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Exploratory Study on BIM-based Information Breakdown Structure for Construction Document Management

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Abstract: ***Construction industry is an aggregate of information that diverse information is integrated and controlled. To implement successful construction projects, it can be said that the information management is very important. In particular, because information of construction sites is controlled in a form of documents, importance of the document management in construction has been increased. But, by controlling information through documents, there are difficult problems in writing and classification of the documents and preservation and utilization of the information. Also, due to incompletion of the information management system, difficulty in systematic info management arises. For this reason, this study intends to suggest the document information breakdown structure for controlling document info efficiently which is generated at construction sites. For this, through the examination of preceding studies, establishment of the concept of the document info breakdown structure, the space breakdown structure, and the info breakdown structure, availability of document information is intended to heighten.***

Keywords: Document Management, Information Breakdown Structure, Space Breakdown Structure, BIM

I. INTRODUCTION

Construction industry has a form of industry which is processed by participants in various fields through mutual cooperation. And, in each stage of construction, because diverse and lots of info occurs and is controlled, construction industry can be said an aggregate of information. Namely, for successful implementation of construction projects, it can be said that it is important to manage info efficiently occurring in the construction stage (J. S. Choi, 2011).

Especially, the construction stage is to shape buildings based on blueprints. In the stage, in each process of construction projects, the most people and resources are input in a short period and the most info is created and controlled (K. Park, 2011).

Management of construction info in this construction stage can help effective construction control and productivity increase. In the future, because it can help the maintenance stage and history control of buildings, among stages of construction, necessity for info control in the construction stage can be said very great. Therefore, various efforts to efficiently control info of construction sites are being made.

However, information of construction projects occurs in a form of documents mostly. Document info is controlled in a form of paper or electronic documents about the info of contents according to the progress and result of each construction process. Since about 80% info for info management of construction sites is controlled in a form of document, it is in a situation that efficiency of work is degraded.

About the info management based on documents, lots of time and effort are spent in writing, classification, and preservation of documents. There is a problem to expend a lot of time and effort in fast examination and check of document info. Also, though info control at construction fields influences effective construction control greatly, contents and flows of document info occurring on spots are not defined clearly. Due to insufficiency of the info management structure for info control, difficulties in consecutive and systematic info control at fields arise. Because of information disconnection and loss from the insufficiency of the info management system, there is difficulty in rational and effective construction control (Y. S. Kwon, 2001).

Plus, due to incompletion of systems for documents control, it is in a situation that construction documents occurring on spots are kept as a form of paper in document control centers of sites or managers in charge of writing documents retain document info individually. So, check and examination of document info on spots need a lot of effort. After the finish of construction projects, due to dispersion of document info occurring at the fields, simultaneously with the end of sites, a case that it is used as just one-time info happen frequently.

Thereupon, the goal of this study is to propose the info breakdown structure for accumulating and using document info efficiently which occurs at fields in order to improve problems of document info control arising at

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sites, as an initial study on the system construction of document info management based on BIM. For this, through the examination of preceding studies, concept establishment of the breakdown structure of document info, the space breakdown structure, and the info breakdown structure, by reclassifying and rearranging document info, efficiency of document information control is tried to increase.

II. Literature Review

A. Construction Document Management

In the construction stage among construction processes, diverse information happens, and most main info occurring at construction sites is controlled through documents (Chen and Kamara, 2011). Therefore, for info management of construction sites, it can be said that effective control over documents occurring in the places is necessary. This document control is defined to be management activity to deal with documents fast and correctly through the writing stage to the disposal stage.

If looking into advanced studies relevant to document control, Ioannou and Liu (1993) proposed a database system for storage and utilization of documents through a classification system for construction info as a way for efficient accumulation of construction info. Furchter and Reiner (1996) proposed a model of sharing and collection of info using the Internet for the construction of the info breakdown structure and developed a prototype of the system.

