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Essay

Architectural Module in Ancient China: The Tianqi Hall of Yedi Village, Jincheng

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Abstract: The construction ruler (营造尺,Yingzao chi) for this hall is 320.6 mm. It adopts the system of large and small rulers that has been in practice since the Tang and Song dynasties. Each large ruler is divided into 10 cun(寸), which is equivalent to 12 small cun(小寸). It uses architectural modulus similar to modern ones. The basic module is 1 chi. Based on this, the macroscopic dimensions are determined and the proportion of the main body is controlled. Four small cun are used as the sub-module, which is one-third of the basic module. Half a chi, that is, six small cun, is also a sub-module of one chi. Based on this, the height of columns, the height of bracket sets, etc. are determined. 0.4 small cun are also a sub-module, which is one-thirtieth of the basic module. This is used to measure various components, such as dou (斗,square blocks), gong (栱,cross-shaped brackets), and fang (枋,horizontal bars).

Keywords: Dai Temple in Yedi (冶底岱庙); construction ruler (营造尺,Yingzao chi); architectural modulus; proportion; Damuzuo (大木作,greater structural carpentry)

1. Overview and Existing Research

The Dai Temple(岱庙) is located in Yedi Village, Nancun Town, Zezhou County, Shanxi Province. Facing south, the temple is situated on a high ground in the west of the village. The terrain of the temple site is divided into three terraces. Along the central axis from south to north, the mountain gate(山门) and Yuzhao(鱼沼) Pond are on the first terrace. The wulou(舞楼,dance tower) is on the second terrace. The foundation of Tianqi(天齐) Hall serves as the third terrace. There are side halls, verandas, etc. built on both sides. In 2001, it was listed among the fifth batch of key cultural relics under national protection, with the cultural relic protection information spanning from the Song Dynasty to the Ming Dynasty.

Tianqi Hall is the main building of the temple. The inscription on the stone columns of the front eaves indicates that they were donated in the third year of the Yuanyou(元祐) reign of the Song Dynasty (1080 AD). There is an inscription on the blue stone doorframe of the front slot dating back to the 27th year of the Dading(大定) reign of the Jin Dynasty. Based on this, it can be inferred that this hall was built in the Song Dynasty and partially renovated in the Jin Dynasty (1187 AD).

Renovation started in November 2009 and was completed in May 2011. In 2019, the "Completion Report of the Renovation Project of Zezhou Dai Temple" was published, releasing relatively detailed survey and mapping drawings (SXZDGJ.2019). There is also one study on the artistic style among the research related to this hall(Li,Ym,.and Bl,Liu.2008).

2. Construction Ruler (营造尺, Yingzao Chi) and the Width of the Bay

As shown in Table 1, the Tong MianKuo(通面阔,The sum of all the widths of the bays) is 10,900 mm, and the Tong Jinshen(通进深,The sum of all depths of the bays) is 10,260 mm. The difference between the two is 640 mm, approximately 2 chi. Usually, the width and depth are in integer chi or integer half-chi and are proportional. The ratio of the depth to the width is 0.9412 to 1, approximately 16 to 17. This non-canonical proportion suggests that the design must derive from integer ratios constrained by whole-chi measurements.

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Table 1. Six Hypothetical Lengths of the Chi (Construction Ruler).

	Raw data	Hypothesis 1		Hypothesis 2		Hypothesis 3		Hypothesis 4		Hypothesis 5		Hypothesis 6	
	mm	Integer Chi	Ancient Chi Length (mm)	Integer Chi	Ancient Chi Length (mm)	Integer Chi	Ancient Chi Length (mm)	Integer Chi	Ancient Chi Length (mm)	Integer Chi	Ancient Chi Length (mm)	Integer Chi	Ancient Chi Length (mm)
Tong Jinshen	10260	32	320.625	33	310.909	34	301.765	35	293.143	35.5	289.014	36	285.000
Tong MianKuo	10900	34	320.588	35	311.429	36	302.778	37	294.595	38	286.842	38.5	283.117
mean value			320.607		311.169		302.271		293.869		287.928		284.058

Some scholars have determined through research that the length of various Song Dynasty chi ranges from 280 mm to 370 mm (Lu,Jx,.and Gm,Qiu. 2001:370). Taking into account the contemporary existing buildings and regional factors, the length of the chi is restricted to the range of 280 mm to 329 mm. Within this range, there are six hypotheses. As shown in the table(Table 1), the depth of Tianqi Hall ranges from 32 chi to 36 chi, and the corresponding width is also in integer chi. From this, six lengths of the chi are calculated.

During the Tang Dynasty and subsequent dynasties, the system of short and long rulers was adopted. In the north, 100 millet grains(黍,Panicum miliaceum) were used to define a short ruler, and 120 millet grains made up a long ruler. The long ruler was the official and commonly used measuring tool, while the short ruler was employed for rituals, music, astronomy, and medical measurements. Among the 41 Tang Dynasty rulers collected in A History of Chinese Science and Technology: Weights and Measures, one was a short ruler and 40 were long rulers. Each ruler was divided into 10 grids. Apparently, the commonly used rulers were all long rulers, and they followed the decimal system. Each long ruler was 10 cun(寸), which was equivalent to 12 small cun(小寸). The length of a small cun was the length of 10 millet grains, and the length of the cun was the length of 12 millet grains (Lu,Jx,.and Gm,Qiu. 2001:318-326,353). This is quite similar to the relationship between inches and feet. This system has been widely applied in many other existing ancient structures. Therefore, when measuring this hall, the use of small cun should also be taken into consideration (Xu,Xg.2025a;Xx,Xg.2025b.).

As shown in the table(Table 2), the main data such as the width of the bay and the height of the column are also restricted by the construction chi. When comparing from three aspects: integer dimensions, proportions, and similarity ratios, Plan 1 is the most reasonable. Based on this, the fitted length of the construction chi is 320.6 mm. See the figure (Figure 1).

Table 2. Validation of Six Hypotheses.

Hypothesis 1: 320.6 mm/Chi (Fitted)

	Raw data		Fitted Value			
	mm	Convert tol cun	cun	small cun	Multiples of 0.4 small cun	Similarity rate
Tong Jinshen	10260	320.025	**320**	384	96	99.992%
Tong MianKuo	10900	339.988	**340**	408	102	100.004%
Column height	4640	144.729	**145**	174	43.5	100.188%
width of the central bay	4500	140.362	**140**	168	42	99.742%

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width of the secondary bay	3200	99.813	**100**	120	30	100.188%
width of the secondary bay in depth	3210	100.125	**100**	120	30	99.875%
width of the central bay in depth	3840	119.775	**120**	144	36	99.998%
Difference between Bay Width and Depth	640	19.963	**20**	24	6	100.188%

Hypothesis 2: 311.2 mm/Chi (Fitted)

	Raw data		Fitted Value			
	mm	Convert tol cun	cun	small cun	Multiples of 0.4 small cun	Similarity rate
Tong Jinshen	10260	329.692	330	396	99	100.094%
Tong MianKuo	10900	350.257	350	420	105	99.927%
Column height	4640	149.100	150	180	45	100.603%
width of the central bay	4500	144.602	145	174	43.5	100.276%
width of the secondary bay	3200	102.828	102.5	123	30.75	99.681%
width of the secondary bay in depth	3210	103.149	102.5	123	30.75	99.371%
width of the central bay in depth	3840	123.393	125	150	37.5	101.302%
Difference between Bay Width and Depth	640	20.566	20	24	6	97.250%

Hypothesis 3: 311.2 mm/Chi (Fitted)

	Raw data		Fitted Value			
	mm	Convert tol cun	cun	small cun	Multiples of 0.4 small cun	Similarity rate
Tong Jinshen	10260	339.432	340	408	102	100.167%
Tong MianKuo	10900	360.605	360	432	108	99.832%
Column height	4640	153.505	155	186	46.5	100.974%
width of the central bay	4500	148.874	150	180	45	100.757%
width of the secondary bay	3200	105.866	105	126	31.5	99.182%
width of the secondary bay in depth	3210	106.196	105	126	31.5	98.873%
width of the central bay in depth	3840	127.039	130	156	39	102.331%
Difference between Bay Width and Depth	640	21.173	20	24	6	94.459%

Hypothesis 4: 293.87 mm/Chi (Fitted)

	Raw data		Fitted Value			
	mm	Convert tol cun	cun	small cun	Multiples of 0.4 small cun	Similarity rate
Tong Jinshen	10260	349.134	350	420	105	100.248%
Tong MianKuo	10900	370.912	370	444	111	99.754%
Column height	4640	157.893	157.5	189	47.25	99.751%

