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OPEN-BUILDING MAINTENANCE MANAGEMENT USING RFID TECHNOLOGY

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ABSTRACT

By applying the Radio Frequency Identification (RFID) technology, this study embedded the RFID tags in the components of open-buildings to store the raw design data so that data can be passed to the maintenance phase and automatically provided to the building users. For this purpose, this paper focused on the application of RFID for developing an Open-Building Maintenance Information System (OBMIS) for OB maintenance management. Three functional modules were developed in the OBMIS, namely (1) the support components information management (2) the infilled components information management and (3) the reanalysis/redesign module. In the support and infilled information management models, users can write and read the components' information, such as material type and construction information etc., within the RFID tags by using Personal Digital Assistant (PDA) for maintain management. Meanwhile, in the reanalysis/redesign module, for building extension or reconstruction, users can acquire and transfer the structure parameters from the components' tags to external analysis systems, such as SAP2000 etc., for structure safety analysis. Summarily, by using the OBMIS, not only the data in the design phase can be transferred to the maintenance phase, but also the data can be provided by the building itself so that the efficiency of OB maintenance management could be enhanced.

KEYWORDS

Open-Building, Support System, Infill System, Radio Frequency Identification, Maintenance Management

1. INTRODUCTION

In Recent years, the number of large scale construction projects is decreasing in Taiwan. The demands of modifications and maintenance for legacy buildings arise day by day. The hazardous waste and the resource consuming resulted from demolishing and re-construction in maintenance phase were increased. Therefore, the idea of reusable building components was proposed to reduce the unnecessary environmental pollution and resource waste. The Open-Building (OB) architecture philosophy was one of the well-known solutions addressed for this sustainable building idea [1].

OB architecture philosophy was proposed in 1960s which advocates the usage of reusable and changeable building elements for enhancing the flexibility of buildings and decreasing the resource consuming situations in the maintenance phase. Generally, an OB building is composed of two systems; namely, (1) the support system and (2) the infill system. Two systems are composed of usable and changeable structure components and fitting components respectively. Therefore, ideally, not only the structure and interior layout of an open building could be remodeled, but also the building could be relocated based on the user's dynamic necessary in the maintenance phase. That is, owners can change the purpose of an open building by remodeling the support and the infill systems. In Taiwan, as purpose conversions occur for a building in the maintenance phase, the relevant design data and a new structure safety analysis report need to be submitted to the superintendent of the Taiwan government. However, since raw design data is usually missed due to improper preservation through the whole life cycle of a building, the raw design data and the structure model may need to be recollected and rebuild. This circumstance decreases the efficiency and advantage of open buildings. To overcome this problem, to store the raw design data within the building itself to provide design data immediately and correctly may be an idea to enhance the maintenance efficiency of open buildings.

Meanwhile, the Radio Frequency Identification (RFID) technology is a wildly-used IT application in these years due to its wireless identification data providing ability [2]-[4]. Many studies have applied RFID for issues of material management, pipe tracking in the construction industry [5]-[7]. The self-data-providing ability against environmental erosions increases RFID's the application potential in construction industry comparing with the barcode technology [8]. Accordingly, RFID might be a proper application technology applied to the maintenance phase in the build life cycle. Based on this concept, this study aims at embedded RFID tags into open building's elements, such as support and infilled system components, so that open buildings can automatically provide the essential design data for remodeling to enhance the maintenance efficiency of open buildings. For this purpose, a RFID-based open-building maintenance (RFID-OBM) model and an Open-Building Maintenance Information System (OBMIS) were proposed in this study. In the RFID-OBM model, the remodeling behaviors relevant to open buildings' purpose conversions was firstly identified, so that the essential information and information flows corresponding to the remodeling behaviors can be determined subsequently. Based on the RFID-OBM model, the OBMIS was developed to be the platform for managing the components' information, and assisting owners with remodeling works. By using the developed OBMIS, users can utilize portable devices, such as personal data assistant (PDA) and laptops, to acquire the components' raw design data from the open building itself, and the acquired data can then be passed to the external structure analysis softwares, such as SAP2000, ETABS etc., to analyze the safety for use conversion of the building. In the following sections, the RFID-OBM model and the development of the OBMIS are discussed.