Simoff and Maher (1998) suggested a study on info use plans of the design stage through collected info by proposing methodology of data collection related to designs on the basis of ontology to improve utilization of existing info in the design stage. Hajjar and AbouRizk (2000) implemented a study on methodology of integrated document info control using common data models of construction companies, projects, and document info, as a plan for integrated document control of construction companies. Kosovac et al. (2000) proposed an info control plan using extensible markup language (XML) targeting subcontractors for the efficiency of document info management. Caldas and Soibelman (2003) suggested methodology of systematic document classification using (CICS: Construction Information Classification System) as a way for assorting documents occurring in construction projects fitting to master format of CSI. Park et al. (2009) studied a way to apply ontology framework including conceptual contents which can express the construction process of earth work to knowledge search systems so as to develop ontology framework for searching construction knowledge. Park (2009) developed a prototype system of document sharing through tag managers for the development of the document management structure of construction material info. Lee (2009) constructed documents of the construction plan stage into Meta-library based on ontology for the development of a prototype system of document control and suggested a document sharing system using the tagging method for search and saving of document info.

Studies on the construction document control were primarily basic things on EDMS systems for EDI and integrated info control for the efficiency of construction work and industry pursuing informatization of the industry from the 1980s to the 1990s. From the late 1990s to the early 2000s, studies on sharing of documents and info and web-based info sharing using XML and EDI were dominant. Studies from the early 2000s to now are mostly contents on search of accumulated info and use of efficient info.

From checking through the analysis of preceding studies, although existing construction info management suggests ways of work analysis to enhance the efficiency of special work or document transfer and measures of efficiency increase of document control, it is in a situation that studies on control and use of overlapped info between documents is insufficient. Additionally, it could be checked that there is a limit that only managers in charge of writing documents in real construction sites grasped correct info included in the documents and there is a problem that search, use, and consistency of information were degraded due to lack of the system of document info management.

Hence, for the accumulation of systematic construction info, enhancement of info utilization, and increase of info consistency, a systematic info accumulation system about document info containing most info of construction fields is necessary. For this, various IT technologies on integration of construction info were checked. Contents on BIM technology as a means for visualization of construction info were confirmed.

B. Building Information Modeling

BIM technology is based on the concept of the building description system of Eastman in the 1970s and is being developed possible for integration and analysis of info through 3D models from design to maintenance including the concept of virtual buildings. The strong point to obtain by this BIM is easy for formulaic amassment and control owing to the accumulation of construction info through model info. Owing to accumulation and control of information through 3D models, communications between participants and sharing and securement of material are advantageous. So, there are merits in contributing to improvement of relationship of people concerned and efficiency of info control.

In addition, by creating environment of automated info control, there are other strong points such as drawing of designs, output of resources, and reduction of resources consumed in various construction control. In the study of Love et al. (2013), budgets were lessened about 40% through BIM application. Since the difference of estimate amounts and real construction expenses is approximately 3%, it was checked that construction processes can be predicted comparatively correctly. It

was confirmed that the whole project period can be contracted about 7% and contract expenses can be lessened about 10%. Among studies on BIM with theses strong points, if checking info management of sites through BIM and relevant preceding studies, the next things are shown.

Dawood et al. (2002) proposed a system of user interface and database for integrating AutoCAD and MS projects in order to develop integrated database for 4D/VR process simulation based on resource info. Lee (2008) checked that it is possible to control construction info through BIM by applying info process to the project of apartments from proposing the process for BIM application in stages of design, building, and maintenance. Eastman et al. (2010) suggested a data conversion system for compatibility of figure info between the IFC file system and the US BIM standard system to smooth info sharing through BIM models. Also, Liu and Issa (2012) examined plans for smooth info compatibility between BIM model info and info of the maintenance system so as to apply the BIM model info to the maintenance system for heightening the availability of BIM of the design stage in the maintenance stage. Ma et al. (2013) developed process maps and algorithm for connecting data between info for bidding and BIM model info through algorithm analysis of a bidding system to apply BIM info to the Chinese bidding system and verified the availability. Lin (2014) proposed a BIM-based construction knowledge control system for the application of knowledge control in the building stage to save related info in the stage through BIM models. These studies mostly focus on info compatibility between stages of construction projects. Advanced studies in an aspect of existing BIM info management were dominantly on data compatibility between stages of construction projects. For instance, to use design BIM info at structure BIM or facility BIM, studies in what ways data should be exchanged were dominant. Though these existing advanced studies focused on the aspect of life cycle and suggested framework about data compatibility and exchange over the whole stage of construction projects, it can be checked that contents on data amassment and control relevant to document control as info sources of construction projects are not sufficient.

