

Tile and Brick Making in China: a Study of the *Yingzao Fashi*

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Introduction

In the Chinese language, the term defining building construction is the “work of earth and wood” (*tumu*), because clay and wood are the principal building materials. Traditional buildings are made of timber frames standing on rammed-earth platforms, enclosed by adobe or masonry walls and roofed with tiles. Standard tiles and bricks were used in constructions where a superior finish was required in China, as specified in the *Yingzao Fashi*, the oldest extant state building standards, issued by the Song sovereign in 1103.¹ Tile and brick making was one of 13 building operations together with carpentry, joinery and stonework, etc. specified in the book.

Tiles and bricks were made of earth, shaped after mixing with water, dried under the sun, and turned into a durable mass by fire. Producing tiles and bricks was a specialised process and the technology was preceded by pottery craftwork from a very early period. Archaeological evidence suggests that pottery drainage pipes appeared in the twenty-first century BC, and building blocks and roofing tiles in the early Western Zhou (1111-771 BC).² It is believed that, like so much in building technology, the use of baked clay tiles stemmed from China.³ To date the oldest known bricks were found in tombs of the Eastern Zhou (771-481 BC), which were large hollow blocks.⁴ Solid walling units emerged gradually from the late Warring States (475-221 BC). Glazing was invented later; a glazed vase dated from AD 260 is the earliest form of such ceramics known in China.

Bricks and tiles were commonly used in architectural buildings and tomb constructions in ancient China, but there is little understanding of the knowledge involved and the underlying technology. In an effort to seek Chinese artistry in clay, this paper will study the *Yingzao Fashi*, chapters 13 and 15, which describe in detail the manufacture and applications of bricks and tiles including glazed tiles. In terms of comparison, other documents will also be discussed. The intention of this paper is to explore the traditional manufacturing process, particularly the shaping method and firing process, together with kiln technology.

Clay Preparation

The *Yingzao Fashi* stated the procedures of preparing clay, ways of shaping form and the methods of heating bricks and tiles, including *qinggun* tiles and glazed tiles, in Chapter 13 and 15 respectively. Chapter 13 deals with tiles, while chapter 15 deals with bricks and kilns.

For making tiles, fine sandless clay was required, whereas for bricks, sandy clay could be used. The clay was mixed with water. To achieve an appropriate uniformity, the moist clay was left to mature overnight before being moulded to forms. Then the clay was worked, for example by foot stepping, until it was thoroughly homogenised. The method of treatment varied depending on the clay, therefore each region had developed its own techniques. Owing to the greater fineness of particles and better cohesion, the tile clay was less readily broken up, but it took longer to make a required mixture than the brick clay.

Tile Shaping and Types

Close to the art of pottery, a number of techniques for shaping tiles were developed in China. By studying the marks left on clay during shaping, or by studying similarities and variations in the shapes and decorations, researchers can tell the progression of technological change: craftsmen might simply pinch the clay into the desired form; or roll it into sheets for further shaping; or stack coils one on top of the other and smooth them together. Tile making techniques were gradually separated from pottery making techniques. The *Yingzao Fashi* informs us that the Song craftsmen had another option: they pressed clay on the surface of a circular mould with a paddle to make tiles. By gradually narrowing upwards, the mould was wider at one end than the other. In a similar way to shaping clay on a potter's wheel, a tub mould was placed on top of a turntable which was powered by hand. The tub was covered with a cloth to keep the surface of the tile even and to help release the tile. Patting the clay bit by bit on the cloth-tub while applying some water, the required thickness was reached. The tile-earth was evened and smoothed, then removed from the turntable together with the cloth-tub to be dried under the sun. This process was tub moulding. The round clay was cut into halves or quarters with a sharp knife to form green tiles when it was somewhat dry. The size of green tiles had to be somewhat larger than the standard products to allow for shrinkage. To ensure that the tile or brick did not crack or shrink unevenly when it was fired, a thorough drying was required before kilning.

