FROM THE BLUE TO THE RED: CHANGING TECHNOLOGY IN THE BRICK INDUSTRY OF MODERN SHANGHAI

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Material History Shift, Blue Brick, Red Brick, Modern Shanghai, Production and Use

Abstract

Modern Shanghai was built mostly of bricks, embedded in an epoch-making shift from “blue brick” to “red brick” in the history of building material in modern China. The classification are customarily defined by the apparent colour. In Shanghai red brick was introduced through the architectural culture from Europe. By the mid-twentieth century red brick had prevailed over the traditional blue bricks in both production and use, a new system was developed locally. The shift took more than half a century with arguably crucial steps in 1866-1936 in the sense of architecture.

The paper addresses the changing technology of brickmaking during the material shift, aiming at the durability of the two kinds of historical bricks, which is important in conservation practice. The problem is generated by the incompatibility between the architectural historians’ ideas and the engineers’ scientific results on the mechanical and physical properties of the two kinds of bricks. It highlights the incompatibility and ascribes it to the technological issues existed in the initial stage of the locally developed modern brickmaking industry, which built on the centuries-old system with western machinery. It presents a brief state-of-the-art on the manufacturing history out of any systematic studies on those delicate and heterogeneous historical bricks. Accordingly, it proposes two most important questions about the argil and the production process that are arguably crucial to the deterioration and the durability of those Chinese bricks, based on referable European studies.

Multi-field sources are utilized. One principal source is the technical publications according to different professionals such as architects, engineers, technological historians, experience-based or science-based, from ancient time to modern period. Another main source is the industrial records from the manufacturing sector. It also carefully considers the unpublished but prevailing knowledge from the local heritage specialists and architectural historians.

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INTRODUCTION: THE GRAND MATERIAL SHIFT

In most territory of modern China happened an epoch-making shift from “blue brick” to “red brick” in the history of the building material[2]: by the mid-20th century the newly arrived red brick of European taste had prevailed over the traditional Chinese blue brick that used to predominate almost the entire Han cultural territory of China before the mid-19th century[3]. That delicate material culture of blue brick is well documented in archaeological and architectural evidences, built or written, throughout hundreds of years. The blue-to-red shift, either in production or use, has not yet been properly documented in Chinese or English.

Shanghai used to be firmly embedded in the blue brick tradition no matter how to regard its natural, cultural and human resources. Starting from a British Settlement, modern Shanghai was built mostly in bricks from 1843 to the mid-20th century, it documented the extensive material revolution as both an epitome and a pioneer. Arguably, such a shift has greatly influenced the urban history, architectural history and construction history in Shanghai, and vice versa. The production and the use of different bricks shaped each other. Crucial steps happened in 1866-1936 in the sense of architecture (Shu 2013)[4]. Since the 1990s the burnt clay bricks have been forbidden to produce on account of environmental protection in China.

The durability and the decay processes of the two kinds of bricks become a focus issue in conservation practice for heritage specialists[5]. Based on the scientific results of brick samples, tested, and the changing technology of brickmaking, recorded, the paper assumes that the properties of the bricks are not necessarily related to the blue or red types as traditionally classified; instead, the raw clay and the production technology are arguably the innate factors affecting the brick deterioration. It calls for a reconstruction of the knowledge system predominated by the apparent brick colour from the modern period up to the present in China.

THE QUALITY OF BRICK: A DETERMINANT OF THE MATERIAL SHIFT?

Throughout the modern period, the call for red brick was remarkably ascribed to the consideration of the material’s quality. It has been widely believed to date that the red bricks mimicked European bricks was or should be of higher quality than the Chinese blue one, as shown in adequate architectural materials since the turn of the 19th century, built or written, in English or Chinese. For instance, in the 1792-4 MaCartney Embassy to China, the attachés such as John Bar-

[2] The term “*blue brick*” and “*red brick*” are literally translated from the two popular Chinese terms qing-zhuan 青砖 and hong-zhuan 红砖. The English term “blue brick” repeatedly appears in the materials to the British MaCartney Embassy of 1792-94 to China published at the turn of the nineteenth century. “Grey brick” is adopted alternatively in English. Today the blue bricks, either ancient or modern ones, appear a bluish grey hue of low saturation to the unaided eye, there might be possible deviation from the “blue” of the original ancient ones. Brick, in this paper, signifies the fired clay block used as a building material, while etymologically the Chinese term “brick” denotes a broader meaning includes “tiles” in ancient time.

