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Towards Modern Ceramics in China

Engineering Sources and *Manufacture Céramique de Shanghai*

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ABSTRACT: The study develops a new perspective on the historiography of architecture and technology of China based on engineering and archival sources, laboratory methods, and fieldwork. It argues that China's move towards modern ceramics involved a paradigmatic shift between two systems of knowledge from the 1840s and that new construction activities induced the modern move. The article engages Shanghai's heyday of high-rise buildings and explores the *Manufacture Céramique de Shanghai* (1914–1935), a factory under the Belgian company *Crédit Foncier d'Extrême-Orient* that introduced the modern manufacture of European architectural ceramics into China at a crucial moment. Architectural ceramics led the paradigmatic shift, aided by increasing efforts from Chinese engineers of diverse fields. Engineering methods were applied to porcelain and pottery studies, too, leading to the birth of "Ceramics Engineering" in China.

In the history of Chinese ceramics, architectural ceramics (principally bricks, tiles, and pipes) are often marginalized since their technology seems less sophisticated than the exquisite, delicate porcelain objects for which China is famous. This article argues that the complete modernization of brick and tile making depended on a systematic shift to Western science and technology; brick technology pioneered China's move to modern ceramics and heralded the birth of "Ceramic Engineering" as a new science. This conclusion is built on a holistic survey of the modern changes in the ceramics industry, with an in-depth investigation into both architectural and engineering activities.

Joseph Needham's *Science and Civilization in China* provides the most comprehensive history of Chinese ceramics technology over the longue dureé. It concludes with "China's decline in the late 19th and 20th centuries," which is blamed on "China's overall economic recession, partnered by her lack of progress in modern science and technology."[1] This conclusion, how-

NOTE: THESE ARE UNCORRECTED PAGE PROOFS. NO IMAGES HAVE BEEN INCLUDED.

1. Rose Kerr and Nigel Wood, *Science and Civilization in China: Ceramic Technology*, 770–72.

ever, lacks nuance, as it places most of its emphasis on pottery and porcelain technology and ignores the new dynamics of the later period. Our research reveals that China had a booming period of construction in the 1840s-1940s, which stimulated the modern brick and tile industry. The industry did achieve technological innovation and renovation, aided by the progress of modern engineering and sciences in China. Meanwhile, the brick and tile industry helped modernize Chinese ceramic technology from agriculture-based Asian craftsmanship into an industry-based Western engineering culture, which finally led to the development of the field of ceramics engineering, incorporating the manufacture of Chinese porcelain as just one branch. The Chinese story is therefore more complex than the nineteenth-century stories of mechanizing potteries (brickyards included) in the USA and Europe.[2] We argue that China's transition involved a shift between two systems of knowledge, accompanied by struggles and communications between the two in the process.

From the year 1864 at the latest, Western bricks and tiles, including ordinary bricks and specific fire bricks (refractory material), were imported from foreign countries into China via Shanghai Port. This is shown in the annually published statistics in the maritime customs' archival collection, "Returns of Trade at the Treaty Ports in China" (see table 1). The same archives also show, simultaneously yet in contrast, that China exported a much larger amount of traditional ceramic materials, including native blue bricks, pottery, chinaware, and earthenware, to foreign countries.[3] Why did China start to rely on certain foreign bricks and tiles despite its high levels of know-how in producing other traditional ceramics for centuries?

By the turn of the twentieth century, ceramic-making yards in Europe and the U.S. had gone through a crucial stage of industrialization. Besides machinery, modern sciences—including geology, chemistry and engineering—had infiltrated the production process, and analytical methods had been largely employed to control and standardize the properties of products.[4] In China, modern sciences were yet to be well-established. In Chinese brickyards, the quality of bricks was still checked by observing colors, textures, and listening to sounds, among other remarkable firing tech-

2. Department of Commerce, *The Pottery Industry*, 93–120; Albert Bleininger, *Writings of Seger*, vol. 2, 762–944; Irving B. Holley, "The Mechanization of Brickmaking"; James W. P. Campbell and Will Pryce, *Brick: A World History*; Alfred B. Searle, *Modern Brickmaking*.

3. *Returns of Trade at the Treaty Ports in China, for the Years 1859–82*.

4. Albert Bleininger, *Writings of Seger*; Edward Cresy, *Encyclopaedia of Civil Engineering*, 708-16; James Fairie, *Notes on Pottery Clays*; George F. Harris, *The Science of Brickmaking*; Allen J. Howe and Allan B. Dick, *Kaolin, China-Clay and China-Stone in Practical Geology*; Robert B. Leighou, *Chemistry of Engineering Materials*, 453-66; Charles Quillard, *La fabrication des poteries*; Searle, *Modern Brickmaking*; Alfred B. Searle, *Clays*; Alfred B. Searle, *The Chemistry and Physics of Clays*; Herman A. Seger, "The Lower Rhine and Belgian Brick Industry"; Ronald Stenvert, *Biografie van de baksteen*.

niques. The inherent differences between local and foreign technologies made it difficult to produce European types of bricks or tiles in the traditional Chinese kilns with only the traditional know-how. But the fact is, Chinese brickmakers from traditional brickyards immediately became the major source of labor in modern factories when Western technology arrived. They learned Western technology while bringing their traditional knowledge into the modern factories.[5] Gradually, a new industry utilizing Western machines and following the Western manufacturing mode prevailed over the traditional Chinese practices, and today Western technology has been adopted to produce bricks both in Western fashions and in traditional Chinese fashions mimicking old blue bricks.[6] How was this novel technology established in China? What was the essential struggle between local and foreign technologies? And what is the legacy of this struggle today?

The relationship between local and foreign technology, including studies of technology transfer and circulation, have been explored at length in the history of technology. However, work on technology transfer that attends to East Asia, in particular China, has grown considerably in recent years. Historians of East Asia have deliberated more deeply over local contexts that might (re)shape forms and meanings of foreign technologies.[7] Attention has also been increasingly put on practical and useful knowledge. Exploring the ways modern practices emerge within a global network of exchange via commerce, engineering, and religion is now a widely shared interest.[8]

Of special inspiration to our article is Gregory Clancey's work, which bridges the subjects of architecture and seismicity and reveals how modern seismology was born in the earthquake-prone country of Japan.[9] In our study, a similar approach shows the birth of modern ceramics in China both from the perspective of the architectural practices employing new ceramic materials and the technology that supported this new material industry. To define the character of the architectural ceramics in use, we did extensive fieldwork and used the results of laboratory analyses for accuracy. We also consulted engineering sources in a wide range of contexts and collated chronology of ceramic factories in China.

European architectural culture and its ideology promoted the production and use of red bricks in China from the mid-nineteenth century onwards. In particular, fire brick with refractory properties and other engineering materials was an instrumental part of China's development of a modern ceramics industry. Western facilities built for the coal and steel

5. Thomas Black, "Refractory and Other Ceramic Products," 18 and 21.

6. Song, *Tian Gong Kai Wu*; Kerr and Wood, *Science and Civilization in China: Ceramic Technology*, 298; Yong-Sheng Xu, "Qin-zhuan."

7. Frumer 2018; Kobiljski 2016; Schäfer 2018; Shu 2019; Wang 2012.

8. Bickers 2013; Elleman & Kotkin 2010; Fang 2018; Högselius & Yao 2017; Sun 2014.

9. Gregory Clancey, *Earthquake Nation*.

industries in China required special refractory materials that were novel to the Chinese. Yet, traditional Chinese brickyards, sometimes aided with limited renovation, continuously supplied considerable quantities of blue and red bricks of acceptable cost-performance ratio and were therefore used in secondary places in modern and Western construction.[10]

Laboratory data suggest, surprisingly, that it was as late as during the decade 1925–1935 when modern bricks made with European technology started, in terms of mechanical and physical properties, to surpass the blue bricks made in the traditional Chinese way.[11] This late and quick maturation of quality was accompanied by a boom industry, too. Our chronology of factories shows that, just in Shanghai, at least twenty-six brickyards were newly established in the twenties and thirties. But in the decades of 1890–1910, our research suggests that China's brick and tile industry was still struggling with tensions between growing market demands and the difficulties of adapting to Western manufacturing.

The industrial literature has repeatedly noted two early foreign manufacturers' novel machinery in brickmaking: the *Yi pin zhuan wa chang* (天津義品磚瓦廠), launched by a Belgian company in Tianjin, and the *De long zhuan wa chang* (德隆磚瓦廠, Western name unknown), established by German merchants in Hankou at the same time.[12] There is no study about either case. The latter soon shut down for reasons unknown. The former, originally named *Manufacture Céramique Française de Tientsin* (later named *Manufacture Céramique de Tientsin*, henceforth MCT), was created in 1909 and started production in 1911. The factory was part of the investment of the mortgage company *Crédit Foncier d'Extrême-Orient* (henceforth CFEO)—translated to "Far East Land Credit" 義品放款銀行 (*Yi-pin Credit Bank*) and later known as 義品地產公司 (*Yi-pin Estate Company*).[13] The CFEO soon established a *Département des Briqueteries*, covering the Tianjin MCT, and started another one in Shanghai in 1914, named *Manufacture Céramique de Shanghai* 上海義品磚瓦廠 (henceforth MCS). WWI delayed the MCS's launch until 1921. The MCT ceased in 1926, while the MCS continued production in Shanghai until 1935.

