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# Application of Mobile Devices in Remotely Monitoring Temporary Structures During Concrete Placement

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## Abstract

During a construction operation, concrete formwork is a temporary structure that contains concrete material in the shape of structural designs. Construction failure often occurs during concrete placement due to the instability of support mechanisms. Therefore, this temporary structure should be constantly monitored during concrete placement to give an early warning of construction failure or instability. Because concrete placement is often executed in a natural area, the monitoring system can be more effective if mobile applications assist the safety manager in accessing sensor data from the sensors on the concrete formwork. This paper presents the schematic design and its prototype model to demonstrate the effectiveness of applying mobile devices in remotely monitoring concrete formwork during concrete placement. A combination of information and communication technologies are integrated to develop the mobile devices, such as mobile phones and smart glasses.

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## 1. Introduction

During a construction operation, concrete formwork is a temporary structure that contains concrete material in the shape of the structural design. This temporary structure is usually composed of plywood, joist, timber, steel pipe support, etc. These components are erected on an earthen or concrete ground and are prone to structural failure. The

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concrete batch can cause a concentrated load on the concrete formwork, and the excessive force may result in the formwork's collapse. Since many construction workers are frequently present at the site and involved in operations, the collapse could cause significant injuries or fatalities. Also, the overall construction process would be delayed, ultimately leading to accompanying extra costs.

Therefore, the concrete structure should be constantly monitored during concrete placement [1]. In some cases, the safety manager designates safety personnel at the construction site to watch for any sign of structural failure. Then, safety staff should visually monitor the operation while the concrete batch is being placed. Contractors can install sensors for monitoring the stability of the concrete formwork. For example, Jhang et al. used load cells to measure a shore load in scaffold-type formwork supporting systems [2]. Also, Yuan et al. [3] proposed Cyber-Physical Systems as a way to monitor the safety of temporary structures.

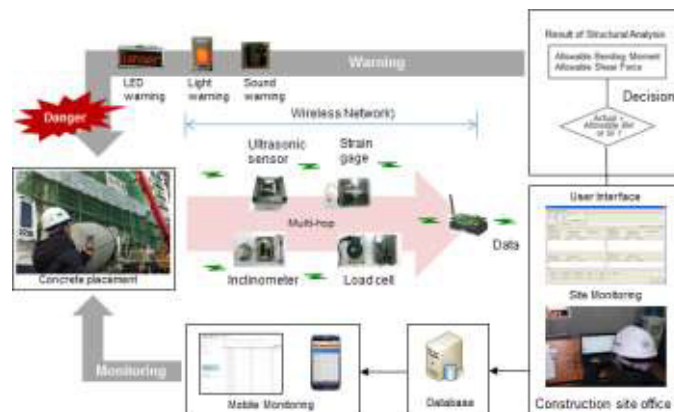
Whether or not sensors are installed, access to the sensory data is very important. The sensory data should be accessible at any time and wherever the safety manager is located. Mobile technology allows for easy access to the sensory data and provides a flexible application of remote monitoring. The construction industry can transform construction management operations by introducing the application of a mobile device [4]. This paper discusses the role of mobile applications in remotely monitoring temporary structures during concrete placement. The mobile application used in this research was applied to a construction operation of concrete placement for a feasibility test.

## 2. Data Management Scheme in Mobile Application

### 2.1. Overall View

Mobile application use in remotely monitoring temporary structures requires a complete integration of sensing, data transmission, alarm display and/or alerts, and decision making. This integration requires development of sensory modules, a wireless network, and mobile devices, and this combination provides a two-way data transmission between the sensory devices and actuators at the construction site and the system server in the site office. Fig. 1 shows the overall scheme of data management in mobile application; it depicts the overall process and data management of sensing, data transmission, decision making, and mobile display.

First, "sensing" means to collect sensory data on any changes in structural formation and stability during concrete placement. Concentrated loads can cause unexpected deformation in concrete formwork, and sensing functions work to detect this deformation. Four types of sensors can be used in this application: 1) an ultrasonic sensor; 2) a strain gauge; 3) an inclinometer; and 4) load cells (Table 1). The ultrasonic sensor is installed under the concrete formwork and then measures the distance between the bottom of the formwork to the top of ground surface. The strain gauge is installed on the surface of the concrete formwork and then measures strain from that position. The inclinometer is installed on the steel pipe supports and then measures the tilting of those supports under the concrete formwork. The load cell can be placed on top of the steel pipe supports directly under the concrete formwork or under the steel pipe supports on top of the ground surface. These sensory devices can measure any excessive loads of concrete material during concrete placement.



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