[3] I draw a geographical distribution of the blue brick tradition in China by the mid-19th century, utilizing European travel books to China throughout the 19th and 20th centuries (Shu 2014). “Archeologists and architectural historians have used the difference between Chinese grey brick [blue brick, author note] and the red brick of West and South Asian peoples as a way of demarcating settlements in the western borderlands of China” (Levine at al. 1995:169).

[4] One original hypothesis is that the Victorian British architects’ ideas in architecture stimulated the rising use of red brick in building Shanghai. The rapid expansion of the city and the municipal control of fire contributed to that. Red brick gradually gained the affections in the locals via the Chinese clients, builders and artisans (Shu 2013).

[5] According to Fabio Fratini at ICVBC (pers. comm., Feb 2015), the brick durability regarding weathering depends on at least: the firing temperature, the porous structure, the quantity of the sandy fraction, the composition of the raw clay, the kiln and the firing cycle, the type of the fuel, the sulphates and salts already existing in the clay.

row considered Chinese blue brick were “ill-burnt”, “half-burnt” stuff (Barrow 1804: 63, 136, 206, 301). In Shanghai, both the British architect William Kidner (RIBA) of the 1866 Holy Trinity Church and the British engineer John William Hart (M. Inst. C. E.) in the 1881 project of Shanghai Waterworks frankly expressed their demands for qualified red bricks. “A serious difficulty was found in obtaining bricks of the quality required” (Kidner 1867). “The bricks obtainable in Shanghai are of inferior quality. In this case, though specially made and extra burnt, and though every care was taken to procure the best that could be obtained in the locality, they were much inferior to those used in England for similar purpose” (Hart 1890: 223). In built evidence, according to my observation in the last seven years, red brick were usually applied to higher forms with the connotation of dignity, or to constructional load-bearing shapes like columns and arches, while blue brick was used in a comparatively inferior way. Contemporary historians also ascribe, or tend to ascribe the different uses of the bricks to the consideration of quality. To say the least, good properties justified and consolidated the fondness of the red, a novel form in Chinese architecture.

Scientific results based on laboratory tests show much more complex situation about the properties of the original bricks. One of my analysis depends on the data from the lab tests carried out by the Material Test Committee of Chinese Engineering Society in Shanghai, in the lab of Nan Yang College of Chiao Tung during 1924-25. The tests aimed at understanding the original properties of the bricks commonly used then at Shanghai. 36 modern samples were selected from the most popular six factories there, including “machine-made red brick”, “handmade red brick”, and “modern handmade blue brick” as called in the report (Ling 1925). They carried out bending test (in natural environment condition), water absorption test, and compression test (both before the water absorption and after), dry bulk density measured by determination of dry weight and dimensions of the bricks[6]. The wide range of values reflects the high variability in the mechanical properties and physical properties of the samples. The test data of those machine-made bricks show the inhomogeneity of the industrial manufacturing process; the qualities of brick depend much on factories, which means the differences in raw material and production process. Also, a wide range of quality is exhibited in the machine-made red brick samples produced in the same factory. In comparable cases, the machine-made type does not exhibit any certain or necessary higher quality than the handmade type in either compressive strength or bending strength. Instead, the samples of machine-made red brick are in quite low quality in different aspects. The compressive strength of the modern handmade blue brick appears generally higher than both the handmade red bricks and the machine-made red bricks; several handmade blue bricks even show a much higher value than many other types of the red one[7]. The test data of water absorption show unusual phenomenon goes much against the law and the experience according to most European studies on physical properties of brick, though the information is quite limited[8]. Another

[6] The procedure is: The brick is dried in a ventilated oven at a temperature of 200°-250°F (93.3°-121.1°C) till it attains constant mass. Then the mass of the brick is recorded (M) (it is not indicated whether or not the brick is cooled to room temperature when the mass recorded).Then dimensions of the brick is measured accurately and the volume is calculated (V). The dry bulk density is calculated as mass per unit volume: Bulk density = M / V.

[7] In the tested samples, the values of the compressive strength of the modern handmade blue brick range from 12.68 MPa to 47.12 MPa with an average value of 28.94, the values of the handmade red bricks range from 9.28 MPa to 31.73 MPa with an average value of 21.43, and the industrially produced red bricks from 5.68 MPa to 30.51 MPa with an average of 15.70 MPa.

