World Conference on
Timber Engineering
Oslo 2023

Development of Timber Roof Frames in Korean Modern Architecture

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ABSTRACT: This study tracks the introduction of foreign timber roof frames into Korean architecture. The foreign timber roof frame introduced in the modern era had not only Western truss but also Japanese conventional timber structure. The traditional roof structure in Korea involves stacking horizontal timber members in a grid shape and placing rafters on top, resulting in thick and heavy horizontal members. To accommodate the introduction of Western trusses, a compromise form was created based on this traditional understanding. However, during the Japanese colonial period, the two foreign roof frames occupied a more dominant position in state-run architecture than that of traditional Korean architecture. Japanese roof frames were applied to small and complex buildings, and Western trusses were applied to large buildings with simple functions. The hidden part of the roof of traditional Korean buildings was also replaced by truss or Japanese roof frame. Both foreign roof frames were designed using *Roof Framing Plan*, and the span and spacing of the structures were determined according to the traditional measuring unit, K. The two types of roof frames shared roles based on their respective strengths and could be used interchangeably. These foreign roof frames were mainstream in modern Korean architecture until reinforced concrete structures became widely distributed.

KEYWORDS: Korean modern architecture, roof frame, timber truss, Japanese roof structure, scale unit

1 INTRODUCTION

Korea has a rich tradition of wood construction, dating back centuries. At the end of the 19th century, two foreign technologies were introduced. This resulted in three types of timber roof frames being used in buildings: the traditional Korean roof frame, the Western truss structure, and the Japanese conventional roof structure. These structures were influenced by one another and coexisted in the majority of buildings until the reinforced concrete structure became more common. This paper aims to summarize the development process of the modern Korean timber roof frames, focusing primarily on the drawings of state-run architecture preserved in the National Archives of Korea.

2 TRADITIONAL TIMBER STRUCTURE AND INTRODUCTION OF FOREIGN ROOF FRAMES

2.1 TRADITION OF KOREAN ROOF CONSRUCTION

One of the defining features of traditional Korean roof structures is the absence of trusses. Instead, horizontal beams are stacked on vertical columns to create right-angled frames, with the beams and short posts supporting the purlins directly. The number of the purlins was limited because they were not only bulky and weighty, but also given Confucian symbolism. [1] It is common for five or seven purlins to be used in formal buildings. The building with the largest number of the purlins in Korea is *Gyeonghoeru* Pavilion in *Gyeongbokgung* Palace, which was rebuilt in 1867, with 11 purlins arranged in a 28.5m span. Therefore, in Korean architecture, the purlin is conceptually more like a longitudinal beam than the purlin used in typical truss structures. Above the purlins, a series of rafters are arranged, and then topped with earth and roof tiles to create a heavy roof.

Figure 1: *The Anglican Church, Ganghwado Island, built in 1900.*

Because the horizontal beams transmit the load to the columns at the intersection with the purlins, the arrangement of the columns creates a square module, which is called *Kan*. *Kan* was the basic unit for combining and dividing spaces. The size of *Kan* determines the horizontal length of the members in the roof structure, which is usually consistent with the dimensions of the

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https://doi.org/10.52202/069179-0536

Kan or is twice or three times as long. This consistency in structure and space is a shared feature of East Asian wood structures, including China, Korea, and Japan. Prior to the 20th century, one *Kan* was typically about 2.4 meter in houses and more than 3 meter in public buildings in Korean architecture, while it was recognized as about 1.8 meter in Japanese architecture. [2]

Although Western-style architecture had become prevalent in modern large-scale construction, traditional Korean roof frames are still used in some cases. For example, the Anglican Church of Figure 1, built in *Ganghwado* Island in 1900, is an example of how the basilica structure can be completed using Korean traditional building techniques. This reflects the missionaries' desire for self-sustaining church architecture in Korea. [3] From *Janglim* Church in 1892 to *Pyeongbuk Jeongju* Church in 1938, a total of 38 churches with Korean traditional timber structures were identified. These structures evolved to emphasize the facade of the basilica, add bell towers, and widely use brick walls. [4]

