IOP Conf. Series: Materials Science and Engineering **775** (2020) 012118 doi:10.1088/1757-899X/775/1/012118

Research of possibility of producing ceramic paving stones by vibrocompression with the purpose of using them in the improvement of urban areas

S A Montaev, S M Zharylgapov, N S Montaeva and B T Shakeshev

West Kazakhstan agrarian-technical University named Zhangir khan, 51, Zhangir khan str., Uralsk, 090009, Kazakhstan

E-mail: montaevs@mail.ru

Abstract. The article presents the results of studying the physic-mechanical and chemical-mineralogical characteristics of raw materials and proposes a clay-based raw material composition to create technology for ceramic pavers by vibrocompression using talc rock. The of ceramic compositions for the production of ceramic pavers are studied taking into account the dominant factors of a two-component mixture to improve the molding, drying and physic-mechanical properties of the finished product. It was found that the introduction of talc into the ceramic composition promotes the formation of high-temperature phases of augite and amphibole, and enhances the processes of mineral formation in clay, with the formation of high-temperature phases - sanidine, ackermanite and augite, which provide samples with high physical and mechanical properties. The basic laws of the structure and phase formation of ceramic compositions at a firing temperature of 1000 ° C, consisting in the occurrence of solid and solid-liquid phase sintering processes at which the phase-mineral composition of the compositions determining the production of ceramic pavers with high strength, frost resistance, are studied, were studied. The possibility of obtaining ceramic pavers that meet environmental and operational requirements in order to use them in the improvement of urban areas (sidewalks, walkways, park areas, playgrounds, etc.) has been proved. It has been established that one of the predominant properties of ceramic paving stones is their significant porosity (up to 30%), which allows quickly absorbing water from atmospheric precipitation and filter it through your body by transferring water to the ground.

1. Introduction

Long-term urban development plans are inextricably linked with an increase in the pace of construction of residential complexes, individual housing and other socially significant objects. In the development of urban areas, a special role is played by the solution of a complex of issues on their improvement for a comfortable living of the population. In this case, one of the important tasks is the improvement of sidewalks, internal courtyards and playgrounds, as well as squares, alleys and park areas, require a large number of wide range of road-building materials. Currently, concrete paving stones of various configurations and asphalt concrete are widely used to solve these problems. However, as practice shows, during the operation of these roads, their destruction is often observed. (Figure 1)

Figure 1. Fragments of the destruction of sidewalks made of concrete paving stones.

The fact is, concrete paving stones are necessarily exposed to the actions of sulfate salts of acids and alkalis, since they are necessarily present in the soil of the laid surface and are additionally exposed to chemicals from the external environment (rain, automobile oils, groundwater, etc.). Under the influence of these chemicals, concrete pavers and products made on the basis of cement binders undergo corrosion, as a result of which they are destroyed over time.

When choosing building materials for the construction of urban roads and sidewalks, it is very important to take into account the environmental factor, which consists in mitigating the effect of "island" heat released from the surfaces of urban roads and sidewalks.

One of the perspective materials for the construction of urban sidewalks and other socially important territories and areas is ceramic pavers.

It is well known that ceramic materials have high chemical resistance (98 - 99%) in relation to solutions of salts, acids and alkalis. Due to this property, the products are not destroyed by the action of sulfate salts, acids and alkalis and also have a more aesthetic appearance. (Figure 2)

Figure 2. Fragments of sidewalks made of ceramic pavers and tiles.

In addition, ceramic materials do not heat up much under the influence of solar heat due to the low coefficient of thermal conductivity. However, for the successful development of the production of ceramic materials it is necessary to take into account the factors of resource and energy conservation [2].The most important technological stage in the production of ceramic materials is the preliminary preparation of raw materials, which requires significant energy and resource costs. As a result of research by scientists [3] on the analysis of modern technology for the production of ceramic tiles using the dry and wet method, it was found that in the process of preparing raw materials, more energy and water are used and, therefore, is more expensive both from an economic and environmental point of view. Scientists have proposed alternative methods for preparing raw materials that can significantly reduce energy and water.

