Comprehending the Sung-Rye-Mun wooden roof structure and BIM implementation of the traditional Bracket-set design modules

Soo-Hoon Park※1, Eunyoung Ahn※2

Abstract

In this paper we are concerned about understanding the roof structure of the traditional buildings Sung-Rye-Mun which share compositional commonalities among traditional buildings in the Northeast Asian region and we focus on GongPo components namely the bracket-sets that are the essential part that connects the middle body parts (MomChe) to the top roof parts (JiBung), considered to be the most elaborate parts of traditional buildings. We follow a procedure to implement the design modules to be applied in BIM tools which are platforms for constructing virtual buildings. The main target building is the Sung-Rye-Mun which has special cultural and social meanings nowadays and we tested our understanding and the design modules such as bracket-sets by constructing a virtual building model of Sung-Rye-Mun and by implementing the core knowledge as a tablet PC Application.in the form of a GongPo Making game.

Key Words: bracket-set (GongPo), design module, BIM, Sung-Rye-Mun

1. Introduction

This paper concerns about traditional wooden roof structure and we focus on the GongPo components namely the bracket-sets. We are examining especially the roof structure because this top-part of the traditional wood building contains the most complicated wooden compositions compared with the middle- and the bottom parts. We focus on GongPo components such that these elements are regarded as the single most important and the most diverse elements in the roof structure of the traditional Northeast Asian buildings. Understanding the GongPo components and implementing them in the current BIM platform such as ArchiCAD as a virtual building with integrated design database would achieve our

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aims in the virtual building construction and contents making of traditional architecture.

The target building we chose for this paper is the Sung-Rye-Mun(SRM) a.k.a. the Grand South Gate. We constructed the virtual building of Sung-Rye-Mun based on the detailed survey data by SamSung Architects[1].

2. Traditional Wood Structure

The composition and the components of the traditional wood structure of the Northeast Asian buildings are quite characteristic in many ways compared to the modern or wooden structures in many regions.

2.1 The Roof Structure

Since the 10th century, Northeast Asian buildings are considered to be understood as a trilogy of three parts (the script on wood structure, 10C): the bottom part (the platform), the middle part and the top part (the roof structure above the connecting beams). Contrasted to the middle and the bottom part, the most diverse, the biggest, the broadest, the heaviest and structurally the most complicated areas are the top part, i.e. the roof structure. Understanding the roof structure of the traditional building, therefore, are essential.

2.2 The Bracket-Set(GongPo)

The bracket-set (GongPo) is considered as one of the most characteristic components in the Northeast Asian architecture. The more frequent use and the more complicated the bracket-sets are applied, the more sublime the building becomes and the change of GongPo components far exceeds the speed of changing the building type such that the comprehension of GongPo became the key in examining and distinguishing traditional buildings.

The main function of the GongPo is to protrude the eaves to the front. Protruding eaves of the roof structure has been quite a critical issue in most of the Northeast Asian countries and the patterns are analyzed in terms of three categories as shown in Fig. 2 namely the protrusion of the rafters, supporting rafters using parallel rafters or using horizontal beams and the use of the bracket sets.

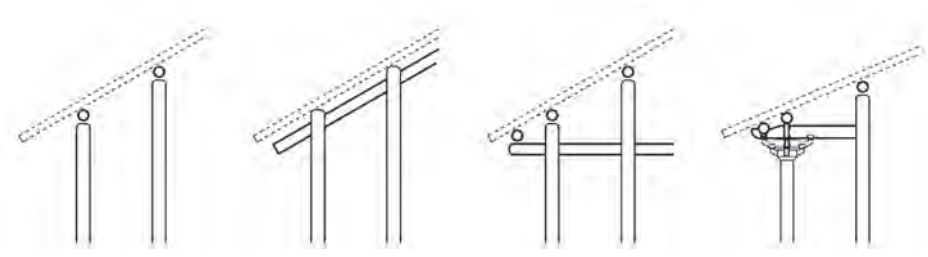

Fig. 1. Historical improvements of protruding eaves[2]

[1] SamSung Architects, Sung Rye Mun detailed survey and analysis report, DongA Publishers, Seoul (2006)

[2] G.M. Lee, The Building Principles and Typology of Roof Structure in the East Asian Wood Architecture, Ph.D. Thesis, Seoul National University, (2009)

3. The Roof Structure of the Sung-Rye-Mun

English naming summary of elements in the roof structure of the Sung-Rye-Mun is shown in Fig. 2 with some English terminologies from Hwang[3]. The loads of the top part of the building are transferred to the middle part where the bracket-sets are used to cope with many functionalities as follows:

- Cantilever eaves:
- Connecting the rafter structures/ inserting structure-sets to the purlin structures/ stacking structure-sets:
- Forming the Façade of the building:

The three directions in the traditional buildings are the column direction (vertical), the crossbeam direction (horizontal) and the purlin direction (horizontal and orthogonal to the beam direction) in Fig 2 and 3. A typical section of the building is conceived in terms of the column and the beam direction. The extension of the building is mostly aligned to the purlin direction.

