FEASIBILITY OF A RFID-BASED MONITORING SYSTEM FOR THE CONCRETE POUR PROCESS

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Abstract

A ubiquitous environment in construction requires integrating hardware and software systems. Currently the Construction System Integration Lab (CSIL) at Pusan National University is currently studying the application of ubiquitous technology for better communication in the construction process. In this paper, a pilot of Ubiquitous Concrete Pour System (u-CPS) has been presented to demonstrate the effectiveness of data exchange in the concrete pour process. The u-CPS environment takes advantage of the RFID technology for collecting construction data. The pilot can automatically generate the data for concrete pour work such as departure time, arrival time, concrete pour time. Construction managers can keep track of the progress of concrete pour work using the information. A case study was done for a building construction using the pilot system, the result of which demonstrated that the RFID-base system can help improve the effectiveness of data communication during the concrete pour process.

Keywords: Ubiquitous, RFID, Tag, Construction Management Process, Concrete Pour, XML, Productivity, Quality

1. Introduction

In the existing concrete pour process, the information exchange between the batch plant and the construction site has not been performed systematically. Usually in concrete pour work, detailed information related to concrete quantities, slump and strength are transferred through invoices. Other operational information related to the departures and arrivals of remicon trucks is recorded and described by manual work.

The overall progress status of the concrete pour is usually transferred such that the batch plant workers dispatched to the construction site transfer information by cellular phones. When concrete pour information is not communicated effectively, workers are likely to fail to share information in real time. Then, remicon trucks should wait for a longer time or they fail to arrive at the site on time, which can damage concrete quality. The waiting of remicon trucks happens partly because there is no systematic information distribution system in the concrete pour process.

Management of concrete pour information has important influences on production and quality. Through the management of pour information, the departure time of remicon trucks can be adjusted so that they donnot have to wait for a long time. Also by predicting expected pour time, it is possible to establish an appropriate work plan. In addition, by saving data during the concrete pour process, they can be referred to or used for production and quality management. Accordingly, it is necessary to share in real time, and manage systematically information generated in the concrete pour process. This improved communication will greatly help the batch plant and site workers make appropriate and timely decisions.

Ubiquitous technology offers technologies that can monitor data generated in construction processes. Construction information exchanged on line can be handled in a wireless ubiquitous environment. Therefore, workers can access design or technology information on the site and continue their work without interruption. This study develops a prototype of the u-CPS by applying RFID (Radio Frequency Identification) technology. In a case study, the prototype was applied to an actual concrete pour work to test the feasibility of a ubiquitous environment for improving the construction communication.

2. Objectives

The objective of this study is to collect data occurring in the process and use the data for properly planning concrete pour activities. Case study has been done on an actual concrete work. For the study, a user environment was developed interfacing on internet with RFID devices that were installed in a batch plant and a construction site. This was intended to facilitate communication between the batch plant and the construction site. The result of the test demonstrated that the RFID-based concrete monitoring can be a feasible approach for improving the communication in the construction process.

3. Technological components for the RFID environment

A ubiquitous system represents an environment in which one can obtain necessary information wherever he or she does [1]. The ubiquitous technology includes USN (Ubiquitous Sensor Network), RFID, wireless communication, etc. Among them, RFID is being applied to replace the bar code technology. In addition to its relatively large storage capacity compared to bar codes, RFID tags are more robust and reliable in such a harsh environment as construction.

Process-related data can be stored in RFID tags to provide information about construction, operation, and maintenance. RFID tags can be implemented together with USN so that the construction process can be monitored remotely. By attaching onto things which enables the acquisition, processing and exploitation of information in real time through wired or wireless network infra. The technology is even being applied to identify the location of construction materials, vehicles and workers.

Due to the high applicability, the RFID technology is widely studied to improve the capability in collecting construction data [2]. For example, Yagi et al. [3] applied RFID tagging to develop a model that integrates physical parts with information packets so as to facilitate the flow of material installation in construction. Tool management is another field of application. Goodrm et al [4] developed a tool tracking and inventory system in an effort to improve the efficiency of tracking tools and improve their availability. In the system, commercially available active tags are used to store operation and maintenance data.

In order to apply RFID technology, there should be 1) tags, 2) antennas, 3) readers, and 4) an application environment to process collected data and convert them into useful information (Figure 1). The following are the components of the technology that have been applied in this study.

- First, a passive-typed RFID tags were used in this study. Unlike the active type that send signals by using their own power sources, the passive type send radio signals with low-frequency energy. Tags do reading and writing through RFID antennas. In this study tags were used as identifiers of remicon trucks.
- Second, tag information is read by antennas. This study installed five antennas that include two in the batch plant and three in the construction site.
- Third, readers process data transmitted from antennas and then send them to a database server. When the amount of the data transmitted is large, middleware technology can be used to facilitate data processing between operational environments.
- Lastly, a user-interface environment is necessary so that users can utilize tag information and, in such an environment, users can search or inquire about information related to tags.

