Research Progress on Production Technology and Equipment of Fired Perforated Brick

Hongmei Liu¹,², Jian Zhang¹, Xingxing Wang¹*, Aidong Zhu³, Dawei Ding⁴, Hongjun Ni¹ and Wenbo Ai¹

¹ School of Mechanical Engineering, Nantong University, Nantong, Jiangsu, 226019, China
² School of Transportation and Civil Engineering, Nantong University, Nantong, Jiangsu, 226019, China
³ Nantong Wall Material Innovation and Building Energy Conservation Management Office, Nantong, Jiangsu, 226007, China
⁴ Jiangsu Zhengcheng Building Material Equipment Technology Co., Ltd, Nantong, Jiangsu, 226600, China

*Corresponding author’s e-mail: wangxx@ntu.edu.cn

Abstract. Fired perforated brick is a common material in modern construction industry. This paper introduced the production technology and equipment of fired perforated brick. Based on the research status of domestic and foreign scholars, technical difficulties and corresponding solutions of production process were analyzed and summarized. And the future of fired perforated bricks production equipment was discussed.

1. Introduction

In China, fired brick and tile products have a long history of production and use, the earliest production of fired clay brick can be traced back to 5000 years before. The reputation of "Qin brick and Han tile" symbolized the maturity of production technology of ancient brick and tile products [1]. After years of development, fired brick and tile products have become indispensable materials for modern construction industry.

With the rapid development of urbanization and the increase of Chinese housing construction area, the demand for brick and tile products is increasing. At the same time, the traditional production process of fired solid brick had many shortcomings, such as low automation, high pollution and energy consumption. Not only is it difficult to meet the increasing market demand in terms of production capacity, but it also brings huge pollution to the environment. While fired perforated brick can save a lot of land resources and fuel, and reduce gas consumption and save costs [2].

In the production process of fired perforated brick, the improvement of production technology become an urgent matter. At the same time, the development and improvement of mechanical equipment that match with the production of fired perforated brick has become a new opportunity and challenge for brick and tile machinery manufacturers.

2. Production technology of fired perforated brick

The production technology of fired perforated brick is mainly divided into four parts: ①Raw material
preparing ②Green brick forming ③Semi-finished product drying ④Finished product firing. The interdependence of the four parts affects the quality of finished brick together [3,4].

2.1. Raw materials preparing
The earliest fired brick was made mainly by clay. But exploitation of clay caused damage of land resources. At the beginning of this century, China has gradually banned the use of clay as raw material to produce fired brick. At present, shale, coal gangue and fly ash replaced clay as the main raw material of fired perforated brick. With the enhancement of people's awareness of environmental protection, new brick-making materials such as industrial waste, construction waste and river silt have been gradually applied to the production of fired perforated brick in recent years. For example, Raju Sarkar et al. [5] replaced the clay with lime slurry, by-product from paper-making process and the highest replacement rate could reach 20% on the premise of meeting the strength requirements. Gaurav Goel et al. [6] used degraded garbage as material to production of fired brick. Not only reduce the use of clay, but also save up to 8% of fuel by utilizing the calorific value of waste combustion. The addition of various new materials not only protects land resources but also saves the production cost of fired perforated brick.

In the preparation process of raw materials, it is necessary to mix and crush raw materials and other processing procedures [7]. As shown in Figure 1, the raw material preparation process of an enterprise is described. In addition, some raw materials need special treatment in the preparation process. For example, high added fired fly ash perforated brick requires high-quality raw materials which need to be weathered for 1.5 to 2 years in order to improve particle dispersion and performance of raw materials. The prepared raw materials should have good plasticity [8] that help next green brick forming.

![Figure 1. Process flow of raw material preparation](image)

2.2. Green brick forming
According to the different production methods, green brick forming can be divided into two types: compression molding and extrusion molding. Compression molding of brick refers to putting the mud into the mould cavity, then closing the mould to pressing the clay formed. In extrusion molding, raw materials are continuously extruded by vacuum extruder and then green brick is formed by wire cutting. Comparing with the compression molding, extrusion molding has the advantages of continuous production, constant pressure and high production efficiency. Therefore, most of the production enterprises use extrusion molding to produce fired perforated brick billets.

Because of plasticity, the clay strip will be deformed in the extrusion process of the green brick. It can be solved by adjusting the moisture content of the raw material [9]. While cracks, core drawing and corner missing are found in green brick, caused by misalignment or wear of extrusion die. Defects can be reduced by regular maintenance of forming equipment [10]. The green brick formed should have a complete shape and structure. In addition, the quality of the green brick directly affects the appearance quality of the finished brick.