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width of the central bay	4500	153.129	152	182.4	45.6	99.263%
width of the secondary bay	3200	108.892	109	130.8	32.7	100.099%
width of the secondary bay in depth	3210	109.232	109	130.8	32.7	99.788%
width of the central bay in depth	3840	130.670	132	158.4	39.6	101.018%
Difference between Bay Width and Depth	640	21.778	20	24	6	91.834%

Hypothesis 5: 287.93 mm/Chi (Fitted)

	Raw data		Fitted Value			
	mm	Convert tol cun	cun	small cun	Multiples of 0.4 small cun	Similarity rate
Tong Jinshen	10260	356.337	355	426	106.5	99.625%
Tong MianKuo	10900	378.564	380	456	114	100.379%
Column height	4640	161.150	160	192	48	99.286%
width of the central bay	4500	156.288	155	186	46.5	99.176%
width of the secondary bay	3200	111.138	112.5	135	33.75	101.225%
width of the secondary bay in depth	3210	111.485	112.5	135	33.75	100.910%
width of the central bay in depth	3840	133.366	130	156	39	97.476%
Difference between Bay Width and Depth	640	22.228	25	30	7.5	112.473%

Hypothesis 6: 284 mm/Chi (Fitted)

	Raw data		Fitted Value			
	mm	Convert tol cun	cun	small cun	Multiples of 0.4 small cun	Similarity rate
Tong Jinshen	10260	361.268	360	432	108	99.649%
Tong MianKuo	10900	383.803	385	462	115.5	100.312%
Column height	4640	163.380	165	198	49.5	100.991%
width of the central bay	4500	158.451	160	192	48	100.978%
width of the secondary bay	3200	112.676	112.5	135	33.75	99.844%
width of the secondary bay in depth	3210	113.028	112.5	135	33.75	99.533%
width of the central bay in depth	3840	135.211	135	162	40.5	100.218%
Difference between Bay Width and Depth	640	22.535	25	30	7.5	110.938%

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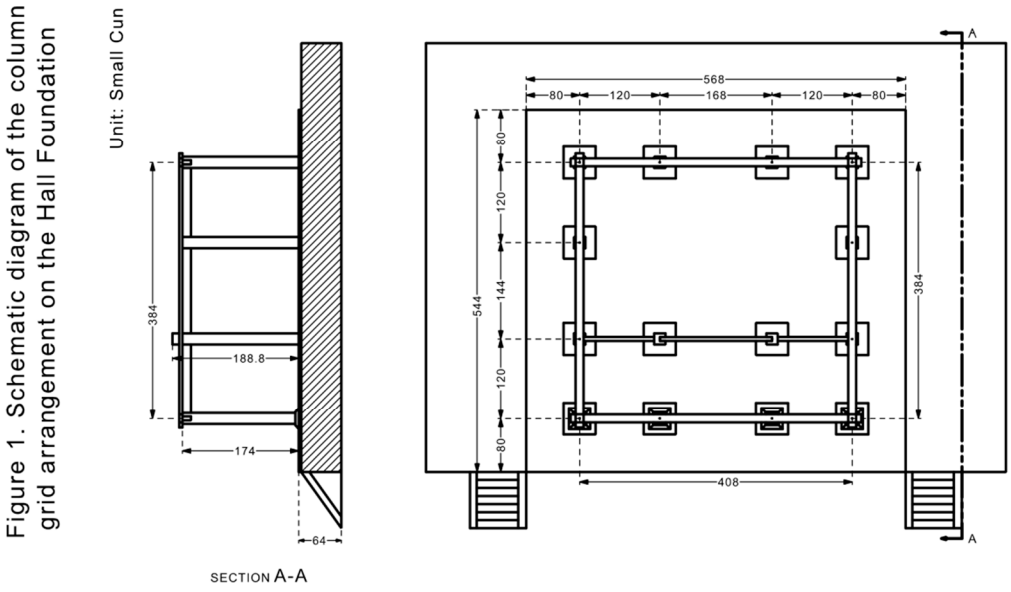

Figure 1. Schematic diagram of the column grid arrangement on the Hall Foundation(Draw by oneself).

The construction ruler should not be only used for the main framework but also for other parts of the building. The following will be verified separately.

3. Cai(材,Similar to Dimension Lumber)

The cai data are listed in table(Table 3). The cai of the Neizhu Puzuo(内柱铺作,inner column bracket sets) are the same as those of the Waiyan Puzuo(外檐铺作,exterior eave bracket set), and they are obviously of the same specification.The width of the cai is 4.4 small cun, the Dang cai(单材,single-sized timbers) is 7.2 small cun, the qi(栔) is 2.8 small cun, and the Zucai(足材,the full-sized timbers) is 10 small cun. Obviously, cun is not the measurement method for cai, but small cun. By comparison, it can be seen that the measurement of cai is expanded in multiples of 0.4 small cun. Therefore, 0.4 small cun is the smallest measurement unit of cai.

Table 3. Cai(Similar to dimension lumber).

Each chi is 320.6 mm

		Raw data			Fitted Value			
		nn	Convert to cun	Convert to small cun	small cun	Convert to cun	Multiples of 0.4 small cun	Similarity rate
Puzuo	widthofthecai	120	3.743	4.492	**4.4**	3.667	11	97.961%
	heightofdangcai	195	6.082	7.299	7.2	6	18	98.646%
	qi	75	2.339	2.807	2.8	2.333	7	99.742%
	heightofZucai	270	8.422	10.106	10	8.333	25	98.951%
Ridge Purlin Joint	widthofthecai	120	3.743	4.492	4.4	3.667	11	97.961%
	heightofdangcai	185	5.770	6.925	6.8	5.667	17	98.202%

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	qi	75	2.339	2.807	2.8	2.333	7	99.742%
upper purlin Joint	widthofthecai	120	3.743	4.492	4.4	3.667	11	97.961%
	heightofdangcai	200	6.238	7.486	7.4	6.167	18.5	98.852%
	qi	70	2.183	2.620	2.6	2.167	6.5	99.233%
	heightofZucai	270	8.422	10.106	10	8.333	25	98.951%
lower purlin Joint	widthofthecai	120	3.743	4.492	4.4	3.667	11	97.961%
	heightofZucai	270	8.422	10.106	10	8.333	25	98.951%
	heightofdangcai	170	5.303	6.363	6.4	5.333	16	100.580%
Sichuanfu (5-purlin beam)	diameter	640	19.963	23.955	24	20	60	100.188%
Pinglang(平梁,3-purlin beam)	diameter	340	10.605	12.726	12.8	10.667	32	100.580%
Dingfu(ding beam)	diameter	360	11.229	13.475	13.6	11.333	34	100.930%
Xitou fu(,side beam frame)	diameter	370	11.541	13.849	14	11.667	35	101.090%
rufu(beam tie)	width	270	8.422	10.106	10	8.333	25	98.951%
	height	410	12.789	15.346	15.2	12.667	38	99.047%
Da Jiao liang(large corner beam)	height	310	9.669	11.603	11.6	9.667	29	99.972%
	width	280	8.734	10.480	10.4	8.667	26	99.233%
Timu(cantilevered timbers) of Puzuo	width	120	3.743	4.492	4.4	3.667	11	97.961%
	height	155	4.835	5.802	5.8	4.833	14.5	99.972%
Timu of upper purlin	width	120	3.743	4.492	4.4	3.667	11	97.961%
	height	130	4.055	4.866	4.8	4	12	98.646%
Timu of lower purlin	width	120	3.743	4.492	4.4	3.667	11	97.961%
	height	135	4.211	5.053	5	4.167	12.5	98.951%
Timu of ridge Purlin	width	120	3.743	4.492	4.4	3.667	11	97.961%
	height	150	4.679	5.614	5.6	4.667	14	99.742%
pu-pai-fang	width	320	9.981	11.978	12	10	30	100.188%
	height	130	4.055	4.866	4.8	4	12	98.646%
outer Laner(architrave)	width	165	5.147	6.176	6	5	15	97.152%
	height	335	10.449	12.539	12.8	10.667	32	102.082%
inner Laner	width	150	4.679	5.614	5.6	4.667	14	99.742%
	height	290	9.046	10.855	10.8	9	27	99.497%
Chuanfang(linking member) of Xitou fu	width	75	2.339	2.807	2.8	2.333	7	99.742%
	height	170	5.303	6.363	6.4	5.333	16	100.580%
Chuanfang(linking member) of lower purlin Joint	width	70	2.183	2.620	2.8	2.333	7	106.867%
	height	170	5.303	6.363	6.4	5.333	16	100.580%
Chuanfang(linking member) of ridge Purlin Joint	width	90	2.807	3.369	3.4	2.833	8.5	100.930%
	height	230	7.174	8.609	8.6	7.167	21.5	99.897%

In “Yingzao Fashi” (营造法式,the Song Dynasty’s building standard manual), there is the concept of “fen”(份,The absolute value varies with the grade of the “cai” and is one-tenth of the width of the “cai”.). “Fen” is a relative length and the smallest measurement unit of “cai”. This is a relative measurement method derived from the cross-sectional proportion of “cai”(Pan,G,.and Jz,He.2017).

