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Determination of Optimal Drying Process for Ceramic Bricks of Semidry Pressing

Gurieva V.A.
Department of construction engineering
Orenburg State University
Orenburg, Russia
victoria-gurieva@mail.ru

Doroshin A.V.
Department of industrial and civil construction
Buzuluk Humanities and Technology Institute,
branch of Orenbyrg State University
Buzuluk, Russia
sanek0007@yandex.ru

***Abstract* – The article presents the results of experimental studies on the identification of the optimal burning conditions for ceramic raw materials based on clay loam from the Buguruslanskii deposit. The most common causes of cracking during drying, as well as measures to improve the crack resistance of manufactured products are presented in the article. The properties of the raw material are determined depending on the molding moisture content and molding pressure at drying temperature of 1050 ° C. The influence of the duration of drying on the burning properties of products with the content of ash and slag waste in the amount of 28% by weight, depending on the drying temperature is revealed. The dependence of the shrinkage value on the moisture level of the ceramic raw material is determined. The developed approaches will allow determining the optimal technological parameters of the drying of ceramic raw materials on the basis of fusible loams and industrial waste produced by the method of semi-dry molding.**

Key words – ceramic brick; drying; shrinkage; crack resistance; green moisture; sensitivity coefficient.

I. INTRODUCTION

The rapid rise in prices for energy and raw materials, the depletion of reserves of standard clay raw materials used for the production of ceramic bricks, pose serious challenges to manufacturers to produce products with improved properties, which inevitably leads to the development of new energy and resource-saving technologies, determines the need for secondary involvement of industrial mineral and raw material resources in production. The solution of the tasks is possible through the development and modernization of existing equipment and technology plants.

Thus, the need to introduce new, cheaper raw materials into the production of ceramic bricks will expand the raw material base for the production of solid ceramic bricks, decrease heat and energy consumption and ensure environmental protection. One of the most interesting and widespread secondary products, the storage and accumulation of which in large quantities in the dumps occurred during the period of using coal as an energy carrier, are ash and slag waste (hereinafter ASW). Ash and slag wastes are close to clayey raw materials by chemical and mineralogical composition. The organic part in the waste contributes to its use in the composition of charge mixture as an additional fuel component. In the process of coal combustion, unbaked microspheres remain which allow reducing fuel and energy costs for product drying. The consumption of high-quality traditional raw materials for the production of bricks is reduced, and the ecological situation in the territories occupied by ash and slag dumps is improved [1, 2].

For the introduction of ash and slag waste into the secondary production in sections with thin clay loams, the most rational method of making ceramic bricks is the dry-press molding method. This method makes it possible not only to give the correct shape and size, but also significantly reduces the drying time, unlike plastic one.

It is a well known fact that the production of ceramic bricks is a complex technological process. It includes several stages of preparation. One of the most important stages is the drying, which determines the quality of products, namely the absence of cracks and chips on the surface of a ceramic product [3, 4]. Drying is carried out in drying chambers to a moisture content of 6-8% inside a brick, which allows the raw brick to acquire mechanical strength for loading it onto drying trucks.

Nowadays the following drying methods are used at the enterprises: contact-diffusion, convective, heating by infrared rays, high-frequency and ultra-high frequency currents, superheated steam. Cameras and continuous driers are used for artificially drying of bricks. The duration of drying depends not only on the size and type of a product but also on the relative humidity of a product, the density of the load on a truck, and also on the physical and technological properties of mass.

Having selected the correct mode and method of drying, it is possible to regulate the intensity of evaporation of moisture from the surface of a product, the shrinkage of semi-finished products, the duration of drying, as well as the properties and speed of the coolant [5–7].

The intense drop in moisture content between the center of the semifinished product and its surface causes the formation of cracks on a product which leads to shrinkage deformations and loss of the strength of raw material [8, 9].

It is possible to reduce the risk of cracking by introducing gypsum into the mixture, contributing to the increase in the strength of the molded raw material; warming the clay in a rotary drier; rolling the side edges of a product; adding 0.5% kerosene from the charge to the clay [10–12].

According to the resulted theoretical knowledge, the technology of obtaining of ceramic bricks without defects based on low-quality aluminosilicate clays in a composition with ASW and sodium silicate was studied.

II. METHODS AND MATERIALS

The object of the research is clays of the Buguruslanskii deposit, the chemical and mineralogical compositions of which are characteristic of low-melting clays from different regions of Russia and clogged ASW of CHP plant - 1of Orsk, Orenburg region.

During the study, the standard methods of research of raw materials, analysis of the structure and properties of raw materials were used.

The preparation of raw materials and the molding of the prepared mixtures were carried out according to standard factory methods.