Figure 1: Operation of RFID-based system for concrete pour monitoring

4. Concrete pour process

A concrete pour process begins with the order sheet which a constructor submits to a batch plant (Figure 2). The constructor notifies the batch plant of the amount and specifications of concrete, dates of transport and batch intervals. The batch plant decides on standard combination, acquires materials to be used, and produces concrete according to a prescribed schedule. The batch plant establishes a concrete work execution plan by considering the transport time from the plant to the site and allots an appropriate number of trucks. Employees of the batch plant are dispatched to the site to check the transport status of remicon trucks, in addition to conducting quality tests. A concrete pour team casts concrete transported using a pump car. Remicon trucks which completed concrete pouring return to the batch plant and prepare for a next round of concrete transportation.

Thus concrete pour consists of cyclic processes of order, production, transport, pour, quality control and truck return. Considering that concrete pour is a multi-stage process, communication between participants in the work is very important for productivity and quality. For instance, the batch intervals of remicon trucks have direct influences on concrete productivity and quality. When a remicon truck fails to arrive in time, it can damage the productivity of concrete pour work. On the other hand, when a remicon truck has to wait for a long time, it may also damage concrete quality.

Currently in the concrete pour process, decisions including batch interval adjustment are made based on the intuitional judgment of a manager with insufficient information. To overcome problems associated with quality and productivity, it is necessary to share the information of concrete pouring in real time and systematically plan and manage the concrete pour process.

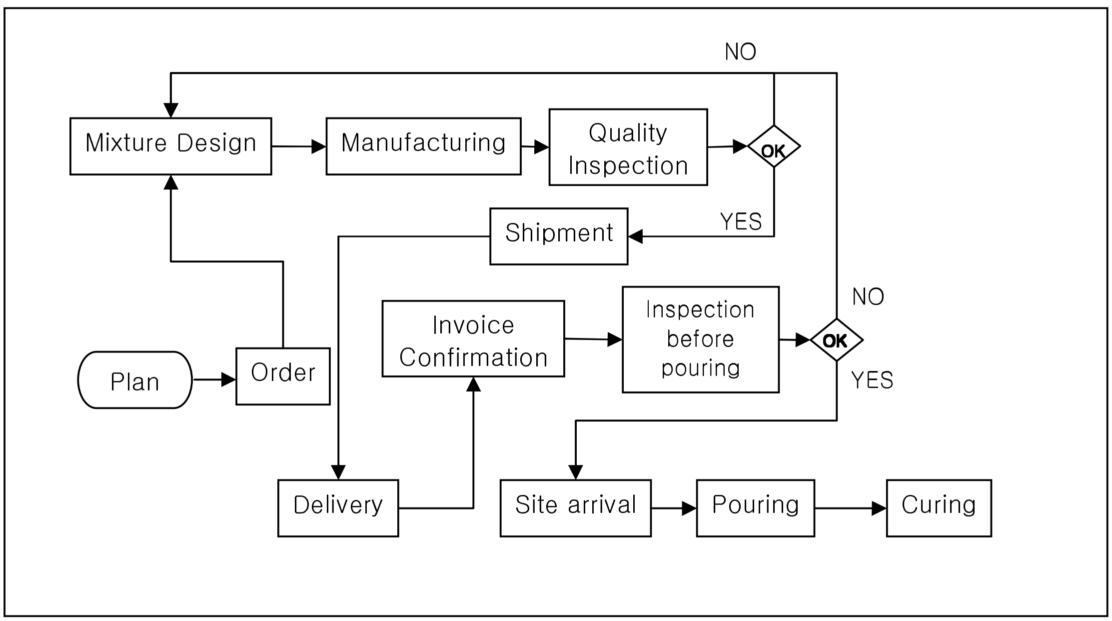

Figure 2: General work flow of the concrete pour process

5. Structure of ubiquitous-based concrete pour management

The u-CPS, a RFID-based concrete pour monitoring system, has a structure to provide the batch plant and the construction site with the status information of the concrete pour process using RFID and tags (Figure 3). u-CPS data are saved in a server and data on concrete transport and pour can be updated in real time at the batch plant and the site through the Internet. u-CPS is connected to the plant management system of the batch plant and can establish an interface to automatically receive batch information. In this study, the plant management system and interface were not presented and the batch information was entered manually.

Tags are attached to remicon trucks to convey information on remicon trucks. Only tag numbers are entered into the tag memories. Meanwhile, the tag-associated information of remicon truck and concrete batch is stored in a database server. Antennas read the information of tags attached to remicon trucks. Antennas are connected to RFID readers. In this study, five antennas were connected to two readers. The readers are connected to PCs in the batch plant and at the site by Internet. Programs installed in the computer server can recognize readers using IP addresses. Different computers are saved in a single database and inquiries can be made on the web. Concrete pour status can be, therefore, always checked at any place.

