Automation of effective tracking and locating precast components at a storage yard

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Abstract: Precast concrete manufacturers have difficulties in tracking precast pieces at their plants and in locating them at their storage facilities. Precast manufacturers typically store the precast components produced for one to six months. This results in the need to store a large number of pieces (up to 5,000 for a large-scale manufacturer) at any given time. As a result, identifying the location of and determining the status of each precast piece require significant resources. This paper discusses an overview of current approaches practiced for tracking pieces and for storing basic tracking information. To minimize the shortcomings of the current approaches, a system utilizing radio frequency identification (RFID) tags for tracking precast concrete pieces in a plant and on a storage yard is suggested. Our discussion revolves around the observations and interviews made at three large-scale precast plants in the US. We conclude with potential benefits of the proposed approach.

Keywords: Precast concrete, material tracking, automatic identification, RFID

1 Introduction

Precast manufacturers produce precast pieces for various clients concurrently, and they need to manage production and delivery of pieces effectively in accordance with changing requests from clients and frequently updated schedules. From a client's/contractor's perspective, a benefit of utilizing precast concrete technology is the fast rate of erection on construction sites. However, if delivery of the pieces to a site is not managed well, time saved from the erection process will be lost [PC 01]. Just-in-time (JIT) management of the deliveries provides an opportunity to minimize material handling related problems at a site. Thus, some contractors are even willing to pay a premium to suppliers for JIT delivery [PC 01].

In order to provide flexible JIT deliveries, precasters need to know the exact status of each piece in the plant. Currently, it is time-consuming to gather real time information about the status of all pieces in a plant since that information is recorded by different teams usually in different databases during production, storage and delivery. Moreover, sometimes, collected information is not reliable or complete due to reluctance of workers to monitor and record the flow of large quantities of elements. This problem is more frequently observed during storage of pieces.

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Precast pieces are typically stored for one to six months for reasons related to production rates, erection schedules, and material strength. At a large-size precast manufacturing facility, up to 5000 pieces are stored in the yard at any given time. Double handling of pieces in the storage areas makes it harder to keep track of the most updated locations of the precast pieces. In some instances pieces are lost and need to be manufactured again.

Automatic identification technologies provide an opportunity for effective tracking of pieces in the plant and during delivery. Various technologies exist for automatic identification; e.g., barcodes, magnetic strips, optical character recognition (OCR), and radio frequency identification (RFID). Finch [FIN et al. 96], amongst others, has identified RFID and barcode technologies as being suitable for data acquisition in construction. Given the mentioned tracking problems above, the precast industry can benefit from the advantages of combining RFID technology with GPS and wireless communication technologies. The aim of this paper is to propose a system that automatically collects and records real time locations of precast pieces along with necessary quality and status information entered by the inspectors. The next section, Section 2, describes the current identification and tracking practice in precast industry. Section 3 introduces the requirements and architecture of the proposed system. In the concluding section the benefits of the system and future work are discussed.

2 Current Practice

Three large-size U.S. precast manufacturing plants specializing in architectural and/or structural precast concrete pieces were visited, and their identification and tracking systems for precast pieces were examined. This section summarizes the observations about the needs and problems encountered related to piece tracking and identifies requirements for monitoring precast pieces.

2.1 Identification and Monitoring the Status of Each Piece

Two of the companies observed use unique Ids assigned to each piece produced for identification purposes. On the other hand, the third company simply uses piece marks, which identify groups of pieces having identical design features, and are therefore inappropriate for tracking pieces individually. Physical tags (labels) used for piece identification should be able to operate under harsh conditions since precast pieces are exposed to changing weather conditions, dust and direct sunlight during production, storage and delivery. In addition, since a stack of pieces can reach up to 4.5m high (see Fig. 1), the identification technique should allow for a convenient way to read tags without the need for direct contact with the pieces.