2. RFID-BASED OPEN-BUILDING MAINTENANCE (RFID-OBM) MODEL

RFID-OBM model is the basis for developing the OBMIS. Three parts were determined in the RFID-OBM model, namely (1) open building remodeling behaviors, (2) essential information for open building remodeling behaviors and (3) RFID-based information management mechanism for open building maintenance. The open building remodeling behaviors are identified to be the first part of the model which not only presents the functional requirements of the OBMIS, but also is the foundation for determining the essential information of remodeling works. Based on the determined remodeling behaviors and essential information, the RFID-based information management mechanism was proposed.

2.1 Open Building Remodeling Behaviors

To identify the remodeling behaviors of open buildings, this study analyzed the causes of conversions to classify conversion types and conversion behaviors and to create the relations between conversion and remodeling behaviors as Figure 1 shows. In Figure 1, seven conversion behaviors were determined. Each conversion behavior has its related component type/s, and each component type has a set of remodeling behaviors; i.e., as one conversion behavior occurs, the components related with it need to be remodeled based on the requirement arisen from the conversion. Three remodeling behaviors were determined in this study, namely (1) redesign (2) reanalysis and (3) reconstruction. Only support system remodeling needs to reanalyze the structure safety due to Taiwan regulations.

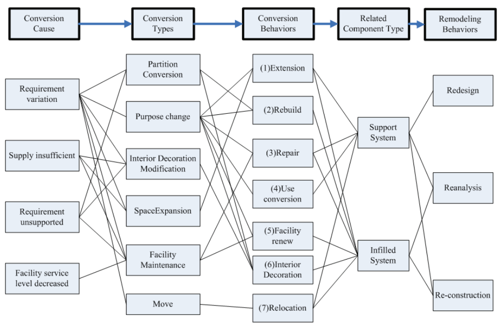

Figure 1 Remodeling Behaviors vs. Conversion Behaviors

Accordingly, once a conversion arises, the necessary information related to the remodeling behaviors needs to provide to the designer. For this purpose, the essential information for remodeling behaviors needs to be identified.

2.2 Essential Information for Open Building Remodeling Behaviors

To store the raw design data in RFID tags embedded, the essential information for open building remodeling behaviors needs to be identified. Once the essential information is embedded to the components via RFID tags, has the open building the self-data-providing ability, so that users can acquire the raw design data from the building for remodeling. However, due to the memory size limitation, all raw design information of a component can not be imported to one RFID tag. Accordingly, only numerical and few textual data essential to the remodeling behaviors can be stored in RFID tags, but the CAD or image files. The large documents can be stored in the database associated with components by key numbers. The essential component information respectively related to support and infilled systems were identified to import to RFID tags.

2.2.1 Essential information of support component

For the components of support system, the essential information related to the reanalysis remodeling behavior, was determined to store in RFID tags for enhancing the efficiency of structure reanalysis. To reanalyze structure safety for the conversion of an open building, the structure plan, relief maps, historical earthquake information, etc. as shown in Figure 2, need to input to the structure analysis software, such as SAP2000 and ETABS. However, due to memory limitation of the RFID tags, only the information related to the support component itself needs to be stored in the tags, so that the structure model of the open building can be generated in SAP2000 and ETABS in accordance with the acquired information of support components.

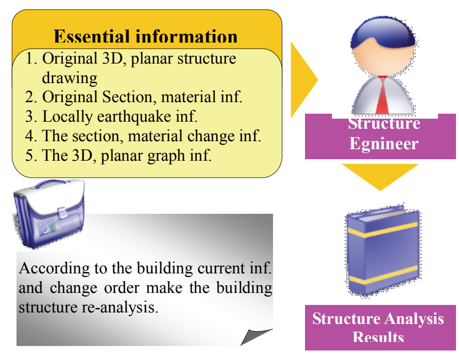

Figure 2 Essential Information for Support System Reanalysis

Moreover, in order to reduce the information volume, the numerical or textual design parameters of support components need to be derived from design drawings, so that parameter data can be stored in RFID tags.

Based on the schema of structure database in SAP2000 and ETABS, the information necessary to be stored in support component RFID tags were determined as Table 1 shows.

The essential data embedded in the support component RFID tags can be acquired with the RFID reader to import to SAP2000 or ETABS. Therefore, according to the imported component information, the structure model can be generated for safety analysis.

2.2.2 Essential information for infilled component

For the infilled system remodeling, the essential design information related to the redesign behavior needs to be determined. Figure 3 shows the essential information for redesigning the infilled system of a open building.

