A STUDY FOR RFID APPLICATION OF CONSTRUCTION MATERIALS

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ABSTRACT: The trend in construction industry, now, lies in improving efficiency and competitive power in construction management and on-the-spot instruction by combining with new IT technology. Above all, it is safe to say that the application of RFID technology can play a pivotal role at this point, but it is not that easy to apply RFID due to the physical, chemical and environmental peculiarities of construction materials. Thus, a study on the standardization of the usable frequency, specifications, protocol, and package administration is required. This study, as part of the study on the standardization, figured out the restrictions by attaching the existing RFID Tag to the construction materials, turned out the prototype of RFID Tag to perform a field test. In result the effective recognition range varies according to the physical and environmental peculiarities of construction materials; and the management efficiency varies as the attaching method and/or applying method. To analyze the management method (media, process etc.) systematically for the existing construction materials; to prepare more various restrictions and its solutions for practical construction spots will be the key for successful RFID implementation.

Keywords: Construction Materials, RFID Tag, Packaging, RFID Code

1. INTRODUCTION

1.1 Background and Purpose of the Study

The construction industry is a comprehensive industry with a big ripple effect in the producers of construction materials such as cement, steel reinforcing, timber and plaster board etc. and related industries of home automation, home appliances as well as the building industry itself, and the trend of the construction industry currently has its purpose to mix IT new technology and enhance the efficiency and competitiveness in the aspect of construction management and site control. Among others, the application of RFID(Radio Frequency Identification) technology plays a pivotal role in achieving such a goal and plans to spread into all the industrial fields before long. However, RFID cannot be easily applied to constructional industry owing to diverse physical, chemical and use-environmental properties of construction materials, so it is essential to research the standardization of RFID code issuance system and control, use frequency, specification, protocol, package method and recognition method etc. The research in the efficient code issuance system and management, the RFID Tag packaging method considering the physical and chemical properties of construction materials and attachment method will suggest a new standard method in this field suffering from the difficulties owing to the environmental property of construction sector and the particularity of application. And we can test and apply the RFID Tag products to the high value-added construction field (material production, process control, safe management, upkeep etc,) and prepare for a standard to provide the site applicability and complementary technology.

Thus in this research we produced a prototype tag with the packaging after the material property as the part of the precedent study to suggest the RFID code issuance system of construction materials and standardize the level(quality, size, recognition ratio, inner environmental conditions etc.) of RFID Tag by the construction materials of RFID Tag and attachment method, recognition method etc., figured out the problems by applying it to the actual distribution step and drew up a guideline on attachment method and recognition method in future.

1.2 Related Study

RFID Technology shows the examples of the application in diverse areas such as logistics, transportation, medical service, airport etc. domestically, and evolves continuously, but the application in the domestic construction field is too slowly proceeding, and there are some examples of the restrictive application of RFID technology in the site.

The Ministry of Information and Communication proceeded with pilot projects to activate RFID technology in 2004 under the leadership of the government in various fields such as aircraft, distribution and livestock farming etc., and in 2005 the efforts to extend the examples of application and building are in the step to spread to various ministries and offices and industrial circles, and in 2006 the RFID spread project is promoted with the u-IT leading project assignment. The demonstration project and spread project of the Ministry

of Information and Communication has its meaning that they achieved the results of the opportunity to get over the gap between the level of domestic RFID technology and that of advanced countries to implant the confidence in RFID and that they realized the creation of a large-scale demand for the commercial use of RFID and the upbringing of related industry through the innovation of operation process, the betterment of service for the people and business promotion process by means of a regular application of RFID in the public sector of the government.

The Ministry of Commerce, Industry and Energy also executed a demonstration project to apply RFID in 2004 and 2005. Especially, the pilot project of the Ministry of Commerce, Industry and Energy has the difference in that they developed a demonstration project in the field of distribution/logistics targeting private enterprises, whereas the Ministry of Information and Communication focused the part of RFID application in the public area.

In the domestic research to really apply RFID to construction materials, Han, Jae-Gu et al. (2004) tested recognition ability targeting ceiling materials to develop a system for monitoring by attaching RFID Tag to finish materials.

