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The Modified Ceramic Mass for Producing Ceramic Paving Stones

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Abstract. *The article presents outcomes of the studying of physical-mechanical and chemical-mineralogical characteristics of raw materials and proposes a raw material composition based on clay for creating a technology of ceramic paving stones by vibropressing method using talc breed. Ingredients of ceramic formulation for production of ceramic paving stones with the consideration of dominant factors of binary blend for improving the molding, drying and physico-mechanical properties of the finished product have been researched. It has been established that the injection of talc into the ceramic formulation promotes formation of high-temperature phases of augite and amphibole, and strengthens processes of mineral formation in clay, with the formation of high-temperature phases – glassy feldspar(sanidine), akermanite and augite, providing high physical and mechanical properties for samples. The main regularities of structure- and phase formation of ceramic formulation at a firing temperature of 1100°C, consisting in the course of processes of solid- and solid-liquid sintering, in which the phase-mineral composition formulation is ensured, determining the production of ceramic stone blocks with high strength, frost resistance have been investigated. It has been proved that it is possible to obtain ceramic paving stones that meet environmental and operational requirements in order to use them in the improvement of urban areas (sidewalks, alleys, park areas, playgrounds, etc.). It is established that one of the advantageous properties of ceramic paving stones is their significant porosity (up to 30%), which allows quickly absorb water from precipitation (in the form of rain, sleet, etc.). and filter through it body by transferring water into the ground. This property of paving stones prevents the accumulation of moisture on the surface of the sidewalk and creates comfortable conditions for the movement of pedestrians, and also excludes the formation of an ice crust in the cold season.*

Keywords: *ceramic paving stones, firing, loam, ceramics, vibropressing, pavement, landscaping, construction, corrosion, bentonite clay.*

Introduction

Long-term urban development plans are inextricably linked with an increase of construction of residential complexes, individual housing and other socially significant facilities. In the development of urban areas, a special role is played by solving a set of issues on their improvement for comfortable living of the population. At the same time, one of the important tasks is the improvement of sidewalks, inside yard roads and playgrounds, also squares, alleys and park areas require a large number of a wide range of road-building materials. Currently concrete paving blocks of various configurations and asphalt concrete are widely used to solve these problems. However, as practice shows, in the process of operation of these roads, their destruction is often observed (Figure 1).

The fact is that concrete paving stones are necessarily exposed to the actions of sulfate salts of acids and alkalis, because of they are necessarily presents in the composition of the soils of the laid surface and additionally exposed to the actions of chemical reagents coming from the external environment (rains, automotive oils, groundwater, etc.). Under the influence of these chemicals reagents, concrete pavers and products made of on the basis cement binders are corroded, as a result of which they eventually are being destroyed.

While 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 material for the

arrangement of urban sidewalks and other socially significant territories and squares are ceramic paving blocks.

It is well known that ceramic materials have a high chemical resistance (98-99%) 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).

In addition, ceramic materials are not heated 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 saving [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 technologies for the production of ceramic tiles by dry and wet methods, it was revealed that more energy and water are used in the process of preparing raw materials and, therefore, are more expensive both from an economic and environmental point of view. Scientists have proposed alternative methods of preparing raw materials that can significantly reduce energy and water.

Perspective researches in this area is the work of scientists who have developed technologies for the production of clinker bricks for the construction of roads and paving slabs [4-6].

Therefore, conducting scientific and experimental in this area is an urgent task, as a result using new raw materials, new scientific approaches are needed regarding the development of technological parameters for the production of ceramic products, taking into account their chemical and mineralogical composition and physical and mechanical properties.

Work objective: Researching of the modified ceramic masses for the production of ceramic paving stones by a method of vibropressing.

Materials and methods of research.

To achieve this goal, bentonite clay of the Ordabadin deposit of the Turkestan region was chosen as the main raw material. As the modifying additive talc breed of the Shieli deposit (Kyzylorda region) was used.

X-ray phase analysis (XRF) was performed on a DRON-3 diffractometer with SiCa radiation in the angle range of 80-640. The sensitivity of the method is from 1 to 2%. X-ray phase analysis was performed on powders of opoka passed through a sieve of 0.315.

