DEVELOPMENT OF MOBILE INSPECTION AND DIAGNOSTIC SYSTEM FOR ELECTRIC POWER CONDUIT

* Sang-Kyun Woo and Kyung-Jin Kim
Korea Electric Power Research Institute
65 Munji-Ro, Yuseong-Gu
Daejeon, Korea 305-760
*(*Corresponding author: wskyun@kepri.re.kr)*

Ki-Jung Kim
CENITS Corporation Incorporated
67-5,Hongsan Bldg., Yangjae-Dong, Seocho-Gu
Seoul, Korea 137-889

Byong-Don Youn
PLANALL E&C Incorporated
Woolim Lions valley 1st, Sangdaewon-Dong, Jungwon-Gu, Sungnam-Si
Kyunggi-Do, Korea 462-121

DEVELOPMENT OF MOBILE INSPECTION AND DIAGNOSTIC SYSTEM FOR ELECTRIC POWER CONDUIT

ABSTRACT

The electric power conduit (EPC) in Korea has been constructed since 1978. Facing the challenge of safety and sustainability of the EPC, it is urgent to develop an inspection strategy and maintenance system for the structure based on the concept of life-cycle management. This paper introduces the newly developed mobile inspection and diagnostic system of the EPC. The novel aspect of this particular system is the integration of non-destructive mobile inspection techniques with BIM (Building Information Modeling) and LBS (Location-Based Service). BIM is an ideal tool and platform for developing an inspection and diagnostic system, and RFID (Radio Frequency Identification) is a useful tool to construct USN (Ubiquitous Sensor Network) for LBS. The goal of this research is to establish an EPC inspection and diagnostic system concept based on BIM and LBS using RFID. In this research, a BIM model of OPEN-TBM tunnel for EPC will be established to show the integration of 3D CAD with the inspection data. An EPC's maintenance database, which includes the deterioration types of the structure, inspection records, and repair methods, was designed to interact with the BIM. The system will be implemented by the BIM with the related database, in which the construction geometry and all related information are stored. The proposed system was designed to utilize the inspection and diagnostic system under the USN environment using RFID in EPC directly.

KEYWORDS

Mobile, Safety inspection, Diagnosis, BIM, USN, RFID, LBS

INTRODUCTION

Generally, it is very difficult to inspect, repair, relocate or dispose an underground structure such as a tunnel or culvert among the social infrastructures due to the spatial restraints, compared to a ground structure such as a bridge or building. Particularly, EPC (Electric Power Conduit) as a long distance underground structure playing a pivotal role of power transmission has been constructed in Korea since 1978 and being increased due to the demand of ground facilities. As of 2012, the total distance of tunnel and culvert type EPCs in Korea is 404 km and approximately 25% of them are more than 20 years old. Though these facilities have been experiencing deterioration such as crack, leakage, efflorescence, the maintenance has not been done enough because most of the design drawings have been lost. Moreover, the construction information and maintenance data have not been managed well enough, thus the management cost has increased while the work efficiency has decreased.

In this research, we developed a mobile inspection and diagnostic system based on BIM (Building Information Modeling) to increase the work efficiency of maintenance and management of the EPC. This system gives a computerized database of maintenance and management information from the construction period to present time under USN (Ubiquitous Sensor Network) based on LBS (Location-Based Service) concept using RFID (Radio Frequency Identification).