The technique used in the Ming dynasty (1368-1644) was similar to the Song (960-1279) but improved further, as recorded in the *Tiangong Kaiwu*:⁵ "For ordinary dwellings, the roofing tile is quarter-circular in shape. Digging a pit minimum two chi (60 cm.) deep to excavate sandless clay, adding water to the clay and tempering it to form a homogeneous mixture. The clay then is shaped into a rectangular block. Slicing the clay block by 0.03 chi (0.9 cm.) with a tensioned wire-bow saw then lifting and placing the clay sheet on a circular tub. The tub has four edgeways outward symmetrically, which divide the sheet into four tiles. When the clay becomes dry, the green tiles can be easily stripped off the tub" (Figure 1).

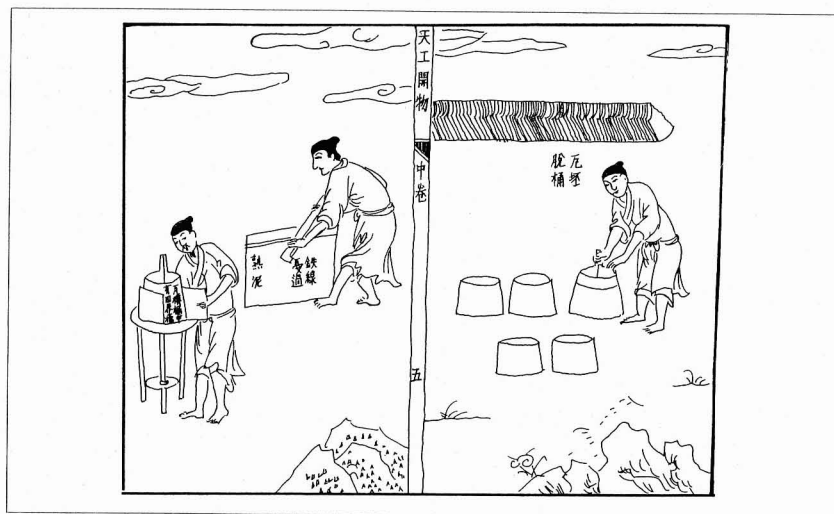


Fig. 1 Tile Shaping (Tiangono Kaiwa, 1637)

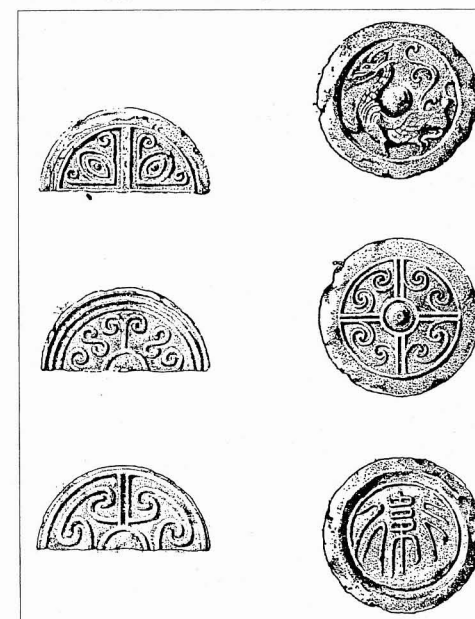
Tiles were characterised according to their functions and applications. The tiles used to cover roofs were quarter-circular tiles (*banwa*) and semicircular tiles (*tongwa*). The former (literally "under tiles") were laid with the concave face up and partly overlapping in layers. The latter, over tiles, were laid with the convex face up to cover the joints. The *banwa* could be used as both under-tile and over-tile, available in seven standard dimensions. The *tongwa* was only used as over-tile on roofs of *diantang*-type buildings,⁶ available in six standard dimensions (Table I).