As an advanced study connected with model-based document control, there is a study of Caldas et al. (2005). The study tried to control document info through models. For this, through the document breakdown structure based on master format, IfcDocument reference of IFC files, and analysis of IfcRelationship, a study for the connection of document info and models was processed. Also, since construction info is managed in a form of control lists of electronic documents in BIM models and info is stored only in a form of documents, there are difficult problems in document info management in a an aspect of synthetic use. Therefore, to accumulate and manage document info efficiently as a basis of construction info, connection of document info through BIM is necessary. For this, the document info breakdown structure through document info and BIM info is needed.

III. Framework of the BIM-based Document Information Breakdown Structure

Information occurring in the construction sites is generated through various documents. Because of insufficiency of the control system to manage the document info and absence of measures to extract info through documents, there is difficulty in construction info management. As a way to control this construction info, field info control through the connection of WBS and CBS is centered.

But, although the connection model of WBS and CBS can be used effectively in work such as work separation in the construction stage and expense calculation, it is difficult to amass and control diverse info arising on sites. In other words, through the link of work in the building stage and construction expenses, it is effective in use of info about field work. However, in problems occurring in construction, use of blueprint info necessary for work, and classification of needed info for work implementation, there are difficulties.

To manage info of construction fields efficiently, it is necessary to manage diverse info such as info of blueprints, construction, expenses, rework, and so on from being linked with one another systematically. For the efficient control of this construction info, it is necessary that location info based on design info and building-staged info are linked and managed. That is, because info and construction works occurring in the construction stage is processed and controlled based on parts and locations of buildings, for work implementation and work examination in construction sites, to manage info based on 3D models is useful in prompt examination and use of info. Later, use, control, and flows of info can be represented efficiently.

Hence, this paper intends to suggest the document information breakdown structure (DIBS) through the space breakdown structure of BIM, the information breakdown structure for classifying document info, and the existing WBS and the CBS as measures to accumulate document info linked with objects of BIM models. The SBS is for the use of classifying space info of BIM models to connect document info on spots with BIM models, and the writing was needed. So, this study tried to construct the SBS by dividing elements of projects, spaces, and parts in order to sort spaces. The IBS was to use for dividing document info in accordance with document properties (documents of construction planning and management and so on) arising on sites. It is because categorization according to document properties to control document info systematically occurring during construction work is needed. The next <fig. 1> is to represent contents on the breakdown structure for constructing construction info database to suggest in this study.

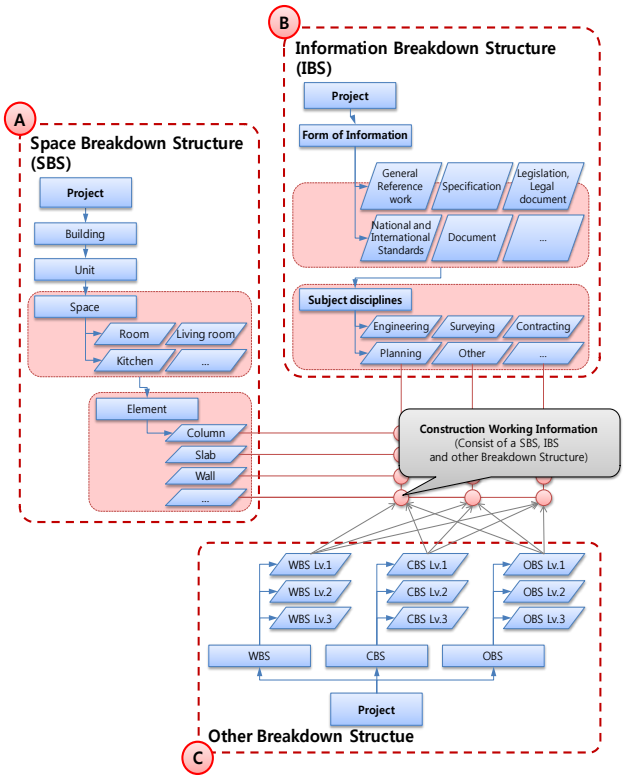

FIGURE I.
CONSTRUCTION OF THE BIM-BASED DOCUMENT INFO BREAKDOWN STRUCTURE

IV. DEVELOPMENT OF THE BIM-BASED DOCUMENT INFORMATION BREAKDOWN STRUCTURE (DIBS)

A. *Space Breakdown Structure*

In most construction fields, due to absence of standardized classification structures, difficulty in the management of info within sites arises (Kwon, 2001). The building stage is to form buildings based on blueprints. It is reality that most construction info is processed and managed on the basis of parts and location info of buildings. Besides, for work implementation and examination in construction sites, formation info of buildings as blueprint info is basically necessary. That is to say, to easily use and examine document info arising on sites, it is necessary that info control should be done by linking constructing info through location info of 3D models.

