Utilizing Radio Frequency Identification on Precast Concrete Components – Supplier's Perspective

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ABSTRACT: Precast concrete material suppliers are responsible for the components that they manufacture from casting until up to 25 years after installation. To effectively manage the production and storage at a the production facility, to streamline the construction process and to quickly repair a component should there be a problem, information about components must be readily available and updated throughout the 25 year life cycle. Currently, suppliers use barcodes to track precast components and paper-based documents to store information about them. These approaches are time-consuming and error prone. Suppliers also face the problem of not finding the right information in a timely manner. This paper discusses the utilization of radio frequency identification technology (RFID) for tracking precast concrete components and their historical information from fabrication to post-construction. RFID is an automatic identification technology that uses memory chips attached/embedded to objects to transmit data about them. Our discussion revolves around one use case that we developed describing the current component tracking approach and the proposed approach utilization of RFID technology from a large-scale precast manufacturer/erector's perspective. We conclude with an assessment of benefits and limitations of the proposed utilization of RFID system for tracking precast concrete materials.

KEYWORDS: RFID; precast concrete; construction; material management

1. INTRODUCTION

A precast concrete manufacturer is liable for a component from the time that they cast the component until 25 years after installation. Precast components used in a facility are expected to maintain their original condition throughout their life cycles. Any problem that might have occurred during the manufacturing and erection of a component might not surface until late in service. Once a problem is detected during service, it is important to know the full history of a component to address the issue effectively.

At the manufacturing phase, the material information about precast components should be documented during casting. After the components are cured the information on where they are being stored should be documented to minimize the time-loss in locating components in a large storage area. At the construction phase, deliveries should be inspected to ensure that the components have the desired quality. Any problems during installation should be documented as part of a component's history.

Currently, critical information about fabrication and installation processes is not stored at all or cannot be accessed easily after the completion of a project, since they are mostly paper-based and stored at different locations. As a result, when a problem occurs with a component, it is hard to access the relevant historical data important to identify the cause of a problem.

Part of material tracking problem, especially at the site or a large storage area is being addressed by barcodes (Bernold 1990). Even though barcodes provide an easier way to track components, it has been noted that barcodes are being damaged in the harsh construction environment. In addition, in some cases, it is difficult to access the tag for scanning (especially in storage areas) since one needs to be next to a barcode to be able to read the information (Furlani 2000). Finally, barcodes do not have any memory and hence it would be impossible to store the history of a component on a barcode.

Radio Frequency Identification (RFID) is another identification technology that uses memory chips attached or embedded to objects to transmit data about them. In this paper, we discuss the utilization of RFID technology to locate and track the precast pieces and to store information about them from their fabrication to installation. Our discussion revolves around a use case developed based on data obtained from a large-scale precast manufacturer.

2. BACKGROUND ON RFID

RFID is an automatic identification technology used to identify, track, and detect various objects. RFID systems are composed of two components: a tag, and a reader. RFID tag is an electronic label that stores data and is attached to objects. Readers, which send RF (Radio Frequency) signals for communication, are used to read data from these tags. A reader is composed of an antenna, a transmitter/receiver and decoder.

Current RFID technologies use three frequency ranges: low (100-500 kHz), intermediate (10-15 Mhz), and high (850-950 Mhz / 2.4-5.8 Ghz). Table 1 lists some of the unique characteristics of each frequency range. Low and intermediate frequencies are commonly used for inventory control, while high frequencies are used for railroad car monitoring and toll collection systems (AIM 2002).

RFID tags can be classified as either active or passive based on the power source. An active tag has an internal battery for power. A passive tag utilizes the energy generated by a reader/antenna. Active tags have a greater read/write range (up to 30 m.). However, they are larger in size, more expensive, and have a limited life span (5-10 years). Passive tags are cheaper, smaller, lighter, and have unlimited life span. However, they require a more powerful reader and have shorter read ranges.