The direction of purlins as the horizontal members shown in Fig. 4, is important not only because it is the building-extension direction but also in the sense that it is the approach and the access to the building. That is why the bracket-sets are elaborated in such a way that the numbers and the composition style of the bracket-sets are increased to form more luxurious façade of the building. The bracket-sets also functions as the position fixer that locks up the rafter structure sets containing many diagonal members to the stacking structure sets composed of much static and safer horizontal and vertical members. The bracket sets are also functioning as the structural support for the cantilever eaves.

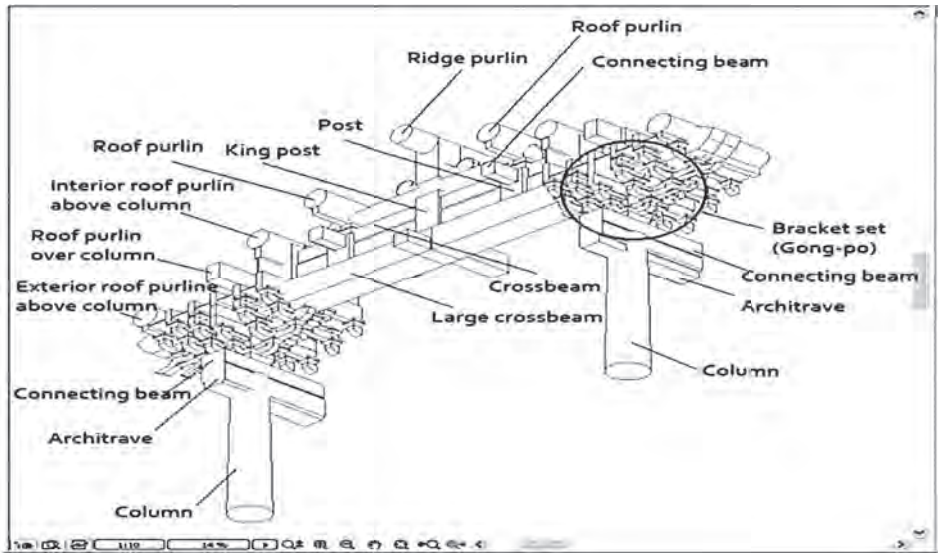

Fig. 2. Element naming surrounding bracket set structure

[3] J.-K. Hwang, J.-W. Kwak and J.-H. Kwak, Resisting capacity of Korean traditional wooden structural systems subjected to static loadings, Structural Engineering and Mechanics, (2008), Vol. 30, No.3, pp. 297-316.

3.1 The Bracket-Sets of the SRM

As shown in Fig. 3, SRM has the bracket-sets with the style of early Chosun Dapo family[4] where the bracket sets are positioned not only on top of columns but also in the intervals of the columns.

The bracket sets of the SRM as in Fig. 3 shows 5-steps (5 po) where the JeGong and the ChumCha (bracket) are crisscrossing to form a well-shaped structure component. The naming and the numbering of these crisscrossing members of the bracket set components are roughly shown in Figure 3. The horizontal members in the crossbeam direction are named as the JeGong which stack one after another. The other horizontal members in the purlin/lintel direction are named as the ChumCha(the brackets) which are positioned along with axis on the center and/or stepped out of the center of the column. These two horizontally crisscrossing stacking members compose the bracket sets and they are used to determine the scale and typology of the bracket sets (GongPo). In Sung-Rye-Mun, there are several variations of the bracket sets showing small differences in their positioning in both floors.

The well-shaped composition of the bracket sets forms the inverted pyramid assembly where the JeGong in the beam direction horizontal members and the brackets (ChumCha) in the purlin/lintel direction horizontal members are increasing in its sizes and number of joints as it stacks on top of each other.

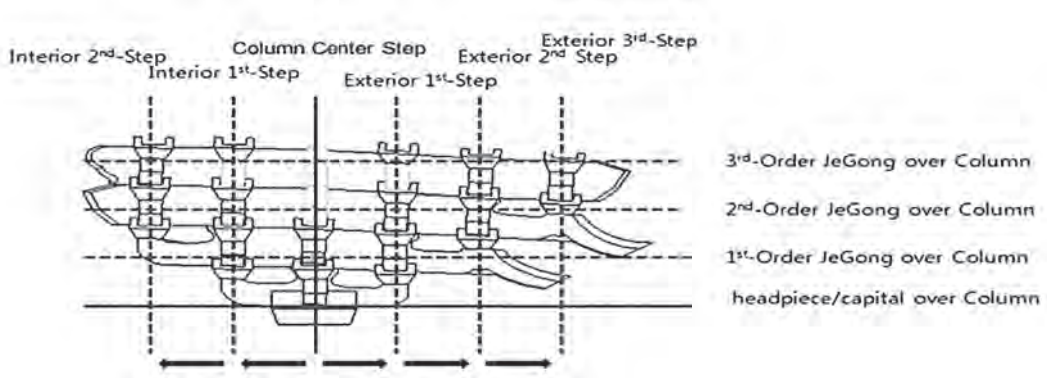

Fig. 3. The numbering of ChulMok (Steps)

