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New Measuring Method for the Scour and the Water level by Temperature Measurement

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ABSTRACT: Bridge scour is the result of the erosive action of flowing water carrying away material from around bridge abutments or piers. The difference between the ground level in water and the ground level without abutments and piers is called “scour depth”. Bridge scour is the main cause of bridge destruction and among the causes of bridge destruction whenever flooding occurs. The largest direct factor causing bridge collapse is the destruction of foundation, resulting from the scour of abutments and piers. Therefore, evaluation of bridge scour in determining the safety of bridges crossing rivers is considered to be a must. Particularly in floods resulting from typhoons or torrential rains, monitoring the scour and water level on a real time basis is more than important for the safety of the bridges and users.

This study was intended to develop the new system using temperature measuring mechanisms for monitoring the bridge scour and water level, as well as to introduce the verification test result on development theory. A bridge scour investigation method using temperature measuring mechanisms is designed to analyse the difference in temperature between the water and saturated soil, so as to predict the ground level in water.

In a bid to prove the development theory, water temperature distribution and temperature difference in saturated soil were identified by measuring the soil and water temperature together, by unit length and at certain depths, along with the air temperature at the stream and in the laboratory. Additionally, the difference in temperature between the air and water was also measured using the same method to verify the water level measurement.

1 GENERAL INSTRUCTIONS

Bridge scour is the result of the erosive action of flowing water carrying away material from around bridge abutments or piers. The difference between the ground level in water and the ground level without an abutment and pier, is called, “scour depth”.

1.1 Necessity of measurement for the scour and the water level in bridges

Bridge scour is the main cause of bridge destruction and among the causes of bridge destruction by flood, the largest direct factor causing bridge collapse is the destruction of foundation resulting from the scour of the abutment and pier. In Korea, land is mostly mountainous, a river bed is relatively steep and about two thirds of annual rainfall is concentrated in the summertime. Aggregate collection and dam construction cause a river bed to become more unstable, making it vulnerable to scour in a flood. Bridge collapse caused by scour in a flood is not only a problem to Korea, where the rainfall is concentrated in rainy seasons but also a common issue throughout the world as it has a great impact on service life of the bridges.

1.2 Difficulties of existing measuring method for the scour and the water level in bridge

The most accurate monitoring of the bridge can be achieved through manual inspection by a monitoring person, but it's often impossible in the situation when a scour occurs rapidly, for the safety and the measurement floating device utilized, or even the use of a boat would be difficult. A scour investigation device using a robotic arm is too costly as well as physically difficult to maneuver in a flood. A scour monitoring device which is applicable to a permanent monitoring system using the electromagnetic field or ultrasonic wave, could provide long-term monitoring, but it takes a long time for analysis and the effect is significantly altered by the turbidity of water or floating matters (Kwak 2006).

1.3 New measuring method for the scour and the water level in bridge

So there is a necessity for a new measuring method for the scour, which can be applied to bridge monitoring systems now. This study was intended to develop the new system using a temperature measuring mechanism for monitoring the bridge scour and water level, as well as to introduce the verification test result on development theory. A bridge scour investigation method using a temperature measuring mechanism is designed to analyze the difference in temperature between the water and saturated soil, so as to predict the ground level in water. A thermometer is placed vertically on a pier, at a certain interval, and as it is structurally and theoretically simple, a real-time monitoring is achievable when a remote control system is equipped, making it possible to monitor the scour and water level even in a flood. It could predict the water level using the same method. In a bid to prove the development theory, water temperature distribution and temperature difference in saturated soil were identified by measuring the soil and water temperature by unit length at a certain depth, along with the air temperature at the stream. Additionally, the temperature change around the ground level in water under scour condition was checked by a scour test instrument in the lab. We set the temperature sensor - which was made of an optical sensor - at a real bridge pier, and presumed the ground level in water in a real bridge condition.

2 NEW MEASURING METHOD FOR THE SCOUR AND THE WATER LEVEL

2.1 Measuring method for bridge scour and the water level by temperature measurement

A new scour and water level measuring method is to place the instrument vertically to the pier, for measuring the temperature sensor at a certain interval, so as to identify the water surface and the ground level in the water. It’s intended to analyze the gap between air temperature and water temperature, and water temperature and soil temperature in the water, so as to estimate the level of water surface and the ground in the water (Joo et al 2009).

