

DEVELOPMENT AND TESTING OF INTEGRATED BRIDGE DISASTER PREVENTION AND MANAGEMENT PLATFORM

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Abstract: In recent years, global warming leads rainfall intensity stronger than before. Therefore, bridge management requires a reliable monitoring platform in current, to monitoring of bridge piers based on the variations of safety and river erosion, can be timely warning of the bridge damage, achieving the maintenance of bridges safety in the flood. In view of bridge design and construction technology, the bridge engineering technology has matured, however monitoring and maintenance are important factors in the safety of the bridge. And increased with time, no matter how good engineering, high safety factor and then the bridge has aged, the incidence of deterioration, plus traffic overload, the role of erosion and earthquakes, needs more strengthen its safety monitoring and maintenance to ensure safety.

Having this in mind, maintaining the safety of the bridge, this research focus on Chung Sha Bridge on Zhuo-shui River. This research installed accelerometer and inclinometer with the correction of the GPS function around substructure and superstructure of bridge, figured out the bridge scour monitoring technologies associated with natural frequency. And used wireless sensor network to monitor bridge disaster, in the end show whole monitor information on web-based system which developed by this research. This research also through long-term monitoring of scour erosion depth and model parameters such as vibration frequency to derive a similar formula. In addition, by way of remote monitoring management platform also improve the accuracy of the bridge monitor, it provide engineers, bridge maintenance unit a more efficient tool.

Key words: *GPS, Wireless Sensor Network, Bridge monitoring, Scour, Management Information System (MIS)*

1. Introduction

In Taiwan, rivers and tributary streams are densely covered, and twenty thousand highway bridges is located in different counties. As bridges take an important role in traffic, the damage of bridge by scouring not only threatens to the safety of users, but also may breakdown traffic then cause resident locked. Therefore, providing engineers and governmental institution to monitor the level of bridge scour instantly is a crucial issue. Thus, the purpose of this research project is to build up a web-based scour monitoring system, in order to instantly monitor the scour degree at the bridge's piers.

In this monitoring system, this research project installs

sensors on the bridge, and transmits the data from sensors to a database server through a 5G antenna device and Internet. In the database server, a dynamic mathematical model is developed to estimate the scour degree at bridge's piers based on the data from the sensors. Finally, the result from the mathematical model will be uploaded online, and engineers could make suggestions based on the result.

The remainder of this paper are shown as follows: In Section 2, the bridge scour monitoring system is explained in detail. Section 3 shows the fundamental descriptions of the bridge which is chosen to test the scour monitoring system in this project. Finally, the conclusion is shown in Section 4.

2. The Scour Monitoring System

Fig. 1 shows the process of the scour monitoring system in this project. There are 4 steps in this system:

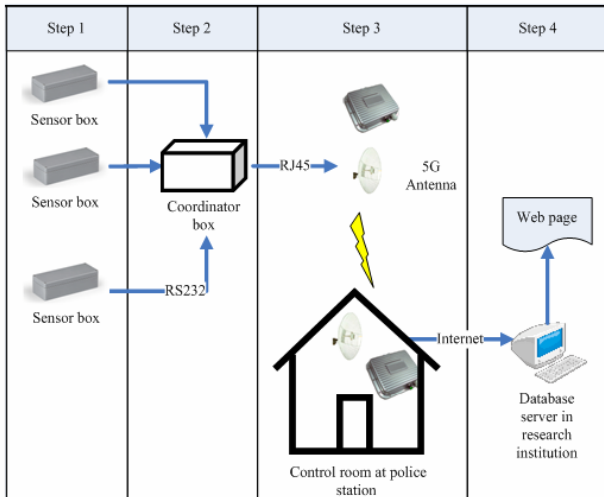


Fig. 1 The process of the scour monitoring system

Step 1: The sensors are installed on the bridge to measure the vibration frequency of the bridge.

Step 2: The data from the sensors will be collected to the coordinator box on the bridge. And then the data will be preliminarily processed and converted from RS232 format to RJ45 format by a computer in the coordinator box.

Step 3: Through the 5G antenna device, the data will be transmitted from the coordinator box on the bridge to the control room in a nearby police station. Then the computer in the control room will transmit these data to the database server in the research institution through Internet.

Step 4: In the database server, the scour degree at the bridge's piers will be estimated based on the sensors' data, and the result will be uploaded online. Engineers can know the instant situation of the bridge by this database system.

