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Problems in Bridge Health Monitoring and Application of Intelligent Monitoring Technology

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Abstract. In view of the current research status of bridge health monitoring system at home and abroad, this paper summarizes the problems existing in bridge health monitoring research and discusses the solutions to these existing problems. On this basis, it also puts forward the advantages and development trends of intelligent health monitoring. Besides, taking the intelligent monitoring of Haiyin Bridge as an example, the modern network technologies such as intelligent collector, networking and cloud platform were adopted to realize the functions of real-time bridge monitoring, intelligent analysis, and safe type-warning. Thus, a complete set of visualized management system for bridge intelligent health monitoring information is finally formed. This shall provide references for the intelligent development of bridge health monitoring

1. Introduction

Bridges play a pivotal role in ground transportation. They are the investment-intensive permanent areas in the construction of ground infrastructure. Generally, the bridge is in a relatively special environment. Under the long-term repeated load, the structural erosion and damage of the bridge are possible, mainly resulting in the reduced load capacity and the safety factor. Thus, in order to ensure the bridge safety, the later operation of bridges must be considered in the process of bridge construction, which should start from the safety monitoring of the bridge. This has very important time significance for the construction of the bridge. At present, the total number of bridges in China is 418,800 for about 22.46 million meters, and 2,155 of them are large bridges[1]. China has a vast territory, and its large, medium and small bridges are distributed very widely. In the construction of high-speed railways and highways, bridges play an important role, that is, the mileage of bridges occupies a very high proportion, and it in many areas even account for more than 40% [2-3]. Therefore, the safety of bridges is directly related to the safety of roads and railways in China. Safe construction and precise monitoring are essential, which puts forward requirements for the construction of bridges in China. In related construction, it requires not only innovating the construction method and design structure of the bridge, but also establishing a perfect mechanism for safety construction. This has very important practical significance for promoting the development of bridge technology[4-6].



2. Existing problems

In summary, China's bridge health monitoring platform only performs basic combing and archiving of data collected by sensors, sorts out some feature monitoring data through trigger mechanism, and uses various processing and analysis tools to perform data analysis and calculation. There is a lack of a systematic pre-warning diagnosis mechanism[7-13]. In the actual storage and access control process of bridge structure health monitoring data, the excessive data volume and the over-high loading speed could block the server to block, bringing great pressure to the operation and maintenance of the background server. The influx of data has overwhelmed existing equipment and then the analytical results obtained are not ideal. The specific disadvantages are as follows:

- The raw data of the health monitoring system is insufficient, the data storage of the project is not perfect, and the data cannot be scientifically processed[14];
- Traditional monitoring cannot effectively analyse data, and the degree of intelligence is low;
- The traditional monitoring method lacks a systematic pre-warning diagnosis mechanism, and cannot respond to the dangerous source in time;
- Data cannot be shared, forming an information isolated island;
- The indicators of health monitoring status assessment are confusing, without uniform standards (Figure 1).

Therefore, it urgently needs a system that can directly make real-time monitoring, intelligent analysis and remote monitoring of the bridge health status. Automated data collection, intelligent data transmission, real-time data analysis and pre-alarming are the development trend of bridge engineering health monitoring technology, and also the inevitable results of construction informatization.

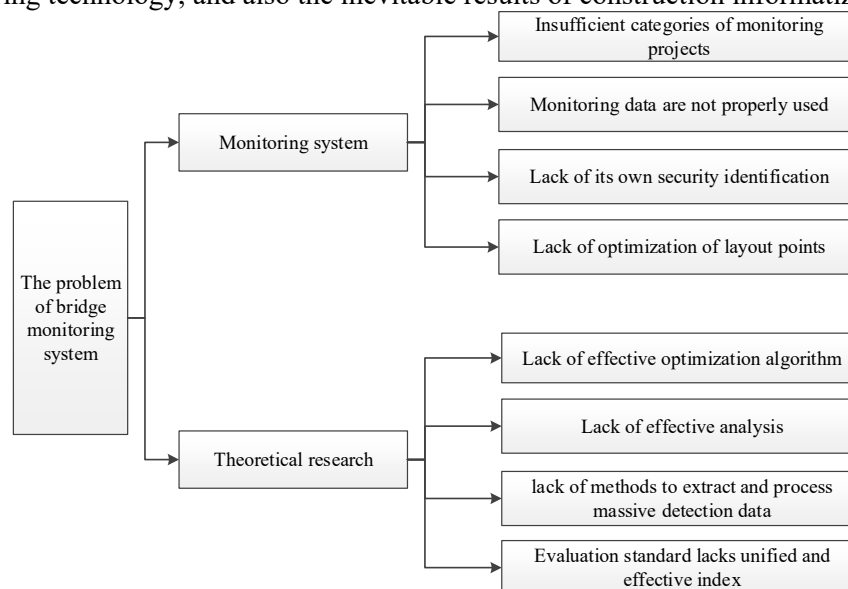


Figure1. Existing problems in bridge health monitoring system

3. Health monitoring system design

3.1 Design guidelines of monitoring system

The purpose and function of the monitoring system should be the core basis for current development and construction. During the construction of the health monitoring system, it should be made clear that the purpose is to collect and preserve the bridge health data, while the function is to ensure the safe operation of the bridge, that is, focusing on data collection and data processing. The above analysis shows that the purpose of the system construction project is very clear, and also in the specific construction, we must consider the limits of investment[15]. Therefore, the construction of the bridge health monitoring system should be analysed from the aspect of cost and benefit, and a relatively reasonable detection range should be established on the basis of functional requirements and cost-

benefit analysis, so as to better realize the construction, development and optimization of the hardware system[16].

