KICEM Journal of Construction Engineering and Project Management
Online ISSN 2233-9582

www.jcepm.org
http://dx.doi.org/10.6106/JCEPM.2014.4.2.001

Practical Issues in Application of RFID to Pipeline Construction and its Benefit Analysis

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Received October 2, 2012 / Accepted January 20, 2014

Abstract: Radio Frequency Identification (RFID) has been applied to the construction industry for improving the efficiency of material and process management. Most RFID-related studies have focused on building or plant construction. The application of RFID has been limited in pipeline construction projects where materials are stored and stacked across a large construction site. This paper investigates practical issues in pipeline construction, improves the read rates of RFID tags, and tests their utility by putting them into practice. This paper demonstrates the benefits that may be expected with the use of improved RFID tags and the development of an automated pipeline construction management system. As a result, pipeline construction management time decreased by 28 hours per month compared to the conventional method. Cost decreased by about 26%.

Keywords: RFID Tag, Pipeline Construction, Construction Process

I. Introduction

Recently, the Korean government accelerated land development for construction of new towns and improvements of the residential environment. The number of large-scale land development projects has increased across the nation. New land development projects include earth work, pavement work, and sewage & rainwater pipeline construction. Sewage & rainwater pipelines can be over 30km in length. As a result, efficient material and construction management is necessary.

When construction materials are stored, stock yards are scattered across a large construction site. As a result, a lot of time and effort has to be spent to manage them. It is rare when checks are made frequent enough to determine if materials were lost or damaged. Further, a considerable amount of time is necessary to determine the status of a pipeline construction project. RFID technologies have been applied to construction sites to overcome inefficient material and process management. However, many RFID-related studies have focused on building (Chin et al, 2008) or plant construction. The application of RFID tags has been limited in pipeline construction projects where materials are stored and stacked across a large construction site.

This paper focuses on improving the read rates of RFID tags for efficient material and process management, and testing their utility by putting them into practice. The results demonstrated in this paper are expected to help improve the material and process management procedures of the pipeline construction industry which are performed at a wide range of construction site.

II. Literature Review

RFID refers to a branch of automatic identification technologies in which radio frequencies are used to capture and transmit data. RFID technology involves the use of tags, or transponders that can collect and manage data in a portable, changeable database within the tag; communicate routing instructions and other control information, and which can withstand harsh environments (Jaselskis et al. 1995). RFID has two prime components: a reader and a tag. A tag, which consists of an electronic chip coupled with an antenna, is attached to an object, and stores data about the object. The reader, combined with an external antenna, reads/writes data from/to a tag via radio frequencies and transfers data to a host computer (Ergen, E et al. 2007).

Jaselskis et al. (1995) introduced hardware and software for applications of RFID technologies to the construction environment. They described concrete processing and handling, coding costs for labor and equipment, and their applicability while materials were under control. Furlani and Pfeffer (2000) presented a further development and experimental testing of Comp-TRAK which involves the use of RFID and bar code identification systems, a prototype system for identification and spatial tracking of structural steel components on a live construction site. In addition, studies on an RFID application for efficient material management in the process of transporting precast concrete (Akinci et al, 2002) and on the application of RFID technologies for efficient tracing and management of pipe hanger and pipe supports on a plant construction site (Jaselskis and EI-Misalami, 2003) have been conducted.

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These studies have mostly focused on building and plant construction. It is difficult to find a study on the improvement of RFID tag read rates and their application that has considered the characteristics of heavy construction works (especially pipeline construction materials) that are carried out across a large construction site.

III. CURRENT PIPELINE CONSTRUCTION PROCESS AND RELATED PROBLEMS

A. Pipeline Construction Process

Pipeline construction begins with a construction plan. After ordering and acquiring construction materials based on the plan, the materials are inspected. Once they pass the inspection, they are piled up on an open storage yard. Then, they are consumed when necessary. After the construction is completed, an inspector inspects the materials to ensure the design criteria have been observed.