In current practice, two of the companies visited write ID's directly on pieces with a marker or attach a piece of paper. This approach is error-prone and not efficient since ID's are not machine-readable. The third company tags pieces with long-range barcodes that have a read-range of 3 feet. Barcodes enable scanning and reading data directly without re-entering it by hand, avoid multiple entries of the same data, and prevent manual entry errors. However, some disadvantages of using barcodes at the precast plant were observed: (1) the reading-range and angle are fixed, so it is not possible to scan the barcode if it is more or less distant than the reading range and/or if the angle is not 45 degrees, (2) under intense sunlight it is difficult to see the red light of the scanner and point it to the barcode, (3) it is hard to reach and scan the pieces that are at the top of a high stack, (4) some of the barcodes are damaged under weather conditions, (5) dust prevents scanning since line-of-sight is required, (6) when pieces are erected, barcodes are either removed or visually blocked by other components in the structure, thus they cannot be used to identify pieces after erection. These disadvantages prevent regular data collection, and make data retrieval tedious, time-consuming and often unreliable.

Figure 1. A stack of precast concrete double tees in a typical storage yard.

The status of each piece is recorded by different people at various phases of the project. Two of the companies use paper-based reports to track the status, while the third scans barcodes and transfers data to a database. Whenever the status of a piece changes, the ID of that piece and the date should be recorded along with additional comment about damage, storage location in storage phase, or trailer number during delivery. All this information should be integrated to enable monitoring of the status of the whole project. The manual approach does not provide real-time status information because of the amount of time required to pull all data from different reports together. The barcode approach, which incorporates identification and scanning of both the storage zones and pieces, and sending data to a central database using radio frequency (RF) communication, seems like an efficient approach. However, in practice it was observed that workers sometimes do not perform the scanning since it is a tedious task to scan a piece and a corresponding location identifier whenever a piece is moved. These all suggest the need for a fully automatic data collection technology to capture the status information at various milestones, and to integrate this data in a database automatically to minimize errors and to enable real-time reporting.

3 Overview of the Proposed System

Among the alternative automatic identification technologies such as barcodes, magnetic strips and OCR, RFID technology is identified as the most suitable technology that meets the needs defined. RFID utilizes radio frequency technology in identifying, tracking, and detecting various objects. RFID systems are mainly composed of a tag and a reader. An RFID tag is an electronic label that stores data and is attached to objects. Tags can be read-only (RO) or read/write (R/W); the latter enables data entry directly to the tag throughout the life of the item that is attached. Readers, which send RF signals for communication, are used to read data from these tags. RFID technology does not require line-of-sight, and also it is durable to harsh environments and can be embedded in concrete. Reading range depends on the frequency at which the tag operates, and it varies from several inches up to about 10 feet. Unlike barcodes, reading range is not a fixed distance - allowing tags to be read at any distance within the range. Finally, RFID enables efficient automatic data collection since readers can be mounted to any structure to detect and read tags in the reading range and each reader can scan multiple tags at a given time.

The proposed system integrates RFID technology with wireless communication technology and Global Positioning System (GPS) to effectively identify, locate and monitor precast pieces in a manufacturing plant (Fig. 2). RFID tags are attached to pieces for identification and for storing necessary quality control or delivery information. Mounted RFID readers on the crane or at the gates will be used to automatically retrieve pieces' IDs in different phases and locations. Handheld readers will be used to enter status or quality related information. Differential GPS is used for automatically determining the locations of pieces at the storage yard, and it is utilized on cranes that move the pieces. Wireless communication is used to transfer status data (ID, date, location, quality etc.) retrieved from RFID readers and GPS to a central database. Central database stores the status data collected during manufacturing, storage and shipping.

When pieces are produced, they are assigned unique IDs by the production information software system used in the plant. Read-write RFID tags with the unique IDs are attached to the pieces. These tags are utilized for automatic identification retrieval in any phase and location. For instance when pieces are inspected after manufacturing, an inspector; (1) reads a piece's unique ID with a handheld reader, (2) fills out a form using the same reader stating post-pour comments during inspection, or defect report number etc. (3) and sends status information directly to a database along with the ID and time stamp using wireless communication.