10. Chang-Xue Shu, "The Blue and the Red"; Chang-Xue Shu, "La 'constructional polychromy'"; Chang-Xue Shu, "Towards Western Construction"; Chang-Xue Shu, "From the Blue to the Red"; Black, "Refractory and Other Ceramic Products"; Chang-Xue Shu and Yi-Bing Fang, "Fire Brick."

11. Joseph H. Ehlers, "Chinese Engineering Materials"; Hong-Xun Ling, Pei-Beng Yang and Kong-Huai Shi, "Zhuan-tou Shi-yan"; Hong-Xun Ling, "Lei-feng-ta Zhuan-tou Shi-yan Bao-gao"; Shu, "The Blue and the Red", 238–52; Chang-Xue Shu et al., "China's Brick History and Conservation," 800; Shu and Fang, "Fire Brick."

12. Da-Jin Yang, *Jin-dai Zhong-guo Shi-ye Tong-zhi*; H. G. W. Woodhead, *The China Year Book*, 570–71. The statistics in *The China Year Book* are probably based on the 1933 industrial census of China; see also Da-Jun Liu, *Zhong-guo Gong-ye*, 552–64.

13. Thomas Coomans, "China Papers"; Leung-Kwok P. Lau and Thomas Coomans, "Modern Architectural Influences."

It is not obvious why and how a Belgian mortgage company invested in ceramics production in China, a country famous for its ceramics, at a time when Chinese consumers' nationalism was rising. Unexpectedly, the archives of the CFEO do not show that the company's ceramics investment in China was especially profitable, while Chinese industrialists and industrial historians often consider the two Belgian factories to be notable models of industrial success.[14] Industrial histories nearly always proudly claim the progress made in manufacturing novel bricks and tiles in China in the 1920s-30s, which is just the moment the Belgian MCS produced European ceramics in Shanghai. What was the factory's real contribution in the big picture?

The archives of the CFEO are conserved in Brussels and contain internal reports between the CFEO's different branches in China and the headquarters in Brussels, including accounting and personal dossiers.[15] A unique photographic album containing 27 photos (partly damaged) with captions dated February 1931 shows the machines and installations of the MCS.[16] Complementarily, the MCS's local activities can be traced in the Shanghai Municipal Archives. The Shanghai archives dated 1931–33 include internal communications between the MCS and the *Service des Travaux Publics, Conseil d'Administration Municipale de la Concession Française à Shanghai* (CAMCFS). They provide the technical details of the MCS products and reveal, for the first time, a list of architectures that employed MCS products.[17] These sources offer excellent information on the infrastructure, human resources, manufacture, sale, and problems of the factory from an inside perspective. We contextualize these new archives with engineering sources and other dispersed Chinese, English, French, and Dutch materials.

High-Rises and the CFEO in Shanghai

In Shanghai of the 1840s–1910s, so-called "European red bricks" referred to the solid plain bricks fired with local clays but made with European methods. European bricks were mostly used for the new Western-style architecture then going up. They were often used in the Western masonry system, in which brickwork required higher strength and solidity than in the traditional Chinese construction.

Native blue bricks and blue tiles had been produced for at least two

14. Yang, *Jin-dai Zhong-guo Shi-ye Tong-zhi*; Liu, *Zhong-guo Gong-ye*, 552–64; Xi-Quan Sun and Hong-Chou Lv, *Shanghai Jing-ji Qu Gong-ye*, 143; Xiao-Jian Wang, *Shanghai Xian Zhi*; Zai-Wei Jiang, *Shang-hai Jian-zhu Cai-liao Gong-ye Zhi*, 122–31; Woodhead, *The China Year Book*, 570–71 (Woodheard's statistics are probably based on Liu's); Zi-Xian Liu, "Zui-jin Shi-wu Nian."

15. AGR, CFEO. René Brion and Jean-Louis Moreau, *Inventaire*. Specific files about brick factories: AGR, CFEO, 206–71 (MCT) and 833–38 (MCS).

16. AGR, CFEO, NA 2 – Joseph Cuvelier repository, *Manufacture céramique de Shanghai*, fund CFEO 2d transfer.

17. CAMCFS - MCS, dossier U38-4-2667 / 721–6.

thousand years. Manufacturing methods employed a sophisticated two-stage oxidation-reduction firing process that generated the typical grayish blue color (see figure 1). Traditional Chinese blue brickwork often played a role in architectural appearance as an elegant surface to sustain the owner's social status in an elite culture. When Western masonry became a mainstream building method and the demand for bricks surged, bricks, either of the new or old types, gradually required industrial supply.[18]

Before 1910, the growing demands for brick and tile were mostly met by Chinese-owned brickyards with limited changes to their manufacturing techniques. Those elements that required specific properties for industrial uses were largely imported. In the 1910s-20s, Chinese brickmakers' dominance was challenged by Western factories established in China. In North China, our survey in local directories and chronicles reveals several strong Western manufacturers besides the Belgian MCT (1911-26): the Brickwork at *Kailan Mining Administration* 開灤礦務總局, under British management making special refractory ceramics as well as ordinary pieces (commenced in 1900-06); the Calcareous Brick Manufacturer by the Italian Egidio Marzoli (commenced in 1904); and another Belgian brick factory E. Fivé & Co. (commenced in 1914-17). This situation may partly explain why Brussels adapted its business strategy by closing the Tianjin MCT in January 1926, while investing more in the Shanghai MCS soon after.

In Shanghai, from the 1910s, early skyscrapers or high-rise buildings—a new building type born in Chicago in the mid-1880s—gradually spread until 1935.[19] Unlike in America or Europe, the world's economic crisis did not affect construction activities in Shanghai; instead, the relatively stable period of the Nanjing Decade (1927–37) and its economic growth favored Shanghai's construction sector further. The trend brought in a new frame structure system that would gradually replace the old building method of masonry. Studies based on architects and urban history have shown that this trend was boosted by large-scale real estate speculation and new design ideas.[20] The years 1925–35 are considered Shanghai's heyday of construction, a dynamic associated with the novel introduction of reinforced concrete as a symbol of modernity. In the new frame structure system, the skeleton could be realized in either steel as adopted in Chicago or reinforced concrete as adopted in Shanghai because of the then-scarcity of steel in China. The non-load-bearing walls always required lightweight and fireproof infill materials, which was a universal trend. Therefore, the solid plain bricks became too heavy for the high-rises and could not be used in the new construction methods. At the earliest stage of high-rise development in Shanghai, hollow bricks met the requirements to act as an infill

18. Shu, "The Blue and the Red."

19. Joanna Merwood-Salisbury, *Chicago 1890*.

20. Shi-Ling Zheng, *Shanghai Jin-dai*; Jiang Wu, *Shanghai Bai Nian*; Qing Chang, *Mo-deng Shanghai*; Edward Denison and Guang-Yu Ren, *Building Shanghai*.

material because their production shared similar raw materials, facilities, and process as European tiles. This inconspicuous yet significant role of the hollow brick has received little attention in either the architectural history or the ceramics history. Only local industrial history of building materials dedicates attention to hollow bricks, but the architectural and technological contexts have been lost.[21]

Starting to produce architectural ceramics in 1921, the MCS engaged in Shanghai's booming period of high growth. MCS products were used in the construction of many prominent modern buildings, as revealed for the first time by our archival research (see table 2, figure 2); these buildings are nearly all considered by scholars as exceptional cases that shaped Shanghai's architectural history. MCS products were supplied to important institutions, including the Shanghai Municipal Council for the International Settlement, the French Municipal Council for the French Concession, the Shanghai Waterworks Co. Ltd., and the French Power Station. Orders for export to places like Manila were duly executed as well.[22]

The first and only industrial census in Republican China, for the year 1933, mentions that before 1921—the date the MCS started production—it seems that demand in Shanghai was so high that they ordered European bricks from Hankou (Wuhan), 690 km away.[23] In Shanghai, according to our survey of factories, there were only about four modern brick factories established between 1890 and 1920 and two of them had to stop production rather soon after their founding, probably due to technical problems. The number, however, jumped to at least fourteen in the decade of 1921–30. At that moment of growing demand, Brussels increased its investment in the Shanghai MCS in 1928, just after closing its Tianjin MCT in 1926. Our study strongly suggests that this adaptation was encouraged by the booming construction of Shanghai. At that precise moment, Sassoon House (1926–29) was under construction on the Bund with MCS ceramic products, becoming the first-ever thirteen-story skyscraper and setting China's new building height record of 77 meters. The MCS continued to be the only foreign factory producing European architectural ceramics in Shanghai, among over a dozen Chinese competitors.

