Charles Mary, *Cours des Routes et Ponts professé à l'École centrale des arts et manufactures par M. Mary*, 1861-62 atlas pl.XL. and pp.300-302 of the edition of that manuscript republished by the *École centrale* in 1874.

16. First published by Féline Romany in the *Annales des ponte et chaussées, 1ere semestre* 1863 pp.280-304 and pl.14 and then only mentioned in Louis-Charles Mary's manuscript p.302
17. A brief mention in Gustave Renaudot (erroneously cited by Mehrtens as "Renandot") who discussed testing the bridge in 1868 (*Annales des pont et chaussées, 1868, 2eme semestre*, p.582-592 is the only mention of this bridge that has come to light so far
18. Arthur Paul Joly, *Le Pont d'El Kantara à Constantine*. Bibliothèque patrimoiniale des ponts et chaussées ENP CO2 ms 346 (1862). Accessed via Internet 06. April 2015
19. gallica.bnf.fr/ark:/12148/btv1b84477549 accessed 06.04.2015
20. personal communication from Thomas Cazentre on, and the evaluation of these photographs. The Paris portfolio comprises a total of 14 images, all anonymous and the BnF owns a further six by Baldus. According to M. Cazentre, it is entirely possible that some or all of the signed Baldus images at BnF originally formed part of the portfolio but were separated either by the original collector or by BnF when they were accessed. The set in a private collection is smaller: 4 anonymous photographs (of which three, one large one and the two in small format are not in BnF) and three by Baldus, (one of which – Fig. 6 here - is also not in BnF).
21. *Photographic views of the progress of the Crystal Palace, Sydenham, taken during the progress of the works, by desire of the directors*. London: Crystal Palace 1855
22. *Reconstruction du pont de Tilsitt*, Lyon 1864. 44.5 x 59 cm. A copy is in BnF. The photographs are in varying formats from 23 x 40 to 44 x 44 cm. Republished for the Exposition de 1867
23. Phillips also trained as a mining engineer. His series was published in *The Forth Bridge in its Various Stages of Construction, and compared with the most notable bridges in the world*. Edinburgh: Grant n.d., but 1889?, with 37pls. of the bridge under construction, expanded 2nd edition, and in *The Forth Railway Bridge; being the Expanded Edition of The Giant's Anatomy*, Edinburgh: Grant 1890 with 20 images + atlas 36pls.
24. personal communication from Andrew Gill
25. Tom F. Peters, *Bibliographical Checklist of the Popular Scientific Works of Louis Figuier*: Bethlehem PA: Lehigh University Libraries 2002
26. Detlor & Waddell's Stereoscopic views of the Oil Country (soon succeeded by Detlor & Dow) was the larger series, and J. West's (possibly Julius S. West? active 1885-1891) Stereoscopic Views of the Pennsylvania Oil Regions, a somewhat smaller one. Both companies were located in Bradford PA and specialized in Pennsylvanian topics.
27. Martin 1865, p.8. See also *Allgemeine Bauzeitung* 1866
28. Tom F. Peters, *Building the 19th Century* Cambridge MA: MIT 1996, pp.218-220
29. Martin 1865, p.2
30. possibly Martin himself? Joly ms., note in the margin on p.1, and pp.1-2
31. Martin 1865, pp.10-14 and Joly
32. Martin 1865, p.10
33. Maya Benton *Roman Vishniac Rediscovered* New York: Prestel 2015
34. Raphael Abramovitch (forword) *The Vanished World* New York: Forward Assn. 1947 and Elie Wiesel (forword) *A Vanished World* New York: Farrar, Strauss and Giroux 1983.

Towards Western construction in China: Shanghai brickwork and printed technical resources 1843-1936

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Abstract

China's move towards western models of construction is documented by an account of the inconspicuous brickwork of Shanghai – one of the earliest western construction methods introduced into modern China. A series of questions are raised, based on extensive fieldwork. This article records the study of printed resources set within the broader context of circulating western knowledge in China, and summarises types of literature important for construction studies. The paper considers three Chinese books to help explore the sources of western masonry and reveal hitherto un-noted facts.

The paper concludes, for the first time, that the simple technology of Victorian brick masonry was a principal source and antecedent of modern Shanghai brickwork. Distinct from the tradition of transmitting construction-related technology by oral instruction, textbooks, handbooks and manuals constituted a new, and powerful means for the dissemination of technical knowledge in modern China. The interpretation of western technology appears to have been selective in Shanghai; a typical example is the brick bonding methods independent of closer bricks compared to English construction. Interestingly, Chinese authors did not fully adopt western construction modes, and old Chinese knowledge was incorporated into new systems of construction, greatly conditioned by material problems, as this study reveals. The spread of construction technology knowledge involved broad cross-field collaboration in and across Shanghai, the complexity of which suggests a shift of knowledge systems, rather than a direct transfer of building technology based on western construction methods.

Keywords

Modern China, Brickwork, Technical Literature, Charles Frederick Mitchell, George Arthur Mitchell, Zhang Ying-Xu, Ge Shang-Xuan, Du Yan-Geng.

The missing closer

Modern construction projects in China were largely built of western style brickwork. This fact was mentioned in passing by Joseph Needham (1900-95) in his tome devoted to traditional Chinese technology.[1] The Needham work, however, did not pay attention to the potentially different origins of western brickwork. In regards to the brick structures built in ancient China, the possible foreign sources of influence have been skilfully addressed in a few Chinese publications.[2] The brick structures built in modern China (1840-1949) display omnipresent western references, but they have not yet been properly studied in either the Chinese or English literature. In Shanghai, western brick masonry became the dominant method to construct western-style buildings in 1843-1910, and it was only from the 1910s

onward that reinforced concrete frames gradually replaced brick masonry structures.[3] Recent technical studies, have begun to reveal the epochal revolution of brickmaking in modern China, showing the slow process of establishing a new manufacturing industry to support brick construction methods.[4] In this transitional period of 1843-1936, the brick construction methods changed significantly, but these changes have been hitherto undocumented.

The author has devoted efforts to the study of the application of western brickwork principally in Shanghai with a comparative view towards other Chinese cities. Approximately 300 brickwork buildings have been identified and examined in particular. Architectural and archaeological methods have been utilised to identify brickworks *in situ*. Repeated comparisons have been conducted between various Chinese and western resources.

The Chinese bonds that Needham noted seem very rare in Shanghai's modern construction projects; and there are no obvious western bonds in traditional buildings built before 1843, the date that the British Settlement was established. Shanghai brickwork appears to be less colourful and to have less diversity than British works in general. Neat English bonds and Flemish bonds have prevailed in both structural masonries and non-structural walls built in Shanghai throughout the period between 1866 and 1949. Compared to the English brickwork built in England during the same period, and in spite of the visible similarities between these two worlds of brickwork, surprisingly, the Shanghai brickwork generally appears to be independent of "closer" brick, which were very popular in England. This hitherto unrecognised detail renders the modern brickwork of Shanghai distinct from not only the English examples, but also the western brickwork built in other Chinese cities such as Guangzhou and Wuhan, where "closers" are visible.

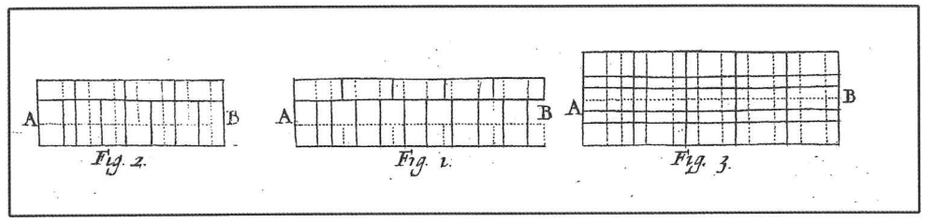
What were the sources of the western brickwork in Shanghai? Architectural literature seems to support the hypothesised link to British sources, and suffice to say that the design of western buildings was dominated by British architects, engineers and clients in the period of the 1840s-1910s. The workmen, however, were almost always Chinese. Remarkably, the architect George Strachan (1821-1899) from Edinburgh opened a construction school to train Chinese workers when he sojourned in Shanghai between 1849 and 1854.[5] The trainees were mostly from Ningbo and subsequently became a noted group among the several groups of workers building Shanghai.[6] Chinese historians often express the idea that the isolated groups of workers probably helped to maintain different construction skills; this idea, however, does not seem to be embodied in the western brickwork surveyed by the author.

How has western (British) technology been circulated, translated and disseminated in brickwork? To answer this question, this paper examines the printed technical materials that have been rather less studied. The aim is not only to explain the phenomena in brickwork but also to draw attention to the potential historical pattern(s) in circulating western construction technology in modern China.

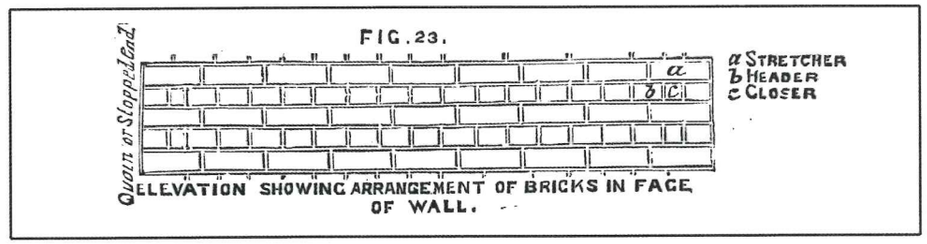
English "closer" and the "Chinese bond"

The bonding of bricks was considered of great importance for structural strength, stability, homogeneity, and the stylistic appearance of architecture; "closers" were used to ensure the proper interlocking of bricks to avoid continuous vertical joints, which would cause the wall to split from top to bottom. This technology is well represented in the English literature from 1700 to the 1930s, and Joseph Moxon (1703) provided what was likely the earliest pertinent record with the detailed descriptions of "closier / closure" both in words (the citation below) and in illustration. (Fig. 1, top)

> "To prevent which Inconveniency, and to make the Wall much stronger, lay a *Closure* on one side, and none on the other; but lay a three quarter Bat at the Quine in the stretching course, and in the Heading course adjoin an Header next to the Header at the Quine, as you may see it done in Plate 3, Fig. 1 and 2. … Also in working a two Brick Wall, I would advise in the Stretching courses, wherein you lay stretching on both sides the Wall next the Line, so also to lay stretching in the middle of the Wall, and *Closiers* next to each stretching Course that lies next the Line, as in Fig. 3 of Plate 3, you may see."[7]



"Closier / Closure" represented by Moxon, 1703



"Closer" represented by Mitchell, 1888

Figure 1. The cohesive continuity from 1700 using closers in English brickworks.

