BUILDING MATERIALS AND PRODUCTS

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INTEGRAL EVALUATION OF DIFFERENT METHODS FOR THE PRODUCTION OF CERAMIC BRICKS

Statement of the problem. This work is aimed at a comprehensive assessment of the various ways stock preparation and molding of ceramic bricks in order to identify a rational technology of its production of local species of clay raw materials Voronezh region.

Results. The work selected the most rational method of making ceramic brick «hard» of this type of molding clay. Defined physical and mechanical properties of raw, dried and fired samples, which allow us to estimate the benefits of a «hard» formation of products as compared to other forms of ceramic bricks.

Conclusions. Analysis of the existing technology of making ceramic wall products shows that the production of quality products from the Peter and Paul clay deposits meet production lines producing molding compositions of low humidity at high pressure molding. In this case, the products made by dry pressing, have a lower frost resistance compared with the products of the «hard» Clay paste.

Keywords: plastic formation, moist pressing, rigid formation, physic-mechanical properties, quality.

Introduction

Ceramic construction brick has been and still is the major wall construction material. The construction of the Russian Federation is increasingly using ceramic brick, especially of high-quality. A high demand for small-piece walls is due to the fact that it enables the construction of complex structures, new architectural and constructional approaches in civil engineering to be employed. Small-piece walls are set to dominate low rise as well as high rise construction and estimated to account for over 50% of the overall construction numbers in the years to come [1].

Addressing the quality of the end ceramic wall products to make it competitive is vital not only due to improve the esthetic appearance of buildings as well as ever-growing integration of the country into the world's economic space.

In view of the fact that many brick manufacturing plants in Russia as well as in Central Black Earth Region employ low-quality natural clays necessitates the evaluation of different methods of the mass preparation and production of ceramic products in order to improve their quality.

Ceramic brick is manufactured in two major ways — plaster pressing and half-dry grinding, the “hard” abode brick is now being commonly used. These differ not only in the amount of water in the original mixture but the pressure of molding of varyingly wet abode bricks [2, 3].

Further on, the influences of different ways of the manufacture of ceramic walls on their properties will be examined.

1. Original data. The object of the study was clayware of Petropavlovsk deposit in Voronezh region which are moisture sensitive adobes according to its granulometric composition (method of B. N. Rutkovsky) and its drying properties (method of A. F. Chizhsky). The plasticity index is 18…24, which puts them into the moderate and average plastic raw material category. The adobe is mineralogically composed of α-silica, calcite and some montmorillonite, halloysite, mica. According to its chemical composition, the clay (with 14…30 % of Al_2O_3) is semiacid.

The clay was dried, averaged and ground in a laboratory grinding unit till it completely passed through the sieve № 063. The clay was then made wet till it was wet enough for semi-dry grinding, hard plastic shaping (Fig. 1) and was thoroughly mixed in the laboratory mixer.

The moulds were used to prepare samples cylinders with the diameter and height of 50 mm for required pressing pressures depending on how much moisture it contained (Fig. 2).

