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Artikel: Monitoring system for a large cable-stayed bridge in a wind and seismic area

Autor: Wenzel, Helmut

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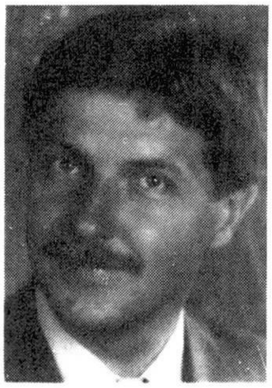
Monitoring System for a Large Cable-Stayed Bridge in a Wind and Seismic Area

Système de surveillance d'un grand pont dans une zone de vents et de séismes

Ueberwachungssystem für eine grosse Brücke in einer Gegend mit Taifunen und Erdbeben

Helmut WENZEL
Dr-Ing.
Vienna Consulting Eng.
Vienna, Austria



Helmut Wenze is member of WC 5 of IABSE. He earned a Ph.D. in Bridge Construction from the University of Vienna in 1978. He is the Managing Director of VCE, with offices in Vienna, Taiwan and Korea. Dr. Wenzel also teaches Bridge Design and Construction at the University of Vienna.

SUMMARY

To understand the behaviour of a major bridge under extreme loading conditions, an innovative Monitoring System was designed to be implemented in the Kao Ping Hsi Bridge in Taiwan. This innovative bridge is located in an area with frequent typhoons and a considerable number of earthquakes per year. The aim is to achieve full understanding of the three dimensional behaviour of the structure and to derive suitable statutes for National Standards.

RÉSUMÉ

Un système de surveillance moderne sera installé sur le pont de Kao Ping Hsi à Taiwan, afin de recueillir et analyser des informations sur le comportement de ce pont pendant des typhons et tremblements de terre, fréquents dans cette région. Le but final de ce projet est de construire des ouvrages encore plus sûrs et de contribuer à l'amélioration des normes nationales.

ZUSAMMENFASSUNG

Es wird an der Kao Ping Hsi Brücke in Taiwan ein innovatives Ueberwachungssystem installiert, das Daten über das Verhalten der Brücke unter den häufig vorkommenden Taifunen und Erdbeben aufzeichnen und analysieren soll. Das Endziel ist es, bessere und sicherere Bauwerke zu entwerfen. Die Ergebnisse sollen in die einschlägigen Bestimmungen der nationalen Normen eingearbeitet werden.

1. THE BRIDGE

The Kao Ping Hsi Bridge in Taiwan is a Cable Stayed bridge with a record breaking cantilever of 330 meters. The overall concept of the bridge is innovative and trend setting. The cross section is a closed steel box, designed to withstand extraordinary dynamic loads. The deck height is 3,20 meters with a width of 34,50 meters and suspended in the middle plane.

