Current Prospects and Research Status on Linqing Bricks and Their Manufacture

Long Zhang[1(✉)] and Jin Yan[2]

[1] Tianjin University, Tianjin 300110, China
[2] Jinke Real Estate Group Co., Ltd., Wuhan 430000, Hubei, China

Abstract. This study reviewed historical documents and existing research results on Linqing bricks, and conducted surveys about the inheritance of the bricks' production method, the development of its industry, the applications of Linqing bricks in some world heritage sites throughout history, and their current use in contemporary repairs. Four main findings were gathered. First, the quality of contemporary Linqing bricks is far worse than that of ancient bricks in heritage sites like the Forbidden City, which results in the failure to achieve adequate repair standards; the high rate of substandard Linqing brick products has always been a challenging problem for craftsmen. Secondly, it is necessary to further determine the history of the production and use of Linqing bricks. Thirdly, there is a lack of efficient technical specifications for manufacturing, and the original tradition of craftsmen engraving their names on their products has been abandoned. Finally, brick factories have little confidence in the cultural background of Linqing bricks, and therefore have less motivation to improve their craft. Based on these findings, further research on the history/genealogy and the standardization of Linqing brick manufacturing will be carried out.

Keywords: Heritage conservation · Historiography · Blue brick · Engraved craftsmen names · History · Genealogy

1 Introduction

From the middle of the Ming dynasty to the end of the Qing dynasty, Linqing has been the manufacturing center of northern Chinese blue bricks. It has paid millions of bricks as a form of tribute to royal buildings in Beijing every year, which were used to create some famous World Cultural Heritage Sites, including the Imperial Palace, the Ming Tombs, and the Temple of Heaven. The firing of Linqing bricks was reestablished in 1996, but it was found that the abrasion resistance, toughness, freeze-thaw resistance, and other properties of newly-made bricks were far inferior to those made in the Ming and Qing Dynasties. This problem is so common in contemporary blue brick firing that heritage sites, like the Palace Museum, do not generally replace weathered, abraded, and even fractured bricks used in their outdoor grounds and walls.

The firing technique of Linqing bricks has been orally taught and understood for centuries. However, this production method that relies only on the experience of craftsmen cannot meet the contemporary requirements of production and development; thus,

S. Xu et al. (Eds.): *East Asian Architecture in Globalization*, pp. 132–141, 2021.
https://doi.org/10.1007/978-3-030-75937-7_11

efforts should be made to record and pass down this information effectively. This project can, therefore, serve as a reference point for ensuring the authenticity and effectiveness of northern Chinese heritage site protection initiatives, and allows for further steps to be taken towards clarifying the history of brick-firing methods and carrying out related research on the standardization of the manufacturing process of Linqing bricks.

2 Present State of Research

With the increase of international cooperation and communication regarding heritage conservation, there seems to be a nationwide consensus that the conservation and research of heritage sites should be based on their original materials. It has been pointed out in many Western studies related to the protection and restoration of brick buildings that the color, scale, and strength of bricks are the most important factors conducive to the success of restoration projects. This research (Nash 1989; Warren 1999; Biswas 2008) also emphasizes the protection of material craftsmanship, and encourages the regular update of inherited crafts-related know-how through modern science and technologies.

At the end of 2016, Shan Jixiang, the president of the Palace Museum and the director-general of the State Administration of Cultural Heritage, made the decision to halt the extensive repair works taking place at the Palace Museum (Han 2017). In an exclusive interview, he underlined that the repair of ancient buildings should be further designated as the research of the protection of ancient buildings, and also proposed that material supply bases for the repair of official ancient buildings as well as material performance standards should be established to save the dying construction technologies of ancient buildings. He emphasized that only in this way could the quality of the repair projects of ancient buildings in the Imperial Palace be improved.

This indicates that existing research has played a significant part in the future development of Chinese heritage conservation, including the exploration of key indexes during production, the improvement of the physical properties of Linqing bricks, and the establishment of a corresponding system of quality control standards. The recent research achievements regarding the Linqing brick (or blue brick) showcase the following trends.