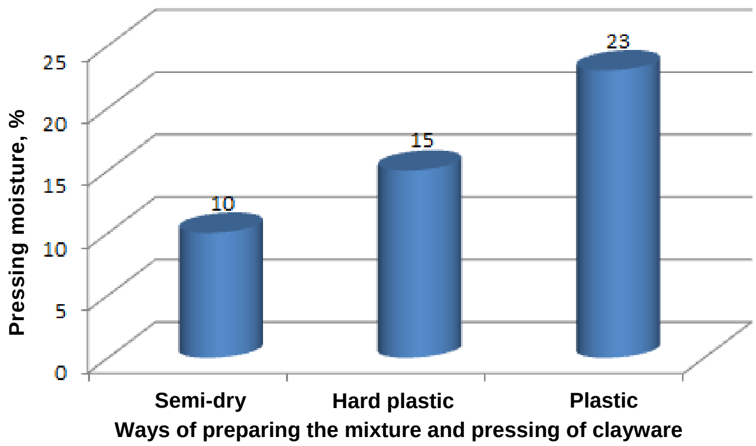

Fig. 1. Averaged wetness of the pressing mixtures

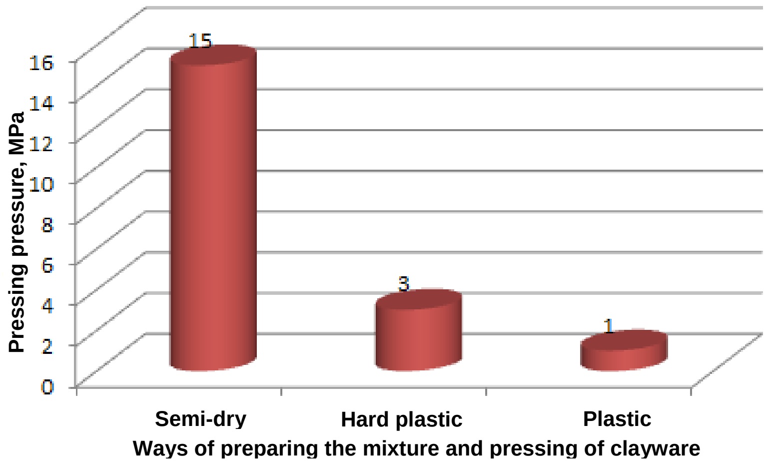

Fig. 2. Pressures for the pressing mixtures

Fig. 3 shows the averaged graphic dependencies "loading-compaction" for different ways of pressing adobe bricks.

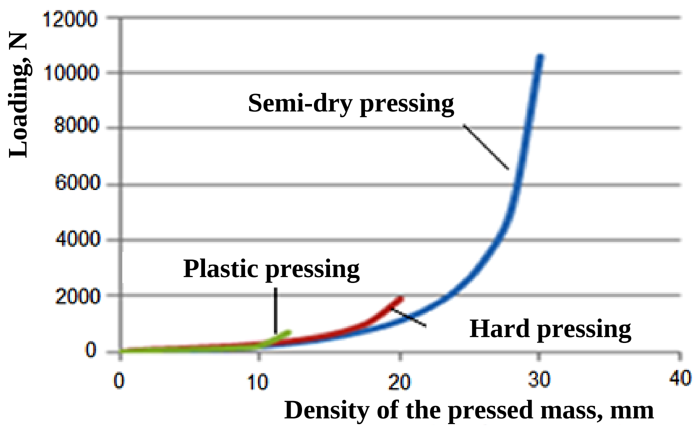

Fig. 3. Graphic dependence "loading-deformation" during the pressing of the clayware samples

It should be noted that the type of the curves is almost identical regardless of the compaction type and the only difference is loading and deformation. At the start of the load application, the compaction of the "clay-water" system occurs owing to the interior forces, among which capillary contraction is to be mentioned [4]. As it takes place, there are substantial deformations with no increase in the loading. The fluidity of the "clay-water" system is inversely proportional to the mass moisture content of the system, i.e. the smallest is the system containing clay obtained using plastic pressing and the largest one is that obtained using semi-dry pressing. The interior forces subsequently give way to the external force impact with the external forces not being crucial for semi-dry and plastic pressing in the compaction of the "clay-water" system. For semi-dry pressing the external pressure largely contributes to the formation of the compact structure of abode bricks.

The resulting dependencies of changes in loading and compaction of the moulds depending on the moisture content (see Fig. 3) can be divided into three areas. The first one is a horizontal line within the deformation range from 0 to 15 mm indicates that the internal; capillary forces dominate the compaction of the system. The second areas (15…25 mm) has an equilibrium of internal and external forces. The third area ("the vertical line") in the deformation range of 25…28 mm indicates the closest the particle come together due to the external pressing pressure.

2. Assessment of the plastic strength is significant for technological transportation and kiln loading of adobe bricks.

The comparative plastic strength data for adobe bricks made using the semi-dry process, pressing, hard and plastic pressing are identified in Table 1 and Fig. 4.

Table 1

Characteristics of newly-molded samples

Ways of preparing the mixture and pressing of clayware	Pressing moisture, %	Pressing pressure, MPa	Average compaction of the pressed samples, g/cm^3	Loading, kN	Compressive deformations, %	Plastic strength, MPa
Semi-dry pressing	10	15.0	2.28	3.52	4.8	4.97
Hard pressing	15	3.0	2.12	0.63	10.5	0.88
Plastic pressing	23	1.0	1.98	0.13	11.9	0.18

