TEST RESULTS FOR LOCATING STRUCTURAL STEEL ASSEMBLIES AND PACKAGES USING RFID

Emre Caner Akcay, PhD Candidate, ecakcay@metu.edu.tr
Department of Civil Engineering, Middle East Technical University, Ankara, Turkey
Semiha Ergan, Assistant R. Professor, semiha@cmu.edu
Department of Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh, USA

ABSTRACT

Radio Frequency Identification (RFID) technology has been in use in the Architectural/Engineering/Construction and Facilities Management (AEC/FM) industry for more than a decade. It has been used to understand the efficiencies it can bring to the relevant parties in terms of locating and accessing information about specific components. Various studies investigated how the technology can streamline location identification, tracking and information access for various types of components that flow in supply chains, such as prefabricated precast components, tool tracking, pipe hangers and spools. This study presented in this paper also provides results of experimentation that were performed in a large structural steel manufacturing yard for locating pieces that would form structural steel assemblies during manufacturing phase, locating assemblies within the storage yard to form packages , and locating assembled packages during the shipment phase. The assemblies have been grouped based on their complexities as simple, medium and complex assemblies depending on the number and size of their main frame and connecting plates. RFID technology has been deployed in the manufacturing yard and time studies have been performed to compare the manual process of locating the pieces that would form the assemblies and packages and the RFID based process to document the benefits of the technology in the manufacturing yard. This study shows that the complexity of the assemblies significantly increase the time to locate components in a manual process, whereas this time is not affected from the complexity of assemblies when the RFID technology is used. RFID technology cuts the time to locate assemblies in large yards by 4/5 and by 3/4 to locate packages during the shipment phase as compared to the manual process.

Keywords: RFID, structural steel assemblies, location identification, manufacturing yards

1. INTRODUCTION

Radio Frequency Identification (RFID) technology has been in use in the Architectural/Engineering/Construction and Facilities Management (AEC/FM) industry for more than a decade. It has been used to understand the efficiencies it can bring to the relevant parties in terms of locating and accessing information about specific components. Various studies investigated how the technology can streamline location identification, tracking and information access for various types of components that flow in supply chains, such as prefabricated precast components, tool tracking, pipe hangers and spools. One of the first studies was on exploration of potential uses of RFID in the AEC/FM industry by Jaselskis et al. (1995). Such potential uses included material identification, tool handling, traction of automatic-guided vehicle, collection of tolls and fees, identification of hazardous material, keeping the maintenance history of equipment, personnel identification and control, and asset location and tracking. Since then the technology use gained momentum in the industry and between 1995—2005, the research on application of RFID on construction and building management constituted %3.6 of the total research on RFID (Ngai et al. 2008).

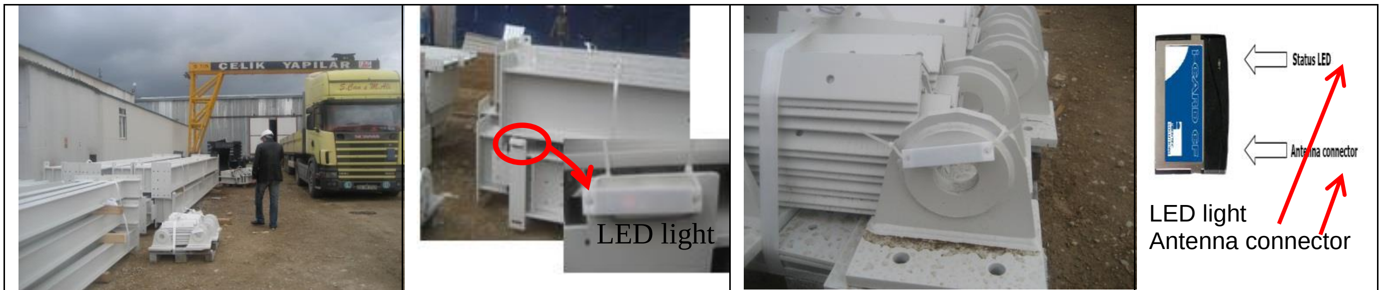
Various studies followed up to explore such potential uses and studied the technology's benefits and limitations in material/component tracking and location identification (e.g., Song et al. 2007; Song et al. 2005; Jaselskis and El-Misalami 2003a; Ergen et al. 2007a, b, Grau et al. 2012) and capturing component history and life cycle information (e.g., Motamedi and Hammad 2009; Jaselskis and Elmisalami 2004; Ergen et al. 2007b; Li and Gerber 2011).