2.1 Inscriptions

The rubbing and research of inscriptions on stone and brick are traditions of historical research in China. Among the numerous books detailing the inscriptions found on ancient bricks, *Illustrated Guide of Ancient Bricks in Qian Bi Pavilion* has been acknowledged as the most comprehensive; the author, X. Lu, has rubbed the inscriptions and ornamentations of more than 1000 bricks ranging from the Han and Wei dynasties to the Tang and Song dynasties. He has also tracked down their ages, origins, sizes, and features in detail. To maintain this academic tradition, Wang (1999) compiled the *Illustrated Guide of Inscriptions of Bricks Used in the Ramparts of Nanjing City in the Ming Dynasty*. With the walls of Nanjing as his research object, he rubbed 249 pieces of brick carvings and wrote extensive corresponding notes. His systematic summary of the weight, craftsman, and place of production of each brick laid a solid foundation for the research of Nanjing City, and even the history of the Ming dynasty.

Osvald Sirén (1924) is the historian who first researched the inscriptions of Linqing bricks. He recorded hundreds of inscriptions found on bricks made in Linqing during the Ming and Qing dynasties, and used this information to investigate the construction history of Beijing City. In modern times, many Linqing bricks with inscriptions have been found in Beijing, Hebei, Tianjin, and Shandong, among other places. They are now located in various local museums, at heritage sites, and with individuals, and the tremendous amount of information that these bricks can offer has not yet been sufficiently gathered or organized.

There also exists a long history of brick production in Europe. The tradition of carving notes on bricks has been kept, and these notes have attracted universal attention from researchers. For example, Juraj Bartík (2011) not only chronicled the history of brickmaking in Slovakia and the modern brickmaking industry, but also systematically sorted the inscriptions of bricks found in Slovakia, and summarized a list of historical Slovakian brick sites. In the book's preamble, the editorial committee recommended advancing international cooperation, breaking through contemporary regional restrictions, and studying the history of brickmaking in Austria-Hungary as a whole. This approach can also be used to research the manufacture of Linqing bricks.

2.2 History of Linqing Brick Firing and Manufacturing

The scholar Fu Chonglan also conducted early research on the history of Linqing brick production. During his research on the development of cities along the Grand Canal in 1981, he conducted a three-day investigation on the kiln sizes, manufacturing technologies, and categories of Linqing bricks in the Ming and Qing dynasties. He wrote an article titled "Investigation on Linqing Brick Kilns in the Ming and Qing Dynasties", which was then published in the Palace Museum Journal under his pseudonym of Yan Fuzhang in the next year, in which it was titled "Linqing Bricks Used in the Construction of the Forbidden City in the Ming and Qing Dynasties" (Yan 1982). It can be argued that Fu's research method, line of thinking, and the focused efforts of his staff formed the basis for subsequent research on the manufacturing history of Linqing bricks. Wang (2006), a researcher from Liaocheng University, took this research a step further by referring to local records and collections to discuss the history and influence of the firing of Linqing bricks on the modes of local development and production management.

Wang (2012; 2013), a scholar from Beijing Normal University, has conducted since 2010 a research project titled "Construction History of Beijing in the Ming Dynasty" with the support of the National Social Science Foundation of China. He has focused on the necessary procedural steps for construction and firing in Beijing during the Ming dynasty, and has published several papers in succession. Via the combination of documental references and archaeological studies, he has collected many remains of kilns and bricks of the Ming dynasty from the riverbanks of the Wei River, and has clarified how the brick firing locations and methods changed in the northern district during the Ming Dynasty. From May 2010 to November 2011, the Water Diversion Project of the Shandong Province Institute of Cultural Relics and the Archaeology Museum of Linqing City (2015) conducted a collaborative, systematic archaeological excavation at the kiln sites of the Ming and Qing dynasties on the Linqing River in Weizhang Village. It was the first time that the official kiln sites at which Linqing bricks were fired had been

disclosed on a large scale. As a result, a substantial amount of first-hand information about the styles of the official kilns and brick inscriptions was obtained.

