PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

ESTUDO DE ROCHAS DE TUFO VULCÂNICO E DESENVOLVIMENTO DE CONCRETO ESTRUTURAL LEVE USANDO O TUFO COMO BASE

STUDY OF OVERBURDEN TUFF ROCKS AND DEVELOPMENT ON ITS BASIS OF LIGHTWEIGHT STRUCTURAL CONCRETE

ИССЛЕДОВАНИЕ ВСКРЫШНОЙ ТУФОВОЙ ПОРОДЫ И РАЗРАБОТКА НА ЕЕ ОСНОВЕ ЛЕГКОГО КОНСТРУКЦИОННОГО БЕТОНА

ZHUMADILOVA, Zhanar O.[1]; ZHUGINISSOV, Maratbek T.[1]; KHAMZA, Yerlan Y.[1]

[1] Satbayev University, Institute of Architecture and Civil Engineering, Department of Construction and Building Materials, 22 Satpayev Str., zip code 050013, Almaty – Republic of Kazakhstan

* *Corresponding author*
e-mail: zhanar_85@mail.ru

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RESUMO

Introdução. O trabalho apresenta os resultados da pesquisa no desenvolvimento de tecnologia para concreto estrutural leve a partir de rochas tufas recobertas. Para desenvolver a tecnologia de concreto estrutural leve, é usada rocha de tufo de cobertura (região de Almaty, na República do Cazaquistão), que é formada durante a extração de tufo vulcânico para a fabricação de telhas de revestimento. **Objetivos**: Estudar as propriedades físicas, mecânicas e químicas básicas do tufo, desenvolvimento de composições estruturais de concreto leve. **Métodos**. A rocha de tufo sobrecarregada foi esmagada em um britador de mandíbula e peneirada por meio de um conjunto de telas padrão. Como resultado, foram obtidos agregados do tufo das frações: 0,16-5 mm, 5-10 mm e 10-20 mm. A composição do concreto tufado foi selecionada por cálculo de acordo com o procedimento padrão. Após o cálculo da composição do concreto tufo, todas as matérias-primas: cimento, agregados, aditivos e água são dosadas e misturadas. A mistura de concreto foi colocada em um molde e compactada por vibrocompressão em uma mesa vibratória. O endurecimento de amostras de concreto é realizado em condições úmidas por 7, 14 e 28 dias, e vaporização em uma câmara de vaporização por 12-16 horas. **Resultados e discussões**. Após o endurecimento, foram determinadas as propriedades: resistência à compressão, densidade média e coeficiente de transferência de calor das amostras de concreto de acordo com métodos padrão. O grau de concreto de tufo está na faixa de 15,0-20,0 MPa. A densidade média do concreto tufado é 1822-1910 kg/m^3. O coeficiente de condutividade térmica (λ) está na faixa de 0,66-0,75 W/m·K. Foi estabelecida a possibilidade de fabricar ladrilhos de acabamento a partir de concreto tufo por meio de lixamento e polimento de sua superfície. A partir de areia tufada, com granulometria de 3-5 mm, foram realizadas por prensagem vibratória pedras de concreto com dimensões de 390x190x188 mm com 2 vazios tecnológicos. O vazio da pedra é de 51% do seu volume total, o grau de resistência à compressão é 2,5-3,5 MPa. **Conclusões**. Como resultados da pesquisa, foram estudadas as principais propriedades físicas, mecânicas e químicas das rochas tufas recobertas como enchimento de concreto estrutural leve. As possibilidades de fabricação de blocos de parede e lajes de revestimento foram estabelecidas.