Table I Standard Dimensions for Tiles (Yingzao Fashi) (1 chi = 32 cm)

Semi-circular Tile (<i>chi</i>)			Quarter-circular Tile (<i>chi</i>)				
Length	Diameter	Thickness	Long	Bigger end		Smaller end	
				Width	Thickns.	Width	Thickns.
1.4	0.60	0.080	1.6	0.95	0.10	0.85	0.080
1.2	0.50	0.050	1.4	0.70	0.07	0.60	0.060
1.0	0.40	0.040	1.3	0.65	0.06	0.55	0.055
0.8	0.35	0.035	1.2	0.60	0.06	0.50	0.050
0.6	0.30	0.030	1.0	0.50	0.05	0.40	0.040
0.4	0.25	0.025	0.8	0.45	0.04	0.40	0.035
			0.6	0.40	0.04	0.35	0.030

Standard tiles used according to the scale of the building.

Tiles used as the first course along the eaves of a roof were shaped differently. They were called starter-over-tile and eaves-under-tile. In order to throw rainwater off the roof, the starter-over-tile had a round flat end while the eaves-under-tile had a deltoid leaf-shaped drip. The end plates varied in decorative motif, moulded inscriptions, shape and detail, and the evolution of roofing tiles can be traced through their ends (Figure 2).



For *diantang*-type buildings, various ornamental tiles were used. The one used to terminate the main ridge at the end is called *chiwei* in the *Yingzao Fashi*. It was made in the form of a sea monster with its mouth swallowing the ridge and its tail bending up, believed to bear the spirit of water and protect against fire. The *chiwei* varied with time and region.

Brick Moulding: "pi", "ji" and "fa"

On the subject of brick making the book describes the way of moulding and compacting the plastic clay into forms. The shaped clay to be further treated by fire is called "pi" by the *Yingzao Fashi*, this term is still in use by the present-day brick makers. "Pi" applies to unfired ("green") bricks (*zhuanni*) and tiles (*wapi*), as opposed

Fig. 2 Decorated end plates of eaves-over tiles

to the fired objects. Sun-dried bricks are named “*ji*”, and may contain chopped straw. Another building unit is “*fa*” which is cut directly from the earth where grass roots have created a thick texture and is ready to use with or without drying.

The green brick was made by pressing the malleable clay into a rectangular mould. The *Yingzao Fashi* stated that the mould was pre-dusted with ash before each application to prevent the clay from sticking to the mould (Figure 3). Firewood was used for firing bricks and tiles, and its ash was used for this purpose.

Bricks were standardised into 13 sizes in the Song dynasty, among them five or six were commonly used for public buildings, pagodas, bridges, city walls, as well as cooking ranges and water wells. The *Yingzao Fashi* specified their dimensions, which directly related to applications (Table II; Figure 4). In Northern China, buildings were usually enclosed by earthen walls, for which bricks were used to build the lower portion of the exterior wall to stop ground water from being sucked up and in effect prevent salt attack. This technique was called *qianxia gejian* (literally “underneath wall salt barrier”) in Song architecture. Bricks made in the Song and earlier were relatively large. However, sizes had a downward tendency associated with upward production towards the end of the Ming dynasty.

Surface Treatment: qinggun tiles and polished bricks

Before proceeding further to Song brick making, it is necessary to make a digression on decorative techniques. Chinese historians have classified bricks into stamped bricks (*huaxiang zhuan*, literally “pictorial brick”) and plain bricks. The basic distinction between the two lies in the mould. For plain bricks, plain moulds were used, whereas to make decorative bricks, a special kind of mould had to be made to imprint geometric, angular, rectangular or other motifs (Figure 5). The stamped bricks after firing could be further painted, which were typically found in tombs or shrines of the Han

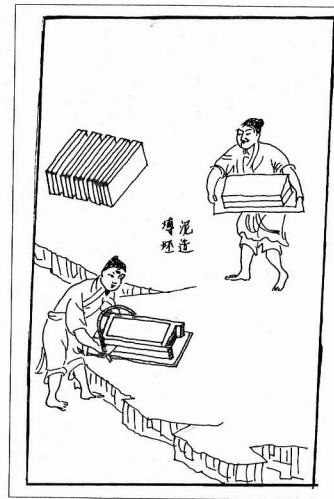


Fig. 3 Brick Moulding (*Tiangong Kaiwu*)