Besides absolute temperature gap, it’s designed to accurately measure the level of water surface and the ground in the water using the diurnal variation between the air, water and underground.

The newly developed scour and water level measuring method adopts a simplidfied analysis system. As the instrument is fixed to the bridge, a real-time measurement of scour and water level - even in a flood - is possible, so as to identify the danger signs in a timely manner, depending on scour and water levels, A commitment to developing and maintain safety management of the bridge in an emergency, is expected.

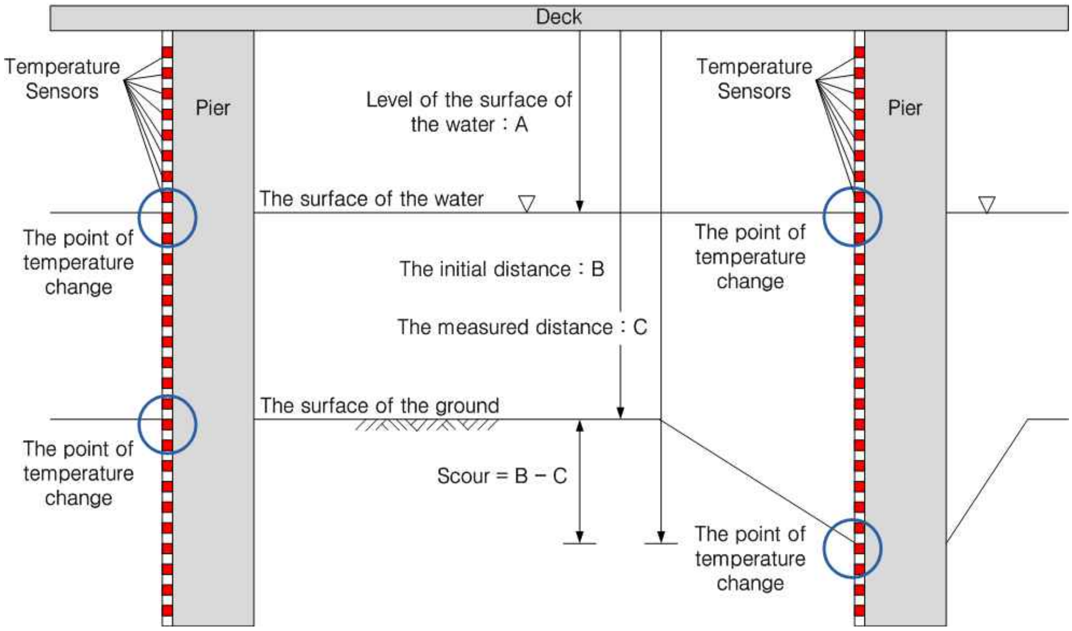


Figure 1. Concept of new measuring method for the scour and the water level (Joo et al 2009)

3 VERIFICATION RESEARCH

3.1 Experiments for the verification

3.1.1 Experiment in a stream

Measurement of air temperature, water temperature and saturated underground temperature was carried out at real stream conditions to identify the absolute temperature gap and variation at the boundary. A 2,000mm-long instrument was equipped with a temperature sensor at every unit length (100mm) and FRP bar was used as the support. Measurement was conducted twice. The first measurement was made at 18℃ and 600mm of water depth, and the second measurement was at 29℃ and 400mm depth. No scour was monitored between two measurements

Figure 2. Measurement surroundings and the installed instrument in a stream

3.1.2 Experiment under scour condition in the lab

To identify the temperature variation around the ground in the water under the potential scour condition, artificial scour was generated with the model river at the lab while monitoring the temperature on the ground in the water. For the test, the water tank was filled with 350mm of sand; the water tank was 1,400mm wide, 900mm long and 500mm high. The scour was generated by 100mm over two stages. Absolute temperature variation before and after the scours and relative temperature variation 24 hours a day, were monitored using the temperature sensor that was installed vertically at a 50mm interval.