Perspective research in this area is the work of scientists who have developed clinker brick production technologies for the construction of roads and paving slabs [4-6]. Therefore, conducting scientific and experimental research in this direction is an urgent task, since the use of new raw materials requires new scientific approaches regarding the development of technological parameters for the production of ceramic products, taking into account their chemical and mineralogical composition and physico-mechanical properties.

2. **Materials and methods.**

Objective: To study the possibility of producing ceramic pavers by vibrocompression based on the raw clay composition - talc rock. To achieve this goal, the clay of the Kyzylorda deposit was selected as the main raw material. The talc rock of the Shieli deposit (Republic of Kazakhstan, Kyzylorda oblast) was used as a modifying additive.

X-ray phase analysis (XRD) was carried out on a DRON-3 diffractometer with CuKa radiation in the range of angles 80-640. The sensitivity of the method is from 1 to 2%. Powder flasks passed through a 0.315 sieve were subjected to X-ray phase analysis.

The chemical and mineralogical composition of the studied raw materials was determined using a JSM-6390LV scanning electron microscope with an energy-dispersive microanalysis system, an X'Pert PRO MPD X-ray diffractometer, and an ICP-MS Agilent 7500cx inductively coupled plasma mass spectrometer (JEOL, Japan).

According to the results of the study, the clay of the Kyzylorda deposit contains up to 12% of the montmorillonite component, which is in the form of mixed-layer formations with hydromica and kaolinite. Of the crystalline phases, clay also contains quartz d / n = 4.23; 3.34; 1.974; 1.813; 1.538 * 10-10m, feldspar d / n = 3.18; 2.286 * 10-10 m, calcite d / n = 3.02; 2.018; 1.912 * 10-10m and hematite d / n = 1.839; 1,686; 1,590 * 10-10m.

In terms of Al2O3 content, clay belongs to the group of acidic raw materials, and in terms of refractoriness to low-melting. By the content of Fe2O3 to raw materials with a high content of coloring oxides. The plasticity number of loam of the Kyzylorda deposit is 12.4 and is classified as moderately plastic.As a result of the analysis of the chemical and mineralogical composition, it was established that the talc rock of the Shieli deposit are talc - magnesite raw materials.The main rock-forming minerals are: talc (49.2–53.6%) and magnesite (35.8–40.6%). In addition, there are the following mineralogical impurities: calcite, chlorite, carbonate, magnetite, chromite, iron hydroxides. Electron microscopic studies showed that talc crystals have a scaly, tabular, hexoganal and rhombic appearance.Talc rock of the Shieli deposit is characterized by high acid resistance and alkali resistance.

3. Results

The raw materials were first dried and ground in a laboratory ball mill to a specific surface of 1200-1500 g / cm2. The preparation of ceramic mass compositions for experimental studies was carried out by adding talc rock to clay in an amount of up to 7.0%. Then the components were weighed in the right quantities and mixed dry. Then water was added to the dry mixture. Cylinders were formed from the mixture obtained by vibrocompression with a diameter and height of 5 cm. The molded products were dried in an oven at t = 100 - 110 ° C to constant weight.

For the study, we selected the most important ceramic performance characteristics such as fire shrinkage, compressive and bending strength, average density, water absorption, and frost resistance.

At the initial stage of the study, in order to determine the dependence of the physicomechanical properties of the ceramic composition on the content of talc rock, calcination was performed at only one fixed temperature. A fixed firing temperature was taken to be 1000 ° C, since in kilns most of the plants producing wall ceramics based on loess-like loams, the temperature in the zone of the maximum firing temperature is usually 1000-1100 ° C.

Firing was carried out in a laboratory electric furnace in a chamber furnace brand SNOL 58/350. Physico-mechanical properties of the ceramic composition loess-like loam-talc rock at a fixed firing temperature are shown in table 1.

