Integrated design of long-term health monitoring system and Routine Bridge Management System

X.T. Zhou, N. Li & C. Zheng
China Highway Planning and Design Institute (HPDI) Consultants, Inc. Beijing

ABSTRACT: More and more long-span bridges have been constructed in China since the end of last century, which appeals for an increasing requirement on effective structural health monitoring and safety maintenance management. This paper highlights the importance of integrated design between long-term health monitoring system and routine bridge management system. The strategy of combing two systems have already been applied in Nanjing Yangtze-Rive Third Bridge, Shenzhen-Hong Kong Western Corridor Bridge, and Guizhou Balinghe Bridge etc. The systems designed for these bridges are currently under implementation.

1 INTRODUCTIONS

Since the end of last century, more and more large scale world-class cable-supported bridges have been constructed and come into operation in Mainland, China. These bridges play an important role in local economic development. With the increasing requirements on efficient management of these bridges, much work regarding on routine management have been done, like transportation volume monitoring, on-site manpower surveillance, repairing and maintenance management, etc. Recently, long-term health monitoring on these bridge structures also has been paid great attentions and attracted great interests, by researchers of university and engineers of design institute. Nevertheless, the research and implementation of long-term health monitoring system are mostly conducted independently with routine bridge management system so far. This paper is devoted to addressing the integrated design strategy of long-term health monitoring system and routine bridge management system.

1.1 *Long-term bridge health monitoring system*

The process of implementing a damage detection strategy is referred to as *structural health monitoring*. This process involves the observation of a structure behaviour over a period of tie using periodically spaced or continuous measurements, executing on the permanently installed sensors equipment. The extraction of features from these measurements, and the analysis of these features to determine the current state of health of bridge structures. The output of this process is periodically updated information regarding the ability of these structures to continue to perform their desired function in light of the inevitable aging and degradation resulting from the operational environments.

Due to the long period of design life-cycle of bridges, the corresponding health monitoring systems should thus also be conducted in long-term manner. Real-

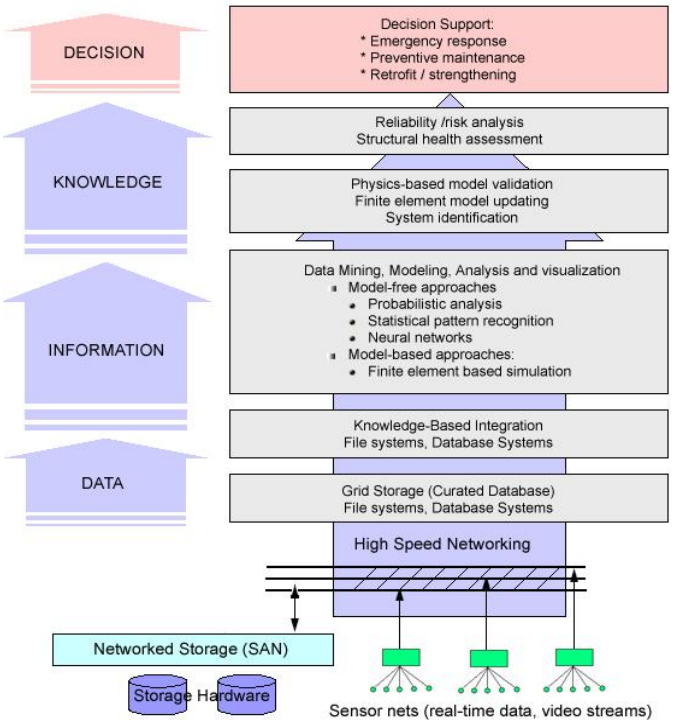

Figure 1 Flowchart of health monitoring system

time health survey for such large-scale civil structures a very complicated commission, covering

many discipline expertise, such as sensor technology, information technology, statistical theory, system identification and structure analysis, etc. A typical flowchart of long-term health monitoring strategy can be interpreted as Figure 1, which demonstrates data flow process from the initial raw sensors data to ultimate decision making.

Despite of much efforts and achievement made in the past decades, long-term health monitoring of civil structures are mainly performed in a research mode, rather than a productive mode.

1.2 *Routine bridge management system*

Bridge management system usually comes up with the born of bridges. Once the new bridges finish construction and come into normal operation, appropriate management system for these bridges will be established subsequently, which is also the case even for small bridge structures. Despite of great attentions paid on such management systems for almost every bridge of China by their owners or maintenance unit, the management are usually accomplished by the conventional way, rather than in the means of modern information technology-based approaches. Furthermore, the routine management work contents are limited to bridge pavement cleaning, concrete structure cracks surveillance, steel components fatigue checking and transportation volume monitoring, etc.

1.3 *Integrated design of long-term health monitoring system and routine bridge management system*

More and more attentions and efforts are being given to the long-term health monitoring for the bridge structures, especially long-span cable-supported bridges of Mainland, China. However, the majority of such system design and implementation are performed independently with the traditional routine bridge management system. As the design institute f long-span cable-supported bridges, we are aware of bridge structure mechanical behaviours, and are often committed by bridge owners to integrately design long-term health monitoring systems and routine management system, together with their structural design. We are currently applying the integrated designing strategy to several bridges under construction in China.