Han, Jae-Gu et al.(2006) presented the problems of RFID technology and the solution through the construction the model system of material control using RFID and the experiment of finishing materials in the building site of skyscrapers. Lee, Min-Woo et al.(2006) grafted material procurement process in the steel-bar processing factory to RFID system, extended the application of existing RFID system to metal materials, and considered Tag packing method and its production

Park Chang-Wook et al.(2007) analyzed the site examples of a steel-frame factory applying RFID and suggested the improvement plan for the material procurement of steel-frame construction and the automation of lifting.

Kim, Yong-Bae et al.(2008) performed a recognition performance test by attaching RFID to a curtain wall, and requested for the research of the deduction of RFID technology in construction environment and the application method.

Ku, Do-Hyung et al.(2008) surveyed the possibility of the technical application of RFID by each construction type and main material, and clarified the current problems RFID technology and its limitation.

2. RESEARCH OF RFID APPLICATION

2.1 The Selection of the Object of Post Test for RFID Application Experiment

1) The selection of RFID equipments of the object of positive test

The RFID frequency bands of commercial use without a separate permit from the Ministry of Information and Communication, the subject of radio regulation contain 125KHz, 13.56MHz, 433MHz, 900MHz, 2.45GHz, 5.8GHz, and out of them we selected the RFID bands of 125KHz, 13.56MHz, 900MHz being much used as Passive Type as the objects of positive test. Especially we focused on testing the 900MHz band being mostly used in the field of logistics and distribution out of ISM band (Industrial Scientific Medical band : 902 ~ 928MHz, 2400 ~ 2483.5MHz , 5725 ~ 5850MHz) which can be the frequency band to be liberally used without permission in the industrial science and medical field.

2) Results of Positive Test

A) Test Method

- Test proceeding over the Frequency Tag on the recognition distance and recognition angle by the type in the same condition
- Average the value of the results by recognizing the Frequency Tag repeatedly 10 times in the same condition
- Observe the domestic standard all in the equipments used
  - 125 KHz Middle Range Antenna used
  - 13.56MHz Long Range Antenna used
  - 900MHz Long Range Antenna used
  - 900MHz portable Reader Output 1W Setting

B) Results of Test

We progressed the Positive Test targeting RFID Tag and Reader of 125 KHz, 13.56 MHz, 900 MHz bands used of general-purpose out of the Frequency band to be used with RFID equipments which can be currently used without a separate permit from the Ministry of Information and Communication. We carried out this test in the lab environment to measure the properties (Recognition Distance and Recognition Angle) of RFID by the frequency band in the general air environment. We used the Tag of Passive Type with Battery Less.

The results of the test in the general air environment showed that the Tag of 125KHz band had the shortest recognition distance averaging 30Cm or so, and that the Tag of 13.56MHz band averaged 50Cm or so providing longer recognition distance compared with the Tag of 125KHz band, while the Tag of 900MHz band expressed the recognition distance averaging 5m which was relatively longer compared with other frequency band.

2.3 Selection of Construction Materials of RFID Application Object

In order to pick out RFID-applicable construction materials, we selected the management-possible objects in the form of standard materials except for the materials of mass transport out of construction materials of Database of the homepage of special construction companies, the Korea Housing Corp. and Korea ON-line E-procurement System. Though RFID out of selected construction material objects can be applied, we selected 5 packaging-required types to complement the performance of RFID owing to different physical, use-environmental properties of materials and existing Tag

difficult to be applied and made a survey on the quality and property of materials.

The materials in the form transported in large quantities have large deviation in size, shape, attachment method, application property etc. and many restrictions to be standardized, so we limited them to standard materials in this research, and we plan to progress their application method after the method of standard management of standard materials is completed in future.

