Treatment of Western Wooden Roof Trusses in Early 20th Century Korea

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Abstract
As a result of investigating 16 architectural technical books and 72 buildings of modern architectural properties, this paper attempts to illustrate the various treatments of Western wooden roof trusses mixed with Korean roof elements in early 20th century Korea. During this time, new styles such as king post truss, queen post truss, wood-steel composite roof truss, and other roof structures were introduced; which resulted in a mixed style of wooden roofs that used braces, like a strut, in traditional Korean roof structures with a horizontal collar tie in the Western style for the purpose of increasing rigidity. Other changes also appeared in the various types of joint details such as rafter joint, principal rafter joint, and eave details.

Korean carpenters tried to accommodate traditional elements and new western style systems in the structural aspect of roof construction. Through the extent to which the findings can be specified for some treatments in the historical and technical standpoint of Korean modern architecture, implications are briefly considered for a unique Korean roof shape in the process of modernization.

Keywords: Korean Modern Architecture; Modern Architectural Technical Book; Wooden Roof Truss; King and Queen Post Roof Truss; Principal Rafter(Injabo)

1. Introduction
Prior to the opening of Korea to foreign countries, Korean architecture was comprised of post-and-lintel wooden structures that were built by the traditional craftsmen and master carpenters. The opening to the outside world introduced new architectural techniques and materials, which brought about many changes in the structural aspects of Korean architecture. The emergence of brick masonry and stone masonry building impacted on the traditional wooden post-and-lintel style, resulting in changes from the foundation, to the wall, and to the roof. In particular, one of the major changes was the transition of wooden roof structures from traditional post-and-lintel style to trusses.

With the opening of Korea to the outside world, the Ordnance Department of Korea, foreign missions, and ecclesiastical architectures introduced the nation a complex form of wooden arch, vault, and above all truss. Subsequently, Western style wooden roof trusses, Japanese-Western mixed style roof trusses, and Korean-Western mixed style roof trusses built by Korean traditional craftsmen began to appear. Later, the wooden roof truss, as a new wooden post-and-lintel style, would actively spread to meet the request of the time and impact of modern architectural technical books. With this background, this study is based on the references of modern architectural techniques and examples of current buildings to provide a history of how Western style wooden roof trusses were introduced and developed in Korea. This study will also present the accommodation aspects based on the practicality of the foreign wood technology. For this purpose, the theoretical aspects of wooden roof trusses reported in technical documents on modern architectural structure are reviewed. Wooden roof trusses of modern architectural properties in the survey reports are classified to characterize each type. In particular, the specific treatments related to traditional Korean wooden roof structures are discussed.

2. Introduction of the Wooden Roof Truss in Korea
2.1 Korean Roof Structure
Before opening to the outside world, the roof structure in Korea was wooden post-and-lintel construction. The roof structure members consisted of a main girder (Daedlbo), middle girder (Jungbo), upper girder (Jongbo), collar tie (Jangyeo), cross beam (Dori), purlin post (dongjaju), king post(Daegong), and common rafter(seokarae). the division into long
rafters(jangyeon) and short rafters(danyeon) started from the 5-beam house. Korean roof trusses hang girders on either the purlin posts(Dongja gidung) or king posts(Daegong), which are erected to hold cross beams which support the roof structure. Korean traditional buildings are classified into four categories: the 3-beam, 5-beam, 7-beam, and 9-beam structure. This is dependent on the number of beams on the cross sectional area, regardless of the number of front compartments.

Firstly, with respect to roof structure of a 3-beam structure, the main girder spanned the capital on top of the column, and was interconnected with collar ties that the pole plate(cheomadori) laid on. The king post was erected in the center of the main girder and ridge beam(Jongdori) was placed on top of it. The ridge beam and pole plate were connected with long rafters, which crossed each other near the ridge beam; the ridge piece(Jongsimmok) was placed on top of the intercrossing rafters. Secondly, in the case of the 5-beam structure, the purlin post was erected in the quarter of the main girder, on which the upper girder laid on. The king post was erected in the center of the upper girder where ridge beam(Jongdori) was placed on top of it. The ridge beam and purlin were connected with a short rafter, and purlin and pole plate were connected with a long rafter as well.