Table 1. Characteristics of frequency bands

Frequency	Characteristics
Low 100-500Khz	Short to medium reading range Inexpensive Low reading speed
Intermediate 10-15 MHz	Short to medium reading range Potentially inexpensive Medium reading speed
High 850-950 MHz 2.4-5.8 GHz	Long reading range High reading speed Line of sight required Expensive

Tags also can be read only (RO), read / write (R/W) or write once / read many (WORM) (Paolo 2002). RO tags are pre-programmed with unique information, and this data cannot be modified afterwards. In R/W tags, additional data can be written by overriding or extending the existing data stored in a tag. In WORM tags, information in a tag can be changed only once. After the data is read from any type of transponder, it can be sent to a host computer, or stored on a reader to be later uploaded to a computer (AIM 2002).

Tag cost, size and memory capabilities vary. Tag information can be limited to a unique code, or include detailed information, e.g., manufacturer, storage conditions, etc. A passive tag can store up to 2k bits of user information (TI 2001) while an active tag can have a memory up to 1MB (AIM 2002). Price of a tag increases with the amount of information that can be stored on a tag. Current prices are between 50 cents to $50 depending on the memory, type (active/passive, RO, R/W or WORM) and operating frequency. However, prices are decreasing as the technology develops. For example, in 1995 prices for various tags were between $10-$100 (Jaselskis 1995).

RFID tags are technically more advantageous than barcodes in material tracking and documenting the history of a component. RFID tags have capability of larger data storage. In addition, they can operate in harsh environments and do not require line of sight like barcodes. Besides, it is much faster to collect information about a batch of components using RFID since RFID technology allows collection of up to forty items per second (Marconi 2002). Data security is achieved in RFID tags with an optional password mode, which requires a password to enable read and write functions. Data in a tag can be locked by the user to prevent future modification (Atmel 2002).

3. PREVIOUS EXAMPLES OF RFID USAGE AT CONSTRUCTION SITES

Several applications of RFID in other sectors include tracking pallets, mail, and automation processes in manufacturing. Schell (2001) suggests that the utilization of RFID tags during the maintenance of a plant's pressure relief valves has reduced manual data entry by 70%.

Jaselskis (1995) proposed some potential applications, such as, cost coding for labor and equipment, and material control, which utilizes RFID technology during a construction project. He identified three major barriers for the utilization of RFID technology at construction sites: (1) lack of standardization among different RFID manufacturers impeding interchangeable usage of RFIDs from different brands; (2) hampering effect of metals caused by the reflection of RF energy from metal surfaces; (3) requirement for a battery management program for the active tags (Jaselskis 2000). Today, current technology has overcome the metal effect problem (Forster 2002), and various industry and standards organizations are working on RFID standards.

4. USE CASES

In this section, a potential application of RFID in precast components is discussed from a supplier/erector's perspective. The data presented is based on real data obtained from a large-scale precast manufacturer.

The large-scale precast manufacturer that we studied works on design-build arrangement, where an architect designs a facility, and then through a bidding process selects a manufacturer to design, engineer, fabricate and erect the structure. Precast components vary from structural beams to miscellaneous items such as columns, and curved sections. Their production is 17,200 pieces per year.

The manufacturer's storage area is approximately 60 acres, and the average number of precast elements stored at the production facility is 3,500 pieces at a given time. After casting, the components are sent to the storage area after one or two days maximum. Once at the storage area a precast component is either shipped within a few days or going to be stored there for months. The main reason for long storage periods is that the manufacturer prefers to fabricate similar pieces in a casting bed at the same time. Thus, some pieces can be produced months in advance since they are similar to the ones that will be delivered in a week. The locations of ones that are stored for longer durations are typically changed several times before their delivery date.

