Bridge Scour Field Inspection System Using Mobile Network and PDA

Jae Hyun PARK[1], Moonkyung CHUNG[2], Ju Hyung Lee[3] and Kiseok KWAK[4]

[1]Member of ISSMGE, Senior Researcher, Earth Structure and Foundation Eng. Research Div., Korea Institute of Construction Technology (KICT)
(2311, Daehwa-dong, Ilsanseo-gu, Goyang-si, Gyeonggi-do, Korea)
E-mail:jaehyeon@kict.re.kr
[2]Member of ISSMGE, Research Fellow, Earth Structure and Foundation Eng. Research Div., KICT
(2311, Daehwa-dong, Ilsanseo-gu, Goyang-si, Gyeonggi-do, Korea)
E-mail:mkchung@kict.re.kr
[3]Member of ISSMGE, Researcher, Earth Structure and Foundation Eng. Research Div., KICT
(2311, Daehwa-dong, Ilsanseo-gu, Goyang-si, Gyeonggi-do, Korea)
E-mail:leejh73@kict.re.kr
[4]Member of ISSMGE, Research Fellow, Earth Structure and Foundation Eng. Research Div., KICT
(2311, Daehwa-dong, Ilsanseo-gu, Goyang-si, Gyeonggi-do, Korea)
(Corresponding Author) E-mail:kskwak@kict.re.kr

Bridge scour field inspection system using mobile network and personal digital assistant (PDA) is developed. The developed system transmits scour inspection data promptly and safely at the bridge site to the database server of the bridge scour management system (BSMS). The database of this system is constructed to be coupled and synchronized with that of the BSMS. The developed system is operated as a client for the BSMS so as to allow the office engineer to monitor field conditions with the BSMS. Techniques of the geographical information system (GIS) are applied to the database system for storage, retrieval, statistics, and display of information regarding bridge scour. The efficiency of the proposed inspection system was thoroughly tested and found to be satisfactory.

Key Words : *bridge scour, feld inspection system, mobile network, PDA, BSMS*

1. INTRODUCTION

Bridge scour is the most common cause of bridge failures[1)3)]. Damages induced by scour are not always limited to localized and tolerable ones and often develop into stages imposing threats to the traveling public and resulting in long-term socio-economical losses. Efforts have been made by many countries to make bridges safer from scour. The largest campaign occurred in the U.S. where 95% of circa 480,000 bridges had been screened and determined against their vulnerability to scour through the FHWA National Bridge Scour Evaluation Program initiated in 1988[11)]. More examples can be found in the literature: New Zealand[10)], the Netherlands[2)], the U.K.[9)], in which they have developed and operated their own scour evaluation programs taking each country's environmental characteristics into account. In the case of Korea where high riverbed slopes are common in the mountainous terrain comprising the majority of its land and two thirds of annual precipitation are concentrated in the summer rainy season, the potential of bridge scour during flood events is inherently high[4)]. Typhoons Rusa and Maemi accompanying localized torrential rainfall wreaked havoc on the Korean peninsular in 2002 and 2003 respectively and left 300 and more bridges damaged or collapsed. This drew attention on bridge scour, which in turn led to the lunching of a funded research aimed at the development of a bridge scour management system (BSMS) based on scour potential of bridges. The BSMS consists of mainly two parts: GIS-based database; and prioritization processes of bridge scour vulnerability that incorporate the change of the bearing capacity of foundations due to scour. The feasibility of this BSMS was verified through many case studies on actual sites[4)].

Field inspection is a key element of the evaluation of bridge scour vulnerability since scour characteristics are site-dependent. In general, field inspection encompasses a wide range of works including: the assessment of geotechnical and structural factors as well as hydraulic conditions in the bridge reach that affect bridge scour stability; stream reconnaissance; and the estimation of potential future scour vulnerability in terms of trends. Comprehensive standardized guidelines for field inspection and plan of actions are provided in FHWA's Hydraulic Engineering Circulars[6)7)12)].

In Korea, the field inspection schemes for bridges on the National Highways, referring to roads managed by the central government, include examinations with naked eye during the dry season and underwater diving inspections at an interval of 3 years. Field examinations, however, are focused mainly on finding structural defects on bridge superstructures and streambed conditions around the foundation. Documenting the results of field inspections requires extra paperwork in office. Recent advances in telecommunication and electronic devises are bringing about many changes in ways of data acquisition and transmission. Real-time monitoring of bridge scour has been possible through transmitting data obtained from fathometers installed at bridge foundations to mobile phones[8)]. Besides this, information technology in a broad perspective can help engineers more efficiently react and perform field inspections for bridge scour.

