Treatment of Brick Wall Systems in Early 20th Century Korea

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Abstract

This paper, which aims to identify the structure and fabric of buildings using the brick structure during modern times in Korea, focuses on connection details at foundation, each floor and roof as the most important structure components in the exterior wall through 21 architectural technical books and investigating 44 existing brick structures in the early 20th century. As a result of findings the following details could be identified. The most important concerns in the exterior wall at ground level include the formation of the foundation and bearing wall to resist lateral earth pressure in case of basements, and the installation of damp-proof courses to block damp from the ground. Other than floor frames with traditional wood girders in the exterior walls adjacent to the floor, concrete slabs with steel girders and reinforced concrete slabs have been introduced. Roof sections interlocking with exterior walls can be divided into three types, those with projecting eaves, those interlocking with the exterior wall, and those hidden behind the parapet. Unlike the eaves in traditional wood structures, the types of roof interlocking with the exterior wall for brick structures have appeared most in religious buildings. Other than these buildings, the advent of parapets to completely hide the eave line foresaw new types of buildings.

Keywords: Korean modern architecture; modern architectural technical book; brickwork; brick wall section; brick wall system; brick structure

1. Introduction

Recent studies on modern architecture included technologies for repair and reinforcing, characteristics of structure and fabric, and the fabrication and details of materials for building. These trends imply that efforts, which have been made to preserve modern architecture until now, are changing into directions to keep the existing building structures in their original condition as much as possible.

In order to keep them in their original condition, the entire data on the current condition of the buildings should first be established. Drawings in detail should exist to identify not only the history and background of buildings but their structure and fabric. There are many details which cannot be identified even from the actual measurement of buildings and there is no way to know whether or not the current conditions of the buildings have been kept as they were at the time of construction. Although accurate identification of the structure and fabric of buildings can be done through dismantlement, it also has various restrictions.

Accordingly, this study aims to identify the structure and fabric of brick buildings during modern times in Korea through comparisons and analyses of existing buildings and technical books that have been published during our modern times, which can be said to have been standards for architectural practice, with regard to brick structures that have comprised most of our modern buildings.

For such purposes, this study selected 44 buildings in brick among recorded reports that had been published until October 2009, as well as 21 books including details on brickwork among architectural technical books that were officially published before the liberation of Korea, in its attempt to analyze the connection details at the foundation, each floor, and roof as the most important structural components of wall sections.

2. Data Related to Brick Structure

2.1 Modern Architectural Technical Books Related to Brickwork

Although architectural technical books during modern times in the National Library of Korea included various books in many fields, there were 21 books related to brick structures, which were written by Japanese. Considering the details in these books, four (Books 3, 4, 8, and 17) consist of designs and drawings and others consist of details and some exemplary drawings. Book 1 that was published between 1913 and 1916 was the first publication...
among the architectural technical books for analysis including three volumes for the first, second and third parts with four volumes of sub-parts, of which the first part describes materials, structures and constructions, the third part carries the history of construction, and sub-parts depict actual measurements and structural calculations necessary for the project site.

Book 5 published in 1925 separately describes the brick structure in its Chapter 2 for the first time and Book 9 published in 1928 consists of drawings and descriptions with no separate chapter regarding the brick structure. Most of the books are organized with the brickwork and stone construction in a separate chapter thereafter. Book 8 published in 1940 summarizes the brick structure with the quoted pictures and drawings as reference in "Korean Architecture Outline II – Brick" published by the author in our country. 2)

Although these books quote original Western texts, descriptions of these original texts are not described well. 3) For such reasons, the unit size is not uniform. Original drawings in Book ① - ③ are based on inches, but Book ① uses inches, Book ② cheek, and Book ③ contains little description on the unit size. Book ⑤ modifies and uses the unit and terms on the original Western drawings and Book ⑬ even shows the metric unit, while other books use the cheek unit.