2.2 Appearance and Development of Wooden Roof Trusses after Beonsachang

The appearance of the Western style wooden roof trusses in Korea started with Beonsachang, which was completed in 1884. The roof of Beonsachang was the first Korean wooden roof truss which was double layered. The lower roof was similar in structure to a combination of a queen truss and traditional rafter. The upper roof was constructed on a complete king truss. With respect to the lower roof structure, the tie beam had a large section, comparable to the conventional type of main girder, and the top portion of the queen truss was removed. Two queen posts were erected on the middle girder and the king truss was placed above it. In order to strengthen the connection between the queen post and middle girder, struts were attached, and the queen posts were raised higher to provide ventilation windows. This truss is the earliest example of the currently existing wooden king trusses, in which such a treatment combining Korean roof elements with Western ones can be seen.

From the late 19th century and early 20th century, before modern architectural technical books were introduced, Western roof truss buildings which were designed and constructed directly by people from the West and not through Japan emerged. Most of the structures at the time were largely for religious and foreign consulate buildings. Yongsan Theological School(Table1,19), built in 1892, already utilized the wooden king truss; Jeongkwanheon in Deoksu Palace(Table1,3), built in 1900, was the first to use a wood-steel composite roof truss. The West Pavilion of Joongang High School(Table1,34), built in 1921, used the wooden queen truss; Seoul Station, built in 1925, already used the valley rafter truss roof. Complex construction using the wooden arch, vault, and truss also appeared at this time, mostly in the construction of religious buildings.

Upon close survey of these existing modern architectural properties, the roof structure can be determined. When a survey of 72 buildings was completed in December 2007, they were classified by roof style. There were 10 Korean-style, 7 Japanese-style and 55 Western-style. 23 units of Western wooden roof trusses were observed with king posts, 12 with double queen posts, and 20 others. Chapter 3 discusses the characteristics and specific details of each style.

| basic form | 3-beam structure | 5-beam structure | 7-beam structure |
|------------|------------------|------------------|------------------|
| variation of basic form | 3 columns | a high column | 2 high columns | 3 columns | a high column | a center high column |
| use | gate & storage | mostly in private house | mostly in temple & palace |

Fig.1. The Basic Form and Variation of Korean Wooden Roof Structure

Fig.2. Wooden Roof Structure, Beonsachang, 1884
2.3 Wooden Roof Truss introduced in Modern Architectural Technical books

Most of the modern architectural technical books in early 20th century in Korea were compiled and published by the Japanese. These books were published around the 1930's when the Western wooden roof truss was being commonly accepted. In first half of the period, books were simply edited with illustrations and descriptions on Western king truss and queen truss in roof parts. They were basic references prepared for beginners. In the latter half of the century, books provided detailed information for the Western wooden roof, members and steel accessories, and even modifications of these structures. Western wooden roof truss in the modern architectural technical books are classified mostly into king truss, queen truss, mansard, and wood-steel composite roof truss.

"Japanese Architecture" summarizes characteristics of Western wooden roofs as follows. Firstly, all roof members consist of a triangular structure which has little deformation even when a thin material is used. Such buildings are often used a gathering places or auditoriums, as there are no columns in the center of the long span. Secondly, the builders needed to understand the structural system of the roof as it is dynamically engineered, as well as pay attention to the use of steel accessories and bolts. Thirdly, it is very convenient to construct long buildings, or several buildings, because an identical scale of roof is used, and the standard materials can be used easily.

What made it possible to slowly modernize the Korean traditional wood construction were the new Western wood construction techniques, rational and easy construction methods, long spans, and the use of nails, bolts, and other steel accessories. In the process, a consensus was gradually made for a unique style adding traditional elements to the Western wooden structure.

