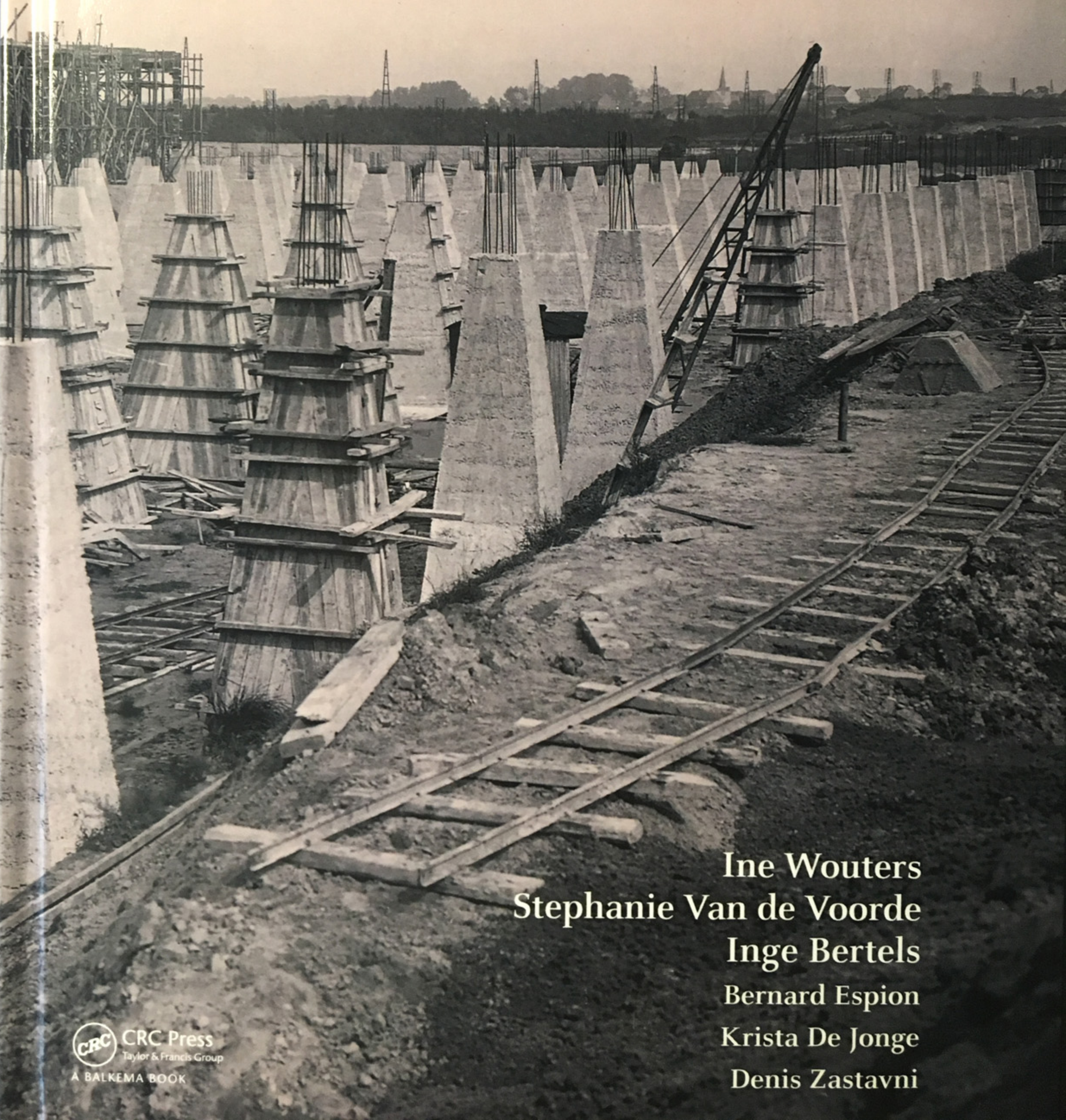
Building Knowledge, Constructing Histories

Volume 2



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Fire brick in China: From mining to architecture

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ABSTRACT: Focusing on fire brick, an industry-based approach is adopted to address the development of refractory material in China. Fire brick was introduced into China in the mid-nineteenth century and stimulated wide application in modern structures afterwards, but it has received very little attention from historians. The study largely depends on different archival materials, rare books, and fieldwork. It reveals, for the first time, that fire brick was locally produced in China starting from the turn of the twentieth century, and that the development pioneered the path to modern ceramics in China thanks to coal mines and industrial constructions. The research opens a broad historical picture of knowledge circulation between Asia, Europe, and the USA, and exposes the scientific value in the historical materials today. It draws further conclusions regarding China's modern shift from traditional to western brickmaking system, as discussed in 5ICCH.