III. RESULTS

At the initial stage of the selection of the optimal technological process of drying, the sensitivity of clays from the investigated deposit to the process of drying was determined on the basis of the Chizhskii method, according to which the loam of the Buguruslanskii deposit belong to the group of insensitive clays with a sensitivity coefficient of 0.78. The critical humidity of the sample from pure loam is shown in Figure 1.

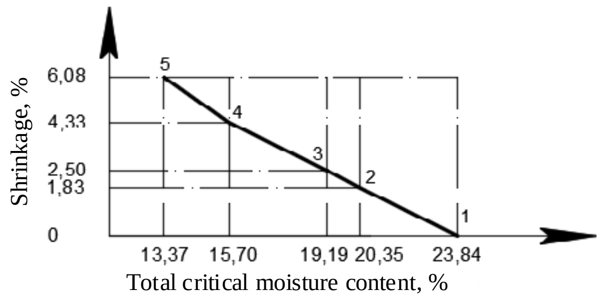


Fig. 1. Critical moisture content

The method of planning the research established a rational addition of ASW to the loam in the amount of 28%. Then, on samples with a 28% content of ASW and adding 10% sodium silicate as an activator of baking, the molding moisture of the press powder was studied. The samples were made by the method of semidry shaping using standard factory technologies and drying temperature of 120 ° C for 2.5 hours. For the research, such samples were taken that retained the shape given to them after de-stressing during pressing. Thus, the boundary values of molding moisture were determined: from 5 to 15 of mass. %

The results of the tests carried out to determine the physicomechanical properties of the samples at various values of the molding moisture of the raw material are presented in Figure 2.

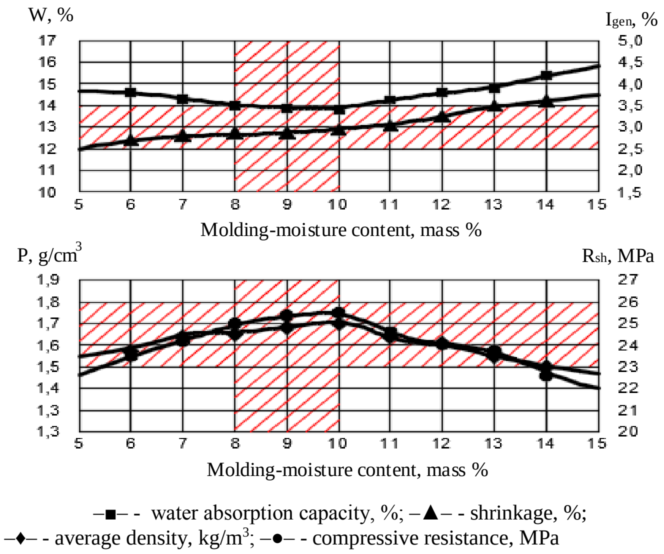


Fig. 2. Changes in the properties of samples based on loam from the Buguruslanskii deposit with the addition of 28% ASW, depending on the molding moisture at burning temperature of 1050 ° C

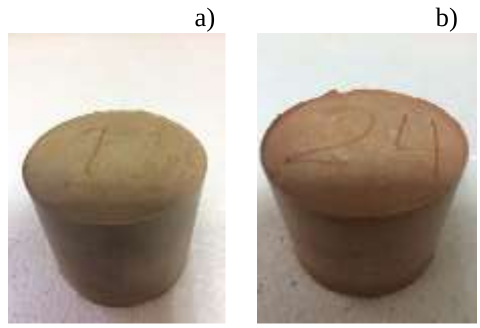
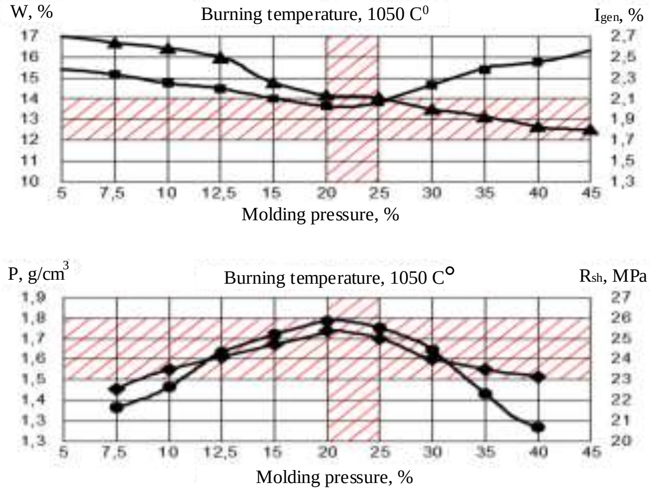


Fig. 3. Images of samples molded from loam of the Buguruslanskii deposit 70% + ASW 28% with molding moisture of press powders - 10 mass%. a – after drying; b – after burning

