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Design Method of Zen-Style Bracket Sets Recorded in the Japanese Carpentry Manual *Kamakura Zoei Myomoku* (Part 1): A Comparative Study with the Chinese Manual *Yingzao Fashi* – A Secondary Publication

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ABSTRACT

Through a comparison with the traditional Chinese manual *Yingzao Fashi* (*Technical Treatise on Architecture and Craftsmanship*), this paper analyzes the composition and design methods of Zen-style bracket sets described in the *Kamakura Zoei Myomoku*, a technical document inherited by the Kawachi family of carpenters at the Kenchoji Temple in Kamakura, Japan from the 13th to 19th century. As a result, the paper suggests that there were some similarities between Chinese and Japanese modular designs, which both used the cross-section of Gong as the basic unit, while other techniques like the use of a baseline for equal spacing and the rafter size as the basic unit, are considered to be Japanese innovations.

Keywords: Zen-style, bracket set, woodworking manuals, *Kamakura Zoei Myomoku*, *Yingzao Fashi*, *Gongcheng Zuofa Zeli*

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1. INTRODUCTION

Zen architecture was introduced from China to Japan in the 13th century. What influence did Zen architectural culture bring to Japan in the medieval period (13th–16th centuries)? From the introduction of ironware in prehistory, the introduction of Buddhist architecture in the 7th century, to the acceptance of Western architecture in the Meiji period at the end of the shogunate period, as well as a series of historical phenomena that followed the world trend and set off the modernist architectural movement in modern era, the history of Japanese architecture is a developmental process of continuously accepting foreign cultures and digesting and transforming them into Japanese culture.

In terms of the Zen-style [1] architecture, the trailblazing research of the pioneers [1,2] such as Hirotaro Ota and Sugashi Iida encountered a huge difficulty of lacking physical evidence to support. Although Japan has more ancient relics like the Horyuji Temple in Nara (7th century) and the Phoenix Hall of Byodo-in Temple in Kyoto (11th century), very few buildings remain in the heyday when Zen architecture was introduced (13th–14th century). The relics of Kanto Zen-style architecture are represented by the Jizo Hall of Shofuku-ji Temple in Tokyo (1407, national treasure) and the Shariden Hall of Engakuji Temple in Kamakura (the first half of the 15th century, national treasure), both of which are three-bay with the surrounding porch, are already the largest of the extant relics. From the scale of the relics, it is difficult to imagine the magnificent five-bay temple depicted in the Ancient Drawings of the Kenchoji Temple (1331), which is 9 *jo* 丈 and 4 *shaku* 尺 wide. Scholars in the past had to speculate on the historical development of Kamakura Zen-style architecture from the rare documents, drawing information and small-scale architecture left in various places.

The newly discovered historical materials group *Kamakura Zoei Myomoku* in the 1980s enriched the historical data of Zen-style architecture. Particularly, the recorder of *Kamakura Zoei Myomoku* is the hereditary carpenter family of Kenchoji Temple, and the historical position of Kenchoji Temple in the history of Japanese architecture determines the importance of this technical manual.

Kenchoji Temple ranks first among the five-mountain temples [2] in the Kamakura period. It was founded in the 5th year of Kencho (1253), so it is named. Although Zen Master Eisai founded the Shofukuji Temple in Fukuoka and the Kenninji Temple in Kyoto before the Kenchoji Temple, they are both temples of Zen Buddhism and other Buddhist sects, not pure Zen temples. The Kenchoji Temple in Kamakura is the first Buddhist temple in Japan to specialize in Zen Buddhism, and it is the originator of authentic Zen temples. From an architectural point of view, this temple was a pioneering work that fully introduced the design methods and rules of Zen architecture in the Song dynasty (960–1279). Although the temple, which took 5 years to build, has not survived, it was very different from the *wayo* 和様 style that has been formed after a long period of Japanization since the acceptance of Buddhist architectural techniques from mainland China in the 7th century. The Kenchoji Temple is considered to be an authentic Song-dynasty

[1] In the 13th century, Japan introduced Zen architecture from China and formed the different architectural style and technologies from *wayo* and *daibutsuyo*, which was named *Zenshuyo*. And *yo* is not totally equal to *style*. Zen-style architecture has its unique characteristics in many aspects, such as form, technology, construction methods, and the source of craftsmen.

[2] The Kamakura shogunate of Japan formulated the temple level (grade) following the Zen temple system of the Southern Song dynasty (1127–1279). The highest-level temple is called “five-mountain.” There are “ten-shrine,” “multi-mountain” and “down-forest” under it. The Kenchoji Temple ranks first among the five-mountain, followed by the Engakuji Temple and the Jufukuji Temple. The temples designated as five-mountain are slightly different due to the different times of the ruling general. In 1386, general Ashikaga implemented the reform and designated five-mountain in Kyoto individually.

style building [3,4] [3]. In the 5th year of Koan (1282), the Engakuji Temple in Kamakura was built, and the prototype of Zen architecture was born out of these temples. At the same time, with the implementation of the five-mountain system of Zen Buddhism, these temples had a huge impact on the construction of lower-level Zen temples within the system.

It is a pity that the halls of the Kenchoji Temple and the Engakuji Temple were repeatedly destroyed by fire and rebuilt many times. Zen monasteries flourished in Japan during the Northern and Southern dynasties (1333–1392), but in the 15th century, the power of the Kamakura nobles declined, their territories were sold, and a large number of monasteries were abandoned. During the Edo period in the 17th century, the temple of Zen was restored with the help of the Tokugawa family. The new group of artisans who worked for the shogunate and the local feudal lords began to shoulder the responsibility of the era, while carpenters in the Kamakura area had been marginalized and lost their former vitality. Because of this, Kamakura carpenters did not merge with the carpenter group of the new era, and the records of the craftsmen still retained the local technical characteristics until the 19th century in *Kamakura Zoei Myomoku*. It can be seen that *Kamakura Zoei Myomoku* is an important historical material for the study of Japanese Zen-style architecture. The first author of this article, Tadanori Sakamoto, took *Kamakura Zoei Myomoku* as the research subject of his doctoral dissertation [5]. This article is based on the Japanese paper, titled "The influence of Chinese architecture in the carpenter's technical book *Kamakura Zoei Myomoku*: About the composition and design method of the bracket sets" by Tadanori Sakamoto in 2015 [6]. On this basis, the framework and content of the thesis have been adjusted for Chinese readers, and descriptions of related terms such as *Kiwari* 木割 manual, *ayita*, and *shiwari* 枝割 have been added. In order to facilitate the understanding of Chinese readers, Tadanori Sakamoto has drawn a large number of schematic diagrams to explain technical terms in this paper, and published for the first time the decomposition model of bracket sets in the Shariden Hall of the Engakuji Temple [4].

This paper tries to trace the developmental process of Japanese construction technology through the analysis of *Kamakura Zoei Myomoku*, and then conducts a comparative study of Chinese and Japanese architecture. After studying the composition and design methods of Zen-style bracket sets in *Kamakura Zoei Myomoku*, it compares with the traditional Chinese manual *Yingzao Fashi* (*Technical Treatise on Architecture and Craftsmanship*) from the Song dynasty, and analyzes which design methods of Japanese Zen-style architecture have been influenced by Chinese architecture.

2. *KAMAKURA ZOEI MYOMOKU* AND KIWARI MANUAL

The Kawachi family in Kamakura during the Edo period was responsible for the construction of the Kenchoji Temple, the originator of authentic Japanese Zen monasteries. *Kamakura Zoei Myomoku* [Figure 1] is the hereditary collection of handwritten records inherited by the Kawachi family. In the late 1980s, these documents about construction were found among the old files collected by the Kawachi family. In 1987, the Zen architecture historian Kinya Sekiguchi [7] introduced the existence of

[3] Kinya Sekiguchi believes that the source of Japanese Zen-style architecture is not from North China, but originated from the architectural style of the late Southern Song dynasty in the Jiangnan region between the south of Jiangsu Province and Zhejiang Province of China. However, there are many views on whether the Kenchoji Temple in the founding period is an authentic architectural style of the Southern Song dynasty. For details, please refer to *Ancient Buildings of Sung and Yüan Periods Seen in Southern Kiangsu and Chekiang Provinces (i): Ancient Pagoda and Detail of Wooden Structure in the Sung Period* and *Ancient Buildings of Sung and Yüan Periods Seen in Southern Kiangsu and Chekiang Provinces (ii): Style of Wooden Structures of Sung and Yüan Dynasties and Zen-style Architectures around the Kamakura Period* by Kinya Sekiguchi.