The MCS: Infrastructure and Global Sources

The two CFEO factories produced a wide range of ceramic types for architectural uses. The MCS had the capacity to produce plain bricks

21. Jiang, *Shanghai Jian-zhu Cai-liao Gong-ye Zhi*, 122 and 125.

22. CAMCFS - MCS, dossier U38-4-2667 / 721–6, page SC016.

23. Liu, *Zhong-guo Gong-ye Diao-cha Bao-gao,* 18. The industrial census was conducted in 1933 by the Institute of Economic and Statistical Research 中國經濟統計研究所 under the direction of Liu Da-Jun 劉大鈞 (old spelling: Liu Ta-chiin or D.K. Lieu) and was published in 1937.

(BPN), hollow bricks (BCI), roofing tiles (TU, including flat tiles, ridge tiles, Marseilles type, and Hankow type), chimney pots, flue pipes, drain pipes, enamel tiles, flooring tiles, hollow tiles, frost-proof facing bricks, and fireproof products (partly shown in figure 3).[24] They could be made in various sizes. The CFEO used to intend a bigger program including pottery production (*faïencerie*).

Nineteenth-century Belgium was at the forefront of manufacturing technology. In developing its industrial methods, it built on a centuries-old tradition of brickmaking in the Low Countries. For instance, Belgium exported its flourishing modern bricks and tiles to the Netherlands and exported important pieces of refractory materials into China for industrial uses.[25] Henry Le Bœuf, the executive director of the Belgian CFEO, worked in modern brickyards in Germany before WWI.[26] Germany had great achievements in modern ceramics, particularly thanks to Hermann August Seger (1839-93), the recognized father of modern ceramics science, and Friedrich Eduard Hoffmann (1818–1900), who invented the most influential continuous kiln system, the Hoffmann Kiln, in 1858. Le Bœuf was confident that investment in a mature, low-tech industry in China was low-risk and likely to be profitable in meeting the growing demand of a changing system.

Ceramic manufacture, however, was a side activity of the CFEO, an opportunity to explore business prospects. The CFEO was part of the Belgian "informal empire" in Late-Qing and Republican China, which invested in the commercial, industrial, and financial sectors such as banking, railway, coal mining, steel, and real estate.[27] Founded in 1907 in Tianjin, the CFEO was a "société anonyme" registered in Belgium with branch offices in Shanghai (1909), Hankou and Hong Kong (1911), Beijing (1915), and Jinan (1918).[28] Apart from mortgage-guaranteed loans and financing for modern technology infrastructure (water supply, telephone, tramways, electricity, etc.), the CFEO's mission statement included construction works, architectural design, production of building materials, and all possible real estate activities. The company was flexible in seizing every opportunity for selling, loaning, building, and managing properties. When contracting a mortgage-loan for constructing a new building, the clients were expected to use the services of the CFEO's architects as well as the bricks and tiles produced by the factories of CFEO. In Shanghai, aside from the

24. CAMCFS - MCS, dossier U38-4-2667 / 721–6, pages SC017–22.

25. Seger, "The Lower Rhine and Belgian Brick Industry"; Stenvert, *Biografie van de baksteen*, 21, 73–76, 95–96, 113, 119, 193–94, 220, 244, 255–58. On export to China see Black, "Refractory and Other Ceramic Products," 21.

26. AGR, CFEO, 923: letter of Le Bœuf to O'Neill, 4 August 1925.

27. Jean-Marie Forchisse, *La Belgique et la Chine*.

28. AGR, CFEO, 8: historical notes, 1921-57; AGR, CFEO, 1-2, 4 and 302: statutes, article 3.

brick factory, the CFEO owned 57 buildings and contributed to the construction of hundreds of others. From 1927, the CFEO restricted its business to Shanghai, Tianjin, Hong Kong, and Singapore. After having suffered from the Japanese occupation of 1937–45 and the Chinese Civil War of 1945–49, the company put an end to its activities in China in 1953.

The beginnings of the MCS were reportedly difficult.[29] They bought a site for their factory in 1914 along Brenan Road in the Beixinjing area 北新泾 (present Changning Road 长宁路), an "Extra-Settlement roads" 越界筑路 area west to the then-International Settlement, which would soon become Shanghai's new industrial area.[30] The brick factory was accessible via a creek connecting to the Wusong River 吴淞江.[31] This location ensured the MCS both independence from the Settlements and efficient communication by road and water. World War I slowed the project; materials were ordered from the USA but arrived in Shanghai with considerable delays. Eventually, in 1921, the MCS arranged the manufacturing facilities and started production, including that of hollow bricks. By 1922, the manufacturing procedure was finally fixed after some technical adjustments.

Studies of Western brickmaking machines used in China are hard to come by. Often in the Chinese literature, Western machines and kilns are considered symbols of modern brick factories. By 1910 only hand-assist machines and steam machinery had been employed in some of the pioneering brickyards of China. The two earliest Shanghainese factories in Pudong installed Hoffmann kilns in 1897 and 1911, respectively, but they both shut down relatively soon thereafter. It seems that Chinese pioneers were not able to run these new technologies properly, although the precise problems they experienced remain unclear. In contrast, the two Hoffmann kilns established in the Belgian MCS brickyard became very successful.[32] By that date, the efficient Hoffmann Kiln system had spread over Belgium with new variants.[33] The MCS grasped probably the first success in utilizing Western facilities to manufacture European architectural ceramics in Shanghai.

The MCS factory was initially steam-powered and later electric-powered. Machines were obtained between 1914–21 and supplemented by a later investment in 1928–31. The factory was semi-automated: raw clay was transferred by iron wagons via an automatic conveyor from clay deposit into the molding room (see figure 4); unfired bricks were automati-

29. Fragmentary archives. AGR, CFEO, 837–39, 922–23, 1083–84.

30. In the *1934 Shanghai Directory of Factories*, the address of brickyard is specified as the Zhou-jia-qiao 周家橋 area at Brenan Road.

31. Customarily, the downstream of Wusong River after the Beixinjing area is called the Suzhou River.

32. Wang, *Shanghai Xian Zhi*.

33. David Johnson, "Friedrich Edouard Hoffmann," part 2, 25: "The so-called Belgian kiln (patented in 1891) is also essentially a Hoffmann except that the fire does not come into contact with the brick, thus giving less discoloration."

cally cut; and the new drying room built in 1929–30 was served with automatic wagon-ways (see figure 5). Automatic belts transported the shaped roof tiles.[34]

Brussels facilitated the MCS based on its global business network. A Corliss 200 HP steam engine, ordered from the USA, powered all the machines thanks to drive belts (see figure 6).[35] There were three molding machines: a Chambers extruder from Philadelphia US, for shaping tiles, purchased before 1921; a Griesemann extruder from Magdeburg, Germany, acquired in 1928 and mainly used for hollow bricks (see figure 7); and another Griesemann, a more powerful extruder, also used for molding hollow bricks and acquired in 1930.[36] A Lobin Druce, a French (?) machine probably purchased before 1921, was used as both crusher and thruster for preparing clay. An automatic wire-cutting machine (see figure 7, in front) was used since 1921, the same type of which was recorded in the Chinese magazine *Jian-zhu Yue-kan / The Builder* in 1935.[37] Furthermore, there were three roof tile presses, one French Pinette from Châlon-sur Saône and two Lobin, probably French machines as well. Electric-drive fans ventilated the kilns and the drying room. Furthermore, there was a water tower and a small bridge in the brickyard. The photos show a certain number of Chinese stores in local style as well as two "villas" in European style for the production manager, the Western technicians, and the offices.

Interestingly, the two Griesemann extruders for making hollow bricks were purchased "through Belgian Fathers," in all likelihood Shanghai's procurator of the Belgian Congregation of the Immaculate Heart of Mary, customarily called Scheut Fathers. The CFEO, indeed, was a Catholic-minded company and had close relationships with Belgian and French missionaries in Tianjin, Hong Kong, and Shanghai, who invested in real estate in the Concessions and generated cash for the mission.[38]

The Human Resources: Technical Staff in the MCS

Figure 8 shows the essential human resources and the hierarchy surrounding the manufacture of bricks and tiles (see figure 8). Both the MCT and the MCS were established by Louis Béra, a French navy officer with industrial skills. He organized the factories, bought the first machines, chose the initial clay pits, and started the sales. In particular, he designed

34. The 1931 photo album and other archival information helped us define the scope and nature of the facilities.

35. Steam engine fitted with rotary valves and variable valve timing, patented in 1849 by the American engineer George Henry Corliss from Providence, RI.

36. Willy Bender and Hans H. Börger, "A Short History of the Extruder," 125–26.

37. Yan-Gen Du, "Ying-zao Xue," 18–19, with an illustration.

38. AGR, CFEO, NA 2 – Joseph Cuvelier repository. About the CFEO's Catholic network, see Thomas Coomans and Puay-peng Ho, "Architectural Styles and Identities in Hong Kong."

the initial machinery system of MCS after having visited several factories in Europe (names not mentioned) and consulted technical references from Europe and the USA. From the archives, there is evidence that Bera's design ideas were based on standardization and efficiency.[39] From 1921, he was the director of the *Département des Briqueteries* but was dismissed in 1926 after the closing of MCT and the reorganization of MCS. Most important were the technical directors, successively Frans Van Reeth (1921–27) and Jean Graindorge (1929–35), both detailed further.