In addition, terms are used in a confusing manner with no uniform definition. Terms for the Japanese roof frames and translations for materials in the Western truss are applied together to roof frames, and their members are described differently in each book.

2.2 Existing Brick Structure

Considering 44 existing brick structures by the period of construction on which the actual survey was carried out, they include 5 in the 1890s, 6 in the 1910s, 13 in the 1920s, 7 in the 1930s, and 6 in and after the 1940s. Considering their use, 13 religious facilities are the most that still remain in addition to 1 educational facility, 6 banks and public facilities respectively,

Table 2. Brick Structures Classified by Period Among the Currently Existing Modern Architectural Properties (As of Oct. 2009)

| NO | Name of Cultural Properties | Use | Location | Year of Construction | Floor | Joint Types |
|----|------------------------------|-----|----------|----------------------|------|------------|
| 1  | RC 248 | Mr. Pheon-芝定 Rock Structure | Bank | Seoul | 1898 | 1 | △ |
| 2  | RC 252 | Yokaham Catholic Church | Seoul | Seoul | 1892 | 10 | △ |
| 3  | RC 255 | Woryong Catholic Church | Seoul | Seoul | 1892 | 26(c) | △ |
| 4  | RC 256 | Mission House in Junghak-dong | Church | Seoul | 1896 | 1 | △ |
| 5  | RC 258 | Myeongdong Cathedral | Cathedral | Seoul | 1989 | 10(c) | △ |
| 6  | RC 259 | Seoul Catholic Church | Cathedral | Daegu | 1902 | 1 | △ |
| 7  | RC 264 | Old Belgian Consulate Office | Consulate | Seoul | 2001 | 10(c) | △ |
| 8  | RC 265 | Daehan Medical Center | Hospital | Incheon | 1905 | 2 | △ |
| 9  | RC 267 | Old Gyeongbok Palace | Residence | Incheon | 1907 | 2 | △ |
| 10 | RC 268 | Former Food Warehouse in Mokpo | Warehouse | Mokpo | 1910 | 2 | △ |
| 11 | RC 269 | Auditory of Jungang School | Schoolhouse | Seoul | 1914 | 2 | △ |

Fig.1. Modern Architectural Technical Books

<From Left ②, ④, and ⑬>
5 residential facilities, 2 medical facilities and 1 warehouse among 44 buildings in total.

As shown in Table 2., most of the buildings are built in two stories or fewer, but religious buildings have a single large hall. In addition, there are some basements under the altar in religious buildings, and most of the buildings with any complete basements have a basement built half under the ground using slopes.

The first floor in these brick structures consists of the traditional wood flooring systems, and the upper floors are composed of concrete slabs with steel girders and reinforced concrete slabs that have been built after the 1930s. Except for the vault and arch, the rest of them show the western wood roof truss.

2.3 Composition of the Brick Wall Section

Fig. 2. shows examples of wall sections and elevations for a two-story brick structure cited from an architectural technical book, and 'a' seems to have referred to an original Western drawing, while 'b' is thought to have been drawn and attached. The left part of the drawing enables us to identify the number of brick courses as it indicates the horizontal joint with descriptions on a decorated brick wall. The height of a building, i.e. the height from the foundation to the top of a tie beam, is 12.06m (39 cheok and 8 chon) with the height of ceiling in the first floor 0.97m, the height of ceiling in the second floor 5.75m. The height of windows for both the first and second floor is 1.88m from the top of the window shelf to the bottom of the transom, the height of the dado 0.97m, and the width of window 1.03m. In addition, the crushed stone bed for the concrete foundation is 0.33m thick, the thickness of concrete 0.73m, its width 1.64m, and depth of the foundation 1.73m. The wall on the first floor is 2.5B thick, and the wall in the second floor is 2B thick by decreasing by a half brick.