[8] For instance, the water absorption tests, which aimed at the change of the compressive strength of the brick samples after the water absorption, show that some samples increased by 140% (industrially produced red brick), 137.2%, 126.5%, 106.5% (handmade red bricks), 114.8% (handmade blue brick) respectively. This unusual phenomenon goes much against the law that water absorption usually brings down the compressive strength of a brick;

test focuses on the quality of some decayed ancient blue bricks, carried out by the same lab with the same methods in the 1920s (Ling 1925b)[9]. Compared with the above-mentioned modern samples from Shanghai, it is not yet possible to tell that the quality of the modern bricks surpasses the ancient decayed ones in any sense in general. A series of recent lab tests also show a high level of heterogeneity in the properties of the historical bricks sampled from Shanghai's modern buildings, they have deterioration to different extents of course; it is also hard to recognize an apparent advantage in the properties of the red than the blue in comparable cases (Dai 2011).

Therefor, the ideas in architecture are not supported by the scientific results based on laboratory tests, very limited though. It seems that the locally developed modern system had not achieved what was initially expected by making European red brick by the year 1936, the eve of the Sino-Japanese War heavily attacking the manufacture in traditional kilns. This incompatibility leads to original questions about the machine-made defects in the reconstruction of the brickmaking industry involving two systems of knowledge.

FROM TRADITIONAL CRAFT TO MODERN INDUSTRY

Multi-field materials outline the changing history of brick production in modern Shanghai. Western tools of brickmaking were published in Chinese as early as in the *Chinese Scientific and Industrial Magazine* (Wang 1996: 42). The increasing publications in the twentieth century such as periodical and magazine provide pertinent knowledge on brickmaking[10]. Studies in architectural and urban history reveals: European red brick arrived at Shanghai in ballast from England (Murphey 1953: 69), and began to be produced locally around 1858 (Johnson 1995: 251); all the red bricks of the Shanghai Holy Trinity Church, 1866-9, was manufactured by the British-owned Shanghai Brick Company with the help of a local Chinese Chum shun-li (Kidner 1867); at latest in the 1870s, both red brick and blue brick were involved in popular new forms and languages of architecture (Shu 2013). Industrial records talk about factories: there used to be three Chinese-owned brickmaking factories opened respectively in 1897, 1900, and 1911, they introduced Hoffman kilns and modern machinery but were all closed up shortly after the establishment (Shanghai-shi she-hui ju 1934; Sun 1986; Jiang 1997). The Belgian-French brick factory Crédit Foncier d'Extrême-Orient achieved the earliest remarkable success there (1912-36).

Introduced western machinery changed the fabrication techniques and operation details in the whole manufacturing process: preparation, tempering, moulding, drying, and burning.

The preparation was closely linked to tempering, both required particular cautions. In old ways, the earth was selected at the very beginning when dug by men. Stone-inclusion earth had to be avoided carefully. In such condition the earth and the fabrication sites had considerable restraint. Tempering was done with shovels by men, or trodden on foot by men or buffaloes, turn-

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or, to say the least, it could be interpretable if the rate of variation was within 30% according to most comparable European studies in heritage conservation.

9 Ancient samples including ten bricks from a 1924 collapsed ancient pagoda Lei-feng-ta at Hangzhou, and some (number not indicated) sampled from the city walls of Nanking and Taiyuan.

10 Bibliographical investigation in Shanghai Library shows that available materials, especially professional journals, were mostly published in the 1920s-1930s, such as *The Journal of the Chinese Engineering Society* (1925-1930, Shanghai), *The Chinese Architect* (1932.11-1937.4, 30 issues, Shanghai), *The Builder* (1932.11-1937.4, 5 vols/49 issues, Shanghai), and *Jian-zhu cai-liao yue-kan* [The Architectural Materials Monthly](1947, Nanking). Obviously, Japanese invasion and occupation in 1937-45 and the Chinese Civil War in 1945-49 were not favourable to the industry of building materials in China. The contemporary brick industry was covered by the regional monthly journal *Block-Brick-Tile* published in Xi'an since 1971, the monthly *China Building Materials* published in Beijing since 1980, and the monthly *Brick & Tile World* in Beijing since 1984, all in Chinese. I have not found a good account of the brick manufacture in the regional industry of Shanghai during the modern period.

ing the clay over repeatedly until it acquired the requisite plasticity. The blue bricks used for the hand-crafted works such as brick carving specifically demand refined brick earth, well tempered. In modern period, excavators were employed for earth-digging which reduced much labour and earned extensive products. Tempering operation also got greatly improved: stone-inclusion earth became available, as the harmful stones could be ground or got rid of with the help of pugmills, rollers, and grinding machines. But the disadvantage could be, the facilities for working up everything to be crushed by the machines might induce many brickmakers to work without proper regard to the nature of the material, resulting in comparatively large pieces of limestone remained.