3.2 The Composition of the Bracket-Set

The bracket set is the building device that supports one or multiple set of purlins (Dori) delivering the load of the roof structure toward the columns[5]. It is basically a structural element that holds the upper rafter structure sets and helps the diagonal rafter members to be protruded to their limit to form cantilever eaves.

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[4] S.-L.Ryoo, A Study on an Alternative Idea of 'Opinion of Roof Style & Structure Changes of Sung-Rye-Mun' following the first Construction in Cho-Sun Dynasty, Architectural Institute of Korea, (2009), Vol. 25, No. 12, pp. 209-220.

[5] G.I. Chang, Wood Structure, Korean Traditional Building Series V, BoSungGak Publishers, Seoul (1993)

4. Design Modules and BIM Modeling

4.1 Gong-Po Design Module

This paper illustrates the development of design modules for the bracket sets consists of typical members such as JeGong, brackets, headpiece and SoRo. The diagram for the implementation process is shown in Fig. 4, which is ① Decisions on # of Steps (ChulMok), ② Decisions on the interval of steps & the brackets, size of JeGong, ③ Decisions on the depth and the height of JeGong, ④ Decisions on the depth and the height of the brackets, ⑤ Decisions on end forms of JeGong members, ⑥ Assembly of the bracket sets using these design decisions

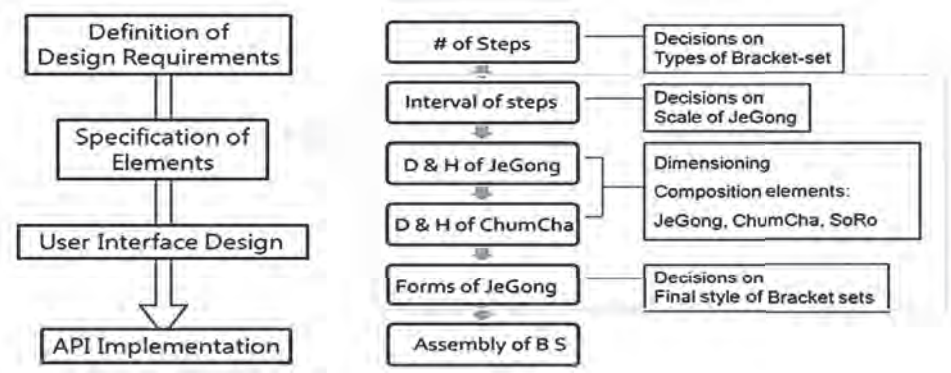

Fig. 4. Implementation of the bracket-set design module

The brief procedure for implementing the traditional building design modules for BIM tools is ① Definitions on design requirements of members based on drawings and/or detailed surveys, ② Specification of elements and scripts on element forms, ③ Parametric design module implementation using GDL, ④ User interface implementation using API, as illustrated in Fig. 5.