In the Victorian period, a "closer" was made the same length and thickness as ordinary bricks and was cut into a shape in which either one or two ends were half the width of the brick, called "King closer" or "Queen closer", respectively. In either the English or Flemish bonding style, a closer brick should be inserted next to the smaller end of the corner brick and laid through the thickness of the wall in every course; it thus appears as half width on the outside surfaces of brick masonries. Consistently, inserting a "closer" became a rule to ensure good English brickwork. This English bonding method was well illustrated in modern Chinese construction books.[8] (Fig. 2)

Traditional Chinese brickworks did not use "closers". The ways in which bricks fit together gained little space in the classical Chinese literature on construction, yet they have been well documented by architectural historians since the twentieth century.[9] In Shanghai, traditional local houses and temples were mostly one or two storeys high, and they depended on timber-framed structures; their brick walls often carried no additional loads or quite low loads. In this system, the Chinese developed a highly-sophisticated craftsmanship culture of brickwork with the effort and skill embedded in the texture, rather than in structural functions. From the mid-nineteenth century, western buildings relying on brick masonry structures were largely realised in all of the Treaty Ports of China; in Shanghai, this trend started with the British Settlement.

Chinese bricklaying methods started to be recognised and compared to western methods. At the Austro-Hungarian Universal Exhibition in Vienna in 1873, a Chinese bricklaying method called "hollow wall" was illustrated by a model of a Chinese house in the section of "illustrative of local peculiarities" from

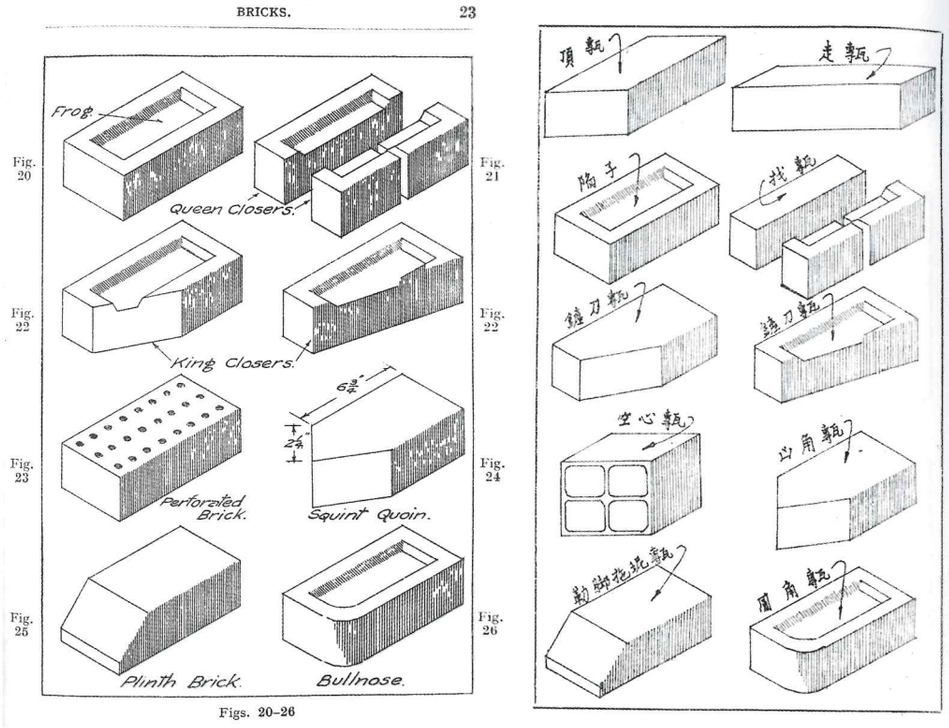


Figure 2. Closers illustrated in the English book Building Construction and Drawing (1926) and in the Chinese publication Yin Zao Xue (1935).

the Treaty Port of Kiukiang (present Jiujiang) in Central China. It was superintended by Henry Charles Joseph Kopsch, the then-British commissioner of the Chinese Maritime Customs at Kiukiang. He strongly recommended the "hollow wall principle of the Chinese" for boundary walls or enclosures.[10] It was called the "Chinese box bond" by Rudolf P. Hommel, who lived in China from 1921 to 1926 and from 1928 to 1930; his fieldwork based in Central China has resulted in a good account of the Chinese "brick bonds used in brick walls".[11] Later, Needham associated Chinese bonds with traditional English building technology and provided two illustrations for the "Chinese box bond" in particular.[12] In fact, the Chinese "hollow wall" or "box bond" is not an European type of hollow wall (or cavity wall) used for improving the physical conditions of architecture but is only a way to economise brick materials; this method was rarely used by westerners and only applied to non-loadbearing walls in single-storey or two-storey Chinese houses. (Fig. 3) shows this type of bonding method, as applied in a modern laboratory building photographed by Needham but never used in his work[13] and illustrated in a modern construction book, *Jianzhu Tu'an,* which is detailed later. This bricklaying method is incapable of carrying powerful loads or ensuring solid stability, as confirmed by recent analyses.[14]

There are two more typical models of Chinese bonds widely used in the modern period. One is the "Chinese cross bond", as Needham called it; in every course, the headers and stretchers were arranged alternately, with the latter placed in groups of three in the front elevation. Zhang Ying-Xu—the Tientsinese professor who taught building construction in Peking—called it simply中国法 (Chinese

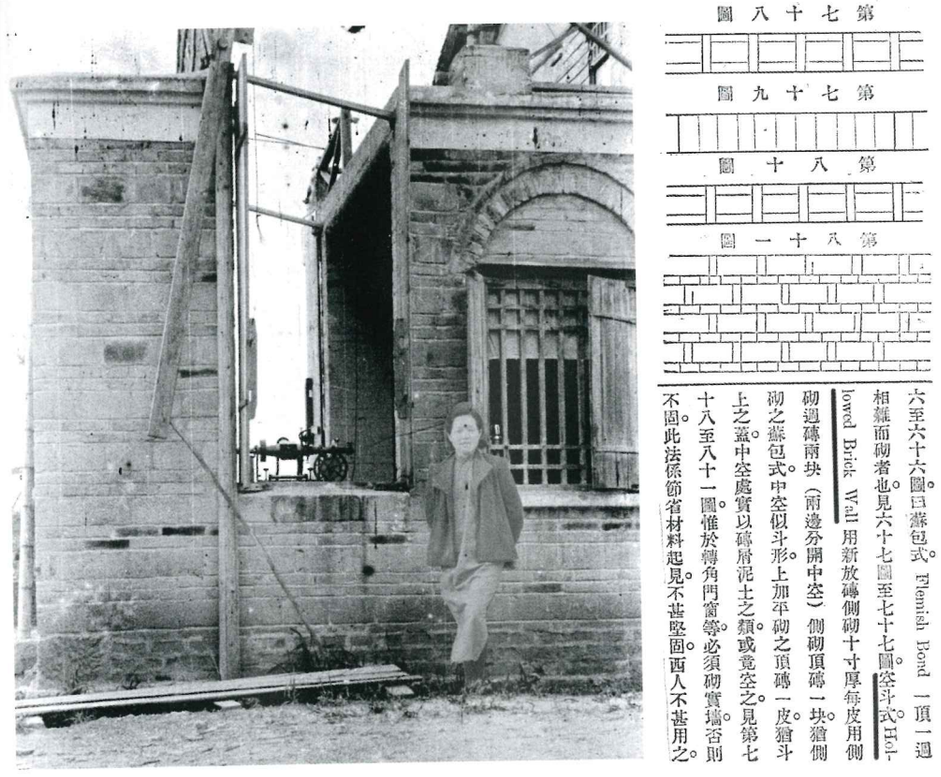


Figure 3. Chinese bond, type I: in Chungshan University Astronomical Observatory, Guangdong, early twentieth century (left) and presented as "Hollowed brick wall" in Jianzhu Tu'an, 1924 (right).

bond) in his 1910 textbook *Building Construction*. (Fig. 4) He stated that this bond was weaker than English bond and stronger than Flemish bond in terms of structural stability; aesthetically, it was as pleasing as English bond but seemed inferior to Flemish bond.[15] As far as the author observed, it has an analogous front pattern to the so-called "(Flemish) garden-wall bond", "boundary wall bond", "Sussex bond", or "Scotch bond",[16] which in Britain was applied to walls one brick thick that were seen on both sides, such as in dwarf walls, boundary walls, and garden walls, instead of in architecture. English books usually state that this method was created on account of the varied lengths of the bricks, and it was advantageous to adjust the back face by decreasing the number of headers.

The third type of Chinese bond, based on the author's fieldwork, consists of one course of headers to two, three, five, or seven courses of stretchers. (Fig. 5) In the front elevation, such bonds might remind one of some of the English bonding methods for one-brick walls, such as so-called "Scottish bond",[17] "Facing bond",[18] or "English garden-wall bond",[19] yet they are not actually the same.

In the modern brick buildings of Shanghai, surprisingly, it is very difficult to find these three types of Chinese bonds. Modern Shanghai generally exhibits a westernised form of brickwork using very common building techniques, indicating a systematic change in construction knowledge.