1 INTRODUCTION

Fire bricks, made from fire clay, had been seemingly never used in ancient China. The annually published statistics in the maritime customs archival collection "Returns of Trade at the Treaty Ports in China", for the years 1859-82, show that both fire brick and fire clay were imported into China from foreign countries from the year 1864 at latest (Table 1). The applications of those imported fire brick / fire clay are unknown. The same archives also show, in contrast, that China largely exported all kinds of traditional ceramic materials including native bricks, pottery, china ware, and earthen ware to foreign countries. The contrast rises big questions: how was the novel technology — the production and use of fire bricks— circulated into China? Why had the country to rely on foreign fire bricks despite its high ability in producing other ceramics? What has been the legacy of the new material? Very little has been said about fire bricks in terms of these questions, either in the field of construction or ceramics.

To study the issue, the authors have conducted a survey in related archives, rare science books, periodicals, and other published or unpublished technical materials throughout the nineteenth and twentieth centuries. For the early-time situation of producing fire bricks in China one should turn to western sources; the Chinese materials about fire bricks exhibit a growth only from the 1910s and especially a sharp rise after 1930.

An archival source discloses unknown details on the leading brand KMA fire bricks made in China. It is a collection of the communication between the Kailan Mining Administration 開灤礦務局 (KMA) and the Public Works Service (*Service des travaux publics*) of the French Municipal Council of Shanghai in 1926-33, conserved in Shanghai Municipal Archives. Freshly revealed are the factory history, international sale agencies, technical parameters of fire brick and fire clay products, as well as the technical

Table 1. Fire brick resources imported into China (via Shanghai Port) from foreign countries in 1864-81.*

Year	Total quantity		Imports from / re-exports to
	Fire brick (pieces)	Fire clay (piculs**)	
1864	17, 036	-	Imports from Great Britain
1864	10, 000	-	Imports from USA
1864	2540	-	Imports from Australia
1864	10, 000	-	Re-exports to Japan
1866	6493	-	Imports from Great Britain
1867	-	15	Imports from Great Britain
1868	-	16.80	Imports from foreign countries
1871	-	420	Imports from foreign countries
1879	-	344.4	Imports from foreign countries
1881	-	1929.42	Imports from foreign countries

* Table 1 is drawn on the statistics from the below mentioned archival collection. All imports/exports were via Shanghai.
** The picul is a traditional unite of weight used in imperial China and later, equal to about 60 kg.

limitation discussed with the French client. This new source was contextualised with other little-known historical facts based on the authors' fieldwork, archival research and literature review.

The KMA was a British-led company involved in engineering and mining in China with multiple resource-based services. The origin should be traced back to the Chinese-led mercantile stock company The Kaiping Mines 開平礦務總局, which was under official control of the then Chinese government and relied on European expertise for mining. The Kaiping was established in 1878 in a top-down context of developing modern industries in late-Qing imperial China (Self-Strengthening Movement c.1861-95). In 1900, Kaiping was transferred to Chinese Engineering and Mining Co., Ltd. (CEMCL) that was newly registered in London, manipulated mainly by a few European financiers as well as Hebert C. Hoover who would become the 31st President of the USA. In 1912 CEMCL incorporated the Chinese-owned Lanchow Mining Company 北洋灤州官礦有限公司 at the fall of the Chinese Qing Empire, finally forming the KMA (Fig. 1). The marked histories of these companies have formed a large *corpus* of literature, either in English or Chinese language, epitomising the epoch-making period of modern China in the powers of empires, nations, and capitals. These histories are often addressed from political and economic points of view, and they provide another base for this specific study of fire brick.

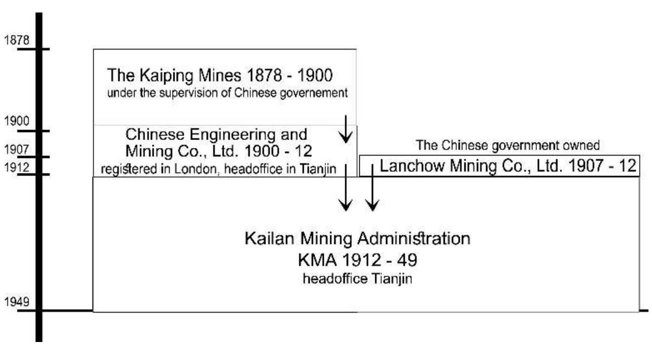

Figure 1. Transformation of Kailan Mining Administration.

