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Development of Classification System for BIM Application into Traditional Wooden Architecture: Guanyin Pavilion of Dule Temple

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Abstract: The traditional architecture of Korea's has evolved with that of China and also given a great impact on Japan. However, are extremely insufficient, resulting in their inevitable disappearance and serious omissions with the passage of time. Meanwhile, BIM has helped reduce aforesaid information leakage while leveraging IFC to enable interactions and exchange among other industries. The example used for the assessment of the framework is Doknak Temple of China. The results verify that under the developed IFC application into the traditional wooden architecture, the majority of previous impediments to BIM application are removed, thus putting forward the future research direction for advancement along with the current status of research. Through, the aforesaid process, the IFC framework constitutes the following four layers: resource import layer, data storage layer, data processing layer and data shared layer. As for the details, geometry resource, property resource and constraint resource created during the production stage of the traditional wooden housing materials are stored as IFCProduct, IFCPropertySet and IFCRelConnect via. extended modules. In this connection, they are all entered into the database of product materials, property and connection. The software user imports respective database assorted within BIM Software by calling on through IFC for each code of "Geon" and "Joe" representing Yingzao Fashi modules or on for the property section under ID (Identifier) and names. The modules are transferred to be made available for the users handling BIM/modeling and analysis and programming software. Any related future work and effort should include further studies on Yingzao Fashi, 4 and 5D interconnection, book of norms for Korea's traditional wooden construction techniques, detailed application method of the framework and last but not least, aggressive support from the government.

Key words: BIM, traditional wooden heritage, Yingzao Fashi, IFC code, classification system, modules

INTRODUCTION

Background and purpose of study: Traditional wooden architecture is a major architectural style in East Asia. Korean traditional wooden architecture developed historically and culturally along with East Asian architecture and has maintained and developed its unique beauty of Korea. Unfortunately, however, architectural references that explain the architectural techniques or constructional level of Korean traditional wooden architecture have not been transmitted (CHA., 2006). This is because the information related to traditional Korean wooden architectural techniques are mainly passed on orally during apprenticeship from one master to the next master and are rarely documented. Records of norms for specific techniques and methods that should be followed during construction that is standard related to construction do not exist (CHA., 2012). The only remaining records are Uigwe (The Royal Protocols of the Joseon Dynasty) that provide some information about how certain buildings were constructed. Hence, it is only natural to introduce the BIM (Building Information Modeling) which is increasingly being adopted in modern architecture, so as to overcome the shortage of and limitations in past documentation. However, existing studies have noted that there are many obstacles to introducing BIM to Korean traditional wooden architecture. In order to overcome the obstacles to introducing BIM and to build an approach taking a building's life-cycle into consideration, standardized name along with a classification system and code that are easy to use in practice are strongly needed. It is necessary to develop a classification system and code that takes into consideration the architectural, structural and aesthetical characteristics of traditional wooden architecture while supporting its compatibility with the properties and classification system used in modern architecture.

Accordingly, this study attempts to provide a basis for managing the integrated data of traditional wooden

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architecture by overcoming the obstacles of introducing BIM in the field of traditional architecture and developing a classification system and code that can be applied to traditional wooden buildings based on the open BIM classification system.

Method and process of study: In this study, research methods were broadly divided into two groups: theoretical (literature) research and practical (technical) research.

Theoretical (literature) research: Theoretical research for this study involved investigation of previous studies and consideration of related theory. Previous studies were examined in reference to open BIM classification system of traditional wooden architecture and its example, BIM and Hanok design process and BIM and traditional architecture classification system.

Practical (technical) research: Development of open BIM classification system and classification code for technical research, key factors of open BIM classification system were extracted from the analysis of the system required for traditional wooden architecture and open BIM. These factors were, then, applied to developing BIM model, so as to apply a classification system and code to traditional wooden architecture. Data were produced in a specific order to represent a BIM Model.

