Development of a Stand-alone Bridge Monitoring System

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1. Introduction

To ensure serviceability and reliability of existing bridges, it is necessary to obtain real structural behaviors to assist decision-making such as maintenance, diagnosis, repair and rehabilitation. Traditionally, engineers obtain bridge performance via current visual inspection and detailed inspection at a fixed time interval. However, absences of sufficient even absolutely necessary measurement information and common need of collecting more information about the condition state of bridges make obstacles for above decision-making. Recent advances in measurement and information technology have created condition to establish a bridge monitoring system for enhancing decision support by introducing some intelligence to in-service structure by applying sensors and by monitoring its behavior even on line.

This article describes a preliminary Stand-alone Bridge Monitoring System(SBMS) applied in laboratory that consists of sensors, data logger, GP-IP interface and data processing software, which is capable of measuring and managing performance data such as stress, cable tension, deflection and temperature and visually displaying them in computer interface in real time. Then, for the purpose of verifying its validity to actual bridge structure, three cases of experiments to cable-stayed bridge model were processed. The experimental examples present the structural responses under change of ambient temperature, change of dead and live load in main girder. The experimental results demonstrate that the easily implemented monitoring system supplies abundant and accurate information about bridge behavior for later diagnosis or assessment. And it also opens up prospects for future application of web-based remote system to actual in-service bridges in field condition.

2. Description of the bridge model

The structure of interest in this SBMS is the model of a cable-stayed bridge across Fuchu Lake in Kagawa prefecture. The two-span structure has totally 200m long with continuous steel box-girder, and the model based on structural similitude shown in Fig.1 is 2m long with a scale of one-hundredth of the actual size.

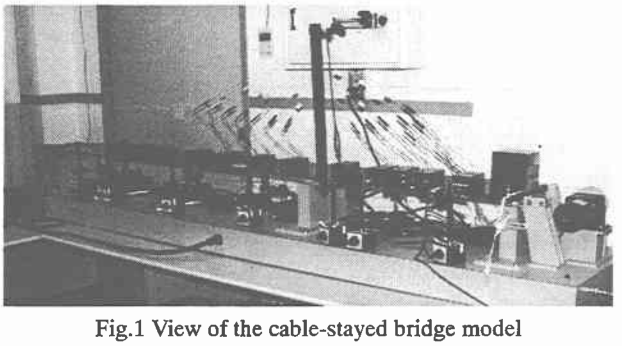


Fig.1 View of the cable-stayed bridge model

3. Framework of the SBMS

This section presents framework of a stand-alone bridge monitoring system in laboratory that consists of sensors, data logger, GP-IP interface and data processing subsystem. Structural performance data acquired with sensors were collected and transmitted to data logger. Then data after A/D conversion were transferred to computer for on-line monitoring and further analysis via data processing subsystem. This framework of the SBMS is shown in Fig.2.

3.1 Sensor layout and test methodology

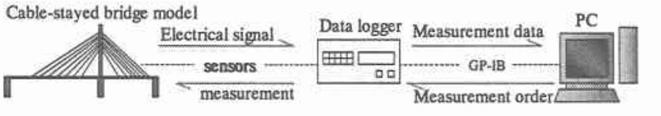


Fig.2 Framework of the SBMS

A schematic of the setup of sensors is shown in Fig.3. Strain gauges were used for cable tension measurements, displacements of main girder and tower were acquired by setting high sensitive displacement sensors (CDP) and cantilever deflection gauges (CE), furthermore, a thermocouple thermometer was applied to measure ambient temperature.

3.2 Test instrumentation

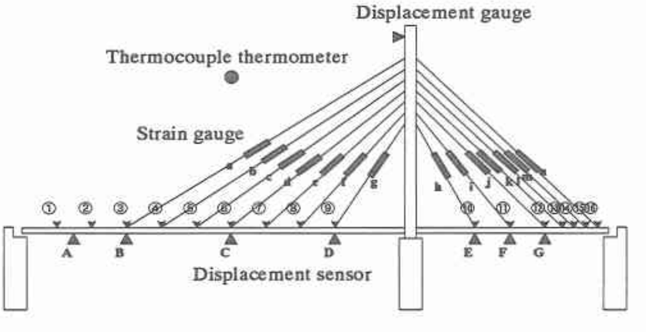


Fig.3 Location of sensors

Structural performance data acquired with sensors were transmitted to portable data logger (TDS-303), which was capable of simultaneously collecting multi-channel measuring data such as strain, ambient temperature, voltage, etc. in addition, the calculation, collection and procession of different measurement data could be fully performed. Data from data logger were transferred to stand-alone computer via communication interface. In general, RS-232C with lower speed was supplied for data communication, in this system GP-IP with higher speed was adopted.

3.3 Data management system

Data Management System implemented using Visual Basic 6.0, as a subsystem of SBMS, was designed so that user can directly acquire monitoring information and easily make interactive information process via an intuitive graphical user interface. The subsystem includes monitoring input module, instrumentation control module, measurement data process module, graphical process module and data saving module.