With the appearance of nails, bolts and other steel accessories, traditional technique was blended with Western method. The roof materials were decreased in weight and the roof size was reduced as well due to use of thinner timber. Western roof trusses constructed through the analysis of dynamic forces had greater roof rigidity. This was based on the principle of the "stability of triangle shape". That was able to prevent weakness of connections with nails and bolts.

3. Characteristics of Remaining Wooden Roof Trusses by Each Style

3.1 King Post Roof Truss

(1) Classification by span distance

The king post roof truss is the most commonly used roof truss and accounts for 23 cases out of 55 Western roof trusses. The king post roof truss can be divided by span distance: 12.5~16.2m, 9.0~12.6m and 4.5~8.1 m. The span can be extended up to 20 m with the interval of 2~3m. Types with spans of 12.5~16.2m have 6 sets of hanging posts(Daldaegong) and struts(Bitdaegong), respectively. Except for Yosu Aeyang Church (1-RC32,1928), which has 6 struts, others have 4 struts and 2-4 hanging posts each. The hanging post in Jeongkwanheon is made out of steel. Types with span distances of 4.5~8.1m have 2 sets of hanging posts.

Fig.4. King Post Roof Trusses classified by Span
Table 1. Wooden Roof Trusses classified by Type among the currently existing Modern Architectural Properties

| NO | PREVIOUS USE | LOCATION   | YEAR | TYPE | BAY(m) |
|----|--------------|------------|------|------|--------|
| 1  | RC 32        | CHURCH     | 1928 | Brick | 14.91  |
| 2  | RC 29        | BANK       | 1929 | Brick | 14.75  |
| 3  | RC 82        | BANQUET HALL | SEOUL | 1900 | Brick | 15.27  |
| 4  | HS 244       | HOSPITAL   | 1908 | Brick | 12.73  |
| 5  | HS 289       | CONSULATE  | 1900 | Brick | 12.06  |
| 6  | RC 56        | OFFICE     | 1941 | Brick | 10.90  |
| 7  | RC 7         | CATHEDRAL  | 1955 | Brick | 10.88  |
| 8  | RC 134       | CHINJU     | 1933 | Brick | 10.84  |
| 9  | RC 138       | AUDITORIUM | KWANGJU | 1911 | Brick | 9.33   |
| 10 | RC 36        | HALL       | 1923 | Brick | 10.00  |
| 11 | RC 178       | SCHOOLHOUSE | IKSAN | 1932 | Brick | 10.00  |
| 12 | RC 162       | CATHEDRAL  | 1955 | Stone | 9.80   |
| 13 | RC 3         | AUDITORIUM | TAEJU | 1923 | Brick | 9.57   |
| 14 | RC 68        | AUDITORIUM | KOHUNG | 1937 | Brick | 9.44   |
| 15 | RC 126       | RESIDENCE  | 1913 | Stone | 9.40   |
| 16 | RC 173       | SHOP       | 1929 | Brick | 9.12   |
| 17 | RC 70        | STORAGE    | 1940 | Wood  | 9.10   |
| 18 | RC 149       | COUNTY OFFICE | CHINJU | 1943 | Brick | 9.00   |
| 19 | RC 149       | CATHEDRAL  | 1892 | Brick | 9.00   |
| 20 | RC 71        | SCHOOLHOUSE | KWANGJU | 1935 | Wood  | 7.93   |
| 21 | RC 74        | SCHOOLHOUSE | KWANGJU | 1957 | Wood  | 7.27   |
| 22 | RC 57        | SCHOOLHOUSE | KWANGJU | 1936 | Wood  | 6.35   |
| 23 | RC 34        | POLICE STATION | NAJU | 1910 | Brick | 5.80   |

* HS : Historic Sites, TC : Tangible Cutural Heritage, RC : Registered Cultural Heritage

