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Development and Application of a 3-Dimensional Scour Monitoring System for Sea-Crossing Bridge Piers

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Local scour refers to the loss of bed materials around the foundation of a bridge by flow change, when structures are built in the water. Local scour depths are usually determined using empirical formulas, and field monitoring is conducted in the construction stage to verify the estimated results. However, in an offshore environment, it is difficult to acquire scour data due to tide and waves. In this study, a 3D scour monitoring system was developed to measure scour contour for sea-crossing bridge piers. The developed 3D scour monitoring system consists of profiling sonar, a rotating driver, and a compact data logger. In the verification test, the water depths measured by the system agreed well with the plumbed depths. For field application, the 3D monitoring system was applied at one main pier of the Incheon Bridge in the Republic of Korea. The results show that this system can effectively measure the real maximum scour depth and the extent of scour around the sea-crossing bridge pier.

INTRODUCTION

Local scour around bridge piers is one of the major causes of bridge failures. Scour washes away bed materials around the foundations of a bridge, which causes a reduction in the load capacity of the foundations. Wardhana and Hadipriono (2003) reported that 50% of bridge failures in the U.S. were caused by local scour in floods.

Evaluation of local scour depths has been undertaken by many researchers in the last several decades. For noncohesive soils, some empirical equations have been extensively used (e.g.: Laursen, 1962; Neill, 1964; Melville and Sutherland, 1988; Richardson and Davis, 2001). On the other hand, a few researchers have been conducted on cohesive soils. Gudavalli (1997) showed that the cohesiveness of soils has no noticeable influence on the maximum scour depth. This indicates the equations given for noncohesive soils can be applied to piers on cohesive soils. In an offshore environment, bridge piers are influenced by a tidal current and waves. Sumer and Fredsøe (2002) have presented results for equilibrium scour depth under the combination of current and waves. However, because these empirical formulas were developed from the controlled laboratory data, they could not describe the variability and interaction of local scour variables present in natural conditions (Mueller and Wagner, 2005). Consequently, it is necessary to carry out in situ monitoring to overcome the limitations of these estimation equations.

The major parts of a scour monitoring system are a sensor and a data logger. The sensor detects streambed elevations, while the data logger controls the sensor and collects data. A variety of sensors for monitoring has been developed, including a sounding pole, an underwater camera, a magnetic sliding collar and a sonar (Nassif et al., 2003). The choice of sensor depends on the targeted field conditions. There are more alternatives for measurement in rivers than offshore. On the other hand, an offshore environment requires a wider area to be monitored due to directional flows and waves, and it is not easy to apply sounding poles and divers in tidal waters due to the deep depth of the water and the height of the waves. For these reasons, a sonar survey is preferred for sea-crossing bridge piers.

The monitoring method with sonar consists of boat surveys and point surveys. As the boat surveys use a vessel, they cover a wide area for monitoring, but the measurement accuracy is low, because the boat is swayed by the wave motion. Also, as pier structures have become more complex and larger recently, many areas cannot be accessed by the surveying vessel. The other method—the point surveys, which attach a sensor to a foundation surface—can provide continuous and accurate results, but it is not an economically feasible idea to install a lot of fixed devices to the surface of a pier in order to cover wide seabed areas around the pier. Also, the measured maximum scour depth may not be the actual maximum, unless the maximum point is included in the measurement range. As a result, the combination of boat surveys and point surveys cannot introduce enough data to evaluate the maximum local scour depth of offshore substructures.

In this study, a 3D scour monitoring system consisting of profiling sonar and a compact data logger was developed to measure the maximum local scour depth around a large pier of a sea-crossing bridge. Attached to the pier surface, this system can have the same effect as applying boat surveys and point surveys together, to also measure the local scour depths and scour extents. For field application, the data logger was designed to have a small size and to effectively control power for long-term monitoring; the monitoring system was then applied to one of the main piers of the Incheon Bridge in the Republic of Korea. The survey was conducted 3 times in 2008. The measured scour information from these 3 surveys was compared with an empirical equation.

3D SCOUR MONITORING SYSTEM

As shown in Fig. 1, the 3D scour monitoring system uses an IMAGENEX profiling sonar head and an IMAGENEX azimuth driver to rotate the head horizontally. The profiling sonar, with a minimum angle of 1.4° between the transducer beams, automatically takes a seabed profile by producing a series of ultrasonic waves; then the sonar head is reoriented horizontally to take another profile of the seabed. The minimum angle of the azimuth driver is 0.3°. The data logger and the attachment device were newly designed for practical applications.

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