Theoretical considerations

Components of traditional wooden architecture: In reference to the components of traditional wooden architecture, Choi (2014) stated that the studies and books by the first generation of traditional wooden architecture scholars such as Jang Gi-in *et al.* describe a four-level elevation composition consisting of gichobu (base or foundation), momchaebu (body or frame), gongpobu (capital order system) and jibungbu (roof). On the other hand, in order to determine the structural members necessary for designing traditional wooden buildings, Sang-Hoon *et al.* (2009) examined the assemblage of members and the construction sequence and presented in a chart the Hanok components for each process following that construction sequence. The Hanok components were first categorized into five parts including gichobu, chuckbu (frame), jibunggagu (roof connection), jibungbu, sujangbu (joints). Then, the components and name of the members were indicated.

Open BIM classification system of traditional wooden architecture and its example: Important studies on BIM classification system for BIM application exist but are very limited. The present study examined Hanok related case studies and classification systems conducted recently for the introduction of BIM and its application to Korean traditional architecture. The existing 2D-based architectural design process follows a sequential work progress method in which a floor plan is initially prepared based on data from the design stage and subsequent work is performed using this floor plan. This method not only increases the amount of design work but also reduces work productivity because outcome from each step are prepared in 2D resulting in repeated tasks that are not related. On the other hand, BIM-based design process, developed by the collaboration of experts in design and other fields and from the integration of information generated in each stage does not use a 3D model simply for visualization purpose but utilizes a model constructed on the basis of 3D geometric information and properties information. Byeong-UK (2012) proposed the following process for the application of BIM to Hanok design process based on Hanok DB. Hyun-Sang (2015), Hyun-Sang and Sung-Woo (2014, 2015) suggested a 4 stage classification composed of jibungbu, gongpobu, momchaebu and gichobu according to the components of traditional wooden architecture whereas Byeong-UK (2012) divided a traditional wooden architecture into four parts including the chuckbu, gagubu (connections), okgaebu (roofing) and sujangbu and proposed a design process. While the studies discussed above suggested a design process for each component of a wooden architecture, Joo-OK *et al.* (2012) divided the design process into five stages and explained each stage in a simple diagram (Table 1).

Traditional architecture classification system based on modern architecture: If the studies discussed above are intended for a Hanok-centered library, the study of Choi (2014) and Boo-Gyun (2013) is about traditional architecture. It proposed a construct of classification system for the spatial information composition of traditional architecture with a case analysis of Sungnyemun and a validity verification of classification system. In demonstrating the case of Sungnyemun, the study not only made use of an information classification system but also utilized the IFC system and the classification system of BIM Software which is an operating system that actually constructs and uses BIM model. This allowed the reproduction of various data by making the Sungnyemun BIM data compatible with the international standard IFC format. Table 2 exemplifies the Hanok members applied to the IFC system in the Sungnye-mun case.

Table 1: BIM process for Hanok

Basic survey	Basic plan	Initial design	Basic design	Implementation design
Legal investigation status survey case study	Placement and cannes plan	Space configuration and shape	Window and interior element design	Detailed design

Table 2: International standards classification code status

Variables	Purpose and contents	Countries
Omniclass	The Omniclass construction classification system is a classification system for the construction industry	USA
Uniclass	UNICLASS 2015 is a development of CPIc's UNICLASS 2 and is now cited in the UK National forward to ISO 12006-2 building construction	UK
Veterans affairs	Attempts to provide a standard for the necessary information that the BIM Model object elements should include step by step	USA

MATERIALS AND METHODS

The following classification system applied in the restoration process of Sungnyemun is the first full-scale attempt at constructing a BIM spatial information system for architectural heritage (Hyun-Sang, 2015). It layed the ground work for traditional architecture classification system by incorporating information from survey report and restoration process into BIM. This classification is based on the five application criteria of construction information classification system facility (i.e., space, element, work type and resource) which was announced in 2012 by the Ministry of Land, Transport and Maritime Affairs. Also, according to the characteristics of work classification system and cost classification system, all members were coded based on categories such as project number, facility name, major work type, element, minor work type, group of members and unit member. However, Choi (2014), CHA. (2012), Lee and Yun (2016), NRICH. (2015) and Kumar *et al.* (2016) pointed out in regards to this attempt that BIM was introduced without full consideration of the usability of preservation and management work of architectural heritage and stressed the need for constructional information classification system suitable for architectural heritage.