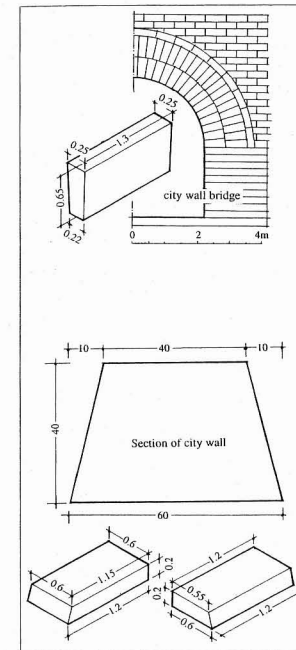


Fig. 4 Brick Dimensions and Applications

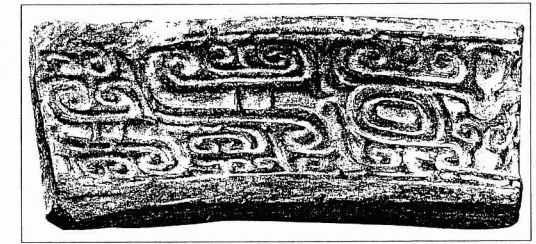


Fig. 5 Pottery mould used to impress bricks (11.7 x 5 x 1.5 cm). Shang (16th-11th century BC)

dynasty (206 BC - AD 8). This pictorial art ranks among the oldest works of art in China. The most notable decline of the stamped bricks must have occurred in the end of Eastern Han (AD 25-220), for hardly any stamped bricks are found in tombs dated from that period onwards. In the Song dynasty, both relief bricks, made by incising ornamentation on bricks and polished bricks firmly established reputation of their own, dominated the brick industry. The relief bricks were mainly used in tomb architecture and remained broadly faithful to this taste from the Song onwards.⁸

The *Yingzao Fashi* put special emphasis on surface polishing for tiles and bricks. For tiles, it documented two methods of surface treatment when the tiles were completely hard prior to firing: talc-powder rolling (*huashi gun*) and white-clay rolling (*tutu gun*). This was done by “rubbing the tile firstly with a piece of tile or stone to remove all the cloth marks, then clean the surface with a wet cloth, press-polishing with a pebble-stone to leave a smooth surface and finally smearing over the surface with talc powder”. Alternatively, white clay, the *tutu*, was applied instead of talc and press-rubbed on the surface. In this way, the surfaces of tiles were made less porous, and the tiles became more resistant to water permeation. Such a technique was originally used by craftsmen to produce black pottery.⁹ After firing, a finishing process was required, which involved cutting, trimming and rocking. All irregularities had to be removed prior to rocking. The rocking applied only to semicircular tiles by swaying and rubbing the tiles within a test half-cylinder to ensure the shape. The process must have been very labour consuming.

In the *Yingzao Fashi*, tiles produced by the *huashi gun* and the *tutu gun* techniques are referred to as *qinggun wa*, which can be translated literally as “grey rubbed tiles”. But, if the tile was produced by the *huashi gun* and a “carbon-impregnation” technique during the later period of firing, it is “soot rubbed tiles”. The *qinggun wa* lasted only until the Ming dynasty when its position was replaced by glazed tiles.

For some type of bricks, a special way of finishing was carried out after firing. For example, floors bricks, usually square in shape, were treated by first pressing-polishing topsides in pairs against each other with water. Then the under-edges were chopped and the bricks laid with their polished sides upwards and filling mortar inside the floor surface, so that there was no joint mortar visible. According to a Ming book on brick making, the *Zaozhuan Tushuo*,¹⁰ the floor bricks used in imperial palaces were soaked in tong oil,¹¹ then polished to give lustre to the bricks (*jinzhuan*). This type of floor can still be seen in the Forbidden City, Beijing.