In order to determine the most rational molding moisture, the plants accept indicators such as water absorption capacity in the range from 12 to 14% and density from 1.65 to 1.98 g / cm^3. Thus, according to the obtained data, it is possible to conclude that the optimum moisture content is in the range of 8 to 10%. The samples with a molding moisture content of 8% are characterized by the lowest strength indicators R_{com} = 24.9 MPa compared with the parameters of molding moisture 9 and 10%, where R_{com} is 25.4 MPa and 25.8 MPa, respectively. It is reasoned by the fact that at the smallest amount of moisture there will be insufficient connection between the particles of material. It is necessary to note that the water absorption of the burned samples is in the range from 13.8 to 14.02%, however, the density changes from 1.64 g / cm^3 at 8% of moisture and 1.69 g / cm3 at 10%. The figure 3 shows the samples after drying with a molding moisture content of 10% and subsequent burning. According to the analysis of the obtained results, 10% is taken for the optimal molding moisture.

Molding pressure plays an important role in the determination of the strength properties of the material. The adopted standard two-stage brick producing technology, with an exposure at a maximum molding pressure for 20 seconds, is characterized by low mechanical strength. In this regard, it was decided to investigate the physicomechanical indices depending on the molding pressure (Figure 4.) while preserving the method and holding time under the press.



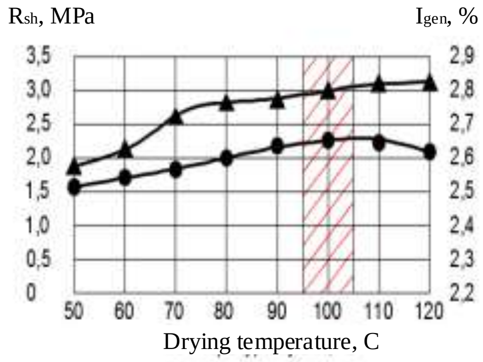
–■– - water absoption capacity, %; –♦– - average density, kg/m^3;
–●– - compressive resistance, MPa; –▲– - shrinkage, %

Fig. 4. Dependence of the properties of samples of ceramics composition: loam of the Buguruslanskii deposit + 28% ASW at W_{mold} = 10% depending on the molding pressure

The dynamics of changes in the physicomechanical properties depending on the molding pressure showed (Figure 4) that the increase in pressure from 7.5 to 20 MPa leads to the increase in the ultimate resistance of the samples from 21.8 to 25.9 MPa, due to the hardening of brick structure. The decrease in strength up to 20.6 MPa and the increase in water absorption up to 16% is observed with the increase in the molding pressure, leading to repressing and separation of raw product. Thus, the smallest water absorption is 13.7%, the average density of 1.76 g / cm3 and R_{com} = 25.9 MPa allows accepting 20 MPa as the optimal molding pressure.

In order to obtain strong wall ceramics, the effect of the drying temperature on the strength of raw product was investigated, where the dependence of air shrinkage on the drying temperature was determined. The results of the experiments are presented in Figure 5.

According to the results of the analysis of the drying properties, it was found that the optimum temperature for drying the samples is 100 ° C, which allows obtaining products with physicomechanical parameters: the ultimate strength of raw material under compression is 2.37 MPa and the air shrinkage is 2.79%. The increase in the mechanical strength of the samples is explained by the increase in the density of raw material during drying due to the increase in the shrinkage of a product.



–●– - compressive resistance, MPa; –▲– - shrinkage, %

Fig. 5. Change of the drying properties of traw product from the press powder of the composition: loam of the Buguruslanskii deposit + 28% of ASW with a molding moisture of 10%

In order to confirm the obtained results and develop products without external deformations, the research was carried out with selected optimal parameters: molding moisture 10% and drying temperature 100 ° C. Heat treatment was carried out according to standard factory technology at burning temperature of 1050 ° C for 4 hours with a gradual decrease in temperature to 600 ° C and subsequent cooling to 150 ° C. The total burning time is 18 hours. The obtained results of physical and mechanical properties are presented in Figure 6.

The analysis of the data presented in Figure 5 confirms the rationality of the chosen temperature mode and molding moisture. According to the results of the physicomechanical properties, the strength parameters increase by 7.2%, the water absorption decreases by 8.7% from 13.8 to 12.6% as compared with samples dried at 120 ° C (Figure 2.) , in consequence of which the density of ceramic bricks increases from 1.69 to 1.78 g / cm^3.

The next stage of the research is the determination of the time of exposure of raw material in drying chamber. Drying from 2 to 5 hours with a temperature range from 90 to 100 ° C was used as the time interval for the presented study. The graphs of the effect of drying time are presented in Figure 7.