As described above, Yosu Aeyang Church(1-RS12,1928), Korea Express Co., Ltd Chechon Office(6-RS56,1941), Chinju Okbong Catholic Church(8-RS154,1933), Taegu College of Education, Main Building(12-RS55,1923) and Auditorium, Former Tongyoung–gun office(16-RS149,1943), and Yongsan Theological School and Wonhyo Catholic Church(17-HS255,1892) followed by basic pattern in principle and the rest of the buildings had less hanging posts and struts as compared to the number of spans. The Mogpo Branch Office of the former Honam Bank(2-RC29,1929) and the main building of the former Daehan Hospital(4-HS248,1908) did not have wooden hanging posts; but horizontal members were attached to principal rafters(Injabo) on each side to supplement of insufficient strength.

In addition, the roof truss structures of Jeongkwonheon in Deoksu Palace(3-RC82,1900), and the former Speer Hall in Kwangju Jennie Speer Memorial School for Girls(9-RC158,1911), have clunky joints where the principal rafter, strut, and hanging post do not meet at one point.

(2) Connection and size of each members

The emergence of nails resulted in changes of ridge parts in roofs. Previously the ridge beam was placed on top of the intercrossing rafters; later ridge beams were placed directly on top of the king post, and rafters with butt joints were placed on top of the ridge beam or attached to its sides.

Connections between the king post and strut on the tie girder was classified into 2 types; one is 'tenon joint with beveled projection' at the bottom of the king post(Kingpost 2,4,12,15/Queenpost 27,29,30,33), the other is a beveled shoulder joint using an iron clamp on both sides (Kingpost 1,7,11,16,22,23/Queenpost 25,26,28). It began with a connection on a beveled projection, but gradually changed to a bevel shoulder simply carving the bottom of the king post.

Each member size of principal rafter, tie beam, and king post were 100 mm (width)×180~200 mm (depth). The 4.5 - 8.1m long span was notably smaller in width and depth. In the case of spans of 9.0 - 12.6m, and 12.5 - 16.2m, they used members which have greater width than depth, and square logs had relatively larger cross sectional areas. The member sizes of strut and hanging posts had a wide range between 100~200 × 60~50 mm.

3.2 Queen Post Roof Truss

(1) Classification by the presence of supporting struts

The queen post roof truss is used for an attic room(Bokookbang) inside the roof or to decorate outside with bent roof trusses. Spans of members are larger than those of king post roof trusses and installed...
under a squared upper girder with a strut of increasing rigidity. Normal spans are determined between 10 -15 m, and the interval of 1.8-3.5 m is appropriate. In general, span and interval of queen post roof truss is wider than that of king post roof truss. Unhyeon Palace Legation of Western Countries(24-HS257,1910) had the biggest span of 20.4 m out of the surveyed buildings.

![w/ supporting strut](image1)

![w/o supporting strut](image2)

![Mansard roof truss](image3)

Fig.7. Queen Post Roof Trusses classified by Type

Queen post roof trusses have struts when the interval between queen posts is 5 m or wider. It can be divided into two types by the presence of strut. This style is clearly shown in the example of Kangkyong Joongang Elementary School Auditorium (23-RC60,1937), where the upper girder and queen post were fixed with the strut. This has the same shape like a batten(Qualsade) shown in Japanese roof truss.

Examples of queen post truss without struts are Chinhae Post Office(25-HS291,1912), West pavilion of Joongang High School(30-HS282,1921), Naju Noanri Catholic Church(31-RC44,1927). A longitudinal section of the Jinhae Post Office shows that the center part was built with a king post and mixed structure, not queen post roof truss, and side wings on each side are made up with king post roof trusses. Tensional members are in the form of wood-steel composite.