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Borrowing the concept of “fen” in “Yingzao Fashi”, if we define 0.4 small cun as each “fen”, then the materials used for this palace can be described as follows: the width of “cai” is 11 fen, the “Dang cai” is 18 fen, the “qi” is 7 fen, and the “Zucai” is 25 fen..

As shown in table(Table 3), the cai used for the ridge purlin, each node of the upper and lower purlins, and the Timu(替木,cantilevered timbers) at each node can also be expressed in terms of fen. The cai used in these parts are similar to those of the exterior eave bracket sets. The width of the cai is basically 11 fen, while the height of the cai shows flexible minor variations.

The cross-section of beam-like components can also be constrained by fen. The Sichuanfu (四椽栿,5-purlin beam) is the thickest and strongest. Its diameter is 60 fen, which exactly equals 2 chi. The Pinglang(平梁,3-purlin beam), the Dingfu(丁栿,ding beam),and the Xitou fu(系头栿，side beam frame) are all round timbers. Their diameters range from 32 fen to 35 fen, approximately half of the diameter of the Sichuanfu . The Dajiaolain(大角梁,large corner beam) and the rufu(乳栿,beam tie) have rectangular cross-sections and are also constrained by fen values.

The width of the pu-pai-fang(普拍枋) is 30 fen, which is equivalent to 1 chi, and its height is 12 fen, equivalent to 4.8 small cun. The outer Laner(闌额, architrave) is larger than the inner Laner, and can also be constrained by fen values. These cai are slightly larger than the Zucai of the bracket sets.

There are Chuanfang(串枋,linking member) on the upper framework. This cai is a connecting component and does not bear weight, so it is the smallest. It is also set at 0.4 small cun.

4. Dou(斗,Bearing Block)

The data of dou are converted into cun and small cun. Comparatively speaking, taking 0.4 small cun as the smallest measurement unit is the most reasonable, as shown in table(Table 4). It can be divided into three categories according to size, as shown in figure(Figure 2).

Figure 2 Schematic diagram of some dou

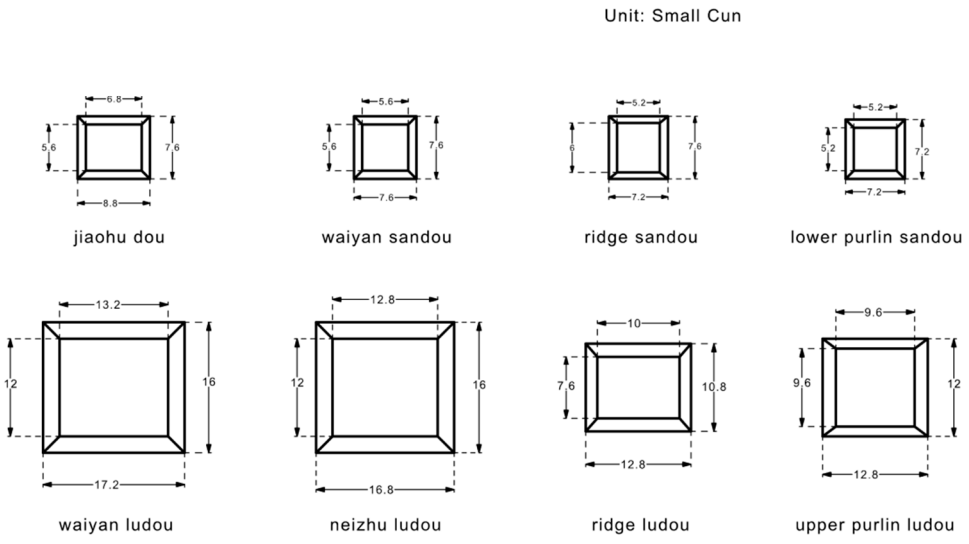

Figure 2. Schematic diagram of some dou (Draw by oneself).

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Table 4. dou (斗,**square blocks**).

Each chi is 320.6 mm

	waiyan ludou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	460	350	430	320	105	50	90	140	245
	cun	14.348	10.917	13.412	9.981	3.275	1.560	2.807	4.367	7.642
	small cun	17.218	13.100	16.095	11.978	3.930	1.871	3.369	5.240	9.170
Fitted Value	small cun	17.2	13.2	16	12	4	1.8	3.4	5.2	9.2
	cun	14.333	11	13.333	10	3.333	1.5	2.833	4.333	7.667
	fen	43	33	40	30	10	4.5	8.5	13	23
	Similarity rate	99.897%	100.760%	99.411%	100.188%	101.778%	96.180%	100.930%	99.233%	100.324%

	waiyan sandou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	200	140	205	150	50	25	50	75	125
	cun	6.238	4.367	6.394	4.679	1.560	0.780	1.560	2.339	3.899
	small cun	7.486	5.240	7.673	5.614	1.871	0.936	1.871	2.807	4.679
Fitted Value	small cun	**7.6**	**5.6**	**7.6**	**5.6**	2	0.8	2	2.8	4.8
	cun	6.333	4.667	6.333	4.667	1.667	0.667	1.667	2.333	4
	fen	19	14	19	14	5	2	5	7	12
	Similarity rate	101.523%	106.867%	99.047%	99.742%	106.867%	85.493%	106.867%	99.742%	102.592%

	waiyan jiaohu dou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	240	180	205	150	50	25	50	75	125
	cun	7.486	5.614	6.394	4.679	1.560	0.780	1.560	2.339	3.899
	small cun	8.983	6.737	7.673	5.614	1.871	0.936	1.871	2.807	4.679
Fitted Value	small cun	8.8	6.8	7.6	5.6	2	0.8	2	2.8	4.8
	cun	7.333	5.667	6.333	4.667	1.667	0.667	1.667	2.333	4
	fen	22	17	19	14	5	2	5	7	12
	Similarity rate	97.961%	100.930%	99.047%	99.742%	106.867%	85.493%	106.867%	99.742%	102.592%

	neizhu ludou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	450	340	425	325	105	50	90	140	245
	cun	14.036	10.605	13.256	10.137	3.275	1.560	2.807	4.367	7.642
	small cun	16.843	12.726	15.908	12.165	3.930	1.871	3.369	5.240	9.170

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Fitted Value	small cun	16.8	12.8	16	12	4	1.8	3.4	5.2	9.2
	cun	14.000	10.667	13.333	10.000	3.333	1.500	2.833	4.333	7.667
	fen	42	32	40	30	10	4.5	8.5	13	23
	Similarity rate	99.742%	100.580%	100.580%	98.646%	101.778 %	96.180%	100.930%	99.233%	100.324%

	ridge purlin ludou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	335	265	285	200	85	40	75	115	200
	cun	10.449	8.266	8.890	6.238	2.651	1.248	2.339	3.587	6.238
	small cun	12.539	9.919	10.667	7.486	3.182	1.497	2.807	4.304	7.486
Fitted Value	small cun	12.8	10	10.8	7.6	3.2	1.6	2.8	4.4	7.4
	cun	10.667	8.333	9.000	6.333	2.667	1.333	2.333	3.667	6.167
	fen	32	25	27	19	8	4	7	11	18.5
	Similarity rate	102.082%	100.818%	101.242%	101.523%	100.580 %	106.867 %	99.742%	102.220 %	98.852%

	upper purlin ludou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	345	260	325	250	85	35	70	105	190
	cun	10.761	8.110	10.137	7.798	2.651	1.092	2.183	3.275	5.926
	small cun	12.913	9.732	12.165	9.357	3.182	1.310	2.620	3.930	7.112
Fitted Value	small cun	12.8	9.6	12	9.6	3.2	1.2	2.8	4	7.2
	cun	10.667	8	10	8	2.667	1	2.333	3.333	6
	fen	32	24	30	24	8	3	7	10	18
	Similarity rate	99.123%	98.646%	98.646%	102.592%	100.580 %	91.600%	106.867%	101.778 %	101.242%

	lower purlin ludou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	350	255	330	235	65	45	75	120	185
	cun	10.917	7.954	10.293	7.330	2.027	1.404	2.339	3.743	5.770
	small cun	13.100	9.545	12.352	8.796	2.433	1.684	2.807	4.492	6.925
Fitted Value	small cun	12.8	9.6	12.4	8.8	2.4	1.6	2.8	4.4	6.8
	cun	10.667	8.000	10.333	7.333	2.000	1.333	2.333	3.667	5.667
	fen	32	24	31	22	6	4	7	11	17
	Similarity rate	97.707%	100.580%	100.390%	100.045%	98.646%	94.993%	99.742%	97.961%	98.202%