RESUTLS AND DISCUSSION

The components of traditional wooden architecture were studied to understand the specific structural members. It was found that there is a lack of connectivity between the members of traditional wooden architecture and modern architecture. Due to the lack of traditional wooden architecture classification system using BIM, existing studies applying BIM to Hanok some extent were considered. These studies suggested various ways to systematize existing design process so as to apply BIM to Hanok. In the branch of Hanok, researches on parametric, member production and member classification are in progress. In fact, national level collaborated research projects between several universities and related agencies have yielded abundant results. However, these studies on

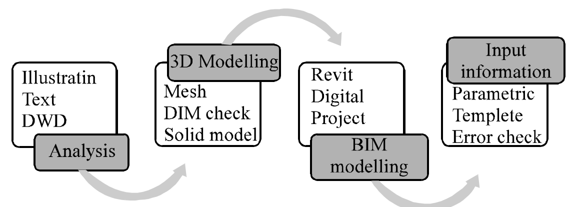

Fig. 1: BIM process for traditional wooden architecture

Hanok mainly involved new constructions and entailed problems. For one thing, it is difficult to apply the suggested methods to the branch of traditional wooden architecture encompassing structures that exist and those that are considered to have existed. In addition, adjusting the traditional wooden architecture classification system to the existing modern architecture classification system carried the disadvantage of code development disregarding the unique process or construction method of traditional wooden architecture. Given the characteristics of traditional wooden architecture which excludes new construction it is important to have the parametric information or library make use of data including information about position control or interrelated information of structural members rather than information such as parameters constructing the geometry of individual member, adjustment of parameter value and the functional formula necessary for such adjustment. In order to maintain existing methods, further research is necessary in the area of implementing BIM on architectural heritage using parametric modeling and creating a library classification system while expanding its availability.

BIM application in traditional wooden building

BIM work process of traditional wooden architecture: Illustrating a building by applying BIM requires information on geometry, topology, object and knowledge. First, it is necessary to have both internal and external work processes to consistently produce digital models from these information, Fig. 1 shows the BIM work process in traditional wooden architecture (Byeong-UK, 2012).

BIM research process is composed of data collection, work journalizing, library production, data implementation, computation and data arrangement. Data collection stage involves collecting existing data in various formats including 2, 3D, documents, 3D scans and images. Work journalizing stage is about collaboration with the server and covers journalizing facility, equipment and human resources in order to perform works. Library implementation stage involves creating a library for reusing mainly used structural members and uploading it on the server for joint use. Data implementation stage is when information other than commonly used members are entered. It is a stage for modeling and information input suitable for traditional wooden architecture through scanned materials, photos and in-site survey. Computation and data arrangement stages involve documentation and hierarchy application so that many people can use and apply the data. BIM is applied in traditional wooden architecture through such work process. Three steps are involved in BIM application. First, BIM experts organize the classification system and related information of traditional wooden architecture before applying BIM. Second, after identifying relevant information, they work on information modeling according to the classification system. Third, BIM experts work with traditional wooden architecture experts to modify and supplement the BIM model produced in the previous step.

Findings: In order to apply BIM to traditional wooden architecture, work process for traditional wooden architecture was examined. Although, the work process for traditional wooden architecture is identical to existing work process for modern architecture it was found that BIM work process for traditional wooden architecture requires the process of massive data collection including data on important proportion system, application of connecting method and historical records of wooden architecture along with frequent use of advanced equipment for 3D scanning or photo scanning. As for domestic and overseas construction information classification systems, classification systems related to modern architecture can be used in practice to great extent. However, it was found that traditional wooden architecture is omitted from the details of domestic and overseas construction information classification systems.