Although the history of Linqing bricks has not yet attracted the attention of foreign researchers, they have nevertheless conducted many investigations on the history of brick firing as related to their local districts and ethnicities, combined with the goal of protecting contemporary architectural heritage sites. In August 2012, the European Association of Archeologists held a seminar in Helsinki, Finland, on the production, construction, and decline of medieval bricks in Europe (Blain et al. 2014; Debonne 2014; Sosnowska 2014; Rieger 2014; Biermann and Heremann 2014; Pela 2014; Malm 2014; Lamm and Lindahl 2014; Ratilainen 2014). There also exists some literature (Lynch 1994; Cook 1998; Stenvert 2012) that is significantly meaningful for the study of the history of Linqing bricks, due to their research methods that combine brick-firing history, construction procedures, and heritage site conservation.

2.3 Craftwork Related to Firing and Manufacturing

The large-scale activities of brick firing during the Ming dynasty have attracted the attention of both literati and officials to the craftwork of firing and manufacturing blue bricks. Zhang, a minister serving during the reign of Jiang Jing (Ming dynasty), thought that the firing of Suzhou Golden Bricks was arduous. Therefore, he composed the *Illustrated Handbook for Producing Bricks*, which recorded each step of the brick manufacturing process along with pictures and notes, and submitted it to the Emperor in an effort to draw attention to this topic and stimulate a reassessment of the process. Unfortunately, the book was not included in the *Complete Collection of the Emperor's Four Treasuries* when it was compiled, and only the abstract remains. Additionally, the types and crafting of blue bricks can also be found in the work *Tiangong Kaiwu*, which was written by Song Yingxing in the late Ming dynasty.

In modern times, with the growing attention to intangible cultural heritage and the increasing trend of designing architecture with ancient styles, the blue brick market has become increasingly more active. Increasing attention has simultaneously been paid to the firing process of Linqing bricks from the perspective of protecting and inheriting intangible cultural heritage. For example, Yu (2007) wrote the reference work *Linqing Brick-Firing Technique*, and Liu (2015) published *Research on Conservation of Firing Craft for Linqing Bricks*. The research conducted on the Suzhou Golden Brick is comparatively deeper than that of Linqing bricks. To imitate the construction of the Suzhou Golden Brick, Yang and Miao from the Jingdezhen Ceramic Institute have quantitatively recorded the related firing process in a laboratory, and used an X-ray and scanning electron microscope (SEM) to analyze the Golden Brick's chemical composition, crystal phase composition, microstructure, and technical properties. The achievements of their efforts to quantitatively study the firing crafts of blue bricks are found in multiple publications (Yang 1994; Miao and Xu 1996; Miao 1996). There also exists research from the perspective of technical improvements (e.g., Xu 2009). These works indicate that quantitative study with the goal of improving the construction of Linqing bricks while considering their heritage is completely necessary and possible.

2.4 Techniques and Standards of Firing and Manufacturing

Faced with increasing technical and legal requirements for protecting heritage sites, some universities and institutes have explored the physical properties, deterioration mechanisms, and material inspection standards of bricks. For instance, Li (2014a; 2014b) from Southeast University tested the moisture absorption isotherms of blue bricks in Taiyuan and Fuzhou historical buildings, analyzed the differences between the isothermal absorption properties of the bricks, and found that the stronger hygroscopic properties of blue bricks in Taiyuan are the catalyst of their deteriorating performance. Huang and Zheng (2011) from the South China University of Technology and Ding et al. (2011) respectively selected 60 groups of specimens of new and old blue bricks from the Guangdong Pearl River Delta region of Hebei Province, and carried out experiments and data analysis according to the industry standards of the Evaluation of the Strength Grade of Common Fired Bricks with a Rebound Instrument (JCT796-2013). They established strength curves for blue bricks in their respective regions, which provided a basis for material detection in heritage protection. In addition, Liu (2006), an expert on bricks and tiles used in ancient architecture in Beijing, put forward the "Reference Quality Inspection Standards for Traditional Bricks" which addresses the following aspects: external appearance qualities, size requirements, crack inspection, trachoma inspection, mute test results, flexural (bending) performance, antifreeze (weathering) properties, water absorption ability, anti-permeability, lime test results, and the burnt-brick fire index.

The testing of blue bricks with contemporary material analysis and detection methods indicate that, via the new measurement systems for material quality testing standards, it is feasible to detect and analyze the physical and chemical properties of Linqing bricks and establish a quality evaluation index system via experiments.