2 NEW CONSTRUCTION, NEW DEMAND

In Europe, a wide range of specific constructions had to be erected in fire bricks and fire clays (used as mortar), because of their refractory resistance to high temperature. In China, the traditional blue brick was not especially made for this refractory character and was used as a secondary material in the new structures introduced from Europe. Recent studies have established a general context for the modernisation of China's brickmaking system, exemplified by the manufacture of ordinary red bricks and tiles that mimicked European types (Shu 2013; Shu 2015; Shu et al. 2017; Shu & Coomans (forthcoming)). It can be ascertained that by 1900 very few modern factories had been successfully established for making even ordinary bricks. The problematic search and use of fire bricks for furnaces and shafts were mentioned in the archive-based works (re-)addressing the histories of steel-making and coal mining in modern China (Fang 2010; Yun 2014). By analysing the reason of importing fire brick resources into China (Table 1) in all likelihood resulted from the construction of this kind of novel industrial facilities.

In the nineteenth century Europe, fire bricks were chiefly used for furnace lining. From the twentieth century onwards they were prepared with widely different characteristics to satisfy various users with increasing requirements from modern industries. Fire bricks were required to resist high temperatures (often over 1350°C) and sudden changes of temperature as well as to withstand abrasive actions. They were thus used for constructing blast furnaces, lime calcining kilns, rotary cement kilns, pottery, glass, and brick kilns, mining shafts, underground supports, railway and road building, and so on (Dobson 1850; 1868; 1882; 1893; 1899; Geikie 1903, 168; Hasluck 1906; FER 1906a; FER 1906b, 337; International Textbook Company 1908, 43 & 47; Searle 1911, 2, 6-8, 16, 340-341 & 370-407; KMA 1931; etc.).

The turn of the twentieth century is probably the starting date of producing fire bricks in China. Facts from the earliest and most leading industries of modern China help the authors draw such a preliminary conclusion.

In 1878 the Kaiping mines ordered "gang-zhuan 缸砖" (vitrified bricks, near clinkers, not really fire brick) for shaft-building from Tao-Cheng-Ju 陶成局, a locally famous producer of traditional ceramics (Zhao 2002). It is unknown, however, whether the Tao-Cheng-Ju successfully made the "gang-zhuan" of required quality for shafts, because it is recorded in other sources (Yun 2014, 128-129) that all the Kaiping shafts built in 1878-92 (i.e., shafts at Tangshan mines and Lingxi mines) were actually in stone. After the Chinese Kaiping mines turned to the CEMCL that was fully under European management led by British, a fire brick factory —probably the first one in China— was established at Tangshan colliery sometime during 1900-06 (Fig. 2). This dating is based on two important facts. A 1900 total report of CEMCL by the then chief engineer Hebert C. Hoover does not mention anything about firebrick production (Yun 2014, 53-54). Soon in 1906, several materials of different sources freshly reported the manufacturing of firebricks in the very CEMCL. "[from 1878] there has been a considerable demand for firebricks for lining the several shafts and as supports underground, and the firebrick factory has up to quite recent times met only this demand"; the output had increased to 2,000,000 per month from a few thousand bricks, and the extensions of the factory was being pressed forward as rapid as possible with general impetus from "the extension of railways, the erection of mints and other public works" in China (FER 1906b, 337; FER 1906c, 136). The price was "about one fourth the cost of the imported article" (FER 1906a).

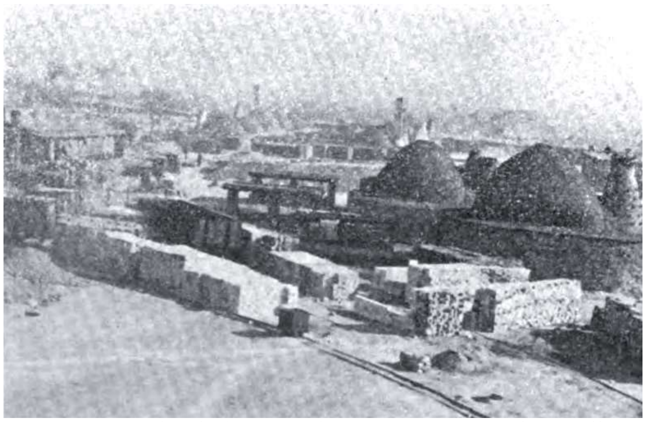

Figure 2. Fire brick factory of CEMLC in Tangshan colliery (FER 1906b, 336).

