APPLICATION OF USN TECHNOLOGY FOR MONITORING EARTH RETAINING WALL

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ABSTRACT: In construction operation, the temporary structure is used to support designed facilities or to provide work spaces for construction activities. Since the structure is used only during the construction operation, the operation may be given insufficient attention. The contractor is likely to try to save cost on the material and labor cost. This contractor's behavior frequently leads to construction accidents. In order to prevent accidents from the failure, the operation should be carefully monitored for identifying the effect of dynamics in the surrounding site area. Otherwise, any unexpected adversary effect could result in a very costly construction failure. This study presents the feasibility of the ubiquitous sensor network (USN) technology in collecting construction data during the construction operation of earth retaining walls. The study is based on the result at the Construction System Integration Laboratory (CSIL) at the Pusan National University. A USN-based system has been developed for monitoring the behavior of the temporary structure of earth retaining walls. The data collected from the sensors were used to understand the behavior of the temporary structure. The result of this study will be used in increasing the safety during the construction operation of retaining walls.

Keywords: Earth retaining wall; Temporary structure; Ubiquitous Sensor Network(USN); Monitoring

1. INTRODUCTION

In construction operation, foundation work should be done in advance for the building structure to be installed safely. This foundation work includes a number of activities such as excavation, ground water prevention, piling, wale installation, etc.

In construction operation, the temporary structure is used to support designed facilities or to provide work spaces for construction activities. Since the structure is used only during the construction operation, the operation may be given insufficient attention. The contractor is likely to try to save cost on the material and labor cost.

However, caution should be taken in the operation because the dynamics of earth movement can cause a significant failure in the temporary structure (Figure 1). This contractor's behavior frequently leads to construction accidents.

Construction failures have been reported frequently, and there may be no way to entirely eliminate failures [1]. Effort should be taken to monitor the structural behavior during construction, and to give out signals on the dangers occurring due to unexpected impacts.

In order to prevent accidents from the failure, the temporary structure, therefore, should be constantly monitored. Even if the temporary structure is built pursuant to shop drawings and technical specifications, unforeseeable conditions at construction site could deteriorate the structural stability. Therefore, the contractor should try to identify the effect of dynamics in the surrounding site area. Otherwise, any unexpected adversary effect could result in a very costly construction failure.

Figure 1. A case of earth retaining wall failure

2. RESEARCH GOAL

Construction sites are exposed to dynamic factors that significantly affect the safety of temporary and permanent structures. Faced with the dynamics, the monitoring system should be able to capture the data from sensors at sites and provide signals for the changes in structural loading.

This study presents the feasibility of the ubiquitous sensor network (USN) technology in collecting construction data during the construction operation of earth retaining walls. A state of art technology is applied in the ubiquitous environment.

A USN-based system has been developed for monitoring the behavior of the temporary structure of earth retaining walls. The data collected from the sensors were used to understand the behavior of the temporary structure. The result of this study will be used in increasing the safety during the construction operation of retaining walls.

The USN-based monitoring system automatically identifies the behavior of the temporary structure in addition to the visual inspection. The autonomous capability of the monitoring system can increase the safety in the construction operation by providing the detailed structural damages of the temporary structures.

The research in this paper is being executed in four steps: 1) development of a USN-based remote monitoring system; 2) monitoring of the structural behavior of earth retaining walls; 3) analysis of collected data; and 4) improvement of safety in the operation of earth retaining walls.

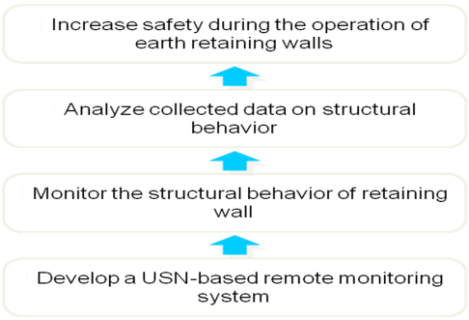

Figure 2. Research procedure

3. RESEARCH METHOD

The USN technology is a promising way to facilitate data collection at the construction sites. The ad-hoc capability of the technology makes it very applicable in monitoring construction operations in remote areas. Researchers have made efforts to provide a systematic approach to monitoring wirelessly constructed structures [2][3]. They used the USN technology in developing Micro Electro Mechanical System (MEMS) and Structural Health Monitoring (SHM). Moon et al. also applied the technology in concrete placement [4].

The operation of earth retaining walls are exposed to unexpected on-site effects, and sometimes result in structural failure. The construction failure can cause severe cost and time delay. Considering the characteristics of the earth retaining walls, this technology can be also applied for monitoring the safety of earth retaining walls.

A prototype of USN-based monitoring system has been developed to collect data from earth retaining walls. The system uses ultrasonic sensors and strain gages for collecting data from the temporary structure. These devices were connected to USN boards to transmit the collected data to the hosting PC. The local network formed within the range of the USN devices allowed for the data transmission wirelessly from the construction site to the staging office. The collected data are stored in a database for data analysis and decision making.

The ultrasonic sensors detected the change in the distance between two walls across the excavated area. The strain gages measured the deformation of the walls as pressure increases. The detected data are transmitted using MicaZ USN boards through relay. The networking program was developed based on the TinyOS [4].

