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# TRADITIONAL CHINESE ARCHITECTURE: THE TRANSMISSION OF TECHNICAL KNOWLEDGE FOR THE DEVELOPMENT OF BUILDING HERITAGE

Cecilia Mazzoli, Caterina Morganti, Cristiana Bartolomei

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## Abstract

The contribution outlines the typical elements of Chinese architecture, which combines the sophistication of technical and aesthetic details, and provides rules and criteria for the sizing and assembling standardized construction of different classes of buildings. These building elements are described in detail, through text and images, in the ancient manuals of Chinese architecture. The most significant document for its completeness and excellent state of preservation is entitled *Yingzao Fashi*: it was written by Li Chieh and published in 1103, after about thirty years of changes and integrations, and has been reissued several times over the centuries by different authors. This manual includes part of the contents of other earlier manuscripts, written since 700. It contains a set of guidelines resulting from the fusion of knowledge related to the theory and practice of building, respectively, transferred through theoretical texts and practical experiences. The contents of this important text were further developed and increasingly refined in other subsequent manuals (e.g., the *Gongcheng Zuofa Zeli* of 1734 and the *Qing Shi Yingzao Zeli - Yingzao Suanli* of 1934). The technical knowledge contained in these manuals allows the dissemination of down-handed practices to support the architects, artisans, and carpenters' activity for constructing traditional works based on a wooden frame structure. The collection of drawings, tables, and rules elaborated over the centuries allows today a deeper comprehension of the genesis and evolution of the main construction elements of traditional Chinese buildings (foundations, beams, pillars, bracketing systems, roofing systems), enabling their analysis, recovery, and reconstruction.

Thus, the contribution presents an overview of the important and complex theme of the transmission of technical knowledge in construction through manuals, based on research carried out at the Archive of the BnF - Bibliothèque nationale de France in Paris.

## Keywords

Traditional Chinese architecture, Transmission of technical knowledge, Technical construction manuals, *Yingzao Fashi*, Wooden structure.

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## 1. INTRODUCTION

The history of Chinese architecture is very ancient, and its origins can be dated both thanks to the recovery of the first written documents dating back to 2000 B.C. and the discovery of artifacts of timber-framed build-



Fig. 1. Detail of the wooden roof structure of the Long Corridor of the Summer Palace or Yiheyuan in Beijing © 2011, C. Mazzoli.

ings in the valley of the Yellow and Blue Rivers, dating back to the Neolithic age [1]. Chinese architecture is, in fact, based on the strict application of standardized criteria and methods, both in terms of geometry and construction, and has been perpetuated over time, never undergoing significant changes. Therefore, it has never detached itself from the original forms, which we can find illustrated in the works of manuals and architecture, representing a fundamental tool for the transmission of technical knowledge (Fig. 1) [2].

Technical knowledge was originally transmitted orally, as was also the case for other oriental arts; this state led to a progressive dispersion of Chinese carpenters' knowledge and information to design and construct buildings. Written records of the criteria and construction methods used are therefore limited and restricted to the publication of building regulations and technical-construction manuals that allowed master carpenters – the only existing figure, distinct from that of the architect, which was spreading in the West at the same time – to satisfy clients even in the absence of a project. The main reference text containing technical and proportional rules, validated by the Chinese government, dating back to the Song dynasty (960-1279), is the (*Li Mingzhong*) *Yingzao Fashi*, which literally means “Precepts of Architecture” [3].

Over time, further manuals followed, important for transmitting technical knowledge, such as the *Qing Shi Yingzao Zeli - Yingzao Suanli*. The *Yingzao Fashi* manual, whose writing by Li Chieh took nearly thirty years and involved three emperors, was ordered by Emperor Shenzong around 1071-1704 and was then completed in

1103, and then widely distributed to all districts of the empire from that moment on [4]. Indeed, the purpose of this building manual was to spread architectural knowledge throughout society, reaching all social targets: not only administrative officials in charge of construction but also literates and artisans. The purpose of the work was to provide the architects-functionaries with the technical tools to exercise precise control over the construction process of each public work, in accordance with the principles of tradition, and thus to control the expenses of the Ministry of Construction. The text arose from the need to provide detailed technical information on the quantity and quality of construction materials and the labor involved in assembling the components. The correct sizing and fitting of the elements, also with regard to the conscious use of materials and the minimization of waste and graft, was controlled through the definition of detailed official standards for building materials and labor based on the principles of modularity and standardization of the construction elements. Therefore, the *Yingzao Fashi* is the first manual to provide precise technical information, in the form of texts, drawings, schedules of components, tables, and formulas, useful for the standardized construction of buildings typical of the Chinese architectural tradition.

## 2. TRADITIONAL CHINESE ARCHITECTURE

Traditional Chinese architecture, since antiquity, has been based on the use of a main structural system consisting of a wooden frame composed of hundreds of components joined together by means of support and interlocking constraints, which determine the geometry, organizational-spatial logic, and structural performance. Unlike in the Western world, in the Eastern world, load-bearing walls were used only for buildings for which the wooden structure was not suitable since it was necessary to guarantee high protection against humidity and fire (such as bridges, underground tombs, archives) [2].

