PROPOSING A NEW PORTABLE DEVICE FOR BRIDGE SCOUR INSPECTION

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Scour is one of the major causes for bridge failures. Bridge failures due to scour tend to occur suddenly without prior signs and lead often to complete collapses. Monitoring bridge foundations is needed for the reduction of bridge damage due to scour; The progress of scour and bridge soundness must be evaluated correctly.

One of the widely used methods for the investigation of bridge scour employs sounding poles or staffs to measure a streambed depth from a footing or a boat on water. Inspection by divers is used together for further detail investigation into underwater condition. However, these methods have problems such that: the degree of accuracy is poor; and investigations are hard and dangerous at high flow velocity and they are, in general, time consuming and ineffective in cost.

In this study, in order to solve these problems a new portable scour monitoring device is proposed to inspect both of bridge scour and foundations. This system consists of three parts: installation deck, automatic operating equipment and measuring devices. Field applicability test was accomplished at the Daehwa Bridge to validate the performance of the prototype device and procedures under real world conditions. Through the test, it is shown that this new portable scour monitoring system enables to perform the bridge scour inspection easily, quickly, and safely.

1 Introduction

The most common cause of bridge failures during flood events is not structural defects of superstructure but bridge scour. In Korea, approximately 100 cases of bridge failures are reported annually. Especially, in 2002, the amount of damage hit a new high by a typhoon 'Rusa' and a heavy flood. 226 bridges were damaged and collapsed by scouring at piers or abutments, not so much as large bridges were also damaged severely.

Recently, the inspection of bridge foundations regarding to scour has become a more concern because recording present condition and identifying indication of potential problems are essential for further accurate evaluation and reasonable countermeasure. There are 3,390 national road bridges under government control and the 2,345 bridges span a waterway in Korea, as of October 2002. The Ministry of Construction and Transportation has been executing both external appearance inspection and underwater investigation at the same time to evaluate the condition of these bridges. Examination with the naked eye has been performed for the most part of waterway bridges during the dry season, and underwater investigation has been accomplished every 3 years for the bridges that naked eye checking is impossible because they are located at a deep river. However, these works require much expense of money and time. When consider limited manpower and budget against many bridges, it may be difficult that preserving and managing these bridges correctly.

During the last ten years, significant progress has been made with various types of fixed and portable instruments for measuring and monitoring scour depths at bridges. Fixed instruments are less favorable to portable ones in terms of cost and practicality because it is very difficult for the former to determine the location of the maximum scour depth. In most cases, portable instruments may be the better solution for bridge scour maintenance.

In this study, a new portable scour monitoring device is proposed to inspect both of bridge scour and foundations quickly and correctly. This system consists of three parts; installation deck, automatic operating equipment and sounding devices. The installation deck enables to mount the system on the shoulder of bridge and to be easily movable to other locations along the shoulder. The underwater camera is equipped to photograph and identify the condition of bridge foundations without divers. The ultrasonic acoustic sensor is also equipped to measure scour depths around piers. They are mounted on the end of the arm of the automatic operating equipment that is allowed to rotate and move to all the directions. All the devices are easily driven using the buttons of the control box placed on the installation deck. Field test was accomplished to evaluate the performance of the new portable scour monitoring device at the Daehwa Bridge.

2 Conventional Scour Monitoring Techniques

Portable scour measuring instruments are physical probing with rod or weights, sonar and geophysical(Richardson, 2002). The worker locates sounding pole from bridge deck to the surface of the water and can measure scour around pier using sounding device that attached at end of sounding pole. Physical probing and sonar are useful for real-time measuring scour during a flood and for routine measurements of bridge cross-sections. Geophysical instruments are better used for scour determination after the flood and scour holes have filled in. However, these methods have some problems such that investigation is hard and dangerous if the water depth is high and/or flow velocity is so fast. These methods also have difficulty in measuring several points around pier because access of equipments to pier is possible for only vertical direction on the bridge deck.

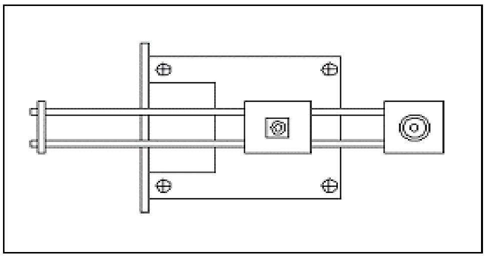
Float based systems permit measurement beneath the bridge and along side the bridge piers. Tethered floats are a low-cost approach that have been used with some success during flood flow conditions. A variety of float designs have been proposed and used to varying degrees for scour measurements, typically to deploy a sonar transducer. Common designs include foam boards, PVC pontoon configurations, spherical floats, water skis and kneeboards(Lagasse, 2001). The size of the float is important to stability in fast moving, turbulent water. A shortcoming of this system is that debris may habit its ability to make accurate scour measurements during high flow condition.