[4] The drawings and photos cited have obtained the publishing permission from the copyright owner.

Kamakura Zoei Myomoku. There are a total of 660 records in this batch of documents, including construction technology, account books of contracted projects, land contract, and so on. The earliest document was written in 1633 and the record continued to the second half of the 19th century. Among them, architectural documents include shrines, Buddhist halls, pagodas, gates, residences, interior furniture, decoration, and many other contents. The Buddhist Hall documents include the precious Zen-style three-bay Buddha Hall, Zen-style five-bay Buddha Hall and five-bay mountain gates, which reflect the architectural tradition of Kamakura five-mountain temples. They are the first-hand historical materials recording the construction technology of Kamakura carpenters with high historical value. These records are tentatively named as *Kamakura Zoei Myomoku* and are rated as "tangible cultural property" (material relics) in Kamakura city. It is known as the double jewels of architectural historical materials, together with *The Construction Drawing* of *Engakuji Temple (Sectional Elevation)* [5] (1573) [Figure 2], which is inherited by the carpenter family—Takashina family—of the Engakuji Temple that ranks second in the Kamakura five-mountain temples.

The ancestor of the Kawachi carpenter family, named Zenshin, died in 1280. His descendants are divided into the main (or stem) family and the branch family. The main family is called Kyuemon Kawachi, and the branch is called Chosaemon Kawachi and Denbee Kawachi. The main family took the position of *takumi-no-suke* [6] and inherited the position of carpenter for the Kenchoji Temple. The historical materials, *Kamakura Zoei Myomoku*, that had been passed down so far are the relics of the Chosaemon Kawachi family. This family inherited the position of carpenter of the Jufukuji Temple and the Eishoji Temple in Kamakura, and has the qualification of *Daikushiki* that can assist the main family to build the Kenchoji Temple.

The main writers of *Kamakura Zoei Myomoku* are Denkichi Kawachi and Kichizaemon Kawachi from the branch family. Denkichi Kawachi (?–1662) wrote five volumes between 1633 and 1638, and Kichizaemon Kawachi (?–1670) wrote 10 volumes between 1649 and 1652. Judging from the age of the craftsman's death, the transcripts may be the notes the craftsman made while studying with the old craftsman, which are not very proficient yet and may be recorded while listening and transcribing.

Figure 1. Records of *Three-Gate Pavilion* in *Kamakura zoei myomoku* Source: Collected by Kamakura National Treasure Museum; photo by the author

[5] The original document is collected in Kamakura National Treasure Museum. It is about 3.5 m long and 2.2 m wide. It is a rare Zen-style architectural drawing of Azuchi-Momoyama period. It was designated as a national important cultural property in 2011.

[6] The official office in charge of construction in the government or palace is called *takumi*. *suke* means second in command.

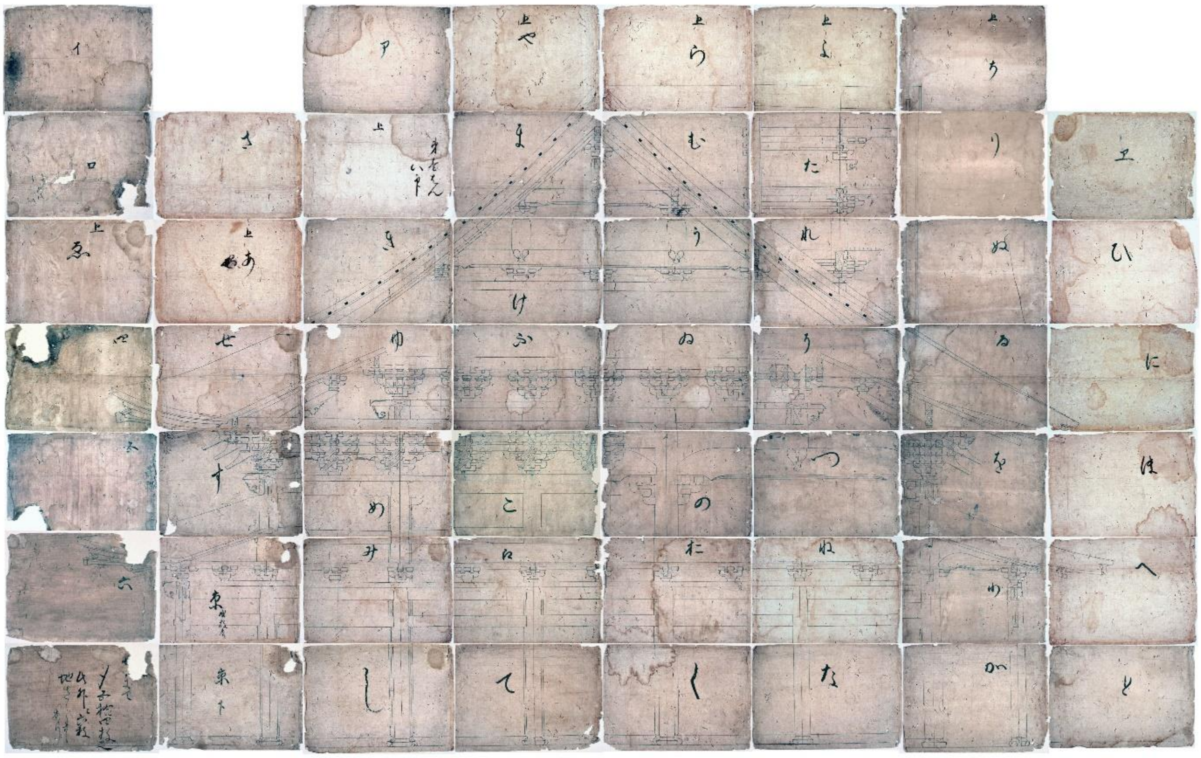

Figure 2. *The Construction Drawing of Engakuji Temple* (sectional elevation). Source: Provided by Kamakura National Treasure Museum (This picture cannot be reprinted, quoted or uploaded to the Internet without permission. If there is a need for publishing, please apply to Kamakura National Treasure Museum.)

The old craftsmen who served as teachers were mainly Sakanaka-takumi, Chikugo Kakuonji, and Soemon Kakuonji. Sakanaka-takumi was from the main Kawachi family and also a carpenter of the Kenchoji Temple. The other two were craftsmen from the Shibuya family, a hereditary carpenter family for the Kakuonji Temple. In addition, there were also sporadic teachings from carpenters in other parts of Kamakura. It can be seen that the carpenters in the Kamakura area had a certain degree of communication when educating their apprentices.

The nature of *Kamakura Zoei Myomoku* belongs to the modern (16th–19th century) *Kiwari* 木割 manual. *Kiwari* [7] is a Japanese architectural term that means a design technique that determines the dimension of each building component, the distance between each component, and the proportional relationship between them. The ancients determined the size of each part when divided (called *wari* in Japanese) woods, so the technique of determining the size and proportion of wood is called *Kiwari*. *Wari* in Japanese means one tenth. Therefore, the "*wari*" in *Kiwari* has the double meaning of cut-off and proportion.