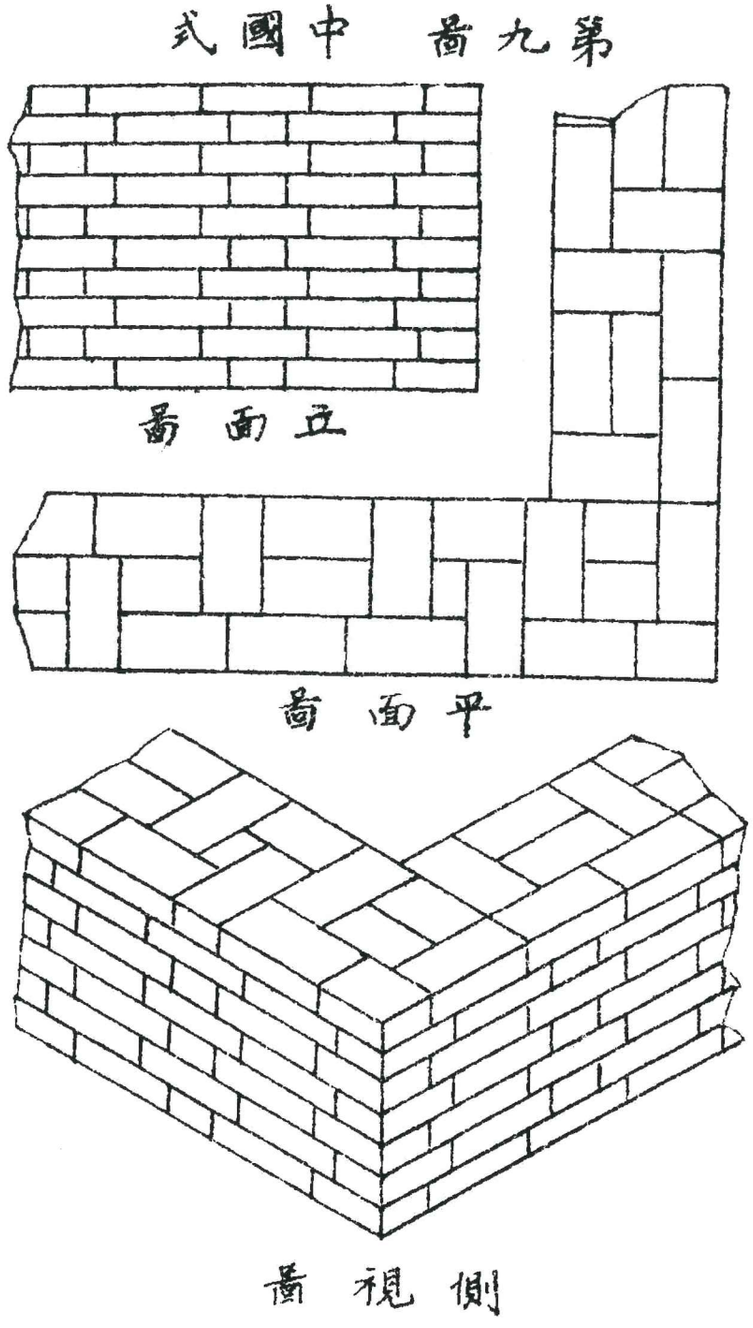


Figure 4. Chinese bonds, type II, as presented in Y. X. Zhang, Building Construction, 1910, p.8.

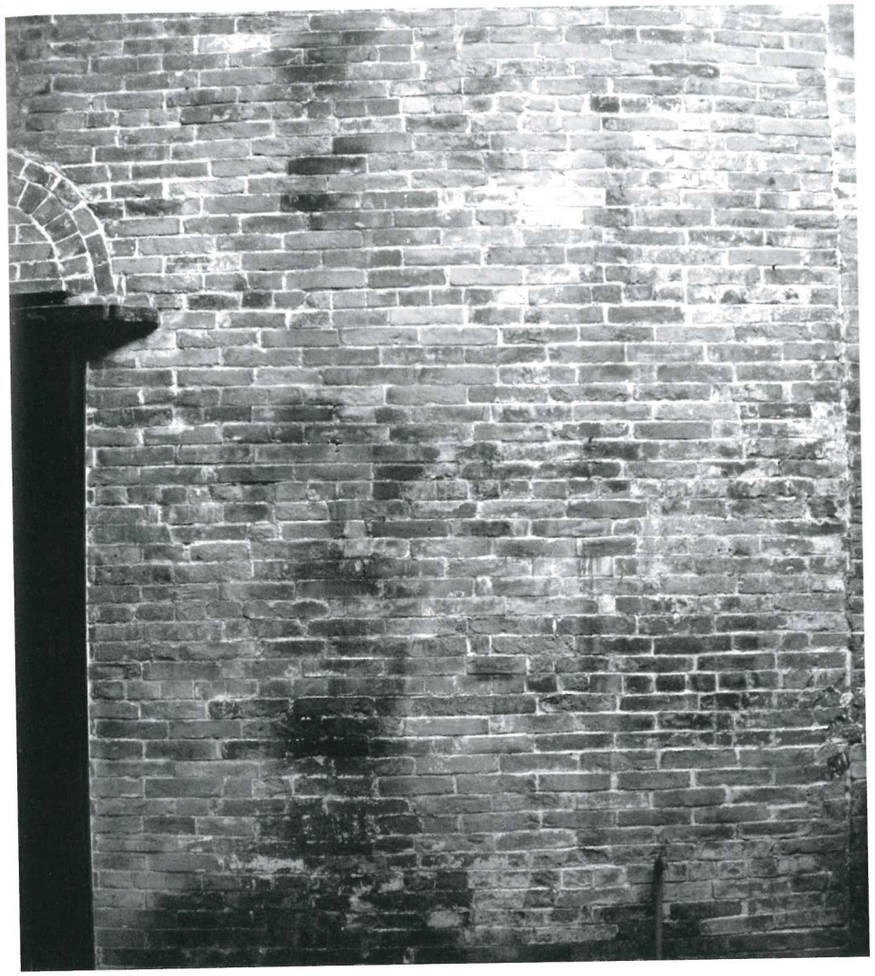


Figure 5. Chinese bonds, type III, in Jinlun Guild Hall (mid-nineteenth century), Guangzhou. (photo: the author)

Printed western resources circulated in Shanghai

There were a large number of construction-related books circulated in modern China, printed in either western languages or Chinese. The Chinese language books largely relied on western source materials with English, French, and German sources consulted. The links to English sources have been partly demonstrated through case-by-case comparison in recent studies.[20] However, very little has been said about the western language books in either the established architectural history or the bibliographical studies of the history of science and technology of modern China. As far as the author can determine, western language books played an important role in circulating new construction technology in China, but the methods of circulating this knowledge were not always the same as the Chinese books. Secondly, the introduction of western construction technology involved not only monographs on building construction but also other technical literature from quite diverse fields, such as the construction of

railways, canals, military works, churches, mining facilities, and material industries; with the use of brickwork widely presented in this literature. Thirdly, engineering sources and resources greatly contributed to the circulation of western construction technology in China. These facts have not yet been recognised, and they are detailed below.

The Translation Bureau of the Kiangnan Arsenal 江南製造局翻譯館in Shanghai introduced a large series of popular western science books and translated them into the Chinese language between 1871 and 1912.[21] They are almost all based on sources in the English language. Although the bibliography shows very few monographs on building construction, one can find interpreted contents about, for instance, new civic buildings, civil engineering, fortification construction, city planning, surveying, and western methods of brickmaking,[22] which are practically linked to construction technology. However, their actual readership in China deserves careful consideration, and very little has previously been said about this.

The way technical books in foreign languages were circulated in China merits further studies. The old Shanghai Library, established in 1849 inside the British Settlement, already held 8,000 volumes by 1870.[23] Aiming to serve western sojourners' social lives, the library was granted by the Shanghai Municipal Council, and it remitted annually to England for the purchase of books—scientific books included—for many years, until the 1890s at least. There was also the library of the Shanghai Club, which allowed its books to be taken out of the institution by members.[24] Different church societies also brought a large number of scientific books to China. In today's Shanghai Library, there are still many construction-related books conserved, mostly in English and some in French and German. (Table 1) is a limited yet representative list showing the books with contents relevant to masonry construction, mostly in English; it covers a broad range of topics that were then popular in Europe. The readership of the western books could be associated with the practitioners engaged in building Shanghai in all likelihood. For practical reasons, they encompassed a wide range of people, including architects, engineers, builders, missionaries, merchants, surveyors, etc. These people, especially in nineteenth-century Shanghai, often did not have professional or orthodox training backgrounds in the sense in that we use these terms today.

Table 1. Shanghai's Western books relevant to brick masonry technology, 1843-1936.

Year	Author	Title	Press
1842	unknown	A series of instructive examples in architectural, engineering and mechanical drawing	London: John Weale.
1850	Edward Dobson	The art of building and foundations and concrete works	London: John Weale.
1850	Edward Dobson	A rudimentary treatise on foundations and concrete works	London: J. Weale
1850	Edward Dobson	A rudimentary treatise on the manufacture of bricks and tiles	London: George Woodfall and Son
1850	Alan Stevenson	A rudimentary treatise on the history, construction, and illumination of lighthouses	London: J. Weale
1854	Edward Dobson	Rudiments of the art of building.	London: J. Weale
1856	Edward Dobson	A rudimentary treatise on masonry and stonecutting: in which the principles of masonic projection and their application to the construction of curved wing walls, domes, oblique bridges, and Roman and Gothic vaulting are concisely explained	London: J. Weale
1861	M. Graeff	Construction des canaux et des chemins de fer	Paris: librairie scientifique, industrielle et agricole de E. Lacroix
1865	Edward Cresy	An encyclopaedia of civil engineering, historical, theoretical, and practical	London: Longmans, Green, and Co.

Table 1. continued

1869	Oliver Byrne	Spons' dictionary of engineering, civil, mechanical, military, and naval	London: E. & F.N. Spon
1875	Par un Religieux-Prêtre du Monastère.	Historique de l'origine, de la construction et la bénédiction du monument de N.-D. du triomphe érigé dans l'enclos de l'abbaye du Port-du-Salut près Laval (Mayenne)	Laval: Impr. De E. Jamin
1877	X. Barbier de Montault	Traite partique de la construction de lámeublement et de la decoration des Eglises, selon les regles canoniques et les traditions romaines, avec un appendice sur le costume ecclesiastique	Paris: Louis Vives
1879	Henry Reid	A practical treatise on natural and artificial concrete	London, New York: E. & F.N. Spon
1880	Ernest Spon	Supplement to Spons' dictionary of engineering	London: E. & F.N. Spon
1882	Edward Dobson, Charles Tomlinson	A rudimentary treatise on the manufacture of bricks and tiles	London: George Woodfall and Son
1882	Wyvill J. Christy	A practical treatise on the joints made and used by builders in the construction of various kinds of engineering and architectural works	London: C. Lockwood and Co.
1886	Edward Spon, Francis N. Spon	Spons' mechanics' own book : a manual for handicraftsmen and amateurs	London, New York: E. & F.N. Spon.
1887	George R. Burnell	Rudimentary treatise on lime, cements, mortars, concretes, mastics, plastrering, etc.	London: C. Lockwood and Son
1890	Henry Faijia	Portland cement for users	London: C. Lockwood and Son
1890	Edward Dobson	Rudiments of the art of building.	London: C. Lockwood and Son
1890	Gustave Oslet	Cours de construction Première partie: Materiaux de construction et leur emploi	Paris: Georges Fanchon
1890	Gustave Oslet	Cours de construction Deuxième partie: Materiaux de construction et leur emploi	Paris: H. Chairgrasse
1891	Edward Dobson, rev. by George Dood	Foundations and concrete works: containing a synopsis of the principal cases of foundation works with the usual modes of treatment and practical remarks on footing, planking, sand, concrete, beton, pile-driving, caissons and cofferdams	London: C. Lockwood and Son
189?	Jones, Burton & Co., Engineers	Machinery required for wood working, flour milling, oil milling, sugar milling, municipal purposes, rope making, textile machinery, and all industrial plants. 4th Edition.	Liverpool: 19 Castle Street.
1901	J. Boero	Fabrication et emploi des chaux hydrauliques et des ciments	Paris: Librairie polytechnique Ch. Béranger
1902	Auguste Perret	Chaux, ciments et mortiers. (Petite encyclopedie de chimie industrielle pratique)	Paris: E. Bernard
1920	J. W. Riley	Building Construction for Beginners	London: Macmillan
1924	George A. Hool, W. S. Kinne	Reinforced concrete and masonry structures	New York, etc.: McGraw-Hill Book Company, Inc.
1926	A. Munier	Construction, decoration, ameublement des eglises	Bruges: de Brouwer
1926	A. Munier	L' eglises a notre epoque sa construction	Bruges: de Brouwer
1929	Whitney Clark Huntington	Building construction: Materials and types of construction. 1st ed.	New York, London: Wiley, Chapman & Hall.