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

According to the results of the research, the clay of the deposit of the Turkestan region contains up to 15% of the montmorillonite component, which is in

Figure 1 – Fragments of the destruction of sidewalks made of concrete pavers

Figure 2 – Fragments of sidewalks made of ceramic paving stones and tiles

the form of mixed layer formations with hydromica and kaolinite. From crystalline phases in 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.

According to the content of Al2O3, clay belongs to the group of acidic raw materials, and in terms of fire resistance to fusible. According to the content of Fe_2O_3 to raw materials with a high content of coloring oxides.

The plasticity number of clay is 15 refers to moderately plastic.

As a result of the analysis of the chemical and mineralogical composition, it was established that the talc breed of the Shieli deposit is a talc-magnesite raw material.

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 researches have shown that talc crystals have a scaly, tablite, hexoganal and rhombic appearance.

The talc breed of the Shieli deposit is characterized by high acid resistance and alkali resistance.

Raw materials were first dried and ground in a laboratory ball mill to a specific surface of 1200-1500 g\/cm2. Preparation of the compositions of ceramic masses for experimental researches was carried out by adding talc breed to the clay in an amount of up to 7.0%. Then the components were weighed in the right quantities and mixed dry. After that, water was added to the dry mixture. From the resulting mixture, sample cylinders were formed by vibropressing method with a diameter and height of 5 cm. The molded products were dried in a drying cabinet at t 100-110°C to a constant mass.

Results and discussions.

The most important exploitation characteristics of ceramics such as fire shrinkage, compressive and bending strength, average density, water absorption and frost resistance were selected for researching.

At the initial stage of the research, in order to determine the dependence of the physical and mechanical properties of the ceramic composition on the content of talc breed, roasting was carried out only at one fixed temperature. For a fixed firing temperature, 1100°C was taken because in kilns most plants which manufactured wall ceramics based on clays, the temperature in the zone of maximum firing temperature is usually 1000-1100°C.

The firing was carried out in a laboratory electric furnace in a chamber furnace of the brand SNOL 58\/350. The physical and mechanical properties of the ceramic composition at a fixed firing temperature are shown in Table.

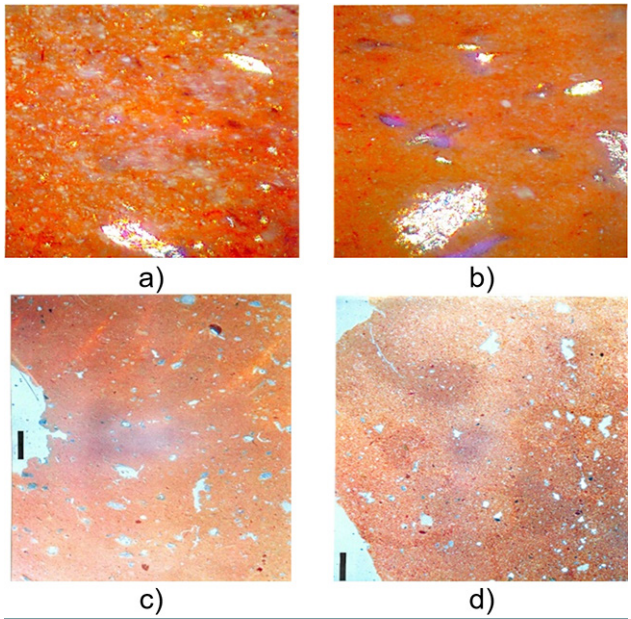
As shown by the results of experimental researches with an increase in the talc content from 3.0% to 7%, there is a general trend of increasing strength during compression of samples. So the strength of samples with a talc content of 3% is 25.67 MPa, and with a further increase, its content to 7% contributed to an increase in the strength of the samples to 31.26 MPa. It should be noted that the increase in the strength characteristics of the samples is accompanied by increasing in fire shrinkage and frost resistance, which indicates an increase in the degree of sinterability of the ceramic composition. This is evidenced by an increase in the average density and a decrease in water absorption of heat-treated samples. The analysis shows that an increase in the content of talc breed only up to 7% increases the rate of fire shrinkage from 2.6% to 3.8%, i.e. by almost 1.5 times.