Song et al. (2007) and Song et al. (2005) showed that by combining RFID and GPS technologies it would be possible to densely deploy low cost RFID tags with a few mobile RFID readers equipped with GPS to form the backbone of a construction materials' tracking system. Jaselskis and El-Misalami (2003a) revealed that RFID tags reduced the time required to download data into a company's material tracking system and could "flag" an item so that an entry would not be repeated. Jaselskis and Elmisalami (2003b) made a case study by using RFID tags to enhance the material management process on an actual construction project. RFID technology was integrated throughout the project life cycle to improve productivity, quality and safety and have better control on cost and schedule. Ergen et al. (2007b) generated an intelligent system, which knows the identity, location and history information of the facilities and share the information to its environment. Song et al. (2006) examined the RFID technology as a possible solution to data acquisition of design, fabrication, interim processing, delivery, storage, installation and inspection stages of pipe spools through automation of the conventional tracking process. The researchers concluded that potential benefits from the use of RFID technology in automated pipe spool tracking are: reduced time in identifying and locating pipe spools upon receipt and prior to shipping; more accurate and timely information on shipping, receiving, and inventory; reduced misplaced pipes and search time, and increased reliability of pipe fitting schedule. Ergen et al. (2007a) developed a GPS integrated RFID system in order to improve the phases in identifying, tracking and locating the highly customized prefabricated components. Goodrum et al. (2006) developed a tool tracking and inventory system which is capable of storing operation and maintenance data using RFID tags. Based on the test results, it was concluded that active RFID can be used to keep operation and maintenance data on the tools in construction environments despite metal interference and low temperatures. Motamedi and Hammad (2009) proposed attaching RFID tags to facility components, where the memories of tags are populated with the accumulated lifecycle information of components taken from a standard Building Information Modeling database. More recent studies evaluated the benefits of using the technology in seamless and integrated information access (e.g., Shin et al. 2011), cost sharing in construction supply chains (e.g., Demiralp et al. 2012), and calibrating locations of construction materials (e.g., Razavi and Haas 2011) and demonstrated the benefits.

The research presented in this paper complements the studies performed related to RFID utilization for location identification and information flow on components. As a difference from the studies listed in literature, this research focuses on structural steel components as a component, and looks at location identification and information access and exchange for these components on various phases (i.e., manufacturing, storage, shipment) of a component's life cycle. The paper provides results of experimentation that were performed in a large structural steel manufacturing yard for locating pieces that would form structural steel assemblies during manufacturing phase, locating assemblies within the storage yard to form packages, and locating assembled packages during the shipment phase. The assemblies have been grouped based on their complexities as simple, medium and complex assemblies depending on the number and size of their main frame and connecting plates. RFID technology has been deployed in the manufacturing yard and time studies have been performed to compare the manual process of locating the pieces that would form the assemblies and packages and the RFID based process to document the benefits of the technology in the manufacturing yard.

2. RESEARCH METHOD

Various field tests were performed at the manufacturing and storage yard of an engineering design firm, specialized in design of heavy steel structures (e.g., airports, bridges, commercial buildings, industrial plants). Before the tests, structural steel parts/pieces that would form assemblies, the finalized assemblies and finalized packages were tagged and tracked/identified in various stages of the manufacturing process. This paper provides the results of the experiments during the manufacturing of assemblies, storage and preparation of packages for shipment and shipment stages. The parts/pieces that form assemblies were tagged with active RFID tags with led light options to locate the relevant ones easier (see Figure 1b). The technology used in the experiment composed of an active RFID kit with led light tags, compact flash card as a reader, an antenna and a handheld device to carry the portable reader.