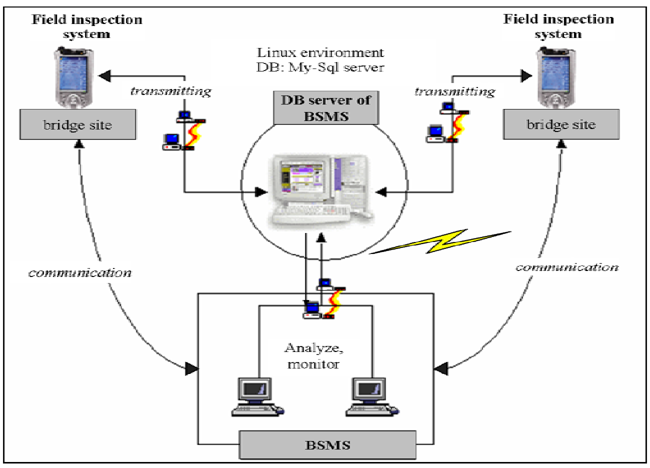
This paper presents a bridge scour field inspection system using commercial mobile network and personal digital assistant (PDA). This system transmits scour inspection information to the database server of the BSMS promptly and safely at the bridge site and retrieves information from it. The database of this system is coupled and synchronized with that of the BSMS.

2. DEVELOPMENT OF BRIDGE SCOUR FIELD INSPECTION SYSTEM

(1) Compostion of system

The field inspection for bridge scour introduced in this paper consists of three parts: (1) the bridge scour field inspection system, (2) the BSMS, and (3) the database server of the BSMS as shown in **Fig.1**. The composition of the bridge scour field inspection system is in two-folded: GIS-based database, data-transmission using commercial mobile network. The GIS techniques were employed in programming the database system for storage, retrieval, and display of information regarding bridge scour. The database of this inspection system is coupled and synchronized with that of the BSMS. **Fig.2** depicts a schematic of the database structure[5)].

The bridge scour field inspection system transmits inspection data through commercial mobile network system built in a handheld computer, PDA. The specifications of PDA, as used, are shown in **Fig.1**. The database server is modified to analyze and manage scour information transmitted from multi-connected field inspection systems at the same time. The BSMS allows office workers to get real-time scour field inspection data and to provide analyzed feedback information promptly.



[PDA specifications]

(a) Operating system : Windows Mobile 5.0
(b) Processor : 520MHz CPU
(c) Display : 2.4″ color TFT LCD
(d) Touch screen: yes
(e) Resolution : 240 × 320
(f) Standard memory : 384MB
(g) Input : Typing and handwriting
(h) Communication port : Direct connection with a PC by a cable USB/series connection
(i) Communication functionality : Wireless LAN 802.11 b/g CDMA 2000 1x EVDO
(j) Camera : 2 million pixel digital photos and video clips

Fig.1 A schematic of bridge scour field inspection system and PDA specifications

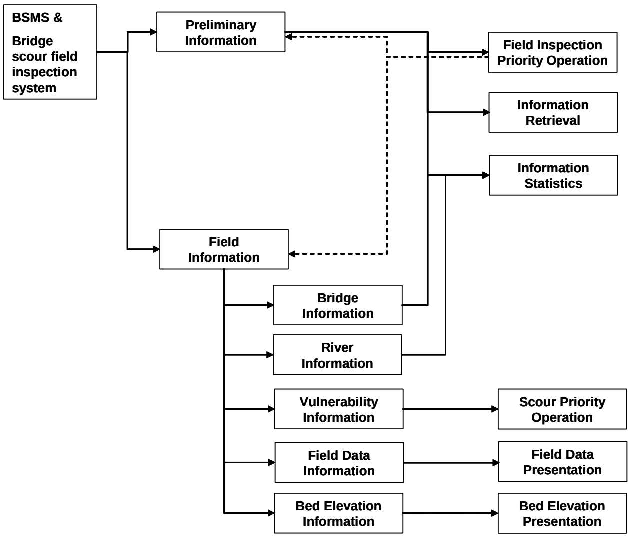


Fig.2 A Schematic of database structure

The bridge scour field inspection procedures using this system are divided into 4 steps. First, basic information on bridge scour and the priority for field inspection is retrieved from the database server of the BSMS. Detailed field inspection at a site follows. In the third step, inspection data is transmitted to the database server of the BSMS promptly and the office workers check out the field conditions through the BSMS computer screen. In case the mobile network is not available, inspection data should be stored in PDA. It is later transmitted to the database server when the mobile network is available. Once the field inspection is complete, the compiled information can be utilized in maintaining bridges. **Fig.3** illustrates the procedures of the bridge scour field inspection system. **Fig.4** shows initial screen of the program.