3 Existing Issues

3.1 Need for Further Clarification of the Histories of Production and Use

Because of the lack of local records and relevant historical materials of Jinyuan, current academic circles generally believe that Linqing gradually became the northern brick-firing center after the Yongle Emperor moved the capital during the Ming dynasty due to its good soil quality and the convenience of water transportation. This consensus has been reached according to the records of the Ming and Qing dynasties (Shen 1989; Qinding Daqing huidian zelie 钦定大清会典则例) and Linqing's local chronicles (Yu 1673; Zhang et al. 1785). These two conditions have been present in Linqing since the opening of the Yongji Canal during the Sui Dynasty; however, Beijing was the capital of the Jin and Yuan Dynasties, during which the palaces and temples were of considerable size, despite soil being the main building material at that time; therefore, it is unknown where the Linqing bricks were used in architecture. Another question that remains to be answered is whether any brick-firing activity existed in Linqing before the Ming dynasty. If there was no traditional *shaozao* 燒造 (i.e., burning of bricks and ceramics for the imperial court) industry before, why did this place become the North *shaozao* production center in the Ming dynasty? In addition, the changes in the Linqing kiln quantities, and their modes of distribution and management in different periods are

unknown, as are the types of kiln heads and the manner in which related information was passed down. Finally, there are gaps regarding the knowledge of which ancient buildings in specific cities utilized Linqing bricks. These problems are not sufficiently clear and require further clarification.

3.2 Issues Concerning Ancient Bricks' Inferior Quality and Low Yield

In the 1970s, the directors of some heritage sites like the Palace Museum and the Ming Tombs attempted to obtain Linqing bricks from Linqing; however, because the craft of Linqing brick construction was lost and the firing activity had ceased, they had no choice but to select other blue bricks with which to repair the ancient buildings. Linqing bricks started to be produced again in 1996, at which time the craft was also included in the list of national intangible cultural heritages. However, the records were primarily qualitative descriptions (Wang 2006), and the quality of newly-made Linqing bricks was not comparable to that of the ancient bricks in terms of the balance of hardness and toughness (workability) and freeze-thaw resistance. This is the reason why many World Cultural Heritage Sites do not quickly replace weathered, worn, or even broken outdoor and wall tiles. It is also why the Palace Museum launched a wall maintenance program in 2017, but only implemented it locally.

In the Ming and Qing Dynasties, Linqing bricks underwent layer-by-layer examination, and only 10% of them were allocated for use in Beijing (Archaeology Museum of Linqing City 2008). Those chosen bricks built a reputation of "knocking with sound and sectioning without hole". However, official records include notes such as "these bricks are coarse" and that they have "too many holes" (Wang 2016) due to insufficient supervision or careless screening. Thus, it is clear that the production of Linqing bricks has been confronted with high rates of insufficient quality and scrapping.

3.3 Lack of Effective Technical Manuals for Passing Down Craft Knowledge

Although each step of the production of Linqing bricks is recorded in the *Tiangong Kaiwu* (Song 1637), the specific process lacks operational and quantitative technical standards or requirements. Even now, for experienced craftsmen to pass the knowledge of their craft on to their apprentices, they can only teach in a qualitative way that tests some important indexes via watching, smelling, and splitting brick specimens. Thus, there will be an information gap between the two generations, thus making it unlikely to achieve sustainable innovation.

"Craftsmen must carve their names on what they make so that regulators have the convenience of examining the quality of products, and once a flaw is found, the relevant producers will be sentenced". To ensure that the quality of building materials could be tracked, a quality control system called "testing work", which required craftsmen to carve their names on the bricks they made, was implemented from the beginning of the early Qin Dynasty. However, to obtain a smooth surface and to simplify production procedures, contemporary blue brick production has abandoned this convention, although it remains in some European and American countries.