At the storage phase, a mobile crane, which is equipped with an RFID reader and GPS receiver, moves the piece in the yard and records its location. The location is automatically captured by the GPS system and is stored in a central database. When a piece has to be moved in a storage area, the system automatically identifies and updates the new location of the piece. The reader can be conveniently activated when the load sensor on the crane cable indicates lifting – in this way the true weight of the piece can also be recorded and transmitted. This functionality ensures that location of a piece is determined and recorded automatically whenever it is moved; therefore it prevents any occurrence of lost pieces.

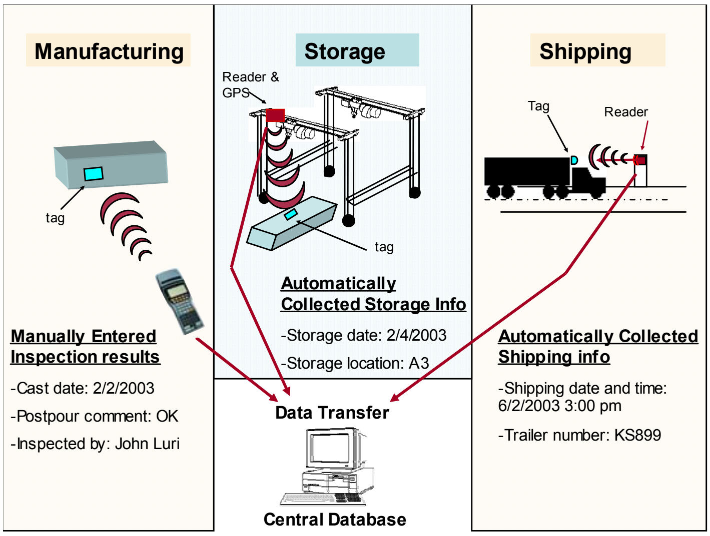

Figure 2: Data collection during manufacturing, storage and shipping

The proposed system would potentially help manufacturers to locate pieces at the storage yard in minimum time with minimum errors, and with no dependency on yard workers. The entire labour consumption previously required for recording locations can be saved, since it is done automatically for each piece by the system. The costs and delays that currently result from re-manufacturing pieces that cannot be located at a storage area would be removed entirely. Manufacturers would be able to manage the plant effectively by monitoring pieces in real-time. Also, erectors could manage the unloading and erection process efficiently by receiving exact delivery time of pieces in advance. Knowing the unique ID of each piece enables erectors to quickly determine where the piece belongs in the structure.

The proposed approach utilizes two emerging technologies, RFID and GPS, which are relatively unknown in the construction sector. Jaselskis [JAS et al 95] identified two major barriers for the utilization of RFID technology with passive tags at construction sites: (1) lack of standardization among different RFID manufacturers; (2) hampering effect of metals. Current technology has overcome the metal effect problem [FOR 02]. Moreover, various industry and standards organizations, including NIST [FS 99] are working on RFID standards, and readers that can read tags from different manufacturers have been developed. Peyret [PT 02] successfully utilized differential GPS for positioning of asphalt pavers with an accuracy of centimetres. Hence, differential GPS can be utilized for the proposed approach.

4 Conclusions and Future Work

In this paper, observations made at three large-size precast concrete manufacturing plants in the U.S. were presented in terms of identification and tracking of pieces. Current approaches depend heavily on paper-based records, and one approach that uses barcodes is not appropriate for construction due to the limitations of the barcode technology. The existing approaches do not adequately address the problems associated with large storage areas and the reluctance of workers to record the locations of pieces. This results in time and efforts wasted in tracking pieces. Based on these observations, a system that utilizes RFID technology and GPS to track precast pieces in a storage area at the manufacturing plant, and to track each piece during its production, storage and transportation, is proposed.

The proposed system has numerous advantages. It is fully automatic, thus reducing the labour costs and eliminating human error associated with tracking and locating the pieces in the plant, in storage areas and during delivery to construction site. It can also be extended to provide production data – such as the duration of finishing and other post-stripping activities in the plant, erection duration for different piece types, etc. –which are unavailable using manual systems. An additional benefit is the ability to retrieve a piece's history at any time during its service life (assuming it is stored).

Our future work includes implementation of the proposed system in a precast manufacturing plant, and determination of the technical and economical feasibility of the system. This requires identifying information items that should be collected throughout the lifecycle of precast concrete pieces.

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