Besides, Chinchon Deoksan Brewery(24-RC58,1930) has erected by high inner post and king post roof truss in the center of tie beam. When examined in connection with upper king post roof truss and lower roof, the queen post roof truss was observed. Hanging posts were extended to the upper part to support the root with ventilation windows on each side.

Kimje Agricultural & Rural Infrastructure Corporation Juksan Office(28-RC61,1926) and Guikoksori Union Office and Storage(29-RC181,1930) were constructed with the mansard roof, a type of queen post roof truss. The roof truss is divided into upper and lower parts; and the slope of the principal rafter in the upper part is bigger than that of lower one, which has a great advantage when used for internal spaces inside the roof.

(2) Joint detail and size of members

According to connection methods for upper girders attached to king posts and principal rafters, the queen post truss was divided into 3 types by '①Attaching both upper girder and queen post to one principal rafter', '②Joining upper girder and principal rafter with each other and with a queen post on center above', and '③ Attaching a principal rafter to the bottom of the upper girder and fixing with common rafters on top'. Most buildings used in the form of type ②.

For the dimensions of queen post roof truss, the principal rafter and tie beam(Pyongbo) are greater than 120 × 200mm in width and depth, which is bigger than the king post roof truss. The member size of the queen post is 150mm square-type and bigger than the king post. Hanging posts, struts and diagonal braces(beotimdagong) are also relatively bigger conforming to the member size of the post.

3.3 Various Roof Structures

(1) Scissor-bracing

Jeongdong Church(32-HS256,1896) has an X-shaped intersecting brace to reinforce the structure and is made with round vault. By the above appearance at the top roof of Myeongdong Catholic Church(36-HS258,1898) and the Taegu Gaesandong Catholic Church(37-HS290,1902), they seem to have the style which were introduced in late the 19th century to early 20th century by western missionaries.

During this period, when the Western roof truss was being introduced, the complete truss structure as a triangle was not a commonly accepted practice. But the basic form of the principal rafter was being structured and reinforced by braces. Scissor bracing with double trusses, girder and brace, and a scissor bracing in particular were used to bond vertical members and horizontal members. In addition, the member placing, vertically or horizontally, at a proper intersection prevented vertical deflection and axial distortion.10) The roof truss at the Curtis Memorial Hall in former Kwangju Jennie Speer Memorial School for Girls(33-RC159,1921), used an X-shaped beam as a bottom chord, and supported the principal rafter with the post above the intersection. This is similar in shape to the roof structure of modern churches as the building was used for a place of worship.

(2) Vault structure and principal rafter

Myeongdong Catholic Church, Daegu Gaesandong
Catholic Church, Chonju Jeondong Catholic Church (39-HS288,1914), Incheon Dapdong Catholic Church (38-HS287,1937), and Ulsan Unyang Catholic Church Main Hall and Auditorium(41-RC103,1936), were built with a vault structure, and principal rafters were installed above the vault. The vault structure above was insufficient to support the load of the roof. Therefore, for increased rigidity, a wooden post was erected from the capital on top of the colonnade columns to the ceiling and closely connected to the principal rafter. Wonju Wondong Catholic Church (40-RC139,1954) has a wooden truss structure, and the ceiling was interconnected with horizontal lumber and short vertical lumber to form an oval. The roof trusses of Ulsan Unyang Catholic Church Main Hall and Auditorium have half circle arches intruding the existing king post roof truss to support the loads. The numbers of tie beams under the truss are gradually reduced as insufficient stress is supplemented by rafter brackets(Seokaraebal).11

4. Western Roof Style mixed with Korean Roof Elements

4.1 Addition of Western Roof Element to Korean Roof Style

Examples of Korean-style roof structures with addition of Western wooden roof trusses are Kanghwa Anglican Church(HS424,1900), Hwasan Catholic Church(HS318,1906) and Donamjang(RC91,1939). Kanghwa Anglican Church, which is double story in height. It has big open hall like a choir loft made by high inner columns(Naejingoju). The roof of the hall was supported by a sub-beam(Tiyeryang) that connected to the high inner columns. A pole plate was placed on the horizontal beam, and a sleeper(mungechangbang) was placed in the middle of the high column with the common rafter hanging on it. The upper roof in the main building is a 5-beam Korean style with a girder between the high columns where a pole plate was placed. The upper girder of the compartment formed by the high columns where a pole plate was placed. The upper girder of the compartment formed by the high columns was divided into three place posts, and a purlin was laid on top of it. Girders and beams were all fabricated of squared timbers. It is considered that the simplified square plate(Napdori) is one of the Korean roof elements.

