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Restoration and Conservation of Traditional Timber Structures in Japan: Japanese Sophisticated Traditional Timber Structure Designs and Five Methods for Restoration and Conservation of Japanese Traditional Timber Structures*

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Introduction

The characteristic of the traditional wooden building construction in Japan is that the prefabricated parts are produced at the carpenter's workshop and assembled at the construction site. A joint system has been developed to facilitate assembly. Therefore, it is easy to exchange and disassemble the parts after construction. It is also possible to reuse the parts after disassembling. Furthermore, in the townhouse called *machiya* in Kyoto, which was the capital of Japan, the standardization of parts has been carried out, not only reuse of structural members but also reuse of fittings and floor *tatami* mats were done. An example of intentionally showing the beautiful structural design of the assembled frame without ceiling will be introduced. The average annual rainfall in Japan is 1500 mm. To protect the buildings especially walls from the heavy rain, not only a sloping roof, but also long eaves have been set up on each floor. In order to support wide eave, a member called *hanegi* has been used. These wide eaves make deep shadow underneath and this is another characteristic of Japanese traditional architecture. These are explained by the following five items.

1. Japanese Sophisticated Traditional Timber Structure Designs
2. Restoration and Conservation of Japanese Traditional Timber Structures of Townhouse in Kyoto
3. A Japanese Traditional Teahouse and Traditional Wood Joinery System
4. The Sequence of the Disassembly Work of the Pagoda in Daigo-ji Temple
5. Wide Eaves and Spatial Organization Created by Eaves on Each Floor as a Characteristic of Traditional Japanese Architecture & The Long Log Called Hanegi Supports the Wide Eaves of Japanese Traditional Timber Structure

1. Japanese Sophisticated Traditional Timber Structure Designs

Hierarchy of the traditional timber structure is visible and designed in a harmony with its components. Jōdo-ji Temple and South Gate of Todai-ji Temple were both constructed by monk Chōgen (1121-1206) and craftsmen he invited from Song Dynasty (960-1279). A technique called *nuki* (penetrating tie beams passing through the drilled columns) has been used. All structural materials and and eaves are exposed in the temples which do not have ceiling surface. That is a typical example of expressing the esthetics of structure and architecture.

1.1. Jōdo-ji Jōdo-dō Temple

Jōdo-ji Jōdo-dō Temple (founded in 1197) stands on a land facing a plain in the west. When the sunset from the west illuminates the three statues of Amitābha (Buddha) from the back, interior of the temple changes into a world of red and gold Western Pure Land. (Amitābha's Buddhist paradise) It is a view that Amitābha will ride on the cloud and welcome the spirits of dead. Drawings are cited from Reference 1: (Kokuhō Jōdoji Jōdo-dō Shūri Kōji Hōkoku-sho: 国宝 浄土寺浄土堂修理工事報告書（図版編) [National Treasure of Japan: Five-story Pagoda of Jyodo-ji Temple Repair Construction Work Report (Illustration)]. Hyogo: Gokurakusan Jyodo-ji Publisher 極楽山浄土寺, 1993. Print.）

Figure 1: Eastern elevation.

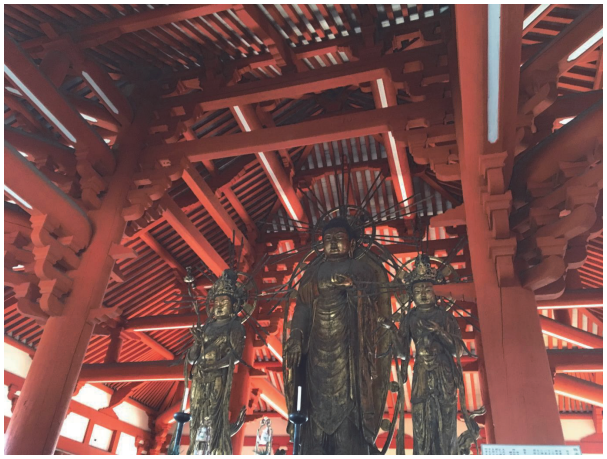


Figure 2: Inside view, Amitābha (Buddha) statue seen from the east side.

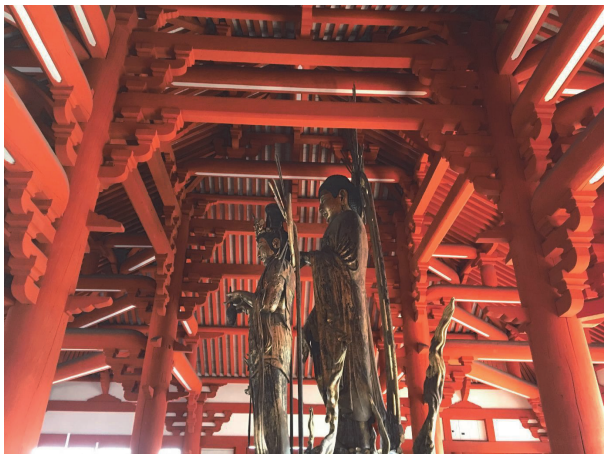


Figure 3: Inside view, Amitābha (Buddha) statue seen from the north side.

Figure 4: There is no ceiling surface, all the structural members are visible. Composition of three beams and extensive use of tie beams.

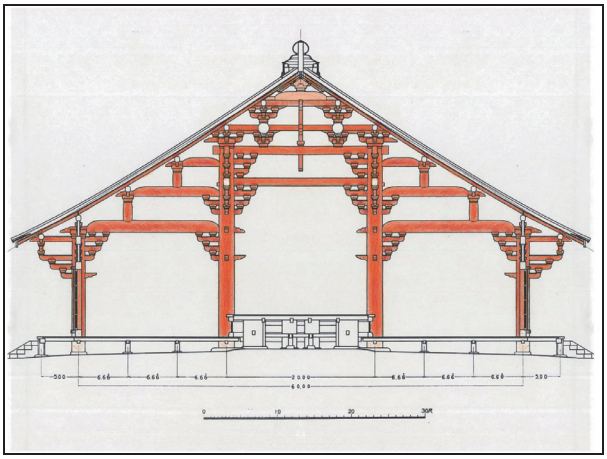


Figure 5: Sectional view Reference 1: (Kokuhō Jōdoji Jōdo-dō Shūri Kōji Hōkoku-sho: 国宝 浄土寺浄土堂修理工事報告書（図版編) [National Treasure of Japan: Five-story Pagoda of Jyodo-ji Temple Repair Construction Work Report (Illustration)]. Hyogo: Gokurakusan Jyodo-ji Publisher 極楽山浄土寺, 1993. Print.）

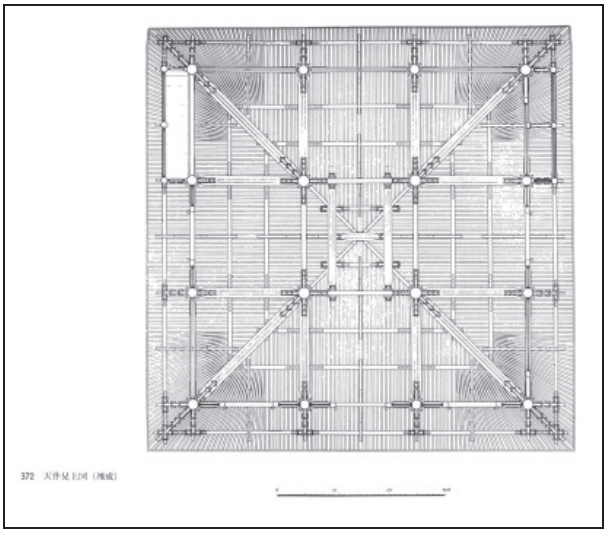


Figure 6: Ceiling plan Reference 1: (Kokuhō Jōdoji Jōdo-dō Shūri Kōji Hōkoku-sho: 国宝 浄土寺浄土堂修理工事報告書（図版編) [National Treasure of Japan: Five-story Pagoda of Jyodo-ji Temple Repair Construction Work Report (Illustration)]. Hyogo: Gokurakusan Jyodo-ji Publisher 極楽山浄土寺, 1993. Print.）