After the turn of the twentieth century, Chinese authors started to undertake the mission of re-interpreting western knowledge based on their own experiences gained through past decades of practice. This re-interpretation makes the Chinese books of this period distinct from the earlier materials translated by the Kiangnan Arsenal in Shanghai. Meanwhile, textbooks for civil engineering and architecture were entire reprints of original sources in western languages in Shanghai.[25] Printed resources covered textbooks, handbooks, manuals, periodicals, magazines, monographs, unpublished theses, published scientific articles, reports and accounts from scientific institutions, newspaper columns and so on. Advertisements and catalogues showed rich, continually updated information. Among these materials, content about brickwork construction still largely relies on English sources, and it has a very large readership, including technicians, builders, artisans, architects and engineers.

There was a notably rising trend in engineering resources. The engineering resources largely came from the United States. This can be partially explained by the United States funding the Boxer Indemnity Scholarship Programme (1909-37) for Chinese students to study in the States, which became the most effective and influential programme for the Chinese. In this period, the whole construction sector was greatly influenced by engineering sciences and technology. In universities, remarkably, the new generation of Chinese engineers started to publish laboratory reports on the physical and structural behaviours of brickwork. In Shanghai, this work was undertaken by the newly established Material Test Committee of the Chinese Engineering Society in 1924-25, based on the laboratory settings in Nan Yang College of Chiao Tung (present Shanghai Jiao Tong University).[26] The society's experimental and analytical studies of brickwork showed a new approach to masonry construction in China. The team leader, Ling Hong-Xun 淩鴻勛 (1894-1981), was an important railway engineer of modern China with rich practical experience. Between 1924 and 1936 he published monographs on railroad engineering (1925), municipal engineering (1926), bridges (1929), and the building design of factories (1933) that discussed construction technology at length; they were all used as textbooks and were reprinted several times, followed by more works by Ling.[27]

Industrial schools constituted another important path for circulating western knowledge. In the *Zhengji* Construction Industrial School正基建築工業補習學校, established by the Shanghai Builders' Association in the autumn of 1930, the western training mode was applied with technical textbooks all in English; *The Builder* provided a complete list of the textbooks for the *Zhengji* school for the year 1936.[28] (Table 2) shows the sources of the *Zhengji* textbooks annotated by the author; most of them were American. British sources included the *Building Construction for Beginners* authored by J. W. Riley (full name unknown) and the textbook *Geometrical Drawing* by Alfred Ernest Holbrow. Riley was a lecturer in descriptive geometry, building construction, carpentry and joinery at the municipal technical school, Rochdale, in Britain, and his book discussed brick masonry construction extensively. Holbrow assisted George Arthur Mitchell in another popular English textbook, *Building Construction* (Fig. 6), and this book became a model for Chinese authors compiling construction books, as elaborated later.

Regulations and by-laws formulated and standardised the practice of western brick masonries at the urban level. The 1869 by-laws of the third *Land Regulation for the Foreign Settlement of Shanghai* specified construction issues for the first time. From 1869 until the end of the 1930s, walling technology continued to be a topic of all the different regulations issued by the three independent authorities of Shanghai: The Shanghai Municipal Council of the International Settlement; Conseil d'Administration Municipale de la Concession Française de Changhai; and the Chinese government. Rules were set to secure structural stability, prevention of fires, sanitary, ventilation, and the proper use of space, and they often strictly controlled the building plans, types, and materials and the width, length, and height of walls to be built. A preliminary review showed that the contents and formats of the rules released by the International Settlement were very comparable to the building acts, by-laws, and regulations enforced then in Britain.

Table 2. An annotation on the sources of the Zhengji textbooks.

Textbook title	About the authors	Publisher
Complete Arithmetic	Wentworth, George Albert (1835-1906); Smith, David Eugene (1860-1944). Author of a series of textbooks in Mathematics, Exeter, New Hampshire, U.S.	Boston, New York, etc.: Ginn & Co.
Elementary Algebra	Wentworth, George Albert (1835-1906). Author of a series of textbooks in Mathematics, Exeter, New Hampshire, U.S.	Boston, New York, etc.: Ginn and Co.
Plane & Solid Geometry	Wentworth, George Albert (1835-1906); Smith, David Eugene (1860-1944). Author of a series of textbooks in Mathematics, Exeter, New Hampshire, U.S.	Boston, New York, etc.: Ginn & Co.
Plane Trigonometry & Tables	Granville, William Anthony (1863-1943). Ph.D., Sheffield Scientific School, Yale University, U.S.	Boston, New York, etc.: Ginn & Co.
Analytic Geometry	Wentworth, George Albert (1835-1906). Author of a series of textbooks in Mathematics, Exeter, New Hampshire, U.S.	Boston, New York, etc.: Ginn & Co.
Differential & Integral Calculus	Love, Clyde Elton (1882-?). Ph.D., Assistant Professor of Mathematics in the University of Michigan, U.S.	New York: Macmillan
Common Science	Washburne, Carleton Wolsey (1889-?). Superintendent of Schools, State Normal School,San Francisco, U.S.	New York: Yonkers-on-Hudson
Geometrical Drawing	Holbrow, Alfred Ernest (1878-1957). A.R.I.B.A., M.I. Struct. E., Assistant of G.A. Mitchell in *Building Construction* since 1925, U.K.	London: George Gill & Sons, Ltd.
Engineering Descriptive Geometry	Moyer, James Ambrose (1875-?). S.B., E.B., A.M.. Director of University Extension, Massachusetts Department of Education. Formerly Instructor in Descriptive Geometry in Harvard University; Professor of Mechanical Engineering in University of Michigan and Pennsylvania State College; Engineer with the General Electric Company and with Westinghouse, Church, Kerr and Company. Member of the American Society of Mechanical Engineers; Fellow of Royal Society of Arts, etc.	New York: J. Wiley & Sons, Inc.
Engineering Drawing	French, Thomas Ewing (1871-1944). M.E., D.Sc. Professor of Engineering Drawing, The Ohio State University. Member American Society of Mechanical Engineers Society for the Promotion of Engineering Education, etc.	New York, London: McGraw-Hill.

Table 2. continued

Materials of Engineering	Moore, Herbert Fisher (1875-?). Research Professor of Engineering Materials, Engineering Experiment Station, University of Illinois, Member American Society for Testing Materials.	New York, London: McGraw-Hill.
Building Construction for Beginners	Riley, J.W. (?). Lecturer in descriptive geometry, building construction, carpentry and joinery, at the Municipal Technical School, Rochdale, U.K.	New York, etc.: Macmillan.
Applied Mechanics	Poorman, Alfred Peter (1877-?). A.B., C.E.. Professor of Applied Mechanics, Purdue University, Indiana.	New York, etc.: McGraw-Hill.
Strength of Materials	Boyd, James Ellsworth (1863-1950). The Ohio State University.	New York, London: McGraw-Hill.
Modern Framed Structures, Part 1	Johnson, John Butler (1850-1902); Bryan, C. W.; and Turneaure, F. E. J. B. Johnson: C.E. and C. W; C.W. Bryan: C. E., M.A., Chief Engineer of the American Bridge Company; F.E. Turneaure: Dr. Eng. Dean of the College of Engineering, University of Wisconsin.	New York: J. Wiley & Sons, Inc.
Reinforced Concrete Construction, Vol.1	Hool, George Albert (1883-?). S.B., Consulting Engineer, Madison, Wisconsin; Professor of Structural Engineering, the University of Wisconsin.	New York: McGraw-Hill.

Three Chinese books of construction

Concerning the development of western masonry technology in China, three Chinese books deserve the most attention (Table 3). The Chinese authors, of distinct backgrounds, all devoted themselves to introducing western construction technology. Considerations, meanwhile, were deliberately given to the practical realities in China. The books were well illustrated and in a recently published list of modern Chinese architectural books, all three are considered as sources of modern Chinese architecture.[29]

Jianzhu Xinfa 建築新法, the English title of which is *Building Construction*, was published by the Printing Commercial Press, Ltd. in Shanghai and was compiled by Chang Ying Hsu (or Zhang Ying-Xu) 張錤緒 (1877-?), with a new edition in 1910. The cover of the book reads, "Building Construction, Mr. Chang Ying Hsu, Prof. Peking Industrial School and Second Assistant Secretary, Board of Agriculture, Work, & Commerce, China". It was used as a textbook of architecture in the Peking Industrial School. Zhang, from Tientsin (Tianjin), received his architectural education at Tokyo Imperial University in Japan. According to him, this work was based on other books on the same subject from both the East and the West; at the same time, he focused on practicability according to his professional experience and years of on-site investigations. The book contains a comprehensive and integrated knowledge of

Table 3. Three Chinese materials on building construction.