The details of these steps are shown as follows:

Step1:

In this step, this project wants to collect some information from the bridge to know the scour degree at the bridge's piers. After the analysis in this research project, the scour degree could be estimated from the bridge vibrating frequency. Thus, accelerometers, inclinometers and GPS

sensors are installed on the bridge in this system, and then the bridge vibrating frequency could be calculated based on these sensors' data. There are totally 3 sensor groups in different locations, and each group includes 3-axis accelerometers, an inclinometer and a GPS sensor. The deployment diagram of sensors is shown as Fig. 2.

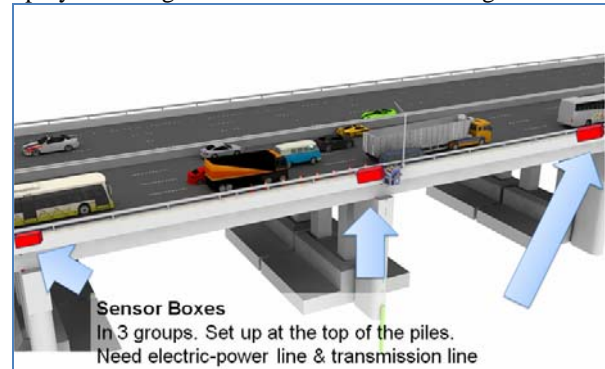


Fig. 2 The deployment diagram of sensors

Another important issue of these sensors is how to maintain them. The chosen bridge in this project is in the intermediate part of a highway. If blocking the way to do maintenance, that will certainly make traffic disturbance and raise safety issue. Therefore, this project attempts to set up the devices in a way of avoiding maintenance. This will induce two problems needed to solve: (1) the source of the power support of sensors, (2) the weather resistant ability of sensors. All the sensors on the bridge need stable power support to make the monitoring data transmitted contiguously. Considering about batteries need replacement in a few months and the traffic disturbance while replacing batteries, this project sets up a power switchboard independently for the monitoring system to provide power stably and persistently. In addition, the sensors are vulnerable to the impact of heavy rain and strong wind. In order to protect the sensors, waterproof box (shown as Fig. 3) made in special fiber glass fiber is used in this project. The waterproof box is with a thickness of 4 cm of its bottom, 1.5cm of its protection layer, and -40°C~110°C of its thermo stability. This device can adequately protect the sensors to avoid being damage by extremely weather.



Fig. 3 The sensors box

Step 2:

In this step, the data from the sensors will be collected to the coordinator box in RS232 format. The coordinator box is shown as Fig. 4, including a computer and the 5G antenna device. The computer combines the data from three sensor groups into single file, and converts it in RJ45 format, then transmits it via 5G antenna device and Internet. The device maintaining is also a consideration in this step, thus we set these devices in a metallic box to resist rain and wind. Moreover, the metallic box is with a ventilation design at below to avoid overheating in the computer.

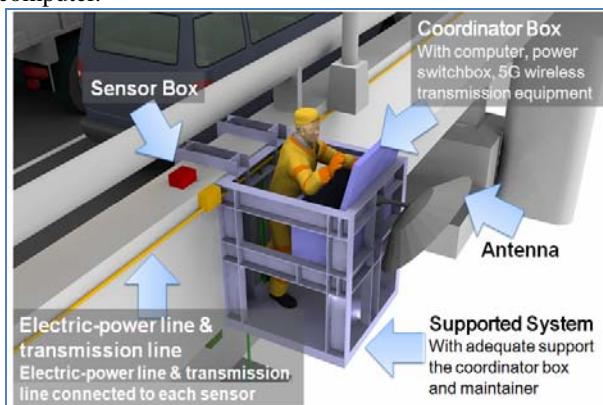


Fig. 4 The coordinator box diagram

Step 3:

After preliminarily processed the data, the computer in the coordinator box will transmit these data to the 5G antenna device (shown as Fig. 5). The 5G antenna device will send the data signal from the bridge to the control room in a nearby police station. And then the computer in the control room will transmit the data to database server in the research institution through Internet. There are several advantages of setting the control room in a police station. First, the police station opens 24 hours; data collection and devices maintenance can be done in every time. Second, when disaster occurred, the police station can be a local command center. Immediately, the decision

maker can decide to evacuate, block the bridge, or execute other necessary actions in advance based on the information from this system.



Fig. 5 the 5G antenna device

Another choice of transferring the data from the coordinator box on the bridge to the database server is via 3.5G high-speed downlink packet access (HSDPA) technology. However, even though the 3.5G network has been developed for years in Taiwan, the stability of signal is still unsatisfying. Thus, this project chooses the 5G antenna device and cable network to guarantee the quality of data transmission.