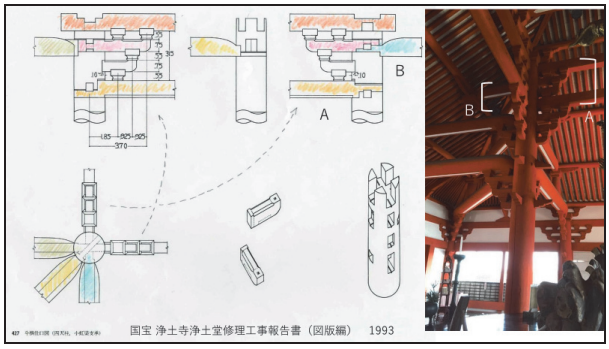


Figure 7: Detail showing the relation of wooden pillar and tie beam Reference 1: (Kokuhō Jōdoji Jōdo-dō Shūri Kōji Hōkoku-sho: 国宝 浄土寺浄土堂修理工事報告書（図版編) [National Treasure of Japan: Five-story Pagoda of Jyodo-ji Temple Repair Construction Work Report (Illustration)]. Hyogo: Gokurakusan Jyodo-ji Publisher 極楽山浄土寺, 1993. Print.）

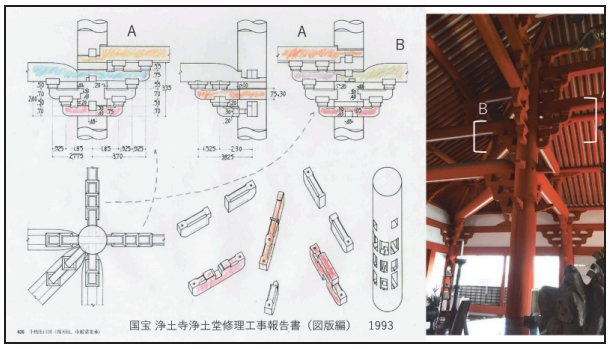


Figure 8: Detail showing the relation of wooden pillar and tie beam 2 Reference 1: (Kokuhō Jōdoji Jōdo-dō Shūri Kōji Hōkoku-sho: 国宝 浄土寺浄土堂修理工事報告書（図版編) [National Treasure of Japan: Five-story Pagoda of Jyodo-ji Temple Repair Construction Work Report (Illustration)]. Hyogo: Gokurakusan Jyodo-ji Publisher 極楽山浄土寺, 1993. Print.）

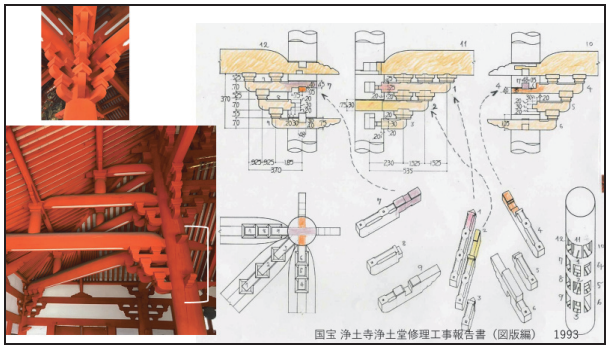


Figure 9: Detail showing the relation of wooden pillar and tie beam 3 Reference 1: (Kokuhō Jōdoji Jōdo-dō Shūri Kōji Hōkoku-sho: 国宝 浄土寺浄土堂修理工事報告書（図版編) [National Treasure of Japan: Five-story Pagoda of Jyodo-ji Temple Repair Construction Work Report (Illustration)]. Hyogo: Gokurakusan Jyodo-ji Publisher 極楽山浄土寺, 1993. Print.）

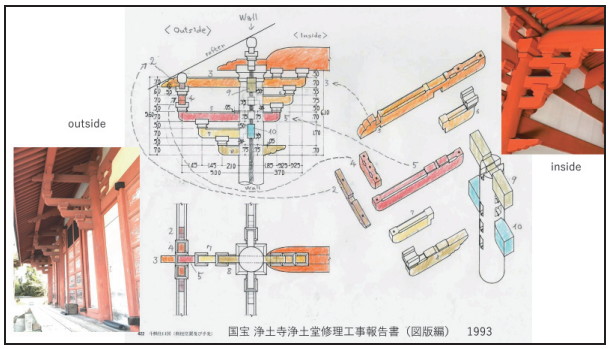


Figure 10: Inside and outside of timber structure Reference 1: (Kokuhō Jōdoji Jōdo-dō Shūri Kōji Hōkoku-sho: 国宝 浄土寺浄土堂修理工事報告書（図版編) [National Treasure of Japan: Five-story Pagoda of Jyodo-ji Temple Repair Construction Work Report (Illustration)]. Hyogo: Gokurakusan Jyodo-ji Publisher 極楽山浄土寺, 1993. Print.）

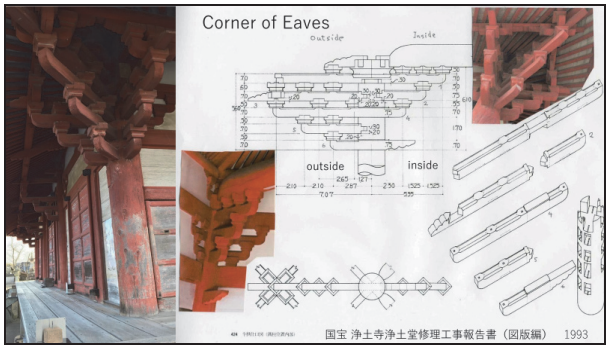


Figure 11: Corner of eaves and inside of temple Reference 1: (Kokuhō Jōdoji Jōdo-dō Shūri Kōji Hōkoku-sho: 国宝 浄土寺浄土堂修理工事報告書（図版編) [National Treasure of Japan: Five-story Pagoda of Jyodo-ji Temple Repair Construction Work Report (Illustration)]. Hyogo: Gokurakusan Jyodo-ji Publisher 極楽山浄土寺, 1993. Print.）

Figure 12: Japanese traditional structure system: Un-anchored pillar under the floor.

1.2. Great South Gate of Tōdaiji Temple

Great South Gate of Tōdaiji Temple was rebuilt by monk Chōgen like Jōdo-ji Jōdodō Temple in 1203. All the structural materials are exposed with a structure in which penetrating tie beams passing through 18 gigantic columns with a height of 21 m. A restoration work were carried out in 1930 and steel reinforcement was made. We also made a proposal of adding reinforcement with wooden components of the same system. The gate was designated as National Treasures of Japan. The following drawings are quoted from Reference 2: (Fujii, Keisuke 藤井恵介 & Suzuki, Kakichi 鈴木嘉吉 & Tōdaiji Temple South Gate Repair Construction Office 東大寺南大門修理工事事務所. Shūri Hōkoku-sho Tōdaiji Nandaimon-shi Oyobi Shōwa Shūri Yōroku: 修理報告書 東大寺南大門史及昭和修理要録 [Repair Report: Tōdaiji Temple Great South Gate History and Showa Period Summary]. Tokyo: Bunsei Shoin Co. Ltd. 文生書院, 2005. Print.) with the addition of the author.

Figure 13: Great South Gate of Tōdaiji Temple.

Figure 14: All Frames are exposed.