As studies to integrate construction info through forms of buildings, the study of Chan et al. (2005) proposed plans for connecting figure info and non-figure info in an aspect of system development. The study of Caldas et al. (2005) suggested plans for linking figure info and document info. The study of Ding et al. (2012) proposed plans for the connection of figure info and business management info based on cases of railroad construction.

But, because these advanced studies put stress on the connection of figure info centered on non-figure info, there was a problem that difficulty existed in changes of the classification structure of non-figure info and connection of the info. The study of Jung et al. (2013) tried to connect construction info (process, production cost, etc.) centered on figure info. For this, by suggesting the concept of the figure info breakdown structure and applying this to a new Korean-style house project, figure info and construction info of new Korean-style houses were linked. Hereupon, automatic connection of figure info and non-figure info was possible. And, in constructing the breakdown structure of figure info, concentrated on the object management of buildings, centered on figure info, non-figure info was linked.

So, this study tried to assort figure info focused on the concept of spaces for the classification of figure info of buildings by applying the concept of the breakdown structure centered on the figure info. Namely, in assorting shape info (figure info) of buildings, focused on the concept of households and rooms which construct spaces of buildings, the breakdown structure on figure info was written. By writing the SBS centered on the concept of spaces, there are strong points that the least objects can be controlled intuitively and the objects can be maintained properly. And, by linking construction info to the lowest stage of space classification, in changing the breakdown structure of non-figure info, it was tried that the breakdown structure of figure info could not be changed. Hereupon, by sorting shape info of BIM models, it was tried that the space breakdown structure was suggested from reflecting factors and spaces of buildings.

The SBS was constructed to connect document info on sites with each object of BIM models. To write down the space breakdown structure, the classification structure was written through elements of projects, spaces, and Elements. Project Factor of the SBS were divided according to sizes and properties of projects like numbers, floor numbers, unit households, and so on of buildings. Space Factors were separated into bedrooms, living rooms, kitchens, bathrooms, entrances, and balconies as elements to divide spaces of household units. In case of Element Factors, by dividing each member of framework of each household of apartments, based on a file construction system which constructs objects of buildings of IFC files as standard format for info exchange of BIM models, they were written. The next <fig. 2> represents elements for the writing of the SBS.

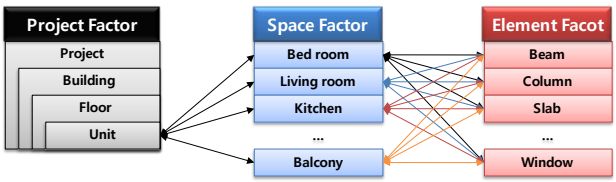

FIGURE II
CONSTRUCTION ELEMENTS FOR WRITING THE SPACE BREAKDOWN STRUCTURE

The part elements as the lowest element of the space classification system are parts that BIM models and work info are connected and also parts pertinent to each object of buildings. Thereupon, the object structure system of IFC files as standard format of BIM models was used.

The next [table 1] shows the object structure system of IFC files.

TABLE I
OBJECT FILE STRUCTURE OF IFC FILES

Ifc Element	Parameter
Ifc Building Element	Beam, Column, Slab, Roof, Stair, Wall, Ramp, Curtain Wall, Door, Window
Ifc Electrical Element	Electric Motor, Light Fixture, Outlet, Electrical Appliance
Ifc Equipment Element	Discrete Element, Accessory
Ifc Furnishing Element	System Furniture Element, Furniture, Built-In

Among the structure systems of IFC files, because IFc building elements are parts which express objects (crossbeams, pillars, slabs, roofs, stairs, walls, slope ways, curtain walls, doors, and windows) of buildings, by using them, part elements of the SBS were constructed. The SBS came to be written by integrating the above elements of projects, spaces, and parts. For instance, as a form of including part elements like walls, doors, windows, and so on as object components to the information on space elements, including properties of spaces and parts, the space classification structure was written. <Fig. 3> presents the structure of the space breakdown system.