In Central China, shortage and misuse of fire bricks consistently bothered the pioneering steel industry based in Wuhan. In 1890-95 when building furnaces for Hanyang Iron works, European engineers repeatedly complained of the problems resulting from the misuse of fire bricks by Chinese workers ignorant in the technology. In 1904, the steel company sent staff overseas to investigate the potential of making first grade fire bricks from the fire clays found in different places of China (Fang 2010, 33-34 & 38). Probably because of a positive result of this oversea investigation, a fire brick factory was erected in Pingxiang colliery around 1906, with two fire brick kilns (Liu 2017, 108-09). Driven by metallurgy, the Pingxiang fire brick factory was probably the earliest Chinese-run body studying refractory material.

In CEMCL, North China, fire clay-based products were far more than fire brick: roofing tiles, water and drain pipes, boiler sealing blocks, free covers, and flooring tiles for kitchens, verandas, and public buildings, as well as special bricks of all shapes and sizes (FER 1906a; 1906b; 1906c).

3 FIRE CLAY AND THE REFRACTORINESS

Fire clay was found throughout the coal measures in Britain. The term was even commonly restricted to clays of this character found in association with coal and not to china and ball clays. This was elaborated in widely circulated English monographs such as Dobson (from 1850-99) and Searle (1911, 6; 1915, 8).

Fire clay was never absent in China, but this refractory material was nearly unknown to the Chinese before certain time because its recognition relied on a modern science. By the 1910s, the science had well progressed in Europe but not in China. The Chinese knew very well about their excellent clays only in terms of making ceramics of their traditional types. Their traditional clays often came from agricultural fields and alluvial beds (Kerr & Nigel 2004).

In China, the CEMCL experts found that "the Kaiping Coal Basin includes extensive deposits of plastic clays capable of vitrification at relatively low temperature, and in consequence of which the district has been famous for many centuries for the coarser kinds of pottery. The deposits of true Fireclay have, however, been practically untouched by these ancient enterprises until a few years ago, and the hole of the outcropping fireclay seams, extending over a distance of about 20 miles, now await exploitation, assuring an ample supply of raw material for many years to come" (KMA 1931). By 1906, "the excellent quality of the fire clay and the practically unlimited supply of that material have induced the company to place its firebricks in the Eastern market with very agreeable results. […] It is no exaggeration to say that these firebricks are unequalled in the Far East, while it is held in some quarter that they are superior to the best Scotch firebricks" (FER 1906b).

The refractoriness was considered as an essential character in both fire clays and fire bricks. European authors largely discussed the specific characters of refractoriness and their manipulating by changing clay composition and firing techniques. The discussion was rendered with both practical know-how and sciences. By the turn of the twentieth century, although the technology of achieving high-quality fire bricks had been still a matter in progress, it had been generally agreed that fire clay may be defined as a natural combination of hydrated silicate of alumina with silica and alumina in various states of subdivision. Among all the authors, Searle (1911, 7) provided a list of refractory characteristics of fire clays, and George F. Harris (1897, 80) —a geologist in practical applications of geology and mineralogy— ascertained that "the refractory character of any sample of fire-clay is determined by the proportions in which the silica and alumina are contained, and by the absence of lime, iron, and other easily fluxible substances". Exploring new fire clays in China required scientific knowledge.

Making fire bricks also required extremely high firing temperatures in kilns so as to gain appropriate refractory characters. In the then China, the maximum firing temperature in ordinary brick kilns (blue or red bricks) were often within the range of 600-1000°C, as reported in literature. To reach an extremely high firing temperature greatly challenged both Chinese and western engineers working for China projects.

In Pingxiang colliery, the above mentioned Chinese firebrick factory could obtain firing temperatures of 1200-1430°C at the beginning years 1906-15. This could not satisfy the steel-making in Hanyang Iron Works. Therefore Hanyang had to continue to rely on European imports. WWI interrupted the European supply and Hanyang had then to turn to substitutes. After 1915, the fire brick factory lastly archived satisfying temperatures over 1650°C thanks to the new mining engineer Jin Yue-You 金岳祐(金衡生) who received his training of mining in Germany in 1911-15 (Gu 1916, 31&55; Jegengren 1923, 262-263; Fang 2010, 65).

In Kaiping colliery, western engineers still had to adopt “primitive means” as late as after 1912: “Since the formation of the Administration [i.e., KMA in 1912], its engineers have, with considerable patience and perseverance, succeeded in producing by primitive means a wide range of high grade refractory material to fill an existing demand in the Far East” (KMA 1931). The adaptation of the technology requests further research.