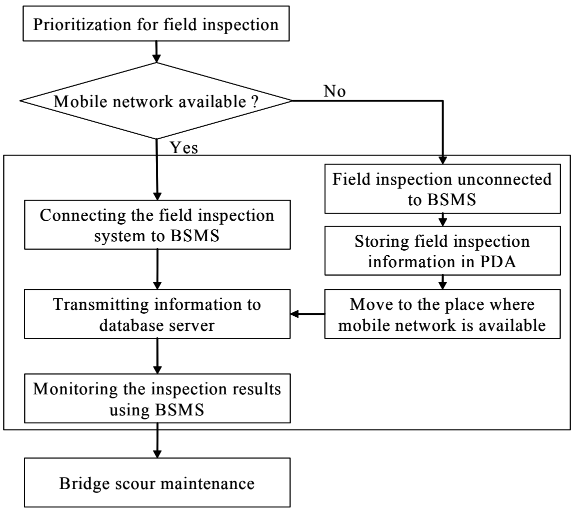


Fig.3 Flow chart of bridge scour field inspection system

Fig.4 Initial screen of bridge scour field inspection system

(2) Functions of system

The developed inspection system is connected to the database server through the commercial mobile network system for real-time data transmission. **Fig. 5** shows a step of PDA's connecting to mobile network.

Because of the PDA's small-sized screen, the inspection lists are needed to be divided into several categories. Furthermore, each category is divided into two groups, so to speak "basic" and "optional", which is alternatively showing on the screen. Two different input methods of a stylus pen writing and one-touch keyboard inputting are available for one's convenience as shown in **Fig. 6**.

Fig.5 PDA's screen that connects to the database server through mobile network

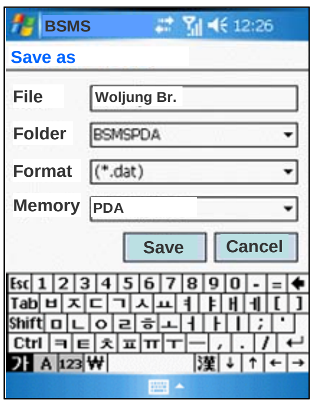


Fig.6 Example of inputting data using one-touch keyboard mode

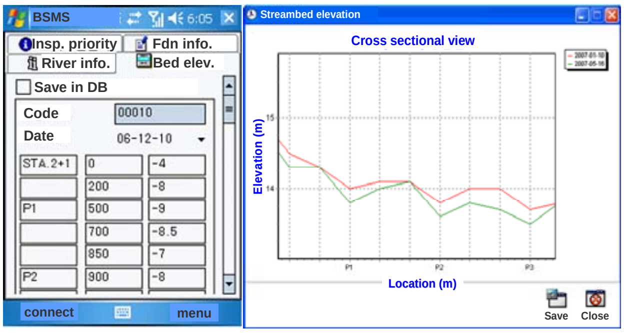


Fig.7 Plotting of streambed elevation

The GIS-based database system also facilitates plotting of the channel cross-section. An example is depicted in **Fig.7**. A two-dimensional vertical streambed elevation graph is produced with maximum 60 points along the channel cross-section. In addition, streambed elevation graphs that were previously saved over time can be recovered on the PDA's screen windows, so that one can see the change of streambed elevation with time.

The system incorporates different types of data format for transmission and reception including text, photo, and video clip. In order for field inspection to have reliability, reality, and objectivity, photos and video clips of a site are indispensable. Digital camera built in the PDA can perform this function. **Fig. 8** shows a step sending a photo file to the BSMS's database server. Data files transmitted to the database server from a bridge site are checked, edited and revised in the BSMS by an engineer in office.

Hand-written field inspection results could be damaged or lost. Moreover, documenting the results requires extra paperwork after the field investigation. The field inspection system developed in this study allows no risk of data loss since it transmits inspection data to the database server of the BSMS safely and promptly at the site through the commercial mobile network and stores it in the PDA.

In an attempt to save time, this system features, also, a function to retrieve the streambed elevation data that were saved at the immediately previous inspection.

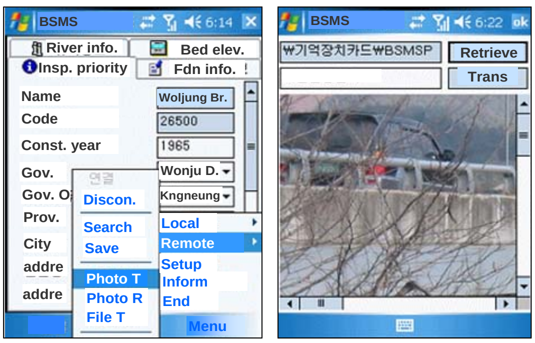


Fig.8 PDA's transmitting and electronic site pictures to the BSMS's database server

3. CASE STUDY

The developed bridge scour field inspection system was tested at an actual bridge, Daehwa-gyo (bridge) located in Goyang-si (city), Korea. **Fig. 9** shows a bird's-eye view of the bridge and field inspection in action using this system.