1) Construction Planning

Construction plans are developed by subcontractors after reviewing the construction site and overall project requirements, estimating the amount of building materials, equipment and manpower required. After confirming the construction plan with the prime contractor, the necessary construction materials are ordered. The prime contractor then attaches the Safety Management Plan and Quality Control Plan and asks its client to approve the construction plan. The client may amend it for any purpose.

2) Ordering Construction Materials

Once a construction plan is approved, the prime contractor supplies construction materials to subcontractors in order for construction to begin as planned. The prime contractor monitors the inventory on the open storage yard throughout the project.

3) Warehousing and inspection

Once construction materials are delivered, the prime contractor examines them to assure the proper quantity, specifications, and quality of the materials. They are then stored on the open storage yard. The prime contractor records the amount delivered on the Carry-in Inventory Sheet by hand and controls the total inventory.

4) Pipeline construction

A subcontractor excavates the ground, pours foundation concrete and lays a concrete-hume pipe. When all construction is complete, the subcontractor reports the completion to the prime contractor. The prime contractor then verifies that the construction was completed in accordance with the specifications, and asks its client to confirm it.

5) Inspection of construction

When a prime contractor requests, its client inspects to ensure the construction has been completed based on a drawing and other specifications. If the construction has been completed as planned, the client shall order backfilling. Once the inspection is completed, a prime contractor manages the status of the construction activity.

B. Problems in Current Construction Management

1) No sharing of Inventory Information

If the construction materials are delivered to the construction site, a manager from the prime contractor counts the number of materials brought in and enters it into a personal computer. Therefore, a construction manager and employees from the subcontractor are not aware of the status of the inventory.

2) Inability to Check Inventory on a Real-time Basis

If only one open storage yard is used when constructing a pipeline in a large-scale land development project, it would take a longer time to deliver the materials to each work site. As a result, inventory storage yards are located adjacent to several workplaces across the construction site, and usually inspected once a month. Considerable time and effort is necessary to check the inventory across the construction site.

3) Occurrence of Lead Time because of Site Inspection

When a pipeline construction task is completed, a subcontractor reports the completion to a prime contractor. The prime contractor inspects the construction site. Work cannot proceed until the inspection is finished.

4) Necessity to check performed quantity

In order for a prime contractor to send a bill to a client and make an interim payment to a subcontractor, it is essential to check the quality of the performance. The quantity is inspected monthly on a regular basis. Additional time and effort is necessary for this.

IV. RFID PIPELINE CONSTRUCTION MANAGEMENT SYSTEM

As described in the previous chapter, all current pipeline construction tasks (ex: ordering and delivery of materials, inventory management before and after construction, etc.) are managed manually. To overcome these inefficient processes, it is necessary to select and utilize RFID tags and equipment which fit for the characteristics of the pipeline.

A. Qualifications of RFID tags and readers

Tags for pipeline construction should be long in terms of reading distance and easily attachable to the pipeline. In addition, the tags should operate normally even though an obstacle is found. Since pipes are piled outside for a long time, they should be resistant against temperature fluctuations and rain. Furthermore, there should be no transmission interference by the wire in the hume pipe.

For a reader, which is a major equipment component along with the RFID tag, reading distance is an important factor. If a reader's reading capability is poor, a problem may occur even though good tags are used. In addition, a reader should be portable and available outside in winter. Table 1 states the selection criteria of RFID tags and readers.

TABLE I
SELECTION CRITERIA OF RFID TAGS AND READERS

Category	Selection Criteria
RFID Tag	○ Reading distance should be acceptable. ○ Reading rates should be over 95%. ○ Resistant against temperature fluctuations ○ Water-resistant ○ Easily attachable ○ Low-price
RFID Reader	○ Longer than the RFID Tag in terms of reading dis tance ○ Reading rates should be over 95%. ○ Available in winter as well ○ Able to read several tags at the same time ○ Portable ○ Fast data transmission

B. Problems of the conventional tags

In RFID tags, the limitation of readable distance and reading rates are very important. Even though a process has been systematically established, the accountability and accuracy of information would decline if tag reading rates are low. When the reading distance is short, it is necessary to get closer to the tag to read it.

In this paper, an actual construction site has been tested to measure the reading distance and reading rates of the conventional RFID tags. The test site was in the early stage of banking up and pipeline construction. It was ideal conditions for testing a new pipeline construction management system.