As technical manuals show, Chinese architecture is based on a strict hierarchy of elements, linked both to structural and functional reasons as well as to the social class to which they belong. Since the earliest architec-

tural manuals, these elements have been defined, illustrated, and described. Their classification and technical characterization have been progressively refined over the centuries, reaching their highest degree with the *Yingzao Fashi*. Reading the manuals reveals the strict hierarchy of the components of the timber frame structure and the degree of complexity with which they were assembled. Not only the structural and architectural elements but also the materials used are well defined for each of the components. They are described in detail within the manuals, also providing a cost estimate for supply and construction. In particular, the materials used are all-natural and consist of stone or bricks for the foundations, wood for the load-bearing frame structure (mainly white cedar, fir, and pine trees), clay bricks, or unfired raw earth bricks for the infill; and ceramic for the roofing.

## 2.1. CONSTRUCTION MATERIALS

The materials found in the Chinese architectural tradition originate from the five main elements of the Universe belonging to Taoism: earth, water, fire, metal, and wood. According to Chinese culture, the architecture of buildings, whether civil or religious, must be perfectly integrated into nature to harmonize with the surrounding landscape. There are many reasons for choosing wood for the load-bearing structure: the abundant availability of raw materials, which reduces production and processing costs; adaptability to various climatic conditions; elastic-plasticity and excellent capacity to respond to seismic action. The high degradability of wood materials was not a limitation for Chinese builders, who were more intent on building nature-friendly artifacts rather than structures of testimonial interest. [5]

The wood is mainly derived from white cedar forests, which are abundant in China and have excellent tensile and compressive strength properties. The characteristics of the material, and thus its use in construction, are influenced by the location of trees, their exposure, and environmental conditions in which they grew. In addition, according to Chinese culture, it was essential to respect the trunks' original exposure when positioning the building's wooden elements. Another important factor in defining the use of logs is the wood's grain

pattern, which influences the reactions to external loads. Finally, several components were often extracted from a single log of different shapes, defined according to the use (such as planks to compose boardings or beams for slab floor). In this context, in order to prevent the formation of cracks following the drying, shrinkage, and deformation of the solid wood, before starting the carpentry work, it was necessary to make a radial cut, up to the heartwood, along the entire length of the pillar, and to consequently insert wooden wedges spaced 60 cm apart from each other, which were removed once the seasoning was complete [6].

The magnificence of Chinese architecture lies in the skillful use of wooden elements, worked by carpenters with exclusively manual tools, and dry assembled without the aid of nails or other connecting elements, but only by means of mortise-tenon connections (*sun mao and mao yan*), according to standardized dimensions and procedures. More than four hundred different types of these connections are known to date [5].

## 2.2. MODULARITY

As anticipated, the concept of modules was essential in the mass production of Chinese art, as well as in the development of Chinese architecture. Indeed, based on a dry assembly wooden construction system, Chinese architecture automatically benefits from the advantages offered by standardized systems. In particular, during the late Northern Song dynasty, a new standard module called *cai* was introduced by the *Yingzao Fashi* and used for designing all parts of a building. The manual classified the *cai* module into eight classes – corresponding to the eight classes of buildings – each characterized by a different dimension, applicable according to the level of importance and structural feature of the building for which they are designed (Fig. 2). Compared to other modules used in earlier manuals (e.g., *Mujing* written at the end of the tenth century), the *cai* module is more precise and convenient for measuring architectural elements. This statement is proven by the fact that even construction manuals were drawn up subsequently up to 1734 (the year of publication of the *Gongcheng Zuofa Zeli* Imperial Regulations) report the dimensions



of components using proportional notations, in terms of multiples and submultiples of the *cai* module, and not as precise metric measurements.

This standard unit assumes eight different values, depending on the eight building classes defined by *Yingzao Fashi*. By way of example, the following is a summary of the dimensioning of the brackets and the criterion for determining the number of spans according to the macro-category and the class of building (Tab. 1) [5].

The dimensional characteristics of the *cai* module are expressed in multiples of the *fen* unit of measurement, which corresponds approximately to 33.33 mm, equal to a tenth of a Chinese inch (*ts'un*). If the *cai* module (10 *fen* width and 15 *fen* height) is combined with the *qi* module (4 *fen* width and 6 *fen* height) above it, the *zu cai* (21 *fen* total height) is obtained, which stands for “full material” and represents a measuring set used for

dimensioning the beam section. Table 2 represents the dimensional criteria presented in the *Yingzao Fashi* manual. The size and shape of the beam vary according to its function and position, but the ratio of 3:2 between height and width remains unchanged.

Modularity also plays a fundamental role in the layout. Chinese timber-framed structures are based on the combination of several structural modules called *jian*, which represent the standard units of living space. Each spatial-structural unit consists of a bay with a quadrangular plan, defined by four columns positioned at the vertices, connected amongst them by a system of transversal beams and longitudinal purlins, with a square and circular cross-section, respectively [8].

The buildings have an extremely simple and regular plan, with axial symmetry and a predominantly quadrangular shape (the width to length ratio never exceeds

Building macro-categories	Building class	Brackets height	Brackets width	Number of spans per building
		[cm]	[cm]	[-]
Major	I	28.80	19.20	from 9 to 11
	II	26.40	16.80	from 5 to 7
	III	24.00	16.00	from 3 to 5
Minor	IV	23.04	15.36	from 3 major to minor pavilions with 5 bays
	V	21.12	14.08	
Inferior	VI	19.20	12.80	for all construction with less than 3 spans and for other components
	VII	16.80	11.20	
	VIII	14.40	9.60	

Tab. 1. Dimensioning of brackets and determination of the number of spans according to building macrocategories and classes © 2022, Authors after [5].