4. Engineering project

Haiyin Bridge is located in the centre of Guangzhou City, Guangdong Province, across the Pearl River. It has a total length of 1,114m, about 2.5km from Haizhu Bridge, with. The bridge has a good wind resistance section. For the temperature stress problem, a unique design structure and processing method are adopted to adapt to the large temperature difference at the bridge site. In the main beam construction, the unique method of the middle box pouring before the side boxes is adopted, and the hanging frame/basket construction is used without the stiff skeleton.

4.1 Detection principle of crack meter

The temperature range (T_{min} , T_{max} are the minimum and maximum temperature of the area) is specified, and the change of the joint is calculated according to the temperature (T_{set}) when installing.

$$\Delta L_r = (T_{max} - T_{min}) \gamma^2 L \quad (1)$$

$$\Delta L_{+} = (T_{max} - T_{set}) \gamma^2 L \quad \Delta L_{-} = (T_{set} - T_{min}) \gamma^2 L \quad (2)$$

L_r —the amount of expansion and contraction caused by temperature changes;

ΔL_{+} —the elongation of the beam caused by the temperature rise;

ΔL_{-} —the amount of expansion and contraction of the beam caused by the decrease in temperature;

T_{max} —the maximum ambient temperature of design;

T_{min} —the minimum ambient temperature of design;

T_{set} —the temperature at which the expansion device is set;

4.2 Working principle of differential pressure deformation sensor

The differential pressure deformation measuring system consists of multiple differential pressure deformation measuring sensors connected together by a liquid-filled PU tube and finally connected to a liquid storage tank. Compared with the pipeline, the liquid storage tank has a large enough capacity, which can effectively reduce the impact of subtle changes in pipeline capacity due to temperature changes. The liquid pressure tank and the differential pressure deformation measuring sensor in its vicinity are regarded as the base point, and the base point must be installed at a position where the vertical displacement is relatively stable or can be measured by other artificial means. Then, based on the data changes of the measuring point differential pressure measuring sensor, the relative settlement at this point can be directly measured. According to the principle of the connecting pipe, for the established system, the measuring points are basically at the same elevation. When one end (tail end) of the connecting pipe is sealed, the liquid in the whole liquid pipe does not flow; when the measuring point is deformed with the structure (settling or bulging), the relative difference between the measuring point and the liquid level in the base point storage tank is changed, and the measured point value changes accordingly. Here, the amount of change is the relative settlement amount of the measuring point. The variable of differential pressure deformation measurement sensor is calculated as:

$$\Delta h = (h_i - h_0) - (H_i - H_0) \quad (3)$$

Δh —the calculated value of the measuring point at the current moment (relative deformation display value), KPa or mm;

h_i —measured value of the measuring point at the current moment, KPa or mm;

h_0 —measured value of the measuring point at the initial moment, KPa or mm;

H_i —measured value of the base point at the current moment, KPa or mm;

H_0 —measured value of the base point at the initial moment, KPa or mm.

4.3 Monitoring scheme

Considering the characteristics of the Haiyin Bridge, the degree of importance and the working environment. In order to achieve all-weather, all-day, high-precision and automatic monitoring of Haiyin Bridge, this project of safety monitoring used a combination of GNSS high-precision

positioning technology and automated sensing monitoring. For the data acquisition part, it included 2 GNSS monitoring stations, 1 GNSS monitoring base station, and eight types of automated sensors (106 in total), as shown in Table in detail. Besides, relying on the mature GPRS/3G/4G network, data communication was quickly established in the network coverage area to realize real-time remote data transmission. Considering the factors such as a variety of data, large amount of data, and heavy processing and analysis work, the cloud service modes of centralized data storage and centralized processing were adopted through the wireless transmission, in order to provide better service for users within 5 years. The specific monitoring contents are summarized as follows:

Table 1 Main monitoring contents

No.	Monitoring items	Distribution location	Number of monitoring points
1	Pier settlement and deflection	The measuring points arrangement section are located in the mid-span of 85.5m span, the mid-span and the quartile point section of each 175m span, and each support, and the position of the support is also used as the settlement point.	2 base points 20 measuring points
2	Bridge pier inclination	The measuring points are arranged on the top of the pier, and each pier is arranged with one measuring point for a total of 2 measuring points.	2 measuring points
3	Bridge displacement	The displacement measuring point of the pylon tower is arranged at the top of the pylon tower, and the base point is arranged at the top of the public toilet next to the south approach bridge machine room.	1 base point 2 measuring points
4	Strain	The monitoring points are arranged at the top and bottom of the three chambers in the main section of the main beam, with 6 measuring points per section. The section is arranged in the mid-span of 85.5 m span, midspan of 175m span and a section of quartile points, with a total of 5 sections.	30 measuring points
5	Cable force	According to the main bridge structure of Haiyin Bridge, 10 magnetic flux sensors are arranged on each side of each pylon.	40 measuring points
6	Vibration	The measuring points are arranged in the middle position of each mid-span beam bottom, and the vibration in the middle part of the beam is relatively obvious by using the D'Alembert principle. At the same time, the span of the mid-span is larger, and the second-order vibration mode is also more obvious. Therefore, the quartile position is also used as the monitoring section.	5 measuring points
7	Expansion joint	The monitoring points are arranged at the expansion joints, and at the inclined webs of the bridge bottom; two at each expansion joint.	4 measuring points
9	Wind speed and direction	Try to install in an open space, depending on the situation	1 measuring point

4.4 Intelligent monitoring of Haiyin Bridge

The sensors at each location were imported into the nearest collection box and then transmitted to the cloud platform via the DTU (as shown in Figure 2).

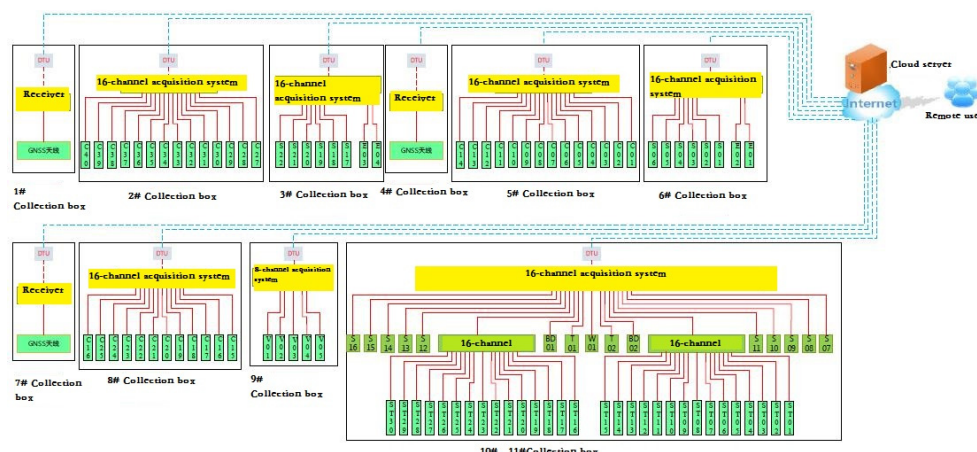


Figure 2. System Networking

4.5 Cloud platform development

After the whole system is assembled, the various sensor modules access the wireless node in a specific way according to their respective communication modes, the master node and the 3G module are connected to the system through the ARM UART. Then, the power of each node module is turned on, waiting for the system to automatically make networking. After successful networking, each wireless sensor node transmits data to the central node (gateway), and then the central node (gateway) sends the data to the server through the 3G module. Finally, we can log in the client server on the PC to view the corresponding data, as shown in Figure 3.

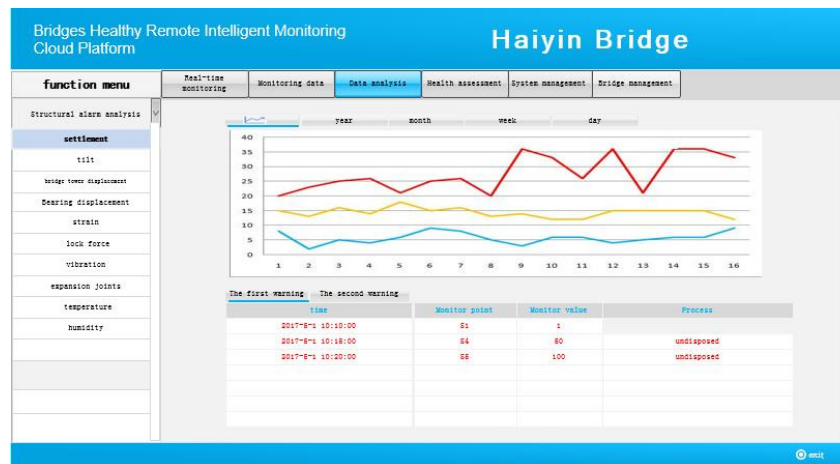


Figure 3. Bridge monitoring cloud platform

5. Conclusions

The structural health monitoring of bridge is not only a simple innovation in bridge monitoring technology, but a comprehensive understanding and analysis of its structural status and environmental content through a combination of modern network technology and communication technology, thus conducting the analysis and evaluation of bridge structure and health status. This shall provide a strong scientific basis for the management and maintenance of bridges. Besides, the development of computer technology makes it possible to realize the healthy and intelligent monitoring of bridge structure. The combination of cloud platform and intelligent bridge monitoring means is applied to monitor the overall safety of the bridge, which has important practical significance for safeguarding engineering safety.

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