

Review

Proportions of Wood Members in Japanese Traditional Architecture—A Comparison of the Kiwari-Sho and Measurements of Building Remains

Byungjin Kim

Waseda Research Institute for Science and Engineering, Waseda University, Tokyo 169-0051, Japan; moray78@naver.com; Tel.: +81-80-4165-5261

Abstract: Since written reference works on ancient design techniques are still extant, it is possible to gain an understanding of the development of these designs. In particular, we are able to investigate dimensional standards used for wood members using the Kiwari (木割: a method of determining the dimensions of all wood members using a proportion determined based on the diameter of the columns) in Kiwari-sho (木割書: a manual of dimensional standards for wood members). The objective of this study was to confirm whether the design techniques that have been collected under the term “dimensional standards for building (木割術: Kiwari-jutsu)” were actually utilized in the construction of buildings and whether they are a sustainable technology. This study will provide an understanding of the correlation between the techniques used and the dimensions of the remains of structures putatively built using such techniques. Furthermore, based on this analysis, this study will be useful in both quantifying the influence that dimensional standards techniques had on buildings at the time of their construction and as reference material that can be used when restoring the remains of cultural properties.

Keywords: Kiwari; Kiwari-sho; traditional architecture; construction scale; complete number system



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1. Introduction

During the ancient age (before 784) of traditional Japanese architecture, a large number of wooden buildings were constructed that had similarities to ancient Chinese and Korean buildings due to the interaction between Japan and the two countries at the time. One such type of traditional architecture, temple-and-shrine architecture, began as a result of the spread of this kind of architecture in the ancient period. It later took on different characteristics that were developed over the passage of time and it still exists in the present day. Since Japan is one of the countries in East Asia in which written reference materials related to design technology are still extant, it is possible to gain an understanding of the development of this technology. In particular, it is possible to confirm aspects of technologies related to dimensional standards using Kiwari-sho (木割書: manuals of dimensional standards used for wood members). In China, one of the representative works on design standards is the 『营造法式: Yingzao Fashi』 (manual on building and construction methods).

In Japan, although research into Kiwari (木割: the dimensional standards for building) has led to the identification of design techniques related to methods used to determine intercolumn spacing, no studies have so far attempted to compare the Kiwari-jyutu (木割術: dimensional standards techniques) with actual measurements of dimensions. Thus, a study of design techniques that have been compiled since the Middle Ages to confirm whether these techniques were actually applied when constructing buildings in the past was utilized in this study. As this analysis will provide an understanding of the correlation between the techniques and the dimensions of the remains, it will enable the quantification of the degree of influence that dimensional standards techniques had at the time. While

Kiwari-jyutu were techniques that originated in the Middle Ages of Japanese history, in the present study, an understanding of their origins is not important. Rather, since the objective of this study was to perform an analysis of the proportional relationships of wood members, important cultural properties were identified as the subject of this analytical study of actual dimensions.

The Kiwari-jyutu (dimensional standards techniques) included in the kiwari-sho have been continually studied by a variety of researchers, including Yōtarō Itō, Takeshi Nakagawa, Akira Naitō, and Katsuhiro Kawata. This study was concerned with the kiwari-sho and dimensional standards techniques in circumstances in which no studies comparing actual measurements of buildings with the dimensional standards techniques included in the kiwari-sho have thus far been conducted. Therefore, in this study, the extent to which dimensional standards techniques were involved in the actual construction of buildings was identified through a comparative study of the proportional relations of wood members based on actual measurements of buildings. It is believed that such a comparative study can prove whether this technology is sustainable.

This study targeted national treasures and important cultural properties whose basic design measures 3Ken (間: rooms) [1] each along the front elevation and the side elevation. The analytical resource consisted of the dimensions obtained from the published repair work reports on cultural properties. This was followed by a comparative analysis of those dimensions and the proportions listed in the kiwari-sho. The specific kiwari-sho used consisted of those that also indicate buildings measuring 3Ken on both the front and side elevations and whose documents can be dated.

Although Japanese kiwari-sho are texts that were written from the Middle Ages to the early modern period (1603–1867), the techniques listed in these works resulted from numerous attempts at construction performed prior to the Middle Ages. As a result, they are believed to also contain techniques that were developed prior to the Middle Ages. The items included in these kiwari-sho reference temple and shrine buildings measuring 3Ken per side. Considering that I conducted a comparison of the dimensions of the remains of such buildings, I analyzed the wood members that were used to construct the buildings by dividing them into four categories: floor plan (平面), foundation and lower supporting section (軸部 jiku-bu), the junction between the columns and the roof (組物部 kumimono-bu), and the roof (屋根部 Yane-bu).

1.1. Japanese Architectural Technology

The following is the theory behind the architectural technology that has been used in Japan up to the present day.

(1) Kansū-sei (完数制: traditional system of measuring proportions based on a standard figure, usually the shaku, which is approximately 30.3 cm).

One old method of design technology is believed to have been the “Kansū-sei for column distance” [2], in which the dimensions (measurements) for the distance between columns were calculated as the integer multiple of a unit of measure (a module);

(2) Shiwari-hō (枝割法: a system used to standardize the cutting of lumber).

Since the Middle Ages, relationships in Japan between the dimensions of columns, the distance between columns, the junctions between columns and the roof, and the Taruki (垂木: rafters) arose, which eventually became the method referred to as Shiwari-hō [3]. This method formed the basis for floorplan designs. The basic units used in the technique were the width of two Taruki and the distance between Taruki;

(3) Nakawaki-sa (中脇差).

Nakawaki-sa refers to a method of calculating the proportions of the floor plan of a building using an equidistant grid. It is the method of determining the distance between columns that was advocated by Kuninobu Ishii [4]. The basic unit of length (u) is determined, then the diameter of the columns (2u) is determined using the integer multiple, and then the grid (the distance $n \times u$) is determined. The distance between the columns

is then determined by placing three column measurements (inside measurement, center, and outside measurement) on this grid;

(4) Proportional method (比例法).

In Japan, research focused on the methods used to determine the distance between columns according to their proportions has been occurring for a very long time. The major methods include the “Theory of Determining Proportional Column Distance” [5], which uses $\sqrt{2}:1$ (◎1.414:1); the 3:2 ratio [6] based on the influence of a Zen Buddhist style advocated by Nobuo Itō; the 4:3 ratio [7] calculated using the dimensions of a structure known as Konjiki-dō at Chūsonji (Buddhist temple); and the 3:2 ratio [8] of Takuichi Takeshima;

(5) Kiwari (木割).

A summary of all the definitions of Kiwari would state that it is a method of determining the dimensions of all wood members using a proportion determined based on the diameter of the columns. Although there are differences based on the scale and style of the building, the proportions prescribed in each Kiwari-sho determine the diameter of the columns and the column diameters in turn determines the proportions of wood members such as the building’s footprint, the beams running between the columns, the Jihuku (地覆), Nagesi (長押), nuki (貫: joint connections), Keta (桁: purlins), Hari (梁: joist beams), and Taruki (垂木: rafters). Kiwari is an empirical method developed by artisans that has existed since prior to the Edo period (1603–1867) and it was recorded in a large number of Kiwari-sho.

The texts that contain the provisions for all wood members determined by the various styles and scales of buildings are known as Kiwari-sho, and the contents of each Kiwari-sho differ according to the carpentry lineage that created it. In simple terms, Kiwari-sho, which contain information related to Kiwari techniques, are a type of technical manual that were created from the Middle Ages and onward for the purpose of handing down to later generations the outstanding traditions of the carpenters of the age. Approximately 500 types of Kiwari-sho are still extant. Many of them were added to little by little by the successors of famous carpentry lineages. The contents of the 500 texts share some of the same guidelines. However, since they are old texts, some have not been discovered in their complete form, which means that the missing portions may be discovered at a later date.

In addition, Kikujutsu-sho (規矩術書) are an example of a kind of old text that is similar to Kiwari-sho. There are many similarities between kiwari and kikujutsu, but kikujutsu contains more detailed information than kiwari on numerical values for smaller wood members as well as joinery methods. Thus, strictly speaking, kikujutsu is a different type of technique. Put another way, kiwari-sho are texts used for the overall planning of a building, while kikujutsu-sho are texts that deal with joining and other parts of construction.

As mentioned above, the kiwari-sho that were the subject of this study were texts from the Edo period, which were studied to determine their sustainability over the ages. The validity of this study had to be confirmed in order to ensure its continuity.

1.2. Methods

The subjects of this study were National Treasures and Important Cultural Properties. A total of 16 National Treasures and 155 Important Cultural Properties were selected. Of these, 58 buildings have had survey reports published that contain all their measurements and dimensions [9] (Figure A2). The subjects of the comparative analyses were 46 items contained in 17 Kiwari-sho [10] (Figure A3). Kiwari-sho was written in “Kuzushiji (くずし字),” a language that is not used today, and therefore needs to be translated into modern languages (Figure 1). After translation, the translated contents were analyzed and between the wood members were arranged to become the Kiwari-kyutu proportional equation. Comparison of this proportionality formula with the actual dimensions of the remains was then conducted.

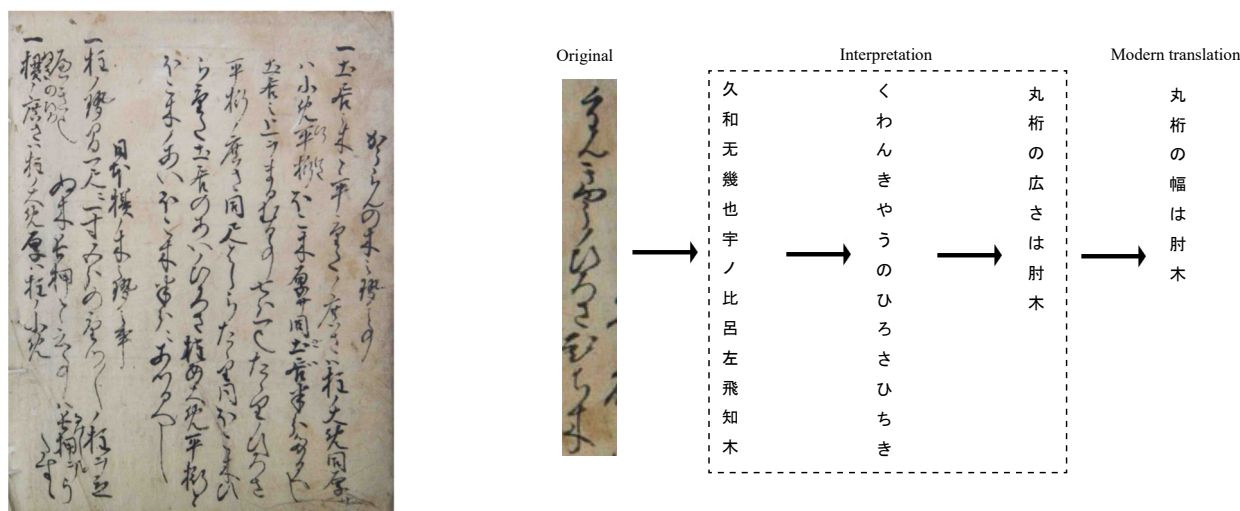


Figure 1. Kiwari-sho and the interpretation process of Kiwari-sho. Adapted from Bj.KIM (2021) [11].

The multiple of integers utilized in this paper are equal multiples. In particular, a margin error of $\pm 0.1 \times$ was applied to multiples of 1.5, $2 \times$, and others. Multiples of $1/3$ to $1/9$ were applied within the integer multiples without the use of any margin of error [12].

Based on the above analysis, the comparisons in this study were performed using the ChuoMa, WakiMa (distance between columns), and Mokosi (pent roofs) shown in the floor plans. Jiku-bu (Measurements taken from the supporting structures); Kumimono-bu (the junctions between the columns and roof); and Yane-bu (the roof) wood members included the diameters of pillars; RaikoHasira (round pillar diameter); Nuki (joint connection) height and width; KasiraNuki (the joint section) height and width; Daiwa (the architrave) height and width; Hijiki (bracket arm) length and width; Daito height, length, and width; Makito height, length, and width; Gagyō (round purlins) height and width; and Taruki (rafter) height and width [13] (Figures A4 and A5).