Building class	<i>Cai</i> width		<i>Cai</i> height		<i>Qi</i> width		<i>Qi</i> height	
	[cun]	[mm]	[cun]	[mm]	[cun]	[mm]	[cun]	[mm]
I	6.00	200	9.00	300	2.40	80	3.60	120
II	5.50	183	8.25	275	2.20	73	3.30	110
III	5.00	167	7.50	250	2.00	67	3.00	100
IV	4.80	160	7.20	240	1.92	64	2.88	96
V	4.40	147	6.60	220	1.76	59	2.64	88
VI	4.00	133	6.00	200	1.60	53	2.40	80
VII	3.50	117	5.25	175	1.40	47	2.10	70
VIII	3.00	100	4.50	150	1.20	40	1.80	60

Tab. 2. Dimensional characteristics of the *Zu Cai* measurement set, consisting of the *cai* and *qi* elements © 2022, Authors after [7].



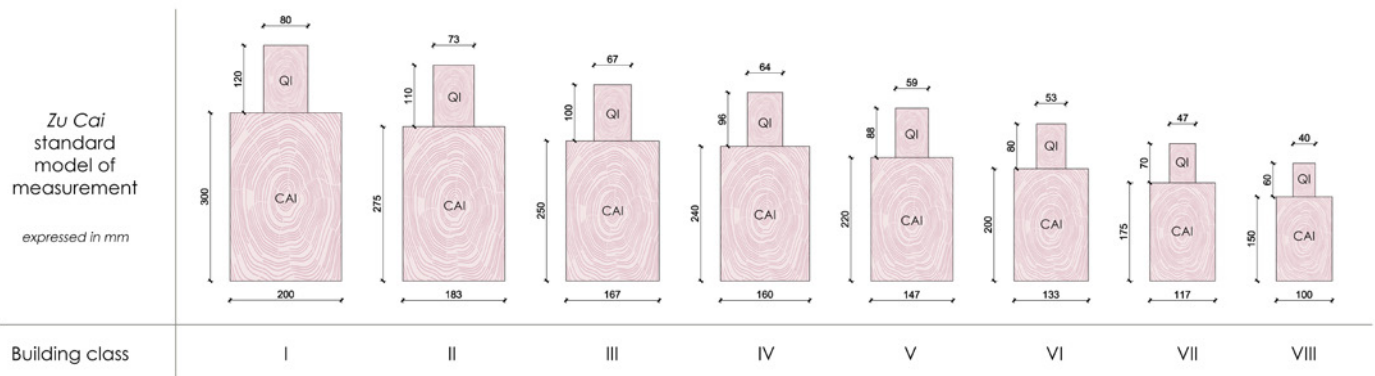


Fig. 2. The eight grades of the Zu Cai standard model of measurement, expressed in mm, depending on the eight building classes © 2022, Authors after [7].

1:2), hexagonal or circular. This factor is advantageous in relation to resistance to seismic action, as it allows the masses and stiffnesses to be distributed uniformly, thus reducing the torsional effect that the building would suffer in the event of an earthquake.

### 2.3. STRUCTURAL AND ARCHITECTURAL COMPONENTS

- The foundations consist of a sort of stone or brick plinth (*soseki*), placed at each pillar, connected by collar beams (*dodai*), and bordered on the perimeter by edge beams, approximately 50-60 cm high, made of the same material. This platform, in which the interstices are filled with rough stone, allows the building to be detached from the ground and to protect it from humidity, as is traditionally the case for western buildings (Fig. 3). However, the peculiar aspect of Oriental architecture concerns the development of the node between the foundation and the pillar, which is solved by simple support and not by means of a rigid connection, as is usually the case for framed structures.
- The wood-frame structure consists of pillars and beams linked to each other by rigid connections made by means of sophisticated interlocking systems. As mentioned above, the frame piers rest on top of stone elements for the base and connection with the foundation. In order to prevent the base of the pillars from deteriorating, the carpenters placed a protective element made of bronze or stone (or even wood for the poorest buildings) directly above the stone basement.

The absence of an interlocking constraint at the base of the pillars is the most important element for the good response of the building to seismic actions. In fact, in this way, the pillars can undergo even a limited deformation following the earthquake, without breaking due to the bending moment that would be generated in the presence of a rigid node: the simple support, therefore, acts as a “wave damper”.

Wooden pillars (*hashira*) always have a circular section tapering towards the top, and their diameter at the base must respect certain dimensional standards. They are covered with a 2-3 cm layer of a mixture of baked clay, rice glue as a thickener, hemp, and cow’s blood, which in turn is covered with a layer of lacquer to waterproof and give it a red color.

The wooden beams, which always have a rectangular cross-section, characterized by a 2:3 ratio between width and height, have a precise dimensioning deriving from the modular criteria handed down by the technical manuals according to the building class.