Fig.2.-b shows examples of a structure with a height of 9.88m from the foundation to eaves. The wall section is done with 2B for the first floor and 1.5B for the second floor. The floor is set 0.85m above the grade. The height of the ceiling for the first floor is 3.94m and a window shelf is located 0.71m from the floor, and there is a hung window with an opening height of 2.12m, while a pivot window is on top of it. The top of the window resists vertical loads above with steel lintels, while the stone lintels in the outer section are decorative. There are swing windows at 1.67m (5 cheok and 5 chon) high in the second floor. A section at the eaves shows the bolt connection detail of the wood roof frame to the stone moulding.

3. Brick Wall Sections at Grade

The most important functions of details are to block damp and to resist lateral earth pressure from the ground in the wall section at the grade. Architectural technical books describe them with sections under the classification for damp-proof courses and retaining walls.

There are three types of brick wall which absorb damp. First is damp from the ground, second is damp absorbed from the brick surface, and third is damp penetrating from the top of a brick wall. The damp-proof courses and wall sections are different as the first floor is located below or above the grade in the case of no underground floor, and if a dry area (open area) exists or not, if there are basements.

3.1 Damp-Proof Course for Floors Above the Ground

Installation of a damp-proof course with the general corbelling brickwork in the foundation can be applied to floors above the ground. The corbelling brickwork in the foundation is done to deliver the load on the top to the foundation, and the depth to the top of concrete foundation is 60.6m. In order to prevent the increase of damp and decay in wood materials, the damp-proof course is installed horizontally between 15cm or higher and 30cm from the ground to the top. The entire wood construction is then carried out on top of the damp-proof course. The plain concrete is placed on the ground under the wood floor, and bricks are used for ventilation in the sealed space between them as shown in Fig.3.

Examples to estimate specifications on the foundation as such might include the Myeong-dong
Cathedral (5-HS258, 1898) and the Main Building of Daehan Medical Center (12-HS248, 1908). Considering that the stone foundation under the continuous walls at the grade in Myeongdong Cathedral is constructed with granite, the foundation wall is thought to be granite and there are openings for ventilation in the middle of the stone ground on both sides Fig. 4.

The structure of the foundation for the main building of the Daehan Medical Center forms load bearing walls with bricks placed on the continuous footing. Base stones are installed up to 30cm from the ground. Holes are filled with casting grilles on top of the ground stones with openings for ventilation. The first floor level is 75cm higher than the ground level. Fig. 5. prepared based on estimates shows the foundation details with corbelling brickwork to make each alternate row vertically aligned in 3.0B thick wall.

### 3.2 Damp-Proof Course for Basements

If the floor is located below the ground, in other words, if the underground floor is constructed under the damp ground, the damp-proof course is formed by injecting melted asphalt into the half brick wall with a 17cm gap, in addition to inside the walls. To construct the cavity wall, plates are inserted between the main wall and the half brick wall to keep the gap and three courses are laid. The asphalt is injected in to the space between the two walls after cleaning the wall surfaces.\(^6\)

The old Belgian Consulate Office (8-HS254, 1905) was the only building with some underground floors at that time, where stones are placed outside of sections interfacing the ground with bricks placed on the inside. The continuous footing was placed on the concrete foundation at the time of construction,\(^7\) and the underground floor is thought to have been built with plain concrete as well. Fig. 6.

When the underground floor is formed, it is necessary to increase the thickness of retaining walls because the pressure on them increases. However, this method is not economical at all, so an arch form retaining wall is adopted to resist the lateral force as shown in Fig. 7.-b. At this time, the space for retaining walls should secure a size for easy cleaning and drainage. Fig. 7.-c shows a case of installing the independent retaining wall with a larger space (Open area), and this space is necessary for the lighting and ventilation for each underground room.