2. Analysis According to Each Part

2.1. Floor Plan (平面)

Figure 2 shows the multiple relationships between the dimensions of the ChuoMa, the WakiMa (中央間, 脇間: distance between columns), and the Mokosi (裳階: pent roofs) based on the diameter of pillars and the Issi (一枝) [14]. The light-colored area in the center of the shaded portion shows the integer multiple, while the dark-colored area shows the $1/3$ – $1/9$ multiples, which are the equal divisions.

The analysis of the ChuoMa based on Figure 2 showed that the integer multiples calculated based on the column diameters were found in 25 locations on the front elevation, 24 locations on the side elevation, and in 17 locations on both elevations. Equal multiples were found in three, two, and two locations (in the order of center, front, and side). In the WakiMa, there were 24, 23, and 21 locations, respectively, and equal multiples in 2, 2, and 2 locations, respectively. In the Mokosi portion, there were six and six locations, respectively, and all the locations were both integer multiples.

Shiwari was used as a standard measure to analyze the proportions of the floor plan. The integer multiples in the ChuoMa were present in 32 locations on the front elevation, 31 locations on the side elevation, and 29 locations on both elevations. In the WakiMa, there were 27, 26, and 25 locations (in the order of front, side, and both) and the equal multiples were in 1, 1, and 1 location, respectively. In the case of the Mokosi, there were five locations on the front elevation and five locations on the side elevation.

No	ChuoMa		WakiMa		Mokosi		Diameter of pillar		ChuoMa		WakiMa		Mokosi		Issi(一棧)	
	Front	Side	Front	Side	Front	Side	Scale(尺)	mm	Front	Side	Front	Side	Front	Side	Scale(尺)	mm
1	11.12	11.12	7.70	7.70	7.70	7.70	1.17	354.51	17.82	17.82	12.34	12.34	12.34	12.34	0.73	221.19
2	9.88	9.88	8.65	8.65	none	none	0.82	248.46	10.00	10.00	8.75	8.75	none	none	0.81	245.43
3	11.36	11.36	6.63	6.63	none	none	1.07	324.21	18.14	18.14	10.58	10.58	none	none	0.67	203.01
4	9.31	9.31	6.66	6.66	4.31	4.31	1.06	320	15.20	15.20	10.87	10.87	7.04	7.04	0.65	196
5	4.55	7.91	4.24	6.57	none	none	1.15	348.45	9.18	15.96	8.56	13.25	none	none	0.57	172.71
6	7.68	7.68	6.58	6.58	none	none	0.90	272.7	14.40	14.40	12.33	12.33	none	none	0.48	145.44
7	13.78	14.70	10.34	14.7, 12.55	none	none	0.44	133.32	4.92	5.26	3.70	5.26, 4.49	none	none	1.23	372.69
8	13.67	14.91	8.71	8.69	7.47	7.47	0.81	245	20.06	21.88	12.78	12.75	10.96	10.96	0.55	167
9	10.27	10.27	6.41	6.41	none	none	0.79	238	5.00	5.00	3.12	3.12	none	none	1.61	489
10	15.60	15.60	15.60	15.60	none	none	0.42	127.26	-	-	-	-	-	-	none	none
11	20.47	20.47	20.47	20.47	none	none	0.32	96.96	-	-	-	-	-	-	none	none
12	10.58	9.81	9.40	9.81	none	none	0.56	169.68	9.00	8.00	8.35	8.35	none	none	0.66	199.37
13	19.09	19.09	16.82	16.82	none	none	0.44	133.3	12.36	12.36	10.88	10.88	none	none	0.68	206
14	12.38	9.66	10.22	9.66	none	none	0.74	224.22	16.07	12.54	13.26	12.54	none	none	0.57	172.71
15	7.04	7.04	7.04	7.04	none	none	1.00	303	4.00	4.00	4.00	4.00	none	none	1.76	533
16	9.92	9.92	6.61	6.61	5.83	5.83	0.78	235	19.76	19.76	13.17	13.17	11.61	11.61	0.39	118
17	9.50	9.50	6.11	6.11	none	none	0.90	272.7	-	-	-	-	-	-	none	none
18	12.33	12.33	9.28	9.28	6.92	6.92	0.60	181.8	26.43	26.43	19.89	19.89	14.82	14.82	0.28	84.84
19	8.98	8.98	7.49	7.49	none	none	0.73	221	17.95	17.95	14.97	14.97	none	none	0.37	110.6
20	9.67	9.67	6.85	6.85	5.24	5.24	0.83	251.49	16.73	16.73	11.85	11.85	9.06	9.06	0.48	145.44
21	10.80	10.80	7.20	7.20	7.20	7.20	0.60	181.8	11.78	11.78	7.85	7.85	7.85	7.85	0.55	166.65
22	11.03	11.03	8.06	8.06	none	none	1.00	303	-	-	-	-	-	-	none	none
23	10.55	9.16	6.68	6.68	none	none	1.10	333.3	4.48	3.89	2.84	2.84	none	none	2.59	784.77
24	7.98	7.98	6.83	6.83	4.51	4.51	0.80	242	14.40	14.40	12.34	12.34	8.14	8.14	0.44	134
25	8.10	8.10	5.41	5.41	none	none	0.86	260.58	24.03	24.03	16.03	16.03	none	none	0.29	87.87
26	7.71	7.71	6.17	6.17	none	none	1.30	393.9	10.03	10.03	8.02	8.02	none	none	1.00	303
27	10.04	10.04	9.21	9.21	none	none	1.20	363.6	-	-	-	-	-	-	none	none
28	10.33	10.33	6.89	6.89	none	none	0.87	265	18.00	18.00	12.00	12.00	none	none	0.50	152.1
29	8.73	8.73	8.02	8.02	none	none	0.70	212	-	-	-	-	-	-	none	none
30	12.96	12.96	12.96	12.96	none	none	0.49	148.47	4.21	4.21	4.21	4.21	none	none	1.51	457.53
31	13.17	13.17	13.17	13.17	none	none	0.48	145.44	4.03	4.03	4.03	4.03	none	none	1.57	475.71
32	13.17	13.17	13.17	13.17	none	none	0.48	145.44	4.10	4.10	4.10	4.10	none	none	1.54	466.62
33	9.26	9.26	10.19	7.40	none	none	0.65	197	10.02	10.02	11.03	8.01	none	none	0.60	182
34	10.41	10.41	6.94	6.94	none	none	0.98	296.94	18.89	18.89	12.59	12.59	none	none	0.54	163.62
35	12.68	12.68	8.45	8.45	none	none	0.95	287.85	12.05	12.05	8.03	8.03	none	none	1.00	303
36	10.18	10.18	6.79	6.79	none	none	0.80	242	9.03	9.03	6.02	6.02	none	none	0.90	272.7
37	12.32	12.32	8.28	8.28	6.42	6.42	0.80	242.4	25.94	25.94	17.43	17.43	13.51	13.51	0.38	115.14
38	10.03	10.03	7.01	7.01	none	none	0.90	272.7	-	-	-	-	-	-	none	none
39	8.90	8.87	7.88	7.88	none	none	0.88	267	17.73	17.66	15.70	15.70	none	none	0.44	134
40	11.80	11.80	9.66	9.66	none	none	0.97	294	11.01	11.01	9.01	9.01	none	none	1.04	315.12
41	10.72	9.51	9.51	9.51	none	none	0.84	256	16.74	14.85	14.85	14.85	none	none	0.54	164
42	10.00	10.00	6.67	6.67	none	none	1.00	303	17.62	17.62	11.74	11.74	none	none	0.57	172
43	13.44	13.44	11.20	11.20	none	none	0.45	136.35	17.79	17.79	14.82	14.82	none	none	0.34	103.02
44	9.78	9.78	7.61	7.61	none	none	0.86	260.58	17.90	17.90	13.93	13.93	none	none	0.47	142.41
45	8.69	8.69	7.66	7.66	none	none	0.84	255	17.04	17.04	15.03	15.03	none	none	0.43	130
46	8.63	8.63	7.51	7.51	none	none	0.70	212.1	7.95	7.95	6.92	6.92	none	none	0.76	230.28
47	9.78	6.52	9.78	6.52	none	none	0.68	206	11.99	7.99	11.99	7.99	none	none	0.55	168
48	9.11	9.11	8.09	8.09	none	none	0.85	257.55	18.00	18.00	16.00	16.00	none	none	0.43	130.29
49	8.77	8.77	7.31	7.31	6.06	6.06	0.97	293.91	18.10	18.10	15.08	15.08	12.51	12.51	0.47	142.41
50	9.63	9.63	8.05	8.05	none	none	0.62	189	4.96	4.96	4.14	4.14	none	none	1.21	367
51	8.85	8.85	7.08	7.08	none	none	0.85	257.55	9.89	9.89	7.92	7.92	none	none	0.76	230.28
52	12.05	12.05	8.12	8.12	6.47	6.47	0.70	212.1	28.12	28.12	18.95	18.95	15.10	15.10	0.30	90.9
53	9.53	9.53	6.35	6.35	none	none	0.60	180.29	19.29	19.29	12.86	12.86	none	none	0.29	89.08
54	8.11	8.11	5.41	5.41	none	none	1.06	320	-	-	-	-	-	-	none	none
55	13.63	6.60	9.07	8.31	7.83	7.73	1.50	454.50	25.89	12.53	17.23	15.78	14.86	14.68	0.79	239.37
56	15.85	15.85	8.78	8.78	none	none	0.82	248.46	9.49	9.49	5.26	5.26	none	none	1.37	413.7
57	14.40	11.83	12.92	9.81	none	none	0.63	190	6.05	4.97	5.43	4.12	none	none	1.49	452
58	9.85	9.85	7.75	7.75	7.75	7.75	1.00	302	7.81	7.81	6.14	6.14	6.14	6.14	1.26	381
59	9.65	9.65	8.44	8.44	none	none	0.83	252	4.59	4.59	4.01	4.01	none	none	1.75	530

Figure 2. Plane dimension proportional analysis.

The results of this analysis showed that the floor plan proportions were determined using Shiwari rather than the column diameters. It is likely that Shiwari multiples were used as the standard module rather than Shiwari applied to the dimensions.

Four buildings had a standard Shaku (尺: 303 mm) as their column diameters, and a multiple of a shaku as the distance between the columns. Repairs are believed to have been made in the early modern period based on the measurement of a Shaku [15].

No relationship was found between the sizes of the floor plans and the integer multiples of the column diameters in these buildings. There was no correlation with the integer multiple in spite of conducting analyses based on regional differences and the time periods in which the buildings were constructed.

Comparison of the proportions of the ChuoMa and WakiMa making up the floor plan and the proportions of the column diameters with the Kiwari proportions (Figure 3) showed that many of the building plans for the ChuoMa used the same dimensions for the front and side elevations and that there were 16 and 9 locations, respectively, in which the proportions were the same as the 0.1D [16] and 0.11D of the Kiwari-jutsu. The 0.12D

was found in only four locations and 0.15D was found in none, indicating that these were few in number. The 0.08D and 0.09D, which are not part of Kiwari-jutsu, were found in nine and five locations, respectively, indicating that, in comparison to the overall distance between columns, the column diameters were smaller. On the side elevation, 0.1D, 0.11D, 0.12D, and 0.15D were found in 18, 11, 4, and 1 location, respectively, indicating concordance with kiwarijutsu. In the case of the peripheral room, in the front elevation, the 0.12D, 0.15D, and 0.16D proportions were used in 9, 10, and 4 locations, respectively, while in the side elevation, they were found in 10, 12, and 4 locations, respectively.

