Parametric Library Components for BIM-based Curtain Wall Design Automation Module

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Abstract –

Recently, the use of curtain wall systems has been increasing. The architect should be able to intuitively select materials and design elements that are the most suitable for the building from among diverse curtain wall systems. However, in the current curtain wall design processes that are mostly implemented in 2D, lots of problems are occurring. Therefore, the BIM-based curtain wall design automation module should be developed. In this research, before developing BIM-based curtain wall design automation modules, general metal curtain wall systems are analyzed in order to classify components necessary for the fabrication of parametric design based libraries. Curtain wall library components are classified according to the locations, functions, and LODs. Finally, basic shape information of components according to LODs is defined.

Keywords –

Curtain Wall, Building Information Modeling (BIM), Parametric BIM Library, Level of Development (LOD), Basic Shape Information

1 Introduction

1.1 Background

Recently, as diverse forms of buildings including super high-rise buildings have been generalized, attention to the importance of curtain walls that are advantageous for construction period shortening, building lighting and quality homogenization has been increasing. In particular, aluminum curtain walls are currently the most widely used in super high-rise buildings because they are light weight and have excellent functions as filters to control and block the flow of elements that affect indoor environments [1].

However, in the current curtain wall design processes that are mostly implemented in 2D, problems such as excessive design drawings, errors in design drawings and documents, and redesign are occurring [2]. Key risk factors that delay the construction of super high-rise curtain walls include excessive unit type designs due to complicated designs, the occurrence of excessive design changes, and insufficient reflection of site conditions and constructability [3]. In addition, current curtain wall design highly tends to utilize data accumulated through existing projects or rely on consulting by enterprises specializing in curtain walls.

Curtain wall design should be performed with BIM by the architect from the beginning, and the architect should be able to intuitively select from among diverse curtain wall systems the materials and design elements that are the most suitable for the building. In addition, constructability should be reflected in design so that design and construction can be connected successively and to help with the preparation of shop drawings.

However, even if attempts are made to utilize BIM authoring tools that enable working in 2D and 3D in design, the utilization of BIM authoring tools is not easy because they have a limitation of not being able to reflect the materials and assembling methods for diverse curtain wall systems.

Therefore, BIM-based curtain wall design automation modules that will enable selecting those materials and assembling methods that are the most suitable for buildings from among diverse curtain wall systems and can help the preparation of shop drawings should be developed.

1.2 Research Purpose and Scope

In this research, before developing BIM-based curtain wall design automation modules, general metal curtain wall systems are analyzed in order to classify components necessary for the fabrication of parametric design-based libraries.

Since the kinds of curtain wall systems are diverse because of materials and assembling methods, the scope of the present study is limited to the analysis of the

currently most widely used general metal curtain wall systems. In addition, curtain wall library fabrication through component classification and the development of BIM-based curtain wall design automation modules utilizing the curtain wall libraries will be performed in follow-up studies.

1.3 Research Procedure

The research was conducted using the following procedures.

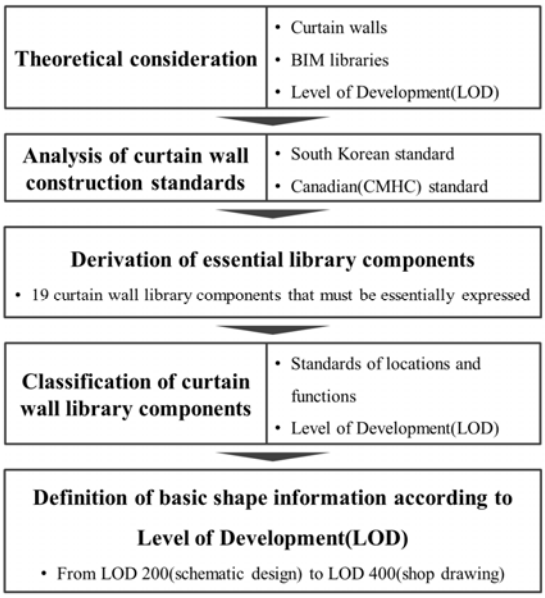

Figure 1. Research procedure

1. Theoretical consideration: Literature data and previous studies on curtain walls, parametric BIM libraries, and Level of Development (LOD) were examined.
2. Analysis of domestic and foreign curtain wall construction standards: The metal curtain wall construction standards in the South Korean building construction standard specification [4] and the Canadian metal curtain wall construction guide [5] were analyzed to derive components necessary for curtain wall library fabrication.
3. Classification of curtain wall library components according to locations and functions: The derived curtain wall library components were classified according to the standards, locations and functions.
4. Classification of curtain wall library components expressed according to LOD: Through LOD standards [6], curtain wall library components expressed in LOD 200, 300, 350, and 400 were classified.
5. Definition of basic shape information for curtain wall library components according to LOD: Basic shape information for curtain wall library components in LOD 200, 300, 350, and 400 were defined.