### 4. Placement of Floor Frame

The floor structures in the technical books can be divided into the wood structure without the fire-resistant functionality, the steel structure with the fire-resistant functionality (using cinder concrete), the concrete structure and the reinforced concrete structure. The brick structure can be joined with all the floors as stated above unlike the wood structure where the wood flooring can only be joined. These floor structures have changed from the wood flooring and steel girder + plain concrete floor to the floor with a reinforced concrete girder. Although there are differences in the classification depending on technical books, floor systems are divided into the wood floor and the fireproof floor in this paper.

#### 4.1 Placement of Wood Floor Frame

In order to support the ends of floor joists on the first floor, the thickness of a wall is reduced by a half brick to install wall plates and place floor joists. However, in reality this method is extremely rare.

Floor joists cannot be supported, unless brick corbelling is done or the thickness of wall is increased to make space for wall plates.\(^8\) Fig. 8. shows the details of the brick corbelling, the thick brick wall from the footing, and anchor bolt to attach wall plates.
to the wall. Although the anchorage detail with anchor bolt is expressed as a wood construction in "Practical Construction" Book, there is a way to attach to brick walls with steel anchorages.

The types of upper floors can be divided into the single floor, double floor and framed floor, where the installation of wall plates can be carried out more easily than on the first floor. Wall plates are attached to the wall for the single floor, floor joists are spaced at 30-40cm and the floor decks are placed on it. However, floor joists are inserted into the wall and reinforced by cross bridging for the small room where the beam is not necessary as shown in Fig.9. Examples of this method include Switchu's House (14-TC24, 1910), Speer Hall (16-RC258, 1911), Missionary Houses (21-RC133, 23-RC233, 1921) and Halls (26-RC26, 1923) for residential buildings with many room sections. For the double floor frame, beams are placed on the wall plates and floor joists are spaced properly on the beam. Finally, floor decks are laid on floor joists. The left drawing in Fig.10. represents the double floor frame for a 5.45m wide span in the brick structure. Twenty-four centimeter wide and 40cm long beams are placed every 1.82m on stone templates and wall plates are attached to the wall. This method is widely applied to buildings for public offices and halls including Mokpo Municipal library (6-HS289, 1900) (Tables 2-12, 18, 24 and 28).

The framed floor is applied to buildings, where the distance between walls is 5.5m or longer, with the girders spaced at 3-4m. Beams are laid perpendicular to girders within 1.8m in this system. The right drawing in Fig.10. shows an example of a framed floor with 6.06m span in the brick structure, where 30.3cm wide and 45.4cm long girders are placed every 3.03m and 15.1cm wide, 21.2cm long wall plates are attached to the wall, and beams are placed on girders every 1.73m. This method is seen in the restaurant Gonghwachun (9-RC246, 1905), Unhyeongung Palace (13-HS237, 1910) with large halls, buildings for banks (31-RC29, 1929; 33-RC181, 1930), classrooms in a school (19-HS282, 25-HS283, 1923), and the first floor of an auditorium (27-RC5, 1923, 38-RC60, 1937).

**4.2 Placement of Fire-Resistant Floor**

Steel beams are placed at a specified distance and an arch is formed with bricks and waveform steel plates between them for the floor in the steel structure floor system, on which a wood flooring is constructed. However, a fire-resistant floor can be constructed with concrete for soundproofing or fire-resistance. Waveform steel plates are also applied not in an arch shape but in a flat shape. At this time, waveform steel plates with a larger arch than normal were used. The steel structure members were connected to the anchor in the brick wall. (Fig.12.-a)

Stone templates are used for the installation of steel beams in the brick wall while free expansion is secured from variations in the temperature as the space around steel beams is filled with bricks or left empty. The ends of beams are not inserted into a wall, but are firmly attached to the wall with steel anchorages at the ends of beams. Depending on the circumstances, wrought iron or steel plates are applied for reinforcement when stone templates are used. (Fig.12.-b) Some of these examples can be seen in the first floor of the old Belgian Consulate Office (8-HS254, 1905), as well as Seokjojeon in Deoksu Palace (Historic Sites No. 124) and Main Building of the Chosen Bank (Historic Sites No. 280) as the existing buildings.