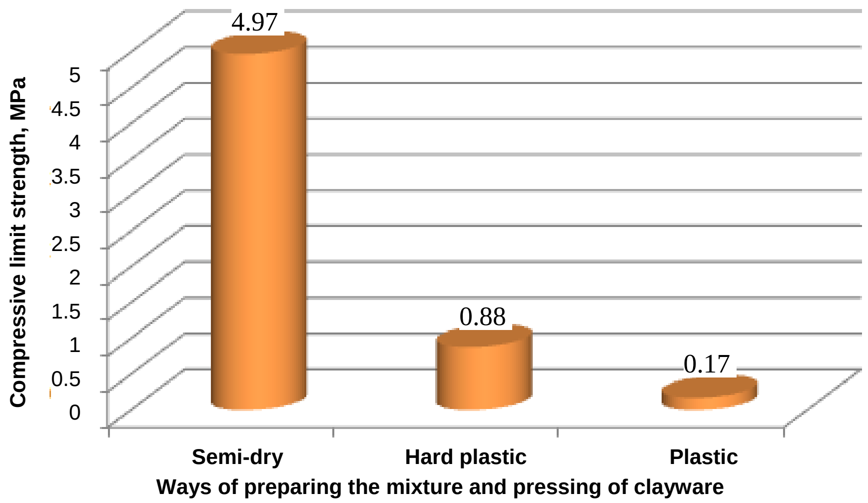

Fig. 4. Plastic strength of the pressed samples

It should be noted the largest plastic strength and thus minimum deformations are observed in the samples prepared using the semi-dry process, which is obviously due to a high pressing pressure and minimum moisture of the mixture. Minimum possible plastic strength for laying adobe bricks onto the firing cars into the chamber without using drying cars should be no less than 0.5 MPa.

3. Results of identifying the air shrinkage, average compaction and compressive strength limit of the dried samples are in Fig. 5 and Table 2.

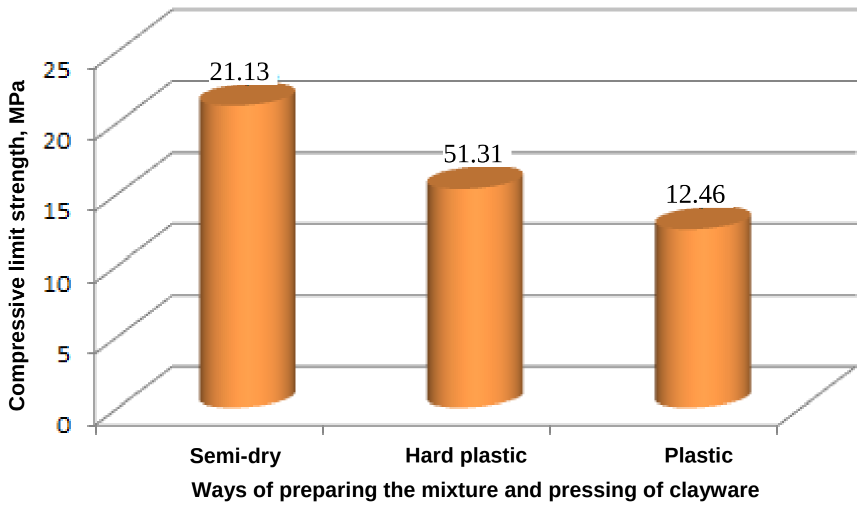

Fig. 5. Dependence of the strength of the dried samples on the way they were prepared

Table 2

Characteristics of the dried samples

Way of preparing mass and pressing	Pressing moisture, %	Pressing pressure, MPa	Average density of the samples, kg/m^3	Shrinkage, %	Compressive strength limit, MPa
Semi-dry pressing	10	15.0	2120	1.66	21.13
Hard pressing	15	3.0	2090	4.47	15.31
Plastic pressing	23	1.0	2070	7.85	12.46

The average density and air shrinkage of the samples prepared in different ways are essentially connected with the pressing pressures and moisture content of the pressing mixtures, while the compressive strength only depends on the pressing pressure.

4. Establishing the sustainable firing temperature. The final stage of manufacturing any type of clayware is firing. In order to identify the sustainable firing temperature, sintering of this type of clay raw material at different temperatures were first found.

As the test results suggest (Table 3), the clay is vitreous as over 5% of water is absorbed at the temperatures.