2 Theoretical Consideration

2.1 Curtain Wall

2.1.1 Overview of Curtain Walls

Curtain wall is a generic name for non-bearing outer walls and refers to those walls that compartmentalize and block spaces in the form of curtains within the structure of their construction. Curtain walls can be largely divided into metal ones and non-metal ones based on the materials used. Metal curtain walls include steel, aluminium, and stainless steel ones. In addition, the assembling methods can be divided into site assembling and shop assembling methods. The materials and assembling methods of curtain walls as such are selected according to building facade designs, construction periods, costs, and required performances.

Figure 2. Curtain walls used in building façade

2.1.2 Consideration of Curtain Wall Related Studies

Previous-curtain wall-related studies in South Korea include curtain wall design improvement-related studies and risk analysis-related studies. The curtain wall design improvement-related studies included studies that derived curtain wall structure design review processes and developed structural design understanding manuals [1]. In addition, there were studies that developed systems that enable sharing of curtain wall design information, cooperation, and support for decision making [2]. Furthermore, there were studies that presented improved curtain wall construction life cycle processes utilizing the VSM technique [7]. Curtain wall

risk-analysis related studies include studies that derived core risk factors for delays in curtain wall construction using the FMEA technique and presented responding processes [3]. Studies related to the development of curtain wall design tools or curtain wall library fabrication using BIM were insufficient.

Among curtain wall-related previous studies conducted in foreign countries, many were related to curtain wall designs in terms of energy efficiency. In addition, there were studies that presented decision making support processes for selection of curtain wall systems in the design development stage [8]. In common with South Korea, studies related to curtain wall library fabrication using BIM were insufficient.

2.2 Parametric Design-based BIM Library

Parametric design is a methodology of architectural design that defines parameters as input values so that complicated shapes can be designed through many constraints based on the parameters. BIM libraries based on parametric design enable giving dimensions, creating diverse shapes from relational expressions defined using variables, and easily revising the shapes through the adjustment of variable values [9].

BIM libraries refer to the sets of individual members contained in BIM authoring tools or firsthand constructed by the user when necessary. Individual libraries include diverse pieces of information on certain members utilized in construction processes such as shapes, dimensions, materials, and prices. By utilizing the libraries in design processes, repetitive tasks can be reduced and data can be directly delivered so that design information can be successively connected to construction work. Constructed libraries can be utilized in drawing extraction, estimation, construction, and maintenance [10].

Currently, technologies to fabricate BIM libraries are largely divided into two types; those that are to fabricate libraries with dimensions and constraints while having library description information in their own formats such as the Family of Revit and those that are to fabricate libraries using languages that can describe parameters and even algorithms such as the Geometric Description Language (GDL) of ArchiCAD [11].

2.3 Level of Development(LOD)

Before fabricating BIM based curtain wall libraries, plans for detailed levels of models are necessary. To this end, standards for Level of Development (LOD) that indicates the level of BIM model preparation should be checked first.

Represent examples of standards that define LOD include The American Institute of Architects (AIA) Contract Documents and BIMForum LOD Specification [6]. AIA first defined LOD in AIA Document E202™-2008 and has developed the contents through E203TM-2013, G201™-2013, and G202™-2013. AIA divides LOD into five levels from 100 through 500 based on the contents of major tasks and model preparation levels.

The contents of the LOD Specification of BIMForum were developed based on AIA Contract Documents. BIMForum more concretely defines the standards for preparation of construction members classified by Uniformat™ into BIM models in individual stages of projects. In addition, BIMForum did not add any separate content to the LOD 500 defined by AIA but added 350 between 300 and 400 to divide the specification into five levels.

3 Analysis of Domestic and Foreign Curtain Wall Construction Standards

3.1 Standard Specifications for Building Construction Work in South Korea

The Ministry of Land, Infrastructure and Transport of South Korea provides standard specifications that can be applied to building construction work performed in South Korea. As sub-items of exterior wall construction work (14000), the specifications describe in detail, the require performance of metal curtain wall construction work (14015), materials, and contents related to construction work. The materials that constitute metal curtain walls specified in the standard specifications are listed in Figure 3.

3.2 CMHC Glass and Metal Curtain Walls Guide

Canada Mortgage and Housing Corporation (CMHC) is a crown corporation of the government of Canada. The materials that constitute metal curtain walls specified in chapters 3 (Components and Materials) and 8 (Specifications) of the glass and metal curtain walls guide provided by CMHC are listed in Figure 3. The glass and metal curtain walls guide describes the require performance of metal curtain wall construction work, materials, and contents related to construction work in more details than the standard specifications for construction work of South Korea along with detailed drawings.