The old way of moulding is to dash the tempered clay into a wooden mould with sufficient man force to make the clot completely fill it, the superfluous clay was stricken with a strike. Traditional mould was a sort of box without top or bottom[11], the faces of both sides were made smooth with the metal wire of the strike. To achieve higher quality, both of the stricken faces need to be smoothen more to and fro with a rectangle-edged wooden block. In 1900 some press moulding machines were used in Rui-he Brick and Tile Factory at Shanghai, driven by man force. In 1920 Xin-da Factory bought a press moulding machine from Japan. Moulding machine had not got into general use until 1928 when Shanghai could produce it locally. Brick-cutting machine was also employed for moulding. Through them dry pressing method was employed in the modern lines, which actually eliminated the operation of tempering, it greatly increased the producing efficiency but would probably affected the properties and the deterioration of brick.

A moderate drying condition and a slow drying process favour the quality of the brick. Great care and attention is required to protect the green bricks from cracking, different clays require different treatments resulting different drying time. In ancient China, shady drying and sun drying were both employed in the brickmaking yards on a case-by-case basis. It seems that sun drying was more popular in the north of China while the shady drying more in the south such as Jiangnan region, Shanghai included; in the more recent history, the sun drying could follow the shady way in order to reduce the time in some places. Bricks were shadily dried in modern Shanghai (Ge 1920: 3). Modern facilities provided efficient artificial space of drying atmosphere, making it easier and faster. In 1918 the brick factory of Crédit Foncier d'Extrême-Orient introduced an intermittent drying facilities in Shanghai for the first time. In 1920 similar equipments were also introduced in Xin-da Factory, with a drying room of about 500 m^2.

The kiln and the firing condition is a crucial issue for durability regarding my case. Innovations and revolutions took place in the kilns. Traditional kilns worked intermittently, with the firing circle about one week. Industrial records generally tell that Hoffman kiln from Europe, round downdraft kiln from United States, and rectangular kiln from Japan were introduced in modern factories of Shanghai. Those introduced continuous working lines were not originally designed for traditional blue bricks burnt through both oxidation firing and reduction firing. The reduction firing is realized after a period of oxidation firing through introducing water to the kiln-chamber to generate water gas. In modern period, the reducing atmospheres within the kilns are achieved by another distinct and different method called "air-starved fuel" reduction, meanwhile that centuries-old technology of water gas is still retained in the modern factories up to 1992 in Shanghai (Kerr 2004: 297). However, my investigation in the publications of the 1920s-40s, mostly jour-

[11] In Nanking a kind of mould box with the bottom was introduced by the poured-in brickworkers from the north China, it became very popular in the workshops of Naking (Mu Z 1947: 20). This might also influenced some workshops in Shanghai though I have not read any records yet. The bottom-inclusion mould actually brought the brick quality down but increased the operating efficiency.

nals, hardly reveals any interesting traces indicating the innovation to the modern kilns. The tunnel kiln system erected later in the 1950s.

After all, a large amount of the red bricks were made in traditional kilns, and blue brick never died out in modern industry, they both were produced in traditional kilns and in new factories.