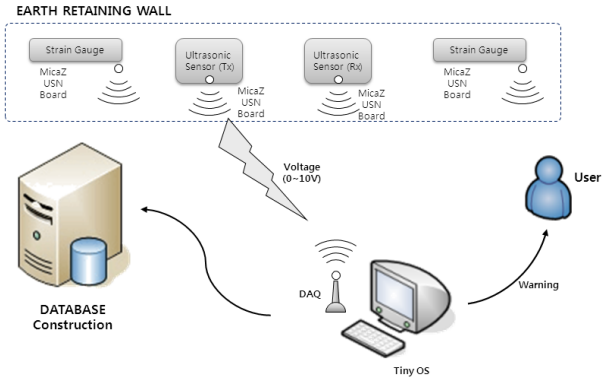

Figure 3. Ubiquitous environment to collect data

Figure 4. Earth retaining wall test-bed of a ubiquitous environment to collect data

4. FABRICATION OF A TEST-BED FOR EARTH RETAINING WALL

The structural design requires to consider not only the design load but also the unexpected effects during construction. The structural safety should be constantly measured through monitoring during the operation. The indoor test-bed was built to simulate actual conditions when the earth retaining wall operation is being executed at construction sites.

The test-bed represents the earth retaining wall in a simplified form, and made up of steel bars, steel plates, and plywoods, eg. steel bars for cross beams, steel plates vertical beams, and plywoods for wood blocks. Sensors were installed on each elements of the test-bed. USN boards were used for wireless data transmission. The sensors were attached at the points where the deformation occurs at maximum value. The ultrasonic sensors are installed at the top of the steel plate; the strain gage at the one third and two thirds of the steel plates.

On the back of the plywood is a water tank which has 1,200mm in height, 1,000mm in width, and 500mm in depth. The water in the tank provided vertical pressure on the steel plates. The water tank is flexible enough to deliver the pressure on the plywood. The water level is controlled to indicate the increase of vertical pressure.

Repetitive tests were done on the test-bed to gain prior knowledge of structural behavior of the earth retaining wall, and the reliability of the sensor devices that were used in this study.

5. DATA COLLECTION

The water level is gradually increased to mimic actual site conditions. It is assumed that only horizontal pressure occurs on the retaining wall. During the experiment, the water tank attached to the plate was filled up to provide horizontal pressure. The water pressure forced a bent of the plate that works as a retaining wall.

The pressure on the retaining wall was measured using the ultrasonic sensors and strain gages. These sensor modules were mounted on the test-bed. As the horizontal pressure increases, the sensor modules sent out sensory data to the hosting PC through wireless network. The frequency of data transmission could be set up at 10 seconds. If the sensory data is not transmitted over the time, the USN-based monitoring system signaled the stoppage of data transmission functions.

The moving average value is used to represent the measurement of sensory data because the data value constantly varies during the experiment. In this test, measurement of distance is important in identifying structural deformation. A hand-held laser device was used to test the precision of the ultrasonic sensors (as the horizontal pressure increases).

Table 1 shows the result of experiment on the indoor test-bed. As the table indicates, the errors were ranged within ±0.22mm, and showed the reliability of the measurement when using the ultrasonic sensors together with USN boards.

Table 1. Comparison of Main Features between Mixed-use and Single-use Projects

Horizontal Loading (Ton/M2)	Measurement by a laser device (mm)	Measurement by ultrasonic sensors (mm)	Error (%)
0.075	1753	1752.8	-0.01
0.100	1753	1753.2	+0.01
0.150	1753	1751.7	-0.07
0.200	1750	1753.9	+0.22
0.250	1745	1747.3	+0.13
0.305	1720	1718.4	-0.09
0.075	1751	1750.6	-0.02

6. DATA DISPLAY

An interface program was developed for the host PC to communicate with the USN boards in the wireless network using the TinyOS program [5]. The program displays the collected data to describe the condition of the temporary structure. The contractors can use the information displayed on the monitoring system, and find out whether the operation is being executed as planned during the concrete placement operation. The USN nodes wirelessly transmitted the data in a form of radio frequency signals to the data acquisition board of the host PC.

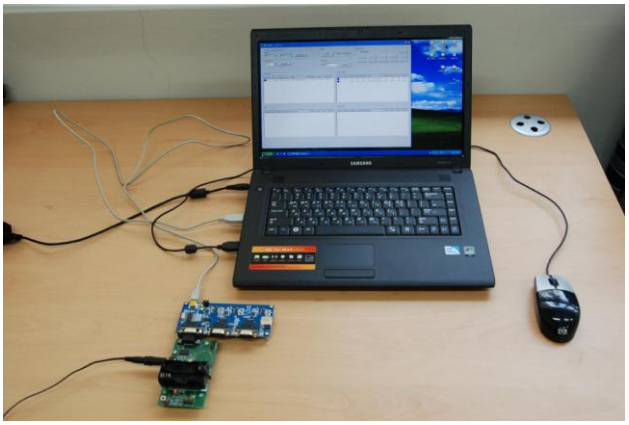

Figure 5. Display of Data collection from sensors on USN boards

7. CONCLUSION

This paper introduced a prototype of the USN-based monitoring system for earth retaining walls. Although the study is at the stage of indoor laboratory tests, the experiment on the test-bed showed that the USN technology is a promising technology in monitoring the structural behavior of the temporary structure. The sensors and the USN boards functioned as designed. These devices could measure the structural response to outside loadings.

In later stage of this study, the USN-based monitoring system will be actually implemented at a construction site. The experiment in a real world condition will provide the limitation of the system and the needs of improvement. Through the on-site test, the system will be able to demonstrate its feasibility in improving the construction safety during the operation of earth retaining walls.

8. ACKNOWLEDGEMENT

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