	lower purlin sandou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height

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Raw data	mm	190	135	205	165	40	30	45	75	115
	cun	5.926	4.211	6.394	5.147	1.248	0.936	1.404	2.339	3.587
	small cun	7.112	5.053	7.673	6.176	1.497	1.123	1.684	2.807	4.304
Fitted Value	small cun	**7.2**	**5.2**	**7.6**	**6**	1.6	1.2	1.6	2.8	4.4
	cun	6.000	4.333	6.333	5.000	1.333	1.000	1.333	2.333	3.667
	fen	18	13	19	15	4	3	4	7	11
	Similarity rate	101.242%	102.909%	99.047%	97.152%	106.867 %	106.867 %	94.993%	99.742%	102.220%

	upper purlin sandou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	195	150	205	155	40	35	70	105	145
	cun	6.082	4.679	6.394	4.835	1.248	1.092	2.183	3.275	4.523
	small cun	7.299	5.614	7.673	5.802	1.497	1.310	2.620	3.930	5.427
Fitted Value	small cun	**7.2**	**5.6**	**7.6**	**6**	1.6	1.2	2.8	4	5.6
	cun	6.000	4.667	6.333	5.000	1.333	1.000	2.333	3.333	4.667
	fen	18	14	19	15	4	3	7	10	14
	Similarity rate	98.646%	99.742%	99.047%	103.419%	106.867 %	91.600%	106.867%	101.778 %	103.182%

	lower purlin sandou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	190	135	190	135	45	25	45	70	115
	cun	5.926	4.211	5.926	4.211	1.404	0.780	1.404	2.183	3.587
	small cun	7.112	5.053	7.112	5.053	1.684	0.936	1.684	2.620	4.304
Fitted Value	small cun	**7.2**	**5.2**	**7.2**	**5.2**	1.6	1.2	1.6	2.8	4.4
	cun	6.000	4.333	6.000	4.333	1.333	1.000	1.333	2.333	3.667
	fen	18	13	18	13	4	3	4	7	11
	Similarity rate	101.242%	102.909%	101.242%	102.909%	94.993%	128.240 %	94.993%	106.867 %	102.220%

	neizhu sandou	Upper width	Lower width	Upper depth	Lower depth	Er(耳)	ping(平)	dou-qi(欹)	qi(栔)	Total height
Raw data	mm	210	160	210	160	50	25	50	75	125
	cun	6.550	4.991	6.550	4.991	1.560	0.780	1.560	2.339	3.899
	small cun	7.860	5.989	7.860	5.989	1.871	0.936	1.871	2.807	4.679
Fitted Value	small cun	7.6	6	7.6	6	2	0.8	2	2.8	4.8
	cun	6.333	5.000	6.333	5.000	1.667	0.667	1.667	2.333	4.000
	fen	19	15	19	15	5	2	5	7	12

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	Similarity rate	96.689%	100.188%	96.689%	100.188%	106.867 %	85.493%	106.867%	99.742%	102.592%

The largest structural components are the neizhu ludou (内柱栌斗, inner column cap block) and waiyan ludou (外檐栌斗, eaves cap block) . Although there are slight differences in their external dimensions, they belong to the same category. The upper width is approximately 42 fen, equivalent to 16.8 small cun, and the height of the qi is 5.2 small cun.

There are ludou at three nodes: under the lower purlin, under the upper purlin, and at the ridge. They have little difference and similar shapes. The upper width of each is 32 fen, equivalent to 12.8 small cun, and the height of the qi is 10 to 11 fen.

The sizes of other dou are similar and are classified into the category of small dou. The sizes of this type of dou are slightly adjusted according to their positions. The upper width of the sandou(散斗,scattered block) on the outer eave columns is 19 fen, the upper width of the jiaohu dou(交互斗,connection block) is 22 fen, The upper width of the sandou at each node of the beam and purlins is 18 fen, and the height of the qi is mainly 7 fen.

On the basis of being divided into three major categories according to the size of the dou, the dimensions of each part of the dou vary slightly. Obviously, there are precision errors in the data in table(Table 4). Such errors include the manufacturing errors during the initial construction, as well as the later wind and rain erosion and surveying and mapping errors. However, beyond these errors, there are obvious differences in the design dimensions of the dou. The dou is not a standard, interchangeable part that is universally applicable. Instead, its size is determined according to the structural requirements. Only the size of the dou is relatively unified for the same type of structure and in the same type of position. Essentially, it is the result of being designed in units of 0.4 small cun.This is the result of being set according to the building modulus.

5. Gong (栱,Bracketarm)

The data of gong are listed in table(Table 5). According to the assembly relationship between gong and dou, the length of the center(栱心长,The center distance relevant to assembly) of gong can be deduced by subtracting the lower width of dou from the length of gong. The distance between the outer ends of the two dous above the gong is obtained by adding the upper width of a small dou to the length of the center. Each set of brackets is shown in Figure(Figures 3–6 and 8).

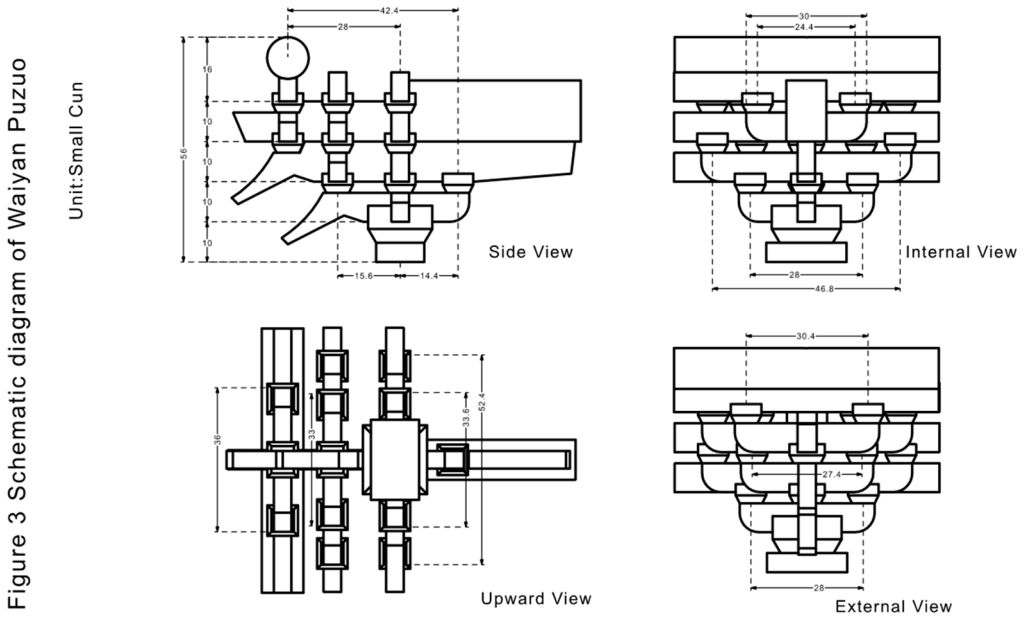

Figure 3. Schematic diagram of Waiyan Puzuo (Draw by oneself).

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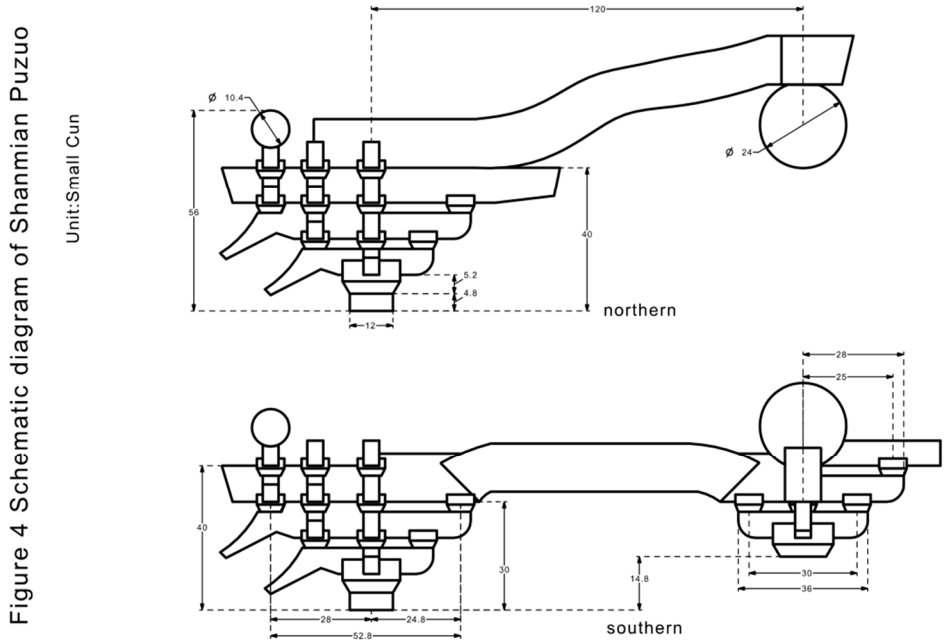

Figure 4. Schematic diagram of Shanmian Puzuo (Draw by oneself).