3.3 Derivation of Essential Curtain Wall Library Components

The materials that constitute metal curtain walls specified in the standard specifications for construction work of South Korea and Canada were compared with each other and nineteen curtain wall library components that must be essentially expressed were listed in Figure 3. The insulations among the derived components include both those insulations that are used in aluminum bars and panels and cavity insulations. In addition, since sealants are used in many areas and are small in size, they were not included in component classification in order to express them as attribute information instead of shape information when curtain wall libraries are fabricated.

Korean Standard	Canadian Standard	Components
Extruded aluminum and panel	Extruded aluminum	Embedment
Steels	Sheet aluminum	Anchor clip
Fasteners	Sheet steel	Fastener
Insulation	Sheet sections	Mullion
Insulation using in bar	Fasteners	Transom
Back panel	Spandrel Panel	Spandrel panel
Glass and glazing material	Bituminous paint	Back panel
Sealant	Vertical glass units	Insulation
Gasket	Sealant	Glass
Setting block	Waterproofing/air barrier membrane	Gasket
Fire stop	Shims, spacers, tapes, glazing, gaskets	Setting block
Anchors	Setting blocks, sealants	Flashing
Flashing and gutter	Spandrel glass	Gutter
Extractor	Spandrel and cavity insulation, stick pins, adhesives	Fire stop
Hardware of openings	Joint backers	Extractor
Screen, louver, cavity insulation	Structural sealant	Sun shade
		Window
		Door
		Louver

Figure 3. Derivation of essential curtain wall library components

4 Classification of Curtain Wall Library Components

4.1 Classification of Curtain Wall Library Components according to Locations and Functions

The nineteen essential library components are divided into eight groups as shown in Figure 4 based on their locations and functions. The components are classified into upper eight items which are *Anchor, Frame, Panel, Insulation, Glazing, Waterproofing, Firefighting, and Accessory* and sub-elements are included in each item. As mentioned above, sealants will be expressed as attribute information instead of shape information.

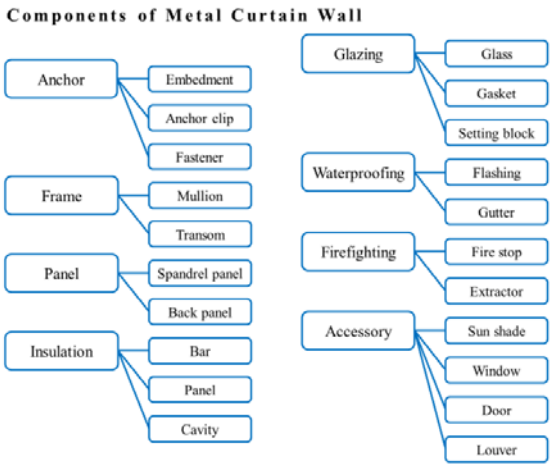

Figure 4. Classification of curtain wall library components according to locations and functions

4.2 Classification of Curtain Wall Library Components Expressed according to LOD

Referring to the newest LOD specification of BIMForum, curtain wall library components expressed according to LOD are classified. BIMForum 2015 LOD specification [6] expresses curtain walls as exterior window walls pursuant to Uniformat™. The detailed model levels from LOD 100 to 400 are not clearly expressed with materials to be used but are shown with descriptions and figures.

The curtain wall library components classified earlier can be prepared as a classification table as shown in Figure 5 based on the LOD standard of BIMForum. Since LOD 100 is the conceptual design level and

expresses the shapes and volumes of masses instead of components, it was not expressed in the classification table. The classification table shows the curtain wall library components expressed differently according to individual LODs ranging from LOD 200 which is a schematic design level to LOD 400 which is a shop drawing level.