No	Diameter of pillar (柱径)				Issi (一枚)							
	ChuoMa		WakiMa		ChuoMa		WakiMa		Mokosi			
	Front	Side	Front	Side	Front	Side	Front	Side	Front	Side	Front	Side
Kiwarijutsu	0.1, 0.11, 0.12, 0.15	0.1, 0.11, 0.12, 0.15	0.12, 0.15, 0.16	0.12, 0.15, 0.16	16, 20, 22, 24	16, 20, 22, 24	16, 14	16, 14	14	14		
1	0.09	0.09	0.13	0.13	18	18	12	12	12	12		
2	0.10	0.10	0.12	0.12	10	10	9	9	none	none		
3	0.09	0.09	0.15	0.15	18	18	11	11	none	none		
4	0.11	0.11	0.15	0.15	15	15	11	11	7	7		
5	0.22	0.13	0.24	0.15	9	16	9	13	none	none		
6	0.13	0.13	0.15	0.15	14	14	12	12	none	none		
7	0.07	0.07	0.10	0.07, 0.08	5	5	4	5, 4	none	none		
8	0.07	0.07	0.11	0.12	20	22	13	13	11	11		
9	0.10	0.10	0.16	0.16	5	5	3	3	none	none		
10	0.06	0.06	0.06	0.06	—	—	—	—	—	—		
	0.05	0.05	0.05	0.05	—	—	—	—	—	—		
11	0.09	0.10	0.11	0.10	9	8	8	8	none	none		
12	0.05	0.05	0.06	0.06	12	12	11	11	none	none		
13	0.08	0.10	0.10	0.10	16	13	13	13	none	none		
14	0.14	0.14	0.14	0.14	4	4	4	4	none	none		
15	0.10	0.10	0.15	0.15	20	20	13	13	12	12		
16	0.11	0.11	0.16	0.16	—	—	—	—	—	—		
17	0.08	0.08	0.11	0.11	26	26	20	20	15	15		
18	0.11	0.11	0.13	0.13	18	18	15	15	none	none		
19	0.10	0.10	0.15	0.15	17	17	12	12	9	9		
20	0.09	0.09	0.14	0.14	12	12	8	8	8	8		
21	0.09	0.09	0.12	0.12	—	—	—	—	—	—		
22	0.09	0.11	0.15	0.15	4	4	3	3	none	none		
23	0.13	0.13	0.15	0.15	14	14	12	12	8	8		
24	0.12	0.12	0.18	0.18	24	24	16	16	none	none		
25	0.13	0.13	0.16	0.16	10	10	8	8	none	none		
26	0.10	0.10	0.11	0.11	—	—	—	—	—	—		
27	0.10	0.10	0.15	0.15	18	18	12	12	none	none		
28	0.11	0.11	0.12	0.12	—	—	—	—	—	—		
29	0.08	0.08	0.08	0.08	4	4	4	4	none	none		
30	0.08	0.08	0.08	0.08	4	4	4	4	none	none		
31	0.08	0.08	0.08	0.08	4	4	4	4	none	none		
32	0.11	0.11	0.10	0.14	10	10	11	8	none	none		
33	0.10	0.10	0.14	0.14	19	19	13	13	none	none		
34	0.08	0.08	0.12	0.12	12	12	8	8	none	none		
35	0.10	0.10	0.15	0.15	9	9	6	6	none	none		
36	0.08	0.08	0.12	0.12	26	26	17	17	14	14		
37	0.10	0.10	0.14	0.14	—	—	—	—	—	—		
38	0.11	0.11	0.13	0.13	18	18	16	16	none	none		
39	0.08	0.08	0.10	0.10	11	11	9	9	none	none		
40	0.09	0.11	0.11	0.11	17	15	15	15	none	none		
41	0.10	0.10	0.15	0.15	18	18	12	12	none	none		
42	0.07	0.07	0.09	0.09	18	18	15	15	none	none		
43	0.10	0.10	0.13	0.13	18	18	14	14	none	none		
44	0.12	0.12	0.13	0.13	17	17	15	15	none	none		
45	0.12	0.12	0.13	0.13	8	8	7	7	none	none		
46	0.10	0.10	0.10	0.15	12	8	12	8	none	none		
47	0.11	0.11	0.12	0.12	18	18	16	16	none	none		
48	0.11	0.11	0.14	0.14	18	18	15	15	13	13		
49	0.10	0.10	0.12	0.12	5	5	4	4	none	none		
50	0.11	0.11	0.14	0.14	10	10	8	8	none	none		
51	0.08	0.08	0.12	0.12	28	28	19	19	15	15		
52	0.10	0.10	0.16	0.16	19	19	13	13	none	none		
53	0.12	0.12	0.18	0.18	—	—	—	—	—	—		
54	0.07	0.15	0.11	0.12	26	13	17	16	15	15		
55	0.06	0.06	0.11	0.11	9	9	5	5	none	none		
56	0.07	0.08	0.08	0.10	6	5	5	4	none	none		
57	0.10	0.10	0.13	0.13	8	8	6	6	6	6		
58	0.10	0.10	0.12	0.12	5	5	4	4	none	none		

Match

Figure 3. Comparative analysis of Plane dimension proportion.

Analysis using Shiwari on the same ChuoMa, WakiMa, and Mokosi portions showed that, first, from the perspective of proportions, there were 13 locations (buildings) using the Mabarakaruki (疎垂木) equidistant placement system. It is thought that this was done in consideration of the scale of the buildings (yellow portion in the Figure 3). Many of the others did not match the Shiwari of Kiwari-jutsu.

An investigation of the floor plan designs showed that many utilized multiples of Issi rather than the column diameters, and that the Kiwari-jutsu corresponded to the proportions derived from multiples based on the column diameters.

2.2. Jiku-Bu (軸部: Supporting Structure)

The wood members that formed the Jiku-bu were the RaikoHasira (来迎柱: round pillars), Nuki (貫: joint connections), KasiraNuki (頭貫: joint sections), and Daiwa (台輪: architraves). Analyses of each of these based on column diameters are shown in Figure 4. In the case of the RaikoHasira, 19 of the 44 buildings had integer multiples derived from the column diameters. Nuki heights were derived from the column diameters in 20 out of 57 buildings, and the Nuki widths were derived from the column diameters in 11 out of 56 buildings. In addition, the heights of the KasiraNuki were derived from the column diameters in 22 out of 54 buildings, as were the widths in 28 out of 52 buildings. In the case of the Daiwa, few of the buildings had these structures, but there were 4 locations out of 23 in which the height was derived from the column diameters and 11 out of 24 in which the width was also derived. Consideration of the overall percentages that these figures represent indicated that the building material dimension with the most commonly used integer multiples was the KasiraNuki width (54%), which is correlated with the column diameters because it is a structure that pierces the column. However, the KasiraNuki structure, which was linked to the columns in the same manner as the Nuki, comprised the lowest percentage (20%). The likely reason for this is that the KasiraNuki was smaller than the Nuki (joint connection).

Analysis of the wood members with integer multiples based on Shiwari indicated that for RaikoHasira, there were 17 out of 40 buildings; for Nuki height, there were 13 out of 49 buildings; and for Nuki width, there were 13 out of 48 buildings. KasiraNuki height was registered to be in 19 out of 47 buildings and KasiraNuki width was used in 14 out of 44 buildings. Daiwa height was registered to be in 7 out of 20 buildings and Daiwa width was used in 12 out of 20 buildings. Overall, few wood members used integer multiples, and there was little correlation with Shiwari. Observation of the percentages based on these results showed that fewer than 43% of all wood members used this method, although Daiwa width used it in 60% of buildings. The Daiwa is a structure used in Zen-style (one of the Japanese architectural styles: a Chinese-style architecture) buildings. Based on its relation to the Kumimono (junction) between the columns and the roof, it is believed that it utilizes Shiwari and integer multiples, but that determination was made in conjunction with results obtained from analyses of the junction between the columns and roof. The lowest values were Nuki height and width, both at 27%, which did not match the results obtained from Shiwari.

An analysis of the proportional relationship of the wood members was conducted by analyzing the proportions of the wood members based on Kiwari-sho and those of the wood members obtained from the dimensions of the wood members in actual buildings (Figure 5). An analysis of the Kiwari-jutsu for the RikoHasira showed there were nine and five locations, respectively, that used 1.2D and 1.3D. There were 14 and 8 examples using 1.1D and 1.0D, respectively, which are not part of Kiwari-jutsu, showing that these were used in larger numbers of buildings. An investigation of the proportions of the RikoHasira showed that the dimensions for the distances between columns were not consistent even within the same proportional method and that the dimensions within the same proportions for column diameters were likewise not consistent.

Basis No	Diameter of pillar (柱径)							Issi (一柱)						
	Raiko Hasira	Nuki(Nagesi)			KasiraNuki		Daiwa	Raiko Hasira	Nuki(Nagesi)			KasiraNuki		Daiwa
		H	W		H	W			H	W		H	W	
1	none	0.63	1.67	0.58	0.42	none	none	none	1.01	2.67	0.93	0.68	none	none
2	1.16	0.61	1.49	unknown	unknown	none	none	1.17	0.62	1.51	unknown	unknown	none	none
3	1.09	0.51	0.28	0.56	0.36	none	none	1.75	0.82	0.45	0.90	0.57	none	none
4	none	0.53	0.30	0.53	0.31	none	none	none	0.86	0.49	0.86	0.51	none	none
5	1.04	0.61	1.39	0.51	0.30	none	none	2.11	1.23	2.81	1.04	0.61	none	none
6	1.00	0.54	0.28	unknown	unknown	none	none	1.88	1.02	0.52	unknown	unknown	none	none
7	none	0.80	0.61	0.82	0.68	none	none	none	0.28	0.22	0.29	0.24	none	none
8	1.92	0.62	0.49	0.66	0.47	0.28	0.86	2.81	0.90	0.72	0.96	0.68	0.41	1.26
9	1.08	0.55	0.32	0.59	0.34	none	none	0.53	0.27	0.16	0.29	0.17	none	none
10	none	0.86	1.69	1.00	0.86	none	none	-	-	-	-	-	-	-
	none	1.13	2.22	1.31	1.13	none	none	-	-	-	-	-	-	-
11	1.25	0.80	unknown	0.86	unknown	none	none	1.06	0.68	unknown	0.73	unknown	none	none
12	2.73	1.70	0.68	2.00	1.19	2.39	1.14	1.77	1.10	0.44	1.30	0.77	1.54	0.74
13	none	0.54	0.58	0.58	0.45	none	none	none	0.70	0.75	0.75	0.58	none	none
14	1.12	0.50	0.30	unknown	unknown	none	none	0.64	0.28	0.17	unknown	unknown	none	none
15	1.12	0.71	0.39	0.90	0.46	0.38	1.06	2.23	1.42	0.77	1.80	0.92	0.76	2.10
16	1.13	0.27	0.67	0.41	0.77	0.33	0.93	-	-	-	-	-	-	-
17	1.56	0.55	0.22	0.57	0.35	0.23	0.60	3.34	1.18	0.46	1.21	0.75	0.50	1.29
18	1.10	0.66	0.27	0.66	0.33	0.30	0.88	2.19	1.31	0.54	1.31	0.66	0.61	1.75
19	1.24	unknown	unknown	1.01	0.58	none	none	2.15	unknown	unknown	1.75	1.00	none	none
20	1.28	0.60	0.35	0.83	0.45	none	none	1.40	0.65	0.38	0.91	0.49	none	none
21	1.05	0.47	0.49	0.45	0.77	none	none	none	none	none	none	none	none	none
22	1.18	0.32	0.20	0.56	0.38	0.27	0.81	0.50	0.14	0.08	0.24	0.16	0.12	0.34
23	1.13	0.78	0.25	0.82	0.44	0.44	1.13	2.04	1.40	0.46	1.49	0.79	0.79	2.04
24	1.00	0.62	0.33	0.66	0.42	none	none	2.97	1.83	0.97	1.97	1.24	none	none
25	1.00	0.54	0.23	0.38	0.48	none	none	1.30	0.70	0.30	0.49	0.62	none	none
26	none	0.75	0.38	0.75	0.50	none	none	-	-	-	-	-	-	-
27	1.13	0.70	0.34	0.77	0.45	0.36	0.99	1.97	1.22	0.59	1.35	0.79	0.63	1.73
28	1.17	0.68	0.31	0.97	0.50	0.37	0.92	-	-	-	-	-	-	-
29	none	0.61	0.39	unknown	unknown	none	none	none	0.20	0.13	unknown	unknown	none	none
30	none	0.67	0.33	0.79	0.83	none	none	none	0.20	0.10	0.24	0.25	none	none
31	none	0.58	0.35	0.85	0.83	none	none	none	0.18	0.11	0.27	0.26	none	none
32	1.14	0.68	0.30	0.79	0.59	0.30	0.95	1.23	0.73	0.33	0.85	0.64	0.33	1.03
33	1.07	0.65	0.31	0.73	0.36	0.33	0.86	1.94	1.19	0.56	1.33	0.65	0.59	1.56
34	1.00	0.59	0.34	0.59	0.34	none	none	0.95	0.56	0.32	0.56	0.32	none	none
35	1.31	0.62	0.25	0.81	0.38	0.38	0.93	1.17	0.55	0.22	0.72	0.33	0.33	0.83
36	1.55	0.63	0.34	0.80	0.46	0.33	1.16	3.26	1.32	0.71	1.68	0.97	0.59	2.45
37	1.14	0.69	0.33	0.78	0.44	0.32	0.89	-	-	-	-	-	-	-
38	1.12	0.75	0.31	0.82	unknown	0.38	0.99	2.24	1.49	0.61	1.64	unknown	0.76	1.98
39	1.13	0.68	0.36	0.85	0.55	none	none	1.06	0.63	0.34	0.79	0.51	none	none
40	1.16	0.59	0.34	0.72	0.47	none	none	1.81	0.91	0.52	1.13	0.73	none	none
41	1.16	0.67	0.36	0.78	0.36	0.33	0.84	2.03	1.18	0.64	1.37	0.64	0.58	1.48
42	1.53	0.73	1.44	0.93	0.49	none	none	2.03	0.97	1.91	1.24	0.65	none	none
43	1.37	0.60	0.67	0.64	0.41	none	none	2.51	1.11	1.23	1.17	0.74	none	none
44	1.19	0.59	0.31	0.73	0.44	0.33	1.00	2.33	1.16	0.61	1.44	0.86	0.64	1.96
45	1.07	0.76	1.41	0.80	0.50	0.44	1.00	0.99	0.70	1.30	0.74	0.46	0.41	0.92
46	none	0.69	0.32	0.77	0.53	0.34	0.88	none	0.85	0.39	0.94	0.65	0.42	1.08
47	1.18	0.82	0.33	1.06	0.47	none	none	2.33	1.63	0.65	2.09	0.93	none	none
48	1.03	0.55	0.57	0.68	0.38	none	none	2.13	1.13	1.17	1.40	0.79	none	none
49	none	0.27	0.59	0.27	0.59	none	none	none	0.14	0.30	0.14	0.30	none	none
50	1.00	0.32	0.55	0.69	0.27	none	none	1.12	0.36	0.62	0.78	0.30	none	none
51	1.71	0.67	0.33	0.80	0.49	0.36	0.89	4.00	1.57	0.77	1.87	1.13	0.83	2.07
52	none	0.64	0.35	0.71	0.52	0.30	0.99	none	1.29	0.71	1.43	1.05	0.61	2.01
53	none	0.70	0.28	0.84	0.37	0.46	0.83	-	-	-	-	-	-	-
54	1.20	0.56	0.37	0.79	0.51	0.41	0.83	2.28	1.06	0.70	1.51	0.97	0.78	1.57
55	1.34	1.18	0.49	0.93	0.63	none	none	0.80	0.71	0.29	0.55	0.38	none	none
56	1.34	0.86	0.65	0.99	0.83	none	none	0.56	0.36	0.27	0.42	0.35	none	none
57	1.06	0.69	0.25	0.67	0.33	none	none	0.84	0.55	0.20	0.53	0.26	none	none
58	1.04	0.49	0.33	0.60	0.69	none	none	0.49	0.23	0.16	0.28	0.33	none	none