- The beams are connected to each other by dry joints and are connected to the columns by a bracketing system, consisting of wooden anchorage-brackets placed between the top of the column and the main beam, forming a sort of wooden support stirrup (Fig. 4). This connecting element, which is strongly characteristic of the Chinese architectural language, can also be placed above a beam to support the overhang of the roof. In both cases, its function is both structural and decorative [9]. The *dou gong*, or *hua gong* if its arms protrude, is made up of the dry assembly of various components: the *dou*, a square block of wood



Fig. 3. Examples of stone foundations for traditional Chinese buildings located in Beijing, Shanghai, and Xi'an © 2011, C. Mazzoli.

resting directly on the top of the column, and the *gong* elements, two or more interlocking arms crossed at right angles to each other, resting on the *dou*, which contribute to the distribution of loads between beams and columns (Fig. 5). The *gong* elements with a cantilevered arm in relation to the underlying bracket are called *ang*. The presence of this bracket complex inserted between the nodes of the frame contributes to increasing elasticity and ductility, thus improving the mechanical performance of the building in case of a seismic event [10]. The *Yingzao Fashi* manual describes in detail this component which, due to its geometric complexity, inevitably also assumes an aesthetic and decorative value. As for most of the other horizontal structural elements, the bracketing system is also dimensioned according to the standard *cai* unit, respecting the proportional ratio of 2:3 for

the dimensioning of its section. The complexity of bracketing was increasingly developed and refined in Chinese architecture as long as, at the end of the Five Dynasties (907-960) and the beginning of the Northern Song dynasty (960-1127), its perception as flowers and flowering trees emerged. This image demonstrates the deep connection between architecture and nature, thus representing bracketing as constituted of cross arms likened to leaves growing on branches, with or without rotating floral leaves or petals. Indeed, at the end of the Five Dynasties and the beginning of the Northern Song dynasty, the perception of bracketing systems as “branches protruding front and back and leaves growing left and right” or “transverse branches and lateral leaves” emerged [4]. Regarding the terminology used in the *Yingzao Fashi*, some elements are named according to their





Fig. 4. Examples of different types of bracketing systems in traditional Chinese buildings located in Beijing and Shanghai © 2011, C. Mazzoli.

structural positions and functions, others to their physical and performance features, and others again to nature and the botanical world. For instance, the bracketing element *hua gong* is translated as “flower arms” [4]. During the pre-Qin period (before 221-206 B.C.), bracket arms were installed only along the wall plane (under the eave) or parallel to the wall plane (under the purlins). Later, during the Eastern Han period (25-220), protruding arms to the front and rear began to appear and led to the development of bracketing systems in both parallel and perpendicular directions to the wall plane. Consequently, the projections of protruding arms and their intersections with lateral arms made the bracket set to look like a flower in full bloom when it was seen from the front, side, or from below. According to this suggestive interpretation of bracketing, beginning in the tenth century, the columns of a building arranged in rows topped by

increasingly complex sets of brackets, placed above each capital, evoked the image of a row of flowering trees (Figs. 6 and 7). As a connection between beam and column, the relevance of bracketing evolved with time, both for its structural and decorative function,

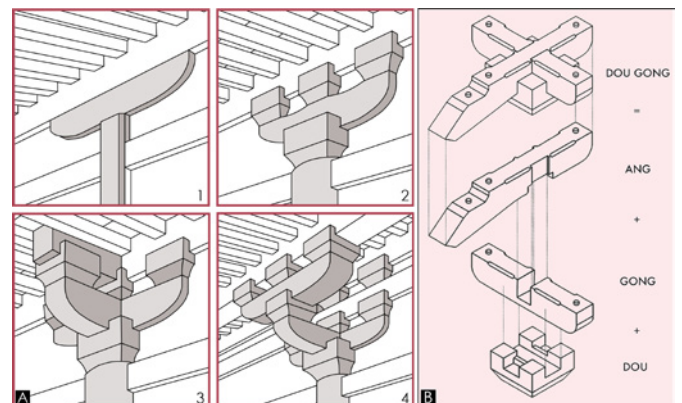


Fig. 5. Description of the elements constituting the dougong (A) and morphological evolution of this bracketing system (B) © 2022, Authors after [7].



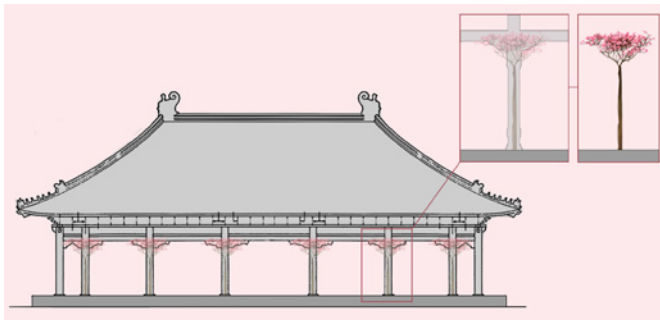


Fig. 6. Schematic section of a traditional building composed of columns, topped by bracket sets, likened to rows of flowering trees © 2022, Authors after [4].

since its peak of development during the Tang Dynasty (618-907). Thereafter, the diffusion of the bracketing system diminished gradually until the Qing dynasty (1616-1911), when it served just for decoration purposes. The first detailed specifications of the bracketing structure were formally stipulated in the *Yingzao Fashi* manual in 1103, and then more details and official specifications were also given in 1743 in *Gong Cheng Zuo Fa* [11].