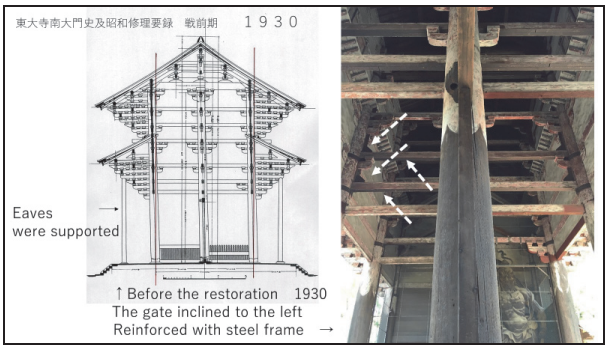


Figure 15: Before the restoration in 1930, the gate had inclined to the left and eaves had been supported. Eaves were reinforced with steel frames.

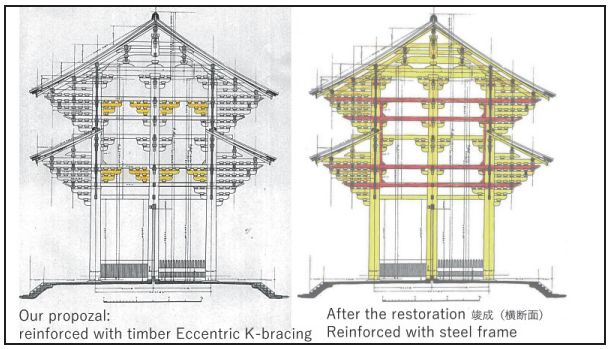


Figure 16: Our proposal (reinforced with timber Eccentric K-bracing) and restoration reinforced with steel frames in 1930.

2. Restoration and Conservation of Traditional Timber Townhouses in Kyoto

Kyoto was the capital of Japan from late 8th century until the latter half of the 19th century. Surrounded by the mountains in the north, east and west, the city was established using grid iron system in the basin opened to the south. On both sides of the road, two-storey wooden townhouses called *kyomachiya* are built in rows. Currently although reinforced concrete and steel construction buildings are built mainly, there are still many kyomachiyas remain. Traditional methods of conservation and restoration are inherited from citizen and carpenters who have protected the townhouses until today and new technical methods have been studied at the same time. It is aimed to preserve the historical

landscape of Kyomachiyas and hand down that abundant urban life to the future generations. In recent years, many foreign tourists fascinated with this urban life are rapidly increasing.

Kyomachiya has inherited a narrow façade facing to the street and a two-story plan extended longitudinally to the back of the block. Inside of the each townhouse, each room is lined up along the passageway and one or two inner gardens are provided at the same time.

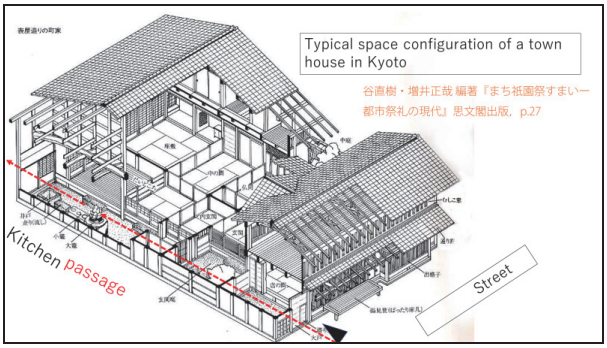


Figure 17: The townhouse in Kyoto is called kyomachiya Reference 3: (Tani, Naoki 谷直樹 & Masui, Masaya 増井正哉編. Machi Gionmatsuri Sumai Toshi Sairei No Gendai: まち祇園祭すまい一都市祭礼の現代 [Town - Gion Festival-House・Town Festival in the Modern City]. Kyoto: Shibunkaku Co. Ltd. 思文閣出版, 1994. Print.)

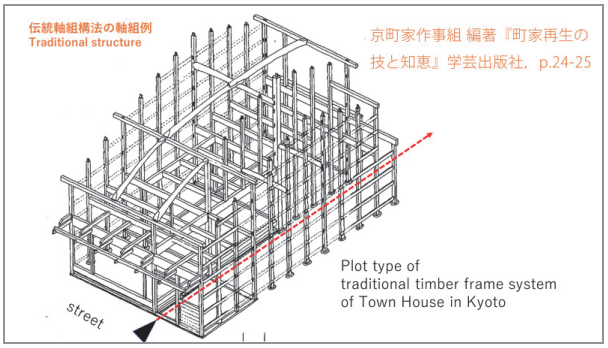


Figure 18: Plot type of traditional timber frame system of Townhouse in Kyoto Reference 4: (Kyomachiya Council 京町家作事組編著. Machiya Saisei No Waza To Chie: 町家再生の技と知恵 [The Techniques and Wisdom of Machiya Revitalization]. Kyoto: Gakugei Publication 学芸出版社, 2002. Print.)

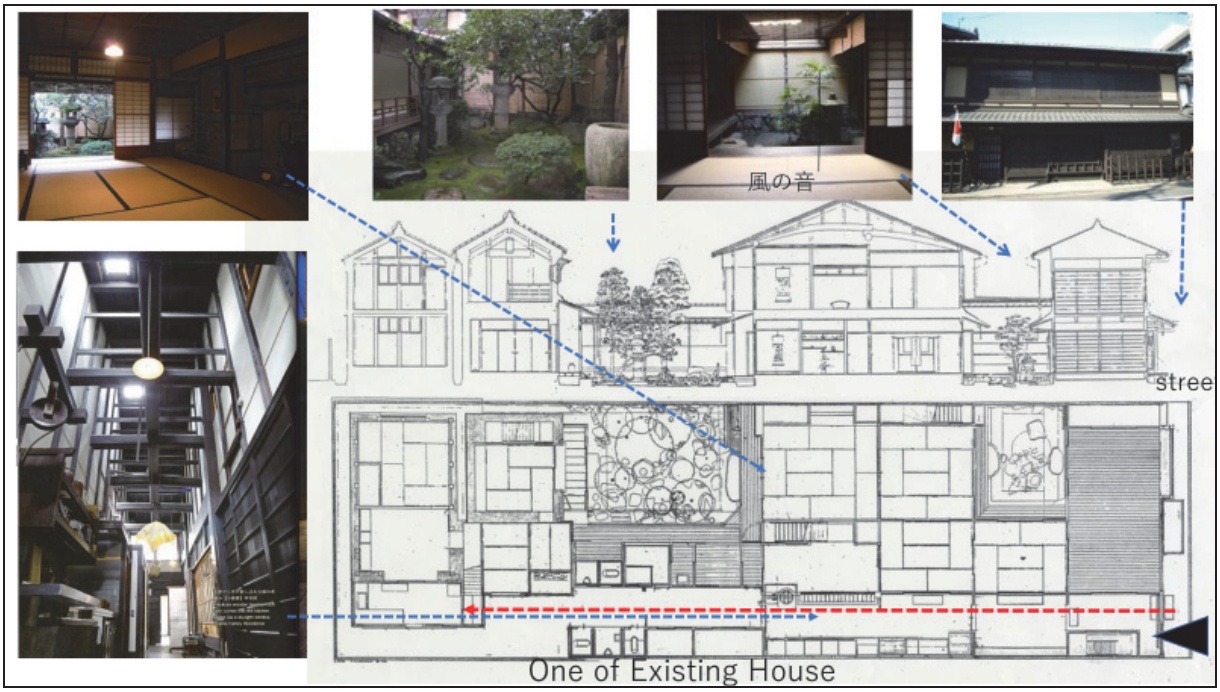


Figure 19: The townhouse in Kyoto is called kyomachiya.

2.1. Replacement of a Member in Timber Structure of Kyomachiya in Case of Need

Figure 20: A member of the timber structure in kyomachiya can be replaced in case of need.

Figure 21: Wall with exposed pillars is called *shinkabe*. It is easy to find its pillar's troubles and easy to repair it.