The basic method to determine *Kiwari* is to first set the standard distance between two columns, that is, the standard column distance L, then determine the proportional factor α according to the scale of the architecture, and multiply those two to obtain the column diameter C, that is, $C=\alpha L$. Then the column diameter is multiplied by another factor β to get the rafter diameter (the side length for the square rafter) T, that is, $T=\beta C$. After the column diameter is obtained, it is used as the datum dimension, and multiplied by the proportional factor of each component to determine the dimensions of beams, purlins (stringers), and various bracket sets. The

[7] In ancient times, it was also called *Kikudaki*.

rafter diameter at the eaves can be used as an auxiliary datum dimension.

The proportional factor varies according to the scale and type of buildings, as well as the sects of craftsmen, regions, and times. Therefore, once seeing the size of the building's bay or column diameter, the craftsmen can immediately judge whether the *Kiwari* of the architecture is thick or thin.

There might have been a proportional relationship between the bay size and the column diameter, or between the column diameter and the size of the main components in ancient Japanese architecture before the 12th century. However, there is no historical materials at present, and a clear conclusion cannot be drawn yet. The proportional relationship itself may only be a general rule, and the quality of design depends more on the personal feeling of the carpenter in charge.

In Japan, the books that clearly stipulate the dimension and proportion relationship between wooden building components appeared in the 15th century. At that time, craftsmen were all run by families. In order to ensure the leading position of the family in technology, obtain the right to monopolize construction projects and achieve the hereditary function of craftsmen, *Kiwari* system, the technical core of the family, must be inherited. Therefore, the *Kiwari* manual that secretly handed down by the family was born. The early *Kiwari* manuals include *Sandaikan* (*Three-generation Scroll*, 1489) [8] and *Kikudaki-no-Chumon* (*The Annotation of Kiwari*,1563 or 1574). This systematic design technology is called Kiwari technology.

In recent years, it has been confirmed that the ancestral secrets of craftsmen began to circulate in the market in the second half of the 16th century. In the mid-17th century, the inheritance of *Kiwari* technology was no longer limited to families, but allowed to be passed on to disciples from everywhere. Therefore, the sects of the carpenter were gradually formed. In 1655, the published *Kiwari* manual finally appeared in public, that is, *Shinpen-hinagata (The Newly Edited Prototype)* [9].

It is unknown whether the Edo shogunate had the intention to promote the standardization of architectural design, so as to promote the publication of Kiwari manuals. However, the widespread popularity of *Kiwari* manuals in the middle of Edo (18th century) is a clear historical fact, which even gradually led to the unification of the design of Japanese temples and shrines. During the Meiji period (1868–1912), some people criticized that the design of Japanese temples and shrines only followed the *Kiwari* manual, which made them all look the same.

The most famous *Kiwari* manual in the Edo era are *Shomei* (written in 1605–1608) by the Tokugawa Shogunate craftsman family, Heinouchi family, and *Kenninjiha-kadensho (The Family Book of Kenninji Temple School*, written in the early 18th century) of another Shogunate craftsman family - Kora family.

Kamakura Zoei Myomoku is about 30 years older than *Shomei*. Compared to *Shomei* and *Kenninjiha-kadensho*, *Kamakura Zoei Myomoku* has no attached drawings but only regulations on the sizes, and it is more like a memorandum. Nevertheless, it uses the common language of the early *Kiwari* manual, which is similar to *The Construction Drawings of Kamakura Engakuji Temple*. Therefore, it can be considered that *Kamakura Zoei Myomoku* is an early *Kiwari* manual of early modern period (16th–19th century) that keeps the characters of the medieval period (13th–16th century). Its content is very different from the mainstream

[8] At the end of the scroll, there are words like *Shungen and Shochin in 1489, Yoshisada Fujiwara* and written by Jokichi Fujiwara. They didn't exist originally, but were copied after 4 times and included in *Gushikenki* written in 1682.

[9] Written in the first year of the Ming dynasty (1655) by Segawa Masashige of Kofu, Toshima County, Musashi (one of the urban areas of today's Tokyo), one volume, 30 cm long. The original meaning of "prototype" was sample and model. This book includes design principles and drawings. Segawa Masashige is the Chief master carpenter who could design according to rules and standards (called *Toryo* in Japanese). According to the preface, this book was co-authored by Segawa Masashige and his son. The earliest original edition is collected in the National Diet Library, Japan.

west Japan technology centered in Kyoto, and it belongs to the Kanto region's unique technology system centered in Kamakura. In other words, *Kamakura Zoei Myomoku* remains in the clique tradition of Kamakura five-mountain temples, which was very popular in the medieval (13th–16th century) Japanese architecture, and retains the strong influence of Song-dynasty Chinese design techniques that introduced to Japan from the Kamakura era. Since none of the five-mountain temples in Kamakura remains today, the architectural image and technology of the time cannot be seen in the relics, so this batch of historical materials is particularly important.

3. THE ZEN-STYLE BRACKET SETS AND ITS DESIGN METHOD IN *KAMAKURA ZOEI MYOMOKU*

There are three documents in *Kamakura Zoei Myomoku* that clearly record the Kiwari sizes of the bracket sets, which are *Three-Bay Buddha Hall* (1663), *Five-Bay Buddha Hall* (1635), and *Three-Gate Pavilion* (1634). The author sorted out the dimension records of the three-extension bracket complex in the body of the hall (called *Moya* in Japanese), and drew Figure 3 referred to the image data of the bracket sets in the same period and the architectural relics.

Kinya Sekiguchi pointed out that the contents of *Kamakura Zoei Myomoku* are very similar to *The Ancient Drawing of the Engakuji Temple* that was drawn in the 4th year of Genki (1573) [7]. Because there is no image data in *Kamakura Zoei Myomoku*, the following morphology analysis of bracket sets refers to the *tatejiwari* [10] in *The Ancient Drawing of the Engakuji Temple*.

All kinds of components of bracket set in *Kamakura Zoei Myomoku* can be classified into four categories: *To* (bearing block, *Dou* 斗), *Hijiki* [11](bracket arm, *Gong* 栱), *Odaruki* [12] (tail rafter, *Ang* 昂) and *Keta* (Purlin, 桁. Bearing block can also be divided into *Daito* bearing block, *Makito* bearing block [*San-dou*, Figure 4], *Kaketo* bearing block [13] [*Jiaohu-dou*, ② in Figure 3], and *Houto* bearing block. Among them, *Kaketo* is the most characteristic bearing block in *Kamakura Zoei Myomoku*. It is the bearing block holding the *Odaruki* tail rafter or the *Hijiki* bracket arm that extended from the vertical wall. Its length and width are 10 percent bigger than that of the *Makito*[14]. The *Houto* [⑥ in Figure 3] is not supporting the crossing bracket arm, but is under the tail of the lower strut [*Sasu*; ⑤ in Figure 3] to support the upper tail rafter of the third extension of the outer eaves.

In Japan, bracket arm is called *Hijiki*, and bracket sets that parallel to the outer wall and

[10] *Jiwari* is the map showing the state of land division. In urban planning, land zoning and plot division design are called Jiwari plan. While *tatejiwari* refers to the drawing that draws half of the elevation and section of a single building on one drawing. *Tate* here means vertical. The *tatejiwari* in *the ancient drawing of The Engakuji Temple* in the text is the sectional elevation.

[11] In order to facilitate the comparison with the *Yingzao Fashi*, this paper takes the use of Japanese Chinese characters as the basic principle for the architectural terms in Japanese, such as Chinese *Hua-gong*, and the corresponding Japanese components still use *Hijiki*. Architectural terms without Chinese characters are expressed by Roman letters pronounced in Japanese or the transliteration of Chinese characters.

[12] Generally speaking, Ang is called *Odaruki* in Japanese, and *Ohtaruki* is a unique term in *Kamakura zoei myomoku*.

[13] *Kake* has no Chinese characters in Japanese. It is literally translated as hanging, which is similar to the meaning of *Jiaohu* (interaction) in Chinese. However, because of its special size, it is different from the *Jiaohu-dou* in China, so here directly uses *Kaketo*.