The MCS employed four other Western technicians: Émile Henry, an experienced French technician with a chemistry background, who moved to a Chinese brickyard at Suzhou (Soochow) in November 1922; François Sermon, a Belgian electrician responsible for the kilns, firing, and other mechanics, who worked at MCS from 1921 to March 1926 and then moved to a Chinese factory called *Da-Zhong*; Kostantin Koslenko, a Russian chief mechanic, in service from 1924 to 1932, and a certain Bowitz, probably a German, mentioned in 1933.[40] These practical persons played vital roles in the direct transmission of technologies. Other Western agents were involved in the accountancy of MCS and the sale of its products. One of them, Auguste Biévez, who had been appointed as accountant and stock manager, turned out to be a good organizer with technical insight. He seemed to have been promised more responsibility at MCS but was murdered by bandits in the factory on December 31, 1928.[41]

Frans Van Reeth was born in a brickyard owners' family from Boom, the most important brick production center in Belgium. When entering the service of the MCS in 1921, he defined himself as a "ceramic technician, professional manager of tile factories, brickyards, refractory products, and cement works." After a scientific education in mechanics, electricity, organic chemistry, and construction, he had gained a rich experience in several ceramics factories, including accountancy and a leading position as director of the *Briqueterie de Sirault et Saint-Ghislain*. Recommendation letters describe him as well acquainted with the manufacture of solid and hollow bricks, continuous kilns, circular kilns, and as having "solid practical knowledge, . . . thorough knowledge of the work of the earth and the problems associated with it (desiccation, efflorescence, etc.)."[42] At the MCS, Van Reeth was well aware of the technical part of the case, the

39. AGR, CFEO, 922–23: personal file L. Béra; AGR, CFEO 922, letter from L. Béra to H. Bourboulon, Directeur-Général de Chine, 9 March 1921; and letter and report of L. Béra to H. Le Bœuf, 8 August 1922.

40. AGR, CFEO, 1053: personal file É. Henry; AGR, CFEO, 1143–44: personal file F. Sermon; AGR, CFEO, 1067: personal file K. Koslenko; AGR, CFEO, 1039–40: letter of E. Molines, 1 May 1933, mentioning Bowitz.

41. AGR, CFEO, 928: personal file A. Biévez.

42. AGR, CFEO, 1164: personal file of Frans or Franz Van Reeth (°Boom 1885, +Shanghai 1927). He wrote two technical reports about a brick factory located in Sirault and a roof tile factory in Huppaye.

Shanghai market conditions, competition, and the possibility of selling the products according to quality, format, and size. In 1925, he proposed that Brussels' headquarters adjust the strategy of brick and tile making according to the Shanghai market.[43] After Béra's dismissal, Van Reeth headed the MCS but died in a motorcycle crash in Shanghai in 1927.

In April 1929, the CFEO appointed Jean Graindorge, who held a degree in chemistry from the University of Liège.[44] The skills mentioned in his CV include "technology, industrial drawing, accountancy cost price, English, basic German, and typing." He had previously worked at the *Briqueteries mécaniques de Welkenraedt* and the *Céramiques et Réfractaires d'Hergenrath*. After applying for the CFEO position, Graindorge passed a technical interview at the *Compagnie Industrielle du Rupel*, one of the largest Belgian brick and tile manufacturers. The interviewer reported his abilities precisely: clays and mixing; fabrication of bricks, hollow bricks, and firebricks; firing with Hoffmann kilns and grilling kilns; artificial drying; and mechanical practice fabrication of roof tiles. Before going to China, he was obliged to complete an internship at the *Tuileries du Progrès d'Hennuyères*. Graindorge's wages were high and his lifestyle expensive.[45] Finally, Graindorge managed the brickyard until the beginning of 1935, just before the collapse of Shanghai's building sector and the stop of the MCS production. Van Reeth and Graindorge's expert contributions to the MCS were inevitably shaped by the historical environment, including local labor and natural resources.

Chinese Workers in the MCS

A group photo, though damaged, shows the names and functions of the Chinese employees, including the leaders of the specialized team.46 Most have a Christian name, which suggests that they were in contact with Westerners and could communicate in English or French. Another group photo shows twenty-five Chinese employees and team leaders (see figure 9), unfortunately without mentioning their functions and names. Several working Chinese are also pictured with the machines; some are pushing a wagon or are coolies carrying clay. But the CFEO archives do not mention the number of employed workers or their wages. The sale of products also involved Chinese. The large group of Chinese workers itself is a statement that traditional know-how of brickmaking was available in the MCS.

43. AGR, CFEO, 922: Confidential note, Social seat, Brussels, 5 May 1925.

44. AGR, CFEO, 1039–40: personal file of Jean Octave Graindorge (°Seraing, 1889, + ?). Also: IBHEC, Association amicale sino-belge, *Liste des Belges résidant en Chine*, 1930–32.

45. AGR, CFEO, 1039–40: his monthly wages were of 6.825 Belgian francs (325 Shanghai Taels) during his first term (1929–31), and 9.450 Belgian francs during his second term (1932–35); he lived inside the urban region, and the company paid for his accommodation and the use of a car.

However, the Chinese knowledge of brickmaking was challenged by the Western manufacturing methods. According to the personnel documents in the Brussels archives, Chinese labor in the MCS mostly executed the basic work, while Westerners took full responsibility for the systematic managing, running, and maintenance of all the machines. In retrospect, this European source might have a colonial or racially chauvinistic attitude because our later story from Da-Zhong shows that there was at least one Chinese individual who gained his expertise with machines at MCS. Nevertheless, the knowledge and skills of managing Western equipment proved an inherent barrier to the Chinese brickmakers who came from traditional kilns, and it took time to adapt.

The MCS staff repeatedly mentioned that most Chinese workers did not work very carefully or efficiently with the machines, resulting in poor quality results. One staff member went so far as to claim that "the mediocrity of our products is due in part to the negligence of the workers."[47] Leaving aside the possibility of discriminatory rhetoric, the incompatibility between Chinese workers and Western machines is explainable on a technological basis. Brickmaking was not high-tech, and almost universally shared the same stages: preparation, tempering, molding, drying, and firing. But it was a challenge for Chinese workers shifting from the traditional system of empirical know-how and handwork to the modern system of accurate efficiency, control, and machinery. In traditional brickyards, high-quality products were guaranteed by meticulous attention and experienced skills based on good knowledge of the local clay and the punctual manipulating of firing in traditional kilns, with which the brickmakers were familiar. But the quantity was always limited. In modern manufacture, the powerful machinery and well-designed infrastructure were employed to obtain standard quality and huge quantity. It required powerful fuel, a sufficient supply of labor, and effective management as well as new, adjunct expertise (like electricity and chemistry) and the cooperation between them. To adapt to this modern manufacturing culture, Chinese workers needed time and resources and to acquire new knowledge.

Manufacturing: Modern Technology, Local Knowledge, and Competition

Hollow bricks were common in both Europe and China since ancient times. From the mid-nineteenth century, the extended use and production

46. AGR, CFEO, NA 2 – Joseph Cuvelier repository, 1931: "Tseu Anger, accountant cashier; Tsu François, general production and firing controller; Lu Johnson, chief warehouseman; Lob Georges, responsible for expedition; Pang André and Tsa Mathias, timekeepers; Chou Joseph, assistant accountant and typist; Yu Lianghong, comprador Ouang's delegate."

47. AGR, CFEO, 1039–40: letter of B. Guillaume, to Brussels headquarters, 15 March 1933; AGR, CFEO, NA 2 – Joseph Cuvelier repository, 1931: caption of picture 4 (both quotes, authors' translation).

of hollow bricks in Europe is well-documented in literature.[48] Hollow bricks, however, did not develop in modern China in the same way.

In nineteenth-century Britain, hollow bricks were formed using a tile-machine.[49] Henri-Jules Borie obtained a patent for his hollow brick in Paris in 1848, and in 1849 in London, the architect Henry Roberts received a patent for his design of two types of interlocked hollow bricks.[50] In 1850, Roberts' ideas were promoted by the *Society for Improving the Condition of the Laboring Classes*. They were soon used in construction of housing for the poor and appeared in the popular technical books.[51] Roberts' novel design for hollow bricks was employed at the 1851 Great Exhibition in London, and was praised: "[with hollow bricks] dryness, warmth, durability, security from fire, and deadening of sound, are obtained, as well as economy of construction to the extent, as compared with the cost of common brickwork, or at least 25 per cent."[52] The economic benefits were prioritized in nineteenth-century Britain, while in the twentieth century, the development of frame structures and building physics set new standards for the bricks. In Britain and the USA, the manufacture of hollow bricks increased greatly to meet the requirements of fire-proof partition-walls and floors in modern buildings from the late nineteenth century onwards.[53] Shanghai later embarked on this trend, thanks especially to high-rises.