D:Pillar Diameter H:Height W:Width

Figure 4. Frame section proportional analysis.

Based on the above results, when I observed the tendencies shown by the horizontal structures (Nuki) other than the RaikoHasira of the supporting structure, I found that they were 0.1 times larger.

The results of proportion analysis showed that of all building material proportions and the percentages that are in accordance with Kiwari-jutsu, overall, only a small percentage of actual buildings were in accordance with Kiwari-jutsu. Over 50% of the buildings had Daiwa, and the heights of the Nuki, the widths of the KasiraNuki, and the heights and widths of the Daiwa were 0.1 times larger than Kiwari-jutsu.

No	Raiko Hasira	Nuki(Nagesi)		KasiraNuki		Daiwa	
		Height	Width	Height	Width	Height	Width
Kiwarijyutu	1.2D, 1.3D	0.5D,0.6D,0.65D	0.3D,0.4D	0.7D,0.8D	0.3D,0.4D	0.3D,0.35D	0.8D,0.9D
1	none	0.6	1.7	0.6	0.4	none	none
2	1.2	0.6	1.5	unknown	unknown	none	none
3	1.1	0.5	0.3	0.6	0.4	none	none
4	none	0.5	0.3	0.5	0.3	none	none
5	1.0	0.6	1.4	0.5	0.3	none	none
6	1.0	0.5	0.3	unknown	unknown	none	none
7	none	0.8	0.6	0.8	0.7	none	none
8	1.9	0.6	0.5	0.7	0.5	0.3	0.9
9	1.1	0.6	0.3	0.6	0.3	none	none
10	none	0.9	1.7	1.0	0.9	none	none
	none	1.1	2.2	1.3	1.1	none	none
11	1.3	0.8	unknown	0.9	unknown	none	none
12	2.7	1.7	0.7	2.0	1.2	2.4	1.1
13	none	0.5	0.6	0.6	0.4	none	none
14	1.1	0.5	0.3	unknown	unknown	none	none
15	1.1	0.7	0.4	0.9	0.5	0.4	1.1
16	1.1	0.3	0.7	0.4	0.8	0.3	0.9
17	1.6	0.6	0.2	0.6	0.4	0.2	0.6
18	1.1	0.7	0.3	0.7	0.3	0.3	0.9
19	1.2	unknown	unknown	1.0	0.6	none	none
20	1.3	0.6	0.4	0.8	0.5	none	none
21	1.0	0.5	0.5	0.4	0.8	none	none
22	1.2	0.3	0.2	0.6	0.4	0.3	0.8
23	1.1	0.8	0.3	0.8	0.4	0.4	1.1
24	1.0	0.6	0.3	0.7	0.4	none	none
25	1.0	0.5	0.2	0.4	0.5	none	none
26	none	0.8	0.4	0.8	0.5	none	none
27	1.1	0.7	0.3	0.8	0.5	0.4	1.0
28	1.2	0.7	0.3	1.0	0.5	0.4	0.9
29	none	0.6	0.4	unknown	unknown	none	none
30	none	0.7	0.3	0.8	0.8	none	none
31	none	0.6	0.4	0.9	0.8	none	none
32	1.1	0.7	0.3	0.8	0.6	0.3	1.0
33	1.1	0.7	0.3	0.7	0.4	0.3	0.9
34	1.0	0.6	0.3	0.6	0.3	none	none
35	1.3	0.6	0.2	0.8	0.4	0.4	0.9
36	1.6	0.6	0.3	0.8	0.5	0.3	1.2
37	1.1	0.7	0.3	0.8	0.4	0.3	0.9
38	1.1	0.7	0.3	0.8	unknown	0.4	1.0
39	1.1	0.7	0.4	0.8	0.5	none	none
40	1.2	0.6	0.3	0.7	0.5	none	none
41	1.2	0.7	0.4	0.8	0.4	0.3	0.8
42	1.5	0.7	1.4	0.9	0.5	none	none
43	1.4	0.6	0.7	0.6	0.4	none	none
44	1.2	0.6	0.3	0.7	0.4	0.3	1.0
45	1.1	0.8	1.4	0.8	0.5	0.4	1.0
46	none	0.7	0.3	0.8	0.5	0.3	0.9
47	1.2	0.8	0.3	1.1	0.5	none	none
48	1.0	0.5	0.6	0.7	0.4	none	none
49	none	0.3	0.6	0.3	0.6	none	none
50	1.0	0.3	0.6	0.7	0.3	none	none
51	1.7	0.7	0.3	0.8	0.5	0.4	0.9
52	none	0.6	0.4	0.7	0.5	0.3	1.0
53	none	0.7	0.3	0.8	0.4	0.5	0.8
54	1.2	0.6	0.4	0.8	0.5	0.4	0.8
55	1.3	1.2	0.5	0.9	0.6	none	none
56	1.3	0.9	0.7	1.0	0.8	none	none
57	1.1	0.7	0.3	0.7	0.3	none	none
58	1.0	0.5	0.3	0.6	0.7	none	none

Figure 5. Comparative analysis of Frame section proportion and Kiwari-jyutu.

2.3. Kumimono-Bu (組物部: Junctions between the Columns and Roof)

Investigation of the Kumomono-bu included the Hijiki (肘木: bracket arm), Daito (大斗), and Makito (巻斗). Analysis of these wood members using the column diameter as the standard is shown in Figure 6. First, when one observes the results that correspond to the integer multiples derived from the column diameters, one can see that the height of the Hijiki matched the building material dimensions in 28 out of 53 buildings and the widths of these structures matched the building material dimensions in 13 buildings. An analysis of the Daito showed that, out of 44 buildings, the height matched in 25 cases, the width in 24 cases, and the length in 21 cases. Analysis of the Makito showed that, out

of 42 buildings, the height matched in 20 cases, the width in 21 cases, and the length in 27 cases. The match rate for the Hijiki was low, at 24%, while that of the Makito length was high, at 64%. An analysis of the integer multiples for the Kumimono-bu based on Shiwari showed that there were matches for the Hijiki heights in 16 cases, for the Hijiki widths in 12 cases, for the Daito heights in 18 cases, for the Daito widths in 21 cases, and for the Daito lengths in 19 cases. In addition, there were matches for the Makito heights and widths in 13 cases each and the lengths in 17 cases. Examination of the match rates showed that only the Daito width had a rate that was over 50%. Overall, the rates were under 50%, with a supporting structure consisting of wood members that support the Taruki (rafters) at a low percentage.