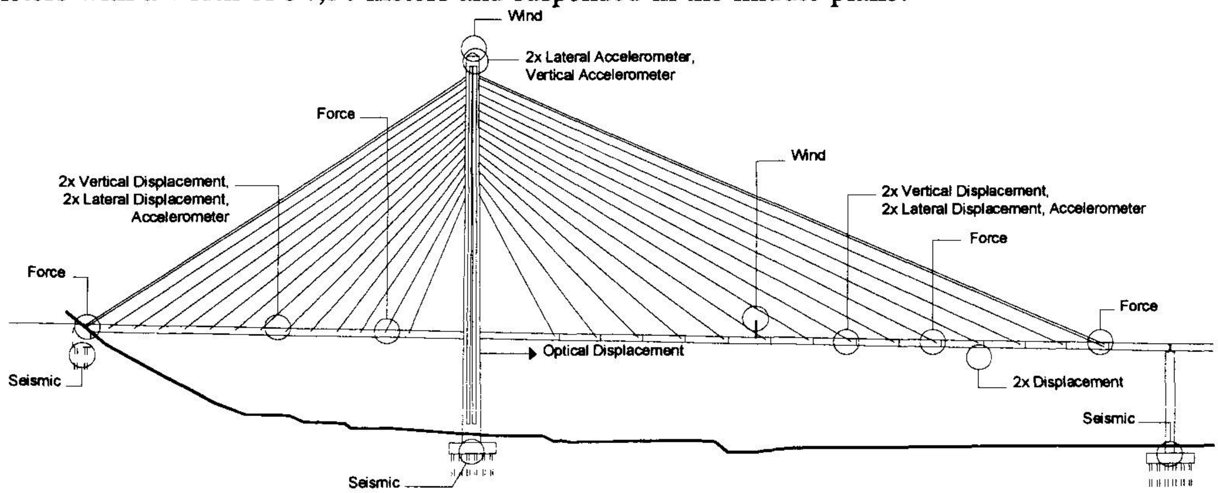


Fig. 1 Kao Ping Hsi Bridge, Taiwan

1.1 The Load Conditions in Taiwan

The island experiences an average of 2 typhoon landings per year. It also receives a total of 65 earthquakes per year, with high potential of a big one within a 60 year return period, that is within the lifetime of the bridge.

The hourly wind speed was determined to be 52 m/sec at deck level, which is 45 m above ground. The peak gust is 76 m/sec with a duration of 4 sec. These loads were determined with the help of a Monte Carlo Simulation considering the 105 typhoons, which have passed through the area within the last 60 years. Turbulence should be below 5% due to the proximity of the sea. A clear Vortex Shedding phenomena was typical recorded with a wind speed of approximately 10 m/sec.

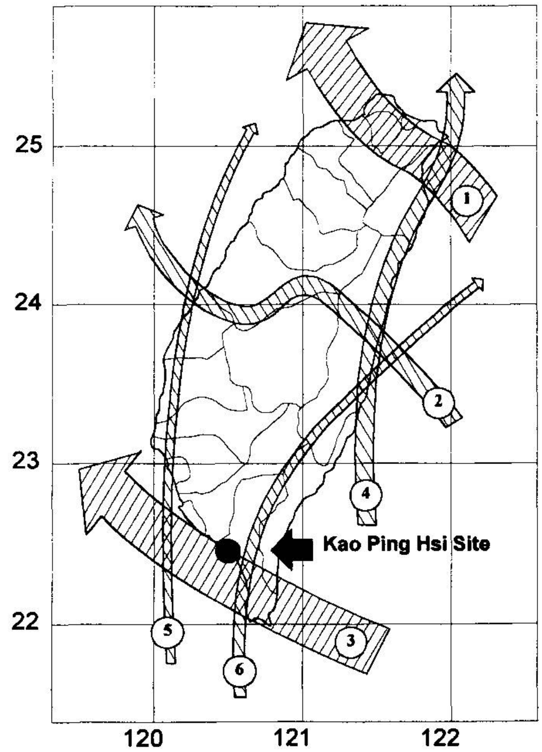


Fig. 2 Paths of typhoons over Taiwan

At a nearby recording station, the seismic record shown in Fig. 3 was recently recorded. There have been a considerable number of similar records by this station, over the last 30 years, of the magnitude illustrated in the figure. Therefore it is highly probable that within a reasonable period the response of the bridge during an earthquake will be measured.