(a) Before (b) After

Figure 3. Figures of the before and after of the scours

3.1.3 Experiment in the river

To identify if the ground level in the water could be measured for analysis of temperature variation patterns during the time under real bridge conditions, a temperature sensor was placed on the pier in 6m of water depth, and temperature variation was monitored for 24 hours. The sensor, which was 7m long and 50mm diameter FRP bar, had 10 FBG temperature sensors on the front end, which were installed at 200mm intervals so as to measure the temperature at 1.8m in height.

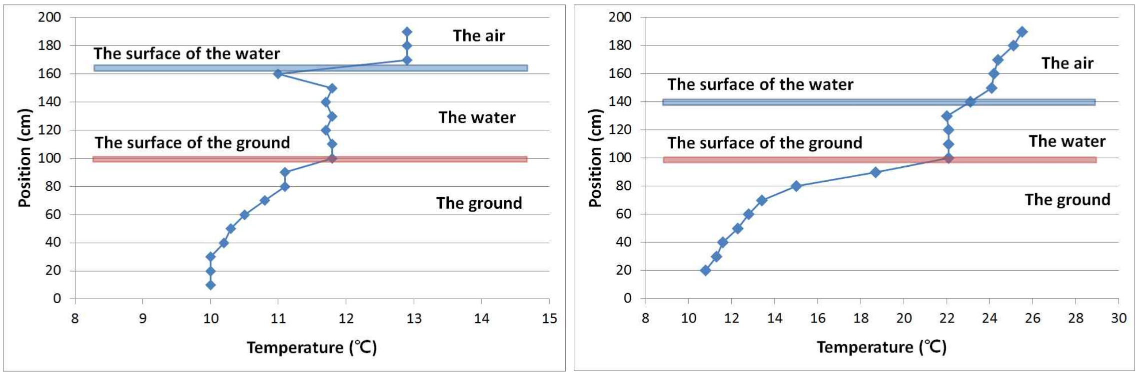
Figure 4. The manufactured instrument for installing in the river and the position of FBG sensors

Figure 5. Measurement surroundings and the installed instrument in the river

3.2 Result of verification experiments

3.2.1 Result of the experiment in a stream

Figure 6 shows the result of temperature measurement by measuring point. To help better understand, the level of water face and ground in the water was also indicated. As seen in the Fig., rapid temperature variation was monitored on the water surface and the ground surface, which are the boundaries of the gaseous, liquid and solid matter. Because the different temperature patterns depend on the matter, the location of the ground surface in the water and water surface could be estimated by measuring the matter temperature. In this case, very little variation in temperature by water depth was monitored and the saturated underground temperature tended to converge to a particular temperature (Joo et al 2009).