It was developed a truck mounted articulated crane to position various measurement devices quickly and safely, supported by the National Cooperative Highway Research Program(NCHRP)(Schall and Price, 2002). This system is composed of crane located at the back of the truck, sonar transducer attached at the end of arm crane, and a variety of sensors(tilt meter, acoustic stage sensor, potentiometer, etc) installed on truck. The crane can reach 5m to 15m below the bridge deck for scour measurement. This system makes it possible to monitor at a wide range of bridges and collect data automatically under flood flow condition. However this system is very expensive and flow condition including high velocity and debris make the measurement difficult. In some cases it may cause obstruction of traffic.

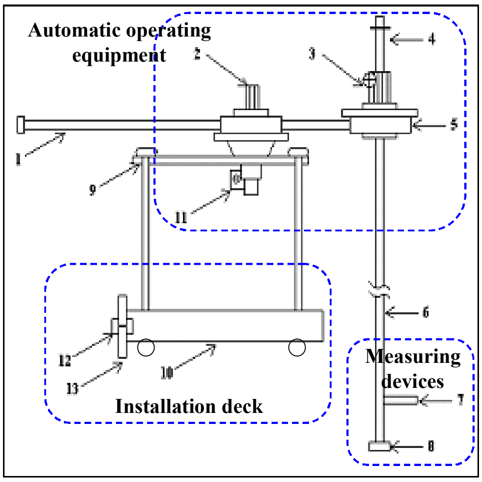
3 Development of a New Portable Device for Bridge Scour Inspection

Generally, two techniques are needed to investigate bridge scour and foundation; (1) a technique for close-photographing the status of bridge foundation and (2) a technique for measuring scour depths around piers. The existing scour monitoring devices as stated above, portable scour measuring equipments and articulated arm crane system, are chiefly focused on measuring scour depths.

The new portable scour monitoring device introduced in this paper can be applied to both of close-photographing the underwater status of foundation and measuring scour depths around piers. This system consists of three parts; installation deck, automatic operating equipment and measuring devices(Fig. 1). The completed system of the device is shown in Fig. 2 and Fig. 3 illustrates the process of investigation in details. The following paragraphs present the feature of each part.



(a) Plane figure



(b) Cross section

1. Horizontal shifter
2. Motor for movement of horizontal shifter
3. Motor for movement of vertical rod
4. Guide of vertical rod
5. Supplementary equipment for vertical rod movement
6. Vertical rod
7. Support of underwater camera
8. Support ultrasonic acoustic sensor
9. The upper support
10. The lower support
11. Motor for rotation of horizontal shifter(360° rotation)
12. Level
13. Equipment to fix

Figure 1. Schematic diagram of a new portable device for bridge scour inspection

Figure 2. Shape of a new portable scour monitoring system

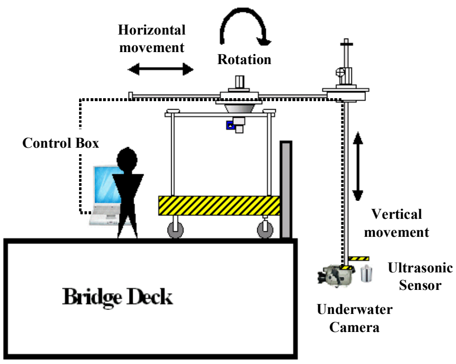


Figure 3. Process of investigation

3.1. *Installation deck*

The installation deck is composed of the lower support, a level and the equipment to fix the system on the shoulder of bridge. The installation deck enables to mount the system on the shoulder of bridge and to be easily movable to other locations along the shoulder. The lower support has a plan dimension 1.0m x 1.0m, and the weight of it is about 50kg that can be handled by two workers. Wheels attached at the bottom of the lower support enable to move easily and to reduce working hours.

3.2. *Automatic operating equipment*

Automatic operating equipment is composed of three motors, horizontal rods, vertical rods and control box. Three motors enable the rods to move horizontal, vertical and rotational direction automatically. All the motors are easily driven using the buttons of the control box placed on the installation deck. This operating equipment has the capability of 1.5m horizontal movement, 15m vertical movement and 360 degree rotation.

3.3. *Measuring devices*

The underwater camera system enables to photograph and identify the condition of bridge foundations without divers. It has LCD monitor so the condition of bridge foundation underwater can be monitored real-time on the ground. It is also waterproofed against 50m water pressure. Scour depth around piers are measured using the ultrasonic acoustic sensor. It uses 170kHz frequency and can sound from 0.6m to 60m water depth. They are mounted on the end of the arm of the automatic operating equipment that is allowed to rotate and move to all the directions.