[14] The professional term "*Kaketo*" is also recorded in other early *kiwari* manuals, such as *Magoshichi-Oboegaki*, Kobayashi family book, a carpenter family of Shonai county (today's Yamagata prefecture), and *Shomei* in the early days of Edo. However, none of these books stipulates that the length and width of the "*Kaketo*" bearing block should be increased by 10%. Kinya Sekiguchi pointed out in The Bracket of the Zen style (1), that generally, the length of the *Makito* bearing block (*San-dou*) is the same as that of the *Houto* bearing block. The phenomenon of enlarging *Kaketo* bearing block is only confirmed in Sagami (today's Kanagawa prefecture), Musashi (today's Tokyo prefecture), Shimousa (today's Chiba prefecture), Kai (today's Yamanashi prefecture), Shinano (today's Nagano prefecture) and other Eastern countries (today's Kanto region).

on the vertical wall all have their own names, but there is no unified name like *Heng-gong* or *Hua-gong*.

The characteristic of Zen-style bracket sets is that the height, width and length of *Heng-gong* and*Hua-gong* are all different. Specifically, the bracket arm of the first extension that parallel to wall is called *Waku-Hijiki* in Japan, and *Waku* means frame. The length and height of *Waku-Hijiki* are all standard sizes. The length of *Hijiki* from the second extension upper is one *Makito* bearing block longer than the standard size, so the component is called *Naga-Hijiki* (Long bracket arm) in Japan [⑧ in Figure 3]. Meanwhile, the section height of bracket arm in vertical wall direction increases, so that it aligns the top of the lower bracket arm to the bottom of the upper bracket arm, and the section width increases 10 percent than that of *Waku-Hijiki*. Since the surfaces of these two components are overlapped, they are called *Kasane-Hijiki* in Japanese [① in Figure 3] that emphasizes the overlapping and integrated state of the upper and lower components. In fact, this integrated state strengthens the overall structure of bracket sets.

The head of the *Ohtaruki* (*Odaruki*; *Xia-ang*/tail rafter) in *Kamakura Zoei Myomoku* is of the angular type unique to the Kanto region, and the third extension, which is the top one, is called *Hashiru-*[15]*Ohtaruki* [④ in Figure 3]. The second extension, the lower tail rafter, is called *Kasane-Ohtaruki* [Overlapping tail rafter; ③ in Figure 3]. Here "overlapping" also means the integrated state of upper and lower components. Although the *Kasane-Ohtaruki* is also the tail rafter looked from the outside, in fact it is a decorative one. It is made of one piece of wood to make two kinds of heads. The inner side is bracket arm, and the outer side is the horned head [16]. Figure 5 shows the decomposition model of the bracket sets under the eaves of the Shariden Hall of the Engakuji Temple in Kamakura. The component with one head of *bracket arm* and one head of horn is the *Kasane-Ohtaruki*. It is a fake support component, and the inclined timber playing the role of structure is a diagonal brace, called *Sasu* [⑤ in Figure 3] extending from the center of the column to the inner side of the roof.

These bracket sets are connected horizontally through bracket arm (*Fang* 枋) or purlin (*Heng)*. The round purlin on the outermost side of the eaves [eave purlin, *Liaoyan-fang*, ⑩ in Figure 3] is the most special component of all. Its sectional height

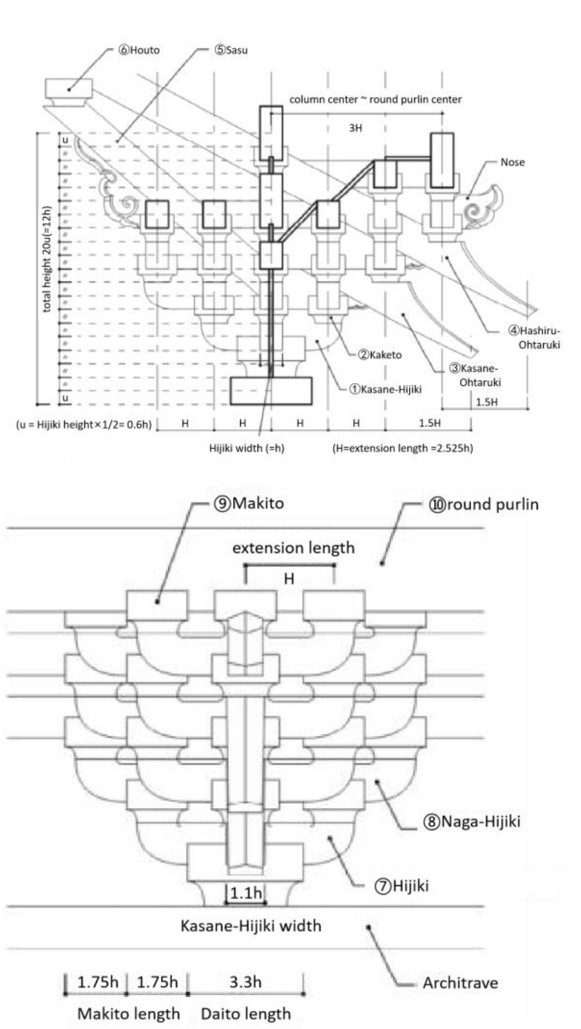

Figure 3. Composition of Zen-style three-extension bracket sets in Kamakura zoei myomoku. Source: Drawings by Tadanori Sakamoto according to the record

[15] In Japanese, *Hashiru* has no Chinese character. It means "run."

[16] Splicing will weaken the structural strength. After the Kanto earthquake in 1923, when repairing the Sarira Hall of Engakuji Temple in Kamakura, this component was spliced with two timbers.

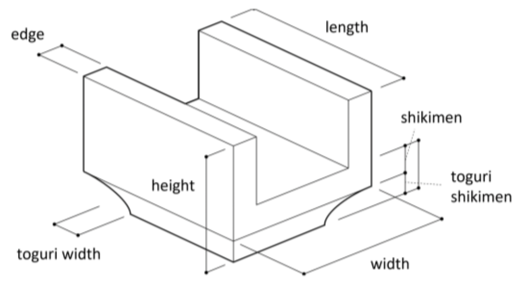

Figure 4. Schematic diagram of each part name of *Makito* (*San-dou*). Source: Drawing by Tadanori Sakamoto

Figure 5. Decomposition model of the bracket sets under the eaves of the Shariden Hall of Engakuji Temple in Kamakura. Source: Produced/collected by Takenaka Carpentry Tools Museum

is twice the standard height of bracket arm, and the sectional shape is rectangular. In addition, *Makito* bearing blocks directly supports theeave purlin, without the *Sane-Hijiki* (purlin-bearing bracket arm).

The bracket sets above are restored by the author according to the *Kamakura Zoei Myomoku*. They are basically the same as the bracket sets of the existing Kanto Zen-style Buddhist Temple[17] [8]. Especially, the record about techniques of *Kasane-Hijiki* and *Kaketo* should be noted. There are no similar records in other modern (16th–19th century) *Kiwari* manuals, except *Kamakura Zoei Myomoku*, which shows that these two techniques are the unique and important characteristics of Kanto Zen-style bracket sets [9].