Development of BIM classification system and code for traditional wooden building

Romanization of traditional wooden architecture and coding of its structural member: The survey subjects for the present were wooden buildings including Guanyin Pavilion of Dule Temple. The selection ranged from the oldest building to the latest standard Hanok and provided relatively abundant data such as 3D scanning, allowing for future additional research. The latest Hanok was selected because there is a consensus about the names used in Hanok construction. Standard Korean Romanization Converter based on the system of Romanization of Hanguel was used because English notations of structural members were inconsistent.

Table 3: Apply IFC classification of traditional wooden architecture

Classification/Construction members	Classification codes	Classfication systems
Base		
Gidan	GIDN	IFCBaseGIDN
Gyedan	GEDN	IFCBaseGEDN
Choseok	CHSK	IFCBaseCHSK
Fram 000		
Pyeongjoo	PYJO	IFCFramPYJO
Gojoo	GOJO	IFCFramGOJO
Hwaljoo	HWJO	IFCFramHWJO
Woojoo	WOJO	IFCFramWOJO
Naejinjoo	NAJJ	IFCFramNAJJ
Changbang	CHBA	IFCFramCHBA
Gong		
Sagaldaejeobjoodwoo	SGDJ	IFCGongSGDJ
Yukgaldaejeobjoodwoo	YGDJ	IFCGongYGDJ
Joosimsocheomcha	JSCH	IFCGongJSCH
Joosimdaecheomcha	JDCH	IFCGongJDCH
Choolmoksocheomcha	CSCH	IFCGongCSCH
Choolmokdaecheomcha	CDCH	IFCGongCDCH
Salmisocheomcha	SSCH	IFCGongSSCH
Salmidaecheomcha	SDCH	IFCGongSDCH
Iljegong	ONJE	IFCGongONJE
Roof		
Daeryang	DARY	IFCRoofDARY
Joongryang	JURY	IFCRoofJURY
Jongryang	JORY	IFCRoofJORY
Gyeryang	GYRY	IFCRoofGYRY
Choongryang	CHRY	IFCRoofCHRY
Toeryang	TORY	IFCRoofTORY
Danjangyeo	DJHY	IFCRoofDJHY
Ginjangyeo	GJHY	IFCRoofGJHY
Choolmokdori	CHDO	IFCRoofCHDO
Joosimdori	JSDO	IFCRoofJSDO
Joongdori	JUDO	IFCGRoofJUDO
Jongdori	JODO	IFCRoofJODO
Hajoongdori	HJDO	IFCRoofHJDO
Sangjoongdori	SJDO	IFCRoofSJDO
Jeoksimdori	JEDO	IFCRoofJEDO
Podaegong	PODG	IFCRoofPODG
SJNG		
Jooseon	JOSE	IFCSjngJOSE
Badak	BADA	IFCSjngBADA
Inbang	INBA	IFCSjngINBA
Banja	BAJA	IFCSjngBAJA

Development of open BIM classification system: Open BIM classification system was developed by coding the large categories and member name which were identified from the components of wooden architectures investigated earlier, after the IFC name (Table 3).