Table 3

Identifying sintering of the clay raw materials

Way of preparing mass and pressing clayware	Index	Firing temperature, ^{0}C			Sintering degree
		950	1050	1100	
Semi-dry pressing	Water absorption, %	10.30	9.90	7.80	Vitreous
	Average density, g/cm^3	1.76	1.97	1.96	
Hard pressing	Water absorption, %	10.50	10.90	8.00	Vitreous
	Average density, g/cm^3	1.77	1.91	1.96	
Plastic pressing	Water absorption, %	10.00	10.00	8.00	Vitreous
	Average density, g/cm^3	1.68	1.73	1.87	

Then, in order to identify the sustainable firing temperature, the strength characteristics of the fired samples were determined at different temperatures and different ways of pressing.

The results of determining the compressive strength limit of the samples using the semi-dry process fired at different temperatures are in Table 4 and Fig. 6.

Table 4

Properties of semi-dry pressed samples

Way of preparing mass and pressing clayware	Firing temperature, ºC	Compressive strength limit, MPa
Semi-dry	950	17.89
	1050	33.41
	1100	16.86

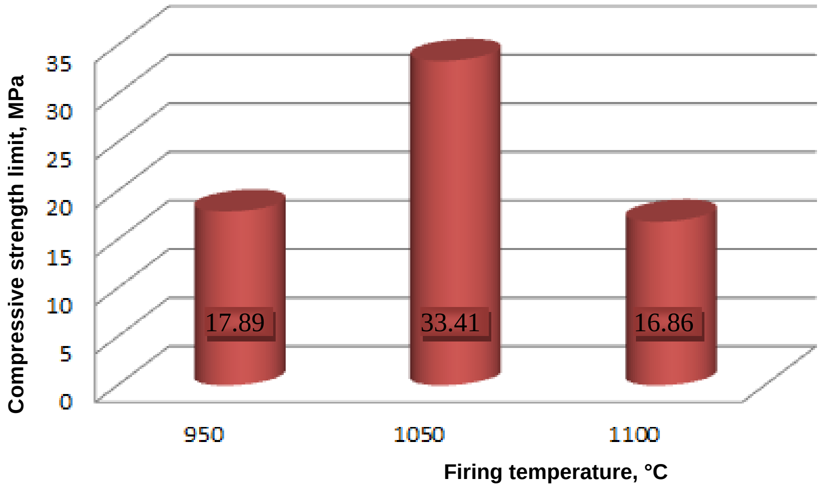

Fig. 6. Histogram of the distribution of the strength and firing temperature

The experimental data for identifying the compressive strength limit for the samples prepared using hard pressing and fired at different temperatures are in Table 5 and Fig. 7.

Table 5

Properties of hard-pressed samples

Way of preparing mass and pressing clayware	Firing temperature, ºC	Compressive strength limit, MPa
Hard	950	23.56
	1050	27.52
	1100	9.25

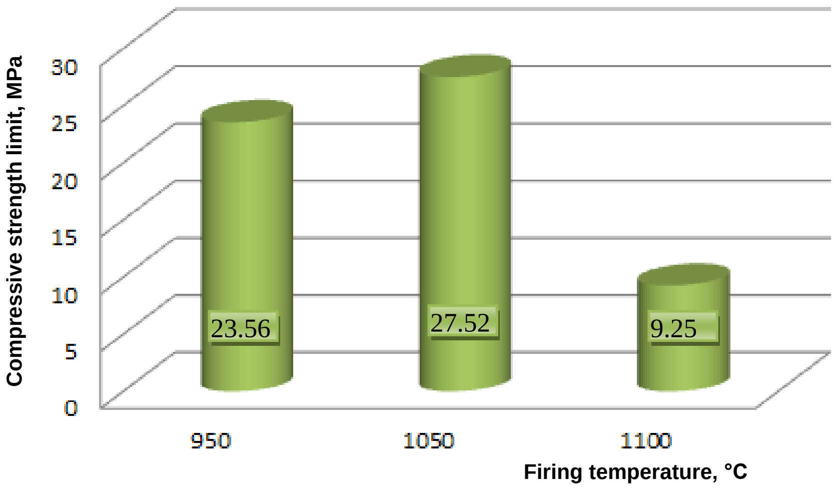

Fig. 7. Histogram of the distribution of the strength and firing temperature

The results of identifying the compressive strength limit of the samples prepared using the semi-dry process and fired at different temperatures are in Table 6 and Fig. 8.