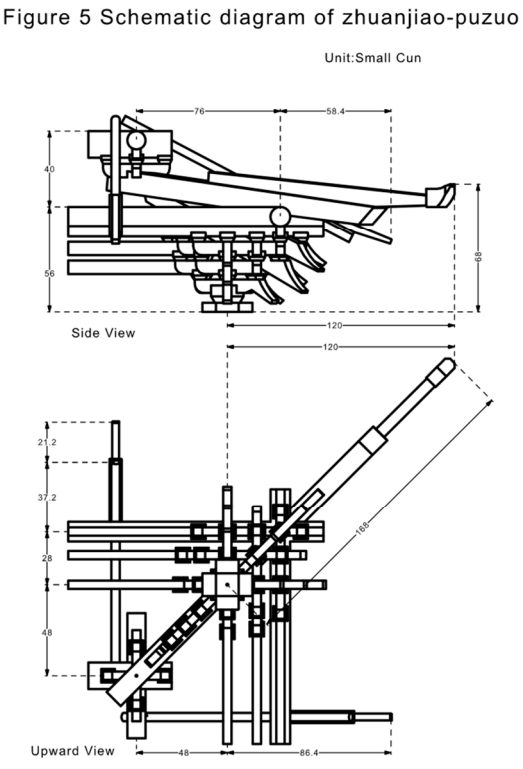

Figure 5. Schematic diagram of zhuanjiao-puzuo (Draw by oneself).

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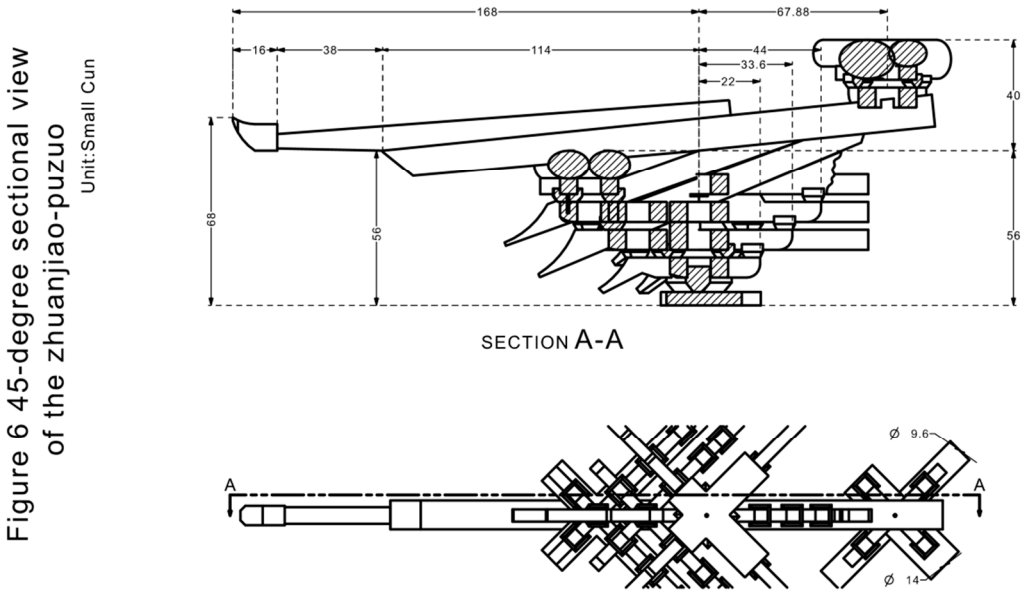

Figure 6. 45-degree sectional view of the zhuanjiao-puzuo (Draw by oneself).

Table 5. length of gong and center(The center distance relevant to assembly).

Each chi is 320.6 mm

		Raw data			Fitted Value				lower width of dou	length of the center/or half of center		
		nn	Convert to cun	Convert to small cun	small cun	Convert to cun	Multiples of 0.4 small cun	Similarity rate	small cun	small cun	Multiples of 0.4 small cun	Convert to cun
waiyan puzuo	nidao-gong	900	28.072	33.687	33.6	**28**	84	99.742%	5.6	**28**	**70**	23.333
	nidao man-gong	1400	43.668	52.402	52.8	**44**	132	100.760%	5.6	47.2	118	39.333
	gong is carved into the third-tier fang (horizontal timber)	800	24.953	29.944	**30**	**25**	75	100.188%	5.6	24.4	61	20.333
	guazi-gong	880	27.449	32.938	**33**	27.5	82.5	100.188%	5.6	27.4	68.5	22.833
	ling-gong	960	29.944	35.933	**36**	**30**	90	100.188%	5.6	30.4	76	25.333

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	outer jump length of the hua-gong	410	12.789	15.346	15.6	**13**	39	101.654%				
	inner jump length of the hua-gong	385	12.009	14.410	14.4	**12**	36	99.927%				
	Second jump	330	10.293	12.352	12.4	10.333	31	100.390%				
	total inner and outer jump length of waiyan puzuo	1125	35.090	42.109	42.4	35.333	106	100.692%				
	outer jump length of waiyan puzuo	740	23.082	27.698	**28**	23.333	70	101.090%				
shanmian Puzuo	outer jump length ofshanmian puzuo	740	23.082	27.698	**28**	23.333	70	101.090%				
	first inner jump length	385	12.009	14.410	14.4	**12**	36	99.927%				
	Second inner jump length	280	8.734	10.480	10.4	8.667	26	99.233%				
	total inner jump length	665	20.742	24.891	24.8	20.667	62	99.635%				
	total inner and outer jump length of shanmian Puzuo	1405	43.824	52.589	52.8	**44**	132	100.401%				
three-layer gong of the inner jump of the zhuanjiao-puzuo	first laye	585	18.247	21.896	**22**	18.333	55	100.473%	2.8	19.2	48	16
	second layer	895	27.916	33.500	**34**	28.333	85	101.493%	2.8	31.2	78	26
	third layer	1175	36.650	43.980	**44**	36.667	110	100.045%	2.8	41.2	103	34.333
	nidao-gong	960	29.944	35.933	**36**	**30**	90	100.188%	6	**30**	75	**25**

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Neizhu Puzuo	nidao man-gong(half)	745	23.238	27.885	**28**	23.333	70	100.412%	3	**25**	62.5	20.833
	tatou	1435	44.760	53.712	**54**	45	135	100.537%				

5.1. Neizhu Puzuo

As shown in figure(Figure 4). The length of the nidao-gong (泥道栱,axial bracket arm) is 36 small cun. The bottom width of the sandou is 6 small cun. The length of the center is 30 small cun. There is only half of the nidao man-gong(泥道慢栱, second-layer axial bracket arm). The length of half of the nidao man-gong is 28 small cun, and the bottom of half of a sandou is 3 small cun. Thus, the length of the half nidao man-gong is 25 small cun. As shown in table(Table 5), the length of the tatou(榻头,The bracket arm of the inclined end under the beam) is 54 small cun.

The width of the narrowest bay of this hall is 120 small cun. There is no bujian-puzuo(补间铺作,bracket sets between columns) between the inner columns, and the length of the gong is not affected by the spacing and width of the sets of bracket arms. Therefore, the dimensions of these three components are all in integer small cun and It is also designed in integer 'fens'.

5.2. Zhuanjiao-Puzuo(转角铺作,Bracket Set on Corner)

As shown in table and Figure(Table 5 、 Figure 6）. The zhuanjiao - puzuo has three inward jumps at a 45-degree angle. The lengths of the half gong are 22 small cun, 34 small cun, and 44 small cun respectively. Calculated based on the width of half the bottom of a small dou being 2.8 small cun, it can be deduced that the lengths from the center of the half gong are 19.2 small cun, 31.2 small cun, and 41.2 small cun. Judging from the data, the integer value of the small cun of the bracket length is prioritized here, and the length of the center of the gong is determined according to the size of the bottom of the dou.