- The infill walls were built on-site using a mixture of “rammed earth” (*hang tu*), made of clay, gypsum, gravel, and straw, compacted in successive layers inside tapered formworks or made by laying unburnt and burnt bricks. Bricks, bamboo canes, or other locally available materials were used for vertical internal partitions. Their arrangement followed the grid of pillars, and, although they have no load-bearing capacity, they contribute to increasing the building system’s rigidity: in case of an earthquake, these partitions fracture or even collapse easily and therefore contribute to limiting damage. In fact, there is an old Chinese saying: “the walls may fall, but the house will not collapse” [12].
- The roof, with its typically curvilinear profile, may be of various types: two-pitch; two-pitch flush with the wall; pavilion; two-pitch and pavilion (hybrid type, with the top part with two pitches, insisting on a pavilion part); pyramidal; with double roof eaves; with a double roof. The construction methods of the Chinese roof frame are not based on the static principle of triangulation (i.e., the non-deformable triangle), as in the case of Western trusses, but on schemes composed of elements at right angles to each other: in the face of a more deformable

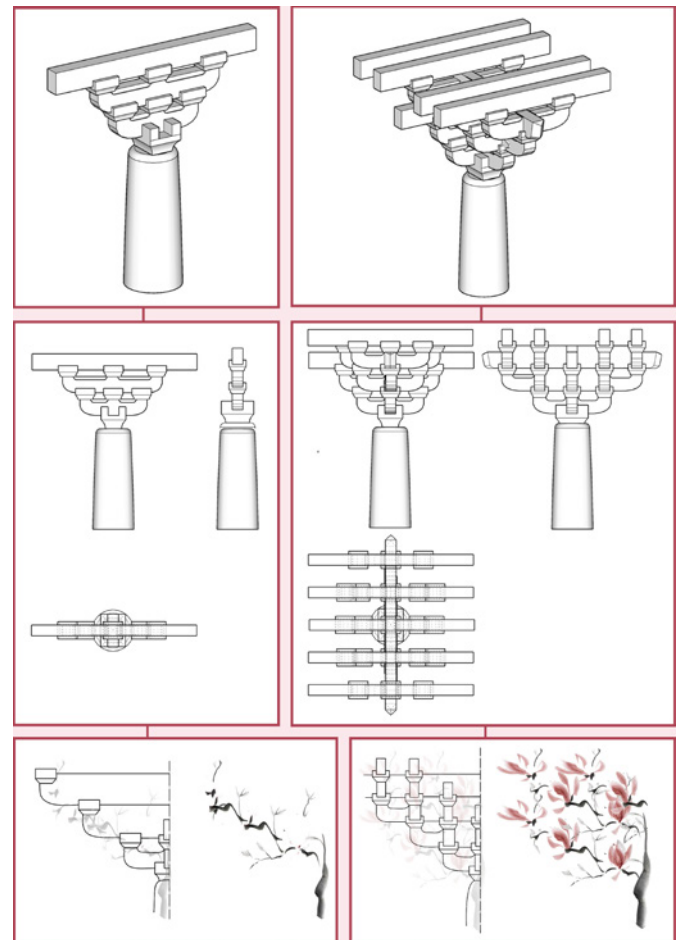


Fig. 7. Schematic representation of bracketing system with no protruding cross-arms on the heads of “flowering” arms (left) and flower-shaped bracketing system with cross-arms (right) © 2022, Authors after [4].

structure, this solution made it possible to vary the inclination of the roof from bottom to top and to use the tenon and mortise joint system easily. The curved shape of the roof derives primarily from spiritual reasons in order to ward off evil spirits [13]. The curved profile, facing upwards and protruding from the outline of the building, also derives from functional reasons, linked – in this order – to better drain rainwater, to maximize the entry of natural light into the interior, and to shelter the inhabitants in the surrounding areas. In addition, a roof with such geometry and made up of many rafters of limited length is better able to resist horizontal stresses imposed by wind and earthquake than flat roofs. In addition, the front of the cover (*yang*) is always 10-30 cm higher than the back (*yin*) [1]. Furthermore, the roof was finished with glazed ceramic tiles in yellow for imperial buildings, green and blue for temples and prince-

ly residences, and grey for ordinary dwellings (Fig. 8), or alternatively with earth and straw. Tin sheets were inserted to prevent water infiltration.

### 3. TECHNICAL MANUALS

The Chinese have never developed philology similar to that of European culture and consequently never concerned themselves, until recent times, with the transmission of texts and their restitution [14] [15]. Printed editions passed from one collector to another were copied and copied by hand and circulated among scholars, who often found themselves the sole owners of a text whose original had been lost. Therefore, it is evident how easily these manuscripts were subjected to errors in copying ideograms or, at worst, to omissions and additions. Despite the criticalities linked to this cultural context, the transmission

of knowledge in Chinese construction was made possible thanks to the production of manuals, compiled over the centuries by various figures – often unknown – who contributed to it, each with different degrees of precision and completeness of detail, and different sensibilities, focusing on different technical and/or artistic-literary aspects.