2.3. Semi-finished product drying
There are two ways of semi-finished product drying: natural drying and artificial drying. Natural drying time is affected by region and climate. It usually takes 10-15 days and needs a larger site to stack semi-finished product [11]. In order to improve the production efficiency and reduce the area covered, in the actual production process, most of the fired perforated brick manufacturers use artificial drying method to dry it out.

Artificial drying means placing semi-finished product in the drying chamber, drying it out by the artificial heating and blowing the hot steam by the fan. Most factories use the waste heat of roasting kiln to provide heat and tunnel drying kiln is used as drying chamber [12]. The drying time of different raw
materials is different. Generally, drying can be completed in 48 hours.

2.4. Finished product firing
The firing method of finished products included once setting in firing-process and twice setting in firing-process according to the number of code bricks. The choice of firing mode depends on the performance of raw materials, water content of wet billet and product characteristics.

Once setting in firing-process puts wet billet on the drying car and directly drying it out in tunnel kiln to get finished bricks. The once setting in firing-process is simple and less investment, but it has some shortcomings such as low productivity, high coal consumption and more cracks \[13\]. It is mainly used for fired shale brick. At the same time, the product size should not be too large and the strength of wet billet is required to be higher.

Twice setting in firing-process means stacking the wet billet on kiln truck and drying it in the drying chamber and then replacing and firing into tunnel kiln to get product bricks. Figure 2 shows the process flow chart of producing fired perforated bricks by twice setting in firing-process in an enterprise. Twice setting in firing-process is suitable for porous bricks of various sizes. Although the yield increases, the equipment investment is higher and the production cycle is longer than once setting in firing-process.

![Figure 2. Production process of fired perforated bricks by twice setting in firing-process](image)

3. Key equipment for fired perforated brick production
Production equipment and production technology complement each other. With the continuous improvement of production technology, the automation equipment used in brick and tile enterprises is constantly updated. The improvement of automation of brick production enterprises greatly reduces the production cost and labor intensity of enterprises, the production efficiency of products has been significantly improved.

3.1. Application of crushing equipment in raw material preparation
The raw material size of fired perforated brick is generally required to be less than 2 mm. One-time crushing can not meet the requirements. It needs coarse crushing, medium crushing even multiple crushing. It also requires the cooperation of various crushing equipment \[14\].

Jaw crusher, impact crusher and hammer crusher are commonly used equipment in the crushing process of raw materials. They are mainly aimed at brittle, medium-hard and low water content raw materials, such as coal gangue, shale \[15\]. Jaw crusher is mostly used for primary crushing of raw materials. The crushed raw materials are crushed twice by impact crusher or hammer crusher to further refine the raw materials. Finally, they are crushed by roll crusher to meet the application requirements.

The energy usage rate of crushers is usually lower than 10%, a large part of which is converted into noise and vibration \[16\]. Improving crushing efficiency and reducing energy consumption are important for crushing equipment.

3.2. Application of forming equipment in green brick production
Since the Chinese first vacuum extruder was successfully operated in Xi’an in 1965, the vacuum extruder has gradually become the most important equipment in brick production. With the development of technology, the performance of the vacuum extruder has been greatly improved. The vacuum degree has
been raised over 96%, the extrusion pressure has reached more than 3 MPa, the extrusion speed of the mud bar can reach more than 30 m/min.

At present, the structure of the vacuum extruder has been basically finalized that mainly consisting of feeding inlet, the vacuum box, the screw rod and mould system. As shown in Figure 3, the structure of the vacuum extruder [17]. When working, The mud successively passes through the inlet, agitator tank and vacuum chamber. Air is extracted in vacuum chamber, and the pressure is provided by the spiral reamer, then the molding of the brick is completed by the mould system.

![Figure 3. Vacuum extruder [17]](image)

(1. Pneumatic coupling 2. Reduction box 3. Motor 4. Clamping coupling 5. Agitator tank 6. Vacuum chamber 7. Machine die 8. Machine head 9. Reservoir mud box 10. Inlet box 11. Clamping coupling 12. Reduction box 13. Pneumatic clutch)

3.3. Application of automatic setting machine in brick billets firing

Brick billet should be placed on the kiln car before entering the kiln. The traditional manual code placement is inefficient and labor intensive, it is not suitable for mass production. The fully automatic setting system is widely used in brick and tile enterprises because of its advantages such as less labor, small land covered, higher efficiency [18].

The automatic setting machine is mainly composed of four parts: moving mechanism, lifting device, holding device and rotating device [19]. When the automatic setting machine is working, the billet is clamped by the billet holding device, the billet is lifted by the lifting device, and the walking device drives the billet to move to the kiln car. In order to improve the firing quality, the two adjacent layers of bricks should be coded crosswise. Therefore, in the process of sending the brick from the conveyor belt to the kiln car, the rotating device starts to work to let the brick turn 90° rotation. Then reduces the brick to the predetermined height through the lifting device. Finally, it loosens the brick by the holding device and forming a whole stack of bricks.