The first step of the bracket sets design method in *Kamakura Zoei Myomoku* is to determine the datum dimension, and then multiply it by the proportional factor to obtain the size of the other components. However, the datum dimension and the proportional factor of various components vary with different *Kiwari* manuals. After analyzing the regulations of *Kamakura Zoei Myomoku*, we can know that it sets the column diameter as the most basic datum dimension, and the bracket arm as the second. The carpenters will set the bracket arms' sectional height, width [h in Figure 3] and extension length [H in Figure 3] as auxiliary datum dimensions [10]. When calculating the vertical direction (facade direction) of bracket sets, the proportional factor needs to be simplified and easy to operate. In *Kamakura Zoei Myomoku*, the vertical upper and lower ends of each bracket sets component coincide with the horizontal line of 1/2 the height of bracket arm, that is, $u = 0.6h$ = Bracket arm length (height) × 1/2, as shown by the horizontal dotted line in Figure 3. These equidistant horizontal baselines have an integer multiple alignment relationship with the upper and lower ends of bearing block and bracket arm. It should be noted that 1/2 the height of bracket arm = the height of *shikimen* [18] (Ping + Qi) in *Kamakura Zoei Myomoku*, which is different from the height ratio of 2:1:2 for the Er, Ping, Qi in *Yingzao Fashi*. This

[17] About the composition of bracket sets in the existing Kanto Zen style Buddhist temples, please refer to *The Bracket of the Zen Style (1)* by Kinya Sekiguchi

[18] That is, the depth of the Dou's mouth (height of Er) and the height from bottom to the bottom line of Dou's mouth (Ping + Qi) account for half of the overall height of Dou. The height of Ping + Qi is called *Shikimen* in Japanese, Figure 4.

equidistant horizontal baseline is not only used in the scale design of the vertical (facade) direction of bracket sets outside, but also the rainbow beams and bracket sets inside and *Naijin* inner sanctum (*daguang*/*neizheng*) bracket sets. The author believes that it is not a coincidence, but proves that the method of using equidistant horizontal baselines to control the height of the components exists at the beginning of the design. Only then can the upper and lower ends of each component highly coincide with the horizontal baseline.

Similarly, the horizontal size of bracket sets is also based on the extension length [H in Figure 3] as the datum dimension. The design method of the bracket arm that is vertical to the wall (*Hua-gong*) is to first draw the axes of the equidistant extension length of bracket arm, H; then the extension length of the *Ohtaruki* tail rafter (*Xia-ang*), the depth of eave; and then the horizontal extension distance of wooden platform (Wooden base), and so on, are all based on the extension length of bracket arm as the basic unit size to calculate. However, there is no multiple relationship between the horizontal extension length of bracket arm (*hen-gong*) and its cross-sectional height, so there is still some ambiguity. At present, it is speculated that Japan uses the principle of *To-chigai* to determine the extension size of bracket arm [11]. *To-chigai* can be literally translated into bearing block staggering, which means not shielding each other. The principle of *To-chigai* is shown in Figure 6, that is, the left contour of the *Daito* large bearing block is aligned with the right contour of each extension's *Makito* small bearing block, and contours of *Makito* small bearing block on the same side are aligned, as well as the right. It decides the extension size of bracket arm based on the principle of aligning contours of the upper and lower bearing block. *Wayo* style does not use the principle of *To-chigai*, which is the unique design method for hen-gong of Zen style.

In *Kamakura Zoei Myomoku*, there is a special term for the distance between the axes of two bracket sets, that is *ayita*. Its pronunciation can be transliterated as *aita*, *anta*, or *ayita*. Terms of other components in *Kamakura Zoei Myomoku* are mostly expressed in Chinese characters, but katakana is specially used here. This pronunciation itself can correspond to the Chinese character 间 *Jian*, but deliberately not using Chinese character indicates that it emphasizes the pronunciation of this term. In addition, the distance between two adjacent columns (*zhujian*) is called *hashira-ma* in Japanese, and the pronunciation of *jian* here is *ma*. The author speculates that there are two reasons for the above use of pronunciation mark. The first may be to pass down the pronunciation introduced by Chinese craftsmen, just as katakana is also used to mark foreign words in modern times [19]. The second may be to avoid confusion between the column distance and the bracket sets' axial distance.

Kamakura Zoei Myomoku stipulates that the size of the larger bay (central bay) is three ayita, and the rib bay (secondary bay) is two *ayita*. It can be seen that in Zen-style architecture, the column distance is specified by *ayita*, the bracket sets' axial distance. However, *ayita* is a unique concept of Zen style. Earlier wayo-style architecture used *shiwari* [20] instead of *ayita* to determine the distance of the columns.

Since the 7th century, the design method of wooden architecture introduced from China and Korea was to determine the distance of the columns first, and set it as the datum size. The rafters were unevenly distributed because the column distance was the full scale. From the end of the Heian period to the Kamakura period, the accuracy of *wayo*-style architecture was improved, and one of the purposes was the pursuit of an even

[19] The author did not find the word with the same pronunciation and meaning in *Yingzao Fashi*.

[20] The Japanese pronunciation is *Shi-Wari*, *shi* is the quantifier of rafters, 1 *shi* = side length of rafters + distance between adjacent rafters, *wari* still means "proportion and scale." Shiwari refers to the method of taking 1 *shi* between rafters as the basic unit size to determine the plane size, so it has a corresponding proportional relationship with the spacing of column and bracket sets.

distribution of rafters. At this time, the Hanegi cantilever [Figure 7] had been used to support the loads of eaves, so the rafters including the corner could be made into parallel, and the section had been changed from the round shape in ancient times (7th–12th century) to square. In the 13th century, the *shiwari* principle that determined the plane size of wayo-style architecture was established [12,13] [21] . The so-called *shiwari*, as shown in Figure 8, means the size of *1 shi* was the side length of a square rafter + the distance between adjacent rafters. *Shiwari* principle was determining the size of 1 *shi* of the equally spaced rafters first, and then the distance of the columns as several *shi*, which means that the size between columns was an integral multiple of the equal spacing of rafters [14]. Therefore, *shiwari* was a *wayo*-style architecture scale principle that determined the relevant dimensions of the plan based on the rafters. Before the formation of Zen style, the *shiwari* system had appeared in *wayo*-style architecture. According to the Japanese architectural relics, the *Rokushigake* [6 rafter arrangement, Figure 9, right] had been widely popularized from the 13th to 14th centuries, that is, the horizontal length of one bracket set exactly corresponds to 6 rafters + 5 spacing.

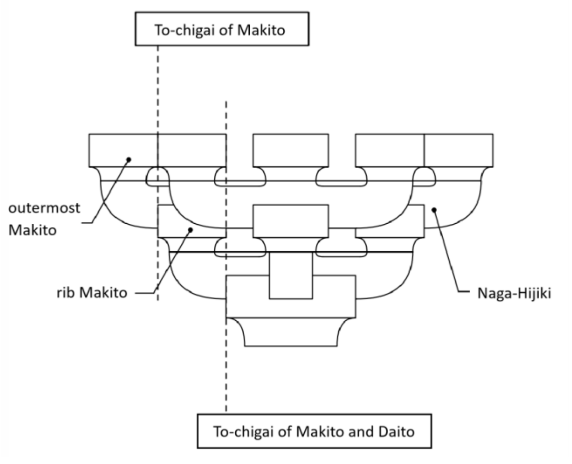

Figure 6. Schematic diagram of *To-chigai* principle in *Kamakura zoei myomoku* Source: Drawing by Tadanori Sakamoto

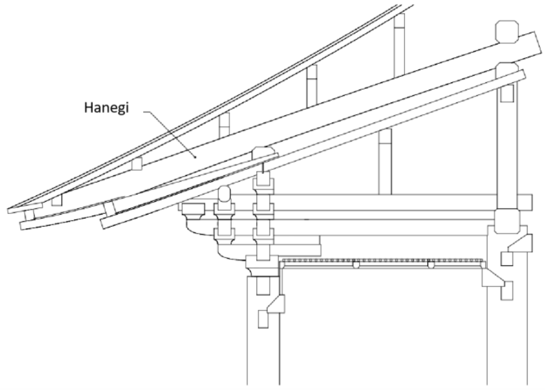

Figure 7. *Henagi* in the model roof of Nara *Yakushiji* Temple east hall (Source: Drawing by Nara ikarugakousya; collected by Takenaka Carpentry Tools Museum

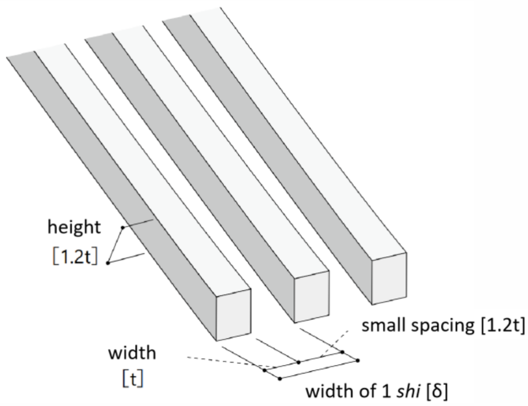

Figure 8. Schematic diagram of the size and name of Japanese rafters. Source: Drawing by Tadanori Sakamoto

Gake refers to the corresponding relationship between the dimensions of the rafters and the bracket sets. In this way, the arrangement of rafters and bracket sets have a neat counterpoint relationship, which makes the eaves to obtain a strict sense of rhythm. The transformation from the principle using the size of the column spacing as the datum size to the *shiwari* system meant the Japanization of Chinese wooden architecture technology. It was one of the characteristics of Japanese architectural history in the medieval period (13th–16th century).