Figure 22: Re-used pillar for grand-beam sleeper.

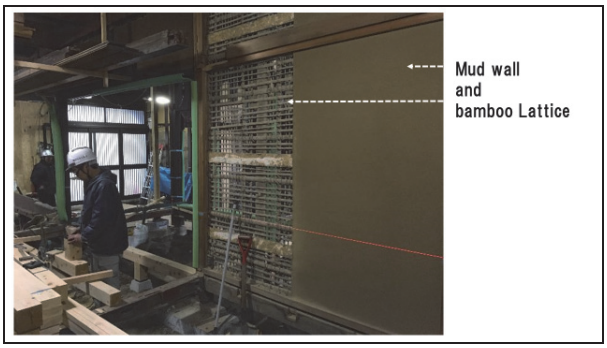


Figure 23: Mud wall and bamboo lattice.

Figure 24: Students practical training for mud wall and bamboo lattice.

2.2. The Standardization of the Size of Tatami Mat, Sliding Door and Inner size of Room of Traditional Townhouse in Kyoto

The size of tatami mat and the size of many kinds of traditional sliding doors have been standardized in the traditional townhouses of Kyoto. Because of this standardization, the inner distance of the rooms and openings of rooms, where Tatami mats and sliding doors are fitted respectively, had to be standardized. The wall core distance of room is ineligible for the standardization. These standardizations achieved the reuse of both sliding doors, Tatami mats and the standardized timbers. The sophisticated townhouse and townscape have been created by these standardizations.

Briefly:
1) The standardization is for the long life of townhouse.

2) For the standardization of timber material, tatami mat and sliding door: inner distance of room should be standardized and wall core distance is ineligible for standardization.
3) Both preservation and reuse of fittings such as sliding doors; fusuma, shoji, etc. should be realized.
4) After all, the sophisticated townhouse and townscape are realized by these standardizations.

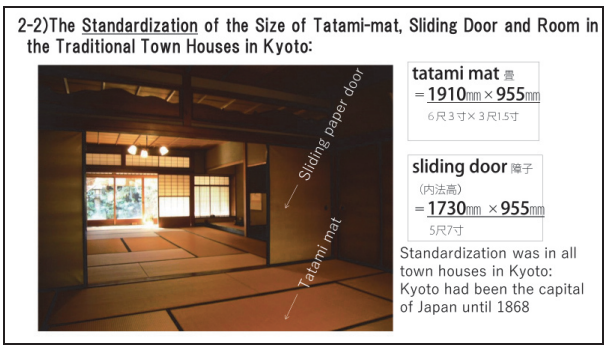


Figure 25: The standardization of the size of tatami mat and sliding door.

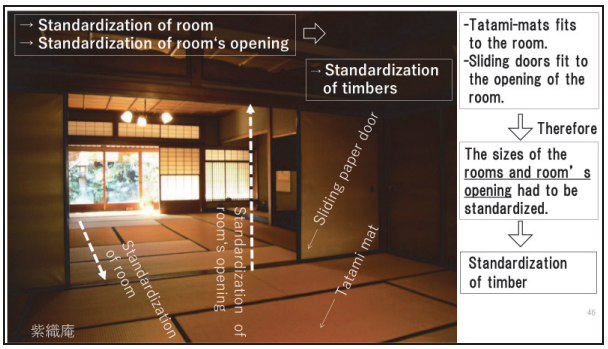


Figure 26: Standardization of the inner size of room.

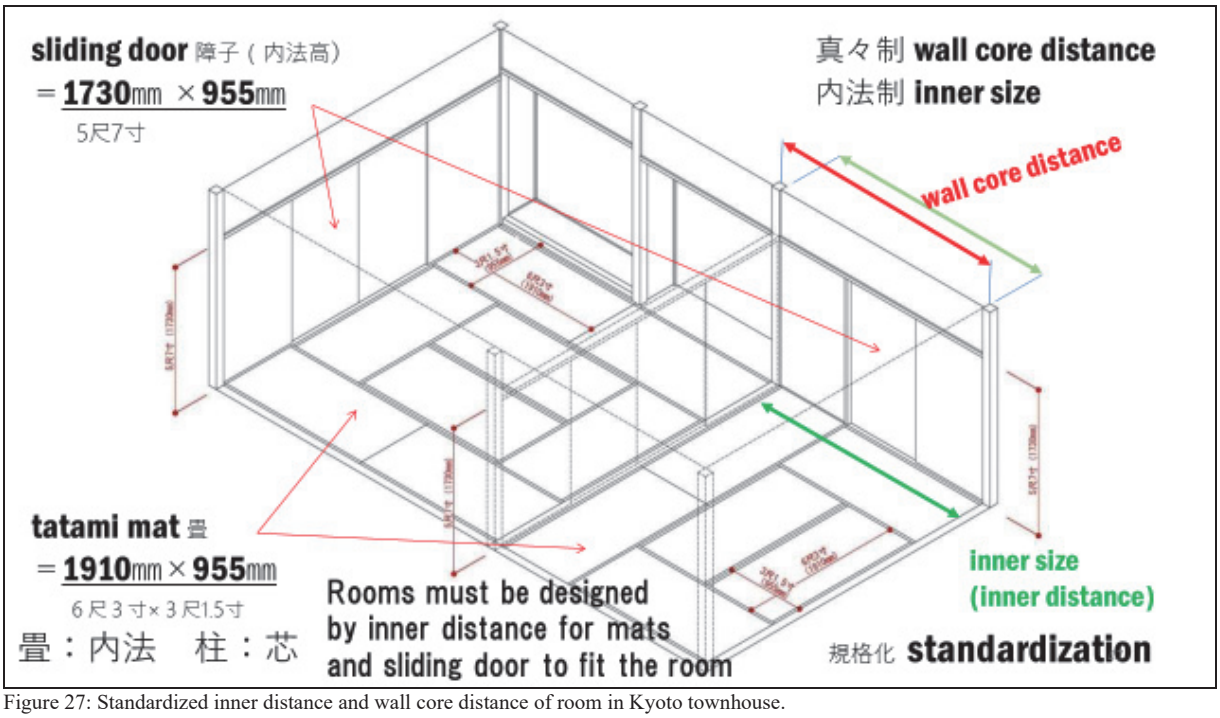


Figure 27: Standardized inner distance and wall core distance of room in Kyoto townhouse.

Figure 28: Various kinds of sliding doors stocked by a carpenter.

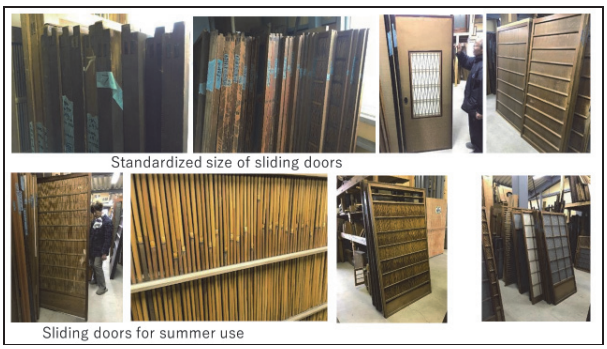


Figure 29: Various kinds of sliding doors stocked by a carpenter/2.

Figure 30: Handle of the sliding paper door.

Figure 31: Sliding door and floor mat for summer.