Hollow bricks were automatically wire-cut at the MCS. The mechanical fabrication of hollow brick required clay and molding methods similar to tiles rather than to plain bricks. Extruding machines were employed and a "plastic shaping process" was used for tiles and hollow bricks throughout the production at the MCS. This method required drying before firing.[54]

48. Remarkably documented in: Charles Tomlinson, *Cyclopaedia*, vol. 2, 448–49. Later the content was completely cited in: Edward Dobson, *A Rudimentary Treatise*, 207–09 (12 editions). Updated documentation in: Searle, *Modern Brickmaking*, 412–17. See also *Official Descriptive and Illustrated Catalogue of the Great Exhibition*, vol. 2, 241–51, 774–75, 800; Henry Roberts, *The Dwellings*; Pierre Chabat and Félix Monmory, *La Brique et la Terre Cuite*, 447.

49. Tomlinson, *Cyclopaedia*, vol. 2., 448.

50. Roberts, *The Dwellings*, 24–25 and 30; S. Bleekrode, "De nieuwere bouwmaterialen."

51. Roberts, *The Dwellings*, 24–25 and 30. The purpose to serve the poor was again recommended in: *Official Descriptive and Illustrated Catalogue of the Great Exhibition*, vol. 2., 775; Tomlinson, *Cyclopaedia*, vol. 2, 448; Dobson, *A Rudimentary Treatise*, 207–209 (and later editions).

52. *Official Descriptive and Illustrated Catalogue*, vol. 2, 774. Economically, Roberts' design could obtain lightness of construction; required less clay and less drying; and was better burned with less fuel. It was also easy to cut or break off and could be perforated for the purpose of ventilation. Tomlinson, *Cyclopaedia*, vol. 1, 448–49; Searle, *Modern Brickmaking*, 412–17; Stenvert, *Biografie van de baksteen*, 96.

53. Jeremy C. Wells, "History of Structural Hollow Clay."

54. Andrea Bresciani, "Shaping in Ceramic Technology," classifies three main forming processes, according to the quantity of water in the ceramic bodies: 1. dry shaping, 2. plastic shaping, and 3. semi-liquid shaping.

The mechanic extrusion for hollow bricks was reported tricky to manage. For making plain bricks, the MCS might adopt the "dry shaping" method, also called the "stiff-plastic process," which was a popular modern method first used in nineteenth-century England. It shaped bricks directly from dry clay using pressing devices and could achieve high efficiency.[55] But this method required special preparation of raw clay and was alien to the Chinese, who were used to plastic methods. Later in the Chinese magazine *Jian-zhu Yue-kan / The Builder*, the extrusion operation via plastic shaping was called *Jian-ni-fa* 堅泥法, while the pressing operation via dry shaping was called *Gan-ya-fa* 乾壓法.[56] These two methods eventually became well-recognized by the Chinese.

From the early 1930s, Chinese brickyards successfully mimicked the products of MCS, which led to fierce competition between Chinese factories and the MCS between 1929-1933.[57] Drying infrastructure as well as the use of electricity and coke as new sources of powers became the most significant changes made to try to gain competitive advantage. In 1921, MCS introduced the first artificial drying infrastructure in Shanghai; it was used before firing bricks in kilns, and thus enhanced efficiency. In the Chinese brickyards, bricks had to be dried in natural air, a process which was often hindered by Shanghai's highly humid seasons (especially from June to August). In 1929–30, Graindorge established a new drying room, together with a new shed for dried clay and brick and tile molding machines. The new drying room consisted of fourteen parallel tunnels, each with six shelves that could be filled with wagons (see figure 5). The fans of the drying room were powered by electricity, with a big "Shanghai Power Cycle" (SPC) transformer. Graindorge also installed a coke stove (*calorifère*) with a fan that only worked in winter to prevent potential accidents from frost and to maintain a proper temperature in the tunnels of the kiln. This ensured the production of bricks and tiles during winter, when Chinese brickyards had to stop production.[58]

These improvements stimulated *Dah Chung Tile & Brick Manufacture Works* 大中磚瓦廠 (pinyin: *Da-Zhong Zhuan Wa Chang*, further Da-Zhong), the strongest competitor of the MCS. In 1931, Da-Zhong equipped a new huge Hoffmann kiln of 34 wickets with a drying room, but only for tiles. The Da-Zhong drying room combined natural ventilation with the

55. Searle, *Modern Brickmaking*, 68–176; Herman A. Seger, "Manufacture of Bricks in England," esp. 794-803; *Stone, Brick, Concrete*, 44; Susan B. Broeksmit and Anne T. Sulliven, "Dry-Press Brick"; Leighou, *Chemistry of Engineering Materials*, 456.

56. Du, "Ying-zao Xue," 17.

57. Jiang, *Shanghai Jian-zhu Cai-liao Gong-ye Zhi*, 129-30.

58. In 1926, H. Le Bœuf suggested to A. Biévez that "MCS should conserve a small boiler for producing steam used for the tunnel dryers (*aéro-condenseurs*). By heating the drying rooms, the steam could save all the products from frost during the winter." The method of heating installed by Graindorge, however, was different. AGR, CFEO, 927: interview A. Biévez by H. Le Bœuf, 29 June 1926.

heat from the kiln; this smart innovation that recycled the heat from the kiln seems to have inspired Graindorge. Later in 1933, Graindorge developed a sustainable system for the MCS drying room also by recycling the heat from the kilns to save coke and steam.[59] For making bricks, Chinese factories started to utilize the recycling system as late as 1957, and this became popular from 1971 onwards. The MCS also introduced electric power, which saved considerably in their costs.[60] In 1929, the drying room established by Graindorge used an electric motor, which was an innovative installation in Shanghai's brickyards. Again, Da-Zhong followed suit. By 1949, it was the only electric-powered, Chinese-owned brickyard in Shanghai.

Competition reached its peak in the years 1931–33, in part because two MCS technicians job-hopped to Da-Zhong. The Chinese factories were then able to produce hollow bricks and roof tiles of equal quality to but at lower prices than those at MCS.[61] The fierce competition between the Belgian forerunner MCS and the Chinese followers, especially the Da-Zhong factory, forced both sides to improve technology. They "jointly"—maybe not their initial purpose but the *fait accompli*—enhanced the infrastructure for brick manufacturing in modern Shanghai, forming the base of the successive progress made afterwards. This was not simply a one-way transmission or a linear localization of exotic technology, but a truly joint development in which the Chinese played a significant role.

Serious worries continuously accompanied the MCS. The inside view from the CFEO archives contrasts with Chinese materials that cite MCS as a successful and powerful pioneer in the modern brick industry. In 1925–26, the CFEO trustees seriously considered stopping production to prevent further losses. The Brussels director Le Bœuf realized the deep gaps between Western tools, Western ambition, and the local practices in China.

> Our equipment is magnificent, but I have to admit that it was designed based on prospects of profits that can never be achieved. . . . I am afraid that we have spent without counting, without paying enough attention to performance: lack or inability of foresight.[62]

In a report, Béra discloses that the automatic cutter machine "Chambers," for instance, got many complaints from the staff.[63] Biévez stated the conflicts between Shanghai's clays and the "Chambers":

59. AGR, CFEO, 1039–40: letter of E. Molines to Brussels headquarters, 1 May 1933 (authors' translation).

60. AGR, CFEO, 927: interview of A. Biévez by H. Le Bœuf, 29 June 1926 (authors' translation).

61. AGR, CFEO, 1039–40: letter of B. Guillaume to Brussels headquarters, 15 February 1933 (authors' translation).

62. AGR, CFEO, 923: letter of Le Bœuf to O'Neill, Brussels, 4 August 1925.

63. AGR, CFEO, 923: critique of Th. Blak's report by M. Béra M. Béra, 1926.

> If the clay is wet, the clay at the outlet of the stretcher will advance continuously, deforming itself to the cutter, hence an inequality in the width and length of the brick. . . . With our automatic cutter the cut of our brick is never regular, either because the clay is too wet or too dry, and is rarely straight due to the front-back movement of the cutter.[64]

To understand the nature of clay is important in the pottery industry. In practice, Chinese brickmakers had extensive traditional knowledge of local clays and had the ability to prepare them properly for all kinds of bricks and tiles, including European-style red bricks. According to the technical literature, the characteristics of clay often determined the brickmaking methods and the machines to adopt. Yet it was very tricky to decide in practice how to proceed because the same press machine or extruder could work well for one type of clay but encounter difficulty with another; even in modern Western factories, the preparation of clay largely depended on empirical knowledge until the specialized sciences like sedimentary geology, clay mineralogy, and geochemistry developed deeper understanding of clays.[65] By 1925, in Europe, to understand a new clay, mineralogical and chemical analyses were often adopted, while in China, such scientific studies for brick clays was yet to be established.

Clay was always a problem for the MCS. The character of Shanghai's climate and clay sources were not taken enough into account in the initial design of the MCS. The CFEO gained its first Chinese experience of ceramic making in Tianjin, where both the climate and the clay were very different from that in Shanghai. The alluvial clays in Shanghai areas did not work well with the quite advanced "dry shaping method" developed in Europe and equipped by Béra in Shanghai in 1921.[66] In May 1922, a drying tube was bought and installed, and a drying hall for clay was built to make the clay suitable for the adopted "dry shaping method," but these attempted solutions proved insufficient. The diverse origins of the clays purchased by the MCS were frequently blamed for production problems, as for example when a bad clay mixture with particles of intermixed lime created serious defects in production for four months in 1925.[67] Moreover, when temporary accidents stopped the disintegrator machine, the Chinese

64. AGR, CFEO, 927: interview of A. Biévez by H. Le Bœuf, 29 June 1926 (authors' translation). Answer to: "Why are our products bad?"