4 DISSEMINATING THE SCIENCE IN CHINA

Developing the science of refractory material in China involved highly international contribution and multi-field scientific sources. In 1878, an article on making firebricks was published in the *Chinese Scientific and Industrial Magazine* 格致彙編 *Ko chih hui pien*. This article is in all likelihood the first literature of firebrick in Chinese language. The magazine was the first to introduce popular western information about materials that were novel to the Chinese, which included glassmaking, ironmaking, ceramic-making machines, and western methods of brickmaking. There was also a large series of popular science books interpreted by the Translation Bureau of the Kiangnan Arsenal at Shanghai between 1871 and 1912, mostly based on English sources (Wang 1995; Fryer 2010; Dagenais 2010). The increasing contents related to new material-making methods were well rendered with western sciences including geology, chemistry, and engineering. However the readership deserves careful thoughts.

Focusing on fire bricks, the authors conducted a comprehensive review of the Chinese literature produced in 1900-49 with original observations. Firstly, there was a rise of industrial research institutions from ca. 1915 onwards. These institutions were nearly all involved in ceramic studies from their establishment or later, often having a particular ceramic department 窑业科. Fire brick technology was closely associated. Amongst others remarkable ones included: Nanman Railway Lab 南滿洲鐵道株式會社中央試驗所 (by Japanese, 1907), Zhili Industrial Lab 直隸工業試驗所(1911), Shandong Industrial Lab 山东工业试验所(1921), Academic Sinica’s Institute of Engineering (1928) and Institute of Chemistry (1928), the Industrial Lab of the Bureau of Social Affairs in Shanghai 上海市社會局工業物品試驗所(1929), and the Industrial Lab of the Ministry of Economy 經濟部中央工業試驗所(1930). Secondly, these institutions conducted investigation, research, and analyses mostly for industrial clients; academic research developed relatively later. Thirdly, they excitingly invested in modern labs and generated series of scientific reports.

Using laboratories to gain knowledge was driven by the mining industry. In collieries, the CEMCL had thoroughly equipped a laboratory by 1906, “prepared to give reliable assays and to undertake analytical work.” The company also intended “to survey and report upon mining concessions in the Province of Chihli [present Hebei], and to carry out borings and other preliminary investigations” (FER 1906b, 337; 1906c, 136). During the period 1906-20 and later, the company continuously extended the brickwork plant and tried to equip it with the most modern machinery; in the new plant built in the 1920s, “chemical laboratories were furnished for the testing of raw clays and the finished products”. However, KMA had to send samples to Stoke-on-Trent in Britain to have some particular analysis done (KMA 1931).

In Europe, the production and use of refractory material was closely associated with applied geology (or economical geology). In China, however, the early generation of Chinese scientists in refractory material remains unclear. Historians studying geology in modern China tell that the Institute of Geology was the first ever modern scientific institution established by the Chinese government; in 1912 under the Ministry of Mining Affairs of the then provisional government in Nanjing. The small group of Chinese geologists, however, were seldom involved in mining; involved were westerners (Xie 1947; Li 2002; Shen 2014).

In CEMCL/KMA’s mines, engineers were nearly either British or Belgians throughout the years (see the integrated data from Yun 2014, 194-196). European authors also published academic articles on Kaiping mines (Mathieu 1927; Günther 1936). In the heyday of KMA, a British Thomas Black (1883-?) was appointed the KMA Brickwork Manager in Tangshan. He had a long experience in the manufacture of refractory material in Great Britain, and in 1925 he was particularly invited to Shanghai to inspect the notable Belgian brick factory of Crédit Foncier d’Extrême-Orient (Béra 1926; KMA 1931).

In 1939-41, a Chinese from the Department of Chemistry, Yenching University, Beijing, undertook a solid study with typical fire clays sampled from the Kailan mine basin and accomplished a master thesis entitled “The Making of Fire Brick with the Flint Fire Clay from North China.” His supervisors were Prof. E.O. Wilson and Prof. W.H. Adolph, both from the USA, and his references were mostly the literature from the American Ceramic Society (Chen 1941).

5 THE KMA PRODUCTS

5.1 *Fire brick*

Technical details of KMA fire bricks are provided by the company and conserved in Shanghai Municipal Archives (Tables 2-3, Figs 3-4). Surprisingly, the compressive strength —the most important parameter for bricks— of the Frist Grade KMA fire brick (20.08 MPa) is even lower than that of traditionally hand-made Chinese blue bricks regarding blue bricks made in a popular Shanghai factory in 1925 (average value 28.95 MPa) and these made in traditional kilns (23.48 MPa, tested max firing temperature is 610°C!) in the 1960s (Shu et al. 2017). KMA depicted the ceramic material in a precise, scientific "language" which was not familiar to the Chinese brick makers. The data can be very useful for identifying and dating historical structures.