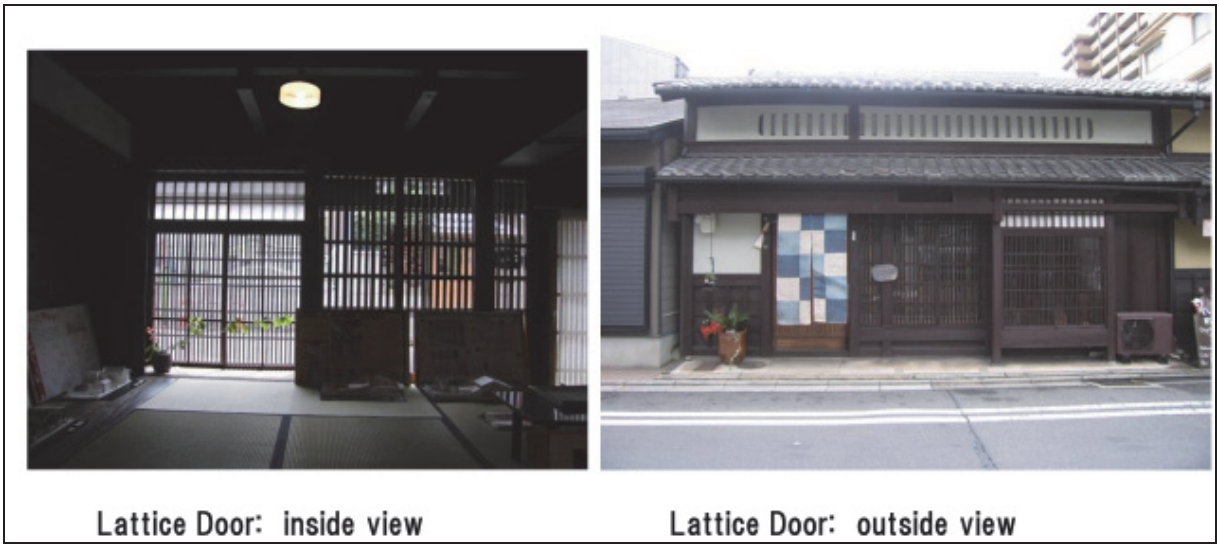


Figure 32: Inside and outside views of lattice door.

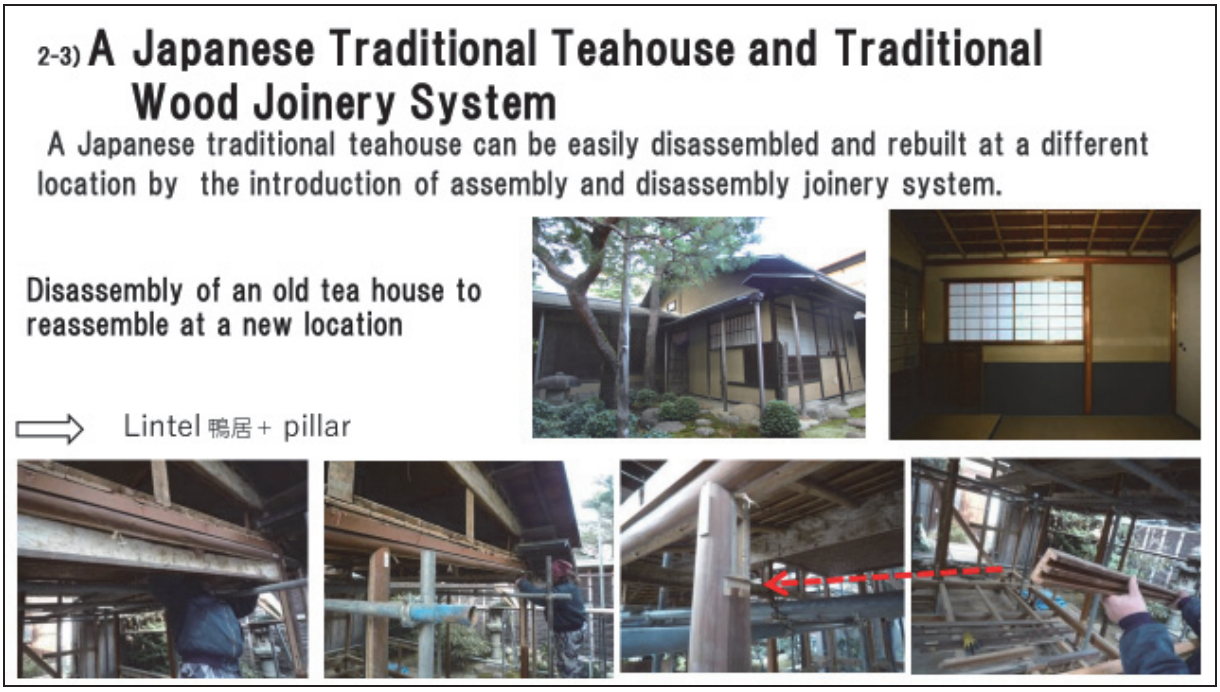


Figure 33: Disassembly of an old tea house to reassemble at a new location.

3. A Japanese Traditional Teahouse and Traditional Wood Joinery System

A Japanese traditional teahouse can be easily disassembled and rebuilt at a different location by the introduction of assembly and disassembly joinery system. In the case of the new traditional teahouse construction, trial assembly of the teahouse is usually executed at the carpenter's atelier: Later on, the structure can be separated into pieces to reassemble at the site.

Figure 34: Disassembly of a joint between pillar and lintel for sliding doors.

Figure 35: Disassembly of a joint between column and doorsill.

Figure 36: Trial assembly of the traditional teahouse in the carpenter's atelier: Later on, the structure can be separated into pieces to reassemble at the site.

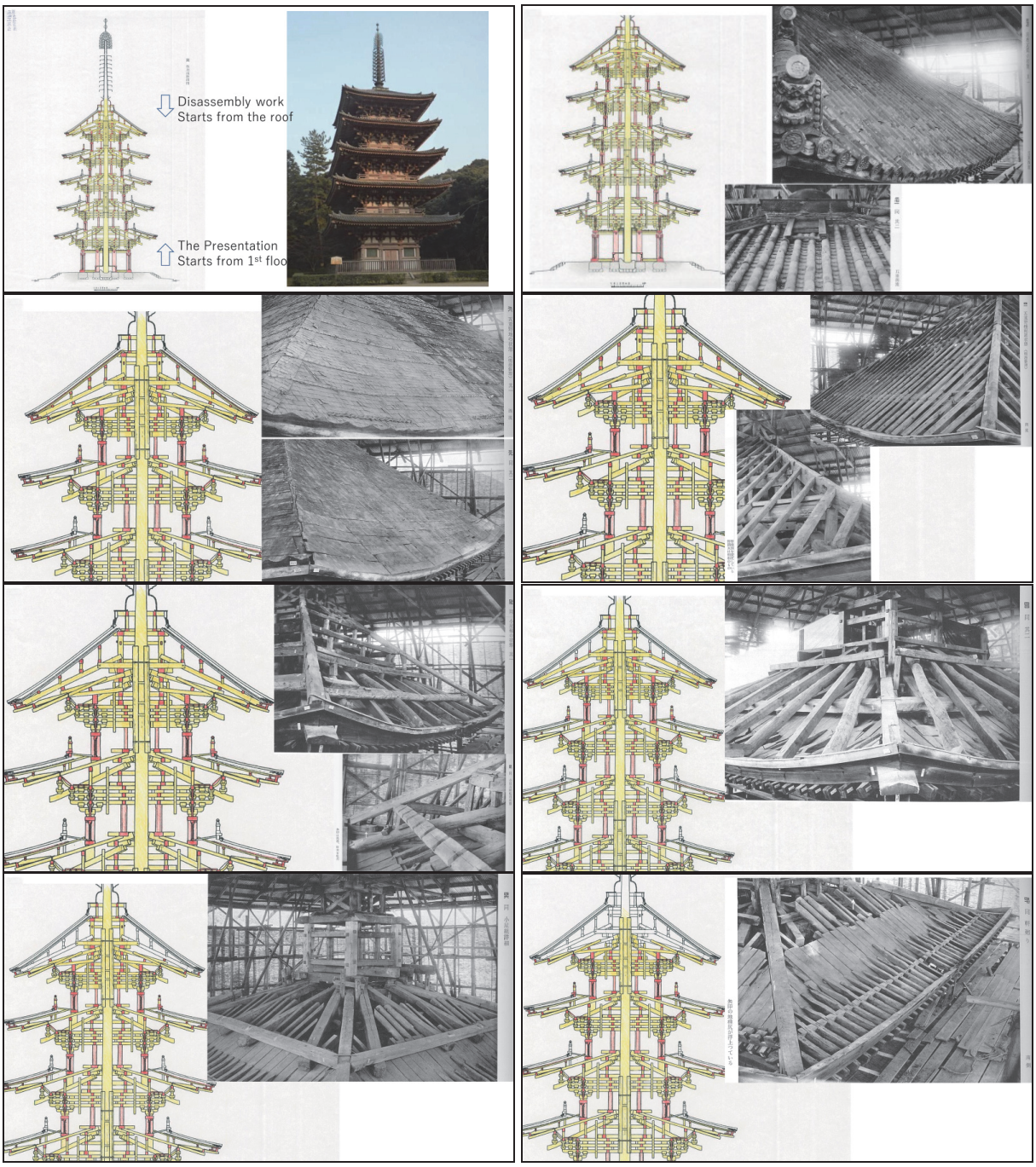
Figure 37: Details of joints.