3.4 Lack of Cultural Confidence and Motivation for Improving Product Quality

At present, there are two blue brick factories in Linqing, one of which maintains the production of traditional handmade crafts, and the other of which actively uses machinery equipment to reduce the intensity of labor, though they are both engaged in the use of the inherited Linqing brick-firing process. However, under the influence of the brick-selling market and engineering factors such as low prices, the improvement of the quality of Linqing bricks, let alone reshaping Linqing as the core material supply base for northern Chinese buildings as it was during the Ming and Qing Dynasties, is not a primary task for them. The standard of products entering the market is MU10, which is the minimum compressive strength standard for common fired bricks (GB5101-2003); thus, there is a lack of motivation to improve quality. In addition, as a result of a development policy for cultural and creative industries, one of the brick factories has spent a lot of time and energy on exploring the possibility of developing tourism products related to firing, such as instruments, dolls, chessboards, and tea sets, using the raw materials of blue bricks. This is the embodiment of the lack of awareness and cultural self-confidence of Linqing bricks, which can be considered to be a historical brand.

4 Research Prospects

4.1 Research on the History of the Production and Application of Linqing Bricks

Based on a complete review of current related research, it is recommended to expand the scope of historical materials, interview current heads of management at production sites, and investigate the changes that occurred in the operation and numbers of official kilns during the Ming and Qing dynasties. Specifically, these actions could support the estimation of the construction dates of royal buildings, and could promote additional research on the construction history and repair of royal architecture from the Ming and Qing dynasties. If more inscriptions on Linqing bricks are extensively collected, and if the manufacturing period, regulators, potters, kiln head types, and craftsmen of the bricks, as well as the places in which they are used, are systematically studied, a sample library could be constructed to contribute for a detailed chronicle of historical and material information.

4.2 Research on the Micro-composition and Physical Properties of Linqing Bricks

Due to modern scientific testing, it is possible to research the microstructure, phase composition, hardness, compactness, toughness, wear resistance, moisture absorption properties, and other aspects of the surfaces and interiors of Linqing bricks. As a result, a quality evaluation index system could be established to provide a scientific basis for the formulation of relevant quality testing standards.

4.3 Quantitative Research on Key Technical Indexes for the Firing Process

The process of firing bricks can be regarded as a thermophysical model; thus, it is plausible that the optimal technical parameters can be determined via a computer simulation method. Whether these parameters are reasonable or feasible could then be tested via experiments. Thus, promising improvements in the yields and qualities of Linqing bricks may arise with the increase of the depth of this critical research. Furthermore, the craft of Linqing brick production could be passed down more effectively, and the repair of architectural heritage sites in Beijing from the Ming and Qing dynasties could be more firmly guaranteed. The local sense of cultural self-esteem and pride would consequently increase, thereby stimulating the development of related local industries.

References

Archaeology Museum of Linqing City: National Intangible Cultural Heritage Declaration for "Linqing tribute brick firing skills". Linqing City, China (2008)

Biermann, F., Herrmann, C.: The origin and rise of brick technology and use in medieval Pomerania, Pomerelia and lower Silesia. In: Ratilainen, T., Bernotas, R., Herrmann, C. (eds.) Fresh Approaches to Brick Production and Use in the Middle Ages, Proceedings of the session "Utilization of Brick in the Medieval Period: Production, Construction, Destruction" held at the European Association of Archaeologists (EAA) Meeting, 29 Aug 2012–1 Sept 2012 in Helsinki, Finland. British Archaeological Reports, Oxford (2014)

Biswas, S.S.: Conservation and Restoration of Brick Architecture (Special Reference to Manipur, North-East India). Kaveri Books, New Delhi (2008)

Blain, S., et al.: Early medieval brickmaking: a cross-channel perspective based on recent luminescence and archaeomagnetic dating results. In: Ratilainen, T., Bernotas, R., Herrmann, C. (eds.) Fresh Approaches to Brick Production and Use in the Middle Ages, Proceedings of the session "Utilization of Brick in the Medieval Period: Production, Construction, Destruction" held at the European Association of Archaeologists (EAA) Meeting, 29 Aug 2012–1 Sept 2012 in Helsinki, Finland. British Archaeological Reports, Oxford

Cook, S.H.: Mexican Brick Culture in the Building of Texas, 1800s–1980s. Texas A&M University Press, Texas (1998)

Debonne, V.: Brick production and brick building in medieval Flanders. In: Ratilainen, T., Bernotas, R., Herrmann C. (eds.) Fresh Approaches to Brick Production and Use in the Middle Ages, Proceedings of the session "Utilization of Brick in the Medieval Period: Production, Construction, Destruction" held at the European Association of Archaeologists (EAA) Meeting, 29 Aug 2012–1 Sept 2012 in Helsinki, Finland. British Archaeological Reports, Oxford (2014)