Tracing the history of the main manuals of architecture found, and of which there is a trace in the literature, the first relevant document dates back to around 700. It is the short official document entitled *Yingshanling* (“Rules of construction and repair”), which represents one of the most important architectural texts written during the Tang dynasty (618-907). Often cited by the *Yingzao Fashi*, it complements it in the parts relating to architectural systems’ social status and provides clarification of the association between many aspects of architecture and social classification.



Fig. 8. Examples of different types of roofing systems in traditional Chinese religious buildings located in Beijing © 2011, C. Mazzoli.

Thereafter, in the late tenth century, the unofficial building manual entitled *Mujing* was spread, representing an important reference in the development of Chinese architectural technology from the Tang down to the early Northern Song dynasty. It showed a conception of architectural modules that positioned his practice between traditional architectural systems and the more advanced system of architectural standardization represented by the *Yingzao Fashi*.

### 3.1. THE YINGZAO FASHI MANUAL

As anticipated, the most significant text of Chinese architectural manuals is undoubtedly the *Yingzao Fashi*, whose transmission from 1103 to the present day is considerably articulated. The fundamental editions on which

the editorial history of *Yingzao Fashi* is based are three, among which other manuscripts and printed copies are distributed, as well as indirect quotations and mentions contained in other later texts: the first edition was completed and printed in 1103 (Fig. 9), a definitive reprint dates back to 1145, and finally, a magnificent edition was published in 1925, as a result of decades of work by a group of erudite Chinese, Japanese and Western [5].

The transmission of the *Yingzao Fashi* manual during the Ming (1368-1644) and Qing (1644-1911) periods was ensured by the official interest in the book shown by the Imperial Court, whose manuscript copies and printing plates were not saved from destruction by the Manchu Conquest. The first editor of a new edition of the *Yingzao Fashi* was Chao Qi-mei, who inherited a collection of miscellaneous volumes and edited it around 1620. Two

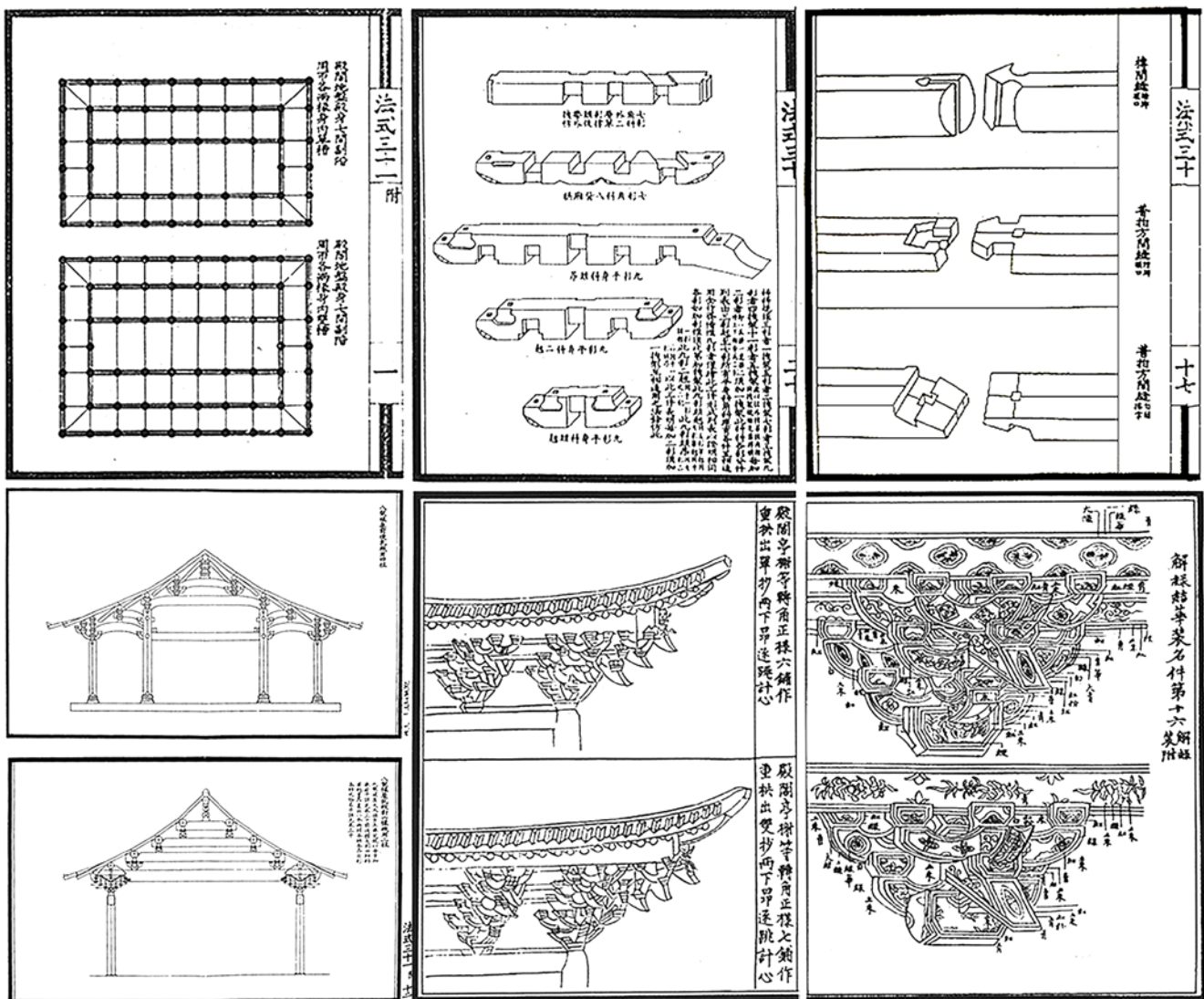


Fig. 9. Tables extracted from the 1103 edition of the *Yingzao Fashi* manual © 1103, Li Chieh.