2 APPLICATION

2.1 *Yangtze-River third bridge*

Yangtze-river third bridge is located in the city of Nanjing, Jiangsu province, China, which is a two steel towers cable-stayed bridge, with the main-span being 648 m. The outstanding characteristic of this bridge is that the towers are arc-shaped and constructed fully by using steel materials, which is unique in all cable-supported bridges of world.

The whole-process design, including structural design, long-term health monitoring system and routine bridge management system, have been already been accomplished by our institute. The bridge is currently under construction and two systems are simultaneously under implementation.

The health monitoring system herein is called structural health monitoring and safety maintenance system, which is constituted by seven sub-systems, named as structural safety synthesis evaluation system, structural state and damage identification system, automatic data acquisition system, acoustic-emission detection system, electrical surveillance & management system, user interface system and central database system, respectively. The overall constitution and sub-systems relationship are depicted in Figure 2 and Figure 3.

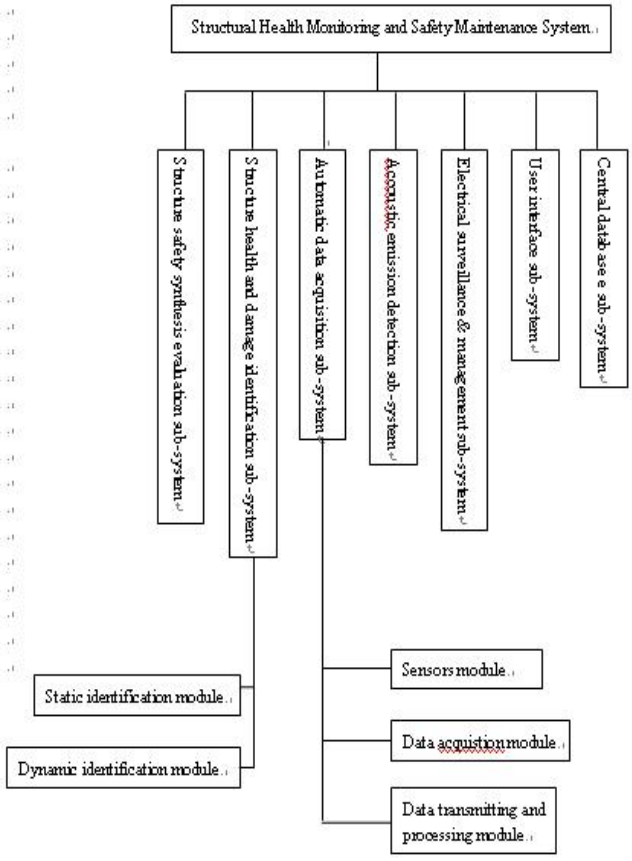

Figure 2 Constitution of structural health monitoring and safety maintenance system of Yangtze-river Third Bridge

Where the acoustic-emission sub-system is used to monitor the breaking and corrosion of stay cables, employing commercial product, *SoundPrint system* , of French Advitam company.

It should particularly be noted that the electrical surveillance & management sub-system is actually serving as bridge management system, which avoids

the conventional handed management manner, utilizing modern information technology and management schemes. The sub-system is also employing the commercial product, *ScanPrint system*, of French Advitam company.