Coding traditional wooden architecture BIM classification: To construct a simple classification system

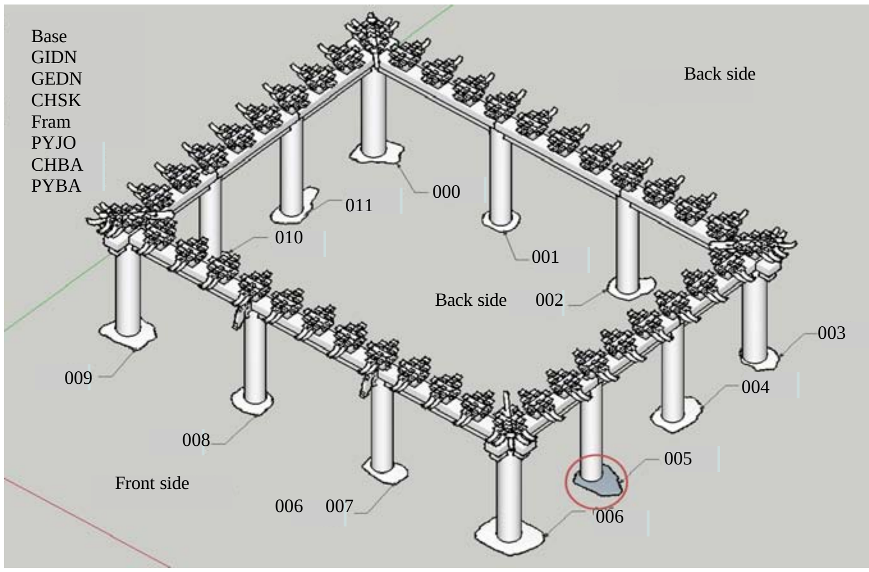

Fig. 2: Example of classification system

in light of construction order it should be noted that traditional wooden architecture is a combination of interrelated vertical members, horizontal members and diagonal members. Accordingly, an exemplification of classification system for a choseok (cornerstone) is shown in Fig. 2.

Selection of construction position: First, the pillar element at the left end seen from the front view is designated as '000'. This element can be changed depending on the situation and, although, each ply can have a different '000' it is better to maintain continuity of information and basically have the vertical elements share the same position. Horizontal direction may be displayed clockwise or counterclockwise. This can also be changed during initial design or maintenance.

Confirming name of structural member: Check the member name of the element. Identify the horizontal position and the vertical position and confirm the correct name taking into consideration the structural properties and order of connection.

Coding of name: For convenience of use, assign a 4-letter code to the name converted with the Romanization Converter or to that previously converted.

Combination of construction position and name of structural member: Then, the construction position and the member name are combined. This is indicated in a three-step sequence; construction order+member name, construction order+member name and construction order. Using this member name, the position and order of stacking the member can be easily indicated. Also, the member name can be combined with existing codes. For example, coding for 005 cornerstone (choseok: CHSK) is indicated as '00-BASE-002-CHSK-005' which can be read as number 6 choseok (005) in the third construction position (002) on the BASE which serves as the foundation (00). The reason 00 or 000 instead of 01 or 001 comes as the first in order is because unknown errors occur during building a database, conducting a search or handling a program.

Application to Guanyin Pavilion of Dule Temple

Guanyin Pavilion of Dule Temple: The Shan Gate and the Guanyin Pavilion of the Dule Temple, located in Jixian City of Hebei Province were constructed during the Liao Dynasty (984 AD) which predates the publication of Ying-Tzao Fa-Shih (Treatise on Architectural Methods of State Building Standards) by 119 years. These buildings, therefore are of great significance as they inherited the architectural technology of Tang Dynasty and were also built during the transition stage when the architectural technology of the Song Dynasty had begun. The following pictures show the front of Guanyin Pavilion of Dule Temple (Fig. 3).

Application of Open-BIM classification to Guanyin Pavilion of Dule Temple

Resource import layer: The architectural structure of Guanyin Pavilion adopts the so-called Temple style (style)