Title	*Building construction* / *Jianzhu Xinfa* 建築新法	*Jianzhu Tu'an* 建築圖案大全 (Architecture illustration)	*Yinzao Xue* 營造學 (Building Science)
date	1910 (new edition)	1920, 1924 (reprinted)	Feb. 1935 – Jan. 1936
type	textbook	manual	monthly
author	Chang, Ying Hsu (or Zhang Ying-Xu) 張錤緒 (1877-?)	Ge, Shang-Xuan 葛尚宣 (1896-?)	Du, Yan-Geng 杜彥耿 (1896-1961)
affiliation	Professor in Peking Industrial School and Second Assistant Secretary, Board of Agriculture, Work, & Commerce, China.	Cartographer, surveyor and architectural engineer. Han-Ye-Ping Iron and Steel Company, Project Bureau of SMC of International Settlement	Builder, journal editor and lecturer, established the Shanghai Builders' Association (1931), the chief editor of *The Builder* and the *English-Chinese & Chinese-English Dictionary of Architecture.*
publisher	Shanghai: Printing Commercial Press, Ltd.	Shanghai, Guangzhou: Chongwen Shuju.	Shanghai: Shanghai Builders' Association.
	The earliest Chinese monograph on modern science of building construction.	The earliest Chinese handbook on building construction.	Published in: *The Builder* / Jianzhu Yuekan.

constructing brick masonry in all aspects from an architect's point of view. In particular, it discusses the typology of brick masonry, brick arches, and bonds (English/Flemish/Chinese bonds of brickwork). This textbook is considered the earliest Chinese monograph based on the modern science of building construction.[30]

*Jianzhu Tu'an*建築圖案大全 (A Complete Collection of Building Construction Illustrated, trans. the author) was first published in 1920 by *Chong Wen Shu Ju* 崇文書局 in Shanghai and Guangzhou and was reprinted in 1924. The author Ge Shang-Xuan葛尚宣(1896-?) was born in Shanghai and later worked as a cartographer, surveyor and building engineer, in that order. He had worked for the Han-Ye-Ping Iron and Steel Company漢冶萍公司in Central China for years before returning to Shanghai in 1918. Only two years later, Ge published this book, stating that it was compiled and interpreted according to his own working experience.[31] In Shanghai, Ge worked in the Project Bureau under the Shanghai Municipal Council of the International Settlement上海工巡捐局. The Han-Ye-Ping Iron and Steel Company hired a large number of foreign engineers and technicians from Britain, Belgium, Luxembourg, Germany and the United States in the period between 1890 and 1912, including "Konstrukteur", with recorded names including Franz Hoffmann and Victor Moyen (both from Luxembourg).[32] It is interesting to note that Ge obtained his building construction expertise in the iron-making industry. This type of inter-field contact is also highlighted in the construction of the then most marvellous brick structure, Holy Trinity Church in Shanghai, 1866-69, which engaged a ship repairing company, Messrs. S. C. Farnham & Co., as the builder.[33] In nineteenth-century China, the sources for developing modern construction were quite complex. The contents of Ge's book cover materials, craftsmanship, and the construction of brick masonry; they are largely based on English knowledge, and the illustrations are almost a copy of English illustrations. (Fig. 7) Ge's book is basically a manual compared to Zhang's textbook.

Yinzao Xue 營造學 (*Building Science*, trans. the author) is the title of ten serialised articles published from February 1935 to January 1936 in the local Chinese periodical *Jianzhu Yuekan*建築月刊 (English title *The Builder)*. It was published monthly in Shanghai from November 1932 to April 1937 for a total of 5 volumes, 49 issues. Although incorporated into the periodical, it is virtually a single piece resembling a textbook and manual. The author, Du Yan-Geng杜彥耿 (1896-1961), was a builder, journal editor and lecturer. He was born into a builder's family in Shanghai,[34] and he was then in charge of his family business and worked on establishing the Shanghai Builders' Association (1931), of which he was on the presidential board. He was the chief editor of *The Builder* and the compiler of the *English-Chinese & Chinese-English Dictionary of Architecture,* the former issued by the same Shanghai Builders' Association. He taught architecture and English in the *Zhengji* continuation school erected by the same association. He also translated a series of essays entitled *Jianzhu Shi*建築史 (architectural history) in *The Builder* from the July 1935 issue onwards. In the text of *Yingzao Xue,* Du emphasised that his material aimed for applied western building science in Chinese practice, and his main source was on-site experience, which he had undertaken for twenty years. He devoted a lengthy discussion to the brickwork technology used at Shanghai, which was well illustrated.

The dates of these publications cover the most prosperous period in construction practices in Shanghai. This fact first made the author speculate on some possible variations between the earlier techniques (as presented in the 1910 book) and the later ones (as presented in the 1920 manual or the 1936 periodical). However, it is difficult to find any significant variation in the content related to brick-walling technology. The actual difference between the materials relies on textual style rather than on technology per se. This fact testifies and confirms the outcome of the author's field investigation; that is, no later than the early twentieth century, the local brick walling technology was fixed and shaped. Because *The Builder*建築月刊devoted a serialised space to recording and disseminating the existing knowledge of brickwork, it is reasonable to infer that the simple technology of brickwork, as a Victorian legacy, was still a very popular building method in Shanghai in 1936.

The contents are all organised in a systematic manner, especially in the textbook of Zhang. Scientific principles, engineering mathematics and science, before the practical details of know-how, are arranged by subject. Walling technology is aligned with other building techniques, such as piling, roofing, plumbing, and water-proofing, in an attempt to achieve an integrated framework. Moreover, Du devoted a large space to the tools, facilities, and machines used in building industry.

All of the technical illustrations are drawn in the western, scientific manner and no longer with the type of Chinese graphics to which Needham and other historians often referred.[35] How to regulate technical drawings scientifically became an important topic in the works of Zhang (1910) and Du (1935-36).

As a whole, these three items represent the level that the Chinese attained in learning and mastering the western technology of construction; a new system developed. In brickwork, the term "bond" was interpreted as "*liansuo* 連鎖" by Zhang (1910) and as "*zuqi*組砌" by Du (1935). Du's work provided the most detailed and comprehensive record of the three. In the Preface of *Yingzao Xue*, Du first stated that he had read Mitchell's "Building Construction and Drawing" twenty years earlier.[36]

Distance between the Mitchell and the Chinese books: Sources and contents

Since the Chinese authors often stated that the books incorporated their own experiences in China, how did the local conditions determine the true practice and knowledge circulating across cultures? To answer this question, the author examined the distance between the Chinese books and their English source

materials, and contextualised the status of knowledge to build a broader picture.

The Mitchell book that Du mentioned belongs to a full series. Charles Frederick Mitchell (ca. 1859-1916) and his assistant George Arthur Mitchell (1868-1952)[37] authored *Building Construction and Drawing: Part 1 Elementary Course* (hereafter, *Construction 1*) (1st ed. 1888), *Building Construction: Part 2 Advanced and Honours courses* (hereafter, *Construction 2*) (1st ed. 1894), *Brickwork & Masonry* (hereafter, *Brickwork*) (1904 and 1908), and *Classic Architecture* (1901). They are all textbooks for students, intensively reprinted and continuously revised and enlarged in London. It is not difficult to find

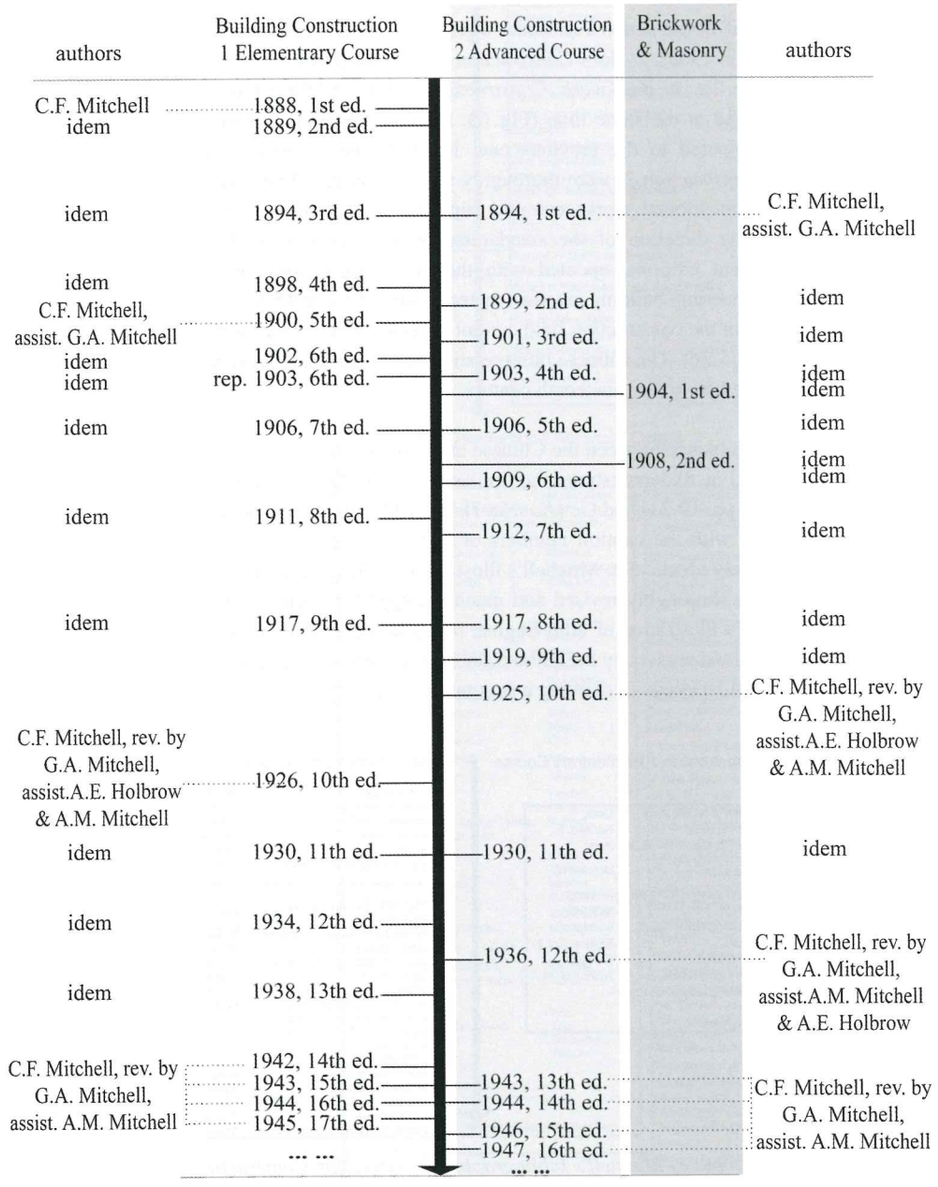


Figure 6. The series of Mitchell books, 1888-1945.

a complete list of all the different editions of the books based on the libraries of Cambridge University, Oxford University, and the Getty Research Institute. The books' contents show that *Brickwork* has been incorporated into *Construction 1* since 1926, 10th ed., after C. F. Mitchell died and G. A. Mitchell took over. Although the Mitchell books could not portray the whole spectrum of construction methods in popular English books on building technology, the continually reprinted contents on the subject of brickwork were largely representative for the time. The Mitchell textbooks present a solid representation of bricklaying methods. Therefore, the three Mitchell books of varied editions are considered an integrated whole in this study. (Fig. 6)

Almost every edition of *Construction 1* provides a reference list (except the 5th ed. of 1900 and the 6th ed. of 1902, reprinted in 1903), as does *Construction* 2 from the 1st ed. of 1894 to the 7th ed. of 1912. There are no reference lists in *Brickwork*. *Construction 2* built on bibliographical sources richer than *Construction 1* compiled at the same time (Fig. 7). Prior to 1906, there were few or slight changes between editions, compared to the previous one. In 1906, the reference lists in both books, viz *Construction 1* and *Construction 2*, were thoroughly revised and greatly enlarged, with approximately half of the previous mentioned works cut and supplemented by new sources "in the science of construction and in the direction of the standardisation of materials".[38] Relatively small changes continued in subsequent editions, updated with the latest, more specialised knowledge covering architecture, civil engineering, building practice, material, sanitation, and by-laws.(Fig. 7) These updates on new developments in the construction field are not reflected at all in the works of Zhang (1910), Ge (1920-24), and Du (1935-36). The Chinese interpretation of English material is based almost entirely on old Victorian technology from the nineteenth century.