Table II Standard Dimensions for Bricks (*Yingzao Fashi*)

Applications		Floor bricks (<i>chi</i>) (square)	Wall bricks (<i>chi</i>) (rectangular)	Steps course (<i>chi</i>)
Multi-storey buildings of <i>diantang</i> type	11-bay	2.00 x 2.00 x 0.30		
	7-bay	1.70 x 1.70 x 0.28	1.30 x 0.65 x 0.25	2.10 x 1.10 x 0.25
	5-bay	1.50 x 1.50 x 0.27		
<i>Tingtang</i> , ⁷ Pavilions and small <i>Diantang</i>		1.30 x 1.30 x 0.25		
Verandas of <i>Diantang</i> buildings, Pavilions and Ordinary Houses		1.20 x 1.20 x 0.20	1.20 x 0.60 x 0.20	
City wall		1.15 x 1.15 x 0.43 0.60 x 0.60 x 0.20	1.20 x 0.55(0.6) x 0.20 1.15(1.2) x 0.60 x 0.20 1.30 x 0.65 x 0.25(0.22)	

Brick shape, for instance, affected by batter. That is in city wall construction, it is so constructed that the thickness of the wall is gradually decreased with its height.

Firing: “Burning-water sealing”

Fire renders bricks and tiles durable. Various methods led to craft differentiation. In the Song dynasty, a burning-water sealing technique (*yaoshui*) was utilised to produce the *qinggun* tiles, the common tiles and bricks. The kiln used for firing the common bricks and tiles was called the *subai yao* (literally “plain kiln”) and the kiln for the *qinggun* tiles, the *qinggun yao*.

The *Yingzao Fashi* stated that “stacking bricks and tiles in the kiln on the first day, firing on the second day, watering on the third day, opening the kiln to cool down for three days, then unloading on the seventh day for the *subai yao* and *qinggun yao*, but on the fifth day for the glazed tiles and bricks”. The *yaoshui* refers to a process of watering the kiln from the top after firing as illustrated by the *Tiangong Kaiwu* (Figure 6). The introduction of water into the hot kiln produced a large amount of water vapour, which prevented fresh air from entering the kiln during cooling down, as well as helping to speed up the cooling. This maintained a reduction condition in which iron in the clay remained in its di-valent form (FeO) giving the bricks and tiles a grey colour. Vice versa, if the kiln atmosphere was rich in oxygen, the bricks turned reddish. The higher the FeO content in the baked clay the darker the brick appeared.

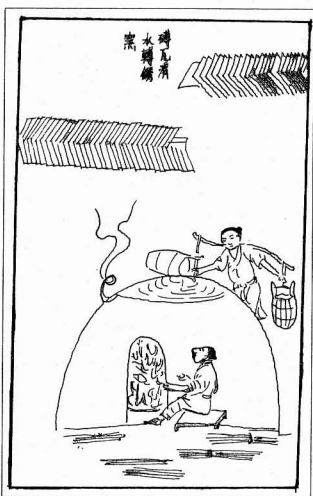


Fig 6 Firing Process: Burning- moistening (*Tiangong Kaiwu*)

Firing bricks and tiles consumed large quantities of fuels. In practice, various kinds of fuels could be used, such as brushwood; wheat straws and wooden twigs are all listed in the *Yingzao Fashi*. The specification of the *Yingzao Fashi* for the firing reads as follows: “In kiln the tiles and bricks are processed by complete combustion of firstly grass, then wormwood, later pine branches. For the *qinggun* tiles, the pine branches are to be covered by a layer of goat / sheep dung, rice husks and heavy oil, (these functioned as emulsifying agent) burned under limited supply of air to make a dense smoke.” The carbon particles in the smoke would condense and stick on or into the surfaces of tiles and bricks. This caused their surfaces to be impregnated with carbon particles to a certain extent resulting in lower porosity and higher quality. This process of carbon-impregnation, however, was not applied to either the *tutu-gun* tiles or glazed tiles due to different aesthetic requirements.