Hwasan Catholic Church is also double story in height with inner high columns; and the roof of the chapel is of Korean structure with 7 beams, and no middle girder or upper girder. Instead of an upper girder, a horizontal collar tie was inserted. Also bracings, such as struts used from Western wooden roof trusses, were inserted based on the principle of "stability of the triangle shape" to increase the strength.
resulting in a long-span building. It also is not the double bend type with long rafters and short rafters, instead all rafters are bent where the cross beams were placed, which was a triple bend type. However, it is similar to the Western single pitched line with gentle curve, unlike the traditional double pitched line. Roof top was intersected with rafters and placed with ridge beam, also ridge piece at the center. Rafters were laid on outer pole plate(Oemokdori) to express Korean traditional style.

Donamjang is a Korean roof truss made of 7 beams. It is a hip-and-gabled roof(Paljakjibung) with single and double eaves consisted of flying rafters(Buyeon). It is a type of square plate house(Mindorijip) having a cross beam right above the collar tie on top of the columns. As compared to other Korean structures, it has a higher ceiling, longer posts, and the shape of the principal rafter without rafter bending at the purlin. This would provide an attic in a Korean building structure.

4.2 Addition of Korean Roof Elements to Western Wooden Roof Truss

The examples which can be seen as additions of Korean roof elements to Western wooden roof trusses show the treatments of traditional features: installing the horizontal collar tie to increase rigidity, extending tie girders beyond the column line to make the traditional eave part, and protruding common rafters and flying rafters. As previously stated, the main building of the former Daehan Hospital(4-HS248,1908), using king post trusses, and Mogpo Branch Office of the former Honam Bank(2-RC29,1929) using wood-steel composite trusses, did not have wooden hanging posts. Instead struts were attached and a horizontal collar tie similar to Korean traditional upper girders were inserted to prevent the buckling of the king post and to increase tensional strength as well.

Iksan Iri Agricultural School, Livestock Department Building(11-RC178,1932), Sunchon Former Missionary Preston House(15-RC126,1913), and Chinhae Post Office(29-HS291,1912) are the examples of making an eave by extending and protruding the tie girder at the joint of the principal rafter beyond the exterior wall line. Also, as in Mogpo City Library, there were some cases to make eaves by extending upper chords.
under the roof, which is a typical way to construct a roof truss. The height up to purlin, the internal member was similar to that of a Korean roof truss and had a similar structure to Korean eaves by laying end angle rafters (Sarae).

5. Conclusion
The evolution of the Western wooden roof truss in the modern age of Korea began with Beonsachang. It was followed by the wooden arch, vault, and combined truss style in religious buildings by people from the West; and the Korean-Western style with bracing such as strut inserted in existing Korean rafter roof structures. With the changes of modern architectural technical books and building construction techniques, the Western wooden roof truss was adopted.

As a result, new techniques such as the Western king post, queen truss, wood–steel composite roof trusses, and all other roof structures were introduced. The style where rafters intersect near ridge beam was developed into a butt joint style where purlin and common rafter meet with the use of Western nails. The roof strength was increased by the insertion of braces based on the principle of the "stability of the triangle shape". The omission of the short rafter caused the shift from the traditional double pitched roof to the Western single pitched roof.