(a) A view from the manufacturing yard with tagged components	(b) An example assembly tagged at the manufacturing yard	(c) An example package tagged	(d) Reader used in the tests

Figure 1: Examples from the tagged components in the manufacturing yard

In this research, we used a mobile card reader, which was more convenient to use at factories and job sites as compared to fixed readers. The reader was an off the shelf reader from a vendor (i.e., IdentecSolutions ©) with a PCMCIA plug into a handheld device or a laptop (see Figure 1d). On the exposed end of the reader, there are an MMCX antenna connector and a bi-color status LED light indicating transmittal, receiving and communication. The active RFID tags were anti-collusion long range tags with a 32 KB capacity and a capability to transmit and receive RF data up to 100 meters. In order to locate components and read/write/update component specific information on tags, we used a prototype system developed for this purpose and the technology provider's own software. Both applications could communicate with the reader and talk to the tags and identify the tag identification numbers (tag IDs). Technology provider's software was a diagnostics utility tool that detect and list the tag IDs that were within the reader's range. The other prototype system was a Java based system that could communicate and identify tags (hence the components on which the tags were attached), enable to write and read information items into the tags. By using the blinking capability, the LED lights on the tags were activated to locate the required tags among various others. A simple user interface that accompanied the system included Connection, Start scanning, End scanning, Enter Tag ID buttons that required user inputs and a text box that listed the tag IDs that were within the reader's range was developed.

Tests were performed for location identification and accessing and exchanging component specific information items during manufacturing and shipment phases. The main reason for conducting these tests was to compare the manual approaches used in the current practice and RFID based framework in terms of time and information accuracies. The tests were conducted for the different types of structural steel assemblies. The assemblies have been grouped based on their complexities as simple, medium and complex assemblies depending on the number and size of their main frame and connecting plates. *Simple assemblies* represented structural steel assemblies that were composed of one main component and five or less parts (such as plates). *Medium assemblies* represented structural steel assemblies that were composed of one main component and between five to ten parts and connecting plates. Finally, *complex assemblies* represented structural steel assemblies that were composed of one main component and more than 10 smaller components, as listed in Table 1.

In addition to these, tests were conducted to find a) the location of the assemblies within the manufacturing yard to form the predefined packages and b) the location of the formed packages within the yard to be shipped to trucks (see Figure 1). The details of the test setup are provided in Table 2.

Table 1: The group of assemblies used for tests during the installation phase (see Figure 1b for an example)

Category of assemblies	Description of the assembly	Number of assemblies used during the tests
Simple Assemblies	The number of the main component= 1 The number of the smaller component < = 5	8
Medium Assemblies	The number of the main component= 1 5 < The number of the smaller component < = 10	19
Complex Assemblies	The number of the main component > 1 The number of the smaller component > 10	16

Using the above described parts, assemblies, and packages, tests were performed both using RFID technology and manual approaches to locate the parts, assemblies and packages. The manual process included the location identification of similar parts, assemblies and packages located around the tagged ones by the manufacturing company's workers. While the workers were working on locating components, the time it took for each part, assembly and package to locate was recorded. Concurrently, the research team tracked the tagged components in the same order the workers located the similar components, and recorded the time to locate them. The tests were repeated twice to eliminate human errors. The mean values of locating the components using RFID technology and manual search/locate approach are provided in the next section.

Table 2: Details of packages that were tracked during the experiments (see Figure 1c for an example)

Package ID	Content of the package	Number of components in the package
Package 1	Assemblies, profiles	4 HE A 450 profiles
Package 2	Assemblies, profiles	7 IPE 240 profile
Package 3	Assemblies, profiles	4 IPE 240 profile
Package 4	Assemblies, profiles, escape barriers	2 HE A 450 profile, 4 L escape barriers of various sizes and 4 escape barriers
Package 5	Assemblies, profiles	3 HE A 450 profile, 4 IPE 240 profile

3. RESULTS

All the test results were analyzed and the average time for locating the parts during the manufacturing phase to form assemblies, and for locating the assemblies and packages at the shipment phase are provided in Tables 3 and 4, respectively.