5.3. Waiyan Puzuo

As shown in figures and table(Figures 3 and 4 and Table 5). The Waiyan Puzuo are relatively complex, with multiple horizontal and vertical gong intersecting with each other. Constrained by the assembly relationship and also influenced by the bay width and the bujian-puzuo, they are crucial to the architectural image.

The length of the ling-gong(令栱,regular arm) be 36 small cun, the length of the guazi-gong(瓜子栱,oval arm) be 33 small cun, A gong is carved on the body of the third layer of the fang. The length of the gong is 30 small cun. The lengths of these three horizontal arches are set in integer small cun, and the length of the central part is determined by the assembly relationship between the dou and the gong.

The length of the nidao-gong is 28 cun, and the length of the nidao man-gong is 44 cun. Different from before, the length of the gong conforms to an integer number of cun. But it is still an integer multiple of 0.4 small cun.

The outer jump length of the hua-gong (华栱,flower-shaped bracket arms) is 15.6 small cun, which is equivalent to 13 cun. The inner jump length is 14.4 small cun, which is equivalent to 12 cun. The length of the center of the hua-gong is 25 cun, which is equivalent to 30 small cun. This set of data gives priority to ensuring integer cun.

The total inner jump of the Shanmian Puzuo(山面铺作,eave bracket set on the gable side) is 24.8 small cun. The outer jump is 28 small cun. The sum of the inner and outer jumps is 52.8 small cun, which is equivalent to 44 cun. For this set of data, the target of 44 cun was first determined, and then each inner and outer node was divided. The measurement was completed in small cun.

Overall, in the design of the gong, efforts are made to ensure that the length of the gong or the length of the center is an integer number of cun or an integer number of small cun. When affected by the structure, it will follow the structure. However, all are integer multiples of 0.4 small cun.

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6. The Parameters of the Puzuo (铺作,Bracket Set) and the Building

6.1. The Parameters of the Waiyan Puzuo

As shown in table and figures (Table 6 and Figures 3 and 4), the cai and qi of each layer of the Waiyan Puzuoare clear. The total height of the pu-pai-fang and the ludou is 10 small cun. Above it, the three layers of Zucai measure 30 small cun. The height of the Timu is 155 mm, approximately 5.8 small cun. The diameter of the liao-yan-tuan(撩檐槫,eaves purlin) is 290 mm, approximately 10.8 small cun. However, since the liao-yan-tuan and the Timu need to be cut to form a mating surface, the actual height of the liao-yan-tuan is approximately 10.4 small cun, and the Timu is approximately 5.6 small cun. The combined height of the liao-yan-tuan and the Timu is approximately 16 small cun. Thus, from the bottom surface of the pu-pai-fang to the upper surface of the Timu of the bracket set, it is a total of 56 small cun, which is the height parameter.

Table 6. Foundation and height of Puzuo.

Each chi is 320.6 mm

		Raw data			Fitted Value			
		nn	Convert to cun	Convert to small cun	small cun	Convert to cun	Multiples of 0.4 small cun	Similarity rate
Foundation of the Hall	Height	1685	52.558	63.069	**64**	53.333	160	101.476%
	Width	15240	475.359	570.430	568	473.333	1420	99.574%
	From the left and right edges of the platform base to the column center	2150	67.062	80.474	80	66.667	200	99.411%
	From the front edge of the platform base to the column center	2140	66.750	80.100	80	66.667	200	99.875%
	Theoretical depth				544	453.333	1360	calculate
tiered component heights of puzuo	pu-pai-fang	130	4.055	4.866	4.8	4	12	98.646%
	ludou	140	4.367	5.240	5.2	4.333	13	99.233%
	three zucai	810	25.265	30.318	30	25	75	98.951%
	Timu	155	4.835	5.802	5.6	4.667	14	96.525%
	diameter of the liao-yan-tuan	290	9.046	10.855	10.4	8.667	26	95.811%
	Total height	1525	47.567	57.080	**56**	46.667	140	98.107%
	liao-yan-tuan and Timu				19.2	16	48	估算

The length of the nidao man-gong is 44 cun. The distance between the outer skins of the two dou on the arch is 54.8 small cun, and this is the widest part of the Puzuo.

The total length of the inner and outer jumps of the Shanmian Puzuo is 44 cun, with the outer jump being 28 small cun. These are the depth parameters of the Puzuo.

6.2. Neizhu Puzuo, Beams and Indoor Space

The Neizhu Puzuo is the structural intersection point of the longitudinal and transverse beams, and it is the key to the structure of the building. The cai and qi are stacked in layers as shown in

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figures(Figures 4 and 7). The inner column is 14.8 small cun higher than the outer eaves column. The distance from the bottom of the front rufu(乳栿) to the bottom surface of the pu-pai-fang is 30 small cun, and the height of the flat column is 174 small cun. Then the height from the indoor floor level to the bottom surface of the front rufu is 204 small cun, which is equivalent to 17 chi. These are the main parameters of the indoor space.

Figure 7 Schematic diagram of the Shang Jia

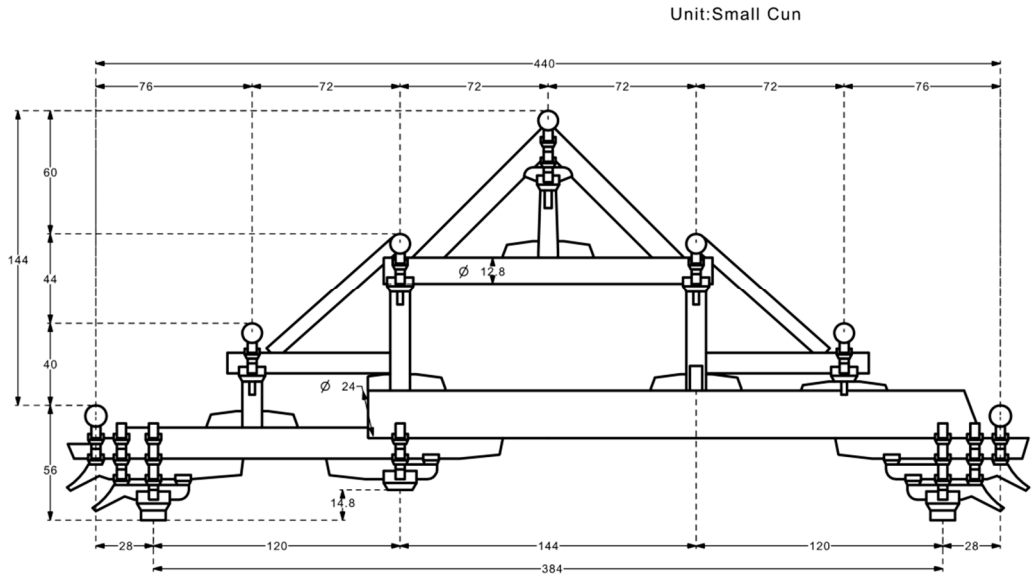

Figure 7. Schematic diagram of the Shang Jia (Draw by oneself).

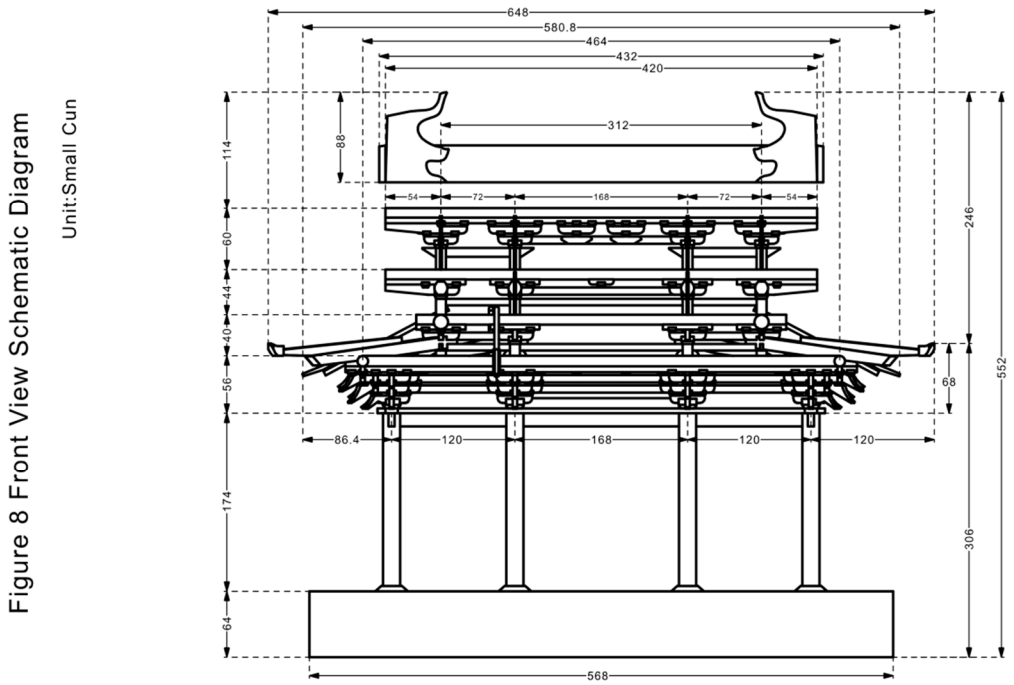

Figure 8. Front View Schematic Diagram (Draw by oneself).

