Real-Time Bridge Scouring Safety Monitoring System

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ABSTRACT

The scour of riverbed is one major cause for bridge failure while the river is in flood. A monitoring system is crucial to give advance warning. In this paper, a real-time bridge scouring safety monitoring system is proposed. It is composed with digital sensors, a control unit and a 3G module. The digital sensors embedded in river bed at designed depth can sense the vibration caused by water flow. The control unit captures signals from digital sensors and sends out scouring condition through the 3G module. This system was installed in field and successfully sent real-time scouring data back during Morako typhoon in 2009 in Taiwan. The result demonstrates the adoptability and potential of this system on real-time bridge safety monitoring.

INTRODUCTION

Most rivers in Taiwan are short and steep. Consequently, the cross-river bridges face a serious challenge of bridge foundation scouring problem. The scour is one of the major causes for bridge failure. The pile foundation of bridge can be erosion under the scouring that could cause the infrastructure of bridge in a dangerous condition [1-5]. There are many typhoons and floods in the period from June to October every year in Taiwan. Floods induced by Typhoon Sinlaku and Morako brought heavy rain and flood, and damaged several bridges in the south of Taiwan recently. It is because the local scouring is the most important, and it generally threatens the stability of bridge pile foundation. Thus, the bridge scouring safety monitor system is necessary to prevent the risk of damage bridges. However, there are many challenges to monitor the depth of

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scouring at bridge piles. According to previous researches, the fiber bragg grating (FBG) sensors have been used in situ scour monitoring [6-9]. Moreover, sonar and radar have also been used to estimate the local scour depth at bridge foundations [10-14]. However, most of the proposed methodologies are complex and lost the cost effect. It is necessary to develop a real-time system to monitor the sour depth of bridge piles in the field.

Mobile wireless technologies provide wireless information transport solutions that bring the end of data collection and the remote local scour depth monitoring devices together. In this paper, we present the mobile wireless technology approach to achieve the real-time bridge scouring safety monitor in situ test. Digital sensor nodes can monitor the scouring depth in each point. Scouring depth or sedimentation depth of bridge piles can be identified by the time-history diagram. Using mobile wireless techniques (Wi-Fi and 3G) can report the rapid scouring depth in real-time, which in order to evaluate the bridge safety.

The rest of the paper is organized as following: First, the concept of the real-time bridge scouring safety monitoring approach is presented in section one. The scour monitoring technique is described in section 2, which consists of digital sensors and system control unit. In section 3, it presents the mobile wireless communication technologies that have been implemented in the real-time bridge scouring monitoring system. Section 4, we discuss the monitoring result and shows the feasibility and stability of our approach and section 5 concludes the work.

COMPOSITION OF SYSTEM

The scour monitoring system proposed in this paper is shown in Fig. 1. In the system, a steel tube containing 16 sensor nodes at an equal distance of 0.5 m is installed into the river bed by drilling a hole on the downstream side. Each sensor has a wire used to activate its corresponding digital switch contained in a switch box under scouring. A control unit located on the top portion of the bridge pier is used to detect the on/off status of the digital switch for monitoring the sensor status.

All the sensors are initially covered by soil and all their corresponding switches are off. When a flood induces scouring, the sensors above the scouring surface vibrate due to water flow and they turn on their corresponding switches, which can be detected by the control unit. The scouring depth is obtained by monitoring the change of switches' status. The mobile wireless technology is used to instantly report the scoring information to a remote station.

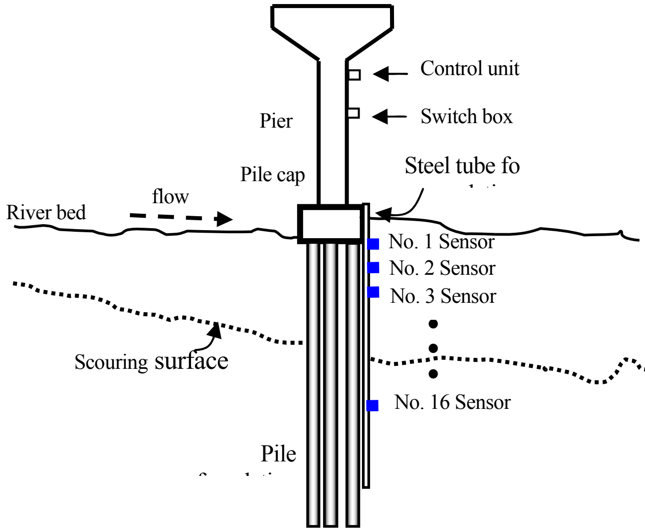

Figure 1. Schematic diagram of the digital sensor.

After flood, part of the sensors may be recovered by soil flushed down from the upstream mountain. Those recovered sensors go back to the initial condition and their corresponding switches are inactive. As a result, the soil recovered depth can be identified by observing the number of the inactive sensors.

The scour monitoring system is mainly composed of digital sensors and a system control unit. The digital sensors and the system control unit are described in the following sections.