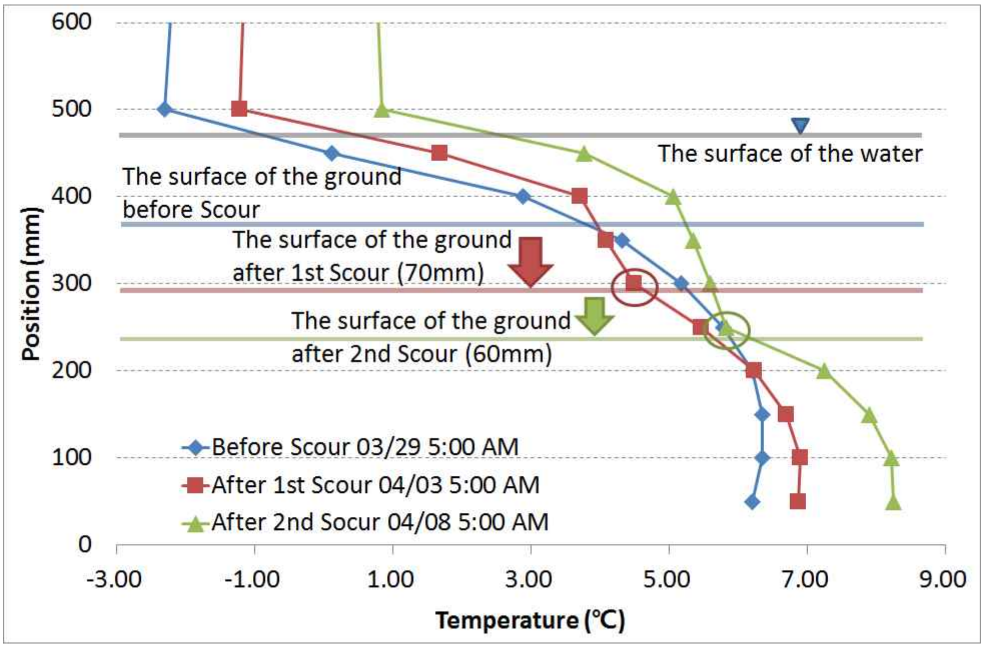


(a) at 18℃ and 600mm water depth (b) at 29℃ and 400mm water depth

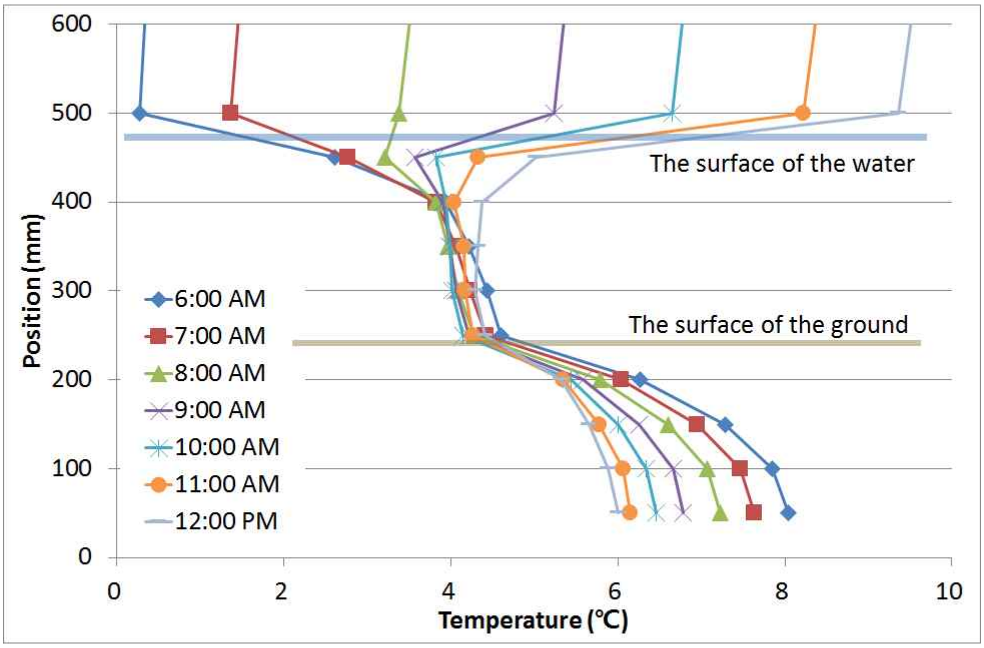
Figure 6. Result of temperature measurement in the stream

3.2.2 Result of the experiment under scour condition in the lab

Figure 7 shows the result of temperature measurement by measuring point under scour condition in the lab. The scour about 100mm was generated twice in the experiment but the actual scour that occurred was 70mm and 60mm respectively, totaling 130mm. Though the condition of the experiment was without the water flow, the scour was accurately measured by simply measuring the temperature. So the location of the water surface and the ground surface in the water could be identified using the characteristics of a different temperature variation pattern by kind of matter (air, water and underground). Thus, if it analyzed absolute temperature pattern by location and temperature variation pattern according to time simultaneously, it could estimate a more accurate location of the water surface and the ground surface in the water.