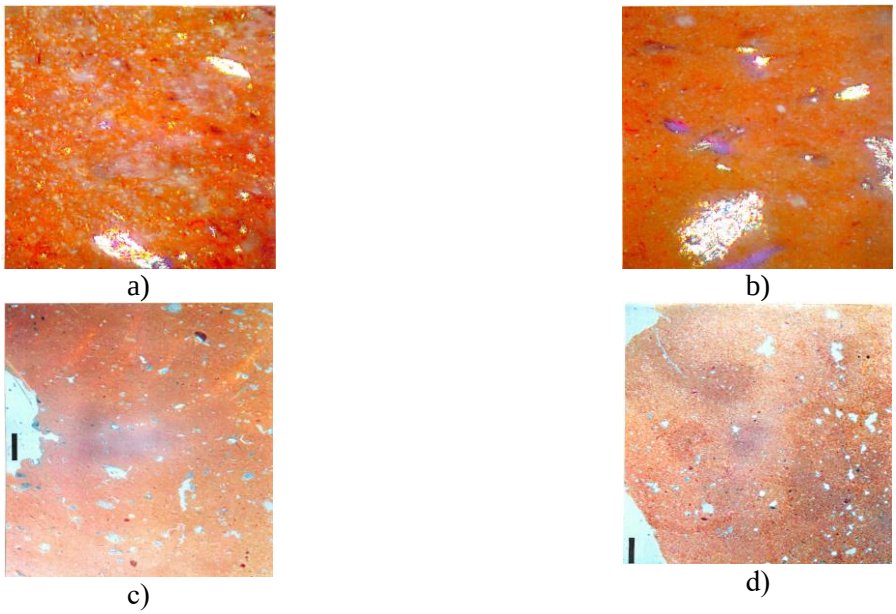
As the results of experimental studies show with an increase in the content of talc from 3.0% to 7%, there is a general tendency to increase the compressive strength of the samples. Thus, the strength of samples with a talc content of 3% is 25.67 MPa, and with a further increase in its content to 7%, the strength of the samples was increased to 31.26 MPa. It should be noted that an increase in the strength characteristics of the samples is accompanied by an increase in fire shrinkage and indicators of frost resistance, which indicates an increase in the degree of sintering of the ceramic composition. This is

evidenced by an increase in average density and a decrease in water absorption of heat-treated samples. The analysis shows that an increase in the content of talc rock only up to 7% increases the parameters of fire shrinkage from 2.6% to 3.8% i.e. almost 1.5 times.

Table 1. Physico-mechanical properties of the clay ceramic composition - talc rock at a fixed firing temperature

Talc content %	Fire shrink,%	Average density, g / cm3	Strength, MPa under compression		Water absorption, %	Frost resistance cycles
3.0	2.6	1.8585	25.67	1.94	20.4	45
5.0	3.4	1.8691	28.85	2.15	19.5	47
7.0	3.8	1.8738	31.26	3.66	18.6	51

The results of the X-ray phase analysis also show that the lines of clay minerals that have been calcined at 10000C are almost absent and the intensity of the diffraction maxima of the high-temperature phases, such as augite and sanidine, increases, the intensity of the diffraction maxima of quartz decreases significantly, calcite and talc disappear. With the introduction of 5% talc in the X-ray diffraction pattern of the sample, when firing 1000 ° C, the amount of sanidine begins to increase, an additional high-temperature phase appears - ackermanite. (Figure 3)



a) b) c) d)

a - talc content 2%; b – also 3%; c – also 5%; d– also 7%

Figure 3. Microstructure of the ceramic clay composition - talc rock

To confirm laboratory research in practice, we molded ceramic pavers at the Mastek-Meteor production unit, operating on the principle of vibrocompression. The ceramic mass was well molded and had good raw strength, which provides sufficient conditions for further technological operations of the finished product. The molded pavers were dried in a ShSP - 0.5 - 70 brand oven at a temperature of 70-75 0 C according to a specially developed regime to a residual moisture content of 5-7%. After drying, the pavers were fired in an electric furnace at a temperature of 1000 0 C with holding at a final temperature of 2 hours. The fired pavers were cooled to room temperature with the oven turned off (Figure 4). The obtained samples had clear faces and a densely sintered structure. However, the

samples had minor cracks, which can be easily eliminated by regulating the drying and firing of ceramic raw materials.