2.4 Existing RFID Tag Verifying Test of Selected Construction Materials

We attached currently marketed RFID Tag by the selected materials, figured out recognition and applicability attached general label Tag, metal-purpose Tag, card type Tag by each material to search for a supplementary point through this and measured recognition and recognition ratio each 10 times repeatedly using the reader of Table 1. (Table 2)

Table 1. Types of Experimental Reader

Section	Model	Model Property
Fixed Reader	OMRON V750	900MHz. EPC C1G2 Support
Fixed Reader	Alien AR9800	900MHz. EPC C1G2 Support
Portable Reader	ATID AT570	900MHz. EPC C1G2 Support

Table 2. Verifying Test Survey Table on Selected Representative Construction Materials

Construction Materials	Section	Verifying Test Results			
		Fixed Reader		Portable Reader	
		Distance (Cm)	Recognition Ratio (%)	Distance (Cm)	Recognition Ratio (%)
Steel (H-Beam)	General Tag (Label Type)	0	0	0	0
	Metal Tag	411	100	197	100
	Card Type Tag	12	82	20	68
Stone (Marble)	General Tag (Label Type)	352	100	126	100
	Metal Tag	391	100	178	100
	Card Type Tag	275	100	138	100
System Windows & Doors	General Tag (Label Type)	13	26	5	30
	Metal Tag	421	100	203	100
	Card Type Tag	32	60	15	47
Glass (Curtain Wall)	General Tag (Label Type)	143 (23)	100	63(18)	20
	Metal Tag	127 (58)	100	79(35)	100
	Card Type Tag	61(42)	100	47(28)	100
Finish Material (Plaster Board)	General Tag (Label Type)	332	100	136	100
	Metal Tag	385	100	178	100
	Card Type Tag	278	100	147	100

As the result of recognition ratio verifying test on existing RFID Tag of selection-targeting construction materials, recognition ratio of metal Tag is the best as a whole, and in case of general Tag, it is thought that metallic steel materials and system windows and doors have a low applicability. The following restrictions were drawn in applying existing RFID Tag.

1) In case of steel-beam, general Tag cannot be recognized in the property of metal quality, and it appeared that the recognition was impossible in the distance of 0Cm. and the recognition rate of card type Tag was not good, so the use of metal type Tag is required, and it requires packaging to consider attachment method (rivet, magnet) depending on recycling and use environment and the size etc. according to the scope of recognition.

2) In case of stone, general RFID Tag can be used in the part of recognition, but the breakage or damage of Tag after attachment is feared, and packaging to protect Tag is essentially required.

3) In case of system windows and doors, metal is inserted in interior frame, and general RFID Tag tends to decrease recognition rate and recognition distance, and metallic RFID Tag is most advantageous out of the types of Tag, and for a practical application, Tag size must be compact to be attached to the inside of windows and doors not to be revealed, and it requires packaging in the form to get over the restrictions of interior metal frame.

4) In case of glass, existing Label-purpose RFID Tag is generally fittest for glass, and in case of curtain wall, metal quality is inserted in the inside of glass and general RFID Tag reduces recognition rate and recognition distance, special Tag is thought to be required to supplement it.

5) In case of finish material(plaster board), general RFID Tag can be used in the part of recognition like stone, but the breakage or damage of Tag after attachment is feared, so packaging to protect Tag is indispensable.

2.5 Production of RFID Prototype of selected Materials

We selected 5 types of construction materials requiring packaging, performed RFID Tag test of 900MHz band with excellent applicability and drew applicability and restrictions. Using the result of such a test, we produced the prototype Tag for construction materials through the survey of the property of matter of the materials, use environment and application part. (Figure 1)

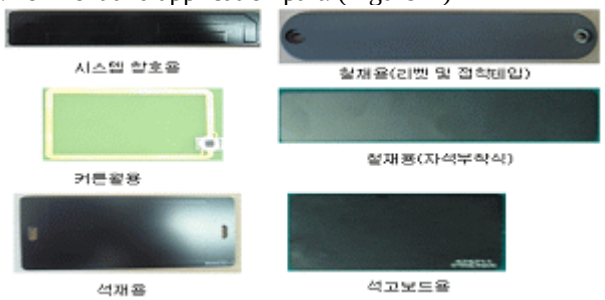

Figure 1. RFID Prototype by selected Materials

All the prototype Tag basically supports EPC C1G2, produced in Memory 512 bit, and the Tag for the purpose of steel, stone, plaster board with difficult interior attachment had packaging containing crashworthy property, waterproof function and pollution-preventive function, and each packaging property is as Table 8.