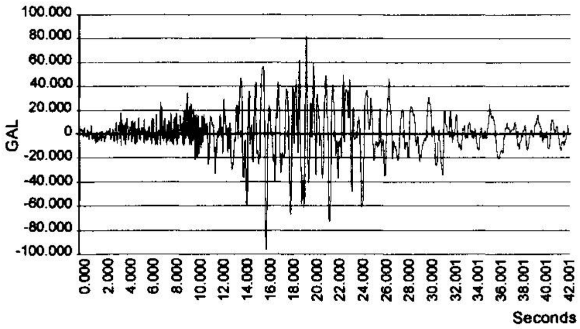


Fig. 3 Seismic event recorded in site area

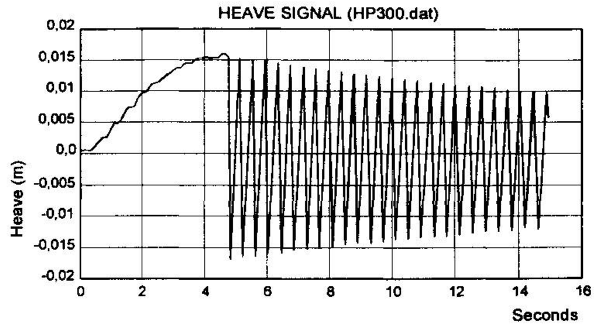


Fig. 4 Bridge damping characteristic

2. THE MONITORING SYSTEM

2.1 The General Concept

In the future, this Monitoring System shall form a basis for research on Cable Stayed Bridge behaviour under wind and seismic loads. The high probability of a recordable event makes the project most interesting. Therefore a number of Universities, Consultants and Bridge Owners are concentrating to make the project successful.

It was clearly demonstrated by the earthquakes in Los Angeles 1994 and Kobe 1995, that simplifications in modelling and calculation, as applied to date are not able to describe the action sufficiently. The Monitoring System must therefore be able to produce data fulfilling the following criteria:

- Three dimensional recording.
- Recording of the differential motion at all supports.
- Recording of all data that might be of influence on the structural behaviour.

The author is of the opinion that only a full three dimensional analysis will be able to realistically describe the response of the structure due to excitation from wind or earthquake.

2.2 Components of the Monitoring System

To receive complete records the following data are acquired:

- Ground motion in three locations.
- Acceleration of deck and pylon.
- Cable forces of significant cables.
- Displacement of the structure.
- Full meteorological data set.

A sketch of the system is shown in Fig. 5. The system will be implemented step by step, beginning during construction, to receive data about the construction history.