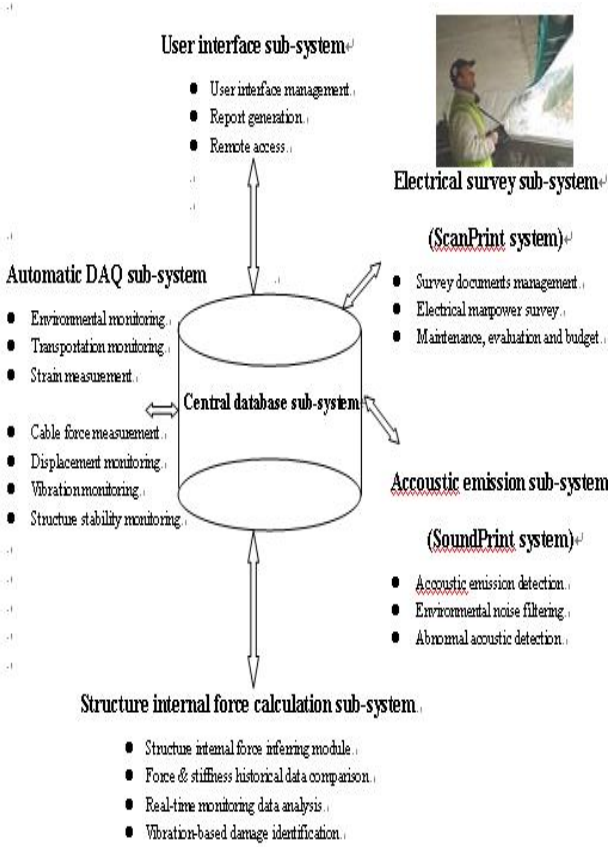

Figure 3 Relationship of sub-systems and their functionality

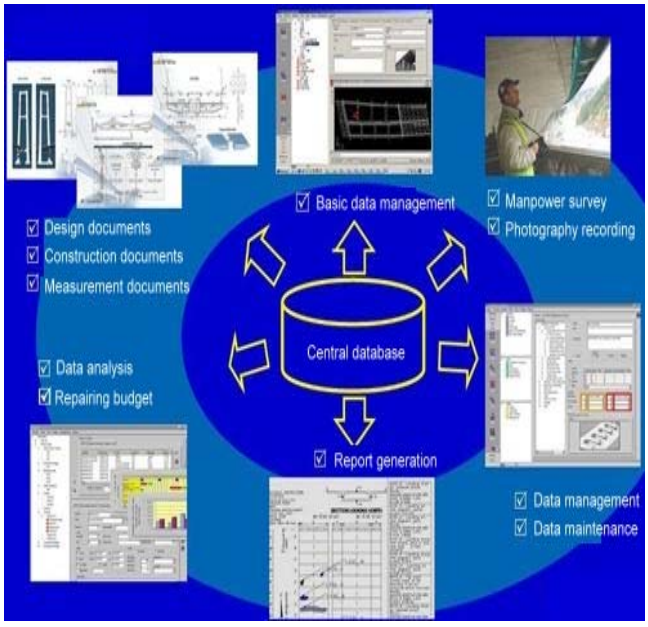

Figure 4 Components functionality of ScanPrint system and relationship with central database

The constitution components functionality of ScanPrint system and their relationship with central database sub-system are illuminated in Figure 4.

2.2 *Extension to other bridges*

The strategy of integrated design of long-term health monitoring system and routine bridge management system implemented in Yangtze-rive Third Bridge is further extended to other bridges application, which are also designed by our institution. For example, Shenzhen-Hong Kong Western Corridor Bridge (Shenzhen-side) is a single-tower cable-stayed bridge, with main-span being 180 m and 90 m; and Guizhou Balinghe Bridge, which is a cable-suspended bridge, with main-span being 1088 m. Both of bridges are currently under construction and their health monitoring and safety maintenance systems are also simultaneously under designing or implementation.

3 CONCLUSION

This paper addresses the current state of long-span bridges construction, long-term health monitoring and routine management system research as well as their implementation, then followed by our designing strategy of integrating long-term health monitoring system with routine bridge manage system, and finally its application on several long-span bridges of China.

From our institute and bridge owners points of view, it is necessary and key important to design long-term health monitoring system tightly integrated with traditional routine management system. Only by combing two systems designing, can the health monitoring system play practical role on ensuring bridge structure applicability, safety, durability and helping bridge maintenance management.

The strategy proposed in this paper will be applied on our later design and implementation for future bridges, and therefore will potentially become a guideline for synthesis management system integration of all bridges in China.

REFERRENCE

Chang, R., Gandhi, T., and Trivedi, M. 2004. Vision Modules for a Multi-Sensory Bridge Monitoring Approach. The 7th Internation IEEE Conference on Intelligent Transportation Systems. Washington, DC.

Conte, J. P., Elgamal, A., Zarki, M., Fountain, T., Gupta, A., Masri, S. and Trivedi, M. Monitoring Civil Infrastrucrure Multi-Disciplinary Research. ITR: Collaborative Research.

Doebling, S. W., Farrar, C. R., Prime, M. B., and Sheviz, D. W. 1996. Damage identification and health monitoring of structural and mechanical systems form changes in their vibration characteristics: a literature review. LA-13070-MS, Los Alamos National Laboratory.

Elgamal, A., Conte, J. P., Yan, L., Fraser, M. and Trivedi, M. 2004. A Framework for Monitoring Bridges and Civil Infrastructure. Proc. of the 3rd China-Japan-US Symposium on Structural Health Monitoring and Control. Dalian, China.

Fraser, M., Elgamal, A., Conte, J. P., Masri, S., and Zarki, M. 2003. Elements of an Integrated Health Monitoring Framework. Proc. of the 2003 SPIE Conference on Nondestructive Evaluation for Health Monitoring and Diagnostics, San Diego, CA

Fraser, M., Elgamal, A., Oliver, K. and Conte, J. P. 2004. Data Fusion Application for Health Monitoring. The first International Workshop on Advanced Smart Materials and Smart Structures Technology, Honolulu, HI.

Ko, J. M. & Ni, Y. Q. 1999. Development of vibration-based damage detection methodology for civil engineering structures. Proceedings of the First International Conference on Structural Engineering, Kunming, China.

Yan, L., Elgamal, A., Fountain, T., Conte, J. P. and Masri, S. F. 2004. System Identification for Bridge Foundation Integrity. Proc. of the International Conference on Geotechnical Engineering, Beirut, Lebanon.