Table 2. The refractory data of KMA fire bricks.

First Grade "F"*	Heat resistance	1770 °C in ordinary test.	1580 °C under the load of 0.34 MPa.
	Crushing stress	20.08 MPa in ordinary test.	20.08 MPa under the load of 0.34 MPa.
	Refractory characters	Can withstand exceptionally high and sudden changes of temperature as well as resistance to abrasive action. It will also be found to resist successfully the chemical action of molten slag.	
	Uses	Hearths and boshes of blast furnace linings. Gas-work retorts. Tin, copper, lead and zinc smelting works. Linings of gas producers. Glass tank furnaces. Oil fuel installations. Rotary cement kilns. Regenerating power plants.	
Second grade "S"	Heat	1690 °C resistance.	
	Contraction	Contraction 0.38% after heating for 2 hours at 1440 °C.	
	Refractory characters	It is not so resistant to heat as the First Grade Brick but where other factors, such as the cutting to corrosive action of dust and gases have to be considered it is just as reliable and under some conditions equally durable as a brick of higher fusion point.	
	Uses	Hot blast stove linings. Reheating furnaces. Foundry cupola linings. Steamship boiler casings. Locomotive arch blocks. Boiler seating blocks and side flue cocers. Potters kilns (inside linings). Lime calcining kilns.	
Third grade "T"	Heat	1670 °C resistance.	
	Contraction	Contraction 0.69% after heating for 2 hours at 1400 °C.	
	Refractory characters	Good average refractory brick. It is more liable to contract under prolonged and excessive heat.	
	Uses	Lining of sugar boilers. Setting of Lancashire and Cornish boilers. Ash pits of all types of boilers. Flues and chimney linings of Babcock boilers. Pottery kilns.	
Fourth grade "SS"	Heat	1650 °C resistance.	
	Refractory characters	Manufactured at a cost no greater than that of ordinary Chinese-made Firebricks an article which shall be in every respect superior to them.	
	Uses	Brick kilns. Base linings to factory chimneys. Native heating stoves. Outside boiler casings. Backing for First Grade Bricks. Boiler flues.	
Special firebricks	character	Special Firebricks are made in irregular forms to special order. They bear the identification marks shown on Figs 3-4 referring to them in addition to the makers brand and grade "F" or "S". These pieces are made by hand.	
	Uses	Muffles, stoppers, rings, seggers, discs, floats, baffles, flue covers, seating blocks, chimney linings, cement kiln linings, cupola linings, boiler arch bricks, locomotive arch blocks, plugs and recuperators.	

* The "First Grade" firebrick data is analysed by Dr. J.D. Mellor in Stoke-on-Trent from material supplied by the KMA in connection with some of KMA's own undertakings.

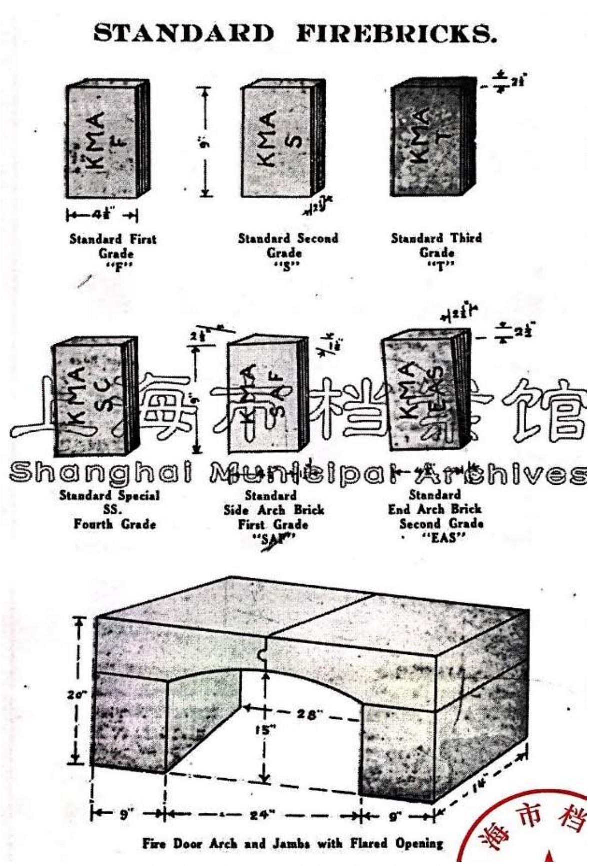

Figure 3. Standard and special fire bricks of KMA.