65. Harris, *The Science of Brickmaking*; Searle, *Modern Brickmaking*, 68–176; Searle, *Clays*; Searle, *The Chemistry and Physics of Clays*; Bresciani, "Shaping in Ceramic Technology"; Ansel C. Dunham, "Mineralogy of Brick-Making"; Paul E. Potter, J. Barry Maynard and Pedro J. Depetris, *Mud and Mudstones*, 4-5.

66. AGR, CFEO, 923: letter of H. Le Bœuf to J. O'Neill, 4 August 1925.

67. AGR, CFEO, 927: interview of A. Biévez by H. Le Bœuf, 29 June 1926; AGR, CFEO, 923: letter of H. Le Bœuf to J. O'Neill, 4 August 1925; AGR, CFEO, 923: critique of Th. Blake's report by M. Béra, 1926.

workers were still able to prepare an excellent clay mixture to ensure the production.[68]

In 1926–28, the CFEO reconstructed its ceramic business. It sold the Tianjin brickyard in January 1926 at a great profit. In 1927–28, to improve the competitiveness of the MCS in Shanghai, Brussels dismissed the former French navy officer Béra, appointed a new technical director Graindorge, and installed advanced machinery. Their new strategy was to improve quality instead of quantity, mainly focusing on hollow bricks and pressed roof tiles. The products of the MCS were publicized in the local Chinese magazine *Jian-zhu Yue-kan / The Builder* from 1932 to 1934 with precise dimensions yet were juxtaposed against Chinese competitors' much stronger advertising.[69]

Inconsistent product quality troubled the MCS in its competition with Chinese factories:

> If we take into account the cost of our brickyard both for its first establishment and its recent transformation, our products are obviously not what we expected. The tiles have a high percentage of cracks—if not, they do not have a clear appearance: defects, sometimes overcooked, sometimes undercooked, various color and rarely very red. The hollow bricks are good, but there is too much wastage. . . . Can we hope to compete with Chinese factories by selling cheaper? This is impossible. The only solution I see is to make better products, and we should be able to do that. I repeated to Mr. Graindorge: "Produce less, if necessary, but of the highest quality."[70] Why could the MCS not produce bricks and roof tiles of the expected qualities?

Graindorge ascribed it mainly to the varied origins of raw clay. The CFEO did not own any pits and purchased clay from different places, often located far away from each other. Clay was shipped by sampan to the creek, then carried by coolies to an open-air storage field flanked with a shed for storing the dried clay. Afterwards, the clay was taken in small wagons into the factory building and placed on an inclined, roofed conveyor. According to Béra's design in 1922, the raw materials were categorized as: 1. plastic clay; 2. semi-plastic clay; 3. clay sand; 4. brick waste; 5. tile waste. The quarry clays in the groups 1, 2, and 3 were carefully disintegrated and mixed according to different standard formulas for bricks or tiles.[71] This

68. AGR, CFEO, 923: critique of Th. Black's report by M. Béra, 1926.

69. MCS products: *Jian-zhu Yue-kan / The Builder*, v.1/ n.1 (November 1932): 58. Advertisements: *Jian-zhu Yue-kan / The Builder*, v.1/ n.8 (June 1933), v.1/ n.9–10 (August 1933), v.1/ n.11 (September 1933), v.1/ n.12 (October 1933); v.2/ n.1 (January 1934).

70. AGR, CFEO, 1039–40: letter of B. Guillaume to Brussels headquarters, 5 March 1933 (authors' translation).

71. AGR, CFEO, 922: letter from L. Béra to to Brussels headquarters, 8 August 1922,

standardized reconstruction of clay mixture aimed to produce standard qualities in products and efficiency in production, but was not so effective for the MCS, partially because of the lack of knowledge of local clays.

To improve quality, the MCS arranged scientific investigation, frequent analyses, and experiments to control the products, including hollow bricks. Graindorge, thanks to his chemical knowledge and practical experience, decided to classify the clays according to their origins and then analyze and mix them to reach an almost identical composition. Technical discussions were held with the Brussels headquarters concerning the properties of the clay acquired from different Shanghai pits and the loss of weight after firing; different cost prices were evaluated as well. The analysis of samples in Shanghai confirmed a loss of 21% to 33% by weight according to the products, instead of 50% roughly evaluated in the cost price.[72] The weight could vary according to the clay's origin and humidity, which could both affect the density. At the end of 1932, Graindorge decided to select clay from a single origin, the surroundings of Yakiten (Shanghainese, presently Yu-ji-dun 虞姬墩), and obtained a constant density of about 1,25 (specific gravity). The director of the Shanghai CFEO office concluded optimistically later in May 1933:

> I must admit that I see a remarkable improvement in manufacturing. Our hollow bricks are beautiful products, our new tiles are good and sell well. . . . If the manufacture continues to be regular as it is now, I shall be satisfied. The . . . order I have in mind is for a building to be built on Broadway Road [present Da-ming Lu 大名路]. We were able to tell that the samples supplied by the Pootung brick factory [that is Da-Zhong factory, discussed later] to the Shanghai Land Investment Company, who owns this building, actually came from our brick factory.[73]

Why did the Chinese manufacturer cheat the customer by providing samples that actually came from MCS? This was probably related to the standardized way the MCS controlled the quality of bricks, from the formulas for clay mixture to the analytical tests of the final products. These admirable working methods might embarrass the Chinese brickmakers,

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appendix about the modification of the clay alimentation system of the two groups of machines. On process and transportation, see: AGR, CFEO, NA 2 – Joseph Cuvelier repository, 1931: caption of pictures 8, 9, 10, 15.

72. AGR, CFEO, 837: letter of J. Baillieux, CFEO's director, 23 November 1932; and Graindorge's answer, 17 January 1933. Tests on 12 full bricks: loss of 28,35% (40,2 kg at the exit of the molder and 28,8 kg after firing); 6 hollow 1 bricks: 28% (19,2 kg and 13,8 kg); 6 hollow 10 bricks: 33,45% (54,1 kg and 36 kg); 12 tiles: 21% (48,6 and 39). It is said that later, the Chinese factory *Zhensu* could reach the loss of 49.6% and 57% by volume in certain types of hollow bricks (Jiang, *Shang-hai Jian-zhu Cai-liao Gong-ye Zhi*, 125).

73. AGR, CFEO, 1039–40: letter of E. Molines to Brussels headquarters, 1 May 1933 (authors' translation).

who thus had little confidence that their products would measure up, despite their reasonably good quality. The Western standards and methods of quality control constituted a language system built on the modern sciences and the engineering culture. The Chinese brickmakers were struggling with accurate, scientific Western languages to communicate their expertise and control the production. Building a modern brick and tile industry required more than machinery. A new science of ceramics would be established in China later but was unknown to most Chinese in the 1930s.

The Shrinking Market, the Rising Da-Zhong

Selling bricks was not easy for the MCS. In 1926, Biévez mentioned that hollow brick was "unsellable" and had "zero market" in Shanghai.[74] In retrospect, this is probably because at that time, the high-rise building—the most competitive application of hollow brick—had just begun its heyday, and the benefit of hollow bricks was not yet well recognized. In 1926, the MCS was still the only producer of hollow bricks in Shanghai, but the market would soon evolve. In 1931, a Chinese factory started producing hollow bricks, too, learning from the MCS. Soon, new capital, either foreign or Chinese, was invested in more avant-garde, lightweight materials like ALC—autoclaved lightweight concrete (1932)—and hollow cinder bricks (1934), both of which were immediately loved by architects. Cement brick, face brick, and glazed brick boomed in the market as well. MCS could not be complacent.

The sales of the CFEO largely depended on foreign customers. It also appointed a Chinese sale agent or "comprador." So, from August 1925, the MCS worked with a certain Paul Tchang and then by mid-1933, worked with a certain B. Ouan. After mid-1933, the real-estate developer Moeller & Co. (懋賚地産公司) was chosen as general agent and then as "sole agent."[75] Compradors and agents caught the trends of the market by consulting the demands of building permits at the administrations of the Chinese City, the International Settlement, and the French Concession. They maintained good social networks with real estate investors, architects, contractors, and builders. These particular trade chains and lobbying agents might have helped the CFEO to avoid the Chinese consumers' National Products Movement in the twenties and thirties, which had affected other industries like clothing fabrics.[76]

74. AGR, CFEO, 927: interview of A. Biévez by H. Le Bœuf, 29 June 1926.

75. AGR, CFEO, 923: critique of Th. Black's report by M. Béra. 1926, II; AGR, CFEO, 923: letter of Le Bœuf to O'Neill, 4 August 1925; AGR, CFEO, 927: interview of A. Biévez by Le Bœuf, 29 June 1926; AGR, CFEO, 1155: personal file Paul Tchang; AGR, CFEO, 1116: personal file B.I.C. Ouan; AGR, CFEO, 1039–40: letter of E. Molines to Brussels direction, 1 May 1931. Advertisements: *Jian-zhu Yue-kan / The Builder*, 1/8, 1/9–10, 1/11, 1/12 and 2/1.