Table 6

Properties of plastic pressed samples

Way of preparing mass and pressing clayware	Firing temperature, ºC	Compressive strength limit, MPa
Plastic	950	10.71
	1050	22.05
	1100	7.81

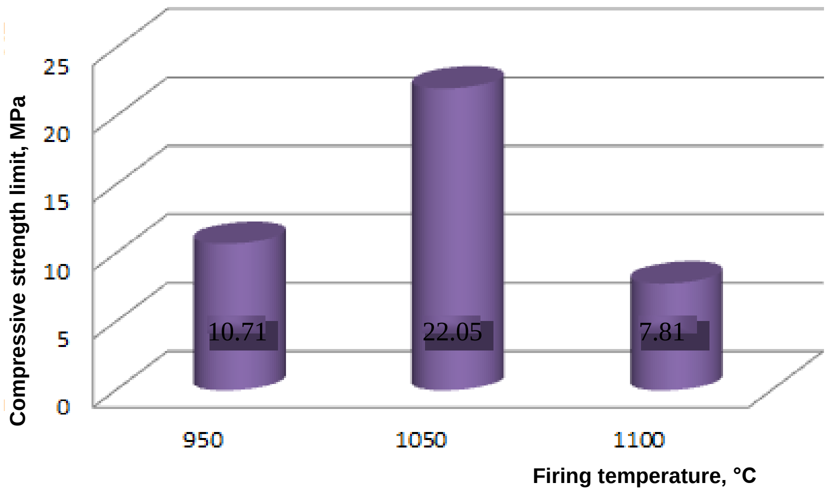

Fig. 8. Histogram of the distribution of the strength and firing temperature

As the above dependencies suggest, the maximum compressive strength of the samples is reached at the temperature of 1050 ^{0}C regardless of which way of preparation is used. Therefore the sustainable firing temperature is considered to be 1050 ^{0}C and it will be used for the subsequent studies.

Table 7 shows the comparative evaluation of the major physical and chemical indices for semi-dry, hard and plastic processes in the manufacture of ceramic brick at the temperature.

Table 7

Comparative evaluation of the properties of the ceramic samples

Way of preparing mass and pressing clayware	Properties of the fired samples						
	Average density of the samples, g/cm^3	Compressive deformations, %	Compressive strength limit, MPa	Water absorption, %	Softening coefficient	Structural property coefficient	Physical view
Semi-dry pressing	1.77	3.0	33.4	9.9	0.62	0.7	No defects and cracks
Hard pressing	1.76	2.0	27.2	10.9	0.79	0.94	No defects and cracks
Plastic pressing	1.73	2.0	22.0	10.0	0.63	0.85	Defects and cracks

Conclusions

1. A lot of experimental data concerning the comparative characteristics of the major ways of preparing wall ceramic products has been obtained. Not only the properties of fired products but also the indices of the newly molded and dried samples have been identified.

2. The results that were obtained are helpful in identifying the advantages of hard pressing which yields almost equally dense crockery as using the semi-dry process but at considerably lower powers of pressing equipment.

3. The compaction coefficient during firing is almost identical and is 1.58, 1.78 and 1.76 for the semi-dry, hard and plastic processes respectively. The strengths are essentially identical to the results for the plastic strength and the strength of the dried products. I.e. the products using the semi-dried processes have the maximum compressive strength and those using the plastic process — the minimum ones. The deformations for all the preparation ways are actually almost the same.

4. All the fired products have the identical water absorption, which is indicative of an equal number of open pores. The products prepared using hard pressing have the maximum softening coefficient, which is also indicative of this method going a long way toward being a way of preparing mass and pressing.

5. The technological lines for “hard” pressing implement some of the processes typical of the semi-dry process — stacking and follow-up drying of adobe bricks on kiln-car decks. In addition, dust emission for this type of manufacturing ceramic brick using pressing mixtures is zero.

6. The analysis of the existing technologies of manufacturing ceramic brick shows that semi-dry and hard plastic processes are appropriate to use to produce high-quality products from clay of the Petropavlovsk deposit, i.e. the technology of manufacturing products using pressing mixtures with a low moisture content at a high pressing pressure. The products manufactured using semi-dry processes are susceptible to moisture (the softening coefficient Kp = 0.63). Wall products manufactured using hard pressing can be employed in both dry and wet conditions (Kp = 0.79).

7. The structural property coefficient [2] is the evaluation of frost resistance of ceramic products. A products is frost-resistant if its structural property coefficient is no less than 0.85. Hence the samples manufactured using hard and plastic pressing can be used at positive and negative temperatures.

8. Plastic pressing does not seem quite appropriate for clay from the Petropavlovsk deposit due to few clay particles and a lot of dust and sand particles.

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