The most marked resemblance between the Chinese and English material are the illustrations; there are larger gaps in the text. (Fig. 8) demonstrates the similarity between the comparable content from Mitchell (*Construction 1*, 1900, pp. 19-21) and Ge (*Jianzhu Tu'an*, 1924, pp. 42-4); the bold numbers marked by the author correspond with the caption numbers of Mitchell's figures. Ge's illustrations of western brickwork are completely identical to Mitchell's illustrations of English bond and double Flemish bond in *Construction 1*—the thoroughly revised and much enlarged 5th edition of 1900 and not the earlier editions. However, Ge's illustration of both English bonds and double Flemish bonds contains serious errors, as marked with bold crosses by the author. The wrong drawing lines indicate that Ge did not truly capture the professional language in drawing a structure.

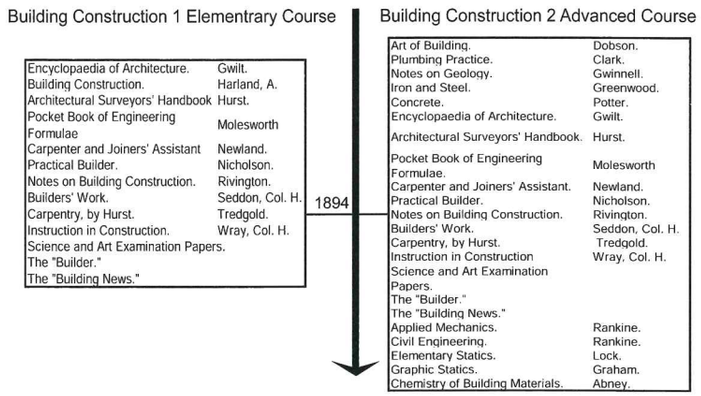


Figure 7. (a, b, c to continue) Mitchell's bibliographical sources for Construction 1 (1894, 1906 and 1911 eds) and Construction 2 (1894, 1906, 1909 and 1912 eds).

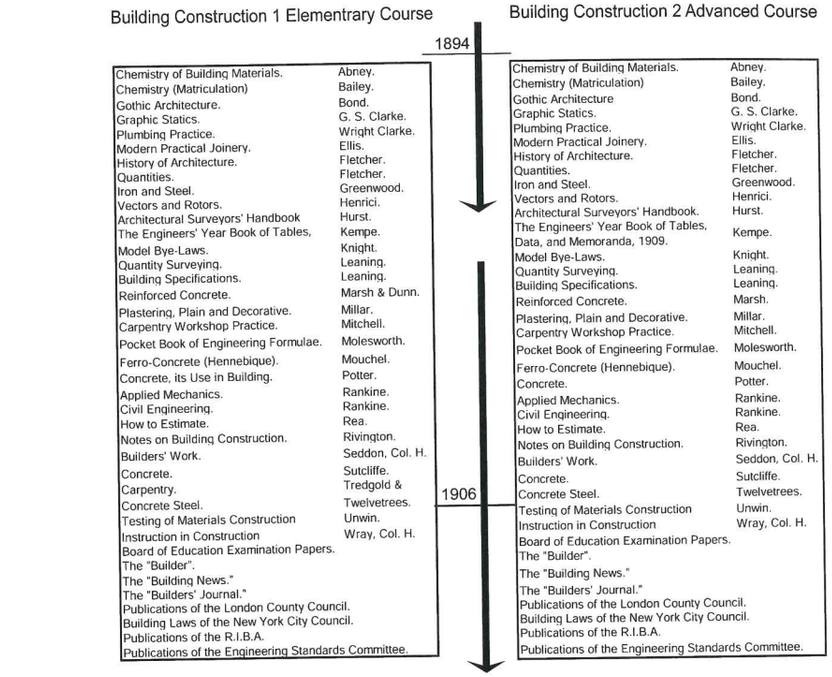


Figure 7.

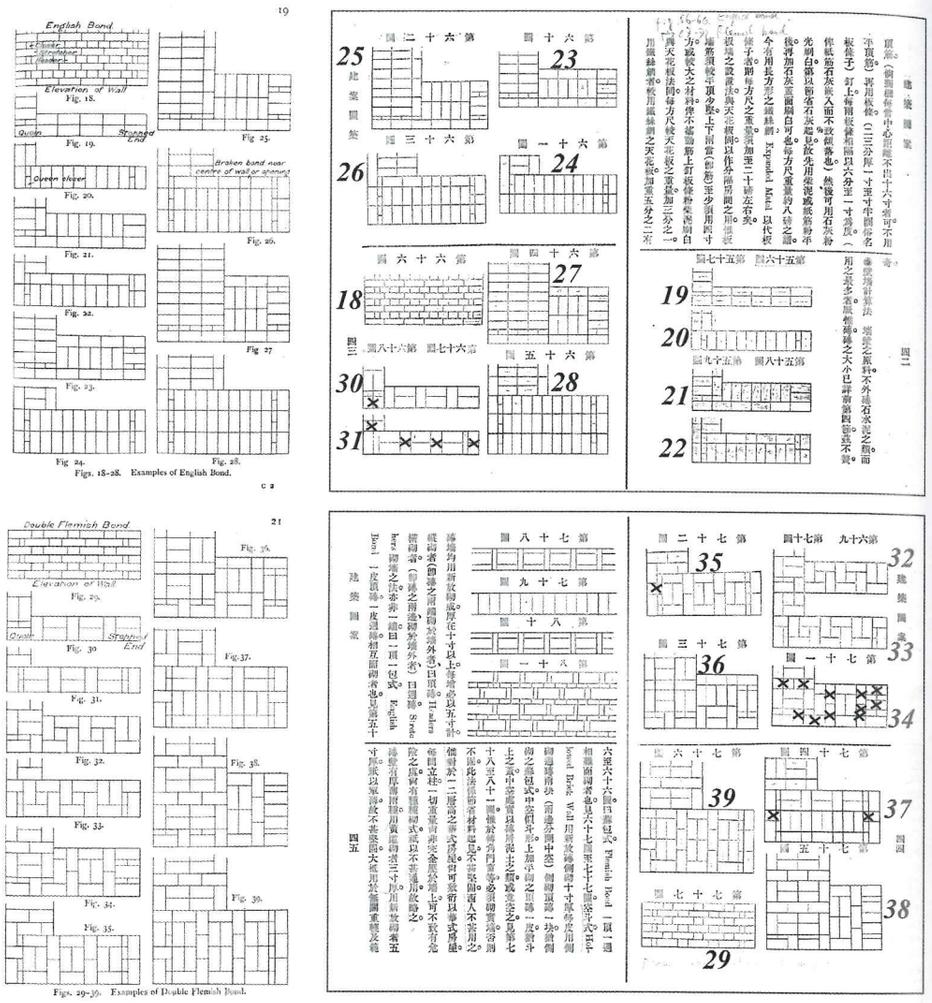


Figure 8. (a, b to continue) The similarity and distance between Mitchell (1900, left) and Ge (1924, right), English bonds and double Flemish bonds.

Between Du and Mitchell, it suffices to say that Du's illustrations of brickwork, annotated with Chinese terms, were almost identical to the corresponding ones in Mitchell's books, the contents of which include English bond, single Flemish bond, double Flemish bond, stretching bond, heading bond, herring-bone bond, diagonal bond, raking bond, and facing bond. Du recorded that English bond and Flemish bond were the most popular types used by the Chinese then; this report concurs with results from the author's fieldwork. Du's knowledge about filling up mortar joints is again analogous to British methods, i.e., so-called "by the trowel", "by larrying", and "by grouting" in Mitchell[39] or "filling up joints", "bed joints", and "larrying" in Rivington,[40] whose work is also in Mitchell's reference list (see also Fig. 7). They seem to correspond to the Chinese methods called "luokehui 螺壳灰", "mandaohui 满刀灰", and "woqi 窝砌", respectively, with slight adjustments by Du.[41] Other content, such as wetting and pointing, consists of almost direct translation from Mitchell. Nevertheless, Du's illustrations do not always correspond to the text he wrote. The lacunas and dissimilarities are repeatedly revealed in Du's interpretation of Victorian brickwork.

The use of closer brick was detailed in nearly all of the English books elaborating on brickwork, including the Mitchell books in the first edition (*Construction 1*, 1888); the three Chinese books also discussed "closers" in either words or illustration. In Britain, closer bricks were all neatly arranged in architectural models designed by, for instance, Augustus Welby Northmore Pugin, William Butterfield and George Gilbert Scott,[42] (Fig. 9, in hatching), as well as in average English houses. In the brick buildings of Shanghai, however, closers are extensively (if not totally) absent, even in those works designed by British architects such as George Gilbert Scott and William Macdonnell Mitchell Dowdall. (Fig. 10) Since the above study has shown that Shanghai brickwork was largely modelled on English prototypes, then what is the hidden reason for the absence of closers?

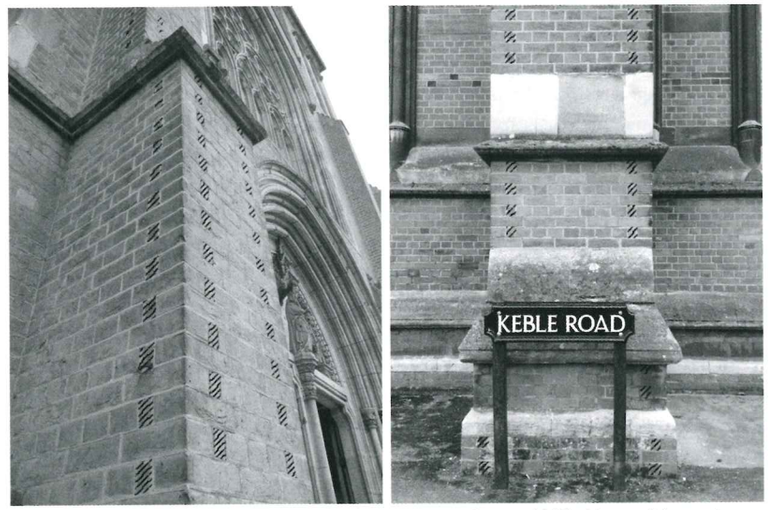


Figure 9. Queen closers in St. Chad Cathedral, Birmingham, 1839-41, architect Augustus Welby Northmore Pugin (left); and in Keble College, Oxford, 1868-70, architect William Butterfield (right) (photos: the author).