4. The Sequence of the Disassembly Work of the Pagoda in Daigo-ji Temple

The traditional prefabrication system for the timber structure made the following items possible:
1) Reducing construction period
2) Reuse of the parts
3) Replacement of parts
4) Improvement of the construction precision
5) Design of sophisticated timber structure

In symposium, 51 recorded photographs showing the demolition process of five-story pagoda of Daigo-ji Temple were introduced with cross section of structure for each disassembly process. But

here, one part of it will be introduced. The 14 step of the dismantling process of the top, 5th floor will be shown. The intermediate floors will be omitted and the dismantling process of the ground floor to the foundation will be shown in 8 steps. First, the dismantling process of the top floor will be shown. The following photographs and drawings are cited from Reference 5: (Kyoto Prefectural Office of Education - Cultural Property Preservation Section - Daigo-ji Temple Five-story Pagoda Repair Office 京都府教育庁文化財保護課醍醐寺五重塔修理事務所. Kokuhō Daigo-ji Gojyū No Tō Shūri Kōji Hōkoku-sho: 国宝　醍醐寺五重塔修理工事報告書　[National Treasure of Japan: Daigo-ji Temple Five-story Pagoda Repair Construction Report]. Kyoto: Cultural Properties Division, Kyoto Prefectural Board of Education 京都府教育庁文化財保護課醍醐寺五重, 1960. Print.)



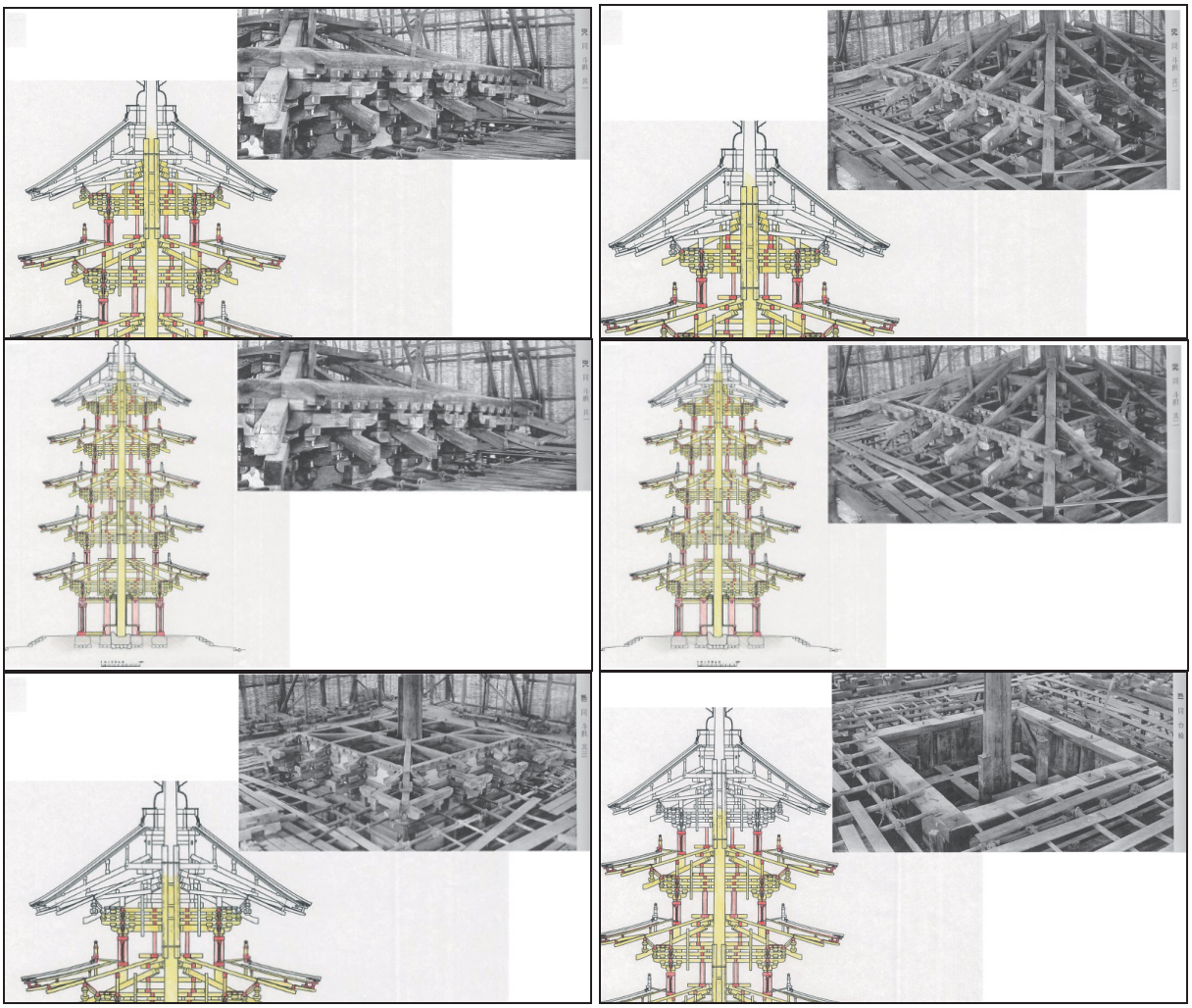
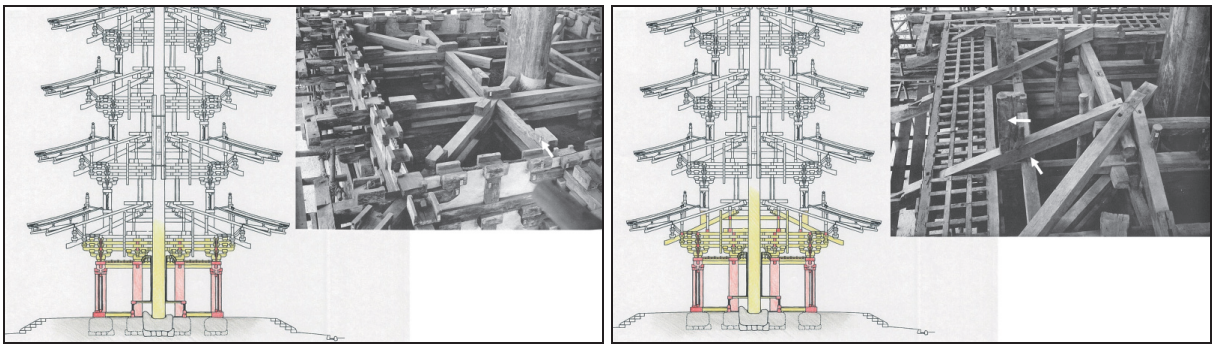


Figure 38: The 14 step process of the disassembly works of the five-story pagoda in Daigoji-Temple.