Step 4:

In the database server, a dynamic mathematical model is developed to estimate the scour degree at bridge's piers based on the data from the sensors. This model firstly calculates the vibrating frequency of the bridge by the data from sensors on bridge. According to the vibrating frequency of the bridge, then this model could estimate the scour degree. Finally, the result from the mathematical model will be shown on the web page (shown as Fig. 6) of a scour monitoring platform built on the database server, and engineers could make suggestions based on the result.

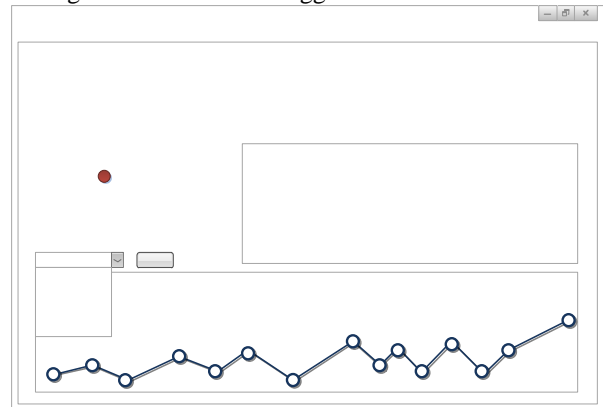


Fig. 6 The web page of the scour monitoring platform

3. Fundamental Descriptions of Experimental Bridge

This project will carry out a test of scour monitoring system on Chung Sha Bridge (as shown in Fig. 7), which is located in DouNan Town of YunLin County in Taiwan.



Fig. 7 Chung Sha Bridge

Table 1. Fundamental descriptions of Chung Sha Bridge

Bridge No./ Name	Chung Sha Bridge
Latitude	23.818
Longitude	120.477
Construction year	Sep-1978
Structure type	Beam bridge
No. of Span	67 spans
Length	2344M
Type of bridge deck	Reinforced Decks
Width of bridge deck	15.22×2M
Angle of attack with flow	90 degree
Material of bridge pier/pillar	Reinforced concrete
Material of bridge pier	Reinforced concrete, several column types
Shape of bridge pier	rectangular
Width of rectangular bridge piers	5.8M
Height of bridge piers	9.45M
No. of foundation piles	26 piles
Material of foundation piles	Concrete
Shape of foundation piles	Circular
Diameter of circular foundation piles	1.00m
Length of foundation piles	25m
Type of bearing	Elastomeric bearing
Type of foundation	Pile foundation
Type of channel	braided channel
River land	P15-P27
Soil property	Sandy soil layer

The fundamental descriptions of this bridge are shown as Table 1. There are two reasons for selecting this bridge in test: First, the aim of this research is to provide a bridge

instant scour monitoring system. Chung Sha Bridge is one of the exposed foundation bridges caused by scouring in Taiwan recently, thus it is exactly match the scope of this research. Second, National Center for Research on Earthquake Engineering (NCREE) of Taiwan is also preceding related experiment in this bridge; therefore, the measuring instruments can be set up with NCREE together to minimize the traffic disturbance.

4. Conclusion and Suggestion

Under an extreme weather, the bridge is likely to collapse because of the long-standing scour at the piers. Thus, an instant bridge scour monitoring system is necessary to evacuate, block the bridges, or execute other prompt actions in advance. This project builds a web-based instant scour monitoring system and provides action suggestions to engineers and government institutions. The experience in this project could be a reference for future research.

This project still has 4 possible ways to improve: first, if this project could found a better power support way for the sensors, wireless connection may be applied to the connection between sensors and the coordinator box. This will make the system more feasible. Second, in the coordinator box on the bridge in this project, a computer is installed to collect the data from sensors and convert the data format into RJ45; however, common used computers may shutdown in extreme environment. In future research, a specific machine which is design for this proposes may be more reliable than common used computers. Third, if the signal quality of 3.5G HSDPA network could improve to a reliable degree in the future, the data may be transmitted to database server via 3.5G HSDPA network from coordinator box directly. In other words, no more transmission equipment is needed, thus it could reduce cost and enhance convenience. Fourth, because this project is still in the development phase, the database server is at the research institution in National Taiwan University now. After this project completed, the database server could transfer to the control room in the police station. This can reduce the time and the process of transmitting the data from police station to research institution.

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