<table>
<tr><th>LOD 200(1)</th><th>LOD 300(9)</th><th>LOD 350(12)</th><th>LOD 400(19)</th></tr>
<tr><td rowspan="8">Metal curtain wall</td><td rowspan="3">Anchor</td><td>Embedment</td><td>Embedment</td></tr>
<tr><td>Anchor clip</td><td>Anchor clip</td></tr>
<tr><td>Fastener</td><td>Fastener</td></tr>
<tr><td>Mullion</td><td>Mullion</td><td>Mullion</td></tr>
<tr><td>Transom</td><td>Transom</td><td>Transom</td></tr>
<tr><td rowspan="2">Panel</td><td>Spandrel panel</td><td>Spandrel panel</td></tr>
<tr><td>Back panel</td><td>Back panel</td></tr>
<tr><td></td><td></td><td></td><td>Insulation</td></tr>
<tr><td></td><td>Glass</td><td>Glass</td><td>Glass</td></tr>
<tr><td></td><td></td><td></td><td>Gasket</td></tr>
<tr><td></td><td></td><td></td><td>Setting block</td></tr>
<tr><td></td><td></td><td></td><td>Flashing</td></tr>
<tr><td></td><td></td><td></td><td>Gutter</td></tr>
<tr><td></td><td></td><td></td><td>Fire stop</td></tr>
<tr><td></td><td></td><td></td><td>Extractor</td></tr>
<tr><td></td><td>Sun shade</td><td>Sun shade</td><td>Sun shade</td></tr>
<tr><td></td><td>Window</td><td>Window</td><td>Window</td></tr>
<tr><td></td><td>Door</td><td>Door</td><td>Door</td></tr>
<tr><td></td><td>Louver</td><td>Louver</td><td>Louver</td></tr>
</table>

Figure 5. Classification table of curtain wall library components expressed according to LOD

LOD 200 expresses metal curtain walls as a single model object and LOD 300 expresses a total of nine components; *Anchor, Mullion, Transom, Panel, Glass, Sun shade, Window, Door, Louver*. LOD 350 expresses anchors and panels in more details compared to LOD 300. Anchors are divided into three components; embedment, anchor clips, and fasteners and panels are divided into two components; spandrel panels, and back panels so that a total of twelve components are expressed; *Embedment, Anchor clip, Fastener, Mullion, Transom, Spandrel panel, Back panel, Glass, Sun shade, Window, Door, Louver*. LOD 400 expresses a total of nineteen components including insulations, glazing, waterproofing, and firefighting components; *Embedment, Anchor clip, Fastener, Mullion, Transom, Spandrel panel, Back panel, Insulation, Glass, Gasket, Setting block, Flashing, Gutter, Fire stop, Extractor, Sun shade, Window, Door, Louver*.

BIM-based curtain wall design automation modules should be developed so that LOD 300 can be selected to make up to design development levels, LOD 350 can be selected to make up to construction design levels, and LOD 400 can be selected to help even shop drawing preparation.

4.3 Definition of Basic Shape Information for Curtain Wall Library Components according to LOD

In LOD 200, information on approximate dimensions (width, depth, and height), shapes, locations, quantities, orientations, and major types of single model objects combining frames, panels, and glasses is necessary.

The nine curtain wall library components expressed in LOD 300 basically require information on design development level dimensions, shapes, locations, quantities, orientations, and materials. In the case of anchors and panels, since sub elements included in them are expressed in LOD 350, information on the shapes of single model objects before segmentation should be necessary in LOD 300. In particular, in LOD 300, mullions and transoms additionally require information on spacing.

The twelve curtain wall library components expressed in LOD 350 basically require information on construction design level dimensions, shapes, locations, quantities, orientations, and materials. Since anchors in LOD 300 are expressed as embedment, anchor clips, and fasteners in LOD 350, shape information on each of embedment, anchor clips, and fasteners should be necessary. This is also the case with spandrel panels and back panels. In particular, in LOD 350, mullions and transoms require accurate information on shapes and spandrel panels require accurate information on dimensions.

The nineteen curtain wall library components expressed in LOD 400 require information on shop drawing level dimensions, shapes, locations, quantities, orientations, and material for actual fabrication stages. As with mullion extrusion profiles that must be perfectly expressed, all components require shape information for fabrication.

5 Conclusion

In this research, as the first stage to develop BIM-based curtain wall design automation modules, curtain wall library components were classified and basic shape information according to LOD was defined.

First, metal curtain wall constituting materials specified in curtain wall construction standards of South Korea and Canada were compared to derive nineteen curtain wall library components that must be essentially expressed. The derived nineteen essential library components were classified into eight groups; Anchor, Frame, Panel, Insulation, Glazing, Waterproofing, Firefighting, and Accessory based on their locations and functions.

Thereafter, referring to the newest LOD Specification of BIMForum, curtain wall library components expressed according to LOD were classified. The curtain wall library components expressed differently according to individual LODs ranging from LOD 200 which is a schematic design level to LOD 400 which is a shop drawing level were classified and organized into a table. Hereafter, BIM-based curtain wall design automation modules should be developed so that LODs can be selected according to design stages.

Finally, basic shape information for curtain wall library components in LOD 200, 300, 350, and 400 were defined. Information of dimensions, shapes, locations, quantities, orientations, and material for each design stages is necessary.

In future studies, for curtain wall library fabrication, not only shape information for components by design stage but also attribute information should be defined in more details. Using IFC property set is could be one solution. In addition, combination relationships between components should be defined.

Acknowledgement

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