4.1 Current Material Tracking Process

Currently, barcodes are used to identify each piece, along with a piece mark that is written on one end with marker. Since thousands of different pieces are stored in the storage area and line of sight is required for barcodes, finding the necessary component becomes very difficult. Currently, about 10 workers work at the storage area, and it takes about 30 minutes to 1 hour to locate a component in that large area. In some cases, when the workers cannot locate some pieces at a storage area, those pieces have to be cast again, resulting in late deliveries. Currently, the manufacturer pays approximately $60,000 for annual penalties for late deliveries, which are mainly caused by delays associated with locating materials.

After a delivery is made, a field engineer is required to inspect each delivery to check if the right pieces are delivered. Then, the precast pieces are stacked in lay down areas for preferably 1-2 weeks (Pheng 2001).

In addition to tracking storage and delivery of precast pieces, precast manufacturers are also liable for any possible defects and failures of the precast pieces for up to 25 years. Different factors, e.g., cement, aggregates, the number of times a component is handled, the site conditions during construction, etc., can cause a defect on a precast component. When there is a defect or failure, they need to quickly identify these factors that the defective component is being exposed to so that they can fix the problem efficiently and prevent any similar failures in other pieces. Currently, much of the information related to the history of a component is not stored at all, and the ones, which are stored in documents, are not easily accessible.

In summary, precast suppliers/builders face two major problems associated with component tracking: (1) locating the precast pieces at their storage facilities and (2) accessing a component's history after construction. Current approaches for locating components and accessing a component's history are time-consuming, costly and not effective. RFID technology provides a way to address both of these problems. The next section describes the proposed system.

4.2 Proposed System

The proposed system utilizes RFID technology to locate each precast piece on a storage area without line of sight requirement, and ensure a reliable delivery schedule to a construction site. Additionally, information about manufacturing, inspection, and construction can be entered to a tag.

When an owner places an order, the designers in the company designs the components, and assigns an ID for each piece. During the fabrication of each piece, passive R/W tags with unique IDs are attached to the pieces. During that time all production related information is entered to the tag (Figure 1). After 1-2 days when the curing is complete, the pieces are checked by the inspector. The inspector's approval about the quality of precast components will also be stored on the tag before the components are sent to the storage area.

A grid of transponders ("tags") are embedded in the floor of a storage area. When a piece is placed in a storage area, first its tag is read to retrieve its ID and all the other information, and then the embedded transponders are read to match the transponder's code with the location in the storage area. This information in the reader is then sent to a supplier's material database. This would enable quick identification of the member at the storage area (Figure 2) and hence just-in time delivery of the pieces to a construction site. Whenever the location of a piece is changed, the same process is repeated, and any new handling information will be stored in the tag as part of the history of a component.

Once components that need to be delivered are identified, they are loaded onto a truck, which is also tagged with a W/R transponder. The IDs of the pieces are read and entered to truck's tag by a handheld reader. When the truck departs, a reader installed at the exit records the components that are shipped. The date, truck ID, component IDs are sent to the supplier's material database, and to the scheduler who works for the erector. Receiving this information, staging areas are determined on a site, and a crane is assigned for unloading.

Additionally, during transportation of materials, the delivery truck can be tracked by GPS; thus, both the manufacturer and the erector can be informed about the real-time location of the truck and the components.

At the entrance of a construction site, truck ID is read, components recorded as arrived in a database, which can be used for invoices and payments, and the manufacturer is notified that the delivery is completed. Another inspector who works for the erector company, checks the pieces, and enters any damage or defect that might have occurred during transportation. Finally, pieces are installed according to their Ids, and the current site conditions, and information about installation methodology are also stored in the tag as part of the history of components

As a result of this new process, delays due to locating materials at a manufacturing storage area and on a construction site are minimized and all the important information about the history of a component is stored on a tag. This information can be retrieved any time after the installation of a component should there be a problem. As a result, a manufacturer can efficiently identify the cause of the problem, effectively manage the problem, and take precautions for similar problems that can be observed in other components.