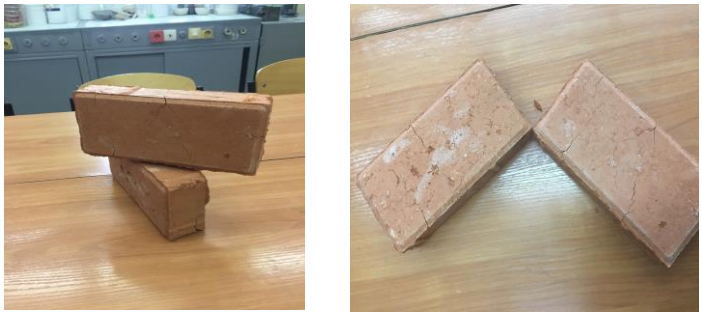


Figure 4. Samples of ceramic pavers based on the raw clay composition are talc rock.

4. Conclusion

Based on the results of studying the physico-mechanical and chemical-mineralogical characteristics of raw materials, a clay-based raw material composition is proposed to create ceramic paving technology using vibrocompression using talc rock.

The compositions of ceramic compositions for the production of ceramic pavers were studied taking into account the dominant factors of a two-component mixture to improve the molding, drying and physico-mechanical properties of the finished product.

It was found that the introduction of talc into the ceramic composition promotes the formation of high-temperature phases of augite and amphibole, and enhances the processes of mineral formation in clay, with the formation of high-temperature phases - sanidine, ackermanite and augite, which provide samples with high physical and mechanical properties.

The basic laws of the structure and phase formation of ceramic compositions at a calcination temperature of 1000 ° C, consisting in the occurrence of solid and solid-liquid sintering processes during which the phase-mineral composition of the compositions determining the production of ceramic pavers with high strength, frost resistance, were studied, were studied.

The possibility of obtaining ceramic pavers that meet environmental and operational requirements in order to use them in the improvement of urban areas (sidewalks, walkways, park areas, playgrounds, etc.) has been proved.

It was established that one of the predominant properties of ceramic pavers is their significant porosity (up to 30%), which allows quickly absorbing water from atmospheric precipitation (in the form of rain, wet snow, etc.) and filter it through your body by transferring water to priming. This property of paving stones prevents the accumulation of moisture on the surface of the sidewalk and creates comfortable conditions for pedestrians, as well as the formation of an ice crust in cold weather.

References

[1] Mohajerani A, Bakaric J and Jeffrey-Bailey T 2017 The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete *Journal of Environmental Management* **197** 522-538

[2] Zhigulina A Y, Montaev S A and Zharylgapov S M 2015 Physical-mechanical properties and structure of wall ceramics with composite additives modifications *Procedia Engineering* **111** 896-901

[3] Mezquita A, Monfort E, Ferrer S and Gabaldón-Estevan D 2017 How to reduce energy and water consumption in the preparation of raw materials for ceramic tile manufacturing: Dry versus wet route *Journal of Cleaner Production* **168** 1566-1570

[4] Mustafm N R and Aschmarin G D 2006 Die Klinkerkeramik auf Grund des Kieselerderohstoffes und der technogenischen Abfallstoffe *Keramische Zeitschrift* **46** 80-81

[5] Mustafin A V and Ashmarin G D 2006 Clinker ceramics based on siliceous raw materials and industrial waste *Building materials* **1** 32-33
[6] Shamshurov A V, Gridchin A M, Lesovik V S and Strokova V V 2003 Raw material for the production of fired road-building materials based on quartz sand and a method for their manufacture *Patent of the Russian Federation* **2205810** 432