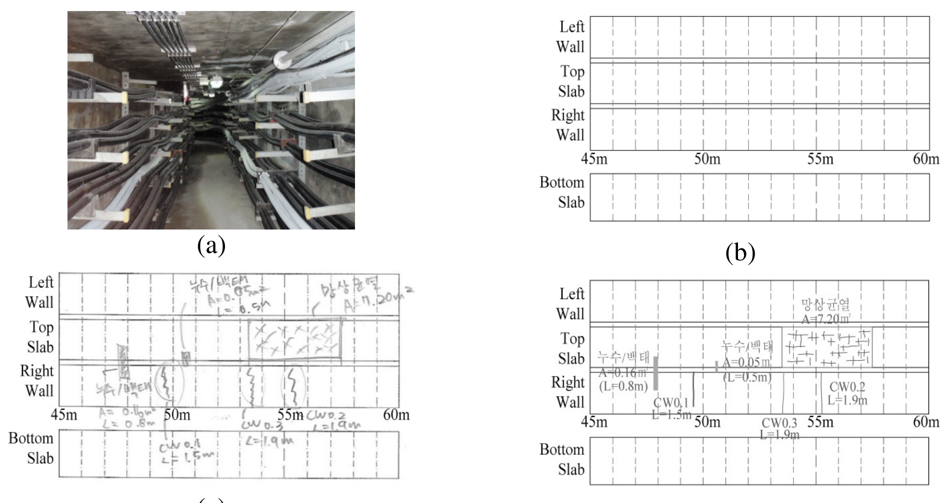
BACKGROUND AND RELATED WORK

Visual inspection is an important data collection process recording the deterioration of the EPC, and the collected data can be used to determine the safety status of the EPC accurately and objectively together with NDT (Non-Destructive Testing) results. In addition, the data can show the deterioration history and the maintenance or repair records. Figure 1 shows example of the ECP by shape type.

(a) (b)

Figure 1 – (a) Box shape culvert ECP; (b) Circle shape TBM tunnel ECP

Figure 2 shows the recording process of the deterioration for the visual inspection in 2D map. For the EPC as shown in Figure 2 (a), a field inspector prepares for a floor map of Figure 2 (b) and records the deterioration by hands as shown in Figure 2 (c) in the field, and then transfer to a final map using a graphic tool like CAD later, Figure 2 (d). This 2D deterioration map is used as the key data for maintenance and repair service during following safety inspection process (KISTEC, 2009).



(d)

Figure 2 – (a) Image of objective ECP for inspection and diagnostic; (b) Basic plan of ECP for visual inspection; (c) Visual inspection sketch by hand writing; (d) Visual inspection drawing by CAD

With the rapid development of IT technology, to maximize the efficiency of the data collected, some new inspection data management methods using mobile equipment, which can offer various analysis of management information through the system, have been developed (C. Legner et al., 2006; E. Ergen et al., 2007; Jo et al., 2008; Yang, 2009; Ko, 2009). The previously developed mobile equipped inspection management methods could help systematic management of the inspection data for the managers to grasp the structure status effectively and provide easy access through internet and intranet to improve the field visual inspection system. Especially, the system can communicate with upper level management system via wire/wireless communication network for the field inspectors to download the location information and previous visual inspection data, inquire the design drawing, search and modify the information at the site directly, and lastly upload the updated information to the main system (Elzarka et al., 1999; Lee et al., 2001; T. Mills et al., 2004; Y. Hu & A. Hammad, 2005; Moon et al., 2012; Song et al., 2012).

PLANNING OF MOBILE INSPECTION AND DIAGNOSTIC SYSTEM FOR EPC

Problems of Classical Method

However, previous mobile-technology equipped methods can work only through GPS or under valid wireless/wired communication system; therefore, in underground environment such as EPC in which radio wave cannot propagate and no internet and intranet can access, the mobile technology using outside network could not be applied. Also, though the new methods have advanced technology compared to hand writing on papers since the field inspector can work rapidly and directly, and collect and manage the data more effectively and easily, all graphic information including the visual inspection map is recorded and stored in 2D, and generated in 3D model through the projected 2D maps only with no basis of exact scale. Therefore, the previous methods can easily make an error when evaluating damaged materials and mapping the design for repair and reinforcement.

To overcome above difficulties that previous methods experienced, this research is to develop a new inspection and diagnostic method and system in which we can record the deterioration information in 2D format but convert into 3D format automatically in a mobile device by the mutual spatial linkage logic of 2D and 3D coordinates in the underground EPC in which radio wave cannot propagate without external support such as GPS or wire/wireless communication network. Also, BIM method can provide the deterioration information in 2D model based on exact scale without image distortion of the EPC so that we can use in evaluating damage quantity and design drawing for repair and reinforcement plan during periodic or detailed safety inspection service. And the deterioration 3D model can make the maintenance managers work in more vivid and realistic situation and improve the work efficiency for the related fields.