copies of this edition seem to have been made, but the first was destroyed by fire in Qien Qien-I's library, while the second, by Chao Chun, was dispersed. The latter reappeared around 1669 in the library of one of the greatest collectors of the time, Ch'ien Tseng, and was later acquired by the Qing imperial court with an edict issued in 1686, thus remaining in the imperial library until 1933. In 1733, during the reign of Qing-lung, a new copy of the *Yingzao Fashi*, purchased by a private individual, was found and included in a collection of manuscripts: this edition is similar to that of Ch'ien Tseng, preserved in Jehol. From the early 19th century onward, many copies of the text were made privately, and it was also disseminated in Japan.

The illustrations, which constitute a fascinating part of the work, deserve a note: with the new and final edition of 1925, a revision of the plates, which often appeared incomprehensible or in a poor state of preservation, was commissioned from Ho Hsin-kang, a senior official of the Beijing Building Department. Some of the illustrations were entirely redrawn, both in form and color, taking up the Ming and Qing style rather than the original Song design. The 1925 edition is the most important of the "Precepts of Architecture", complete with texts, construction details of structural elements, instructions on the ornamentation of wooden and non-wooden structures, and the use of colors [16]. This edition consists of eight volumes, on rice paper, and follows as closely as possible the order used by the author Li Chieh: volumes 1-4 contain ideograms, while volumes 5-8 contain all the drawings of the original manual, some in black and white, others in color [17]. In the years following the 1925 edition, with the founding of the Architectural Research Society of China, studies on the *Yingzao Fashi* gained new impulse, and more original textual fragments were found.

### 3.2. THE MAJOR MANUALS OF THE LATER PERIOD

The *Yingzao Fashi* manual remained the main reference for building theory and practice for many centuries, and even today, this text plays an important role in analyzing the existing heritage and planning resto-

ration interventions and new construction in the traditional style. However, in 1734 another fundamental text was published, containing a collection of structural and construction rules: the *Qing Gongcheng Zuofa Zeli*, Imperial Construction Regulations of the Qing Dynasty (1644-1911), written by Prince Yunli and published by the Ministry of Construction. This detailed engineering manual explains Chinese construction techniques and structural design rules. Unlike the *Yingzao Fashi*, all dimensions are expressed in precise metric units and no longer in standard units as in the Song manual. In fact, the idea of standard units proper to the Song culture (960-1279) seems to have vanished for the Qing builders (1644-1911) [18].

Based on this manual, two centuries later, the architect and historian Liang Si cheng carried out in-depth research into the transmission of technical knowledge and drew up the *Qing Shi Yingzao Zeli - Yingzao Suanli*, published in 1934. The work consists of two volumes containing photographs, construction details, diagrams of the evolution of the beam-pillar node over the years, and tables of the dimensions of the elements. There are also 28 technical tables (Fig. 10) containing: plans and elevations of different types of buildings; construction details of roofs, nodes, beams, and columns; illustrative diagrams of the various types of roofs with varying inclination; indications of stratigraphy for horizontal partitions [19].

An important work of collection and analysis of the technical drawings by Liang Si cheng, as well as of translation of the captions from Chinese to English for the construction details, was carried out by Wilma Fairbank, who in 1984 published the work entitled *A pictorial history of Chinese Architecture: A Study of the Development of its Structural System and the Evolution of its Types* [20].

In general, it is important to note that the Chinese manuals mentioned above prefer to use technical drawings in the form of sections or axonometric projections, unlike Western culture, which opts for a graphic representation based on the use of plans and perspectives. In fact, according to the Chinese architectural approach, the cross-section plays a key role in the conception of the wooden frame structure, which varies according to the