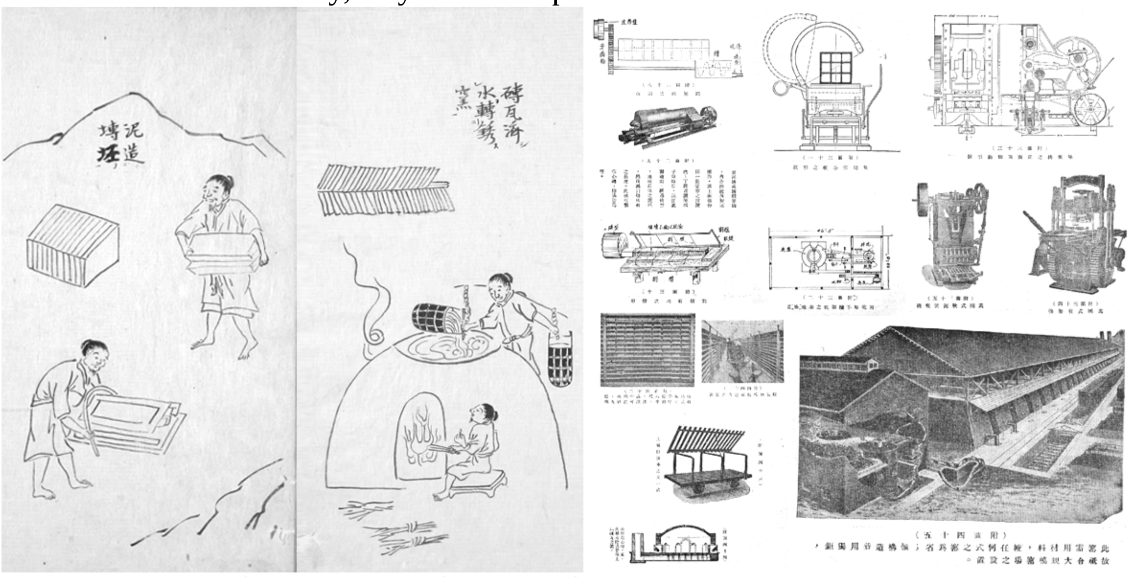

Figure 1: The change of brickmaking: the fabrication of traditional blue brick and the modern industry at Shanghai. (Song 1637) (Du 1935)

ISSUES ON THE PRODUCTION

Recently, limited laboratory tests show a generally homogeneous composition in red bricks with a high content of clay minerals and a comparatively low content of sand; the firing temperature is speculated to be 900°C; through comparing different blue bricks, it seems that modern kilns guaranteed a higher firing temperature than those made in traditional kilns (Dai 2011).

The Raw Clay

Very little attention is paid to the analysis of clay to understand the nature of Shanghai's modern bricks. It is not well documented either the argil deposits or how the raw clays were processed in producing the diverse bricks there. Heritage professionals have little knowledge or scientific data on the mechanism of decay through raw materials. According to Qian Zong-hao (pers. comm., 18 June 2010), the earliest locally-made modern red bricks utilized the mud dredged up from the bed of Huangpu River, a tidal river that had to be dredged every year. Immense quantities of mud was piled up along the river bank in the suburban districts of Yangshupu and Pudong, where located many kilns in the 19th century. When this area was gradually occupied by docks and factories as the city grew, the dredged mud had to be dumped into the deepwater sea outside the estuary. Simultaneously, new brickmaking factories were established in the comparatively upper regions of the Huangpu River and Suzhou Creek respectively. By the 1930s, the big brick companies such as Crédit Foncier d'Extrême-Orient and Taishan had moved their brickmaking factories to Huzhou beside the Tai Lake, about 150 km away from the downtown Shanghai[12].

[12] Shanghai is located on an alluvial plain with rich water resources passing through, remarkably Huangpu River and Suzhou Creek. The lower reaches of Yangtze River brings lots of mud and sand there. Qian's knowledge is

The Generation of the "Blue"

Theoretically, there are a number of factors which may affect brick colours (Firman 1994). Experience-based materials show that the colour of brick is used as a handy index to see whether or not the product is in good quality in a traditional kiln (Wang 1934; Mu 1947; Zeng 1958). Contemporary literature, science-based, prevailingly ascribes the colour "qing" to the reducing process of the clay's red ferric (iron III) oxide to its black, ferrous (iron II) state ($Fe2O3 \rightarrow FeO$), generated by the deliberate reduction-firing (and reduction-cooling) towards the end of firing.

The generation of "blue" is changing revolutionarily. The colour of contemporary "blue brick", in many occasions, does not result from reduction-firing, they are mimicked. Make-up materials are applied to the brick surface, or specific agents are used to dye them – they are surface colours and textures. Similar colours are achieved as well by means of reconstructing the constituents of the raw material in some factories in China (Xu 2008, 2009). In Shanghai, innovative blue brick was realized in Pu-nan Brick and Tile Factory in 1984 (Jiang 1997), yet the revolutionary details are not well documented. Predictably, the degradation and deterioration behaviors of these bricks will be quite different from the traditional ones with regard to the potential conservation treatment in the future.

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compatible with my investigation about the distribution of the traditional kilns and the modern brick factories based on the local industrial almanacs (Shu 2014).

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