(a) Change of the pattern by scour

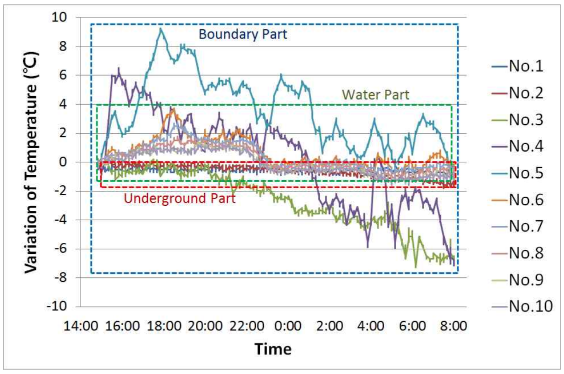


(b) Change of the pattern according to time

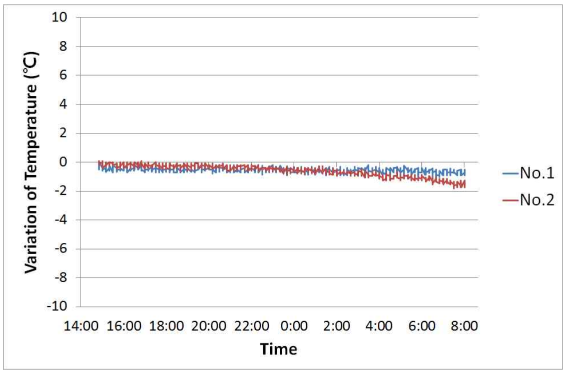
Figure 7. Result of temperature measurement under scour condition in the lab

3.2.3 Result of the experiment in a stream

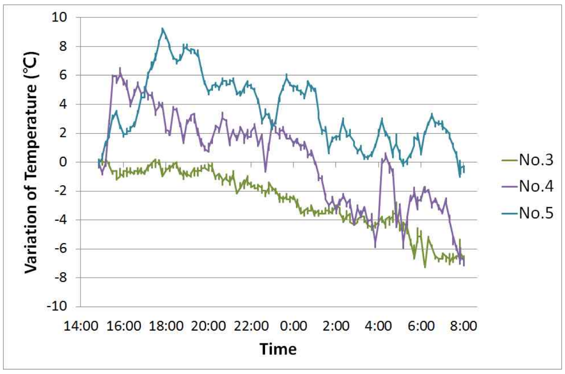
The instrument for measuring temperature was placed on a pier of the bridge in use that is over the river. The temperature variation according to time was measured and the result is as shown in Figure 8. As a result of measuring temperature variation with the measurement start set at “0” for 24 hours, the temperature variation patterns were different to each other, which were underground - the ground surface (boundary) in the water. Temperature variation patterns were indicated separately in Figure 8. The underground temperature changed very little and the water temperature changed a little, but the boundary temperature changed much around 10 ℃ showing significant variation. Viewing the result above, the location of the boundary between ground and water could be roughly estimated by monitoring the temperature variation according to time. As a result of analyzing the patterns, ground surface was estimated at between No3 and No 5, which indicated 6m depth from the water surface and is similar with the actual depth. If more various and steady temperature data patterns are measured and analyzed further, more accurate estimation of the scour will be possible.



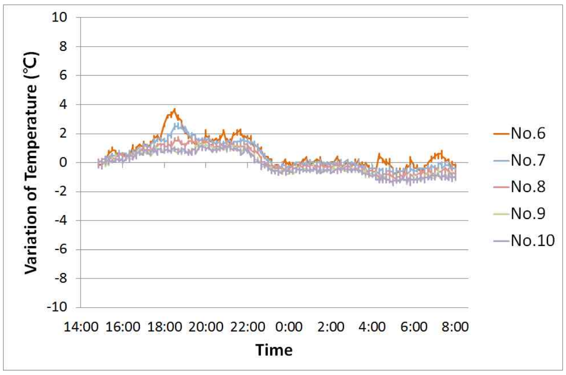
(a) Measurement data



(b) Pattern of underground



(c) Pattern of the boundary



(d) Pattern of water

Figure 8. Result of temperature measurement in the river

4 CONCLUSION

Through various experiments and efforts to develop the measurement method of scour and water level, based on temperature measurement, the following conclusion was made:

1. Measurement of bridge scour and water level using temperature measurement proved to be appropriate
2. There were differences in absolute temperature distribution of air, water and saturated underground and in temperature variation according to time, and such variation was greater at the boundary.
3. The absolute temperature distribution analysis and temperature variation analysis reviewed as part of the method for identifying the location of water surface and ground surface in the water proved to be effective in estimating the scour and water level.

5 ACKNOWLEDGEMENTS

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6 REFERENCE

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