In other words, due to the capability of modeling 3D deterioration information in the underground EPC directly in the mobile device, the possible human errors that can occur during the transformation period from 2D to 3D modeling may be prevented and the reliability of the visual inspection and diagnosis information can increase. Also, the virtual reality of the 3D modeling can make it possible for the maintenance managers to check and access the deterioration or damage information more easily and vividly even without visiting the EPC field.

Troubleshooting Idea

As described above, we designed a process in which we download the EPC management information from an exterior server using a portable memory device and connect the memory to the mobile device we will use in the EPC. Here, the management DB server includes the basic, management/maintenance records and graphic information of the entire EPC. It provides the required information to the mobile device we use in the field before inspection, and store the updated data collected after the inspection to make the database.

To make use of a mobile device for inspection and diagnosis in underground circumstance, which GPS or wire/wireless network is not valid, RFID tag must be installed at each designated location in the EPC in advance. The LBS is implemented by displaying the required information of each location of the EPC that was downloaded from the main server according to each RFID tag. Particularly, 2D and 3D modeling which are coupled by linked spatial coordinates are displayed together to show the deterioration history of each location. And the 2D to 3D transformation is executed by the transformation matrix of 2D local coordinate system to 3D global coordinate system.

DESIGN OF MOBILE INSPECTION AND DIAGNOSTIC SYSTEM FOR EPC

System Component Design

We designed a system that can execute various inspection and detailed diagnosis in underground EPC using only mobile device independently without external support such as GPS or wire/wireless network. Figure 3 is a system architecture diagram of the mobile inspection and diagnostic system. As shown in the figure, the mobile system includes the maintenance server and mobile equipment; the maintenance server stores a database of basic, maintenance and graphic information and provides/receive the information to/from the mobile equipment. Through this server, the maintenance manager can register, search, modify, delete or save the information. The mobile device as a tool used in the actual EPC field, can be a notebook or tablet PC or even a smart phone. This device should include pre-installed input/output module, database, graphic module, inspection/diagnostic module, control module with RFID sensing system.

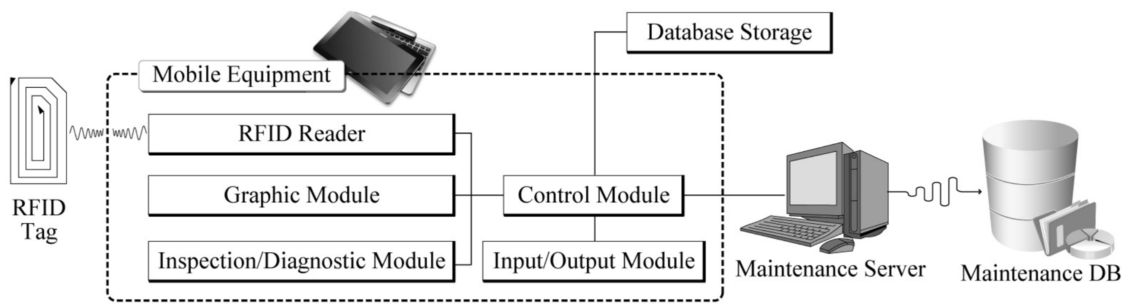


Figure 3 – Architecture of mobile inspection and diagnostic system for EPC

The input/output module displays the GUI (Graphic User Interface) for the inspection and maintenance of the EPC and executes the input command and deterioration information. Particularly, this module displays the deterioration 2D model based on the exact scale without distortion of the image and also can display 3D modeling in virtual reality mode. The input/output module interface can be a mouse, keyboard or monitor but touch-pen or touch-pad can also be possible due to the characteristic of mobile device. The database storage is a mobile memory device such as a mobile external HDD, SD, MicroSD or USB that can store and delete easily. On this storage, the field inspector can download the pre existing information from the maintenance server and save the updated information during the inspection.

The graphic module executes the graphic information such as deterioration, NDT location, repair, maintenance information and damage status. Particularly, the graphic module executes the transformation matrix of 2D local coordinate system (x, y, z) to 3D global coordinate system (x', y', z') or vice versa. Consequently as show in the figure 4, the input information in 2D coordinate can be displayed in 3D coordinate and the input in 3D can be shown in 2D, too. This module can give a realistic graphic of the deterioration information in VR (Virtual Reality) model.