Reinforced concrete slabs and girders appear for the first time in descriptions of the flat roof in "Knowledge of Architectural Structure" Book (1925). Among details in other books, examples of the reinforced
concrete slab can be identified in a separate chapter for reinforced concrete structures. 

"Japanese and Western Architectural Structure" Book ⑲ and "Brick structure" Book ⑳ show examples of connections for brick walls in the middle of floors with concrete slabs and girders.

The reinforced concrete slab has been applied to the ground floor since the early 1900s. It was introduced to the main structure of buildings since the construction of the Chosun Government General in 1916. Its main use can be said to have started from the 1920s with the construction of Seoul City Hall. It seems to have been used from earlier times by the Dong-yang Cheoksik Company (22-RC98, 1921) as the existing building, and the reinforced concrete slab and girder are seen in almost all buildings since the 1930s. The previous wood floors have been changed to reinforced concrete slabs for the old Belgian Consulate Office (8-HS254, 1905), the Seobuk Institute Hall (10-RC53, 1907) that has been moved and restored recently, and Choyang Hall in Hyomokdong (24-RC4, 1922).

5. Placement of Roof Frame

The section where exterior walls interface with the roof in a building shows the style and design intent of the building, which can be seen as a compromise between the East and West or as a style trend. Under the classification depending on the shape of eaves, there are three types in the division such as the projected eave line from exterior walls, the exterior wall line which aligns with the roof line without eaves, and the hidden roof line behind parapets. Fig.18. shows 3 types of roof details of existing buildings classified based on the period.

5.1 Types with Eaves

Sixteen types with eaves like those in wood structures were 16 out of a total of 44 buildings, occupying about 1/3 among buildings for the research. This ratio is smaller than 20 buildings in types without eaves.

The end of a brick wall is constructed without any cornice in general as shown in Fig.15.-a. The major example includes Nagasaki 18th Bank(11-RC372, 1907). The structural and decorative roles are done with stone cornices as stone templates for 'b' and the brick corbelling for 'c'. It is general for pole plates supporting wall plates and a common rafter supporting the tie beam at the center line of a truss tie beam and a principal rafter to be located in a straight line.

Although most of the examples do not expose a common rafter with soffit, the examples for the exposed common rafter without ceiling among types of eaves only include Suwitchu's House (14-TC24, 1910) and Curtis Memorial Hall (28-RC259, 1924) as Western buildings.

5.2 Types of Roof Lines Interlocking with Exterior Wall

Methods to extend exterior walls in line with the roofs without eaves occupy most types among brick structures. These 'a'-'d' types are mainly seen in religious buildings. They are seen through all periods, starting from the Yakhyeon Catholic Church (2-HS252, 1892), Wonhyo Catholic Church (3-HS255, 1892), Myeongdong Cathedral (5-HS258, 1898) in the 1890s to the Catholic Church in Seongnae dong (44-RC141, 1957) in the 1950s.

Decoration and waterproofing are solved by cornice details on the upper wall, and consist of two types such as the decorative cornice without stone plates as shown in Fig.16.-a and cornice as stone template 'b'. At this time, rectangular gutters or semicircular gutters are located on the top of stones.
shows that the location is a little lower than the contact point. No gutter is shown in 'g', which is assumed to have installed metallic materials, not bricks or stones, for cornices on the upper wall.

5.3 Types with Parapets

The brick wall is extended and the end of the roof frame rests on a wall plate attached to parapets reduced by a half brick. One side of the rectangular gutters is attached to brick walls and the other side is extended to the lower section of the roof tiles. Parapets are extended as high as not to hide the entire roof and to function as a gutter. These types appear in 6 out of 44 cases.