Basis	Diameter of pillar (柱径)									Issi (一丈)								
	Hijiki			Daito			Makito			Hijiki			Daito			Makito		
	No	H	W	H	W	L	H	W	L	H	W	L	H	W	L	H	W	L
1		0.51	0.43	0.79	1.16	1.13	0.68	0.72	0.70	0.82	0.68	1.26	1.85	1.81	1.08	1.16	1.12	
2		0.77	0.65	none	none	none	none	none	none	0.78	0.65	none	none	none	none	none	none	
3		0.45	0.37	0.57	1.03	1.03	0.42	0.71	0.87	0.72	0.60	0.91	1.64	1.64	0.67	1.13	1.39	
4		0.50	0.38	0.73	1.18	1.16	0.37	0.55	0.55	0.82	0.61	1.19	1.92	1.90	0.61	0.90	0.90	
5		0.48	0.42	0.70	1.02	1.01	0.52	0.75	0.66	0.96	0.84	1.40	2.05	2.04	1.05	1.51	1.33	
6		0.52	0.51	0.67	1.13	1.13	none	none	none	0.98	0.96	1.25	2.13	2.13	none	none	none	
7		0.79	0.78	none	none	none	none	none	none	0.28	0.28	none	none	none	none	none	none	
8		0.37	0.53	0.65	1.19	1.17	0.48	0.60	0.59	0.54	0.78	0.95	1.74	1.72	0.71	0.89	0.86	
9		0.51	0.59	0.80	1.21	1.18	0.54	0.80	0.80	0.25	0.29	0.39	0.59	0.58	0.26	0.39	0.39	
10		0.90	0.86	none	none	none	none	none	none	—	—	—	—	—	—	—	—	
		1.19	1.13	none	none	none	none	none	none	—	—	—	—	—	—	—	—	
11		0.50	0.27	none	none	none	none	none	none	0.43	0.23	none	none	none	none	none	none	
12		1.31	0.55	2.18	1.55	2.69	1.43	1.25	1.59	0.85	0.35	1.41	1.00	1.74	0.93	0.81	1.03	
13		0.55	0.45	0.73	1.08	1.08	0.50	0.85	0.85	0.72	0.58	0.95	1.40	1.40	0.65	1.11	1.11	
14		0.46	0.46	none	none	none	none	none	none	0.26	0.26	none	none	none	none	none	none	
15		0.41	0.31	0.64	0.98	0.96	0.40	0.62	0.49	0.82	0.62	1.27	1.96	1.91	0.79	1.24	0.97	
16		0.37	0.29	0.54	0.94	0.63	0.34	0.42	0.42	—	—	—	—	—	—	—	—	
17		0.25	0.20	0.45	0.63	0.62	0.27	0.37	0.40	0.54	0.43	0.96	1.36	1.32	0.57	0.79	0.86	
18		0.70	0.66	0.68	0.18	0.27	0.27	0.44	0.17	1.40	1.32	0.36	0.53	0.53	0.88	0.33	0.40	
19		0.29	0.30	0.48	0.90	0.92	0.30	0.49	0.55	0.50	0.52	0.83	1.56	1.58	0.52	0.85	0.96	
20		0.35	0.30	0.48	1.00	0.98	0.38	0.55	0.48	0.38	0.33	0.53	1.09	1.07	0.42	0.60	0.53	
21		0.44	0.35	0.61	1.05	1.03	0.42	0.68	0.52	—	—	—	—	—	—	—	—	
22		0.29	0.24	0.42	0.75	0.75	0.29	0.36	0.44	0.12	0.10	0.18	0.32	0.32	0.12	0.15	0.19	
23		0.44	0.38	0.54	1.00	1.00	0.41	0.52	0.74	0.79	0.68	0.98	1.81	1.81	0.75	0.93	1.34	
24		0.34	0.26	0.45	0.81	0.81	0.34	0.52	0.26	1.00	0.76	1.34	2.41	2.41	1.00	1.55	0.76	
25		0.38	0.54	none	none	none	none	none	none	0.49	0.70	none	none	none	none	none	none	
26		0.48	0.36	0.54	1.08	1.08	0.50	0.67	0.67	—	—	—	—	—	—	—	—	
27		0.35	0.30	0.53	0.91	0.89	0.35	0.51	0.51	0.62	0.52	0.92	1.59	1.56	0.62	0.89	0.89	
28		0.34	0.29	0.52	0.91	0.90	0.34	0.46	0.49	—	—	—	—	—	—	—	—	
29		unknown	unknown	none	none	none	none	none	none	unknown	unknown	none	none	none	none	none	none	
30		unknown	unknown	none	none	none	none	none	none	unknown	unknown	none	none	none	none	none	none	
31		unknown	unknown	none	none	none	none	none	none	unknown	unknown	none	none	none	none	none	none	
32		0.36	0.30	0.62	1.03	1.03	0.38	0.46	0.56	0.39	0.32	0.67	1.12	1.12	0.41	0.50	0.60	
33		0.31	0.21	0.40	0.76	0.76	0.27	0.40	0.41	0.56	0.39	0.72	1.37	1.37	0.48	0.72	0.74	
34		0.55	0.67	none	none	none	none	none	none	0.53	0.64	none	none	none	none	none	none	
35		0.35	0.27	0.48	0.83	0.83	0.34	0.56	0.43	0.31	0.24	0.43	0.73	0.73	0.30	0.50	0.39	
36		0.40	0.35	0.60	1.06	1.06	0.40	0.69	0.53	0.84	0.74	1.26	2.24	2.24	0.84	1.45	1.11	
37		0.33	0.27	0.51	0.82	0.82	0.31	0.42	0.41	—	—	—	—	—	—	—	—	
38		0.45	0.39	0.66	1.02	1.02	0.47	0.70	0.70	0.90	0.78	1.32	2.03	2.03	0.93	1.40	1.40	
39		0.44	0.39	0.63	1.17	1.13	0.43	0.89	0.59	0.41	0.36	0.59	1.09	1.06	0.41	0.83	0.55	
40		0.48	0.30	0.65	0.92	0.92	0.48	0.67	0.64	0.76	0.48	1.01	1.43	1.43	0.74	1.04	0.99	
41		0.33	0.26	0.50	0.84	0.84	0.32	0.40	0.40	0.58	0.47	0.87	1.48	1.48	0.56	0.70	0.70	
42		0.58	0.44	0.82	1.42	1.42	0.56	1.07	1.07	0.76	0.59	1.09	1.88	1.88	0.74	1.41	1.41	
43		0.47	0.37	0.58	1.16	1.16	0.45	0.76	0.76	0.85	0.68	1.06	2.13	2.13	0.83	1.38	1.38	
44		0.36	0.33	0.62	1.00	1.00	0.40	0.59	0.59	0.70	0.64	1.21	1.96	1.96	0.78	1.15	1.16	
45		0.39	0.36	0.51	1.09	1.01	0.41	0.71	0.69	0.36	0.33	0.47	1.00	0.93	0.38	0.66	0.63	
46		0.35	0.28	0.50	0.88	0.88	0.33	0.50	0.50	0.43	0.35	0.62	1.08	1.08	0.41	0.61	0.61	
47		0.41	0.33	0.59	1.00	1.00	0.34	0.68	0.49	0.81	0.65	1.16	1.98	1.98	0.67	1.35	0.98	
48		0.41	0.36	0.55	1.03	1.03	0.41	0.36	0.71	0.85	0.74	1.13	2.13	2.13	0.85	0.74	1.47	
49		0.48	0.48	0.79	1.33	1.33	none	none	none	0.25	0.25	0.41	0.69	0.69	none	none	none	
50		unknown	unknown	none	none	none	none	none	none	unknown	unknown	none	none	none	none	none	none	
51		0.36	0.29	0.53	0.89	0.89	0.37	0.54	0.46	0.83	0.67	1.23	2.07	2.07	0.87	1.27	1.07	
52		0.42	0.26	0.52	0.91	0.92	0.31	0.47	0.54	0.85	0.53	1.05	1.84	1.87	0.63	0.95	1.09	
53		0.38	0.30	0.50	0.83	0.83	0.30	0.52	0.53	—	—	—	—	—	—	—	—	
54		0.45	0.41	0.43	1.00	0.99	0.36	0.75	0.75	0.85	0.78	0.82	1.90	1.87	0.68	1.43	1.43	
55		unknown	unknown	none	none	none	none	none	none	none	none	none	none	none	none	none	none	
56		none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	
57		0.47	0.42	0.72	1.16	1.20	0.37	0.68	0.69	0.37	0.34	0.57	0.92	0.95	0.30	0.54	0.54	
58		0.56	0.64	none	none	none	none	none	none	0.27	0.30	none	none	none	none	none	none	

Figure 6. Kumimono section proportional analysis.

Analysis comparing Hijiki heights with Kiwari-jutsu (Figure 7) showed that there were 9, 21, 12, and 15 examples, respectively, that matched the Kiwari-jutsu measurements of 0.3D, 0.4D, 1.2 width, and 1.3 width, while there were 13 and 11 examples, respectively, that measured 0.5D and 1.1 width, which are not part of kiwarijutsu. In the case of width, 20 and 28 examples of Daito widths matched the kiwarijutsu measurements of 0.3D and 1/3 width, respectively. Non-Kiwari-jutsu measurements found 3 examples of 0.2D, 16 examples of 0.4D, and 13 examples of 0.4 Daito width. Based on these results, I found that the heights of Hijiki were 0.4 and 0.5 times the column diameter, and the widths were 0.3 and 0.4 times the column diameter.

No	Hijiki				Daito				Makito						
	Height		Width		Height	Width	Length	Height	Width		Length				
Kiwarijyutu	0.3D, 0.4D	1.2W, 1.3W	0.3D	1/3Daito W	0.5D	1.5Hijiki H	0.8D,D	0.8D,D	Hijiki H, 0.9Hijiki H	5/3 Hijiki W	0.3D, 0.4D	4/6Daito W	2Taruki Sitaba + Koma	0.48D, 0.52D	1.2,1.3 Hijiki H
1	0.5	1.2	0.4	0.4	0.8	1.5	1.2	1.1	1.3	1.7	0.7	0.6	0.8	0.7	1.4
2	0.8	1.2	0.6	none	none	none	none	none	none	none	none	none	none	none	none
3	0.4	1.2	0.4	0.4	0.6	1.3	1.0	1.0	0.9	1.9	0.7	0.8	1.0	0.9	1.9
4	0.5	1.3	0.4	0.3	0.7	1.5	1.2	1.2	0.7	1.5	0.6	0.5	0.7	0.6	1.1
5	0.5	1.1	0.4	0.4	0.7	1.5	1.0	1.0	1.1	1.8	0.7	0.6	0.9	0.7	1.4
6	0.5	1.0	0.5	0.5	0.7	1.3	1.1	1.1	none	none	none	none	none	none	none
7	0.8	1.0	0.8	none	none	none	none	none	none	none	none	none	none	none	none
8	0.4	0.7	0.5	0.4	0.6	1.8	1.2	1.2	1.3	1.1	0.6	0.5	0.7	0.6	1.6
9	0.5	0.9	0.6	0.5	0.8	1.6	1.2	1.2	1.1	1.4	0.8	0.7	0.3	0.8	1.6
10	0.9	1.1	0.9	none	none	none	none	none	none	none	none	none	none	none	none
	1.2	1.1	1.1	none	none	none	none	none	none	none	none	none	none	none	none
11	0.5	1.9	0.3	none	none	none	none	none	none	none	none	none	unknown	none	none
12	1.3	2.4	0.5	0.4	2.2	1.7	1.5	2.7	1.1	2.3	1.3	1.0	0.8	1.6	1.2
13	0.6	1.2	0.4	0.4	0.7	1.3	1.1	1.1	0.9	1.9	0.9	0.8	0.8	0.9	1.5
14	0.5	1.0	0.5	none	none	none	none	none	none	none	none	none	none	none	none
15	0.4	1.3	0.3	0.3	0.6	1.5	1.0	1.0	1.0	2.0	0.6	0.5	0.7	0.5	1.2
16	0.4	1.3	0.3	0.3	0.5	1.5	0.9	0.6	0.9	1.5	0.4	0.4	unknown	0.4	1.1
17	0.3	1.3	0.2	0.3	0.5	1.8	0.6	0.6	1.1	1.8	0.4	0.6	0.6	0.4	1.6
18	0.7	1.1	0.7	2.5	0.2	1.3	0.3	0.3	0.6	0.3	0.2	0.7	0.3	0.2	0.3
19	0.3	1.0	0.3	0.3	0.5	1.7	0.9	0.9	1.0	1.6	0.5	0.6	0.7	0.6	1.9
20	0.4	1.2	0.3	0.3	0.5	1.4	1.0	1.0	1.1	1.8	0.6	0.5	0.4	0.5	1.4
21	0.4	1.3	0.3	0.3	0.6	1.4	1.0	1.0	1.0	1.9	0.7	0.5	unknown	0.5	1.2
22	0.3	1.2	0.2	0.3	0.4	1.4	0.7	0.7	1.0	1.5	0.4	0.6	0.2	0.4	1.5
23	0.4	1.2	0.4	0.4	0.5	1.2	1.0	1.0	0.9	1.4	0.5	0.7	1.0	0.7	1.7
24	0.3	1.3	0.3	0.3	0.5	1.3	0.8	0.8	1.0	2.0	0.5	0.3	0.5	0.3	0.8
25	0.4	0.7	0.5	none	none	none	none	none	none	none	none	none	none	none	none
26	0.5	1.3	0.4	0.3	0.5	1.1	1.1	1.1	1.0	1.9	0.7	0.6	unknown	0.7	1.4
27	0.4	1.2	0.3	0.3	0.5	1.5	0.9	0.9	1.0	1.7	0.5	0.6	0.6	0.5	1.4
28	0.3	1.2	0.3	0.3	0.5	1.5	0.9	0.9	1.0	1.6	0.5	0.5	unknown	0.5	1.4
29	unknown	unknown	unknown	unknown	none	none	none	none	none	none	none	none	none	none	none
30	unknown	unknown	unknown	unknown	none	none	none	none	none	none	none	none	none	none	none
31	unknown	unknown	unknown	unknown	none	none	none	none	none	none	none	none	none	none	none
32	0.4	1.2	0.3	0.3	0.6	1.7	1.0	1.0	1.1	1.5	0.5	0.5	0.5	0.6	1.5
33	0.3	1.4	0.2	0.3	0.4	1.3	0.8	0.8	0.9	1.9	0.4	0.5	0.5	0.4	1.3
34	0.6	0.8	0.7	none	none	none	none	none	none	none	none	none	none	none	none
35	0.4	1.3	0.3	0.3	0.5	1.0	0.8	0.8	1.0	2.1	0.6	0.5	0.3	0.4	1.2
36	0.4	1.1	0.4	0.3	0.6	1.5	1.1	1.1	1.0	2.0	0.7	0.5	0.8	0.5	1.3
37	0.3	1.3	0.3	0.3	0.5	1.5	0.8	0.8	0.9	1.6	0.4	0.5	unknown	0.4	1.2
38	0.4	1.2	0.4	0.4	0.7	1.5	1.0	1.0	1.0	1.8	0.7	0.7	0.9	0.7	1.6
39	0.4	1.1	0.4	0.3	0.6	1.4	1.2	1.1	1.0	2.3	0.9	0.5	0.4	0.6	1.3
40	0.5	1.6	0.3	0.3	0.6	1.3	0.9	0.9	1.0	2.2	0.7	0.7	0.7	0.6	1.3
41	0.3	1.3	0.3	0.3	0.5	1.5	0.8	0.8	1.0	1.5	0.4	0.5	0.5	0.4	1.2
42	0.6	1.3	0.4	0.3	0.8	1.4	1.4	1.4	1.0	2.4	1.1	0.8	1.0	1.1	1.8
43	0.5	1.3	0.4	0.3	0.6	1.3	1.2	1.2	1.0	2.0	0.8	0.7	1.0	0.8	1.6
44	0.4	1.1	0.3	0.3	0.6	1.7	1.0	1.0	1.1	1.8	0.6	0.6	0.8	0.6	1.7
45	0.4	1.1	0.4	0.3	0.5	1.3	1.1	1.0	1.1	2.0	0.7	0.6	0.5	0.7	1.8
46	0.3	1.2	0.3	0.3	0.5	1.4	0.9	0.9	1.0	1.8	0.5	0.6	0.5	0.5	1.4
47	0.4	1.3	0.3	0.3	0.6	1.4	1.0	1.0	0.8	2.1	0.7	0.5	0.7	0.5	1.2
48	0.4	1.1	0.4	0.4	0.5	1.3	1.0	1.0	1.0	1.0	0.4	0.7	1.0	0.7	1.7
49	0.5	1.0	0.5	0.4	0.8	1.6	1.3	1.3	none	none	none	none	none	none	none
50	unknown	unknown	unknown	unknown	none	none	none	none	none	none	none	none	none	none	none
51	0.4	1.3	0.3	0.3	0.5	1.5	0.9	0.9	1.0	1.9	0.5	0.5	0.8	0.5	1.3
52	0.4	1.6	0.3	0.3	0.5	1.2	0.9	0.9	0.7	1.8	0.5	0.6	0.8	0.5	1.3
53	0.4	1.3	0.3	0.4	0.5	1.3	0.8	0.8	0.8	1.7	0.5	0.6	unknown	0.5	1.4
54	0.5	1.1	0.4	0.4	0.4	1.0	1.0	1.0	0.9	1.8	0.8	0.8	1.0	0.8	1.7
55	unknown	unknown	unknown	unknown	none	none	none	none	none	none	none	none	none	none	none
56	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
57	0.5	1.1	0.4	0.4	0.7	1.5	1.2	1.2	0.8	1.6	0.7	0.6	0.5	0.7	1.5
58	0.6	0.9	0.6	unknown	none	none	none	none	none	none	none	none	none	none	none