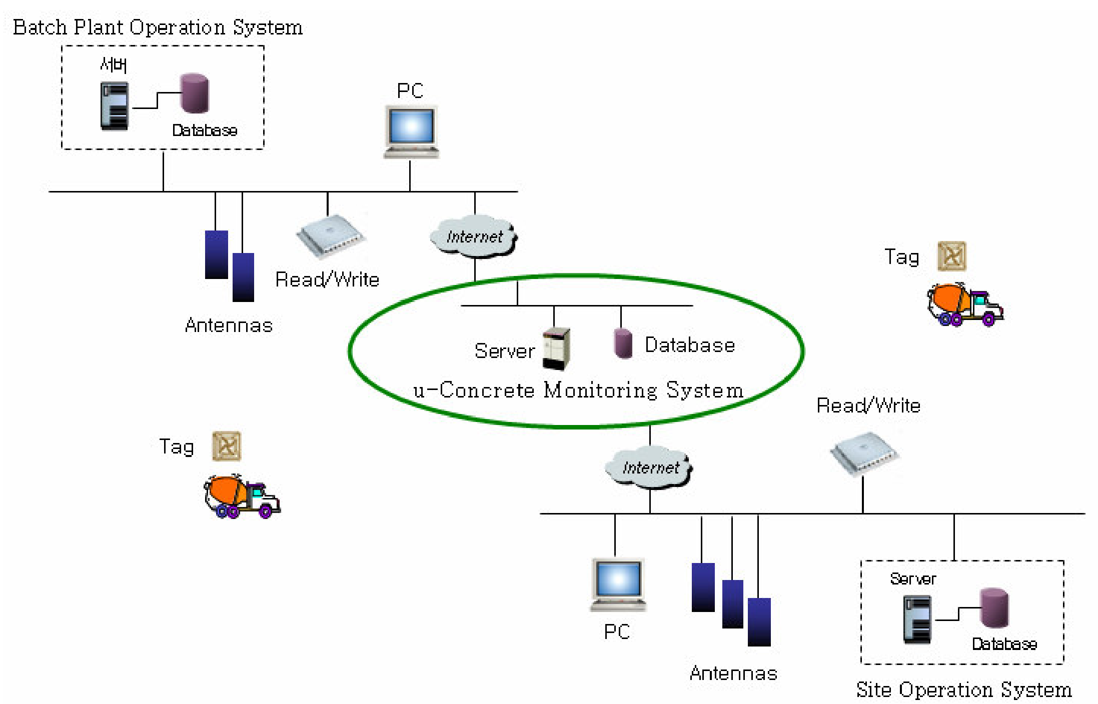

Figure 3: Description of structure of the u-CPS in the web environment

6. RFID-based concrete process monitoring

This study selected an apartment construction field as a demonstration site and established a concrete pour monitoring process that applied RFID technology to the demonstration site. The distance between the batch plant and the site was about 8km and the concrete pour amount was 120M^3. Figure 6 shows a concrete pour data acquiring process which uses a ubiquitous system by installing antennas at the entrances and exits of the remicon factory and the construction field and the pour locations and attaching tags to remicon vehicles.

Concrete pour work is carried out in the cyclical stages of order, production, transport, quality control and vehicle return. Tags with identification numbers are attached to remicon trucks. Tag-related remicon information is saved in the system server before the beginning of concrete batch. To read tag information, two surveying stations were installed at the batch plant and three surveying stations were installed at the pour site. The two surveying stations at the batch plant include one to check the forwarding of remicon trucks and another to monitor the arrival of remicon trucks. The three surveying stations at the pour site are to monitor (a) the arrival of remicon trucks at the site (b) the starting of pour, and (c) the ending of pour.

Figure 4: RFID-base concrete pour monitoring

7. Conclusion

Construction information systems have improved rapidly owing to the development of IT technology in the 21st century. The arrival of the ubiquitous environment necessitates the reestablishment of construction information systems as well as requiring modifications of the existing construction information systemization strategies. Simple web environment development cannot meet the needs for real-time data processing. As discussed in the concrete pour monitoring based on the RFID technology presented in this study, a decision-making support system that combines a ubiquitous environment should be available in order to instantly store generated construction data in a database and convert them into information for construction management.

This study applied RFID technology to a concrete pour management process and examined the applicability of a ubiquitous system. The u-CPS prototype of this study was developed by combining an RFID hardware device with a web-based software program. For an experiment at a demonstration site, antennas were installed at the batch plant and pour site. The antennas read tags attached to remicon trucks and monitored and transmitted the information on occurrences of events including departures, arrivals and pour starts at each surveying station. By doing so, the information on the concrete pour progression state was made available on the web. The concrete pour information transmitted in real time improved communication between the batch plant and construction site workers and facilitated production and quality control such as adjustment of batch intervals and concrete quality.

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