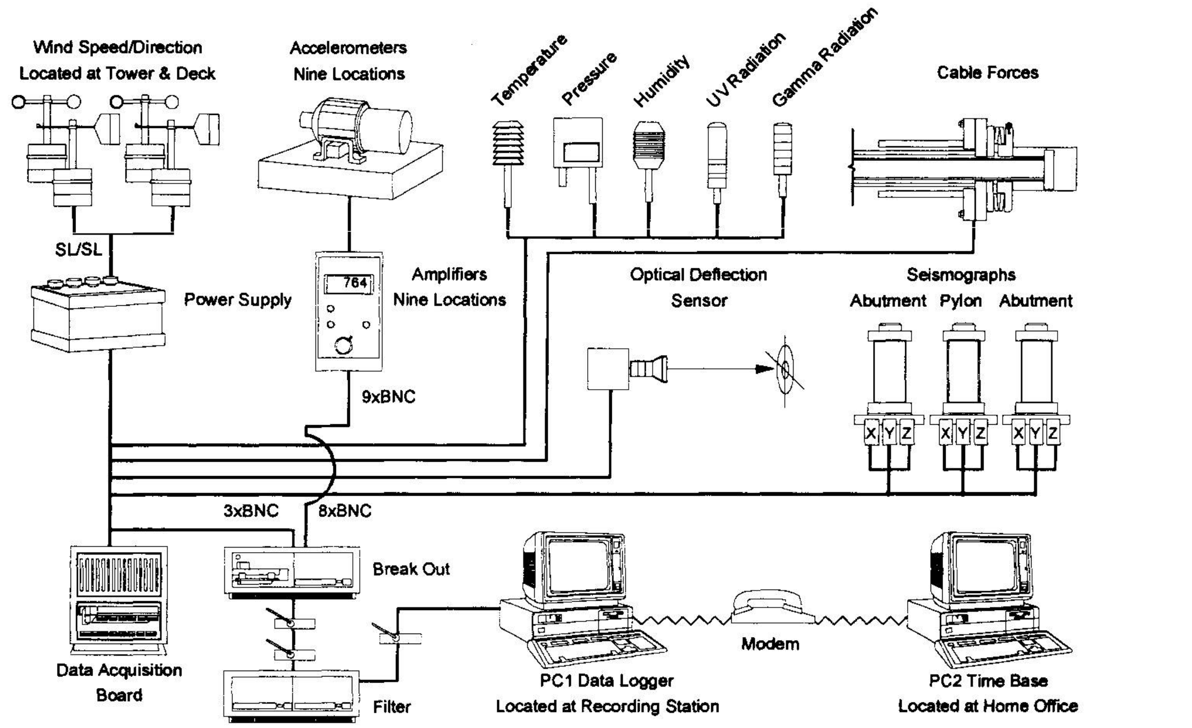


Fig. 5 Monitoring system diagram

2.3 Details of the Sensors

The variations of the cable forces during vibration, as well as temperature changes and traffic loads, are monitored through simple devices that have been developed for this purpose. High quality metal rings will be placed below the cable anchor on top of the pylon. To obtain the best results, each ring has 12 special strain gauges mounted concentricly around it. Relatively weak signals from each strain gauge will be amplified and transmitted up to 500 m, to the location of the data acquisition unit.

The data acquisition unit represents an intelligent system designed to receive analog signals.

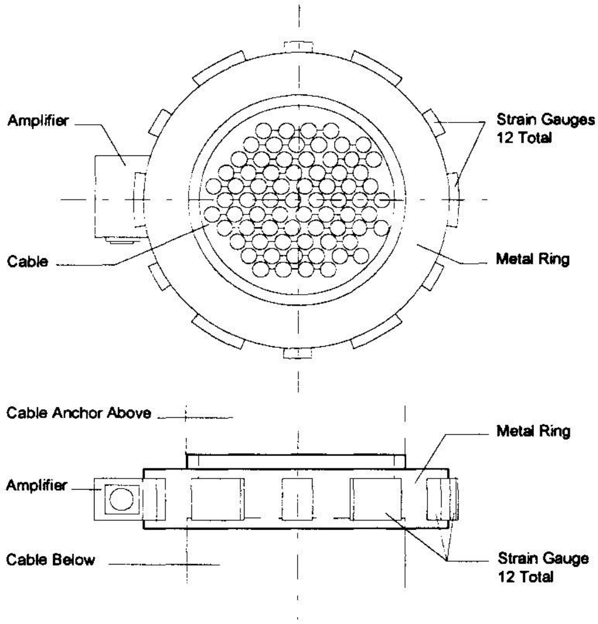


Fig. 6 Cable forces sensor

The measurement of acceleration of the structure is performed in correlation with the measurements from the full model wind tunnel test. This will allow a direct comparison of results and provide information on the reliability of the test. To support the results from the acceleration measurement, an optical displacement instrument will be installed. It consists of a laser controlled deflection measurement unit. This will allow data from different sources, which should conform, to be compared.

The wind recording shall enable the engineers to define the wind profile at the location of the bridge and generate data about turbulence and coherence of the wind field. This is particularly important, since these types of measurements are not currently available in Taiwan.

2.4 Data Recording Unit

For data recording, analysis and control, an integrated multi-synchronous channel system was chosen. This system allows on-line or time controlled conditioning of the signals from the sensors by amplifiers, filters or counters. The data can be recorded simultaneously and are transferred to an event recorder, which can be freely programmed to suit the requirements. The system might be also used as data logger or printer.

The sampling rate for the accelerometers is 100 Hz, which generates huge quantities of data. A selection process was designed to record considerable events only. The basic concept is:

- To record any event that reads above a predetermined target value.
- To record major events and their history dated back at least 48^h to find out if there is any visible indication in the data on the force of the coming event.
- A customer defined program segment shall enable the user to record in any other mode.