[21] For the establishment of the *shiwari* system, please refer to *About the Development of shiwari, especially the Occurrence of Rokushigake-tokyo* by Kenji O and *On the Determinable Method of the Measurement of a Span between Rafters in Buddhist Main Halls in the First Half of the Medieval Period* by Akinori M.

Wayo-style architecture had the *shiwari* system, but there was no concept of *ayita*, which means there was no bracket sets' axial distance. So, what was the relationship between the unique *ayita* of Zen style and the *shiwari* of *Wayo*? The author analyzed the size of the Three-Bay Buddhist Monastery in the *Kamakura Zoei Myomoku*, calculated the result that, 1 ayita = 8 shi. And combined with the form of bracket sets from the sectional elevation of the *The Construction Drawing* of *Engakuji Temple*, the author restored the multiple size relationship between *ayita* and *shiwari* of *Sanken-butsuden* (the *Three-Bay Buddhist Monastery)*, as shown in Figure 10.

Although there was no direct relationship between *ayita* and the size of the bracket arm, the equidistant baseline obtained after eight equal divisions of *ayita* basically aligned with left and right end contours of the *Makito* bearing block, so it can be assumed that *ayita* was about eight times the length of the *Makito* baering block [11].

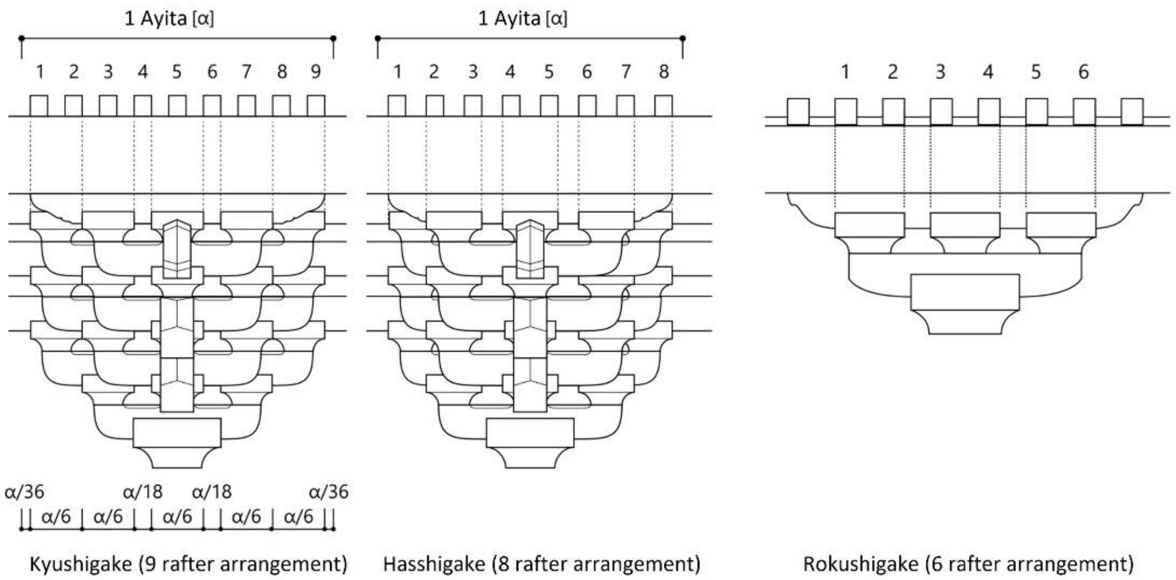

Figure 9. The corresponding relationship between shiwari and the size of bracket sets: wayo-style Rokushigake (6 rafter arrangement), Zen-style Hasshigake (8 rafter arrangement) and Kyushigake (9 rafter arrangement). Source: Drawing by Tadanori Sakamoto

4. THE COMPARISON WITH THE DESIGN METHOD OF BRACKET SETS IN THE SONG-DYNASTY *YINGZAO FASHI*

It can be said that the architectural technology recorded in the *Yingzao Fashi* was the source of Japanese Zen-style architecture. Bracket sets were the most characteristic components of Zen-style architecture, thus the comparison between *Kamakura Zoei Myomoku* and *Yingzao Fashi* was limited to bracket sets. In Japan, Takuichi Takeshima [22] was the first architectural historian who studied *Yingzao Fashi*.

In *Yingzao Fashi*, the number of bracket sets is counted by *duo*. It is stipulated that two

[22] Takuichi Takeshima (1901–1992), Japanese architect graduated from Imperial University of Tokyo (now the University of Tokyo) in 1927. He has followed Mr. Tadashi Sekino to visit China for many times. He once talked with Qiqian Zhu and Xiang Tao about the lithographic version of *Yingzao Fashi* and the collation of the imitation song version. From 1939 to 1942, Takeshima basically completed the first draft of the interpretation and research of *Yingzao Fashi*, but it was burned down by the air raid in 1945. The rewritten manuscript was submitted to the University of Tokyo as a doctoral thesis in 1949. In 1970, he published *A Study on Yingzao Fashi* and reprinted it many times.

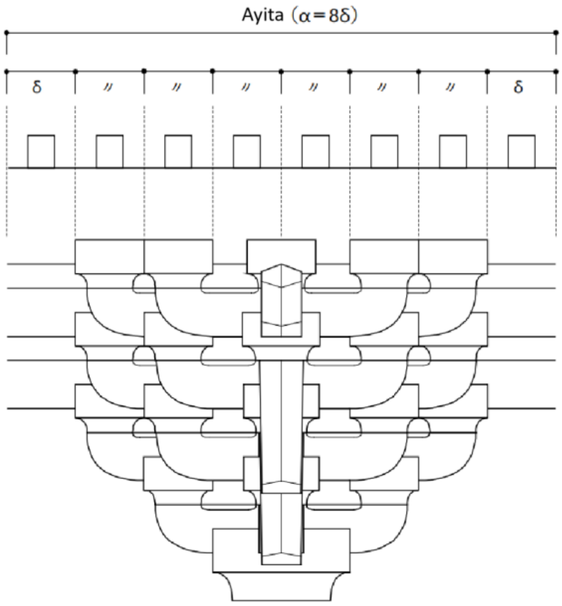

Figure 10. The dimensional correspondence between *shiwari*, *ayita* and the length of Makito (Small bearing block) in *Kamakura zoei myomoku* and *The Construction Drawing of Engakuji Temple*. Source: Drawing by Tadanori Sakamoto

duo of bracket sets are used in the middle bay, one in the secondary bay and one in the tip bay (called "end bay" in Japan), according to the principle of equal distance distribution. It also means that the size of each bay is restricted by the number of bracket sets [23]. The compositional method of the bracket sets in *Yingzao Fashi* is shown in Figure 11, and the types and sizes of the bracket arm are shown in Figure 12. It should be noted that the technique of making the top of *Tsu-ts'ai Hua-gong* 足材华栱 and the upper extension integrating and supporting each other in *Yingzao Fashi* is exactly the same as the technique of *Kasane Hijiki* bracket arm in *Kamakura Zoei Myomoku*. *Nidao-gong* bracket arm is equivalent to *Waku-Hijiki* bracket arm, with a length of 62 fen°. *Guazi-gong* bracket arm is equivalent to *Hakari-Hijiki* bracket arm, with the same length as *Nidao-gong* bracket arm. *Ling-gong* bracket arm is equivalent to the outermost *Hakari-Hijiki* bracket arm in Japan, which is slightly longer than *Nidao-gong* bracket arm, with a length of 72 fen°, the same as the first extension's *Hua-gong*. *Man-gong* bracket arm is equivalent to *Naga-Hijiki* bracket arm, with a length of 92 fen°.