Table 3: Experiment results for locating parts that were used to form the assemblies (manufacturing phase)

	Simple assemblies		Medium assemblies		Complex assemblies	
	With RFID (seconds)	Without RFID (seconds)	With RFID (seconds)	Without RFID (seconds)	With RFID (seconds)	Without RFID (seconds)
Average time for locating the main component	11	66	12.5	63	11.58	81.38
Average time for locating a part in the assembly	12.4	63	11.52	68.33	12.5	82.58

If RFID based location identification and the current manual search practice are compared for the durations for each step, RFID based system saves approximately 80% of time. It was also apparent from the test results that the complexity of assembly in the RFID based location identification does not play a significant role on the average, as seen from Table 3, whereas the complexity of assemblies (hence the number of parts that compose an assembly) increases the time needed to find all parts by approximately 60 % in the manual approach.

Table 4: Experiment results for locating assemblies (shipment phase)

	With RFID (seconds)	Without RFID (seconds)
Average time for locating an assembly for a package	14.11	74.2
Average time for locating a package for shipment to a truck	8.4	32.4

Analysis of the results provided in Table 4 shows that RFID technology cuts the time to find an assembly by 4/5 and to find a package by 3/4. These time savings are much dramatic when the manufacturing yard is large and dispersed where workers have to manually walk longer distances to search and locate components. When the time to locate a part, assembly and package are compared, it is apparent that as the size increases (hence the tag becomes more apparent to see), it is easier to locate the components with less amount of time devoted for it.

The tests that were conducted in different phases of the lifecycle of steel components clearly showed that RFID based framework has tangible advantages in terms of reduction in time to locate components, reduction of human errors, increased accuracy for accessing information about components and ease of handling as compared to manual and document based approaches. As it can be seen in the test results, RFID technology reduces the time to locate components, assemblies and packages drastically (within 75-80%) as compared to the manual approach searching. This has implications not only in preparing bids and responding customers early on, but also in reducing the direct and overhead costs in manufacturing yards and construction sites.

In addition to bringing time efficiencies, RFID technology reduces human errors in handling packages. It has been observed at the manufacturing yard that workers tend to miss some components that need to be put in a package or misplace components in wrong packages. Such instances result in having packages transported to job sites with missing/wrong assemblies; hence additional cost of reshipments, which can be expensive when shipments are made to overseas.

In the current practice, mainly a document based information exchange process is used. This approach is not an efficient way at manufacturing yards, or operation level at job sites, as the documents get lost while being transferred from one location to another and not easy to handle. RFID eliminates document handling and provides ease of access to information about components via tags and results in a component based access to information rather than document based access.

4. CONCLUSION

This paper provides the details of the tests conducted to see the impact of RFID technology at a manufacturing yard of a structural steel manufacturing company for various stages of production line. Various tests were performed at the manufacturing phase with three categories of assemblies, namely as simple, medium and complex assemblies; and at the shipment phase with assemblies and packages. The results show that RFID technology cuts the time to find structural steel assemblies by 4/5 as compared to manual approaches and cuts ¾ of the time to locate a package for shipment. This study complements the previous studies performed with RFID technology utilized for other types of components (e.g., precast engineered to order components, small equipment) and shows how the technology can improve the location identification of structural steel members.

Although some practitioners claim that RFID based framework is expensive system and is not efficient to use, if the benefits and usage areas of RFID technology (in terms of location identification, tracking, information access and accuracies) are examined, it can be seen that using RFID based approach is more reasonable than using the current manual and document based approaches.

As a further study, the study can be performed during the inspection phase which comes after installation phase into the life cycle of the steel component. After a component is installed and inspected, other component information, such as component history, location, connectivity and material information will be needed during operation and maintenance phases of a project. A major issue for many facility managers is ensuring that component data is up to date, correct and protected from damage. Such information items need to be readily available to facilities management personnel to reduce time wasted on locating components and associated information on documents.

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