They can be divided into those with stone cornices (Fig.17.-a & b) and others with brick walls only (c & d), depending on the presence of decoration in parapets. Stone cornices are projected out from parapets to function as stone plates and decoration. Stone plates separated from the cornice decoration are also installed to a height different from the tie beam, unlike the location of cornices. These examples include the Daehan Medical Center (12-HS248, 1907), the old Dongsan Hospital (34-RC15, 1931), and the First Bank, Yeosu Branch (40-RC170, 1942).
Types with brick walls only are constructed in a flat style without any decoration or provide an elevation with variations through the brick corbelling, and their capstones are all made of stone materials. The lower section of a tie beam is mainly supported with stone templates, i.e. stone materials. However, even wood wall plates are applied and both stone templates and wall plates are also used. These examples include the Nippon preferential stock company (1-RC248, 1888), old Naju Police Station (15-RC34, 1910), and Gonghwachun (9-RC246, 1905).

6. Conclusions
As a result of findings with the focus on connection details at foundations, each floor and roof as the most important structure components in the exterior wall through 21 architectural technical books related to the brick structure that had been published in the early 20th century and field survey of 44 existing brick structures, the following details could be identified.

The most important concerns in the exterior wall at the ground level include the formation of foundations and bearing walls with the proper thickness to deliver vertical load from the upper structure to the ground and to resist lateral earth pressure in the case of basements, and the installation of damp-proof courses to block damp from the ground.

Other than the single floor and double floor with traditional wood girders, cross bridging was also used. As reinforced concrete slabs with steel girders and steel plates in an arch shape have been introduced since the 1930s, these materials have reduced the thickness of walls by 1/2 in some place members, corbelling brickwork, and the placement of an arch in the top of holes after members (wood beams or steel beams) are placed on stone templates inserted into a hole drilled into the wall and corbelling brickwork.

Roof sections interfacing with exterior walls can be divided into three types which are the projected eaves, flush with the exterior wall, and hidden behind the parapet. Unlike the type of eaves in the traditional wood structure, the types of roof flush with the exterior wall for brick structures have appeared most in religious buildings. Other than these buildings, the advent of parapets to completely hide the eaves line foresaw new types of buildings.

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Endnotes
1 Modern architectural cultural properties as of October 2009 include 510 cases in total, including 215 wooden buildings, 159 brick buildings, 46 stone buildings, 5 cement block buildings, 60 RC buildings and 21 other buildings. Among them, 131 cases have been published with actual survey reports, of which the brick structure with detail drawings for the exterior walls include 44 cases.
2 Architectural technical books were not published from 1943 to the early 1960s after the liberation.
3 Although the same illustration as that in "Brick & Masonry" by Charles F. Mitchell could be seen in many books, there was no description in the original text. Any description for the quoted literature was only shown in Book ①, ⑪ and ⑫.
4 As 1 cheok = 30.303cm, this study applied 30.3cm to any conversion and the calculation results are rounded out at the second digit from the decimal point. Hereinafter, the unit is unified in the metric measurement.
5 Shounosuke Shikakame, "Architectural Structure Descriptions", 1928, p. 48, damp proof course is described as D.P.C in abbreviations on drawings.
6 Katsushi Ishikawa, "Western House Structure", 1925, pp.101-102.
7 It has been known that concrete was applied to the foundation of the English Consulate Building, which was established in 1891 in Korea.
8 Joichi Kogure, "Architectural Design Drawing", 1923, p.313.
9 This method was used for the second floor of the Belgian Consulate, and this floor is called the single floor. In such a case, a larger size of floor joint is applied than the general size.
10 The structural method to form a brick arch with a concrete finish was used for the first floor of the old Belgian Consulate, which was restored with a modified design using the reinforced concrete slab when it was dismantled and moved in 1980.
11 Byoung-Ok Jeon, Hoon Yi, Tai-Young Kim (2006), "A Study on the Appearance and Structural System of Concrete Slab in the Early 20 Century", Journal of the Architectural Institute of Korea, pp.173-180.

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