The technique of making the end of *Hua-gong* bracket arm into the horned head in *Yingzao Fashi* is similar to the *Kasane-Hijiki* bracket arm in *Kamakura Zoei Myomoku*. However, this technique in *Yingzao Fashi* is only limited to four-layer bracket sets 四铺作, which is different from *Kamakura Zoei Myomoku*. The *Shang-ang* strut is equivalent to the component called *Sasu* strut in *Kamakura zoei myomoku*.

Qixin-dou bearing block in *Yingzao Fashi* is still called *Makito* bearing block in Japan, and *Jiaohu-dou* bearing block is equivalent to *Kaketo* bearing block. The width of the *Jiaohu-dou* bearing block is 18 fen°, which is slightly larger than that of the *Qixindou* bearing block with a width of 16 fen°. It is the same as the relationship between *Kaketo* bearing block and *Makito* bearing block in *Kamakura Zoei Myomoku*. The width and length of all the *Ludou* bearing block are all 32 fen°. The width of *Daito* bearing block in *Kamakura Zoei Myomoku* is three times that of bracket arm. Assuming that the width of *Gong* is 10 fen°, the width of *Ludou* bearing block is 30 fen°. It can be seen that the size of *Ludou* bearing block in *Yingzao Fashi* is slightly larger than that in *Kamakura Zoei Myomoku*. *Yingzao Fashi* stipulates that *San-dou*'s short side (width) should be taken as the front, which is also different from the way of using the long side of the *Makito* bearing block as the front side in the *Kamakura Zoei Myomoku*.

In *Yingzao Fashi*, the *Er* of the *Ludou* bearing block is equivalent to the *gan* of Japanese, *Ping* is equivalent to the *Shikimen* of Japan, and *Qi* is equivalent to the *Toguri* of Japan. The height ratio of *Er*, *Ping*, *Qi* is 2:1:2, which is the same as the proportion and size specified in the *Gomawari* (five-bay arrangement) in the *Shomei* 匠明 and the *Kiwari* in *Kamakura Zoei Myomoku*. It is worth noting that the calculation method of

[23] However, when the size of each bay is different, the distance between bracket sets is allowed to change within one *shaku*. It can be seen that there is also a design method that gives priority to determining the size of the bay.

the bottom size of bearing block is the same as that in *Kamakura Zoei Myomoku* and *Yingzao Fashi*, but different from that in *Shomei*. In *Yingzao Fashi*, the bottom width of bearing block is obtained by cutting 2 fen° inward from the upper end dimension, and *Kamakura Zoei Myomoku* also calculates how much *Toguri* needs to be cut inward from the lower end dimension of the *Makito* bearing block [Figure 4]. While *Shomei* directly specifies the lower end width of bearing block.

Next, let us discuss whether there is a vertical alignment of the *gong* on facade [Figure 12] in *Yingzao Fashi*, that is, whether there is a *To-chigai* principle.

The distance between the axes of the two *San-dou* bearing block on *Nidao-gong* blacket arm is 52 fen°, and the width of *Ludou* bearing block is 32 fen°. The short side of *San-dou* bearing block is 14 fen° long, so the width of *Ludou* bearing block + width of *San-dou* bearing block = 46 fen°, which is 6 fen° less than the distance between the axes of two *San-dou* bearing block. Similarly, the distance between the axes of the two *San-dou* bearing block on *Man-gong* bracket arm is 82 °, and

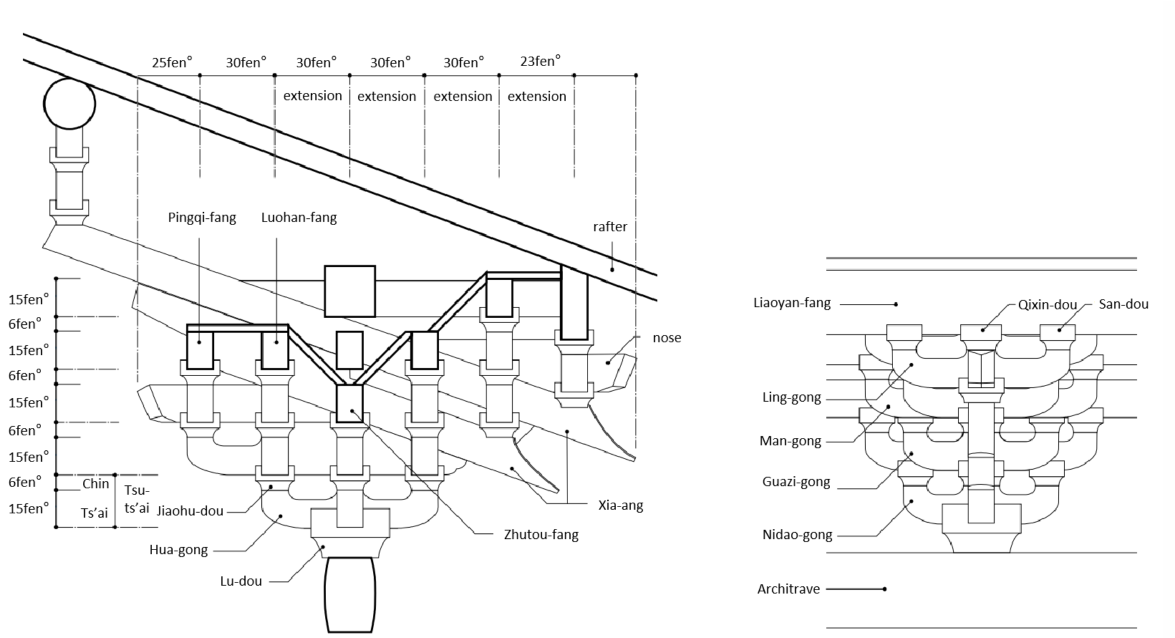

Figure 11. The composition of six-puzuo bracket sets in *Yingzao Fashi* (referred to Figure 240 in *The Annotation of Yinzao Fashi* written by Liang Sicheng [15]. Source: Drawing by Tadanori Sakamoto

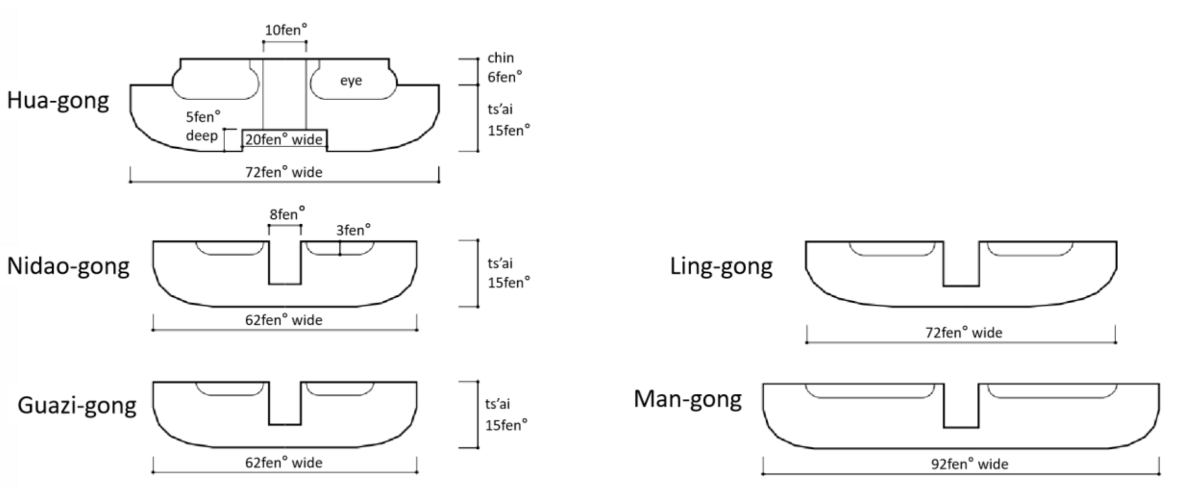

Figure 12. The types of Gong in Yingzao Fashi (referred to Figure 241 in The Annotation of Yinzao Fashi written by Liang Sicheng [15]. Source: Drawing by Tadanori Sakamoto