Ding, W., et al.: Study on modern handmade grey brick rebound curve. Constr. Qual. **31**(8), 18–21 (2011)

Han, S.: Gujianzhu xiufu "renqu yi-wang", Gugong yong Beijing hukou liuzhu gongjiang 古建筑修复"人去艺亡", 故宫用北京户口留住工匠 (2017). http://society.huanqiu.com/article/2017-02/10090611.html. Accessed 14 Jun 2017

Huang, W., Zheng, L.: On the strength-rebound-curve of the grey brick from ancient buildings. Sci. Technol. Eng. **11**(13), 3111–3113 (2011)

Bartík, J.: Laterārius: dejiny tehliarstva na Slovensku. Slovenské Národné Múzeum-Archeologické Múzeum, Bratislava (2011)

Lamm, J.P., Lindahl, A.: A recently excavated medieval brick kiln at Saltsjö Boo, Sweden and the HXRF analyses of its products. In: Ratilainen, T., Bernotas, R., Herrmann, C. (eds.) Fresh Approaches to Brick Production and Use in the Middle Ages, Proceedings of the session "Utilization of Brick in the Medieval Period: Production, Construction, Destruction" held at the European Association of Archaeologists (EAA) Meeting, 29 Aug 2012–1 Sept 2012 in Helsinki, Finland. British Archaeological Reports, Oxford (2014)

Li, Y.: Comparative study of isothermal sorption properties of traditional blue bricks in history buildings. J. Build. Mater. **17**(6), 1092–1095 (2014a)

Li, Y.: Experimental research on isothermal sorption properties of early modern and modern gray bricks in Wujiang, Suzhou, China. J. Southeast Univ. (Natural Sciences Edition) **44**(2), 441–444 (2014b)

Liu, D.: Quality inspection standard of traditional brick for reference. Trad. Chin/ Archit. Gardens **4**, 56–62 (2006)

Liu, K.: Research on the Conservation of the Linqing Tribute Brick Firing Techniques. Department of Art Studies of the Chinese National Academy of Arts, Beijing (2015)

Lu, X.: Illustrated Guide of ancient bricks in Qian Bi Pavilion. Zhejiang Ancient Books Publishing House, Zhejiang (2011)

Lynch, G.: Brickwork: History, Technology and Practice. Donhead, London (1994)

Malm, G.: (2014) Facts and thoughts on medieval brick building in the northern periphery of Europe. In: Ratilainen, T., Bernotas, R., Herrmann, C. (eds.) Fresh Approaches to Brick Production and Use in the Middle Ages, Proceedings of the session "Utilization of Brick in the Medieval Period: Production, Construction, Destruction" held at the European Association of Archaeologists (EAA) Meeting, 29 Aug 2012–1 Sept 2012in Helsinki, Finland. British Archaeological Reports, Oxford (2014)

Miao, S.: Traditional processing of large blue and white tiles and "Golden Bricks". Ceram. Stud. J. **11**(4), 190–193 (1996)

Miao, S., Xu, N.: The traditional firing kiln and technique of blue and white titles and "Golden Bricks". Ceram. Stud. J. **11**(3), 131–136 (1996)

Nash, W.G.: Brickwork Repair and Restoration. Attic, Powys (1989)

Pela, W.: Bricks in historic architecture: the research experience of Warsaw. In: Ratilainen, T., Bernotas, R., Herrmann, C. (eds.) Fresh Approaches to Brick Production and Use in the Middle Ages, Proceedings of the session "Utilization of Brick in the Medieval Period: Production, Construction, Destruction" held at the European Association of Archaeologists (EAA) Meeting, 29 Aug 2012–1 Sept 2012 in Helsinki, Finland. British Archaeological Reports, Oxford (2014)

Ratilainen, T.: Unfired bricks used for a medieval oven in Turku, Finland. In: Ratilainen, T., Bernotas, R., Herrmann, C. (eds.) Fresh Approaches to Brick Production and Use in the Middle Ages, Proceedings of the session "Utilization of Brick in the Medieval Period: Production, Construction, Destruction" held at the European Association of Archaeologists (EAA) Meeting, 29 Aug 2012–1 Sept 2012 in Helsinki, Finland. British Archaeological Reports, Oxford (2014)