Figure 7. Comparative analysis of Kumimono section proportion and Makito and Kiwari jyutu.

Analysis of Daito height showed that there were 18 and 13 examples, respectively, of 0.5D and 1.5 Hijiki height, which matches Kiwari-jutsu, while there were 3, 11, 7, and 2 examples, respectively, of the non-Kiwari-jutsu 0.4D, 0.6D, 1.4, and 1.6 Hijiki height. The 1.5 Hijiki height for Kiwari-jutsu was 0.3D when calculated using the proportional method; 0.45D and 0.6D when using the 0.4D method; and 0.36D and 0.39D, respectively, when based on 1.2 Hijiki width and 1.3 Hijiki width. Therefore, the Daito height was determined to be 0.4D, 0.5D, and 0.6D. In the case of width, the proportional method of Kiwari-jutsu resulted in 0.8D and D, of which there were 6 and 12 examples, respectively, while there were 7 and 5 examples, respectively, of the non-Kiwari-jutsu measurements of 0.9D and 1.1D. Length determinations were 0.8D and D, as was the case with width. The number of matches was the same as with width.

Investigation of Makito height showed that the determinations made using Kiwari-jutsu were Hijiki height and 0.9 Hijiki height and that 19 and 7 examples, respectively, matched these measurements. Investigation of the 1.1D proportion found that there were 8 examples. In the case of width, there was a wide variety of dimensions, with 4 examples matching 5/3 Hijiki width and 0 and 7 examples, respectively, when calculated using 0.3D and 0.4D. In the analysis of the length measurements in accordance with Kiwari-jutsu, 13, 6, 7, 11, 7, and 6 examples, respectively, matched 4/6 Daito width, 2 Taruki width + between Taruki, and Taruki, 0.48D, 0.52D, 1.2 Hijiki height, and 1.3 Hijiki height. There were few (six) examples of 2 Taruki width +between Taruki and Taruki, which were related to Shi-wari. There were seven and six examples, respectively, of 1.2 times and 1.3 times, which were measurements based on Hijiki height. Measurements not determined this way included two examples of 1.1 times and eight examples of 1.4 times.

Based on the above results, the percentages of the whole that were made up by Kiwari-jutsu show that the measurement with the highest match rate was the Hijiki, with a match rate of 70% for height and 57% for width. The heights of Daito and Makito had percentages of over 60%, but the widths and lengths had low percentages. Looking at the overall results for the Kumimono-bu, the vertically oriented wood members utilized Kiwari-jutsu while the horizontally oriented wood members did not.

2.4. Yane-Bu (屋根部: Roof)

Analysis based on the wood members that made up the roof—the Gagyō (丸桁: round purlins) and Taruki (垂木: rafters) (Figure 8)—showed that the Gagyō were included in the reference materials but were mentioned only rarely. Thus, analysis of Gagyō using materials for 25 buildings in terms of height was conducted. There were 11 examples in which the integer multiples were based on column diameter and 14 examples in the reference materials for the 24 buildings related to Gagyō width. Based on the analysis of the reference materials for 57 buildings, there were 10 examples of Taruki height and 5 examples of Taruki width. Few of the integer multiples were based on column diameter. Thus, it was determined that there was little correlation between column diameter and Taruki size. Analysis using Shiwari showed that there were 9 examples of Gagyō height in the reference materials for 19 buildings and 5 examples of Gagyō width in 18 buildings. An examination of the Taruki showed that integer multiples were used in 20 examples for height and 14 examples for width in the 50 buildings investigated.

Figure 9 shows the results of comparisons with Kiwari-jutsu. Examination of the height of the Gagyō indicated that there were 5, 6, 4, and 4 examples, respectively, that matched the following Kiwari-jutsu measurements in 25 of the target buildings: 0.5D, 0.6D, 0.7D, and 0.8D. Investigation of width showed that there were 2, 10, and 2 examples, respectively, of 0.25D, 0.4D, and Makito width measurements as well as 2 examples of 0.9 Makito width. Taruki height presented 11 and 9 examples, respectively, that matched 1.2 (1.25) and 1.3 measurements. Investigation of other proportions (1.0, 1.1, and 1.4 width) found that there were six, seven, and five examples, respectively, of each, indicating inconsistency. Width was 0.2D with 33 examples matching, while there were 17 examples that matched the non-Kiwari-jutsu 0.3D.

Basis	Diameter of pillar(柱径)				Issi(一枝)			
No	Gagyo		Taruki		Gagyo		Taruki	
	H	W	H	W	H	W	H	W
1	0.64	0.43	0.26	0.21	1.03	0.68	0.42	0.34
2	unknown	unknown	0.38	0.26	unknown	unknown	0.38	0.26
3	unknown	unknown	0.32	0.26	unknown	unknown	0.51	0.42
4	unknown	unknown	0.25	0.23	unknown	unknown	0.41	0.37
5	unknown	unknown	0.27	0.23	unknown	unknown	0.54	0.46
6	unknown	unknown	0.30	0.19	unknown	unknown	0.56	0.35
7	unknown	unknown	0.28	0.51	unknown	unknown	0.10	0.18
8	unknown	unknown	0.30	0.20	unknown	unknown	0.44	0.29
9	unknown	unknown	0.32	0.29	unknown	unknown	0.16	0.14
10	unknown	unknown	0.90	0.75	—	—	—	—
	unknown	unknown	1.19	0.98	—	—	—	—
11	unknown	unknown	0.39	0.30	unknown	unknown	0.33	0.26
12	0.91	0.95	0.86	0.57	0.59	0.62	0.56	0.37
13	unknown	unknown	0.32	0.27	unknown	unknown	0.42	0.35
14	0.46	0.43	0.33	0.21	0.26	0.24	0.19	0.12
15	0.90	0.47	0.31	0.19	1.79	0.93	0.62	0.37
16	0.78	0.42	0.28	0.21	—	—	—	—
17	unknown	unknown	0.30	0.15	unknown	unknown	0.64	0.32
18	0.49	0.34	0.30	0.20	0.99	0.69	0.61	0.41
19	unknown	unknown	0.25	0.20	unknown	unknown	0.44	0.35
20	unknown	unknown	0.38	0.28	unknown	unknown	0.42	0.31
21	0.74	0.44	0.30	0.30	—	—	—	—
22	unknown	unknown	0.31	0.19	unknown	unknown	0.13	0.08
23	unknown	unknown	0.35	0.23	unknown	unknown	0.63	0.41
24	0.56	0.40	0.21	0.17	1.66	1.17	0.62	0.50
25	unknown	unknown	0.25	0.22	unknown	unknown	0.32	0.28
26	0.58	0.42	none	none	—	—	—	—
27	0.45	0.38	0.29	0.22	0.79	0.66	0.51	0.38
28	0.68	0.43	0.28	0.25	—	—	—	—
29	unknown	unknown	0.49	0.37	unknown	unknown	0.16	0.12
30	unknown	unknown	0.48	0.33	unknown	unknown	0.15	0.10
31	unknown	unknown	0.48	0.38	unknown	unknown	0.15	0.12
32	unknown	unknown	0.34	0.26	unknown	unknown	0.36	0.29
33	0.71	0.34	0.21	0.21	1.30	0.61	0.39	0.39
34	unknown	unknown	0.26	0.26	unknown	unknown	0.25	0.25
35	0.94	0.41	0.29	0.23	0.83	0.37	0.26	0.20
36	unknown	unknown	0.28	0.23	unknown	unknown	0.58	0.47
37	0.80	0.27	0.20	0.16	—	—	—	—
38	0.77	0.39	0.30	0.24	1.53	0.78	0.60	0.49
39	0.62	unknown	0.39	0.36	0.58	unknown	0.37	0.33
40	unknown	unknown	0.30	0.21	unknown	unknown	0.47	0.34
41	0.53	0.50	0.22	0.20	0.93	0.87	0.40	0.35
42	unknown	unknown	0.47	0.31	unknown	unknown	0.62	0.41
43	unknown	unknown	0.34	0.24	unknown	unknown	0.62	0.45
44	0.74	0.53	0.28	0.20	1.44	1.04	0.55	0.39
45	unknown	unknown	0.36	0.31	unknown	unknown	0.33	0.29
46	0.63	0.42	0.30	0.24	0.77	0.52	0.36	0.29
47	0.71	0.47	0.29	0.21	1.40	0.93	0.58	0.42
48	0.75	0.53	0.29	0.20	1.55	1.09	0.60	0.40
49	unknown	unknown	0.38	0.34	unknown	unknown	0.20	0.18
50	unknown	unknown	0.28	0.27	unknown	unknown	0.32	0.30
51	0.60	0.50	0.27	0.16	1.40	1.17	0.63	0.37
52	0.96	0.47	0.39	0.22	1.94	0.95	0.78	0.44
53	0.89	0.45	0.25	0.17	—	—	—	—
54	0.95	0.71	0.20	0.22	1.81	1.35	0.38	0.42
55	unknown	unknown	0.33	0.33	unknown	unknown	0.20	0.20
56	none	none	0.55	0.37	none	none	0.23	0.16
57	unknown	unknown	0.21	0.21	unknown	unknown	0.16	0.17
58	unknown	unknown	0.43	0.33	unknown	unknown	0.20	0.16

Figure 8. Roof section proportional analysis.