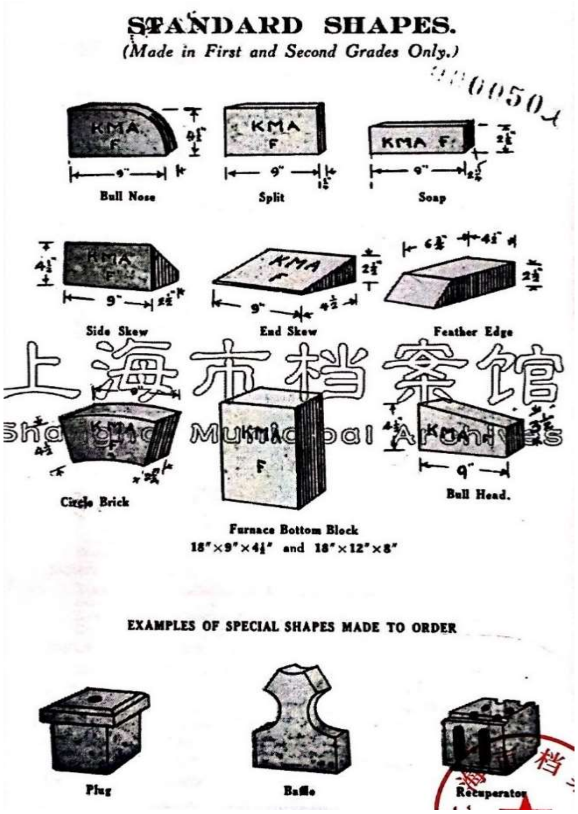

Figure 4. Standard and special shapes of KMA fire bricks.

Table 3. Chemical analysis of different grades of KMA fire bricks (all data in %).

	1st	2nd	3rd	4th
Silica (SiO_2)	51.40	59.55	64.04	60.08
Lime (CaO)	0.50	0.97	1.05	0.86
Titanic Oxide (TiO_2)	2.06	1.31	1.46	1.57
Potash (K_2O)	0.88	Alkali:	0.88	Alkali:
Soda (NaO)	0.52	1.57	0.46	2.48
Alumina (Al_2O_3)	42.32	33.10	28.01	31.69
Ferric Oxide (Fe_2O_3)	1.32	2.78	3.08	1.99
Magnesia (MgO)	0.27	0.50	0.79	0.43
Loss on ignition	0.28	0.22	0.23	0.18

5.2 *Fire clay*

Fire clay is prepared in two grades in KMA: first and second. First grade fireclay should be used with first grade brick; second grade fire clay with second, third and fourth grade bricks. In building the structures KMA provided specific instructions (KMA 1931):

"Use good fireclay and mix to the consistency of thick soup. Do not leave wide joints, nor empty spaces during the building process. The brick should be dipped in the fireclay grout and rubbed to make a brick-to-brick joint. Wide joints provide ready receptacles for ashes and clinker and therefore additional exposed surfaces to destructive chemical action. Warm up the furnace slowly to expel all moisture bearing in mind that the clay must necessarily contract when first heated. It is most essential that the process be even and gradual to ensure a permanent and homogenous lining to the structure."

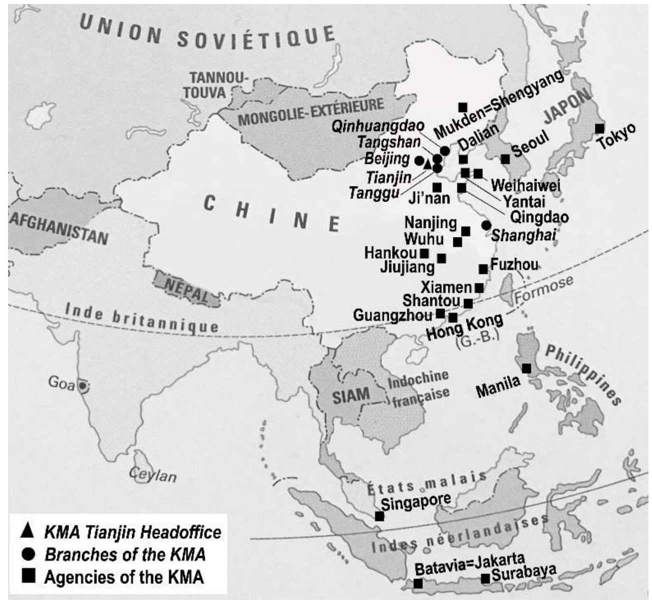

Figure 5. Network of the KMA in Asia in 1931 (the background map is an alteration of the map from Charlier et al. 2002, 93).