Fig. 1 shows the most common RFID tag. This paper has investigated the problems of conventional tags by measuring their reading rates. The reading rates of conventional tags were measured while construction materials were in storage and after the pipeline const-ruction was completed, using 20 samples. According to the measurement on each sample (Table 2), the reading rates were low with 12 and 5 respectively because tags were exposed to the external environment and vulnerable to weather changes. In general, pipeline materials are stored outside. Because they are distributed across large construction sites, it would be very unlikely to build a warehouse for them.

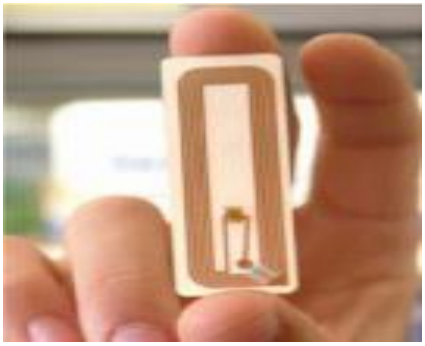

FIGURE I
CONVENTIONAL RFID TAG

C. Improvement of tags

To address the RFID tag problems shown in the above section 4.2,, the position and attachment methods for the tags have been improved. Fig. 2 shows an improved tag. Even though the frequency band is the same as the conventional tag, the improved tag has a bigger antenna to increase reading rates. In addition, the data chip has been coated to make it resistant against rain, snow and temperature changes.

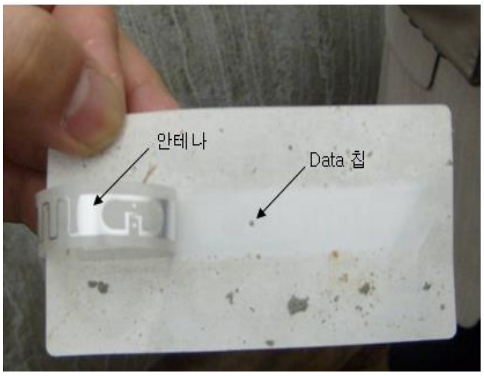

FIGURE II
IMPROVED RFID TAG

It was specified to attach a tag to the spot adjacent to a socket of concrete hume pipe. The conventional tags were attached to any position. If they were positioned facing downward, they would touch the ground, which caused a problem reading. Also, if there was a tag in the joint between hume pipes, it could be damaged. An attempt was made to increase tag reading rates by taking advantage of space between the pipe and ground after changing a tag position to the socket. Fig. 3 shows the position of a RFID tag.

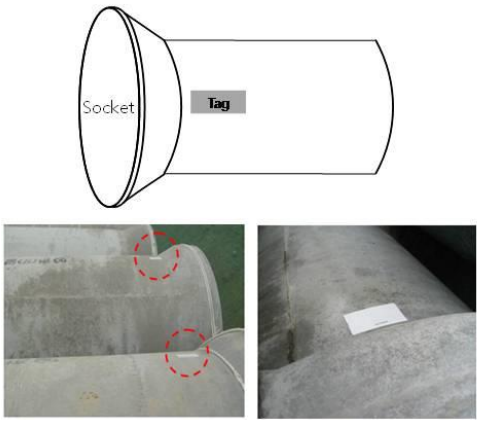

FIGURE III
POSITION OF RFID TAG

TABLE II
MEASUREMENT OF THE CONVENTIONAL RFID TAG

DESCRIPTION	**<CASE-1>** ○ A test of the reading functions of the tags attached to 20 concrete hume pipes - The reading level was measured after attaching 20 tags to the construction materials - The tag reading levels of 20 pipes were measured - After applying the scan function to a reader, a test was conducted to determine the number of tags that could be read. **<CASE-2>** ○ A test of the reading functions of the tags attached to 20 concrete hume pipes in the construction area - The tag reading levels of 20 pipes were measured - After applying the scan function to a reader, a test was conducted to determine the number of tags that could be read.
TEST RESULTS	**<CASE-1>** ○ No. of measurements: 20 - Tag reading rates: 60% (12 tags were read) - Tag reading angle: Right angle direction of the tag - Tag reading distance: 0.5-1.0m **<CASE-2>** ○ No. of measurements: 20 - Tag reading rates: 25% (5 tags were read) - In the process of piling on the open storage yard, tags are damaged. Since they are positioned on the outside of pipes, they may not work if it rains. - If a tag touches the ground, it would not be read. - A reading problem may occur from the concrete paste after pouring concrete.