5. COST / BENEFIT ANALYSIS

The following cost/benefit analysis attempts to assess costs and benefits of locating materials on in a large storage area using RFID. The analysis is based on the quantitative data obtained from the manufacturer and on the current RFID costs. It is assumed that all precast components are tagged with a passive R/W tag, and workers are using three readers (Table 2).

Table 2: RFID equipment cost for one year

	number	Cost ($)
tag	17,200	172,000
reader	3	6,000
Total		178,000

As Table 2 shows, the cost of embedding tags and retrieving information from the tags is $178,000. To recover this cost, nominally 7,120 hours of worker time should be eliminated as seen in Table 3. We believe that using tags will save at least half of the actual time spent on locating the components. This corresponds to approximately 5 workers, which is 9,600 hours of worker time. This exceeds the 7,120 hours required to nominally recover the cost of implementing the RFID system and hence suggests that the savings will outweigh the cost of utilizing RFID tags

Table 3: Worker time need to be saved

Tag cost ($)	Hourly rate for a worker ($)	Worker time (h)
178,000	25	7,120

The cost benefit analysis based on the quantitative data shows that it is beneficial to use RFID for material tracking purposes. Also, there will be additional savings associated with just in time (JIT) delivery of components. Since currently the cost of delayed delivery is $60,000 per year, the JIT delivery of the components will enable additional savings up to that amount.

The proposed analysis, however, does not consider the potential additional benefits that will be received when the tags are also used for storing historical information of a component as described in Section 4.2. It is foreseeable that additional benefits will be incurred when same tags are used for storing historical information. Current memory capacity of a R/W passive tag, which is around 2k bits, might not be sufficient to store all information necessary. In the next phase of this research, we will be performing tests to assess how much of the necessary historical information. Regardless, the technology is developing rapidly, and memory capacity is likely to increase significantly in few years. With that, additional benefits associated with storing historical information will be achieved. This will create significant savings to the precast suppliers since currently majority of their consultants' time is spent in collecting historical data rather than analyzing it to repair a component.

In the future, when the memory capacity increases, the digital picture of any defect can also be stored in the tag.

6. CONCLUSION

In this paper, we propose a system, which utilizes RFID technology to locate precast components in a storage area at the manufacturing plant, tracks the delivery of the components, and stores all the necessary information about the components for the future use. In this system, passive RFID tags are suggested to be used for storing data, and for tracking precast pieces.

The system improves the efficiency of locating the components in storage areas in manufacturing plants. In addition, tracking the components during the delivery process is beneficial for just-in-time delivery. Finally, storing the necessary information in the tag helps the manufacturers to retrieve the history of a component quickly and identify the cause of any problem that might occur after construction.

Our future work includes the implementation of this system in a precast manufacturing plant. Through that, we will further identify the technological capabilities of current RFID tags in storing historical information and develop a more comprehensive cost/benefit analyses for the proposed use case.

7. REFERENCES

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FIGURES

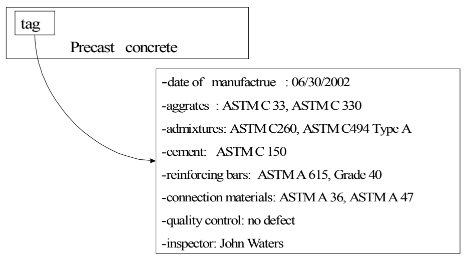

Figure 1: Information entered to a tag during casting of a precast member

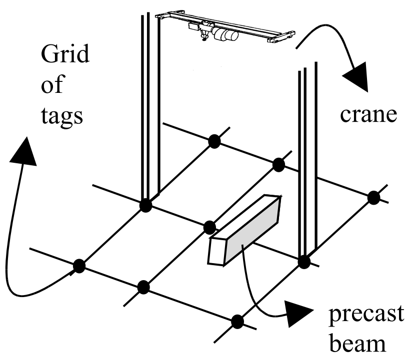

Figure 2: Grid of transponders in the storage area