76. Karl Gerth, *China Made,* esp. 68–124.

The number one competitor of the MCS was the Chinese manufacturer *Da-Zhong* (full name *Dah Chung Tile & Brick Manufacture Works* 大中磚瓦廠), established in the Nanhui area of Pootong (Pudong), Shanghai in 1930. It was a remarkable actor in the local history of the ceramic industry. The Brussels archives repeatedly mention this factory (termed "Dah Chung" or "the Pootung brick factory") because Da-Zhong achieved the capacity to manufacture similar products as those of MCS, including plain bricks, hollow bricks, and tiles of equal or even higher quality. The MCS thus lost its monopoly on hollow bricks and, even earlier, on solid red bricks. Da-Zhong's first advertisement in *Jian-zhu Yue-kan / The Builder* (January 1933) proudly announced that it employed specialists and the newest German machines, publicizing the types, forms, and the architectural application of its products. Three years later in April 1936, a new advertisement appeared in Shanghai's the first-ever China Architecture Exhibition, including a table of compressive stress data of Da-Zhong products, that declared the quality of Da-Zhong's products in scientific language (see figure 10 in comparison).

Da-Zhong, however, had problems with making hollow bricks in its early years. In 1931, two technicians who previously worked for MCS joined Da-Zhong and obviously brought technical knowledge with them: first, Xu Zhi-Fang 许志芳; second, a certain "Belgian engineer 山尔蒙" (Pinyin: *Shan-er-meng*; Shanghainese: *Seiermon*), who was in all likelihood François Sermon.[77] At Da-Zhong, both worked together on the molding of hollow bricks. Sermon, as we have seen, was not an engineer but an electrician, who had been "chef monteur" and "chef de service des machines" at MCS from 1921 to 1926 and had developed strong knowledge of all the details of the manufacturing equipment.[78] His monthly salary at Da-Zhong was 400 Shanghai Taels, even higher than that of MCS director Graindorge.

For Da-Zhong in 1931, using extruder machines to mold hollow bricks was still a challenge. Chinese staff, indeed, still lacked good skills in managing Western facilities. Therefore, an electrician with a strong capacity for managing machines was a critical human resource. Modern industry was approaching an integrated system based on different special technologies, including the use of new power sources like electricity. Technically, the

77. About Xu: Jin-Bing Zhu, *Hang-tou Gong-she*. Zhu Jing-Bin 朱锦冰 (1907–2001), a nephew of Zhu Hongqi 朱鸿圻 (the founder of Da-Zhong factory), calls Xu Zhi-Fang "engineer," but we have not found any evidence about his engineering education, including in the MCS archives. About Sermon: Zhu, *Hang-tou Gong-she*; Jiang, *Shanghai Jian-zhu Cai-liao Gong-ye Zhi*.

78. Sermon's work at Da-Zhong is not mentioned in the CFEO archives (AGR, CFEO, 1143–1144). Lists of expats mention him at the "Garage Anglo-Belge" in Shanghai in 1926 and at the "Cie de tramways et d'éclairage de Tientsin" in 1944. Brussels, IBHEC, Association amicale sino-belge, *Liste des Belges résidant en Chine*, 1926, 31; 1930, 25; 1932, 26; 1944, 21. According to his CFEO curriculum, he spoke French, Dutch, German, Russian, a little English, and Shanghainese.

making of hollow brick greatly depended on powerful extruders. That is why the MCS updated its old Griesemann machine acquired in 1928 with a more powerful one in 1930. Da-Zhong also adopted electricity to power its machines and so became the first Chinese brick factory to use electricity in Shanghai and remained the only one until 1949. In the fall of 1931, Da-Zhong started to sell its own hollow bricks and tiles, which both had characteristics different from those of its competitor's products.[79]

Da-Zhong initially inherited the modern system and the spirit of machinery manufacturing from the MCS. Gradually, Da-Zhong developed more independently. By 1936, it had started a novel line of coal-cinder bricks, which the MCS did not attempt. The products of Da-Zhong were applied to Broadway Mansions (1930–34, 21 storeys), the Joint Savings Society Building (1930–34, 22 storeys), Hamilton House (1931–33, 14 storeys), the new Department Store of Yong'an Company (1930–33, 22 storeys), etc., and even reached Singapore and other Southeast Asian countries. After 1949, Da-Zhong became state-owned and generated remarkable innovations, including developing hollow bricks from non-load-bearing into load-bearing material. After an experimental stage in 1960–65 with contributions from different institutions in China, in 1966, Da-Zhong turned its production lines entirely to load-bearing hollow brick, becoming the number one manufacturer of all kinds of hollow bricks, including perforated bricks (a variation of hollow brick) in Shanghai.[80] It developed glass production, too, but ceased all activities in the 1990s when national policies pushed clay-based bricks out of the industry in order to protect agricultural land in China.[81]

In 1933, Graindorge ascribed the decline of the MCS to the high production costs and the unsold brick stocks of inconsistent quality (inconsistencies that were caused by the supply of clay).[82] There were other factors. At that time, the Chinese-owned factories were maturing, utilizing Western methods to produce highly-qualified modern bricks, while traditional kilns continuously made articles of low cost to satisfy the middle-low market. Meanwhile, newly-trendy types of bricks were competitively transforming the middle-high market.

In a letter dated June 1935, the Shanghai director of the CFEO described the sudden collapse of the flourishing Shanghai market.[83] In July 1935, the CFEO decided to stop production. Afterwards, the machines and the kilns were maintained, and the stocks were used for CFEO's other con-

79. Jiang, *Shanghai Jian-zhu Cai-liao Gong-ye Zhi*; Zhu, *Hang-tou Gong-she*.

80. Jiang, *Shang-hai Jian-zhu Cai-liao Gong-ye Zhi*, 125 and 132; *Zhong-guo Jian-zhu Zhan-lan Hui*, the advertisement of Da-Zhong.

81. Personal interview of the local life-time brickmakers, 2015.

82. AGR, CFEO, 1039–40: internal report of B. Guillaume, mentioning J. Graindorge, to Brussels headquarters, 15 February 1933.

83. AGR, CFEO, 1039–40: letter of E. Molines to J. Graindorge, then in Belgium, 11 June 1935.

struction and repair works. The French architect Guy Derevoge, head of the CFEO's architecture bureau of Shanghai, supervised this reduced business and controlled the site during the war. In 1946, the CFEO sold the grounds of the former brick factory at a considerable profit.[84]

Calling for Ceramics Engineering

The modern ceramic industry in China was greatly driven by the considerable demands for new architectural and engineering materials for construction; the sources and resources of the science largely came from different engineering fields outside ceramics. Laboratory methods, the shared approach in all kinds of engineering, became the backbone of this new science and modernized the studies of ancient Chinese porcelain and pottery in the same way.

In China, studies of ceramic production with laboratory methods were first pushed by the steel and coal industries, and the earliest laboratory in colliery was established by 1906 at the latest.[85] After the fall of the Qing Empire (1911), there was a noticeable rise of industrial laboratories (Gong-ye Shi-yan Suo 工業試驗所). They largely engaged in ceramic studies and even established Ceramic Departments (Yao Ye Ke 窯業科). Meanwhile, the increasing communities and networks of engineers, either foreigners or Chinese, rendered a new, powerful culture in China, thanks to the local engineering education that began from the 1870s onwards.[86] Engineers, with support from industries, governments, and universities, eagerly invested in modern labs and undertook analyses to improve ceramic materials. It became a trend to submit materials to labs for tests, yet some analyses were limited; others still depended on overseas labs when necessary.[87]

In 1921, the Chinese magazine "Science 科學" published an article calling for scientific perspectives and research methods to improve the changing Chinese ceramics industry generally.[88] In 1922–25, Pei Yang University

84. AGR, CFEO, 837: letter dated 13 June 1936, mentions houses at Jessfield Road, present Wan Hang Du Lu 万航渡路; AGR, CFEO, 991-992: personal file G. Derevoge. Jiang, *Shanghai Jian-zhu Cai-liao Gong-ye Zhi*, erroneously mentions that the CFEO sold the factory and the land at the price of 1.2 M Yuan in 1936 (instead of 1946).

85. Shu and Fang, "Fire Brick."

86. Shu-Tian Li, "Engineering Education in China"; *Journal of the Association of Chinese and American Engineers*, 1-21 (1920-40); *Shanghai Society of Engineers and Architects. Proceedings of the Society and Report of the Council* 1-12 (1901-13); continued as *The Engineering Society of China. Proceedings of the Society and Report of the Council* 13-37 (1913-39).

87. Zhi-li Gong-ye Shi-yan Suo, *Industrial Laboratory*; Shan-dong Gong-ye Shi-yan Suo, *Industrial Laboratory*; Shanghai Shi She-hui Ju Gong-ye Wu-pin Shi-yan Suo, *Industrial Laboratory*; Jing-ji Bu Zhong-yang Gong-ye Shi-yan Suo, *Industrial Laboratory*; Liu-Quan Gu, *Industrial Laboratory*. For overseas analyses, see KMA 1931.