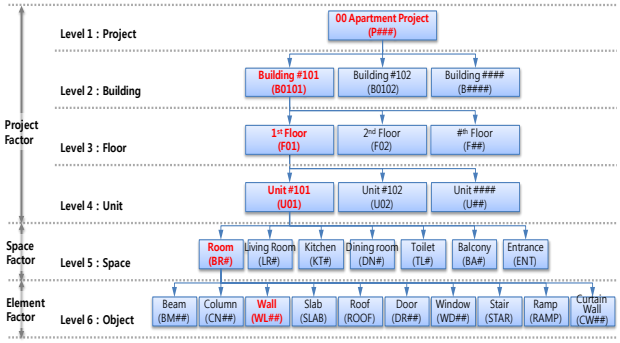

FIGURE III
PROCESS DIAGRAM OF SPACE BREAKDOWN STRUCTURE

The SBS was written by being divided into six stages. Level 1 to 4 is project elements. Level 1 is projects. Level 2 is buildings. Level 3 is the number of floors. Level 4 was constructed with unit households. Level 5 was written with elements constructing spaces of apartments as space elements. And, level 6 was written with elements structuring objects of the IFC file system as part elements.

Through the space breakdown structure, codes of members of framework can be written about each member of framework of buildings. For example, the code about the first wall of the first bedroom of household unit 101 of unit 101 can be written with P010-B0101-F01-U01-BR1-WL01. The following <fig. 4> is a picture representing the code system of the space breakdown structure.

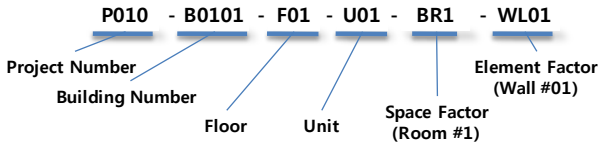

FIGURE IV
STRUCTURE OF SPACE BREAKDOWN CODES

In the space breakdown structure written like this, info occurring in sites can divide into info per project, per building, and per unit household. By allotting info (ex: rework, defect repair, start/end day of work, etc.) of sites occurring in each unit household to each member of framework of buildings, they can be linked with each other.

B. Information Breakdown Structure

The info breakdown structure is a part to systematically control info occurring in sites and was intended to structure forms and fields of document info of sites in order to heighten the availability by separating them like that. By separating contents of documents which arise in sites fitting to the info breakdown structure, info can be amassed from assorting document info of sites into categories such as references, specifications, contracts, blueprints, and so forth, through them, info will be managed efficiently.

In case of the existing representative classification structures to sort this construction info, there are MasterFormat of the US and Uniclass of the UK. In MasterFormat, because the classification structure is constructed centered on work types, info on activity of sites can be assorted efficiently but there was a problem that it is improper to assort and manage document info comprehensively. In case of Uniclass, since it represents info on overall construction fields, info occurring on sites can be separated. However, it was judged that to use info by selecting systems to separate info for the classification of info in sites is easy because classification systems on all courses of construction are used.

Therefore, in this study, it was judged that classification according to “A: forms of info” and “B: classification of subject fields” among classifications of Uniclass can be arranged by separating info systems occurring on sites. This study tried to write the info breakdown structure based on the structure system of Uniclass. Hereupon, among classification systems of Uniclass, “A: forms of info” and “B: classification of subject fields” were checked. Contents on info forms of Uniclass A express the formality and character of information. These are sorted into general references, legal documents, domestic/foreign standards, other regulations/guidelines, specifications, standard contracts, blueprints, documents, and media. Contents on subject fields of Uniclass B are technology contents like measurement of structure technology, city planning and building plans related to projects plans, and so forth. They include contents of the aspect of construction management.

By integrating A (forms of info) and B (subject fields) of Uniclass, the information breakdown structure was constructed. Through the info breakdown structure written like this, owing to assorting info into forms and subjects, info of construction sites can be managed systematically. The following <fig. 5> is a picture to represent the info classification system.