Fig. 3: Guanyin Pavilion of Dule Temple

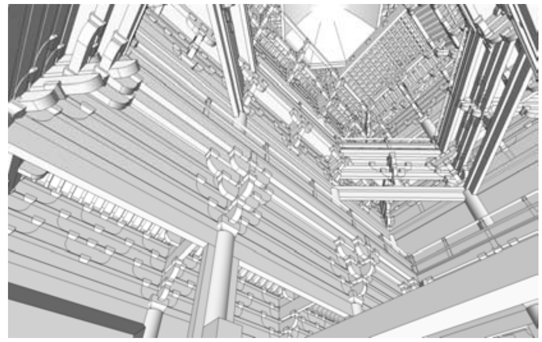

Fig. 4: 3D model of the Guanyin Pavilion inside

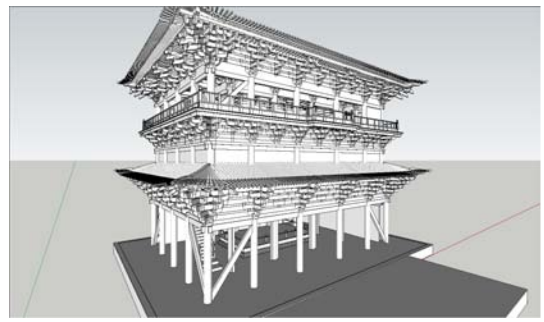

Fig. 5: 3D model of the Guanyin Pavilion outside

in which the column layer-columnar bracket cluster layer or the column layer-columnar bracket cluster layer-roof connection layer of each story form independent structures. Also, the columns in the upper level and the lower level are not directly connected but use the so-called fork column construction (the column) method by which the lower part of the upper level column is connected to the upper part of the columnar bracket cluster of the lower level column. The front and rear inner columns in the central section (your between) and the middle columns (middle column) in the left and right side section (inter folder) on the upper level are interconnected with square-shaped structural members to form a hexagonal empty space (empty wall) which prevents the overall deformation of the building. In addition, diagonal support beams (diagonal column) are installed inside the hidden level and the upper level outer wall to resist external force. Unlike the hexagonal empty space built on the upper level, the lower level is structured with a square-shaped empty space. This arrangement prevents deformation of the empty spaces and also serves to strengthen the rigidity of the entire structure of the pavilion.

The distance between columns is connected at the top of the column while the weight of cluster is supported by architectural materials such as the horizontal beam and horizontal plank. These structural members also served as important elements in the classification of Korean architectural style. For example, Jusimpo style refers to the architectural style in which the bracket cluster is placed only at the top of a column while Dapo style refers to the style when supplementary brackets are placed between columns. In Jusimpo style buildings, horizontal planks are not used except for special occasions since bracket clusters are not placed in between columns. When supplementary brackets are placed in between columns, another structural member called horizontal plank is placed as a reasonable measure to withstand the weight of the clusters. The sectional plan of the horizontal beam in the lower-eave of Guanyin Pavilion and in the Shan Gate of the Dule Temple shows an approximate ratio of 2:1 which was common during the Tang Dynasty. The head of the horizontal beam protrudes from the column and shows a straightly cut form devoid of any carvings or decorations. This method is similar to the head of the horizontal beam used in Geungnakjeon Hall of Bongjeongsa Temple in Korea. In the Song Dynasty, upper-eaves evidently show that the cross-sectional ratio of the horizontal beam changed to 3:2 which is the standard of structural member in Ying-Tzao Fa-Shih. (Jang-Sub, 1999)

Data storage layer: At this layer, all the information collected in the previous layer are refined and stored to suit IFC. This stage was carried out using product, property set and Connect. Basic information was entered for structural layers of which fabrication and application of specific structural members were easier. Then, the overall structure can be matched and compared against the resource (Fig. 4 and 5).