2.2 INTRODUCTION OF FOREIGN ROOF FRAMES IN KOREA

In the late 19th century, foreign timber roof frames were introduced along with buildings that served new functions such as factories, government offices, and churches. Since most of these buildings were designed by foreign architects, their space, design, and structure were all different from traditional Korean architecture. However, the brick walls and the two- or three-story buildings with trussed roofs became the representative form of modern Korean architecture. Western-style houses began to be built in the palaces as well as the foreign settlement at the open ports. Starting with *Gwanmungak* Pavilion in *Gyeongbokgung* Palace in 1888, several Western-style buildings were built in *Gyeongunggung* Palace during the Great *Han* Empire (1897-1910). [5] Accordingly, the use of Western truss frames became widespread in high-level architecture. The truss structure was also applied to repair the traditional buildings in 1908 in the project of renovating the *Injeongjeon* Hall of *Changdeokgung* Palace in pursuit of the *Meiji* Palace in Japan, replacing the invisible part of the existing traditional roof frame. [6] Based on the traditional understanding of building techniques, in some cases, structures were compromised with each other. *Beonsachang* Factory of Figure 2, Korea's first timber trussed building, was built in 1884 as a weapon-making factory. Its trusses were fabricated within the traditional concept of placing posts on a thick beam. All members are thick and heavy, and traditional mortise and tenon joints that do not use hardware have been applied. The use of cylinder-shaped round purlins can also be seen as an inheritance of the Korean building tradition. [7] The cross-sectional areas of the top chord, bottom chord, and post of the trusses at *Beonsachang* Factory are 648 ㎠, 2,052 ㎠, and 375 ㎠, respectively. These dimensions are from two to seven times larger than the average cross-sectional area of truss members since the 1920s. [8] This use of larger members can also be observed in the trusses of *Yongsan* Theological School, which was constructed in 1892. It can be interpreted as an adaptation process in the early stages of the truss structure's introduction.

Figure 2: *The Beonsachang Factory, Seoul, built in 1884.*

3 TIMBER ROOF FRAMES UNDER JAPANESE COLONIAL RULE

3.1 CHARACTERISTICS OF JAPANESE CONVENTIONAL TIMBER STRUCTURE

With the introduction of Western structural engineering in the *Meiji* period (1868-1912), traditional Japanese timber structures were criticized for being heavy in their roof design, having isolated columns, significant timber loss for joints, and temporary member fixation [9]. Especially in Japan, where there was a high risk of earthquakes, the traditional timber structure was improved to focus on enhancing seismic performance. This process led to the reinforcement of structures through braces, the use of hardware, and a method for tightening the foundation and column, which is known as *the Conventional Construction Method* in Japan, distinguishing it from the traditional one.

The Japanese conventional construction method favored the *kyouro-gumi* method, which was popular in private houses during the *Edo* period. The *kyouro-gumi* method involves first combining purlins that act as beams on columns to form an outer frame and then placing transverse beams on top of it [10]. This method has the advantage of being easier to add and move roof structures compared to the *orioki-gumi* method, in which transverse beams are joined first on the columns and purlins are placed on them. In addition, the *kyouro-gumi* structure is relatively lightweight. The conventional construction method was widely used not only in the private sector but also in public buildings by governments because it allowed for improved building performance while still preserving traditional building practices.