We tested recognition distance and recognition rate by applying the produced prototype to construction materials (Figure.4) and verified the maintenance of initial performance by adding repeated stress (shock, heat, moisture etc.), and the result is as follows. (Table 3)

Table 3. The Result of Prototype Verifying Test

Construction Materials	Size (mm)	Tag Type	Result of Verifying Test			
			Fixed Reader		Portable Reader	
			Distance (Cm)	Recognition Rate(%)	Distance (Cm)	Recognition Rate(%)
Steel (H-Beam)	150*34*4	Metal Tag	430	100	215	100
Stone (Marble)	70*50*2	General Tag	359	100	186	100
System W/D	30*21*2	Metal Tag (Interior Attachment)	63	100	32	100
Glass (Curtain Wall)	120*80*0.3	Film Type Tag	410	100	206	100
Finish Material (Plaster Board)	70*50*2	General Tag	359	100	186	100

In case of prototypes produced by supplementing restrictions, recognitions rate showed all good results. The recognition distance of steel and glass showed the best, and in case of system windows and doors, they, owing to the attachment to the inside, recognition distance appeared the smallest by the property of transmittance.

3. RFID Prototype Site Application Test

3.1. RFID Prototype Application test in the site of materials warehousing

We performed the site experiment to verify the possibility of the betterment of productivity through clear delivery and material control by detecting the delivery particulars of the materials in the distribution step of cold and hot steel place using the steel-purpose prototype RFID Tag out of 5 selected materials.

The main experiment content and results are as follows.

(1) Experiment Date

A. Date: Feb. 20, 2008

B. Place: Dongbu Steel Co., Ltd. Incheon Factory

C. Equipments used: 900MHz Fixed Reader and Antenna 2 type of steel-purpose prototype Tag each 10 pieces

(2) Experiment Method

After attaching steel prototype Tag to the interior/exterior of cold and hot steel plate, we loaded attached cold and hot steel plate in the delivery truck, installed RFID reader and antenna in both sides of the delivery gate and measured the recognition level of attached RFID Tag in repeated vehicle delivering/entering (each 20 times) according to attachment position, attachment height, measuring distance.

(3) Experiment Scenario

A. Attach 2 types of developed steel-purpose Tag (rivet-typed, magnet-typed) to 3 sheets of cold and hot steel plates with each one sheet in the interior and the exterior totaling 6 pieces by the type.

B. Load Tag-attached cold and hot steel plate on the delivery vehicle.

C. Install the reader, antenna, other measuring device to detect the cold and hot steel plate being delivered at the delivery gate.

D. Test the recognition rate of RFID Tag attached to cold and hot steel plate in the delivery from the warehouse repeatedly totally 10 times.

E. Based on the results of measurement, draw applicability and supplementary affairs, select added test items and measure them.

(4) Test Results and Consideration

As shown in Table 9 after the results of test, recognition rate and recognition distance are higher in attachment to the exterior of cold and hot steel than its interior, which is judged as a general phenomenon affected by the noise of the radio waves with diffused reflection inside the cold and hot steel owing to the property of radio waves and the reduction of in sending and receiving radio waves. Therefore, it is judged that cold and hot steel requires exterior attachment and the use of Tag-exclusive prop is a method for the interior attachment. Though the difference of interior recognition rate according to the attachment position from the bottom didn't act much, but the exterior recognition rate at 2.5m of attachment position all marked 100% recognition rate, so we shall have to consider our study about the correlation between the height of antenna and attachment position. In case of cold and hot steel plate, overall recognition rate more than 95% at exterior attachment, which can be used for the delivery and material control, but in order to satisfy recognition rate 100%, we shall have to satisfy another factor.

As the effective recognition distance varies according to material/environmental properties by the materials and there occur changes in the control efficiency according to attachment method and application method, for the standardization of RFID application, it will be a key point to apply RFID successfully to analyze the management method(media, process) of current construction materials and apply it to the practical construction site and prepare for more diverse limit factors and overcoming method.

Further, it is necessary to establish Tag Packaging method to supplement the frequency band and environmental change to be used according to the material property of construction materials. Thus in order to facilitate the general-use in the construction site, the Tag packaging method of low/high performance has to be developed, which will enable RFID technology to be introduced in the actual construction site.