Coal was widely used in the Ming era in South Eastern China, evidenced by the *Tiangong Kaiwu*, Chapter 11, and archaeological remains of the Song kilns which suggest that coal was used in Northern China from the tenth century.¹² Bricks produced by coal-fired kilns appeared

lighter in colour, and those by wood darker.¹³

With improvements in brick making techniques, masonry architecture both above and under ground gained in popularity in the Tang dynasty (618-905). That is, the capacity of the Tang manufacturers to produce large quantities of bricks made a significant contribution to masonry architectural development, such as pagodas, tombs and defence walls from the seventh century onwards. The demand for bricks increased correspondingly causing manufacturers to attempt its production. The *yaoshui* technique increased the output and reduced the production cycle. The archaeological remains demonstrate that the kilns in the Song were bigger than those in the Tang. The *Yingzao Fashi* states that bricks and tiles stacked according to their temperature requirements are fired together.

Glazing

When *qinggun* tile manufacture clearly reached the limits of its technology, glazed tiles established themselves. The *Yingzao Fashi* specified both. Glazing is a process of forming a thin layer of glass of brilliant colour on exposing surfaces of tiles, bricks and other clay wares to make them more attractive in appearance and less permeable to water. Twice firing was required to turn the products into glazed tiles or bricks. The Chinese invented porcelain and developed complicated glazing techniques based on the achievements introduced from West Asia, exhibited by “three-colour” glaze objects attained in the Tang during the seventh-to-eighth century. A recipe for glaze was given in the *Yingzao Fashi*, Chapter 15. It was a mixtures of metal oxides and minerals: “Brushing with a paste of litharge (monoxide of lead, PbO), quartz (powder) and copper powder (ratio 3:0.3:1) mixed with water (warm water in winter) on exposing surfaces of baked tiles.” The tile was then fired again, resulting in a rich effect of colour on the glazed surfaces. By modern knowledge this recipe makes green colour, which has a special quality of sheen, and imparts a jade-like character. Glazes derived from copper and iron with lead were melted together at a temperature of about 700°C giving a colour of brownish-yellow, or green or orange-red depending on the proportion of the component parts. The *Yingzao Fashi* added that “If litharge is not available, it can be replaced by heating black tin and nitre in a pot for one day. After the mixture has cooled down, it is crushed, milled into powder and parching, then heating again while covering the pot with bricks for another day.”

Although glazed wares were mostly green, a brownish-ochre glazed pagoda of ground scale has survived at Youguo Temple (1049) in Kaifeng, Henan Province. It demonstrates the fine craftsmanship of the Song dynasty. In fact, as early as the time of the Tang, lead-bearing glazed tiles with various shades of colours had been available for imperial palaces, state buildings, temples and pagodas.

Kilns: Downdraught kilns

In the earliest form of kiln, the earthenwares and tiles to be fired formed their own kiln of circular or oval shape. The tiles and pottery were stacked in a manner that accommodated the fuel and permitted ignition and stoking, and circulated the fire and heated air upwards. The entire structure was covered with a layer of earth, except a passage (or passages) on top for air extracts. After firing the cover was partly or totally dismantled to allow easy access to the baked products. This was the early type: up-draught kiln. Later, the kilns were operated differently as horizontal-draught type. The kilns specified by the *Yingzao Fashi* were the down-draught type, namely *da yao* (literally “big kiln”) and *pu yao* (literally “exposed kiln”). The down-draught kiln was characterised by a hearth in front and a chimney at rear. It was made to allow the burning air flow, first up then down before escaping from the chimney so as to make a good use of energy (Figure 7). The Song kilns were constructed for successive operations, that is, green bricks and tiles were stacked in turn after the fired ones were removed.