3.2 COLONIAL RULE AND STANDARDIZATION OF MODERN SPACES

The Joseon Government-General's government facilities were supplied with wood through *Yeongrimchang*, which was established during the Korean Empire. *Yeongrimchang* opened its headquarters in *Sinuiju* in

https://doi.org/10.52202/069179-0536

1907 to develop abundant timber in the two river basins bordering China, and later oversaw the entire Korean forest organization. *Yeongrimchang* began operating a direct sawmill in *Sinuiju* in 1909 and supplied timber for construction in earnest. [11]

In *Yeongrimchang*'s sawmill, logs were cut into lumber using the traditional measurement units S and K used in East Asia. One K translates into six S. Since one S corresponds to 30.303cm, one K corresponds to 1.818m. The lumber produced in the *Yeongrimchang* sawmill had general dimensions of 1S in width and depth and 4K in length, which corresponds to 7.272m. This lumber was superior in quality and size compared to that supplied to the private sector. [12] Additionally, various standardized 2K-long construction timbers were supplied with names indicating where they should be used. In some cases, timber was supplied by separately ordering the type and dimensions of timber according to the design document of the specific construction work.

As a result of Japan's annexation of Korea as a colony in 1910, the urgent need to establish colonial governance facilities quickly and affordably led to the construction of numerous timber structures. In this process, *the Joseon Government-General Building Standards* were enacted in 1916, and standard regulations were applied to buildings such as government offices, schools, hospitals, prisons, and official residences. Standardized designs were repeatedly reproduced through *the Common Drawings*. Among the blueprints of the 1910s, the application examples of *the Common Drawings* were found in the drawings of local courts, weather stations, secondary education facilities, national hospitals, and other facilities. [13] The use of standardized construction members and building plans became widespread and characterized the typical form of roof structures.

3.3 DECLINE OF TRADITIONAL KOREAN ROOF STRUCTURE

During the modernization process, traditional Korean roof frames were marginalized in favor of Western-style truss structures and improved Japanese-style roof structures, which were exclusively used for constructing modern facilities. In the 1910s, many Korean traditional buildings were renovated and repurposed as government offices or schools, but these renovations were limited to changes in floor plan and elevation. Moreover, any new additions were constructed in Western or Japanese styles, rather than in the traditional Korean style. The use of traditional Korean timber structures was limited to community facilities in rural areas with strong national conservatism or houses for Koreans. While the number of such buildings was not insignificant, the potential for expanding and developing traditional Korean architecture was limited.

The decline of traditional Korean timber structures can be attributed to the malicious intent of colonial rule. However, weaknesses in the architectural industry contributed to this decline as well. The large and heavy structures of traditional Korean buildings made construction economically inefficient, and their lack of braces and hardware were considered vulnerable to earthquakes. Specifically, the government sawmill did not provide timber of an appropriate size for Korean-style structures. The cross-sectional width and depth of timber used in modern trusses in Korea ranged about 120-180×120-240mm, with a decreasing trend after 1920. [14] In contrast, traditional Korean structures utilized large, rounded sections for their members. As a consequence, architects were unable to effectively represent the Korean roof structure through efficient design drawings.

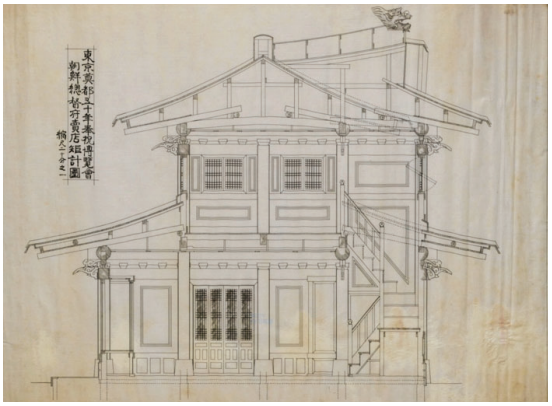

Figure 3: *The section drawing of a Korean-style pavilion with Japanese roof frame at the 50th anniversary Expo of Tokyo's capitalization, 1917, source: National Archives of Korea.*