Digital sensors

Fig. 2(a) shows a schematic illustration of the digital sensor used in situ. The sensor consists of a steel plate hinged on a steel tube and a wire attached to the steel plate. The steel plate is originally embedded in the river bed and it is still in a close status. When a scour occurs, the steel plate is opened under a water flow and the attached wire then turns on a switch as illustrated in Fig. 2(b). The switch is located in a switch box installed on the top portion of the pier to avoid water flow. The activation of the switch conveys 5V digital signal to a system control unit.

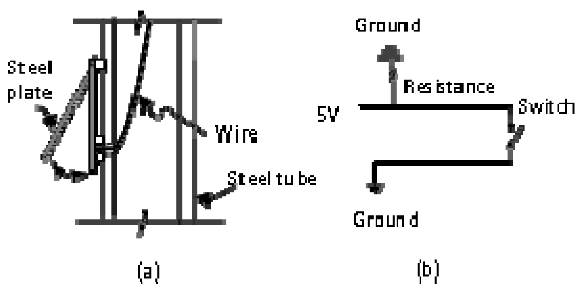

Figure 2. Schematic diagram of the digital sensor.

Control unit

The system control unit consists of computer and monitoring software. To get rapid monitoring data, we use laptops, smart-phone or PDA with WiFi communicable device in field monitoring, while in remote control monitoring, we use desktops or laptops instead. Monitoring software comprises Graphical User Interface (GUI), as shown in Fig. 3, controlled by mouse and touch panel with the setting of argument. It may also record monitoring data with time history diagram for long term.

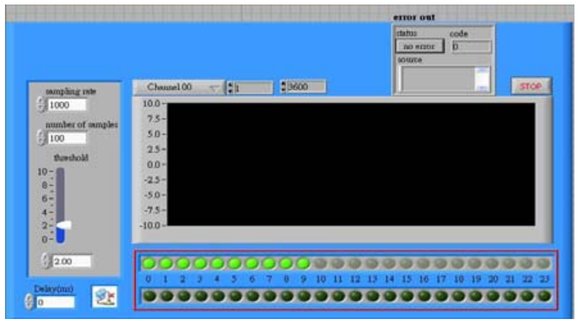

Figure 3. Graphical User Interface (GUI).

Networking

Generally, the mobile telecommunication operators have offered several alternative mobile wireless network solutions to support long distances wireless communications, such as, 3G (3rd-generation), HSDPA (High-Speed Downlink Packet Access) and GPRS (General Packet Radio Service). On the other hand, Wireless Local Area Networks (WLANs) provide wireless network communication over short distances using radio signals instead of traditional network cabling (Ethernet). Both mobile wireless networks and WLANs have provided the significant broadband capability in different methods. In describing our real-time bridge scouring safety monitoring solution, we observe that the improvement of both reliability and efficiency of wireless communications is necessary. In order to achieve the long distances of wireless communications, a 3G network card has been deployed on our system that enabled the TCP/IP communication between the bridge monitoring system and the remote control unit. However, there were several challenges regarding the mobile wireless networks. The 3G network was designed for broadband data and voice users and not for application awareness or the need to support the remote real-time control for the bridge monitoring system. To overcome some of these shortcomings, one approach considered from our case study is a capability for hand-over with several wireless network interfaces. Technologies such as ad-hoc and multi-hop wireless networks were also considered to extend the coverage of the wireless transmission range. For example, if the primary mobile wireless network is unable to allocate a data channel, perhaps because of an outage or all channels consumed, then the device is able to transmit over an alternative WLANs. The alternative WLANs can provides the short range of wireless communications and be able to extend as ad-hoc and multi-hop wireless networks by using the proper wireless routing protocols.

RESULTS

Fig.4 shows a continuous monitoring diagram during Morako typhoon flood in 2009, starting scour at 6 am on 8 August at a pier named P30R of Chushang highway bridge, reaching a maximum scouring depth of 5.5 m at 6:30 pm on 9 August.

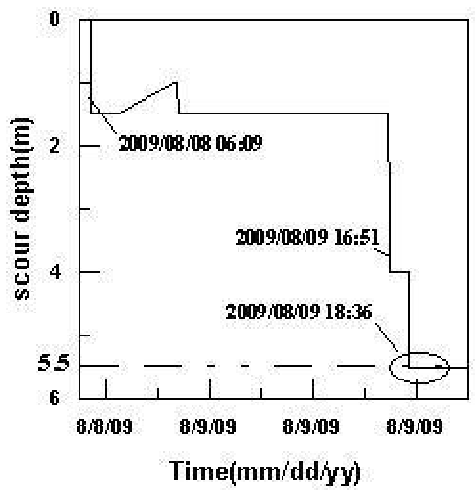

Figure 4. real time monitor scouring depth during the Morakot typhoon flood.

CONCLUSION

The scour is one of the major causes for bridge failure. In this paper, a cost-effective and real-time monitoring technique is adopted to trace the scouring depth of bridge pile foundation. A simple mechanical principle combined with a digital I/O switch forms a scour-sensing device. The digital sensing devices are embedded in the river bed. The scouring depth can be identified by monitoring the responses of these digital devices. The mobile wireless techniques (Wi-Fi and 3G) make the scour monitoring job safe and real-time. The proposed system was applied successfully in the field during Morako typhoon in 2009 in Taiwan. This demonstrates the capability of the system for real-time scouring-depth measurement.

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