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7. Foundation of the Hall

The relevant data is shown in table(Table 6). The foundation of Tianqi Hall is rather special as it takes advantage of the terrain of the terrace. The front of the terrace foundation is about 1,685 mm high, which is approximately 64 small cun when converted, about at the same level as an adult's head and shoulders. The left and right terrace foundations are connected with those of the east and west side halls to form an integrated whole, with only a height difference of 14 to 15 centimeters. The ground level behind the hall is higher than that in front of the hall. The rear terrace foundation is integrated with the ground, and the eave wall is built from the ground level behind the hall. There are no steps in the middle in front of the hall. On the left and right of the front terrace foundation, corner columns are erected as the boundaries of the terrace foundation. There are two sets of steps, one on the east and one on the west, outside the corner columns.

As shown in figure(Figures 1, 8, and 9). The width of the hall foundation is 568 small cun, and the depth of the hall foundation is 544 small cun. The height is 64 small cun.Neither of them is an integer number of cun, but both are multiples of 4 small cun.

8. Shang Jia (上架,Beam Frame)

The relevant data fitting is shown in table and figures(Table 7 and Figures 7–10).

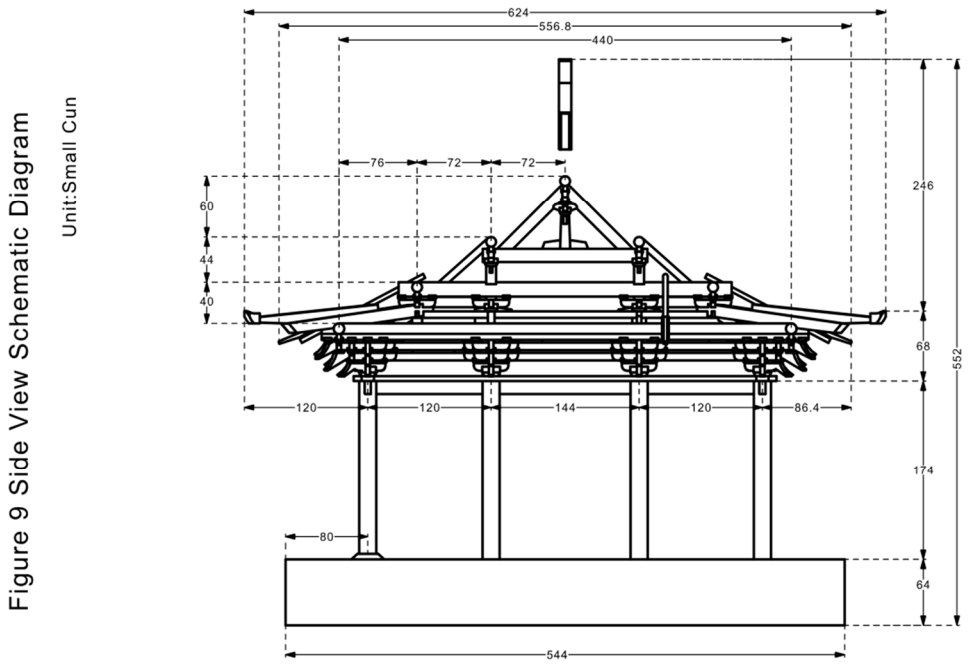

Figure 9. Side View Schematic Diagram (Draw by oneself).

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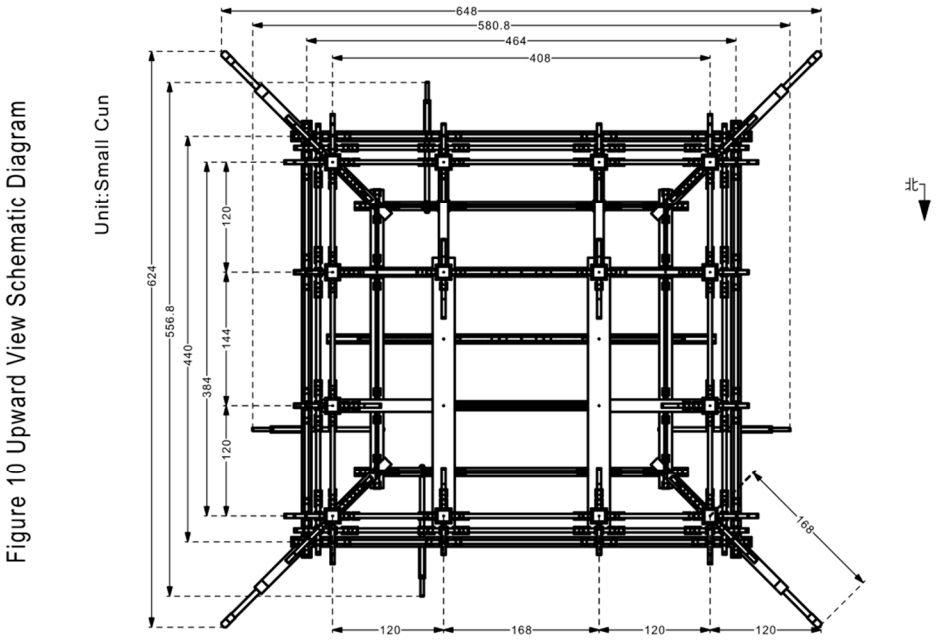

Figure 10. Upward View Schematic Diagram (Draw by oneself).

Table 7. Shang Jia (上架,Beam Frame).

Each chi is 320.6 mm

		Raw data			Fitted Value			
		nn	Convert to cun	Convert to small cun	small cun	Convert to cun	Multiples of 0.4 small cun	Similarity rate
Ceyang (Lateral structural elevation)	horizontal distance from ridge purlin to upper purlin	1920	59.888	71.865	72	**60**	180	100.188%
	horizontal distance from lower purlin to upper purlin	1900	59.264	71.117	72	**60**	180	101.242%
	horizontal distance from liao-yan-tuan to lower purlin	2050	63.943	76.731	**76**	63.333	190	99.047%
	Length of out-jump of puzuo	740	23.082	27.698	28	23.333	70	101.090%
	istance between front/rear liao-yan-tuan	11740	366.188	439.426	440	366.667	1100	100.131%
Zhengyang(Principal structural framework)	distance between the Xitou fu and the Pinglang	1890	58.952	70.742	72	**60**	180	101.778%
	distance between two xitoufu	8280	258.266	309.919	312	260	780	100.671%
	chu-ji	1480	46.163	55.396	54	**45**	135	97.480%
	main ridge(Not including roof tiles)	11240	350.593	420.711	**420**	**350**	1050	99.831%

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	istance between left / right liao-yan-tuan	12380	386.151	463.381	464	386.667	1160	100.134%
height	from liao-yan-tuan to lower purlin	1060	33.063	39.676	40	33.333	100	100.818%
	from lower purlin to upper purlin	1170	36.494	43.793	44	36.667	110	100.473%
	from ridge purlin to upper purlin	1600	49.906	59.888	60	50	150	100.188%
	total lift	3830	119.464	143.356	**144**	**120**	360	100.449%

8.1. Ceyang (侧样,Lateral Structural Elevation)

The Tong Jinshen is 320 cun, which is equivalent to 384 small cun. The Length of the out-jump of the puzuo is 28 small cun. The horizontal distance from the ridge purlin to the upper purlin is 72 small cun. The horizontal distance from the lower purlin to the upper purlin is 72 small cun. The horizontal distance from the liao-yan-tuan(撩檐槫,eaves purlin) to the lower purlin is 76 small cun. They are all integer multiples of 4 small cun.

8.2. Zhengyang(正样,Principal Structural Framework)

The Tong MianKuo is 408 small cun. The Length of the out-jump of the puzuo is 28 small cun. The distance between the purlins at the eaves on the east and west sides is 464 small cun. Excluding the tile, taking the surface of the gable fascia board as the boundary, the length of the main ridge (between the chu-ji) is 420 small cun. When including the tile components, the estimated length of the main ridge is 432 small cun,equivalent to 360 cun. the chu-ji(出际,outward extension of the gable purlins)is 54 small cun.