4 Field Test

A field test was accomplished to evaluate the new portable scour monitoring device at a real site, representing a range of bridge and site conditions. The purpose of this testing was to validate the performance of the prototype device and procedures under real world conditions. Field testing was completed at the Daehwa Bridge in Koyang City, Korea. The evaluation of the device included a range of bridge conditions(high bridge decks, clearance, etc), flow conditions(high velocity and sediment concentrations, floating debris, water pressure, etc) and durability of the device(water resistance, luminous intensity, etc). The Daehwa Bridge has 4 couple piers with spread footing, and the total length of it is 50m. The diameter of pier is 1.0m and average height from streambed is 10.0m. The average water depth is about 1.0m and the maximum velocity is about 1.5m/s. The channel bed material is primarily sand and silt.

The measured points around pier is shown in Fig. 4. The water depth from streambed was measured with ultrasonic acoustic sensor at 12 points around a pier, and the surface condition of pier was visualized and recorded through the underwater camera. Investigation points are composed of 6 points at vicinity of pier and 6 points at intervals of 1.5m from pier(Fig. 5). At front three points, pier scour was detected and the scour depth was about 0.5m. Fig. 6 is one of the images on the pier surface condition collected through the underwater camera, and small crack was detected at the surface of pier.

Total elapse time investing a pier was about 2 hours including both assembling and dismantling the device. Two works was enough to assemble and dismantle the device. As a result of field testing, a new scour monitoring device can be installed at bridge deck easily and has high mobility and workability. This method may be more correct in comparison with measuring using sounding poles or staffs and faster and easier in comparison with inspection by diver. But connecting vertical rods is complicate and vertical rods long connected shook slightly by wind or flow. Therefore improvement of vertical movement equipment should be needed for correctly investigation.

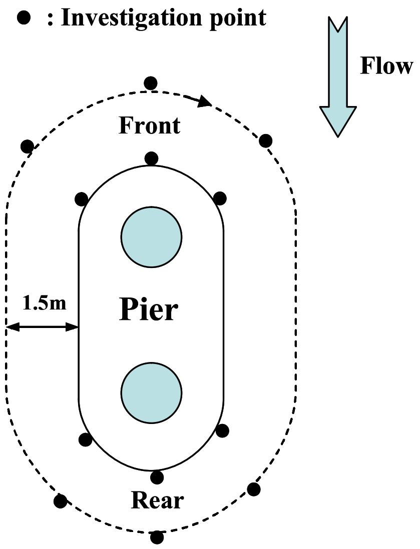


Figure 4. Measured points around pier

Figure 5. Scene of preparation for measuring pier scour

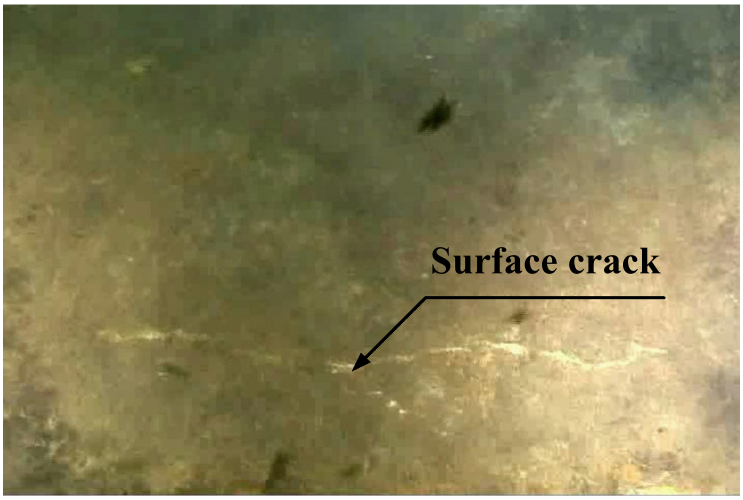


Figure 6. Image on the pier surface condition

5 Conclusions

This paper presents a new portable monitoring device developed to inspect bridge scour and foundations. This device consists of three parts: installation deck, automatic operating equipment and measuring devices. The installation deck enables to mount the device on the shoulder of bridge and to be easily movable to other locations along the shoulder. The underwater camera is equipped to photograph and identify the condition of bridge foundations without divers. The ultrasonic acoustic sensor is also equipped to measure scour depths around piers. They are mounted on the end of the arm of the automatic operating equipment that is allowed to rotate and move to all the directions. All the devices are easily driven using the buttons of the control box placed on the installation deck. Through the field test accomplished at Daehwa Bridge, the performance of the new portable scour monitoring device was verified. The scour monitoring device is proposed to practical use of the bridge scour and foundation inspection as a meaningful and cost-effective method.

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