No	Gagyo			Taruki	
	Height	Width	Width	Height	Width
Kiwarijyutu	0.5D,0.6D, 0.7D,0.8 □	0.25D,0.4D	Makito W	1.3W,1.25W, 1.2W	0.2 □
1	0.6	0.4	0.6	1.2	0.2
2	unknown	unknown	unknown	1.5	0.3
3	unknown	unknown	unknown	1.2	0.3
4	unknown	unknown	unknown	1.1	0.2
5	unknown	unknown	unknown	1.2	0.2
6	unknown	unknown	unknown	1.6	0.2
7	unknown	unknown	unknown	0.6	0.5
8	unknown	unknown	unknown	1.5	0.2
9	unknown	unknown	unknown	1.1	0.3
10	unknown	unknown	unknown	1.2	0.7
	unknown	unknown	unknown	1.2	1.0
11	unknown	unknown	unknown	1.3	0.3
12	0.9	1.0	0.8	1.5	0.6
13	unknown	unknown	unknown	1.2	0.3
14	0.5	0.4	none	1.5	0.2
15	0.9	0.5	0.8	1.7	0.2
16	0.8	0.4	1.0	1.3	0.2
17	unknown	unknown	unknown	2.0	0.2
18	0.5	0.3	2.1	1.5	0.2
19	unknown	unknown	unknown	1.2	0.2
20	unknown	unknown	unknown	1.4	0.3
21	0.7	0.4	0.6	1.0	0.3
22	unknown	unknown	unknown	1.6	0.2
23	unknown	unknown	unknown	1.5	0.2
24	0.6	0.4	0.8	1.2	0.2
25	unknown	unknown	unknown	1.1	0.2
26	0.6	0.4	0.6	none	none
27	0.5	0.4	0.7	1.3	0.2
28	0.7	0.4	0.9	1.1	0.3
29	unknown	unknown	unknown	1.3	0.4
30	unknown	unknown	unknown	1.4	0.3
31	unknown	unknown	unknown	1.3	0.4
32	unknown	unknown	unknown	1.3	0.3
33	0.7	0.3	0.8	1.0	0.2
34	unknown	unknown	unknown	1.0	0.3
35	0.9	0.4	0.7	1.3	0.2
36	unknown	unknown	unknown	1.2	0.2
37	0.8	0.3	0.6	1.3	0.2
38	0.8	0.4	0.6	1.2	0.2
39	0.6	unknown	unknown	1.1	0.4
40	unknown	unknown	unknown	1.4	0.2
41	0.5	0.5	1.3	1.1	0.2
42	unknown	unknown	unknown	1.5	0.3
43	unknown	unknown	unknown	1.4	0.2
44	0.7	0.5	0.9	1.4	0.2
45	unknown	unknown	unknown	1.1	0.3
46	0.6	0.4	0.8	1.2	0.2
47	0.7	0.5	0.7	1.4	0.2
48	0.8	0.5	1.5	1.5	0.2
49	unknown	unknown	unknown	1.1	0.3
50	unknown	unknown	unknown	1.0	0.3
51	0.6	0.5	0.9	1.7	0.2
52	1.0	0.5	1.0	1.8	0.2
53	0.9	0.5	0.9	1.4	0.2
54	1.0	0.7	0.9	1.3	0.2
55	unknown	unknown	unknown	1.0	0.3
56	none	none	none	1.5	0.4
57	unknown	unknown	unknown	1.0	0.2
58	unknown	unknown	unknown	1.3	0.3

Figure 9. Roof section comparative analysis of Kumimono section proportion and Kiwarijyutu.

These results indicated that Gagyo height matched Kiwari-jutsu measurements in over 70% of cases and that there were many widths in the 0.4D proportion. Investigation of Taruki showed that there was little correlation between column diameter dimensions and integer multiples. As for height, there was great inconsistency in the measurements, and width was determined using both the Kiwari-jutsu measurement of 0.2D and the non-Kiwari-jutsu measurement of 0.3D.

3. Analysis Based on the Matching Rates between Kiwari-Jutsu and Actual Measurements

Analysis of the usage of Kiwari-jutsu proportions in the wood members of the 58 buildings targeted in this study showed that 21 buildings had at least 16 matches in the 31 analytical items used in the comparisons. It was further identified that those 21 buildings were constructed between the 15th century and the early 17th century. The analysis according to region showed that there were three buildings in Fukushima, one in Saitama, three in Chiba, one in Aichi, one in Ehime, one in Hiroshima, one in Aomori, one in Kanagawa, and one in Oita. This indicates that many of the buildings were located in the Tōhoku and Kantō regions of Japan and that there was a particularly high kiwarijutsu match rate in Chiba.

Based on the match rates for all wood members, it was found that those that had a match rate of at least 50% in the target buildings were ChuoMa (central room) on the front elevation and side elevation, Nuki (joint connection) width, KasiraNuki (joint section) height, Daiwa (architrave) height and width, Hijiki (bracket arm) height and width, Makito height, Gagyo (round purlin) height, and Taruki (rafter) width. Analysis of floor plans showed that there were many buildings with 3Ken structures in which the lengths of the peripheral rooms and the ChuoMa were the same. If the proportional method of Kiwari-jutsu for ChuoMa is applied to WakiMa, the matching rate becomes the highest among all materials. These results indicate that there is a high probability that the floor plan designs were made using Kiwari-jutsu. However, overall, in the case of buildings in which Kiwari-jutsu was used in at least two of the measurements for wood members, no correlation was found with the size of the building remains in which the proportional method was Kiwari-jutsu. In addition, there was no fixed format for the proportional formula and the size of each member in the applied Kiwari-jyutu.

4. Conclusions

The conclusions and the main findings of this study can be formulated as:

1. The analysis of floor plans showed that the ChuoMa, WakiMa, and Mokosi had an integer relationship to Shiwari rather than column diameter and did not match the Shiwari included in Kiwari-jutsu. Analysis comparing Kiwari-jutsu to the remains showed that there was a tendency for proportions to be smaller than the Kiwari-jutsu proportions. Some column diameters were based on a standard Shaku (303 mm), and the distance between columns was based on the integer multiple of that figure. However, it was also found that all other wood members had no proportional relationship to that multiple;
2. It was found that over 50% of the buildings had Daiwa and that the heights of the Nuki, the widths of the KasiraNuki, and the heights and widths of the Daiwa were 0.1 times larger than Kiwari-jutsu;
3. An analysis of the Kumimono-bu showed that the vertically oriented wood members utilized Kiwari-jutsu while the horizontally oriented ones did not;
4. The Gagyo of the roofs had a high match rate with Kiwari-jutsu, and the Taruki had a low match rate with column diameter and Kiwari-jutsu;
5. There were 21 buildings that had Kiwari-jutsu proportions. These buildings dated to between the 15th and early 17th centuries. The regional analysis results showed that many of the buildings were in the Tōhoku region of Japan and that buildings in Chiba had a high match rate with Kiwari-jutsu. Based on the match rates for all types of wood members, there were 11 examples in which there were matches for at least 50% of the

19 items. Of these, it is highly likely that the floor plans—which are an important part of the composition of the buildings—utilized Kiwari.

Analysis of the dimensions of architectural remains showed that Kiwari-sho, which are technical manuals from the Japanese Middle Ages, were used to design the buildings studied. In addition, based on the fact that I found no relationship between the regions and historical periods investigated, I believe that the dimensions of these architectural remains were changed during later restorations. Comprehensive assessment of the extant texts in Japan known as Kiwarisho showed that they record a method that is sustainable.

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Data Availability Statement: Data available in a publicly accessible repository. The data presented in this study are openly available in [1–19].

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Conflicts of Interest: The author declares no conflict of interest.

Appendix A

(1) The minimum standard used for the standard scale of buildings was 3 Ken (間: rooms) on the front elevation and 3 Ken on the side elevation. There are a few buildings with a configuration of 5 Ken $\times$ 5 Ken or 7 Ken $\times$ 7 Ken. In this paper, a 3 Ken $\times$ 3 Ken building was used as the target subject of the study as this is the minimum spatial standard, excluding the Mokosi and spatial extensions such as Hisasi. (Figure A1.)

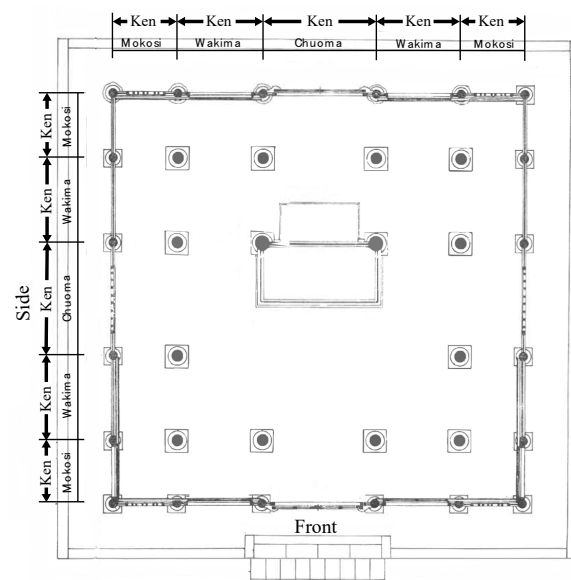


Figure A1. Position of ChuoMa, WakiMa, Mokosi.

(2) [13].

(3) From the Middle Ages in Japan on, relationships between the dimensions for columns, the distance between columns, the junctions between columns and the roof, and the Taruki arose, which eventually became the method referred to as Shiwari-hō [14].

(4) [15].

(5) [16].

(6) [17].

(7) [18].

(8) [19].

(9) List of buildings that were the target subjects of this study. Figure A2 [1].

Based on a survey report published by the Cultural Heritage Administration, Japan.