the distance + the width of *San-dou* bearing block × 2 = 80 fen°, with a gap of 2 fen°. It can be seen that there is no counterpoint relationship between the left and right outer contours of the *Ludou* bearing block and the inner contour of the *San-dou* bearing block on *Nidao-gong* bracket arm, as well as between the outer contour of the *San-dou* bearing block on *Nidao-gong* bracket arm and the inner contour of the *San-dou* bearing block on the *Man-gon*g bracket arm [right side of Figure 11, *Heng-gong*], that is, there is no Japanese *To-chigai* principle as in *Yingzao Fashi*.

5. HISTORICAL SIGNIFICANCE OF *KAMAKURA ZOEI MYOMOKU*

To conclude, the comparison results between *Yingzao Fashi* and *Kamakura zoei myomoku* are summarized as follows.

(i) *Yingzao Fashi* not only distinguishes between *Hua-gong* bracket arm and *Heng-gong* bracket arm, but also the name and size of *Heng-gong* vary due to different locations. For example, *Guazi-gong* bracket arm and *Ling-gong* bracket arm are called *Hakari-Hijiki* bracket arm in Japan. *Ling-gong* bracket arm is longer than *Guazi-gong* bracket arm, while the *Hakari-Hijiki* bracket arm in Japan has no length change. It can be seen that *Kamakura Zoei Myomoku* only distinguishes bracket arm that is vertical or parallel to the walls, and which are not subdivided in the same direction. There is no change in the length, which simplifies the classification of bracket arm in *Yingzao Fashi*.

(ii) The technique of making the top of *Tsu-ts'ai Hua-gong* 足材华栱 and the upper extension's bracket arm integrating and supporting each other in *Yingzao Fashi* is similar to the technique of *Kasane-Hijiki* bracket arm in *Kamakura Zoei myomoku*. However, the width of *Kasane-Hijiki* bracket arm is 1/10 wider than that of ordinary bracket arm. And there is no similar stipulation in *Yingzao Fashi*.

(iii) In *Yingzao Fashi*, *Jiaohu-dou* bearing block on the head of the *Hua-gong* bracket arm is slightly larger than *San-dou* bearing block, which is similar to the technology of *Kaketo* bearing block. But there is no record that *Qixin-dou* bearing block is larger than *San-dou* bearing block, which can be seen that it has been simplified.

(iv) The size of *Qi* (*Toguri* in Japanese) reduces with the width of bearing block. This processing method is the same as that of *Toguri* [24] in *Kamakura Zoei Myomoku*. Referring to Figure 4, width refers to the width of the *Makito* (Small bearing block, 卷斗). Then cut inward, the eliminated width is called *Toguri* width.

(v) When a piece of wood is used to make the inserted *Odaruki* tail rafter obliquely, the processing method in *Yingzao Fashi* is the same as that in *Kamakura Zoei Myomoku*, and *Odaruki* tail rafter plays a structural role in supporting the eaves. However, there is a big difference between the methods of the two manuals when they are using the double *Odaruki* tail rafter. In *Yingzao Fashi*, the two components are all made of a whole inclined wood, both of which stretch out under the eaves, which is consistent with Japan [Figure 3]. The difference is in the second extension. In Japan, its head is in the shape of *Odaruki* tail rafter, called *Kasane-Hijiki* overlapping bracket arm which is a fake decoration. Together with the bracket arm of the second extension indoors, they are processed from the same piece of wood [refer to the decomposition component in Figure 5]. Nevertheless, the technique of inserted *Odaruki* tail rafter in four-layer bracket sets or inserting *Odaruki* tail rafter inward from the center of bracket sets in the *Yingzao Fashi* has been confirmed in *Kamakura Zoei Myomoku*.

[24] *Toguri* is a nominalization of verb "Kuru", which means "cutting inward."

(vi) The cross-sectional height of the eave purlin (*Liaoyan-fang*) is twice that of bracket arm and directly supported with *San-dou* bearing block, which is also confirmed in *Kamakura Zoei Myomoku*.

(vii) There is no detailed description of the size of the column bay in *Yingzao Fashi*, which can be considered that the size of the column bay is determined by the number of bracket sets, and that in *Yingzao Fashi* can be understood as similar to the *Ayita* in *Kamakura Zoei Myomoku* used as intermediate datum units.

(viii) Using *Ts'ai* as the basic dimension in the *Yingzao Fashi* is similar to the method of taking the sectional width and height of the bracket arm as the auxiliary basic dimension in the *Kamakura Zoei Myomoku*, but the calculation methods of the two are completely different. *Yingzao Fashi* uses the concept of fen°, while the *Kiwari* is used in *Kamakura Zoei Myomoku* to determine the component size. That is the most fundamental difference between them.

(ix) There is no auxiliary dimension similar to *Chin* in *Kamakura zoei myomoku*. However, it sets the *Shikimen* height [Figure 4] as one-half of the section height of bracket arm, and uses it as the basic dimension unit in the design of the facade. The height ratio of *Ts'ai* to *Chin* in *Yingzao Fashi* is 15:6, which obviously has no intention of using equidistant baseline. However, *Kamakura Zoei Myomoku* takes the *Shikimen* height that equal to the size of *Chin* as the datum scale for controlling the size of components, which is similar to *Yingzao Fashi*. In addition, there is no Japanese facade design principle of *To-chigai* as in *Yingzao Fashi*.

Japanese Zen-style architecture was formed after the introduction of late Southern Song-dynasty Chinese architecture. So, the content of *Kamakura Zoei Myomoku* naturally has a strong connection with *Yingzao Fashi*. Especially the technique of the *Kasane-Hijiki* overlapping bracket arm in *Kamakura Zoei Myomoku*, that is, increasing the sectional height of the bracket arm to extend perpendicular to the wall to fill the gap between the upper and lower bracket arm components and overlap them to strengthen the structure. In Japan, this technique was only used in the Kanto region and its surroundings, and there is no record in other technical books. Therefore, it can be inferred that the bracket sets technique introduced from China to Kamakura in the late Southern Song dynasty was only spread and handed down in some areas. The background may be that the *Hanegi* cantilever technology which supported the eaves in medieval Japan (13th–16th century) [Figure 7] had been used widely, and the main load of the eaves did not need to be supported by bracket sets. Since there was no need to strengthen the structure in the direction that perpendicular to the wall, so the *Kasane-Hijiki* overlapping bracket armtechnique had not been spread widely.

In addition, there are records of increasing the scale of *Kasane-Hijiki* overlapping bracket arm and *Kaketo* bracket arm by one tenth in *Kamakura Zoei Myomoku*, but no similar record in *Yingzao Fashi*. Therefore, this technique should appear after the publication of *Yingzao Fashi*, and whether it appeared in China first, or was created and developed after the introduction of late Southern Song dynasty's architecture into Kamakura, it remains to be studied. For details, please refer to the follow-up paper *Design Method of Zen-style Bracket Sets Recorded in the Japanese Carpentry Manual Kamakura Zoei Myomoku (Part 2): A Comparative Study with the Chinese Manual Gongcheng Zuofa Zeli.*

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