An attempt to improve tag reading rates after the construction was also made by making the tag face upward during the installation of hume pipes. Fig. 4 shows a reading of RFID tags in the construction stage.

FIGURE IV
PIPELINE CONSTRUCTION AND READING

TABLE III
Measurement of the Reading Rates of the Improved RFID Tag

Description	- No. of measurements: 20 tags - The reading level was measured after attaching 20 tags to the concrete pipes - After applying the scan function to a reader, a test was conducted to determine the number of tags that could be read. - Whether or not a tag was read in the hume pipe was examined - The tag position was adjusted (attached adjacent to a socket)
Test Results	- Tag reading rates: 100% (all 20 tags were read) - Tag reading distance: 0.5-1.0m (similar to the conventional tag) - It was confirmed that a tag can be read in a hume pipe. - Coating of the tag made themselves resistant against bad weather and outside condition - A space could be secured by attaching a tag adjacent to a socket - A decline in tag drop rates depended on the use of glue attached to a tag

All 20 tags attached to the pipes were read, and the test results indicated that reading rates had improved. However, reading distance for the improved tag was similar to the conventional tag. Since the reading direction had to be right-angled with the surface of the pipe, it was difficult to improve reading distance.

After the test and before the field application, pipe suppliers attach RFID tags. The tags were attached adjacent to a socket which was positioned to show the firm name and quality assurance mark. No additional time or cost was required for pipe suppliers to attach a tag since a tag was attached after the firm names were manually marked.

D. Pipeline Construction Management System

The automated pipeline construction management system consists of hardware and software. The former includes a reader or PDA and RFID tags in which material information can be stored on, while the latter is a software system that processes information and can be used to help monitor the progress of construction. A reader reads tags, enters information, and transmits data to a personal computer. The computer system that receives the data monitors construction material, and compares the progress of construction in comparison with the drawing specifications on a real-time basis.

Fig. 5 shows the input of warehousing and construction information through a PDA while Fig. 6 shows the searching of the entered information which is transmitted to the pipeline construction management system.

FIGURE V
INPUT OF INFORMATION

FIGURE VI
PIPELINE CONSTRUCTION MANAGEMENT SYSTEM

V. UTILITY VERIFICATION

A. Improvement of the Pipeline Construction Process

Fig. 7 shows the application effect of the improved RFID tags and inventory management system with respect to the management and work processes and the characteristics of pipeline construction. When RFID tags and inventory management systems are applied, the information on construction materials can be registered through a reader at each stock yard. The materials stored on the open storage yard can be easily checked. In the construction stage, the amount of inventory consumption, the construction position and related information can be automatically updated using a reader and PDA before, during, and after the pipeline construction. Previous time constraints for inspecting the materials after the construction is completed can be overcome.

B. Case Study

To consider the applicability and utility of the improved RFID tags and pipeline construction management system, they were put into practice. Time and costs were compared and analyzed. As shown in Table 4, the construction lasted from July 2007 to June 2010. When the improved tags and system were applied, the construction was partially completed (10%).

TABLE IV
OVERVIEW OF APPLICATION PROJECT

Category	Description
Title	New Town Land Development Project
Client	Korea Land & Housing Corporation
Area	811,637㎡
Land Usage	Single-family house, apartment, commercial building, office facility
Construction Period	July 2007 - June 2010

According to an analysis of the effect of work improvement resulting from the application of the RFID-based pipeline construction management system to the construction site, it has become possible to check inventory on a real-time basis. In addition, it has been able to avoid ordering unnecessary materials as a result of its ability to check inventory on a current basis. Under the conventional system, time was necessary to manage construction information, check the amount of construction materials and prepare a current construction sheet.