Even in special situations where Korean-style buildings needed to be reproduced, Western trusses and Japanese roof structures were used as roof structures that were not visible from the outside. Several instances of Korean-style buildings having their roof structures replaced with trusses or Japanese roof structures can be observed in various buildings at *Gyeongbokgung* Palace and *Changdeokgung* Palace. Additionally, many Korean pavilions built at the *Taisho* Expo (1914), the 50th anniversary Expo of *Tokyo*'s capitalization (1917) of Figure 3, the Peace Memorial *Tokyo* Expo (1922), and the *Joseon* Expo (1929) were representative, and there were buildings with strong national colors such as the *Kaesong* Museum (1931) and the *Suungyo* Headquarters memorial service house (1936). [15]

4 CHARACTERISTICS OF TIMBER ROOF FRAMES IN KOREAN MODERN ARCHITECTURE

4.1 COMBINATION OF TRUSS AND JAPANESE ROOF FRAME

Most of Korea's early modern architecture had a western appearance. Until reinforced concrete construction became popular, the most monumental buildings, such as *Seokjojeon* Hall of *Gyeongunggung* Palace, were built of stone, while important government offices, such as the Ministry of the Interior in Figure 4, were made of brick, and the rest were built of wood. In either case, a timber roof frame was an essential requirement for building a

sloped roof. The choice of roof frame was determined by the span of the building. *Shoukou Hikkei*, translated into the Builders Manual, written by *Shishikichi Shibada* in 1886, explained that the king post truss could span up to 30S (9m), the queen post truss could span up to 45S (13.5m), and the compound one could span up to 60S (18m). [9] The truss was able to create a large space that was not easily achievable with traditional roof structures. Therefore, large and important buildings were built with trusses, while smaller buildings were built using Japanese conventional methods.

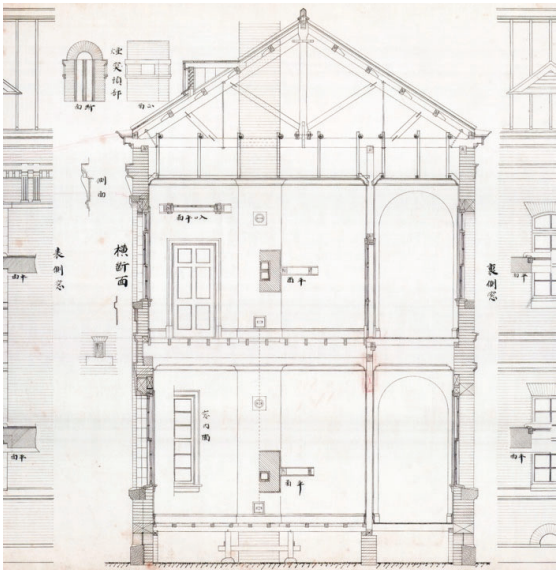

Figure 4: *The section drawing of the Ministry of the Interior, part, built in 1910, source: National Archives of Korea.*

The central government offices in Seoul, customs offices in ports, provincial government offices, police stations, and state-owned factories in each region used trusses in their roof structures, while Japanese official residences, local offices, branch offices, and weather stations used Japanese roof frames. [16] However, some hospitals, schools, courthouses, and prisons, which required rapid construction in the early colonial period, were built using Japanese roof frames regardless of size.

In modern state-run architecture in Korea, it was popular to arrange the main building and annexes in parallel, connecting them with a corridor to form an H-shape or extending wings from both ends of the main building to the rear. At this time, the use of timber structures was allocated specific roles in the architecture. For example, the main building was constructed with trusses, and Japanese roof frames were applied to the wings or other annexes. Even when trusses were applied to the main building, it was common to use a Japanese roof frame for the entrance.

The *Gyeongnam* Provincial Government Office, built in 1924, is an exceptional example of architecture that incorporates both Japanese roof structures and truss structures. Initially designed as a prefectural hospital, the main building was constructed with a Japanese roof frame. [17] Later, both wings were extended to the second floor, and trusses were added to the roofs of the wings. The main building is approximately 13.5 meters wide, with a 2.7-meter-wide (9K) corridor in the middle. The Japanese roof frames were adopted using 280mm thick log beams. In comparison, the left and right wings were approximately 8 meters wide and were built using a king post truss structure. The distance between the king post and the side post of truss is 1.8 meters (6K). The truss timbers were 120mm wide and varied in thickness, and as seen in Figure 5, they differed from the logs used in the main building in terms of size and species of tree.