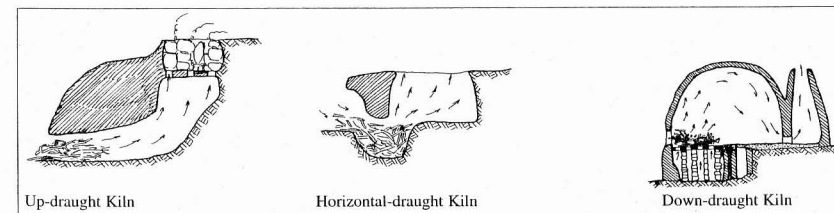


Fig. 7 Kiln Development

The *da yao* used for firing bricks and tiles was larger than the *pu yao* which was for producing glazed ones. The former was 22.4 *chi* (7.2 m) in height and 18 *chi* (5.8 m) in diameter with a doorway of 5.6 x 2.6 *chi* (1.8 x 0.8 m), the latter 15.4 *chi* (4.9 m) in height and 12.8 *chi* (4 m) in diameter with an opening of 5.6 x 2.4 *chi* (1.8 x 0.75 m). These were standard sizes for official-run kilns. Administered by the Ministry of Works, the Song government operated state kilns (*guan yao*), whose function was to supply the needs of officialdom, the finest of products were used at imperial palaces.

The single most important feature of the Song brick-tile industry was standardisation and regulation. The standardisation in measurements and material quotas made it possible for bricks and tiles to be produced from different kilns in different places for state projects, and the kiln specialised in one production line. Skilled craftsmen were registered, and they were assigned to serve the state either permanently or periodically, each assisted by several labourers.¹⁴

In practice, for local construction, kilns were usually built near the building site and clay was taken from near by. It was abandoned after the building was completed. There are no remains of the Song state kiln except for the text of the *Yingzao Fashi* written in a concise form. Two kilns excavated at Luoyang in Henan Province and Chenggu in Shaanxi province show us the layout of the same period (Figure 8).¹⁵ Fortunately, this type of kiln can still be found today, for instance, in Shaanxi and Shanxi provinces: in the thick loess reaches of the Yellow River the kiln is underground or partly so.

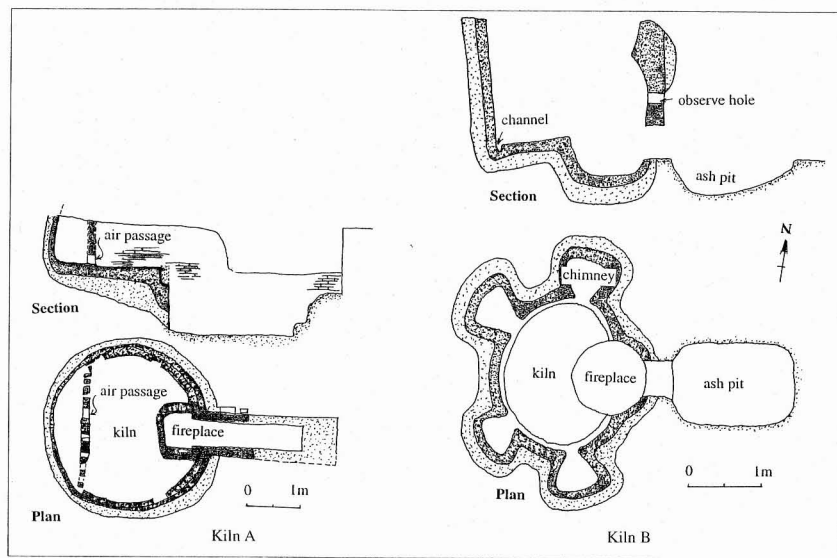


Fig. 8 The Song Kilns
A: Kiln at Luoyang, Henan Province
B: Kiln at Chenggu, Shannxi Province

The *Yingzao Fashi* highlights the quality and visibility of tiles and bricks, and leads to a revised awareness of building material technology as an architecturally formative activity. The book contributes greatly to knowledge of the extent and scope of ancient architecture and provides an alternative framework for viewing the built environment in China.

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