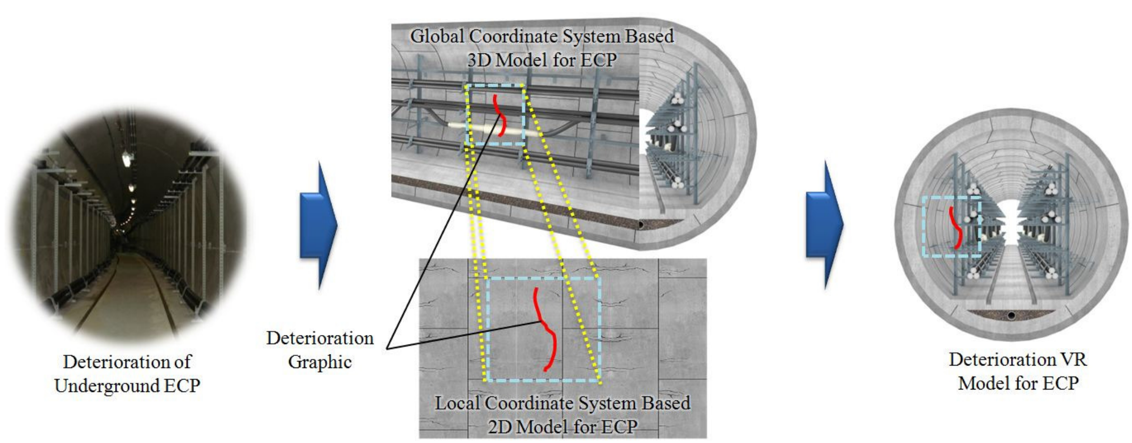


Figure 4 – Creation process of deterioration VR model for ECP using 2D and 3D model

In the inspection/diagnostic module, one can register, modify, search the basic information, specification of the ECP, management authority, design drawing, inspection/diagnostic criteria, visual inspection, NDT criteria, the results of safety ranking, inspection/diagnostic report, repair/reinforcement history/methods and their design drawing. The control module retrieves the information of each location from the database with the RFID sensing system and then provides the inspection/diagnostic data to the input/output module via graphic module. It also processes the input information through the inspection/diagnostic or graphic module and updates the information in the database once it is connected to the maintenance server.

Figure 5 shows the maintenance database structure of the inspection and diagnostic system. As show in Figure 5, the database in Figure 3 consists of basic information DB such as design & construction data and manual data, maintenance information DB such as inspection & diagnostic data and rehabilitation data, and graphic information DB such as 2D and 3D model data. The basic information DB includes basic data and standards, management authority and design & construction drawings and documents. And the manual data includes the specification of inspection and diagnosis, visual inspection and NDT. The maintenance information DB includes the results of visual inspection, NDT, safety ranking and the report of inspection and diagnosis in inspection & diagnostic data and result of repair, reinforcement, rehabilitation method and the design document in rehabilitation data. Graphic information DB includes basic, deterioration, NDT location, rehabilitation and safety ranking model in 2D and 3D respectively

.

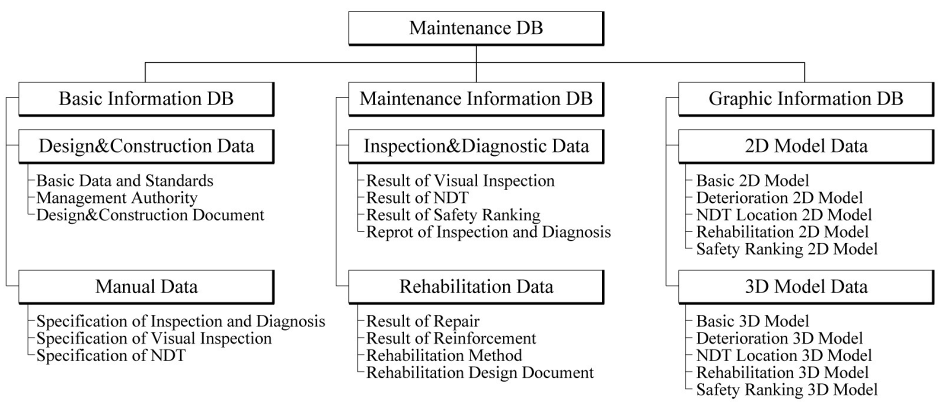


Figure 5 – Configuration of maintenance DB

Usage of System

In Figure 6, the process steps of the system are shown. First, the field inspector requests and downloads the maintenance data of the selected EPC from the maintenance server. This step is required for the field inspector to use the mobile device independently in the underground environment in which wire/wireless communication is not valid. The download can be done while the mobile device is directly connected to the maintenance server or through other devices.