Figure 5: *Original roof frames from the Gyeongnam Provincial Government Office, built in 1924, expanded in 1931, source: Seokdang Museum of Dong-A University.*

While truss could form large spaces, the advantage of the Japanese roof frame was that it allowed for a greater degree of flexibility in shaping the roof surface. By supporting purlins with standing posts on a stable foundation, a complex or curved roof shape could be achieved more easily. A hybrid structure was also created by combining trusses and Japanese roof structures. The roof volume could be expanded by adding posts on top of the truss and arranging purlins, allowing for the creation of curved domes or arches. This was a simple method even when the building was expanded horizontally. Additionally, the Japanese roof frame could protect the building and its walls made of wood by extending the eaves, and the use of both log and timber as building materials was advantageous.

4.2 STANDARDIZATION TRENDS DEPENDENT ON FLOOR PLAN

In the context of modern state-run architecture in Korea, both Japanese roof structures and Western-style trusses were extensively used, with the latter being considered structurally superior. This was due to the fact that the tradition of wood construction could not be easily abandoned given the circumstances of the building production system of that time. Particularly, in a situation where the construction organization and distribution system were not sufficiently mature, the truss structure did not have an overwhelming comparative advantage in terms of price or mass production. The market share of

https://doi.org/10.52202/069179-0536

trusses depended on the industrialization of lumbering and sawmills, the standardization of timber, the expansion of transportation networks such as railways for delivery from production sites, communication between designers and builders, construction methods on the site, and other factors. From the perspective of consumers, converting long-standing living customs to the Western style was also a challenge for both Korean and Japanese architecture. However, during the era of colonial rule, the Japanese-style timber frame was chosen as an alternative to the truss, while the Korean timber structure became increasingly marginalized.

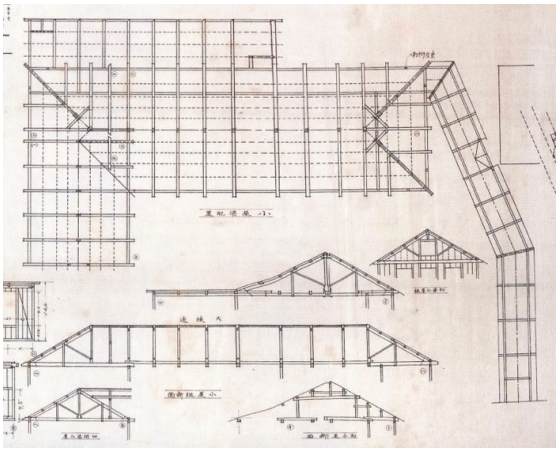

Figure 6: *The Roof Framing Plan of the Pyeongbuk Provincial Government Office, part, built in 1918, source: National Archives of Korea.*

To address the large-scale construction demands, it was imperative to adhere to familiar construction methods that were based on traditional metrology units. In 1921, the Japanese government enforced *the Weights and Measures Act* with the primary aim of mandating the use of the metric system, and in 1926, *the Joseon Government-General* declared *the Joseon Weights and Measures Ordinance*, making it obligatory to use only meters in all tasks. However, due to strong opposition from the industry, a grace period was soon granted. Although the government office buildings were given a grace period of 10 years and others 20 years, the implementation of the law was essentially postponed indefinitely, and it was only after World War II that it was effectively enforced. Hence, the truss structure in the modern era was also inevitably designed based on the traditional unit.