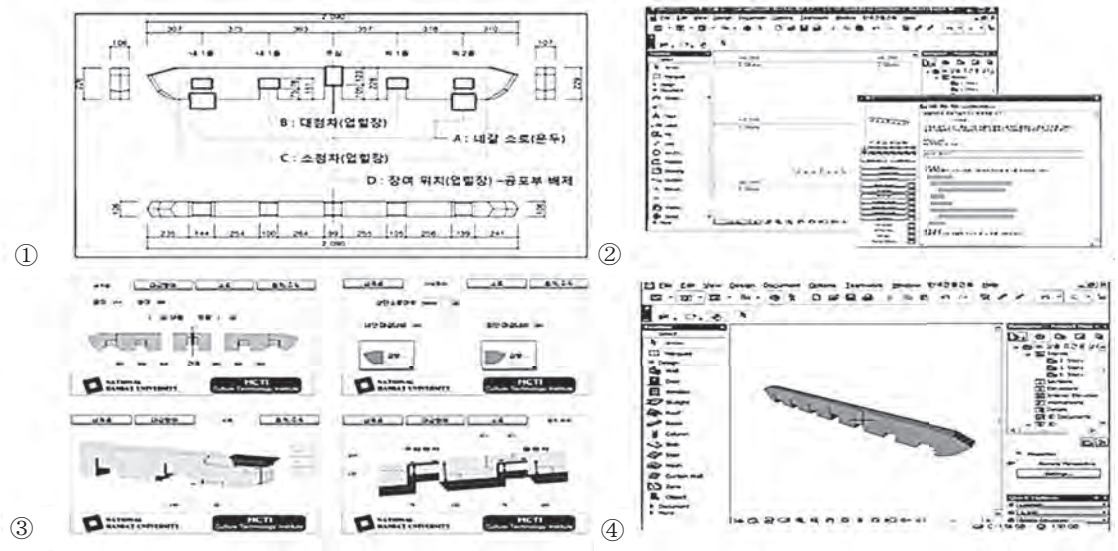

Fig. 5. Design module implementation for a large crossbeam :
① Design requirements, ② Scripts on elements, ③ User interface using GDL & AP, and ④ Members in the BIM tool

4.2 Implementation of the Bracket Sets

Typical members of the bracket sets such as headpiece, 4-way and 2-way SoRo, brackets and JeGong are implemented using the design modules in the BIM tool called Graphisoft ArchiCAD version 14 on Windows mostly with GDL[6][7] script language.

The 3D forms of the SRM building are handled in the BIM tool platform called ArchiCAD version 14 where various traditional building design modules are implemented. All these numeric data for each design module is based on the detailed survey and measure report of SRM in 2006[1]. Patterns such as DanCheong coloring on the elements of roof eaves and columns are separately produced based upon photographs of many sources and they are drawn using the tools such as Photoshop and mapped onto each design module as shown in Fig. 6.

This virtual building modeling of the SRM and the process of making them prove the validity of BIM methods in creating virtual building models of traditional buildings. This BIM method contrasts highly with those existing 3D modeling methods in the following senses:

- The bilateral associativity among various architectural 2D drawings and 3D, 4D and/or 5D models such that any change of a drawing is simultaneously applied to other views and/or models.
- The parametric design aspect[8] so that particular members, when they are already defined with appropriate design parameters in many aspects, could be easily created and more importantly be easily joined with proper positional, joining relationships and subtractive formal details.
- Schedule and reports where numbers, costs and other estimate related information is handled properly.

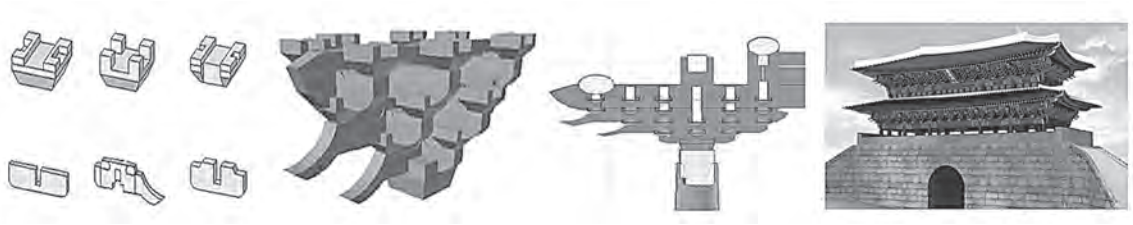

Fig. 6. Bracket-set modeling with the components and the virtual SRM

5. Conclusions

Traditional buildings in the Northeast Asian region are huge in numbers and yet the cutting-edge building modeling tools are not taking this matter seriously in embracing them as their subjects. We therefore tried to fill this gap between current building modeling tools

[6] D. Nicholson-Cole, The GDL Cookbook 4 The source of all that is good in GDL and ArchiCAD Tips and Tricks, Marmalade Graphics (2004)

[7] Graphisoft, ArchiCAD 12 GDL Reference Manual (2009)

[8] J. D. Park, A Study on the BIM-based design for the elements of wooden structure of Korean traditional buildings through a parametric design methodology, Society of CADCAM Engineers, (2011), Vol. 16, No. 2, pp. 104-113.

and these alienated subjects by implementing design modules for building components suited for the BIM tools such as ArchiCAD version 14. Modeling a component is one thing and understanding the traditional building and/or constructing virtual building models in their context is another matter so that we needed proper knowledge, concepts, measures, names and assembly knowhow in order to avoid distinctive mistakes. The models along with all the construction information including sizes, unit costs, materials and positions could turn out to be valuable sources of the cultural contents such as this SRM example. Most BIM tools provide the integrated tool for handling most of these data in terms of a complete virtual building. We could measure individual members in developing modules. We could assemble building devices as meaningful components. We could assemble the roof structures, the floors and the stone structures respectively and view them separately. We could also disassemble them, slice them to make section views, count individual members and calculate their material volumes. All these design and construction information has the possibility to be examined further and with more intention of future applications.