Next, the disassembly process of 8 steps of ground floor is shown.



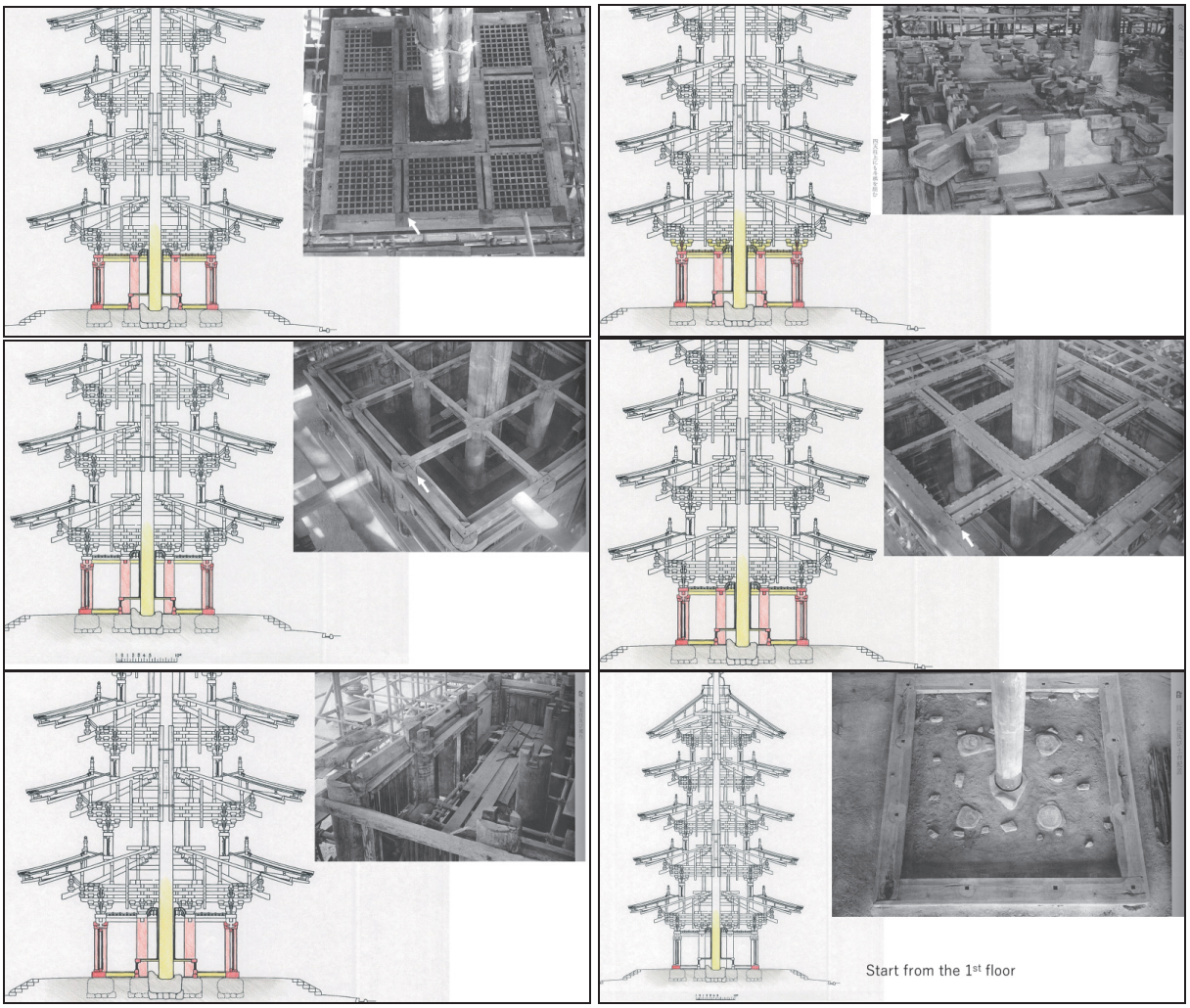


Figure 39: The 8 step process of the disassembly works of the ground floor of pagoda in Daigo-ji Temple.

In our university (Mukogawa Women's University), there is a full-size wooden model which is reconstruction of the eave in ground floor of five-story pagoda, Daigo-ji Temple. This model is assembled from many parts. It is possible to introduce working principle of assembly and disassembly to the students any time. In the symposium, assembly and disassembly process were presented through animation. The video, presented at the symposium, shows that carpenters and students work for disassembly and assembly of the mockup of the square framing (*masugumi* - interlocking wooden brackets) of five-story pagoda of Daigo-ji Temple in Kyoto.

Figure 40: The Five-story pagoda of Daigo-ji Temple. The mockup of the square framing surrounded by a red frame was built in our architecture department.

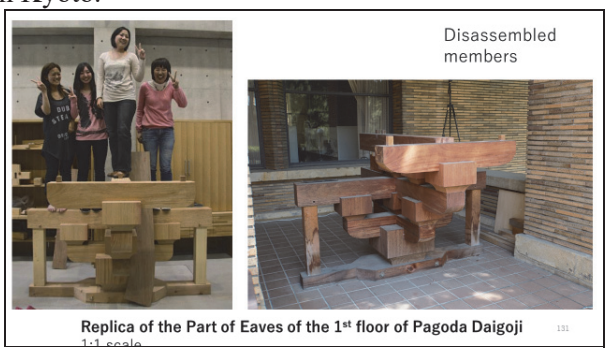


Figure 41: The mockup of the square framing of the 1st floor eaves of the pagoda of the Daigo-ji Temple.

Figure 42: The disassembled parts of the square-framing of the pagoda of Daigoji-Temple.

Figure 43: Assemble process of the mockup of square framing of eave of pagoda.

5. Wide Eaves and Spatial Organization Created by Eaves on Each Floor as a Characteristic of Traditional Japanese Architecture & The Long Log Called Hanegi Supports the Wide Eaves of Japanese Traditional Timber Structure

Architect Kenzo Tange attached beautiful eaves to each floor in the design of the Kagawa Prefectural Office Building. It has a high reputation in the worldwide for expressing the traditional space of Japanese architecture with reinforced concrete. Japanese castles have eaves on each floor with roof. But the ones belong to the west has only a roof. There are no eaves on each floor. F. L Wright was impressed with the eaves of the Japanese pavilion Phoenix Hall of the Expo in Chicago in 1883, and designed Robie House with wide eaves in 1910.

Figure 44: Architect Kenzo Tange attached beautiful eaves to each floor in the design of the Kagawa prefectural office building. It has a high reputation in the worldwide for expressing the traditional space of Japanese architecture with reinforced concrete.

Figure 45: Japanese castles have eaves on each floor with roof. But the ones belong to the West has only a roof. There are no eaves on each floor.

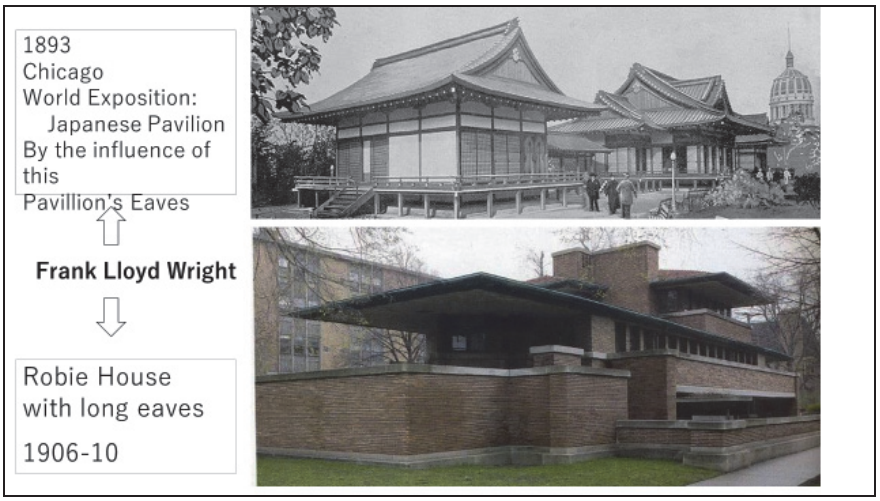


Figure 46: F. L Wright was impressed with the eaves of the Japanese pavilion Phoenix Hall of the Expo in Chicago in 1883, and designed Robie House with wide eaves in 1910.