9. Ju Zhe(举折,Raising the Purlin)

As shown in table (Tables 7 and 8). The total lift is 144 small cun. The result of the fitting is as shown in figures(Figure 11). By taking 13/15 of the total rise and connecting it to the upper surface of the liao-yan-tuan, the height of the upper purlin can be obtained. By taking 12/15 of the total rise and connecting it to the upper surface of the liao-yan-tuan, the height of the lower purlin can be known. The essence of this calculation method is proportional distribution.

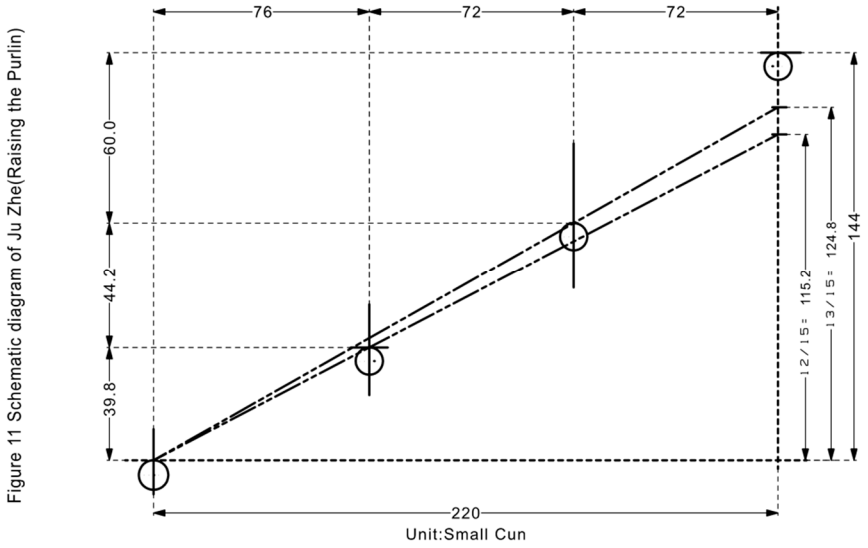

Figure 11. Schematic diagram of Ju Zhe(Raising the Purlin) (Draw by oneself).

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Table 8. raising the purlin(ju zhe).

Unit: small cun

	horizontal distance	vertical distance	slope
from ridge purlin to upper purlin	72	60	5/6
from lower purlin to upper purlin	72	44	11/18
from liao-yan-tuan to lower purlin	76	40	10/19

10. External Shape Parameters

Roofing tiles, decorative ridge beasts and the like are exposed to the elements for a long time and are very likely to have been replaced in history. However, （Li,Ym,.and Bl,Liu.2008） mentions that more than 85% of the roofing tiles and ridge beasts on the roof are original items from the Song Dynasty. The renovation report contains more detailed records of the roofing tiles. The roofing tiles were severely damaged, with differences in age, specifications. During the maintenance, a large number of roofing tiles were replenished according to the old ones (SXZDGJ.2019： P34, 39, 47, 63, 64). Apparently, the roofing tiles are the most vulnerable part. Every time in history when maintenance was carried out, old tiles were replaced and new ones were added. However, if old and new tiles are used simultaneously during each maintenance, tiles of the same size or with little difference must be given priority, and the maintenance will also be carried out according to the original state of the roof. When the main framework of the building is the original one, the current state of the roof can still reflect the appearance of its initial construction..

10.1. Jiao Liang (角梁, Corner Rafter), Tao Shou (套兽, Mythical Beast Ornament at the End of the Corner Rafter) and Boundaries

As shown in table and figures(Table 9 and Figures 5, 6, 8–10).the Da Jiao liang(大角梁,large corner beam) is placed at a 45-degree angle, with the Zi Jiaoliang (仔角梁,secondary corner beam) positioned above it. The beam ends are adorned with taoshou . The taoshou heads protrude from the column center at a 45-degree angle, with a horizontal length of 168 small cun, and a front-side horizontal length of 120 smal cun,Exactly 1 zhang(丈,a traditional Chinese unit of length, equal to 10 chi).

As illustrated in figures(Figures 8–10), the distance between the eastern and western taoshou heads is 648 small cun, equivalent to 5 zhang 4 chi, while the distance between the northern and southern taoshou heads is 624 small cun, equivalent to 5 zhang 2 chi .This is the boundary of the building and is very important for building layout, planning, and design.

10.2. Chiwen(鸱吻,Ridge-Swallowing Ornament)

As shown in table and figures(Table 9 and Figures 8–10), the net height of the chiwen is fitted to 88 small cun, the distance from the upper surface of the ridge purlin to the upper surface of the chiwen is fitted to 114 small cun, and the distance from the bottom of the platform base to the upper surface of the chiwen is 552 small cun, which is equivalent to 4 zhang and 6 chi. These are the height parameters of the building.

Table 9. Height and Boundary.

Each chi is 320.6 mm

	Raw data			Fitted Value			
	nn	Convert to cun	Convert to small cun	small cun	Convert to cun	Multiples of 0.4 small cun	Similarity rate

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Height	Foundation of the Hal	1685	52.558	63.069	64	53.333	160	101.476%
	Column	4640	144.729	173.674	174	145	435	100.188%
	puzuo	1525	47.567	57.080	56	46.667	140	98.107%
	From liao-yan-tuan to ridge purlin	3830	119.464	143.356	144	120	360	100.449%
	From ridge purlin to upper skin of Chiwen	3040	94.822	113.787	114	95	285	100.188%
	From Hall Foundation Base to Chiwen Ornament Upper Surface	14720	459.139	550.967	552	460	1380	100.188%
	From the upper surface of the hall plinth to the upper surface of the ridge purlin	9995	311.759	374.111	374	311.667	935	99.970%
	Chiwen	2350	73.300	87.960	88	73.333	220	100.045%
Boundary	From taoshou Head to Column Center	3186	99.361	119.233	120	100	300	100.643%
	distance between the eastern and western taoshou heads	17271	538.710	646.452	648	540	1620	100.240%
	distance between the northern and southern taoshou heads	16631	518.747	622.497	624	520	1560	100.242%

10.3. Main Parameters and Proportions

As shown in table and figures(Figures 8–10 and Table 10).This hall is 5 zhang and 2 chi deep from north to south, 5 zhang and 4 chi wide from east to west, and 4 zhang and 6 chi high. These are three parameters designed in integer chi, not classical proportions.

Table 10. Main Parameters.

	cun	small cun	Multiples of 0.4 small cun
distance between the eastern and western taoshou heads	**540**	648	162
distance between the northern and southern taoshou heads	**520**	624	156
Total height	**460**	552	138
length of main ridge	**360**	432	108
From the upper surface of the hall plinth to the upper surface of the ridge purlin	311.667	**374**	93.5
height from the bottom surface of the column to the upper surface of the liao-yan-tuan	191.667	**230**	57.5
height of column	**145**	174	43.5
height from the indoor floor level to the bottom surface of the front rufu	**170**	204	51

Excluding the tiles and the Bofengban(博风板,gable eave board) on the gable ends, the length of the main ridge is 420 small cun. Estimating that the overhang of the tile ends is 6 small cun, the length of the main ridge is then 432 small cun, which is equivalent to 3 zhang and 6 chi. The ratio of this length to the distance of 5 zhang and 4 chi between the east and west tao shouis 2:3.

The overall height of the Damuzuo (from the bottom surface of the column to the upper surface of the ridge purlin) is 374 small cun. The height from the bottom surface of the column to the upper surface of the liao-yan-tuan is 230 small cun. The ratio is 0.6149, which is the golden ratio of 8 to 13.

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11. Conclusions

11.1. Construction Ruler

The construction ruler is 320.6 mm long. It conforms to the system of large and small rulers implemented since the Tang and Song Dynasties. The large ruler is the official ruler, the commonly used ruler in daily life, and also the construction ruler for this palace hall. One chi (Chinese foot) is equal to 10 cun, which is equivalent to 12 small cun.

11.2. Architectural Modulus

This palace hall adopts a series of modular systems.

The basic module is 1 chi. Based on this, the macroscopic dimensions of the building are determined, and the main body proportion is controlled.

4 small cun serves as a sub-module, which is one-third of the basic module. 6 small cun is equivalent to half a chi and is also a sub-module, which is one-half of the basic module. Based on these, the height of the palace foundation, the width and depth of the palace foundation, the height of the columns, the height of the bracket sets, the length of the purlin bays, chu-ji, etc. are set.

0.4 small cun is also a sub-module, which is one-thirtieth of the basic module. It is used for various small-sized components, such as the cross-sections of dou, gong , fang (枋,horizontal members), and beam elements.

This set of modular systems is different from the cai-fen system. Its basic theory is the same as that of modern architectural modular systems. (MOHURD.*2013.*)

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org.

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