The drawings prepared by the modern government office for construction include various detailed drawings as well as floor plans, elevation drawings, and cross-sectional drawings. One of these drawings is *the Roof Framing Plan* drawing, which displays the horizontal arrangement of the roof structure. *the Roof Framing Plan* helps to determine the location and quantity of timber required for the roof structure by indicating the layout of beams, purlins, hip rafter ridges, and other components. This drawing is comparable to the field drawings traditionally produced by craftsmen on wooden boards. *The Roof Framing Plan* was useful not only for the Japanese-style roof frame but also for the arrangement of trusses. Nonetheless, it is often challenging to differentiate between trusses and Japanese-style roof frame shown in construction plans such as Figure 6. This is because the spacing between the members is similar, and their location is frequently determined by the same traditional dimensional unit.

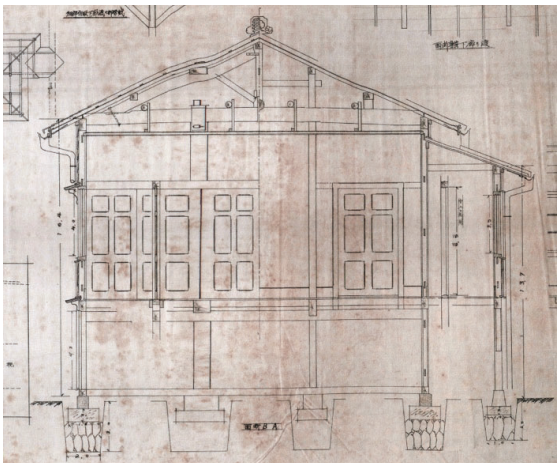

Figure 7: *The Section Drawing of Hwanghae Provincial Government Office, part, built in 1910, source: National Archives of Korea.*

The size and layout of the roof structure became more typical as floor plan was standardized for the rapid dissemination of colonial governance facilities. For example, in school architecture, the width of the school building was fixed at approximately 10m (5.5K) and the width of the students' waiting room and auditorium was fixed at approximately 14.5m (8K), in accordance with the standardization of educational space. [18] Accordingly, the role of each roof structure became clearer, and the possibility of interchangeability between different types of roof structures increased.

For spaces that did not require a large span, the Japanese timber roof frame could replace the truss. About 50% of the existing modern trusses in Korea have a span of less than 10m, and about 80% have a span of less than 12.5m. In addition, the spacing between trusses is often 1.8m, with most of them being less than 3m apart. [8] This means that in many cases, a Japanese-style roof frame, which is not suitable for creating a large space, can be used instead. If columns are inserted indoors to partition the rooms, the possibility of replacing the truss with a Japanese roof frame is further increased.

The spacing between trusses was often determined as a multiple of the traditional metrology unit S or K, which made it similar to that of the Japanese roof frame and suited the standardized floor plan. However, there were exceptions to this pattern, such as the *Myeongdong* Cathedral in *Seoul* (1898), Bell Memorial Chapel of Jennie Speer Memorial School for Girls in *Gwangju*

(1925), *Eonyang* Cathedral in *Ulsan* (1932), where the spacing between trusses was more than 5m. Interestingly, these buildings were all constructed by Western missionaries and did not follow Japanese standardized architectural methods.

5 CONCLUSIONS

In modern Korea, timber roof frames existed alongside Korean, Japanese, and Western styles. However, Korean-style was not used for state-run architecture and was limited to buildings with strong ethnic features such as houses and temples. Public buildings were constructed using Western and Japanese styles. Large-scale buildings were built using trusses, and small-sized buildings were built using Japanese-style roof frames. However, in some cases, the two roof frames were interchangeable as they were designed with the same module that uses traditional metrological dimensions.

After the Great Kanto Earthquake in 1923, the importance of earthquake-resistant structures increased, and reinforced concrete structures rapidly expanded. In addition, the revitalization of private commercial activities and the active involvement of private architects led to the trend of modernism, resulting in the reduction of sloped roofs. The design trend of reinforced concrete structures and modernism began to break away from the long tradition of timber construction.

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