5.3 *A global network*

The company CEMCL/KMA kept its prestigious role in manufacturing refractory materials based in coal mines. In 1906, CEMCL possessed a fleet of steamers especially suited for the coast trade of China. Cargos moved among Yingkou, Yantai, Weihaiwei, Qingdao, Shanghai, Hankou, Hong Kong, Guangzhou, and other ports. The company had its own wharves and warehouses at Tianjin, Qinghuangdao, Tanggu, Shanghai, and Guangzhou, and godowns and property storage of cargo at Yingkou and Yantai (FER 1906b).

In 1931, KMA had five office branches respectively in Shanghai, Tangshan, Qinghuandao, Tanggu, and Beijing in China and in total 24 sale agencies all over Asia (Fig. 5). Their advertisements widely dispersed in newspapers and magazines including *The Far East Review* published in Manila, Shanghai, and Yokohama (firstly appeared in May 1906) and *The Builder* published in Shanghai. Their oversea influence deserves further research.

6 THE ARCHITECTURE

Several architectures using fire bricks have been identified via fieldwork in China (Table 4). The fire bricks are uniformly of size 230 x 114 x 63 mm, in very good condition compared to local ordinary bricks made in the same age. They were innovatively used in the architectures with different design ideas.

Although it is hard to identify the earliest use in architecture, fire brick probably served for fireproof function at the beginning. The Fulhee Building in Shanghai, used as the department store of Hall & Holtz, suffered a major fire destruction and the reconstruction (1904-06) equipped it with solid fire-proof

Table 4. A limited list of the architectures using fire bricks.

	Date	Architecture	Producer
1	1904-06	Department store of Hall & Holtz (Fulhee Building), 14 Nanjing Road, Shanghai.	Unknown
2	1904-07	Mansion of the minister plenipotentiary, the former legation of Belgium, Beijing.	CEMCL
3	1911	Senior staff's club of KMA, 2 Nanshan Street, Qinghuangdao. The KMA paving blocks are recycled from Kailan Road.	CEMCL & KMA
4	1926-27	House for a Chinese merchant, later used by China Federation of Trade Unions. Youyi Street, Hankou.	Silico-calcareous bricks by Hanyang
5	1920, rebuilt 1944	Siemens Building, 1004 Zhongshan Avenue, Hankou.	Iron Works
6	1928-29	Power station, Qinghuangdao.	KMA
7	1926-30	Road pavement in the French Concession of Shanghai	KMA

designs made by Algar & Beasley; fire doors and fire bricks were employed at ground floor, which was said very innovative in the then Shanghai (FER 1904; Denison 2006).

Later fire brick was used as a compositional element in facade to form architectural identity (Table 3, cases 2-6). The Belgian legation mansion, Beijing, probably for the first time in China, used fire brick as a facing material yet in a traditional Belgian facade (Fig. 6); the merchant house in Hankou and the power station in Qinghuangdao both exhibit fire bricks as a more thoughtful embodiment of modern designs. The construction in cases 2, 4, and 6 all involved Belgian entities, to be discussed further (Coomans & Shu (in prep.)). Today a few fire bricks have been collected by Chinese museums, e.g. Qinghuangdao Power Station Museum and Wuhan Hanyang Iron Work Museum, but the collections are often out of architectural context.

7 CONCLUSION

Refractory material driven by leading industries —especially mining—was finally established as a scientific field in the high education system of China. The science was built on highly diverse sources from abroad. The technology pioneered the path to modern ceramics in China; the related western sciences and experimental methods were introduced in China's ceramic industry at a time when they were all very new to the Chinese. Experimental method, institutionalised as laboratory, was systematically adopted to gain knowledge and to improve the refractory industry, leaving us considerable legacies. Historical structures of refractory materials retain the scientific value to date, though it has not yet been addressed in either the architectural history or the built heritage studies.

Figure 6. The Belgian legation house in Beijing, built in CEMCL fire bricks, ca.1904-07. (photography 1910, private collection)

A remarkable discovery is: the KMA fire bricks did not have a convincingly superior compressive stress at all compared to the Chinese blue bricks made in traditional way at more or less the same time. Therefore, why the bricks made in European technology were granted the status of superiority deserves further historical explanation. Regarding the issue of the modern shift from Chinese traditional to western system of brick making, which has been raised and discussed recently (Shu 2013; Shu 2015; Shu et al. 2017; Shu & Coomans (forthcoming)), we think it was not only a conceptual, cultural, or technical issue, but a paradigm shift leading to modern European science and technology.

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