Rieger, D.: The use of early bricks in secular architecture of the 12th and early 13th century in Lübeck. In: Ratilainen, T., Bernotas, R., Herrmann, C. (eds.) Fresh Approaches to Brick Production and Use in the Middle Ages, Proceedings of the session "Utilization of Brick in the Medieval Period: Production, Construction, Destruction" held at the European Association of Archaeologists (EAA) Meeting, 29 Aug 2012–1 Sept 2012 in Helsinki, Finland. British Archaeological Reports, Oxford (2014)

Shandong Province Institute of Cultural Relics, Archaeology Museum of Linqing City: Haidai Kaogu, vol. 7, pp. 325–362. Science Press, China (2015)

Shen, S.: Records of Ming Dynasty, vol. 190, pp. 963–965. Chung Hwa Books, Beijing (1989)

Sirén, O.: The Walls and Gates of Peking. John Lane, London (1924)

Song, Y.: Tiangong Kaiwu. Manuscript (1637)

Sosnowska, P.: Approach on brick and its use in Brussels from the 14th to the 18th century. In: Ratilainen, T., Bernotas, R., Herrmann, C. (eds.) Fresh Approaches to Brick Production and Use in the Middle Ages, Proceedings of the session "Utilization of Brick in the Medieval Period: Production, Construction, Destruction" held at the European Association of Archaeologists (EAA) Meeting, 29 Aug 2012–1 Sept 2012 in Helsinki, Finland. British Archaeological Reports, Oxford (2014)

Stenvert, R.: Biografie Van De Baksteen 1850-2000. WBooks, Zwolle (2012). Rijksdienst voor het Cultureel Erfgoed, Amersfoort

Wang, K.: Illustrated Guide to Inscriptions of Bricks Used in Ramparts of Nanjing City in Ming Dynasty. Nanjing Press, Nanjing (1999)

Wang, Y.: The production and social influence of tributary bricks made in Linqing in the Ming and Qing Dynasties. Palace Mus. J. **6**, 61–72 (2006)

Wang, Y.: A study of kiln-firing production for construction of Beijing in the Ming Dynasty: focus on the change of kiln sites, product structure and manufacture system of supplies. Palace Mus. J. **2**, 21–71 (2012)

Wang, Y.: Research on wall bricks production around Wei River in the Ming Dynasty. Cultur. Relics Central China **6**, 92–97 (2013)

Wang, Y.: Shan Jixiang jiaoting Gugong xiushan beihou de wunai: Baogongtou zhao lianjia mingong 单霁翔叫停故宫修缮背后的无奈: 包工头找廉价民工 (2016). http://news.xinhuanet.com/local/2016-12/11/c_1120093652.htm. Accessed 9 Feb 2017

Warren, J.: Conservation of Brick. Butterworth Heinemann, Oxford (1999)

Xu, Y.: Study on the process of producing and development of brick. Brick Tile World **3**, 38–42 (2009)

Yan, F.: Linqing Bricks used in the construction of Forbidden City in Ming and Qing Dynasties. Palace Mus. J. **1**, 94–96 (1982)

Yang, W.: Research of Golden Brick's imitating crafts. China Ceram. **134**(1), 57–60 (1994)

Yu, H.: Exploration, Recall and Reappearance: Investigation and Research of the Intangible Cultural Heritage in Qi and Lu Area, pp. 108–117. Shandong University Press, Jinan (2007)

Yu, R.: The records of Linqing. Manuscript (1673)

Zhang, D. et al.: The records of Linqing directly under the central government. Manuscript (1785)

Zhang, W.: Illustrated Handbook for Producing Bricks. Manuscript (1522–1566)

Shutongwen Ancient Books Database: Qinding Daqing huidian zelie, Juan 128 钦定大清会典则例,卷一二八 (2016). http://guji.unihan.com.cn/web#/book/QHD/page?pageId=Mjc5NTE%3DODAyNA%3D%3DOA%3D%3D. Accessed 9 Feb 2017