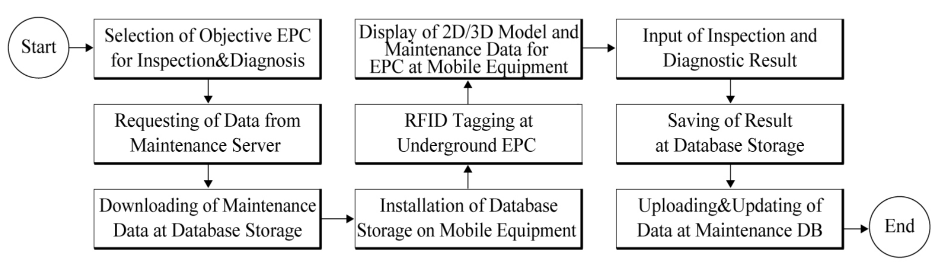


Figure 6 – The process steps of the mobile inspection and diagnostic system for ECP

After the downloaded database is installed in the mobile device, the RFID reader can detect the RFID tag installed in the EPC. Once the RFID sensor reads the tag number, the information corresponding to the tag is displayed via the 2D and 3D modeling. The field inspector can now modify the information and the updated information is stored in the maintenance server later.

Figure 7 shows the simplified diagram of the application plan of the system. The mobile device can detect the RFID tag at designated location of the ECP with the RFID reader. The RFID reader can be connected to the mobile device directly or via Bluetooth. The RFID tag is installed at the designated location and passive Gen 2 contactless tag can be used. A technical specification of RFID equipments was shown in Table 1.

Consequently, as shown in Figure 7, once the field inspector detects a RFID tag on a designated location in the ECP, the control module processes the 2D and 3D models and maintenance information of the location then displays the GUI on the input/output module. The input information in the GUI updates the information in the inspection/diagnostic database in the mobile device and it can also be downloaded to the maintenance server later.