Table 1 Data Stored in the Support Components

Attribute	Essential data of support component	
General	1. Project ID	
Material	2. Materials type 3. Component level 4. Section size 5. Weight 6. Length	7. Strength 8. Unit 9. Components type 10. Regulations
Position	11. Node i coordinate 12. Node j coordinate	13. Axes

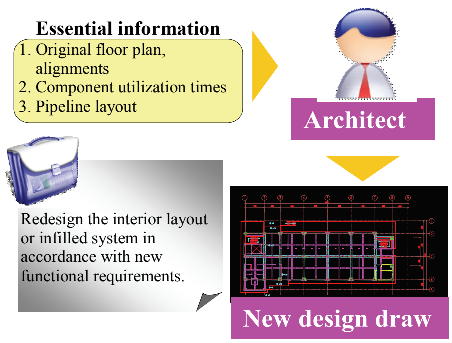

Figure 3 Essential Information for Infilled System Redesign

Similar to the data stored in the support component RFID tags, the design parameters of each infilled components were derived from the original design drawings as Table 2 shows. As the parameters are stored in RFID tags, architects can acquire the infilled system information to redesign the interior layout or infilled system of the open building.

2.3 RFID-based Information Management Mechanism for Open Building Maintenance

Since the essential information of support and infilled components were stored in the RFID tags embedded in the components, the RFID-based Information Management Mechanism was proposed to be the basis for developing the OBMIS. Three functional modules are included in the proposed mechanism, namely (1) support system information management, (2) infilled system information management, and (3) reanalysis/redesign modules.

Table 2 Infill System Necessary Data

Data attribute	Essential data	
General	1. Project ID 2. Manufactory	3. Constructor 4. Designer
Material	5. Materials type 6. Components layer 7. Section size	8. Weight 9. Unit 10. Components type
Position	11. Node i coordinate	12. Node j coordinate

2.3.1 Support system information management module

The support system information management module provides the functions to read, write, and update the components information within RFID tags embedded in support components. After acquiring all support components information as shown in Table 1, the structure engineers can redesign the structure plan for purpose conversions in accordance with the acquired information, and subsequently, the newly-design result can be exported to SAP2000 and ETABS for safety analysis. Meanwhile, as the open building is reconstructed based on the redesign results, system users can update the components' design parameters within the RFID tags. Accordingly, by using RFID-OBMIS, the support components design information can always be acquired/updated from/to the building components.

2.3.2 Infilled system information management module

Similar to the support information management, the infilled system information management module provides the functions to read, write, and update the components' design parameters within the RFID tags embedded in infilled components. However, since no redesign activity is necessary for infilled system remodeling (as shown in Figure 1), the acquired information is provided to architects for redesign the infilled system, but to export information to any external analysis softwares.

2.3.3 Reanalysis/redesign module

The reanalysis/redesign module provides structure engineers with the functions to export the acquired support components' design parameters to SAP2000 and ETABS softwares. Figure 4 shows the information transformation mechanism to summarize the acquired components' information and transfer them to be input files of SAP2000 or ETABS softeares. Therefore, structure engineers can acquire structure information from building it self and export to structure analysis softwares for redesign and reanalyze newly structure plans for structure conversions of open buildings.

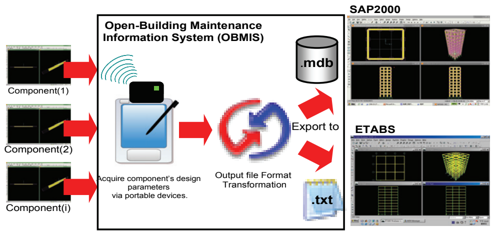

Figure 4 Support Component Information Transformation Mechanism of OBMIS

3. OPEN-BUILDING MAINTENANCE INFORMATION SYSTEM (OBMIS)

Based on the RFID-OBM, OBMIS was developed. Due to page limitation, only system runtime environment and the functions of read/write components information from/to tags, and export support system information to SPA2000 were illustrated.

3.1 Runtime Environment of OBMIS

Figure 5 shows the runtime environment of OBMIS. Since the OBMS adopts PDA portable device to acquire components information from the building (as shown in Figure 6), and store the data in the database server, two operation systems, namely (1) Windows Mobile 2003 and (2)Windows XP, provide different runtime environments respectively to PDA and database server.