Data processing layer: This layer involves generating a 3D model from the collected resource and data as

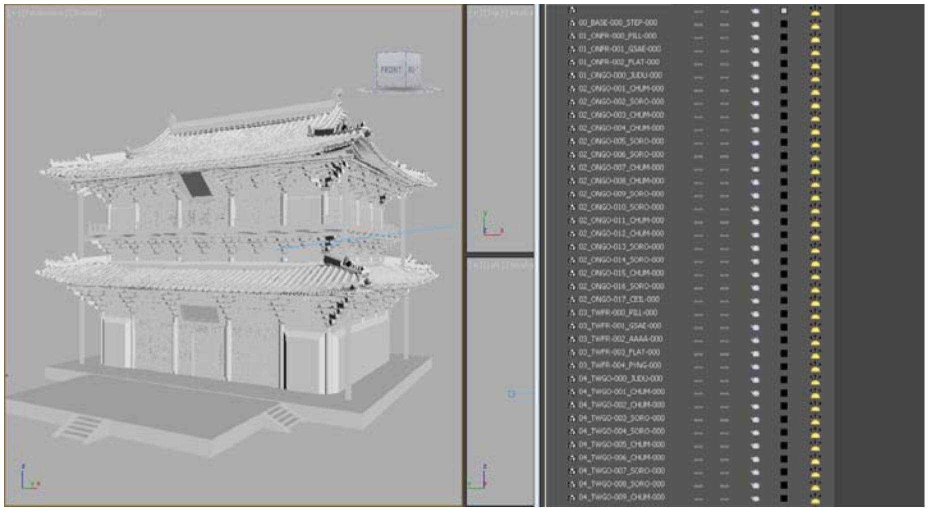

Fig. 6: IFC Model and code

well as entering additional information. Geometric information and property information can be confirmed at this stage.

Data shared layer: This stage is a process of making the BIM-generated model compatible with other programs using formats such as XML and FBX (Fig. 6).

Findings: In this chapter, the classification system and codes are applied to the structural members of Guanyin Pavilion of Dule Temple, a representative China wooden architecture to examine their usability in fields other than the construction industry. It was confirmed that the whole BIM model can fully support the representation of Geungnakjeon, a wooden building presumed to be dated to the Liao Dynasty from identifying its construct and structural members, assigning their characteristics and combining them. Therefore with future applications of classification system and codes to more traditional wooden buildings it is expected that the contents developed in the present study will be used for the development or usage of BIM guidelines for traditional wooden architecture and also contribute to the international standard guidelines. The classification system developed in the present study was exported in FBX file format for compatibility between programs often used in engineering and design. FBX file format is compatible with other programs as well as BIM program. And since it includes geometric information, position information and material information, models built in architecture can be used in IT, movies and games as well.

CONCLUSION

The subject of this study are traditional wooden buildings which exist or presumed to have existed. While various tasks such as survey and research, partial repair and dismantling and repair may be involved in them as occasion demands, the top priority for these traditional wooden buildings is long-term unkeeping and restoration. In order to maintain and manage these traditional wooden buildings, the use of BIM method which contain object-specific information is increasingly considered over existing CAD method. However, the current standard and method of BIM, based on information construction utilizing structural members their characteristics and interrelationship are tailored for modern architecture and lack possible suggestions for other buildings. Moreover, the characteristics of traditional buildings were lost in the process of describing traditional buildings according to the standard and method required in modern architecture which in turn became an obstacle to introducing BIM, making it difficult to exchange information with other industrial fields. Therefore, information management necessary for handling the priorities of traditional wooden buildings involves the generation and management of three-dimensional information which requires open BIM classification system and code. In order to solve these problems this study deduced an improvement based on theoretical analysis and practical consideration of previous studies and consequently presented a classification system and classification code that can be utilized in many traditional wooden buildings. The presents study developed an open BIM-based classification system and classification code for traditional wooden architecture and presented a plan for their usage as well as example. However, the classification system and classification code for the application of BIM to traditional wooden architectural proposed in this study need to be reviewed in detail, so that each layer and module can be used widely used in practice. In addition, it is necessary to extract the main information which is used in the design and maintenance stages for each component and to present it as common properties. The IFC propety set definition for these common properties and the grouping of properties should be also be proposed in the future. Above all, the developed contents should be widely shared among participatory agents of traditional wooden architecture through practical applications and dissemination. Institutional efforts are called for to this end.

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