3.4. Application of automatic packaging equipment in packaging of finished product

In order to transport the finished bricks, which are usually stacked in 1-1.5m³ stacks before being packed. So, the automatic packaging equipment includes the automatic setting device. The working principle of the automatic setting device is similar to that of the automatic setting machine used in brick kilning. But unlike the automatic setting equipment, the automatic packaging equipment is to put the finished brick code cooled from the kiln car on the stack board of the packer.

After the stacking is completed, the transmission device transports the stack of bricks to the work station of the baler. The vertical and horizontal baling are completed respectively [20]. As the last step in the production of fired perforated bricks, the packaging of finished bricks accumulates errors in the whole production process, which still needs manual supervision in the use process. The automatic packaging equipment still needs continuous improvement.
4. Summary and Prospect
(1) With the implementation of national policy and the change of market demand, new building materials, including fired perforated bricks, have broad prospects for development.
(2) With the enhancement of people's awareness of environmental protection, brick and tile enterprises need to consider not only the economy but also the environmental protection of raw materials when choosing and processing raw materials.
(3) With the increase of labor cost, the mechanical equipment that is used in brick and tile enterprises is constantly invented and improved. Automation level of brick and tile enterprises will be higher and higher in the future.

Acknowledgments
This work was financially supported by a project funded by the Jiangsu Wall Material Innovation Research Project (201702), A Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD) and Nantong City Applied Research projects (JC2018115).

References
[1] Yang Y., Yu S Y., Zhu Y Z., et al. (2014) The Making of fired clay bricks in China some 5000 years ago[J]. Archaeometry, 56:220-227.
[2] Zhang M., Feng X P., Feng J S., et al. (2018) Design and optimization analysis on hole shape of the sintering self-Insulating porous brick[J]. Bulletin of the Chinese Ceramic Society, 37:3957-3962.
[3] Yue Z Y., Yin Y., Gao Y X. (2014) Choose of firing process on fired brick[J]. Brick-Tile, 10:14-15.
[4] Jiang J Y., Zhang D. (2002) Hard plastic extruding and one time palletizing burning technology for full coal gangue sintered porous brick[J]. New Building Materials, 12: 8-10.
[5] Sarkar R., Kurar R., Gupta A K., et al. (2017) Use of paper mill waste for brick making[J]. Cogent Engineering, 4: 1-15.
[6] Gaurav G., Ajay S K. (2017) Degraded municipal solid waste as partial substitute for manufacturing fired bricks[J]. Construction and Building Materials, 155: 259-266
[7] Zhuang H F. (2016) Aging and examples of brick making materials[J]. Brick & Tile World, 12: 38-13.
[8] Cao S P. (2016) Quality control in sintering brick production process[J]. Brick & Tile World, 03: 37-44.
[9] Zhou R Y., Cao S P. (2014) Brick extrusion (II)[J]. Brick-tile, 3: 19-24.
[10] Wang Y C. (2017) Nine ways to deal with defects of bricks in molding workshop[J]. Foshan Ceramics, 12: 45-46.
[11] Celestino G., Chiara G., Alberto De B., et al. (2015) Traditional brick productions in Madagascar: From raw material processing to firing technology[J]. Applied Clay Science, 150: 252-266.
[12] Mei H., Zhang Y M., Zhang P G., et al. (2017) Effect of drying program on properties of sintered block made from lake sediment in tunnel kiln[J]. New Building Materials, 2: 53-58.
[13] Chen R S. (2014) Preconditions and measures for realizing high output of tunnel kiln with single firing[J]. Brick-Tile, 3: 25-28.
[14] Lang T. (2010) Choice and design of crusher[J]. Brick-Tile, 8: 38-41.
[15] Chen R S. (2007) Use of hammer mill and impact crusher in brick factory. Brick-Tile, 9: 75-77.
[16] Daniel L., Ron Z. (2014) Assessing the energy efficiency of a jaw crusher[J]. Energy, 74:119-130.
[17] Yang X Y. (2013) Simplified and improved structure of vacuum extruder[J]. Brick -Tile, 5: 29-30.
[18] Liu H M., Mi L., Wu C Q., et al. (2016) Research progress of control system foe automatic setting machine[J]. Architecture Technology, 47: 316-318.
[19] Wang H C. (2008) Application of automatic blanking machine in sintering brick factory[J]. Brick-Tile, 9: 75-76.
[20] Zhou S C. (2017) Pallet-free automatic brick unloading and packing system for sintered blocks[J]. Brick & Tile World, 09: 47-48.