3.2. RFID Prototype Application Test in Construction Site

In the second site experiment, we verified the control process of construction materials through RFID application and figured out the complementary points in the control scenario and real site through RFID application targeting finish material (tile), kitchen furniture and doors etc. for the generation work as a part of the methods to draw the optimum plan on the attachment position and attachment method of RFID Tag in the application of RFID prototype.

(1) Experiment Date

A. Date: 1st Dec. 16, 2008 ~ Dec. 18, 2008
2nd Jan. 13, 2008 ~ Jan. 14, 2009

B. Pl ace: Osansegyo e-Comfortable World Apartments Construction site

C. Use Equipments: 900MHz Fixed Reader and Antenna, 900MHz Portable Reader, Label Tag 50 pieces Card Tag 200 pieces, Metal Tag 50 pieces

(2) Experiment Method

We proceeded over the study by figuring out warehoused materials in the construction site of apartments, classifying and moving them to the construction site by the household, introducing RFID to grasp the construction site by the household and composing the scenario for the accuracy of management and real-time understanding. We attach RFID Tag to the box, the lowest control unit of each material for the classification and distribution of materials by the household in time of finish working of the construction step by the household, then check the state of classification and distribution through RFID Reader, store it in the server and figure out real-time material distribution state and inventory state.

(3) Experiment Scenario

A. Collect the information on the property and size of test object materials and put it into DB.

B. Pick out material list by the test object household and secure RFID Tag issuance list.

C. Select the tag fitted for the property of test object material (metal tag, card tag, label tag)..

D. Progress the issuance of test-targeting application tag (tag issuance code application).

E. Attach issuance tag to the control unit of each test-targeting material. (Figure 2)

F. After attachment, progress recognition test for the classification. (recognition distance, recognition rate, recognition method etc.)

G. After distribution by the household, progress recognition test. (recognition distance, recognition rate, recognition method etc.)

Figure 2. Management Material Tag Attachment

(4) Testing Results and Consideration

As the result of RFID verifying test of the part of finish materials out of facility construction materials, Some the attachment methods by the control units of the materials in the scenario were the same as the control units in the

real construction site, but we detected different part in the current construction progress rate and the construction proceeding method by the household. Though the tag attachment method in accordance with the property of materials and control units was important enough, there loomed large the necessity to prepare the attachment method fitted for the construction proceeding method by the household in the construction site. When we call the property of RFID Tag as the identification and uniqueness of each material, the household construction progressing method is judged to be more efficient in the control method focusing on the identification than the uniqueness of materials. That is, checking the quantity for the distribution of the materials is more effective than the method to identify the objects of the same materials, so if we manage mainly the check of the warehousing details of the materials by the household through distribution and the inventory of the materials, we will use RFID as a means of the quick identification each material and its real-time grasping.

As for the attachment method of RFID tag, it is basically a general method to classify and apply materials based on the physical and environmental properties, it will be also a key point to find out an attachment method fitted for the changes of the control methods in the practical construction site. For this purpose, we shall grope for the method to enhance the use of RFID Tag in the construction sector through the added study on the tag selection and attachment method the similarity and difference between the control method of construction materials and the material control method of the actual construction site.

4. CONCLUSIONS

In order to apply RFID to the actual construction site, we shall have to suggest diverse methods such as the RFID code issuance and its management system, Tag packaging to secure recognition rate of RFID Tag, Tag attachment method according to the material property and control units in the real site etc. For this purpose, we shall have to prepare RFID code control system, establish applicable RFID standard of representative construction materials, apply it to the real construction site as well as developing a prototype thereby, and perform the research to present supplementary points and betterment direction. In this research, we prepared RFID code issuance and control system through Construction Material Information System under being built by Korea Institute of Construction Technology, and progressed the experiment to draw up a guideline concerning the attachment position to apply RFID according to the types of construction materials, the standard of RFID Tag and attachment method, recognition method etc. As the application of RFID expresses many differences between the application in the lab and that in the real construction site, we will have to prepare a standardization plan and a guideline through the application of RFID considering diverse construction scenarios.

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