From the main user interface, users can move to input module as shown in Fig.4 where they can set sensor parameter and channel of data logger, interval time of data collection and clock of data logger, etc. then run the instrumentation control module, where the user can convey setup information to the channel of data logger and control the start and end time of data collection. The next measurement data process module provides the function of converting the collected data into intuitive bridge performance data. The graphical process module as shown in Fig.5 makes graphs of these converted data and enables the user to interact with bridge behavior, for example, the system conveniently supplies change of bending stress of concerned section along with the time via screen

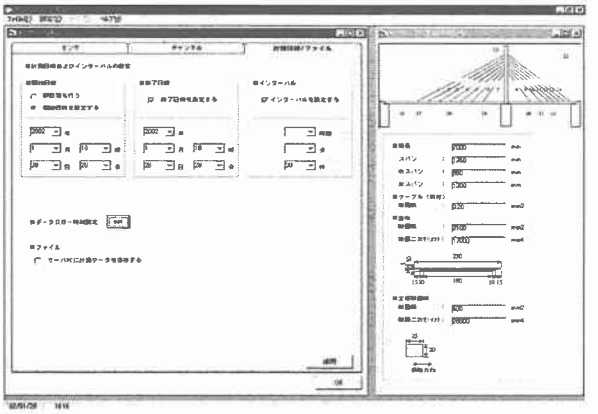


Fig.4 Example of screen display of input module

display and it also raises the alarm as measurement data exceed allowable value. In addition, the data saving module performs the functions of saving the multiple data as files for further analysis.

3.4 Further development

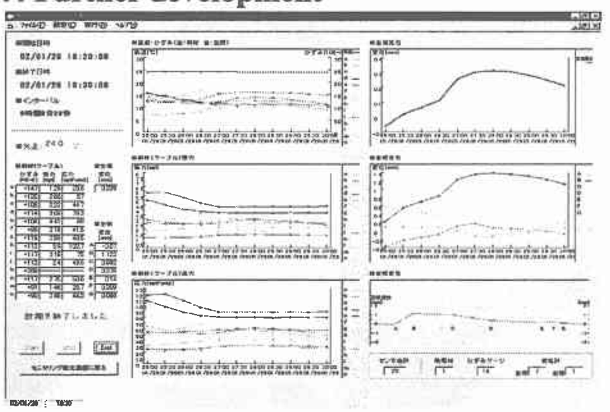


Fig.5 Example of screen display of graphical process

The proposed SBMS based on stand-alone has limitation to extended application. The rapid development of IT stimulates the application of network technology to establish a remote web-based monitoring system.

4. Monitoring experiment and results

In this section, three experimental examples that depend on above cable-stayed bridge model are used to demonstrate the capability of the established SBMS.

Example 1: The influence of seasonal and daily variations of ambient temperature on bridge structure is a fundamental measurement item. In this article, the proposed SBMS was implemented to investigate the change of cable tension, deflection of tower and displacement of main beam under dead load with respect to ambient temperature change. Fig.6 shows an experimental result. It is found that cable tension, deflection of tower and displacement of main beam reach to peak value as the ambient temperature reaches to peak value. Note also that the general tendency of tension, deflection and displacement is clearly in accord with ambient temperature change.

Example 2: Three 0.5kg weights that simulate the actual normal live load acted on practical bridge structure was moved to load point set in ③, ⑥, ⑨, ⑩, ⑪, ⑫ of main beam in turn. The measurement data of cable tension, deflection of tower and displacement of main beam were collected by SBMS. Then, above experiment was implemented again after adjusting of cable tension to decide whether the system was appropriate to future structural control.

Example 3: As mentioned above, the same load points as example 2 were each set in the form of six, nine and twelve 0.5kg weight respectively to simulate the abnormal live load that may act on main beam.

From above three experiment examples the following observation can be made: (1) The integrated SBMS applied to monitoring a practical bridge model is capable of simultaneously collecting and processing multi-channel measuring data and supplying a rational graphical user interface. (2) 24-hours monitoring experiment shows that the cable tension as one of the most important measurement item that directly reflects the actual work performance of cable-stayed bridge, is highly sensitive to ambient temperature variation, which strengthens the possibility to execute SBMS for a long-term monitoring. (3) Examples 2 and 3 suggest that the proposed system is an effective approach to the implementation of on-line monitoring and even for future structural control of real structure.

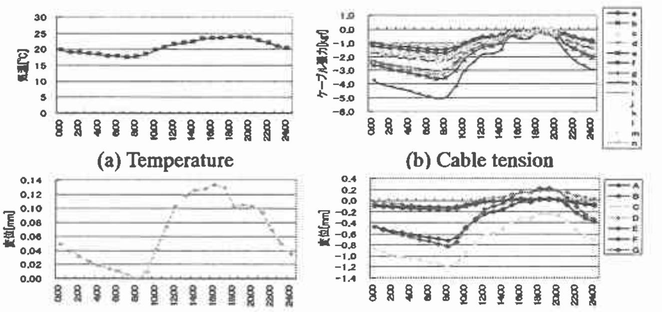
5. Conclusions

A preliminary stand-alone bridge monitoring system that consists of sensors, data logger, GP-IP interface and data processing software has been developed for monitoring of a cable-stayed bridge model. Based on three cases of experiments to cable-stayed bridge model, the following conclusions can be made:

(1) The monitoring system can be easily implemented and it supplies abundant and accurate information about bridge behavior for later or further analysis.

(2) The proposed SBMS provides a tool to establish an on-line system that is capable of collecting and processing real-time data and executing a long-term monitoring.

(3) The success of applying the monitoring system to practice relies on its abilities of data collection, data procession, on-line damage detection, damage assessment and future passive even active structural control. This article only introduces a preliminary stand-alone bridge monitoring system and opens up prospects for future application of web-based remote system to actual in-service bridges in field condition.



(a) Temperature (b) Cable tension

(c) Deflection of tower (d) Displacement of beam

Fig.6 Changes of structural behaviors by ambient temperature

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