The results of X-ray phase analysis also show that there are practically no lines of clay minerals burnt at 1100°C and the intensity of the diffraction maxima of the high-temperature phases – augite and sanidine – increases, the intensity of the diffraction maxima of quartz decreases significantly, calcite and talc disappear. With the introduction of 5% talc on the X-ray sample, when firing 1000°C, the amount of sanidine begins to increase, an additional high-temperature phase appears – akermanite (Figure 3).

To confirm laboratory research in practice, we have molded ceramic paving stones at the Mastek-Meteor production plant, working on the principle of vibropressing. The ceramic mass was well molded and had good adobe strength, which provides sufficient conditions for further technological operations of the finished product. The molded paving blocks were dried in a drying oven of ШСП brand – 0.5-70 at a temperature of 70-75°C according to a specially developed mode to a residual humidity of 5-7%. After drying, the paving stones were fired in an electric furnace at a temperature of 1100°C with exposure at a final temperature of 2 hours. The baked paving stones were cooled when the furnace was turned off to room temperature (Figure 4). The

Physical and mechanical properties of the ceramic composition clay-talc breed at a fixed firing temperature

Talc content %	Fire shrinkage %	Average density, g/cm³	Strength, MPa		Water absorption %	Frost resistance, cycles
			during compression	during bending		
3,0	2.6	1,85	25,67	1,94	20,4	45
5,0	3.4	1,88	28,85	2.15	19.5	47
7,0	3.8	1,91	31,26	3,66	18,6	51



a – talc content 2%; b – the same 3%;
c – the same 5%; d – the same 7%

Figure 3 – Microstructure of modified ceramic compositions

resulting samples had clear edges and a tightly sintered structure.

Conclusion

1. Based on the results of the study of the physical-mechanical and chemical-mineralogical characteristics of raw materials, a raw material composition based on clay is proposed to create a technology of ceramic paving blocks by vibropressing.

2. The compositions of ceramic compositions for the production of ceramic paving stones have been researched, taking into account the dominant factors of the two-component mixture for improving the molding, drying and physico-mechanical properties of the finished product.

3. It has been established that the introduction of talc into the ceramic composition contributes to the formation of high-temperature phases of augite and amphibole, and the enhancement of mineral formation processes in clay, with the formation of high-temperature phases – sanidine, akermanite and augite, providing samples with high physical and mechanical properties.

4. The main regularities of structure- and phase formation of ceramic compositions with a firing temperature of 1100°C, consisting in the course of the processes of solid- and solid-liquid-phase sintering in which the phase-mineral composition of the compositions is ensured, determining the production of ceramic paving blocks with high strength, frost resistance.

5. The possibility of obtaining ceramic paving stones that meet environmental and operational requirements for the purpose of using them in the improvement of urban areas (sidewalks, alleys, park areas, playgrounds, etc.) has been proven.

6. It has been established that one of the predominant properties of ceramic paving stones is their significant porosity (up to 30%), which allows quickly absorb water from precipitation (in the form of rain, sleet, etc.). and filter through it body by transferring water into the ground. This property of paving stones prevents the accumulation of moisture on the surface of the sidewalk and creates comfortable conditions for the movement of pedestrians, and also excludes the formation of an ice crust in the cold season.

Figure 4 – Samples of ceramic paving blocks based on the raw material composition clay – talc rock a – molded raw material; b – burnt samples of ceramic paving stones

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Керамикалық төсемдерді өндіруге қажетті түрлендірілген керамикалық масса