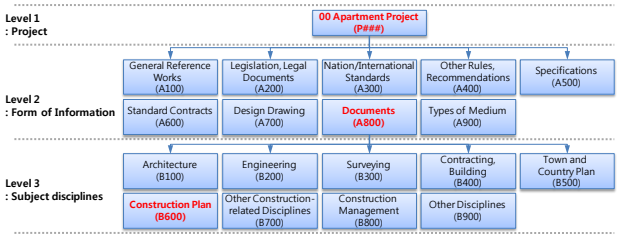

FIGURE V
CONSTRUCTION OF THE INFO BREAKDOWN STRUCTURE

If classification of info in the info breakdown structure is explained with examples, in case of a "quality test plan" as documents which occurred on sites, in a form of info of Uniclass A, it can be specified as "A820. Plan". In subject fields of Uniclass B, it can be specified as "B630. Quality planning". The info classification code through them can be written into "A820-B630".

V. CASE STUDY OF APPLYING BIM-BASED DIBS

Documents of construction work contain diverse information. Among various construction documents, by applying the document info breakdown structure suggested in this paper to info of a daily work report, document info was tried to sort. The daily work report is documents written for the purpose of reporting daily work contents in construction work. It can be one among important field documents containing everyday work contents. In this daily work report, info on documents, projects info, general info of work, and location info are contained. The info can be managed efficiently when it is controlled synthetically. But, because document info in construction sites is controlled just as a form of documents, there is difficulty to use it effectively. The next <fig. 6> is a picture to present info which is contained in the daily work report as a kind of documents generated in sites.

So, this study tried to manage document info after assorting it by using the space breakdown structure, information breakdown structure, and work breakdown structure as document info breakdown structures so as to control document info efficiently. Info of the daily work report includes info structures, project info, general info of work, location info, and work info. The info can be classified through the document information breakdown structure (DIBS) such as the space breakdown structure, information breakdown structure, and work breakdown structure. The next <fig. 7> is a picture that the DIBS is applied to the daily work report.

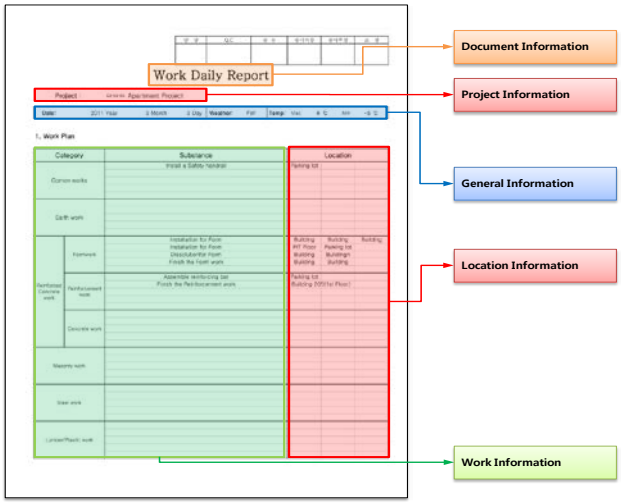

FIGURE VI
INFO INCLUDED IN A DAILY WORK REPORT

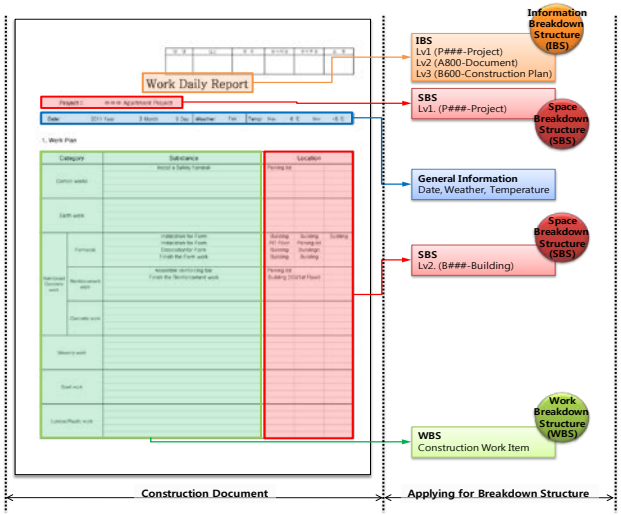

FIGURE VII
APPLYING DIBS TO THE DAILY WORK REPORT

As checking in <fig. 7>, info structures of the daily work report can classify info through the information breakdown structure. In case of project info, info can be assorted with projects of Level 1 of the space breakdown structure. In case of location info, it can be separated with buildings of Level 2 of the space breakdown structure. And, in case of work info, info can be separated with work contents through the work breakdown structure.
Info classified by the document info breakdown structure can be managed as assorted info like <fig. 8> below.