The data shall be transferred via modem to a PC, where the data are processed. The program is installed under "Windows", which makes the application easy and comfortable to use. The data are controlled by powerful macros, which provide comfort and flexibility in the handling of the system. It allows:

- Comfortable adjustment of the measurements by the recording unit.
- Automatic data transfer from the logger to the PC.
- Triggering of measuring programs on customer's requirement.
- On-line display of any channel required.
- Data reduction and compression to save storage space.
- Control of complex measurement programs by way of synthesizer, controller and digital input/output.

2.5 Data Processing

The main target is to find a relevant spectrum for seismic activities in the area and to confirm the accuracy of the results of the wind tunnel tests. The quality of the results will be highly dependent on the number of readings available. The various earthquake recordings will be superimposed to find similarities.

Typical examples are the detection of Vortex Shedding excitation as determined in the wind tunnel tests. Refer to Fig.7. The target is to close the gap between wind tunnel results and the very rare site measurements. Another interesting result would be real figures for the damping of the structure. A typical vibration is shown in Fig.4, which represents the response after an impact.

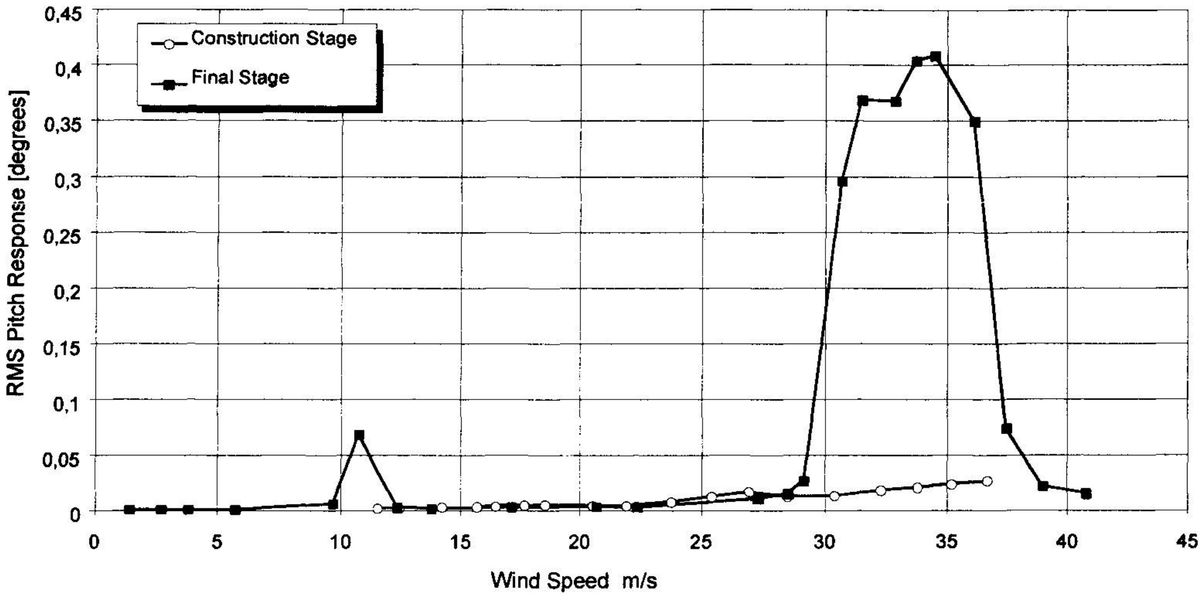


Fig. 7 Predicted vortex shedding excitation

3. CONCLUSION

The proposed Monitoring System will produce data that will help structural engineers understand their structures and arrive at realistic loading conditions for extraordinary structures. The proposed Monitoring System shall fulfil all requirements of flexibility and interactive control to react on recorded events. It is intended to take a step forward in bridge engineering for countries with high risk potential.

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