The long log called hanegi supports the wide eaves of Japanese traditional timber structure. The wide eaves had been created by the development of hanegi system as a result of the conservation of the timber structures against Japanese climate. Annual rainfall averages 1500 mm. The wide eave creates the shadows and a feeling of serenity inside the room.

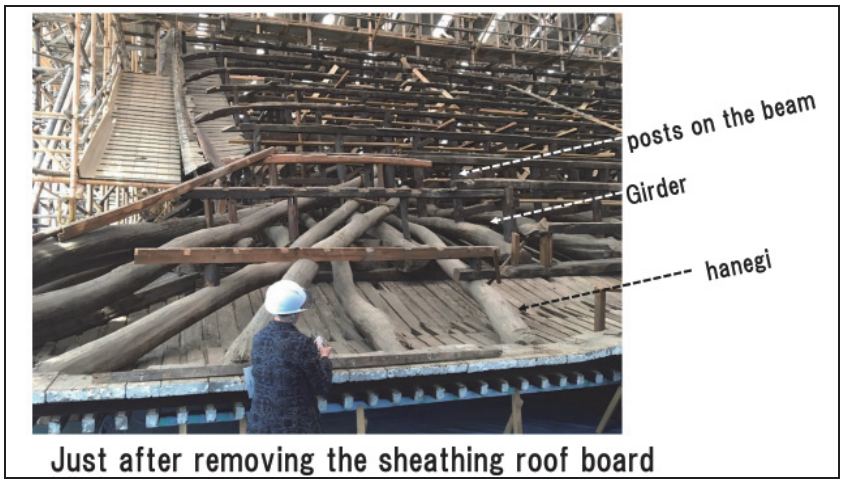


Figure 47: The long sloping logs called hanegi holding up the eave at the restoration site of Honryu-ji Temple, Kyoto.

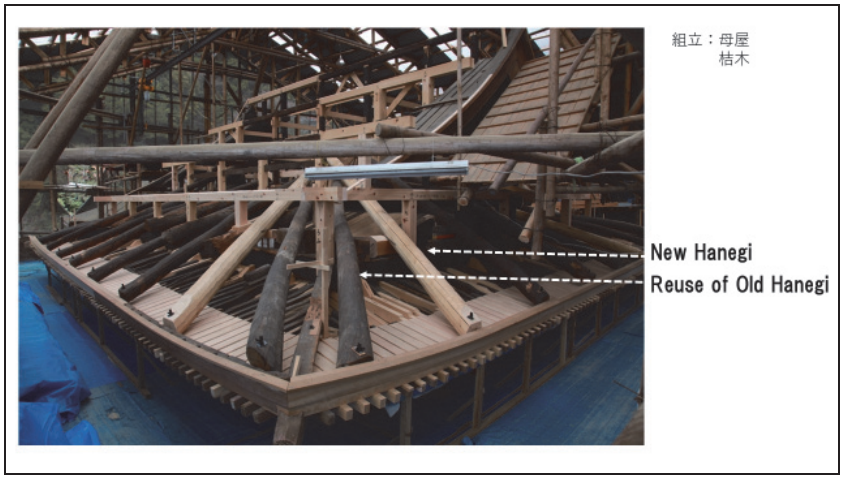


Figure 48: New hanegi and old hanegi reused.

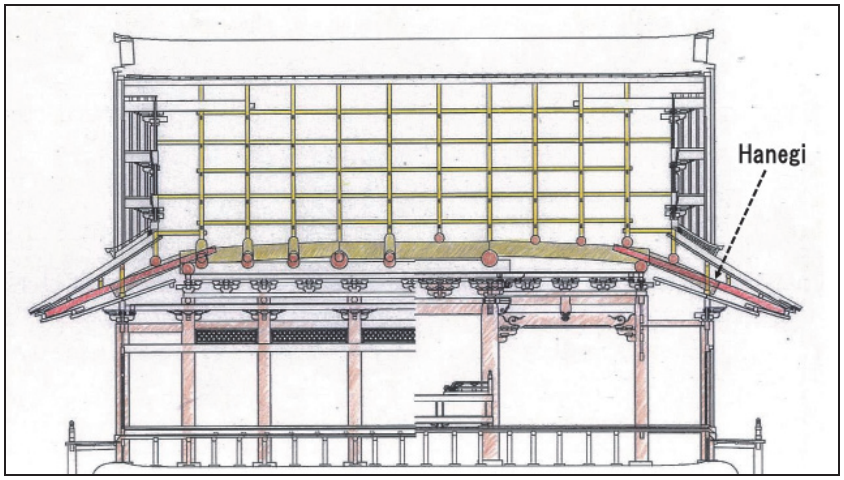


Figure 49: Hanegi in section (Drawing provided by 京都府教育庁文化財保護課 [Kyoto Prefecture Board of Education])

REFERENCES

1. Kokuhō Jōdoji Jōdo-dō Shūri Kōji Hōkoku-sho: 国宝 浄土寺浄土堂修理工事報告書（図版編) [National Treasure of Japan: Five-story Pagoda of Jyodo-ji Temple Repair Construction Work Report (Illustration)]. Hyogo: Gokurakusan Jyodo-ji Publisher 極楽山浄土寺, 1993. Print.

2. Fujii, Keisuke 藤井恵介 & Suzuki, Kakichi 鈴木嘉吉 & Tōdaiji Temple South Gate Repair Construction Office 東大寺南大門修理工事事務所. Shūri Hōkoku-sho Tōdaiji Nandaimon-shi Oyobi Shōwa Shūri Yōroku: 修理報告書 東大寺南大門史及昭和修理要録 [Repair Report: Tōdaiji Temple Great South Gate History and Showa Period Summary]. Tokyo: Bunsei Shoin Co. Ltd. 文生書院, 2005. Print.

3. Tani, Naoki 谷直樹 & Masui, Masaya 増井正哉編. Machi Gionmatsuri Sumai Toshi Sairei No Gendai: まち祇園祭すまい一都市祭礼の現代 [Town - Gion Festival-House・Town Festival in the Modern City]. Kyoto: Shibunkaku Co. Ltd. 思文閣出版, 1994. Print.

4. Kyomachiya Council 京町家作事組編著. Machiya Saisei No Waza To Chie: 町家再生の技と知恵 [The Techniques and Wisdom of Machiya Revitalization]. Kyoto: Gakugei Publication 学芸出版社, 2002. Print.

5. Kyoto Prefectural Office of Education - Cultural Property Preservation Section - Daigo-ji Temple Five-story Pagoda Repair Office 京都府教育庁文化財保護課醍醐寺五重塔修理事務所. Kokuhō Daigo-ji Gojyū No Tō Shūri Kōji Hōkoku-sho: 国宝　醍醐寺五重塔修理工事報告書 [National Treasure of Japan: Daigo-ji Temple Five-story Pagoda Repair Construction Report]. Kyoto: Cultural Properties Division, Kyoto Prefectural Board of Education 京都府教育庁文化財保護課醍醐寺五重, 1960. Print.