Without major modification to the existing analysis model developed by the research team, the mitigation effectiveness of nonlinear viscous dampers may be assessed and compared with other types of dampers.

Recommendations for Further Research (3a)

3. Research on Parametric Excitation of Stay Cables

- Current research is based on the simplifying assumption that the deck and tower are fixed or immovable with respect to the stay cables.
- Recent studies presented by others suggest that vibration of bridge deck or tower could significantly affect the vibration of stay cables under wind loading.

Recommendations for Further Research (3b)

- Amplitude of cable vibration response to parametric excitation is known to be a function of the magnitude of support displacements, damping characteristics, and the ratio of the bridge (deck/tower) natural frequencies to the fundamental natural frequencies of the cable.
- Parametric excitation amplitudes are reported to be most severe when the bridge's natural frequencies are equal, or very close, to the cable's fundamental frequencies.

Recommendations for Further Research (3c)

- Finite element analysis of an extended domain including the deck, tower as well as stay cables may be carried out by expanding the existing analysis model.
- Clarification of the issue of parametric excitation would add a substantial value to the current research study by releasing the simplifying constraint of immobile deck and tower.

Recommendations for Further Research (4a)

4. Testing Mitigation Systems and Strategies under Larger Spectrum of Wind Profiles

- Different mitigation strategies involving cable crossties and external dampers have been tested via finite-element time-history analysis under limited set of wind profiles so far.
- These wind profiles used in analysis are based on the wind records from a limited number of bridge sites.

Recommendations for Further Research (4b)

- Currently, a study on wind load criteria for cable supported structures is in progress by other research team at Turner-Fairbank.
- Development of a set of expanded input wind profiles and testing the effectiveness of different mitigation strategies under these wind profiles would allow more reliable conclusions to be drawn regarding the effectiveness of such mitigation strategies.

Thank you!