No	N a m e	No	N a m e
1	Amida-do hall 阿弥陀堂 (白水阿弥陀堂)	30	Amida-do of Shinchokoku-ji Temple 新長谷寺阿弥陀堂
2	Yakusi-do of Chuzen-ji Temple 中禪寺薬師堂	31	Shaka-do of Shinchokoku-ji Temple 新長谷寺釈迦堂
3	Amida-do of Nyoi-ji Temple 如意寺阿弥陀堂	32	Yakusi-do of Eihuku-ji Temple 榮福寺薬師堂
4	Kaizan-do of Todai-ji Temple 東大寺開山堂	33	Kannon-do of Shinkomyo-ji Temple 信光明寺観音堂
5	Amida-do of Myodo-ji Temple 明導寺阿弥陀堂	34	Dainichi-do of Shoren-ji Temple 正蓮寺大日堂
6	Hon-do of Raiko-ji Temple 来迎寺本堂	35	Yakusi-do of Zenko-ji Temple 善光寺薬師堂
7	Shin-do of Horyu-ji Temple 法隆寺新堂	36	Hon-do of Joko-ji Temple 定光寺本堂
8	Shaka-do of Zenpuku-in Temple 善福院釈迦堂	37	Amita-do of Saigan-ji Temple 西願寺阿弥陀堂
9	Mici-do of Murou-ji Temple 室生寺御影堂	38	Kannon-do of Johou-ji Temple 成法寺観音堂
10	Goma-do of Ishite-ji Temple 石手寺護摩堂	39	Hon-do of Chikurin-ji Temple 竹林寺本堂
11	Iwaya-do of Fudoin Temple 不動院岩屋堂	40	Hon-do of Matuo-ji Temple 松尾寺本堂
12	Hon-do of Jinkaku-ji Temple 神角寺本堂	41	Hon-do of Entu-ji Temple 円通寺本堂
13	Hon-do of Enpuku-ji Temple 圓福寺本堂	42	Kongo-do of Engyo-ji Temple 円教寺金剛堂
14	Kannon-do 観音堂	43	Shaka-do of Onsho-ji Temple 遠照寺釈迦堂
15	Jizou-do of Enmei-ji Temple 延命寺地藏堂	44	Kannon-do of Gotoku-ji Temple 護徳寺観音堂
16	Yakusi-do of Johukuin 常福院薬師堂	45	Amida-do of Uonuma Shrine 魚沼神社阿弥陀堂
17	Shariden of Engaku-ji Temple 円覚寺舍利殿	46	Yakusi-do of Isido-ji Temple 石堂寺薬師堂
18	Entuden of Jotoku-ji Temple 常徳寺円通殿	47	Kannon-do of Kiyomizu-dera Temple 清水寺観音堂
19	Jizo-do of Shofuku-ji Temple 正福寺地藏堂	48	Godai-do of Zuigan-ji Temple 瑞巖寺五大堂
20	Buddha Hall of Seihaku-ji Temple 清白寺仏殿	49	Goma-do of Chomei-ji Temple 長命寺護摩堂
21	Yakusi-do of Kichijo-ji Temple 吉祥寺薬師堂	50	Aizen-do of Jizoin Temple 地藏院愛染堂
22	Kannon-do of Toshun-ji Temple 洞春寺観音堂	51	Buddha Hall of Tokei-ji Temple 旧東慶寺仏殿
23	Kannon-do of Enman-ji Temple 円満寺観音堂	52	Kaizan-do of Senpuku-ji Temple 泉福寺開山堂
24	Benten-do of Okunoin 奥之院弁天堂	53	Shoin-do of Manpuku-ji Temple 萬福寺松隠堂舍利殿
25	Kannon-do of Kannon-ji Temple 観音寺観音堂	54	Daihododen of Manpuku-ji Temple 萬福寺大雄宝殿
26	Kannon-do of Kyushoo-ji Temple 旧松應寺観音堂	55	Sosi-do of Manpuku-ji Temple 萬福寺祖師堂
27	Omi-do of Kotoku-ji Temple 広徳寺大御堂	56	Hutarasan Shrine 二荒山神社別宮本宮神社拝殿
28	Kannon-do of Horai-ji Temple 鳳来寺観音堂	57	Kaizan-do of Rinno-ji Temple 輪王寺開山堂
29	Daishi-do of Shinchokoku-ji Temple 新長谷寺大師堂	58	Yakusi-do 薬師堂

Figure A2. Analysis Building List.

(10) List of kiwari-sho that were the target subjects of this study. The historical periods for the kiwari-sho listed in Figure A3. are based on the following works: [2–10].

Age	Item name	Kiwarisho	Age	Item name	Kiwarisho
1	1562,1574	Kikudakichumon	24	1633	SankenButuden
2	1562,1574	YutamosanButuden	25	1577,1624 ~ 1644	20 SankensimenDo
3	1562,1574	Nihonyo no Kinoikioinoji	26	1577,1624 ~ 1644	25 Karayo no Butuden
4	1562,1574	Nihonyo no Kinoikioi	27	1651	Hondotukuri no koto
5	1562,1574	Nihonyo no Kisakunokoto	28	1651	kotoButuden no koto
6	1562,1574	Naisitu no Butuden no Chumon no koto	29	1651	Hotautukuri
7	1562,1574	JyorakujiButuden KorehaMukasinoBun	30	1651	Karayau no Butuden no koto
8	1562,1574	Yuta no koto	31	1677 ~ 1710	SankenButuden
9	1562,1574	DaichijiButuden no Chumon	32	1677 ~ 1710	Yuta nasi SankenButuden
10	1573 ~ 1603	DoTukuri	33	1677 ~ 1710	SankensimenDo Naisitutukuri
11	1573 ~ 1603	KarayoButuden(Kenninjiyo)	34	1603 ~ 1868	SankenButuden Tadasi Yutanokoto
12	1593	Sankensigodo no Kikudaki	35	1603 ~ 1868	Irukawa no koto
13	1608	Dokishu, SankensimenDo no Zu	36	1674	Sankensha no koto tadasi Kyoryunari
14	1608	Dokishu, YutaTukuri KarayoSankenButuden no Zu	37	1643	3 Karayo no Butu
15	1614	SankenSihou no Tukurita no koto	38	1689	SankensimenDo
16	1614	Karayau no Subututen no koto Tadasi Kenninjiyau Sankensihou no Bututennari	39	1689	SankenButuden
17	1614	KarayauBututen no koto Tadasi Yutanokete Sankensihounari	40	1700	Sankensihou no Do tadasiwaki no IManiGejinarimokuroku
18	1615	KarayauBututen no koto Kenninsi Yaunari	41	1700	SankenSihou Gomado tadasiSouji no Donari
19	1615	HotauYukuri no koto	42	1746	Butuden no koto
20	1615	KarayauBututen no koto Kenninsi Yaunarihasi	43	1746	Hotautukuri no koto
21	1615	Mitautukuri no koto Hasirawakimate	44	1759	SankensimenDoKikudaki
22	1629	Sankensihou no Nihonyau no tau no koto	45	Late 1700 ~ Early 1800	Do(Sankensimen no mono)
23	1629	KarayauBututen no koto Tadasi Yutanasi	46	1875	SankensimenDo no koto

Figure A3. Kiwari-sho List.

(11) The terms for the wood members mentioned in this study can be found in Figures A4 and A5.

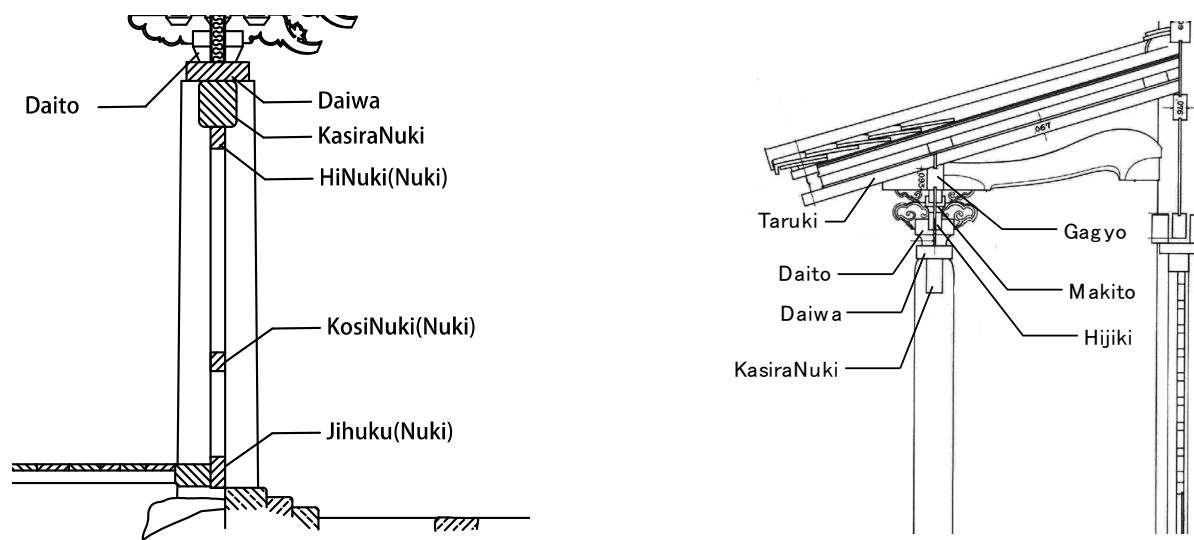


Figure A4. Member position in Cross-section.

Japanese	English
ChuoMa	Core bay
WakiMa	Side bay
Mokosi	Pent roof
Nuki	Penetrating tie beams
Kasiranuki	The horizontal head penetrating tie beams
Hinuki	A neck penetrating tie beam which extends through a pillar
Gagyo	The beam which supports a rafter
Taruki	Rafter
Daito	The support which secures the top of the column to the base of the bracket
Makito	A piece which secures and supports the intersecting pieces of the bracket
Hijiki	A support placed underneath the entire purlin lengthwise
Daiwa	Bracket set supporting beam
Kumimono	Bracket set

Figure A5. Architectural Terms.

(12) The standard unit used in Shiwari-hō is Issi (一枝: two Taruki widths + the distance between Taruki).

(13) The unit of length used in Japan prior to the adoption of the metric system was the Shaku (尺). The length of a shaku in the metric system has changed over time.

(14) Column diameter is referred to as "D". Unit: mm.

References

1. Cultural Heritage Administration. *Analyzes 1 to 58 Survey Report*; Cultural Heritage Administration: Tokyo, Japan, 1956–2002.
2. Sekiguchi, K. *"Kamigata" Style on the Architectural Manuscript of Kamakura*; Architectural Institute of Japan Academic Lecture Collection Summary Collection: Tokyo, Japan, 1990.
3. Inui, K. *The History of Japan's Mechanical Engineering Technology*; Japan Society for the Promotion of Science: Tokyo, Japan, 1961.
4. Nagai, N.; Niimi, K. *About the Kiwarisho of the Saito Family*; Kinki Branch of the Japanese Institute of Architects: Tokyo, Japan, 1981.
5. Fushimi, Y. *About Hayasike Kiwarisho (1): The History of Hayashiya*; The Japanese Institute of Architects Kanto Section Research Report: Tokyo, Japan, 2007.
6. Nagai, Y.; Ibuchi, K. *Kiwarisho Before Keichouki of Kobayasike and Kiwari of Kumimono Seen in Them*; Technical Report of the Japanese Institute of Architects: Tokyo, Japan, 1995.
7. Sakamoto, T.; Fushimi, Y.; Nakagawa, T. *About Kiwarisho "Yorozukikudaki"*; The Japan Association of Architectural Institutions: Tokyo, Japan, 2013.

8. Ito, Y. *Shomei Gokanko*; Kajima Institute Publishing: Tokyo, Japan, 1971.
9. Naito, A. *About of Kiwarisho "Magosichioboekaki" Part1–4.*; Tokai Branch Research Report Collection: Tokyo, Japan, 1969.
10. Kanagawa Prefecture Kanazawa Bunko. *Kanazawa Bunko Documents*; Convenience Hall Volume 9; Benrido: Kanagawa, Japan, 1988.
11. Kim, B.J. Comparative Study on Proportion of Korean Traditional Architecture from the Viewpoint of Japanese Kiwarisho—Focusing on the Three-Bay-Square Buddhist Halls. Ph.D. Thesis, Waseda University, Tokyo, Japan, 2021.
12. Kim, B.J.; Koiwa, M.; Nakagawa, T. A study on Sujangpok in the Korean traditional architectural design technologies. *Proc. Archit. Inst. Jpn.* **2020**, *85*, 443–451.
13. Sekino, T. Golden Hall, Toba, inner gate of Horyu-ji Temple non reconstruction theory. *J. Archit. Build. Sci.* **1905**, *218*, 67–82.
14. Omori, K. *Technology of Shrines and Temples—History, Techniques and Designs Mainly in the Middle Ages*; Rikogakusha Publishing: Tokyo, Japan, 1998.
15. Ishii, K. Study on Dimension Planning in Japanese Ancient Building. Ph.D. Thesis, Waseda University, Tokyo, Japan, 1975.
16. Ito, C. Golden Hall, Horyu-ji Temple Architectural Theory. *J. Archit. Build. Sci.* **1893**, 83.
17. Ito, N. *Study on the Wayo Architecture in the Middle Ages of Japan*; Shokokusha: Tokyo, Japan, 1961.
18. Mizoguchi, A. *Design Technology of Horyuji Temple Architecture*; Kajima-Publishing: Tokyo, Japan, 2012.
19. Takeshima, T. *Plane Composition of Horyuji Five Storied Pagoda*; Tokai Branch Research Report Collection (2): Tokyo, Japan, 1963; pp. 27–34.

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