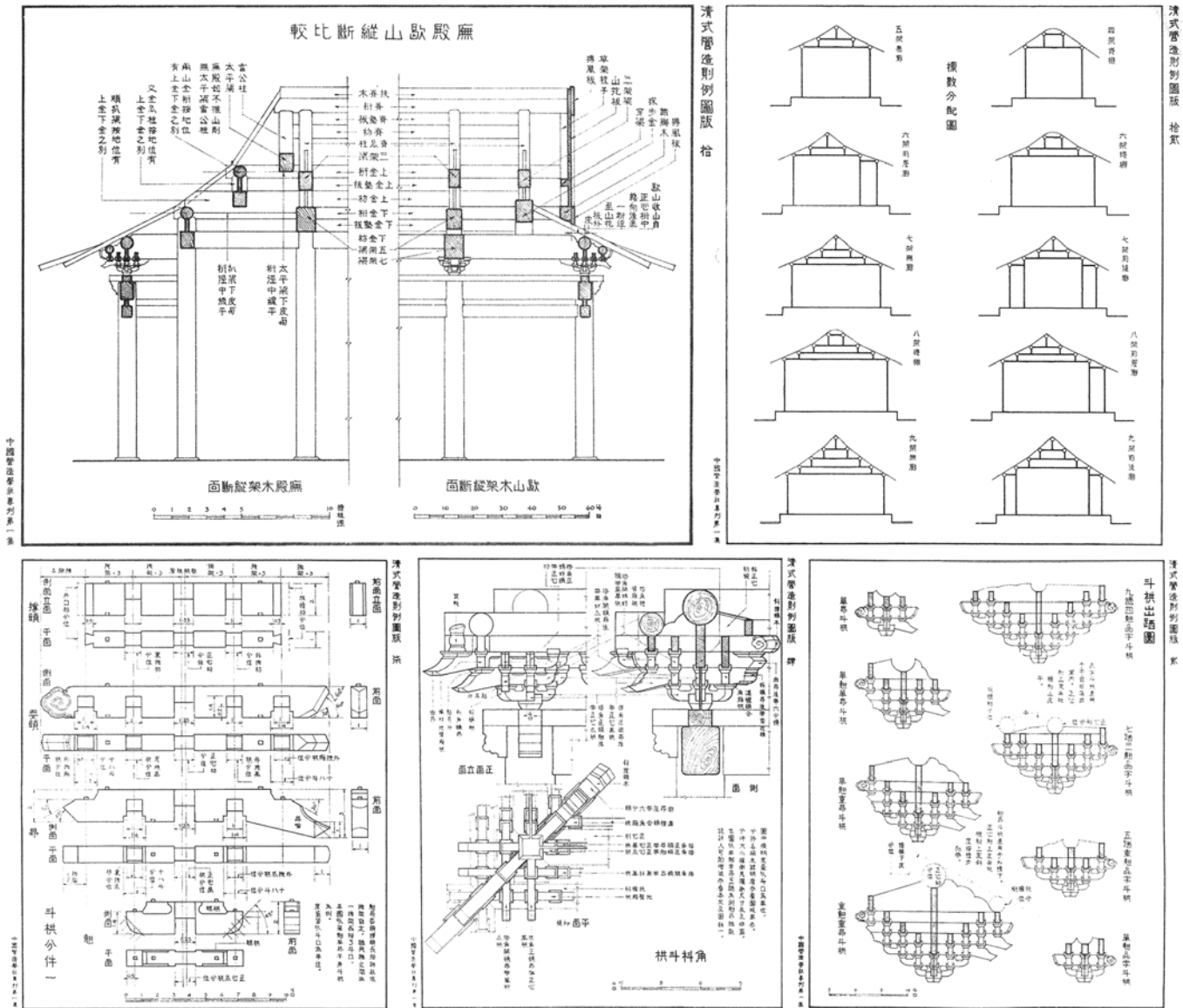


Fig. 10. Tables extracted from the Qing Shi Yingzao Zeli - Yingzao Suanli manual of 1934 by Liang Si cheng © 1934, Liang Si cheng.

type of building. It constitutes the load-bearing skeleton of the buildings and therefore, the proportion of the primary vertical and horizontal elements, repeated serially in length or height, is fundamental. [5]

### 4. CONCLUSIONS

Since ancient times, the practice commonly adopted in China to ensure a good state of preservation and proper functioning of the existing building heritage is based on the cyclic and periodic demolition and reconstruction of buildings imposed by the natural obsolescence of wood [21]. The replacement of deteriorated parts, or even the

total renovation of buildings – which cancels their *monumentum* value (Latin for “memory, monument”) – is a good illustration of how, for oriental culture, symbolic value prevails over material conservation [22]. This *modus operandi*, based on faithful reiteration over time, clarifies the importance of the transmission of technical knowledge as a testimony to traditional Chinese architecture’s construction techniques and practices.

Even today, the technical drawings and the criteria for proportioning and sizing the elements, as well as the rules for assembling them, contained in architectural manuals (above all the *Yingzao Fashi*), represent a fundamental reference point for scholars, researchers,

and designers working in the field of Chinese and other building traditions. In particular, the literature contains numerous citations of the *Yingzao Fashi* manual with regard to the analysis of the mechanical performance of architectural and structural elements of the existing heritage, for which the reconstruction of the most complex elements (such as bracket systems and the mortise-tenon connections between beams and columns) is based precisely on the combination of data obtained from geometric surveys with laser scanning technologies with the technical data reported in the 1103 manual [23]. These studies mainly aim to identify intervention strategies for the recovery of existing buildings. However, the same manual is also frequently cited in the framework of the design of new construction works, both within the Chinese tradition and beyond it, in areas located geographically and culturally far from it [17].

In general, the contents of the *Yingzao Fashi* manuals are derived from the fusion of two kinds of resources: theoretical texts and practical principles. Therefore, this document represents a complete synthesis between the classical and earlier manuscripts and, principally, the practical methods that, for a long time, have been transmitted among artisans, carpenters, and architectural professionals, also through oral accounts. These features make the *Yingzao Fashi* a unique source for both traditional and contemporary building culture and a reference document for the distinctive Song construction practices in relation to the technical and social spheres.

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