By the application of the wooden roof truss, detailed treatments with Korean roof elements, such as the use of braces, like struts, in Korean roofs; and the use of the horizontal collar tie in the Western king truss with the purpose of increasing rigidity. However, the active application of certain techniques, such as extended eaves or a roof curve treatment by flying rafters was not observed.

Endnotes
1) Korea section, the 8th part, Engineering Military affair consisted of 1045 books of Modern Architectural Technique and collected in The National Library of Korea. These are classified into 8-30 architecture, 8-32 architectural design and HVAC, 8-33A architectural ornament, 8-33B Furniture, 8-34 Japanese architecture, 8-35 The Eastern Architecture, 8-36 the Western Architecture, 8-39 architectural miscellaneous. It's been reviewed for 16 books written about wooden roof truss among 1045 books of Modern Architectural Technique. The details of the 16 books are stated in journal 'The Receptiveness of Wooden Roof Truss in Modern Age of Korea., Journal of Architectural Institute of Korea, Aug. 2006, pp.163-170.
2) Currently there are total of 115 units of Modern architectural properties surveyed as of December 2007. Among 115 units, 72 units have been selected for this research except for 43 units which have flat roof or no truss structure observed. 19 units of the Roof details were surveyed out of the 72 units.
3) In Japan the appearance of the Western style wooden truss began in 1861 at Bakubunagaski Iron Foundry. After Novubi Earthquake in 1891, reasonable opinion of wooden structure was revised by Earthquake Prevention Investigation Association (震災予防調査会) and its four proposals were announced as a guideline to restore earthquake disaster in the Yamagadakenshiwuden (山形 县酒田) on October 22, 1894. The guideline emphasized to use trusses which is based on the principle of "stability of triangle shape", and stressed to construct all parts in triangular shape and to reinforce the connection with steel accessories.
4) Composite roof truss was first introduced in the book "Practical Western Style Architectural Structure, Book 9" which was published in 1930.
5) First introduced in "Illustrated Basic Architecture Structures, Book 6" which was published in 1928.
6) The Western style roof truss was reportedly produced from centering arch. Italian architect Andrea Palladio (1518-1580) first used dynamic truss in the 16th century. Later, Sir Christopher Wren (1632-1723) in Great Britain succeeded in application of truss and actively used in 18th century in Great Britain. The analysis of truss dynamics began in the first 19th century in the United States when various wooden truss bridge was actively constructed (Teijiro Muramatsu, Modern Japanese Architecture Technology, Shokokusha, 1974, p. 80). The Western style wooden roof trusses are consisted of tie beam, principal rafter, king post, strut, hanging post, ridge beam, purlin, common rafter, roof board, bolts, and other iron accessories. Dimensions of each member of roof are slightly different depending on the interval of the post and the roof, but all made out of pine tree and cedar tree. (Fig.3.)
7) The modern architectural technical books are as follows. The Tapanae House, Zenzo Y., 1919, The House, Koichi D., Bunken shoin, 1920/Building Structure2, Jouban S., 1932-1934/Construction Structure, Dadekoura S., Yodoyabashi S., 1933/The Timber House Structure, Ooniwa H., Kouyoushuka, 1927/The Western Construction Structure, Matsugeko, S., shugenoko, 1930/ The Western Building Structure, Keichi S., Yodoyabashi Shoten, 1937/The Western Architecture, Tarou Shinowara, 1931.
8) Japanese Architecture, Koro S., Kazu N., Shobundou, 1926.
9) In Former Honam Bank Mokpo Office (RC29,1929) which has long span, and Jeonju Joogang-dong ex-Park Daok's Dwelling (RC173,1929) metal usages to hanging posts were observed to increase tensional rigidity.
10) History of Western Architectural Technology, Robert Mark and Others, Translated by Taeyong Kim and Hyeongrae Cho, Gyeongnam University Publishing Department, 1999, pp.274-275.
11) History of Western Architectural Technology, pp.280-281, it described how to make the high ceiling and to increase the strength structurally.

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