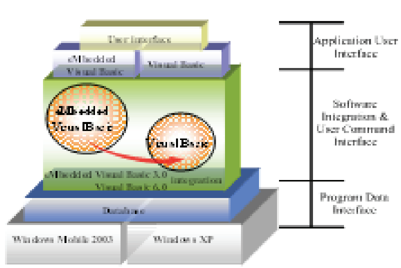

Figure 5 System Environment

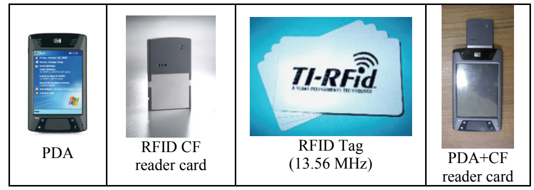

Figure 6 RFID Equipments for RFID-OBMIS

3.2 Read/Write RFID Tags

Accessing data from RFID tags embedded in the building components is the basic function of the OBMIS. By using PDA with RFID CF reader card (as shown in Figure 6), the origin data can be read from RFID-tags, and the newly-design parameters corresponding to one component cab be written to the specific RIFD tags associated with one unified identification (UID) number. Figure 7 and 8 respectively show the read and write functions of the client end user interface on the PAD.

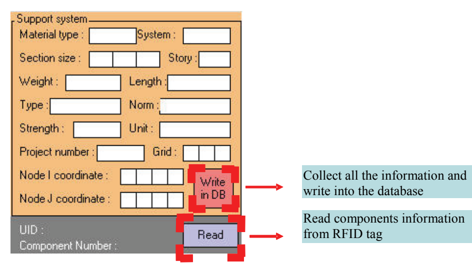

Figure 7 Read Tag Information from Support Components

3.3 Support System Information Exportation

All acquired components' design parameters will be stored in the back-end database server. Once all the design parameters of support system are acquired, users can export the support system information from database to a formatted output file. Two formatted output files can be generated by OBMIS, namely (1) SAP2000 database importation file and (2) ETABS importation text file. Figure 9 shows the exportation function of the OBMIS. Once the output file name is specified, the support system information is exported. The structure engineers can import the output file to SAP2000 for structure plan redesign and reanalysis.

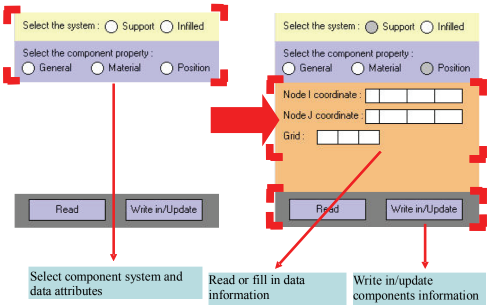

Figure 8 Write/Update Tag Information to Support Components

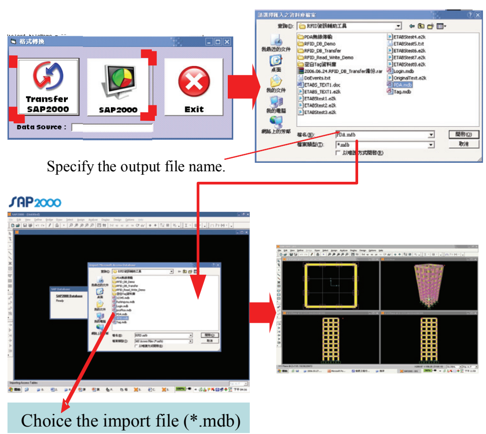

Figure 9 Export Support System Information to SPA2000

4. SUMMARY

To enhance the maintenance efficiency of open buildings, this study facilitated the idea of self-data-providing mechanism for open buildings by developing the Open-Building Maintenance Information System (OBMIS). To develop OBMIS, firstly, the idea of embedding RFID tags in support and infilled system components was addressed; sequentially, the RFID-based Open-Building Maintenance (RFID-OBM) model was proposed to determine the remodeling behaviors and required information in the open building maintenance phase. Therefore, as an open building needs to be remodeled, by using OBMIS, structure engineers can, in the one hand, acquire structure information by PDA device; once all the support system data is acquired, data can be exported to SAP2000 and ETABS for redesign and reanalysis; in the other hand, architects can acquire the original infilled components' data to redesign a new infilled system for purpose conversions of the open building.

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