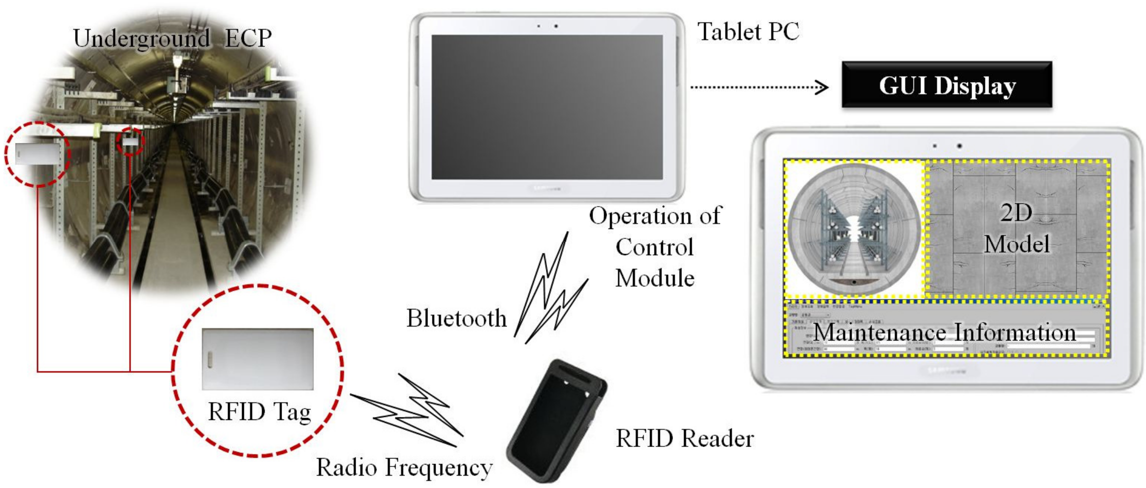


Figure 7 – Application plan of mobile inspection and diagnostic system for EPC

Table 1 – Technical specifications of RFID equipments

Equipment	Division	Specification
RFID Tag	Type	Contactless read/write
	Operating frequency	902MHz to 928MHz
	Data coding type	EPC Class1 Gen2
	Test read range	Maximum 3.0m
	Dimensions	86mm(L) ×54mm(W) ×1.8mm(H)
	Installation interval	Inspection unit length(Approx. 30m)
	Attached location	Lining surface
RFID Reader	Type	Internal ceramic antenna
	Operating frequency	917MHz to 923MHz(World Wide)
	Protocols	ISO 18000-6C, EPC Class1 Gen2
	Interface	Bluetooth 2.1 + EDR & USB

Dimensions	117mm(L) ×61mm(W) ×20mm(H)

CONCLUSIONS

Through our system developed in this research, we can acquire the 3D deterioration modeling data as well as corresponding 2D deterioration modeling data without any additional process during the safety inspection and diagnostic process in the EPC. Therefore, we can reduce the time and work force that should be done in the classical methods to regenerate 3D model after the field work with the 2D data collected in the EPC. Particularly, acquiring the deterioration 2D data based on exact scale without image distortion, which can be used as the more exact basic information for estimating damaged BOQ (Bill of Quantities) and design drawing in repair/reinforcement design stage is expected to greatly improve the effectiveness of the safety inspection and detailed safety diagnosis process.

REFERENCES

KISTEC (2009). *Guideline for safety inspection and detailed safety diagnosis (tunnel)*. Retrieved from http://www.kistec.or.kr

C. Legner, & F. Thiesse (2006). *RFID-Based maintenance at Frankfurt airport.* IEEE Pervasive Computing 5 (1), pp. 34-39.

E. Ergen, B. Akinci, B. East, & J. Kirby (2007). Tracking components and maintenance history within a facility utilizing radio frequency identification technology. *Journal of Computing in Civil Engineering (ASCE),* 21 (1), pp. 11-20.

Jo, B. W., Yang, Y. S., Park, J. H., Shin, B. C., Yoon, K. W. & Kim (2008). Development of Software for Bridge Structure management on Ubiquitous based. *Proceedings of Computational Structural Engineering Institute of Korea (COSEIK),* pp. 532-537.

Yang, Yo Sub (2009). *A basic study on bridge maintenance using RFID* (Unpublished master's thesis). Hanyang University, Seoul.

Ko, Chien Ho (2009). RFID-Based Building Maintenance System. *Journal of Automation in Construction*, Vol.18, pp. 275–284.

Elzarka H. M., L. Bell & R. Floyd (1999 Nov.). Automated data acquisition for bridge inspection. *Journal of Bridge Engineering (ASCE),* Vol. 4, No. 4, pp. 258-262.

Lee, M. K. & Cho, D. Y. (2001). *Structure damage mapping system using PDA*. Paper session presented at the 2001 KSCE Annual Conference, Seoul.

T. Mills, R. Wakefield, & W. Bushman (2004). *Modernizing Bridge Safety Inspection with Process Improvement & Mobile Computing.* ASC Proceedings of the 40th Annual Conference, Utah.

Y. Hu & A. Hammad (2005, June). *Location-based mobile bridge inspection support system*. Paper session presented at the 1st CSCE Specialty Conference on Infrastructure Technologies, Management and Policy, Toronto, ON.

Moon, H. S., Kim, H. S., & Kang, L. S. (2012 Oct.). Development Strategies and Feasibility Evaluation of Maintenance Operation System for Railway Bridge Based on Ubiquitous-BIM Technology. *Journal of the Korean Society for Railway*, Vol.15, No.5, pp. 459-466.

Song, Y. K., Kim, T. H., Oh, J. R., & Son, Y. J. (2012). Development of a Mobile System for Investigating and Maintaining Steep Slopes. *The Journal of Engineering Geology (KSEG),* Vol.22, No.2, pp. 185-194.