The obtained data allow concluding that the optimal drying time is 3.5 hours at a drying temperature of 100 ° C. As the temperature rises to 105 ° C, water absorption increases to a maximum rate of 16.7% after 2 hours and the average density of the samples decreases to 1.63 g / cm^3. The decrease in temperature to 95 ° C characterizes the reverse process in the direction of increasing the density over 2.0 g / cm^3 and reducing water absorption to 11.7% at 3.5 hours, which allows concluding that the brick is overburned.

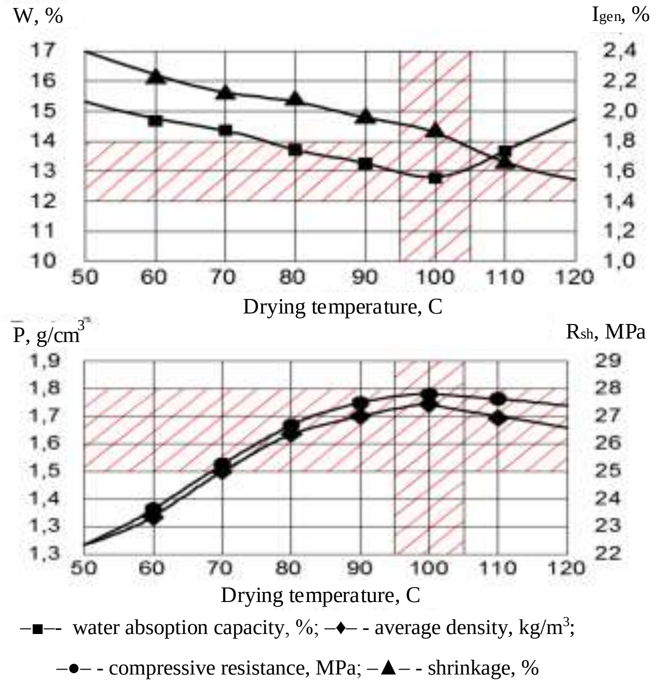


Fig. 6. Change of burning properties of ceramics from press powder of composition: Buguruslanskii loam + 28% ASW with W_{mold} = 10%, P = 15 MPa, t_{bur} = 1050 ºC

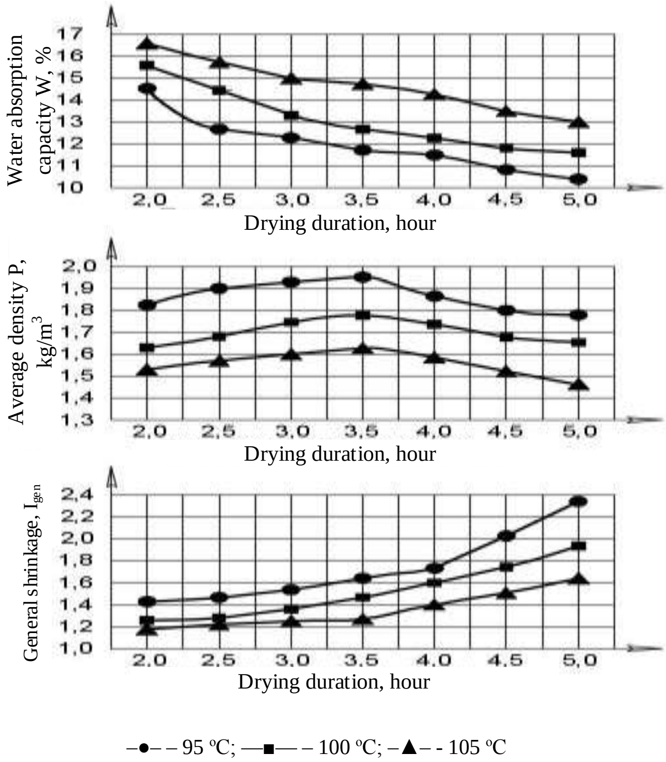


Fig. 7. Effect of drying time on burning properties of products with the content of ASW in the amount of 28% by weight, depending on the drying temperature

IV. CONCLUSION

Thus, during the course of the research, optimal parameters were determined for the mode of molding moisture of raw product and its drying, making possible to produce high quality ceramic bricks with a molding pressure of 20 MPa. The authors studied the physicomechanical parameters of raw material during the change in molding moisture from 5 to 15%, change in the drying properties of raw product in the temperature range from 50 to 120 °C and the effect of drying temperature on burning properties of bricks at tbur = 1050 °C. Based on the set of developed technological parameters, it is possible to conclude that the optimum molding moisture content of the obtained press powder is 10% and the time in the drying chamber for 3.5 hours allows obtaining defect-free raw material and reduce the temperature of the heat carrier from 120 °C to 100 °C. Regulating the technological process of drying, it became possible to produce ceramic bricks using 28% ASW.

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