Access to the commercial mobile network at the field was fully available and the bridge scour information was downloaded from the database server of the BSMS. **Fig. 10** illustrates the proposed bridge scour field inspection system in operation.

Time efficiency of inputting using either stylus pen or one-touch keyboard was evaluated. Both the methods were found to be interchangeably used at one's preference with no technical difficulties. Input data was transmitted to the database server and the office worker was able to check the inspection data and field conditions with the computer screen of the BSMS. Subsequently, the office worker could provide analyzed feedback information to the field inspection system promptly. **Fig.11** shows the BSMS's screen of monitoring the field inspection data transmitted from the field.

4. CONCLUSIONS

The bridge scour field inspection system using mobile network and PDA was developed in an attempt to conduct field inspections efficiently and help maintain bridges safe from scour.


Fig.9 Bird's-eye view of Daehwa-gyo(bridge)


Fig.10 Photo showing the proposed bridge scour field inspection in operation

The database was constructed to be coupled and synchronized with that of the pre-existing BSMS. This system is operated as a client for the BSMS during field inspection. The developed system transmits field data to the database server promptly and safely when mobile network is available. The BSMS is improved so that it can handle and analyze scour-related information transmitted from multiple field inspection systems at the same time. For the sake of efficiency, various data formats are adopted for the database system. In addition, both input methods - stylus pen writing and one-touch keyboard input - were also applied. To overcome the size constraints of the PDA's small screen, long-listed inspection items are sorted and grouped.

The developed inspection system was applied at a real bridge site. Its efficiency in terms of real-time data transmission, field monitoring, user convenience, and data storage was found to be satisfactory.

REFERENCES

1) Briaud, J.L., Ting, F.C.K., Chen, H.C., Cao, Y., Hand, W.W., and Kwak, K. : Erosion Function Apparatus for Scour Rate Prediction, *J. of Geotechnical and Geoenvironmental Engineering*, Vol. 127, No. 2, pp. 105-113, 2001.
2) Hoffmans, G.J.C.M., and Verheij, H.J. : *Scour Manual*, A.A. Balkema, Rotterdam, the Netherlands, 1997.
3) Hunt, B.E. : Establishing a Scour Monitoring, Erosion of Soil and Scour of Foundations, *Geotechnical Special Publication* No. 135, ASCE. pp. 24~34. 2005.
4) Kwak, K. : A Bridge Scour Management System, *Proc. 3rd Int. Conf. on Scour and Erosion*, Amsterdam, the Netherlands, pp. 21-29, 2006.
5) Kwak, K., Park, J, H., Lee, J. H., and Chung, M. : Bridge Scour Prioritization and Management System for National Road Bridges, Erosion of Soil and Scour of Foundations, *Geotechnical Special Publication* No. 135, ASCE. pp. 35~45. 2005.
6) Lagasse, P.F., Schall, J.D., and Richardson, E.V. : *Stream Stability at Highway Structures*, Hydraulic Engineering Circular No. 20, 3rd Ed., FHWA NHI 01-002, Federal Highway Administration, Washington, D.C., USA, 2001.
7) Lagasse, P.F., Zevenbergen, L.W., Schall, J.D., and Clopper, P.E. : *Bridge Scour and Stream Instability Countermeasures –Experience, Selection and Design Guidance*, Hydraulic Engineering Circular No. 23, 2nd Ed., FHWA NHI 01-003, Federal Highway Administration, Washington, D.C., USA, 2001.
8) Lee, J., Yeo, W., and Kim, S. : Automatic Real-time Coastal Bridge Scour Managements, *Coastal Sediments '99*, Vol.3, pp. 2294-2305, 1999.
9) May, R.W.P., Ackers, J.C., and Kirby, A.M. : *Manual on Scour at Bridges and Other Hydraulic Structures*, Construction Industry Research and Information Association, Research Project 611, CIRIA C551, London, UK, 2002.
10) Melville, B.W., and Coleman, S.E. : *Bridge Scour*, Water Resources Publications, LLC., Highlands Ranch, Colorado, USA, 2000.
11) Pagan-Ortiz, J.E. : Impact of the Federal Highway Administration's Scour Evaluation Program in the United States of North America's Highway Bridges, *Proc. 1st Int. Conf. on Scour of Foundations*, Texas, USA, pp. 636-641, 2002.
12) Richardson, E.V., and Davis, S.R. : *Evaluating Scour at Bridges*, Hydraulic Engineering Circular No. 18, 4th Ed., FHWA NHI 01-001, Federal Highway Administration, Washington, D.C., USA, 2001.