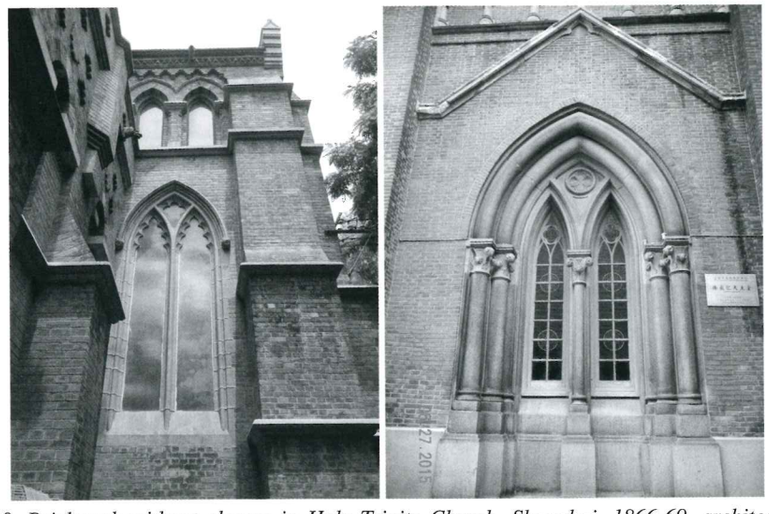


Figure 10. Brickwork without closers in Holy Trinity Church, Shanghai, 1866-69, architect George Gilbert Scott (left); and in St. Ignatius Cathedral, Shanghai, 1904-10, architect William Macdonnell Mitchell Dowdall (right) (photos: the author).

The brick industry: Economy and standardisation

One important yet unstudied cause could be related to the supply of bricks at Shanghai. Throughout the period of 1843-1936, the brick industry underwent a shift from a traditional system to a new mode, and the supply of bricks depended on both the traditional brickyards, which produced Chinese "blue bricks", and the new, not yet developed modern factories which aimed at manufacturing "red bricks" mimicking European types and methods. The latest study revealed that, in the period of 1843-1925, the mechanical qualities of industrially processed red bricks did not outperform the bricks made in traditional brickyards in general.[43] This transitional period in brick making coincided with the time when Chinese workers adapted to building western brick masonries and developed new skills.

In Shanghai, it seems that, using machinery, bricks were produced more expensively than by hand prior to 1933. The local magazine *The Builder*建築月刊 (November 1932 - April 1937, 5 vols., 49 issues) provided the monthly market prices for all types of building materials. Based on these data, (Fig. 11) shows the trends in the prices of the bricks from eight popular producers in Shanghai; modern machine-made bricks are marked with filled shapes, while traditionally made bricks are hollow, and different shapes represent different producers. It is clear that, prior to October 1933, traditionally made bricks were less expensive than the machine-made ones of the same size and from the same company. Between October 1933 and January 1936, the prices of the traditionally made bricks and the machine-made ones were not provided in the magazine, likely indicating that they were the same price; from February 1936 on, conversely, machine-made bricks became less expensive than the comparable traditional ones. The consequence of the prices can be very well observed in the built brickwork: different types of bricks were tactfully used in combination, and usually, machine-made red bricks were employed in complex forms and/or in decorative positions of the architecture, while traditionally made blue brick was used in simple forms and/or in hidden positions. The economy of blue bricks favoured their wide application late into 1936.

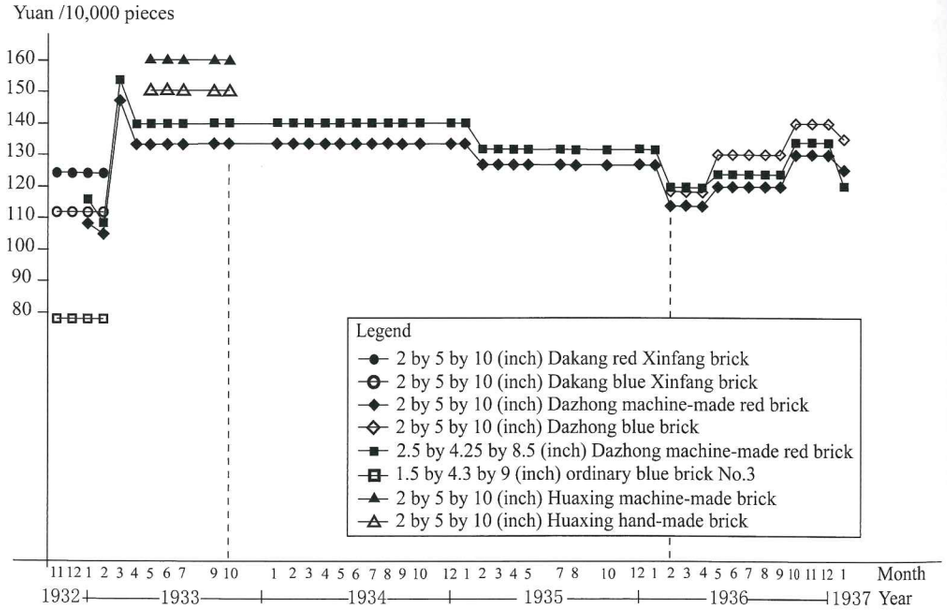


Figure 11. Price trends of bricks in Shanghai, 1932-37, drawn by the author based on The Builder.

Non-standardisation is another problem. The bricks used in Shanghai had very diverse sizes and dimensions from one another, and they were not standardised until 1953.[44] Bricks of different sizes were usually mixed in bonding for economic or aesthetic, architectural reasons. For instance, often the backing bricks were not the same size as the facing bricks, which would frequently result in bad bonds. Non-standardisation in bricks was an innate weakness of model brickwork based on British archetypes.

In Britain, the industrialisation of brick making and the standardisation of bricks greatly favoured the use of bricks to satisfy architectural tastes, so industrially made bricks were in general use by the 1880s.[45] In British brickwork, the uniform and proportional dimensions of brick units were considered a condition to ensure good bonds. Mitchell's textbooks devoted notable space to the matter. The standardisation of brick size commenced on May 1, 1904, as agreed upon between Royal Institute of British Architects and the Brick Makers' Association, in consultation with Institution of Civil Engineers; this information was continuously updated in later editions.[46] The British Standard Specification No. 657 for Dimensions of Clay Facing and Backing Bricks of 1936 specified the dimensions of closers and suggested the same sizes for the backing bricks and the facing bricks.[47]

Three measurement systems had been used at Shanghai by the 1930s: the customary Chinese system; the British imperial system; and the international metric system. According to the 1915 law of measurement, article 2, the Chinese system and the international metric system were both legal and official. In 1929, the then newly established Chinese government re-defined the metric system as the only standard; the Chinese system was permitted to be used in a subsidiary manner, but in fact, British imperial units prevailed in the brick industry until the 1930s.[48]

(Table 4) presents some typical data of the brick dimensions (with tolerances) based on the author's survey both in the literature and in fieldwork. It partially demonstrates the diversity of the brick forms late into the 1930s, although it is far from the whole spectrum. In traditional Chinese kilns, the dimensions of bricks could be decided by clients. Remarkably, the bricks used in the 1866 Holy Trinity Church–designed by George Gilbert Scott and William Kidner–exhibit unique dimensions of all of the Shanghai bricks but identical to those used in A. W. Pugin's Saint Chad's Cathedral, Birmingham (Table 4, Fig. 12), which is a British size. The red bricks were especially made for this Holy Trinity Church architecture in Shanghai in 1866-67.[49] The thickness (75 mm) was exceptional and was never exceeded by any other plain brick produced in Shanghai afterwards, with thickness dimensions varying from 25 to 70 millimetres according to the author's survey.

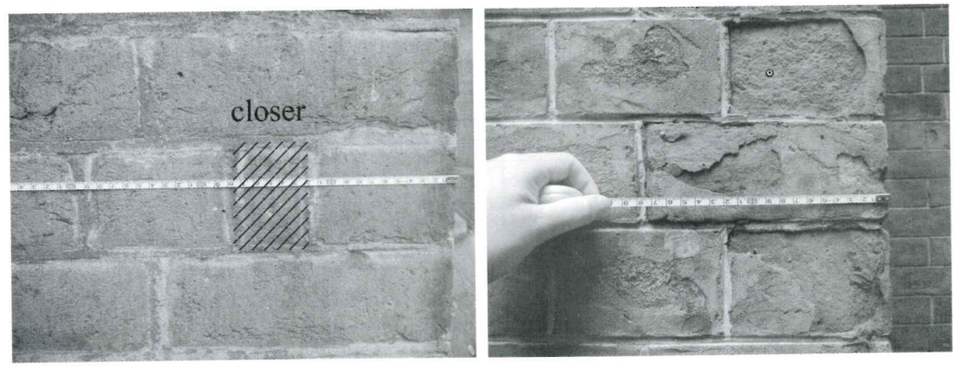


Figure 12. The identical dimensions and different bonding techniques, comparing Pugin's St Chad Cathedral at Birmingham 1839-41 (left) and Scott's Holy Trinity church at Shanghai 1866-69 (right). (photos: the author)

Table 4. Typical sizes of the solid bricks used in Shanghai.