As info classified through the DIBS is connected with each other and creates new info, info extracted through documents can be reclassified and rearranged. For example, as project info of level 1 of the SBS and general info of projects are mixed like <fig. 8>, weather and temperature according to the relevant weather of a project can be checked. From mixing building location info of level 2 of the SBS and work info, work contents according to the pertinent location can be checked. Since existing document info management controls info as documents themselves, there was difficulty in searching

and using info. However, by controlling document info from classifying info through the document information breakdown structure, classified info is connected organically and document info can be used. Therefore, availability of info can be enhanced.

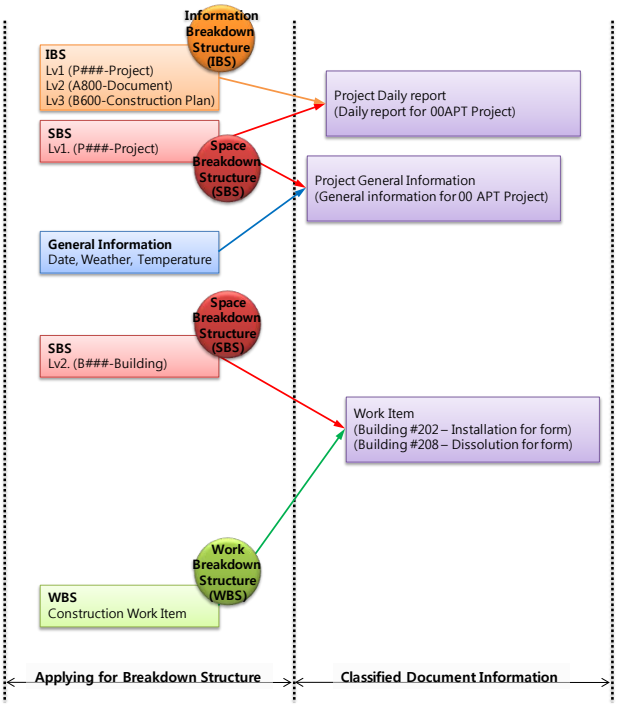

FIGURE VIII
CLASSIFIED DOCUMENT INFORMATION

VI. CONCLUSIONS AND LIMITATIONS

In construction industry, efficient control is difficult due to the problem of manpower-centered process. Also, although a lot of info in the construction stage is generated, there is difficulty in info management due to lack of structures and systems to control it effectively. From these properties of construction sites, construction info at sites is stored in a field document depository as a form of documents or it is controlled in a state that writers of document info keep it individually.

So, for document info on sites, because it disappear simultaneously with the end of field work and the case that it is used just one-time info occurs very often, this causes damage to the accumulation of construction know-hows of construction companies.

Hereupon, this study tried to suggest the document information breakdown structure to amass document info efficiently occurring in construction projects. For this, the DIBS was written for classifying document info by connecting classification structures such as the space breakdown structure (SBS) to separate shape info of BIM models, the info breakdown structure (IBS) to separate info and kind of documents, and the existing work breakdown structure (WBS). And, after applying this info to the daily work report, by reclassifying and rearranging it from extracting document info, availability of info could be heightened.

Thereupon, through the breakdown structure to amass occurring document info, foundation to control document info effectively can be constructed. Additionally, through the SBS, since classification on spaces of buildings can be done, it is expected that measures to link BIM models and info of construction sites directly can be structured later.

Although this study proposed the classification system to accumulate document information efficiently, there are some aspects that generated document info itself is extracted automatically and contents about the classification are not sufficient. So, there is necessity for studies on the integration of document forms at sites like standard templet. Also, it is considered that there is necessity of studies on the construction of document information control systems through info management database construction in order to amass and manage document info consecutively.

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