Improved process management has become possible because the number of construction materials can now be checked on a real-time basis. In addition, construction materials which have been stored across a large construction site and poorly managed can now be efficiently managed. Unknown losses can be prevented. Table 5 below shows the effects of improvements after the application of a new system.

For a quantitative analysis of the effects of improvements after the application of the new pipeline construction management system, the work time required was compared using the conventional management method and using a new management method under the new system. Table 6 shows a comparison for pipeline construction management. Work time for the conventional work method has been reflected, according to the opinions of field workers. No additional time is shown for a new system to manage, because it is automatically managed.

In Table 7, the total decrease in cost was estimated by converting work time into cost and comparing it with the cost consumed for the development of a system.

- Using conventional management methods, 36 months were applied to the construction period.
- For labor cost, inventory workers' monthly pay was divided into 25 days to estimate daily labor cost.
- Cost estimates for a new system included purchases of equipment, and new system development cost.
  - It was difficult to estimate the development cost for a separate pipeline construction management system in connection with the PMIS.
  - A quotation from a developer was used to estimate the cost to develop a new automated system.

The inventory management system was compared to conventional management. Cost savings experienced with the new system were estimated to be USD 5,526 during this period.

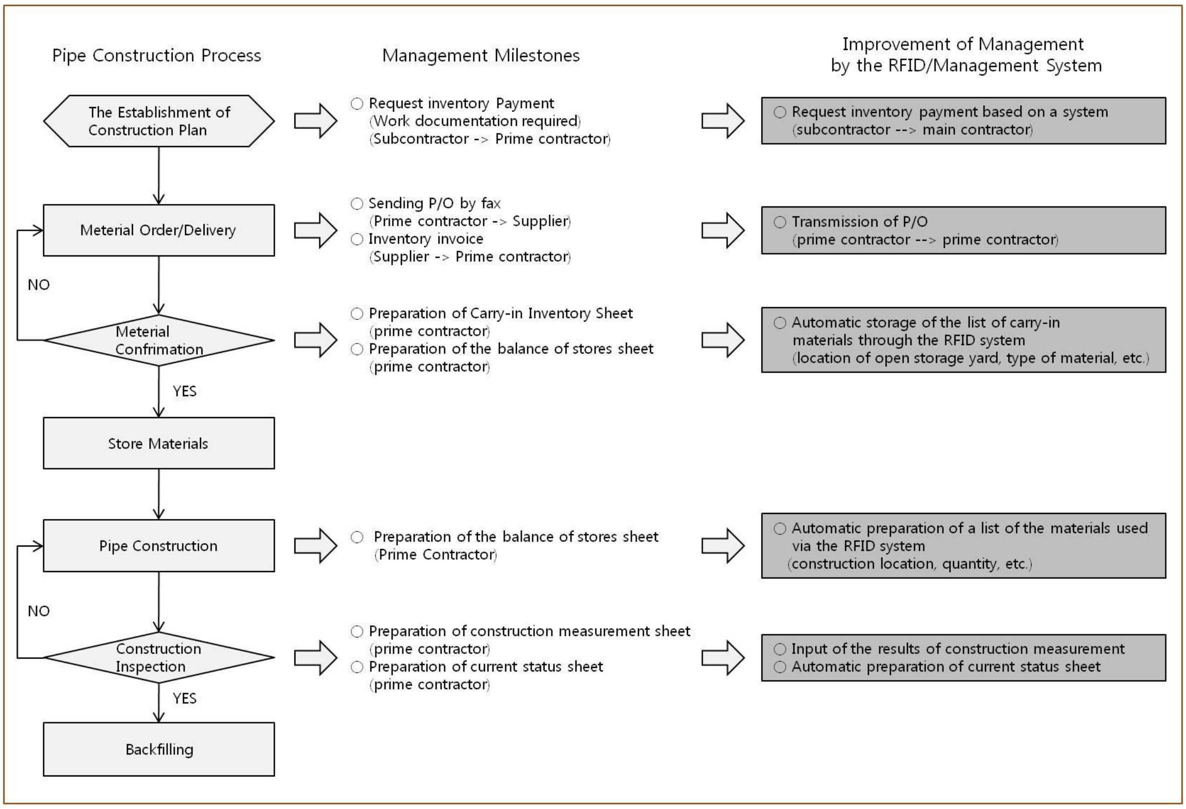

FIGURE VII
THE APPLICATION EFFECT OF THE IMPROVED RFID TAGS AND INVENTORY MANAGEMENT

TABLE V
IMPROVEMENT EFFECTS BY APPLICATION OF THE SYSTEM

Category	Problem	Improvement Effect
Warehousing Management	○ Unable to check warehoused inventory on a real-time basis - Preparation of carry-in inventory invoice by hand ○ Discontinuance of work due to loss of invoices	○ Able to check the inventory as soon as it is warehoused ○ Easy to check the inventory when placing an order ○ No discontinuance of work due to a loss of invoice
Construction Management	○ Construction management based on construction workers' information ○ Difficult to check the actual number of construction materials ○ Separate time is required to check the number of construction materials and to complete the construction material sheet.	○ Able to check the actual input as soon as the construction begins ○ Efficient process control by monitoring construction information ○ Easy to prepare related data using construction information