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***Аңдатпа.** Мақалада шикізат материалдарының физика-механикалық және химиялық-минералогиялық сипаттамаларын зерттеу нәтижелері ұсынылған және тальк жынысын қолдана отырып, вибропрессивті керамикалық төсеу технологиясын жасау үшін саз негізіндегі шикізат құрамы ұсынылған. Дайын өнімнің қалыптау, кептіру және физика-механикалық қасиеттерін жақсарту үшін екі компонентті қоспаның басым факторларын ескере отырып, керамикалық төсемдерді алуға арналған керамикалық композициялар зерттелді. Талькты керамикалық композицияға енгізу авгит пен амфиболдың жоғары температуралық фазаларының пайда болуына және саздағы минералды түзілу процестерінің күшеюіне, жоғары температуралық фазалардың – санидин, акерманит және авгиттің пайда болуына ықпал ететіні анықталды, бұл үлгілерді жоғары физикалық және механикалық қасиеттермен қамтамасыз етеді. 1000°С температурада керамикалық композициялардың құрылымы мен фазасының қалыптасуының негізгі заңдылықтары зерттелді, бұл қатты және қатты сұйық фазалық синтездеу процестерінің жүруінен тұрады, онда жоғары беріктігі, аязға төзімділігі бар керамикалық төсемдердің алынуын анықтайтын композициялардың фазалық – минералды құрамы қамтамасыз етіледі. Қала аумағын абаттандыруда (тротуарлар, аллеялар, саябақ аймақтары, балалар алаңдары және т.б.) пайдалану мақсатында экологиялық және пайдалану талаптарына жауап беретін қыш кеспе тастарды алу мүмкіндігі дәлелденген. Керамикалық төсемдердің басым қасиеттерінің бірі олардың едәуір кеуектілігі (30%-ға дейін) болып табылатыны анықталды, бұл атмосфералық жауын-шашыннан (жаңбыр, дымқыл қар және т.б. түрінде) суды тез сіңіруге және суды жерге жібере отырып, денесі арқылы сүзуге мүмкіндік береді. Тас төсемдердің бұл қасиеті тротуар бетінде ылғалдың жиналуына жол бермейді және жаяу жүргіншілердің қозғалысы кезінде жайлы жағдай жасайды, сондай-ақ суық мезгілде мұз қабығының пайда болуына жол бермейді.*

***Кілт сөздер:** керамикалық брусчатка, күйдіру, саздауыт, керамика, вибропресстеу, тротуар, абаттандыру, құрылыс, коррозия, бентонитті саз.*

Модифицированная керамическая масса для производства керамических брусчаток

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***Аннотация.** В статье представлены результаты изучения физико-механических и химико-минералогических характеристик сырьевых материалов и предложена сырьевая композиция на основе глины для создания технологии керамической брусчатки методом вибропрессования с использованием тальковой породы. Иссле-*

дованы составы керамических композиций для получения керамической брусчатки с учетом доминирующих факторов двухкомпонентной смеси для улучшения формовочных, сушильных и физико-механических свойств готовой продукции. Установлено, что введение талька в керамическую композицию способствует образованию высокотемпературных фаз авгита и амфибола и усилению процессов минералообразования в глине, с образованием высокотемпературных фаз – санидина, акерманита и авгита, обеспечивающих образцам высокие физико-механические свойства. Изучены основные закономерности структуро- и фазообразования керамических композиций при температуре обжига 1100°С, заключающихся в протекании процессов твердо- и твердожидкофазного спекания, при котором обеспечивается фазово-минеральный состав композиций, определяющий получение керамической брусчатки с высокой прочностью, морозостойкостью. Доказана возможность получения керамической брусчатки, отвечающей экологическим и эксплуатационным требованиям в целях использования их в благоустройстве городских территорий (тротуары, аллеи, парковые зоны, детские площадки и т.п.). Установлено, что одним из преимущественных свойств керамических брусчаток является их значительная пористость (до 30%), что позволяет быстро впитывать воду от атмосферных осадков (в виде дождя, мокрого снега и т.п.) и фильтровать через свое тело передавая воду в грунт. Это свойство брусчаток предотвращает скопление влаги на поверхности тротуара и создает комфортабельные условия при передвижении пешеходов, а также исключает образование ледяной корки в холодное время.

Ключевые слова: *керамическая брусчатка, обжиг, суглинок, керамика, вибропрессование, тротуар, благоустройство, строительство, коррозия, бентонитовая глина.*

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