88. Jin Wang, "Zhong-guo Gu-dai Tao-ye zhi Ke-xue Guan."

in Tianjin 北洋大學 and Nan Yang College in Shanghai 上海南洋大學—two of the earliest Chinese engineering colleges—ran the first series of analytical tests for brick materials within the Chinese university context. The tests were conducted by the Engineering Materials Laboratory of Pei Yang University and the Material Test Committee of the Chinese Engineering Society 中國工程學學會材料試驗委員會, respectively. They investigated the properties of bricks (and other engineering materials) and their behavior in masonry structures, comparing Chinese kiln bricks with those produced by Western methods. Representative brick samples from different places of China—modern and ancient periods—were tested. Both American and Chinese engineers engaged in the work. The investigation in Tianjin was urged by the Ministry of Communications and the Railway Department of China.[89] In Shanghai, the investigation was led by Ling Hong-Xun 淩鴻勛 (1894–1981), a notable railway engineer trained in China and the USA. The result, unexpectedly, revealed broad inferiority in industrially-processed red bricks compared to the blue bricks made in ancient times. This disappointing data made Ling and his Chinese colleagues doubt the well-assumed "progress" of technology, ascribing inferiority to the poor standards of the modern manufacturing system.[90]

These doubts, however, did not deter engineers from forging ahead with their sciences, and they soon applied similar methods to Chinese porcelain. In 1930, the National Ceramic Laboratory 中央陶瓷試驗場 published its first-ever report on Chinese porcelain in Shanghai (see figure 11); the laboratory was jointly organized by the National Research Institute of Engineering at the Academia Sinica and the College of Engineering at the National Central University. One year later, driven by the same scientific spirit, the National Research Institute of Chemistry at the Academia Sinica also published a preliminary survey of the famous pottery industry of Yixing 宜兴 in East China (see figure 12).[91] The laboratory approach to different types of ceramics started to be institutionalized at the academic level.

By 1933, as the MCS story shows, mechanical and physical data from laboratory analyses had become basic indicators in controlling brick properties and in decision making for contracts. From today's perspective, however, these data were not enough to indicate the brick properties without chemical or mineralogical analysis. The modern methods, tools, and theories would become the language of Chinese brickmakers, too. At the initial stage, this was obviously tricky—we have mentioned how in 1933 the Da-Zhong factory even tried to cheat clients by submitting the samples from the MCS—but in retrospect, this forecasted the birth of ceramics engineering in China.

89. Joseph H. Ehlers, "Chinese Engineering Materials."

90. Ling, Yang and Shi. "Zhuan-tou Shi-yan"; Ling, "Lei-feng-ta Zhuan-tou Shi-yan Bao-gao"; Hong-Xun Ling, *The Oral Biography*.

91. Academia Sinica, *First Report*; Jin Wang and Da-Gang Liu, *A Preliminary Chemical Survey of the Pottery Industry of Ihing*.

In 1936, the national magazine *Engineering Weekly* 工程週刊, funded by the Chinese Engineering Society at Shanghai, published an urgent call to establish the discipline of "Ceramics Engineering" in the higher education system of China. The author, Ren Guo-Chang 任國常 (1901–91), was a pioneer electrical engineer in China. He criticized the modern fall of the traditional Jingdezhen 景德镇 ceramic industry and envisaged a new framework of ceramics engineering consisting of seven categories: 1. building materials including all kinds of bricks and tiles, 2. refractory materials, 3. pottery and porcelain wares, 4. glass, 5. enamels, 6. emery, 7. cement and lime. Ren stated that by 1936, there had been no higher education in ceramics in China, and in total fewer than twenty Chinese students had been overseas to study modern ceramics. This greatly restricted the development of the silicate industry, in which many Chinese factories were already involved. "Therefore, there is no time to delay, the discipline of Ceramics Engineering should aim at building professionals for the practical production and the industry, on the one hand, on the other focusing on scientific, theoretic studies."[92]

In 1939–41, several Chinese academic theses on the brick industry were finalized.[93] The researchers came from civil engineering, architectural engineering, and chemistry. Their research was mainly based on foreign references, including the work of their American supervisors and the American Ceramic Society. The works showed a completely new approach to brickmaking in China. In this new context, clay was no more a material handily taken from agricultural fields and brickmaking was no more the technology between natural clays and hands. Instead, clays and bricks became industrial materials, mineralogical and engineering objects depending on machines and the language of analytical science. In 1945, the Chinese Ceramic Society was established. The subsequent development of ceramics in China can be traced in the Society's official journal.[94]

Conclusion

China's transition to modern architectural ceramics in the late-nineteenth and twentieth centuries was a proactive process to acquire Western technology. Mechanization was introduced to China's brickmaking industry as a symbol of modernity from the very beginning, unlike in the USA, where it was adopted for labor-saving reasons.[95] The enthusiasm for new

92. Guo-Chang Ren, "Yao-ye Gong-cheng," 55–56 (authors' translation).

93. Tung-Nien Lee, "Zhuan Gong"; Shih-I Hsu and Chin-Chi'ih Li, "Guo-huo Zhuan"; His-Ch'en Li, "Zhuan yu Hui-jiang Zhi Yan-jiu"; Dai Chen, "Yong Hua-bei Sui-shi-zhuang Huo-tu Zhi-zao Nai-huo-zhuan zhi Yan-jiu."

94. Chinese Ceramic Society, *Gui Suan Yan* 硅酸盐, commenced in March 1957; it has continued as *Gui Suan Yan Xue Bao* 硅酸盐学报 / *Journal of the Chinese Silicate Society* (quarterly) since February 1962.

95. Holley, "The Mechanization of Brickmaking," 89.

sciences and technologies, especially among the Chinese industrialists and engineers, encompassed the overwhelming belief in the superiority of Western technology. Even under the consumers' National Products Movement, Chinese-owned modern factories all processed brick and tile products in Western technology to different extents on the basis of practicability.

The common characteristics of industrialization, e.g., the use of machinery, standardization, and production efficiency, were all on display in the MCS in Shanghai. The Belgian CFEO, however, made its profits in China mostly from real estate speculation, not ceramics manufacturing. This was partly due to the considerable supply of inexpensive materials from traditional Chinese brickyards and the simultaneous maturation of modern Chinese factories that were able to produce qualified novel architectural ceramics mimicking European types. The real contribution of the CFEO is that it introduced into China a complete industrial system for making ceramics and trained Chinese brickmakers from traditional kilns at the crucial moment when the local brick and tile industry was struggling with increasing tensions between growing market demands and the difficulties of adapting to Western manufacture. Moreover, the CFEO's broad construction activities set up models for using new architectural ceramics in China. In particular, the MCS hollow brick (1921–35) greatly favored new construction methods—reinforced concrete skeleton with infilling lightweight materials—at its earliest phase, and boosted Shanghai's heyday of high-rise buildings. This hollow brick story is very different from, for instance, Victorian Britain, where the development of modern hollow bricks were initially aimed at improving housing stock for the poor.[96] Afterwards, hollow brick technology was taken up by the Chinese, who further developed hollow bricks from non-load-bearing to load-bearing material in the 1960s. In the process, the Chinese construction sector took up the reinforced concrete skeleton as a dominant method for construction in the second half of the twentieth century, leaving considerable architectural legacies.

These ends were achieved through a broad cross-disciplinary dialogue. Appeals from architects, builders, civil and railway engineers, mechanical and electrical engineers, and chemical and geological engineers—all outside the ceramic field—directed the modernization of Chinese ceramics. This kind of inter-field complexity has not yet been well recognized or studied.

China's modern changes in ceramic technology need to be understood as an integral part of the systematic shift towards Western science and technology, not merely a history of a particular technology/(sub-)discipline. The modern move started with new requirements from the diverse engineering and architectural practices outlined in this article, with indus-

96. Roberts, *The Dwellings*, 24–25 and 30. The purpose, to serve the poor, was again recommended in: *Official Descriptive and Illustrated Catalogue of the Great Exhibition*, vol. 2, 775; Tomlinson, *Cyclopaedia*, vol. 2, 448; Dobson, *A Rudimentary Treatise*, 207–209 (and later editions).

trial innovations preceding scientific, theoretical studies. In the 1920s–30s, engineering sciences helped to improve the industrial production of bricks by pursuing standardization and scientific quality control. Laboratory methods constituted a common approach to acquiring new, institutional knowledge in engineering sciences of all sorts, and by the 1930s were applied not only to modern ceramics but also to ancient Chinese porcelain and pottery. The new science of ceramics engineering was established in China soon after. This modern transition turned out to be a paradigmatic reconstruction of knowledge from Oriental craftsmanship based on agriculture and elite culture to Western industry based on modern sciences and mass production, with interactions between the two systems. In the long run, the Chinese did attain new expertise and did achieve higher productivity in developing a modern industry. Western ceramic technologies were subject to deeper innovations in China, but at the same time, there has been an inevitable loss of traditional Chinese technology in the process.

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