Inventory Management	○ Difficult to check the warehoused materials ○ A lot of time is required for inventory observation ○ Unable to manage the history of inventory loss and damage	○ Able to check the inventory on a real-time basis ○ Reduction of the time required to inventory ○ Early defect defection with the management of loss and damage

TABLE VI
WORK TIME COMPARISON TABLE FOR PIPELINE CONSTRUCTION MANAGEMENT

Category		Conventional Method		Under the New System	
		Preparation Cycle	Time Consumed	Preparation Cycle	Time Consumed
Inventory Management	Warehousing	Weekly	3 Hours	Automatic	None
	Inventory Status	Monthly	5 hours	Automatic	None
Construction Management	Construction Status	Weekly	2 hours	Automatic	None
	Estimation of the Current Quantity	Monthly	3 hours	Frequently	None

TABLE VII
COST FOR THE CONVENTIONAL MANAGEMENT METHOD

Category		Estimation Grounds	Work Days	Management Cost (USD)
Inventory Management	Warehousing	1 (time/week) × 36 months × 4 weeks × 3 hours = 432 hours	54.0	8,962
	Inventory	1 (time/month) × 36 months × 5 hours = 180 hours	22.5	3,734
Construction Management	Construction	1 (time/week) × 36 months × 4 weeks × 2 hours = 288 hours	36.0	5,975
	Estimation of Current Amount	1 (time/month) × 36 months × 3 hours = 108 hours	13.5	2,240
Total		-	126.0	**20,913**

TABLE VIII
COST FOR NEW MANAGEMENT SYSTEM BASED ON RFID

Category	Qt.	Unit price	Cost(USD)
Portable reader	2(each)	2,000,000	3,509
Tag	5,654(Sheet)	450	2.228
System development cost	1	10,000,000	8,773
Miscellaneous cost	1	1,000,000	877
server	Existing PC		
Total	15,387		

VI. CONCLUSION

This paper has investigated problems in pipeline construction and demonstrated the benefits that may be expected with the use of improved RFID tags and the development of an automated pipeline construction management system. RFID tag data chips were coated to make them resistant against temperature changes and rain. In addition, tags were attached adjacent to a socket. The tags were positioned facing upward to improve reading rates.

After applying those to an actual pipeline construction site, time and costs were analyzed. Pipeline construction management time decreased by 28 hours per month compared to the conventional method. In addition, the construction duration decreased by 126 days. Cost decreased by about 26%. Therefore, it was concluded that the improved RFID tags and pipeline construction management system were more efficient than the conventional management method.

To facilitate development of a system similar to the system mentioned in this paper, it is important to test the applicability of RFID for other pipeline materials as well. In addition, a further study needs to be conducted on automatic RFID tag attachment methods and methods to manage all processes such as delivery of materials, warehousing and construction with a single system.

ACKNOWLEDGEMENTS

This research was supported by a grant (06 CIT A03) From Research Policy & Infrastructure Development Program funded by Ministry of Construction & Transportation of Korean government.

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