Date	Dimension (mm)			Dimensions (inch)	Type (as called)	Reference
	length (L)	width (W)	depth (D)			
1866	235	120	75	9.3 × 4.7 × 3	Red brick	Holy Trinity Church, Shanghai, surveyed (average size, façade and interior)
1904	240	120	40	9.5 ×4.7× 1.6	Red brick	St Ignatius Cathedral, Shanghai, surveyed (façade and nave)
1904	240	115	45	9.5 ×4.5× 1.8	Blue brick	St Ignatius Cathedral, Shanghai, surveyed (inner leaf of north chapel)
1906	305	152	53	12 × 6 × 2	of most popular size	'Chinese Bricks', *Manila, P. I., Shanghai and Yokohama, The Far Eastern Review*, Vol.2, No.11 (April 1906), p.311.
1920, 1924	279	76	25	11 × 3 × 1	*Huangdao*	S. Ge, *Jianzhu Tu'an Daquan*, Shanghai: Chongwen Shuju, 1924. p.3. Also surveyed.
1925	203	102	62	8 × 4 × 2.4	Machine-made red brick	H. Ling, et al., '*Zhuantou Shiyan*' (Report on brick tests), *Shanghai, The Journal of the Chinese Engineering Society,* Vol.1, No.2, Jun 1925, pp.150-68. Also surveyed.
1925	210	102	32	8.3 × 4 × 1.3	Hand-made blue brick	Ibid.
1932	229	121	54	9 × 4.4 × 2.1	Red brick	'Price List of Building Materials', *Shanghai, The Builder*, Vol.1, No.1, Nov 1932, p.58. Also surveyed.
1935	216	104	64	8.5 ×4.1× 2.5	Machine-made brick	Y. Du, 'Yingzao Xue', *Shanghai, The Builder*, Vol.3, No.5, May 1935, p.23. Also surveyed.
1935	229	109	38	9 × 4.3 × 1.5	Ordinary 3° brick	Ibid.
1935	229	109	64	9 × 4.3 × 2.5	Machine-made brick	Ibid.
1906, 1920, 1924, 1935	254	127	51	10 × 5 × 2	Machine-made brick, or *Xinfang*	Ibid.; S. Ge, *Jianzhu Tu'an Daquan*, Shanghai: Chongwen Shuju, 1924. p.3; 'Chinese Bricks', *Manila, P. I., Shanghai and Yokohama, The Far Eastern Review*, Vol.2, No.11 (April 1906), p.311. Also surveyed.
1953	216	105	43	8.5 ×4.1× 1.7	8½-inch traditional blue brick	'Jieshao Dazhong Zhuanwa Chang Chupin', *Shanghai Shi Yingzao Gongye Tongye Gonghui Huiwu Baodao* (Reports of the Shanghai Society of Building Industry), No.24 (1953). Also surveyed.
1953	240	115	53	9.5 ×4.5× 2.1	Standardised brick	'Jieshao Dazhong Zhuanwa Chang Chupin', *Shanghai Shi Yingzao Gongye Tongye Gonghui Huiwu Baodao* (Reports of the Shanghai Society of Building Industry), No.24 (1953).

With such diverse bricks in Shanghai, the Chinese artisans developed another way to obtain the proper overlaps for western brick masonries. They simply cut the first brick of every course into the qualified lengths – usually ¾ bats — to ensure correct overlaps; that is, they used three-quarter bats at the ends of the stretcher courses to omit the closers next to the end headers. The 1866 Scott church was built in this manner—the quoins were cut into ¾ brick bats to achieve the style of English bond (Fig. 12, right). The drawings in (Fig. 13) represent Shanghai's "English bond" of a one-brick thick wall in the case of stopped ends and in the case of an external right-angle junction of two walls; the appearance is the same with plain or rebated jambs for openings.

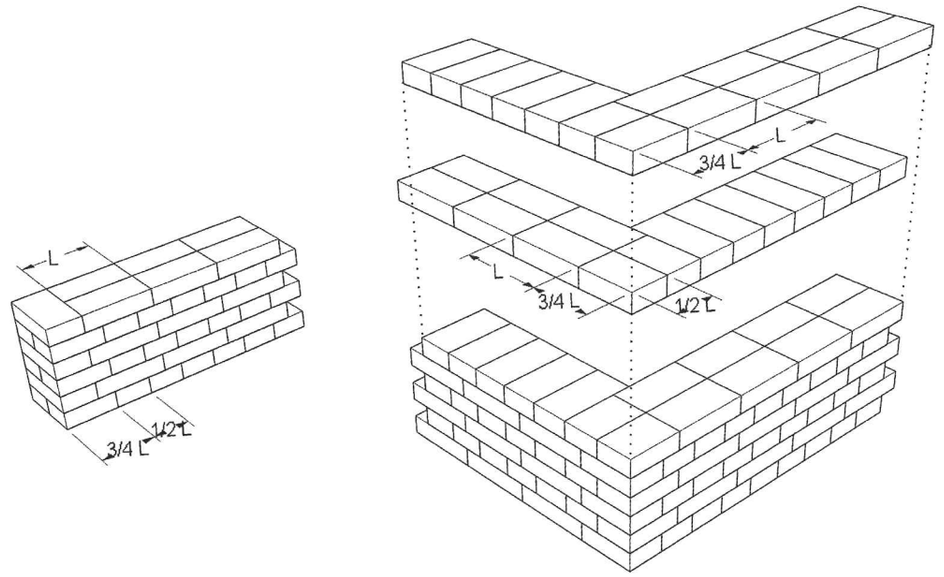


Figure 13. The popular bonding method in modern Shanghai using a three-quarter bat in lieu of a closer (one-quarter bat) to arrange overlaps in brickworks. (drawing: the author)

Conclusions

Western brick masonry–a traditional construction method in Europe–became a modern method for the Chinese and constituted one of the earliest paths to a western construction system at Shanghai. The evolution of brickwork in modern China experienced the overlapping of two approaches: from Chinese technology to western technology, and from traditional technology to modern engineering technology. This study places brickwork in the broader context of technical knowledge circulation.

The traditional "Chinese bonds" (including variants) were not used at all in building modern Shanghai. This study concludes that the British Victorian technology of ordinary brick masonry was a principal source that Shanghai brickwork inherited throughout the period of 1843-1936. However, the basic British bonding method of using closer bricks (either queen closers or king closer) was rarely (if ever) adopted in the practice of Shanghai, and Chinese workers employed Victorian technology in a reduced and adaptive manner. Building practice and printed materials were both involved in circulating the technology.

The study showed that, from the twentieth century onwards, textbooks and manuals, in either Chinese or

foreign languages, became a new popular approach of knowledge transfer; the technology of brickwork was also widely disseminated in this manner, distinct from the traditional method of oral instruction. This path is crucial to western models of construction in modern China, and it features the modernisation of the construction industry. On the one hand, the Chinese authors—from professors to builders—took up the mission of introducing and disseminating western science and technology, and largely and directly drawing content from western sources, they actively followed a learned western mode in disciplinary language and considered their works "science books科學書籍".[50] On the other hand, the secondary Chinese authors of construction books still had difficulties and made mistakes in translating British brickwork across cultures; by 1936, the brickwork that the Chinese authors devoted much space to was still a matter of craft rather than the type of "science of construction"[51] that the Mitchell books evidently displayed after 1906, while the Chinese authors intentionally considered the local reality in their books, which thus honestly reflected how the Chinese reconstructed their knowledge system and mastered their practical skills when confronted with western cultures. In China, modern engineering sciences have influenced brick masonry construction by the introduction of new brick making methods and new laboratory research methods, for instance; however, it is an overstatement to consider the three Chinese construction books as examples of modern construction engineering.

Thirdly, compared with constructed brick buildings, there are both similarities and differences between Victorian brickwork and Shanghai brickwork, indicating the development of local craftsmanship in modern Shanghai. Chinese workers' new skills had been formulated by the end of the nineteenth century at the latest, which can be also confirmed in the built typology of structures. Nevertheless, there are observable gaps and lacunas between the Chinese construction books and the built brickwork, such as the missing "closer", which has been featured in the modern buildings of Shanghai in a very subtle yet omnipresent fashion. An important reason is hidden in the supply of brick materials, as revealed in the paper.

Finally, the study discovered broad connections across different areas of activities in circulating western construction methods and technology. The development of the western construction system, at least in terms of brickwork, involved sources and resources from very diverse fields, such as steel making, ship repairing, and railway, bridge, and canal building. Shanghai was also embedded in a network together with other Treaty Ports, such as Hankou (now part of Wuhan). In addition to Shanghai's internationality, which has been well recognised, this inter-field and inter-space network has been under-studied, and it actually characterises an early phase of establishing a western construction system in China (c. 1843-1910).

Acknowledgements

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13. Fig. 3, left: image courtesy of the Needham Research Institute (SE3/28), original caption "Astronomer Chou Yi-Hsin (Zou Yixin 鄒儀新) at the Chungshan University Astronomical Observatory (Zhong shan da xue tian wen tai 中山大學天文臺), Pingshih (Pingshi) 坪石, Kuangtung (Guangdong) 廣東". The contrast of the building image has been adjusted by the author in order to show the brick bonds clearly.
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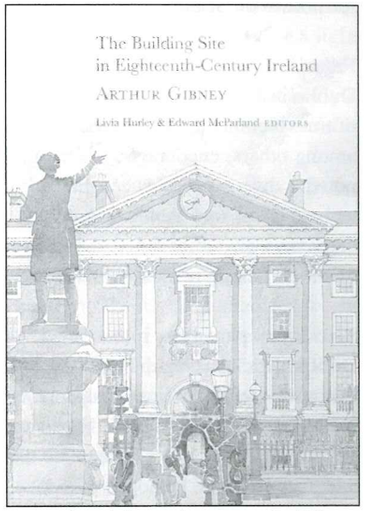
Book reviews

The Building Site in Eighteenth-Century Ireland

Arthur Gibney (author), Livia Hurley and Edward McParland (editors) Four Courts Press Ltd: Dublin, 2017. 368 pp. £30 hardcover. ISBN: 978-1846826382



It is not always easy to say what is the difference between architectural history, building history and construction history. A new comprehensive study by the late Arthur Gibney (and edited by Livia Hurley and Edward McParland) presents the history of the building site in eighteenth century Ireland and this does feel like 'construction history' proper. In this book, the skilled artisan builder is more present than the patron - and even the architect. The various roles of masons, bricklayers, joiners, carpenters and plumbers, plasterers and painters, are all explored and explained, in ambitious detail, based principally on studies of original documentary sources (accounts, receipts, correspondence, contemporary manuals). Their work is also illustrated by well-chosen details from paintings and engravings, which provide an immediate visual exposition of the building process (including quarrymen and brick makers – men and women).

The author was an experienced architect who had worked on many major eighteenth-century buildings in Ireland. He used both these original documents and his own observations drawn from 'hands-on' experience of working on buildings of the period, to put together their perceptive study of the whole *dramatis personae* of those involved in the construction process. This was originally Mr Gibney's PhD, and has been ably re-shaped and introduced by his two editors, and the resulting book is a useful guide to building techniques and practices in Ireland from the later seventeenth century to the end of the eighteenth. The range of Mr Gibney's reference is wide, from contracts to roof trusses, the choice of slates or pantiles to pattern books, brick import and manufacture and stone-quarrying.

The book opens with an investigation of the organisation, management and contractual practice of the period. The evolution of the trade association structures during the early eighteenth century gives a vivid illustration of the changing world of the artisan – in 1670, Dublin bricklayers and plasterers left the long-established Carpenters' Guild to form a new Guild of St Bartholomew. In the same year the painters (whose work was booming with the increased use of imported fir for interior finishes and windows) formed a new Guild of St Luke, with the stationers and cutlers.

The contractual arrangements were either the measured contract, the day works contract or contract in gross. The measured contract was the usual mode, over which the client's agent would have the general organisational control. The measured contract gave rise to an increasing reliance on well-trained 'measurers'. Dayworks contract were the norm for minor works, including repairs and occasional maintenance. The contract in gross, effectively a lump sum agreement with a general contractor was not favoured by patrons in mid eighteenth century Ireland, one commentator in 1769 describing

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