Palavras-chave: *construção, agregados energeticamente eficientes, shungite, condutividade térmica, porosidade.*

ABSTRACT

Introduction. The work presents the research results on the development of technology for lightweight structural concrete based on overburden tuff rocks. To develop the technology of lightweight structural concrete, overburden tuff rock (Almaty region of the Republic of Kazakhstan) is used, which is formed during the extraction of volcanic tuff for the manufacture of facing tiles. **Aim.** Study of the basic physical, mechanical and chemical properties of tuff, development of lightweight structural concrete compositions. **Methods**. The overburden tuff rock is crushed in a jaw crusher and screened through a set of standard screens. As a result, aggregates from tuff of fractions were obtained: 0.16-5 mm, 5-10 mm, and 10-20 mm. The composition of tuff concrete was selected by calculation according to the standard procedure. After calculating the composition of tuff concrete, all raw materials: cement, aggregates, additives, and water are dosed and mixed. The concrete mixture is placed in a mold and compacted by vibro-compression on a vibrating table. Hardening of concrete samples is carried out in humid conditions for 7, 14, and 28 days and steaming in a steaming chamber for 12-16 hours. **Results and Discussion.** After hardening, the properties were determined: compressive strength, average density, and heat transfer coefficient of concrete samples according to standard methods. The tuff concrete grade is in the range of 15.0-20.0 MPa. The average density of tuff concrete is 1822-1910 kg/m^3. The thermal conductivity coefficient (λ) is in the range of 0.66-0.75 W/m·K. The possibility of manufacturing finishing tiles from tuff concrete by grinding and polishing its surface has been established. Based on tuff sand, with a grain size of 3-5 mm, concrete stones with dimensions of 390x190x188 mm with 2 technological voids were made by vibration pressing. The hollowness of the stone is 51% of its total volume, and the compressive strength grade is 2.5-3.5 MPa. **Conclusions.** As a research result, the main physical, mechanical and chemical properties of overburden tuff rocks as a filler for lightweight structural concrete were studied. The possibilities of manufacturing wall blocks and facing slabs have been established.

Keywords: *construction, energy-efficient aggregates, shungite, thermal conductivity, porosity.*

АБСТРАКТ

Введение. В статье приведены результаты исследований по разработке технологии легкого конструкционного бетона на основе вскрышных туфовых пород. Для разработки технологии легкого конструкционного бетона используется вскрышная туфовая порода (Алматинская область РК), которая образуются при добыче вулканического туфа для изготовления облицовочной плитки. **Цель.** Изучение основных физико-механических и химических качеств туфа, разработка составов легкого конструкционного бетона. **Методы.** Вскрышная туфовая порода подвергается дроблению в щековой дробилке и просеиванию через набор стандартных сит. В результате получены заполнители из туфа фракций: 0,16-5 мм, 5-10 мм и 10-20 мм. Состав туфобетона подбирался расчетным путем согласно стандартной методике. После расчета состава туфобетона все сырьевые компоненты: цемент, заполнители, добавки и вода дозируются и смешиваются. Бетонная смесь укладывается в форму и уплотняется вибропрессованием на вибростоле. Твердение бетонных образцов осуществляется во влажностных условиях в течении 7, 14 и 28 суток, а также пропарированием в пропарочной камере в течении 12-16 часов. **Результаты и обсуждение.** После твердения были определены свойства: прочность при сжатии, средняя плотность и коэффициент теплороводности бетонных образцов по стандартным методикам. Марка туфобетона находится в пределах 15,0-20,0 МПа. Средняя плотность туфобетона составляет 1822–1910 кг/м^3. Коэффициент теплопроводности (λ) находится в пределах 0,66-0,75 Вт/м·К. Установлена возможность изготовления отделочной плитки из туфобетона, путем шлифования и полирования ее поверхности. На основе туфового песка, с размерами зерен 3-5 мм, методом вибропрессования были изготовлены бетонные камни с размерами 390 x190x188 мм с 2-мя технологическими пустотами. Пустотность камня составляет 51% от общего его объема, марка по прочности на сжатие 2,5-3,5 МПа. **Заключение.** В результате исследований изучены основные физико-механические и химические качества вскрышных туфовых пород в качестве заполнителя для легкого конструкционного бетона. Установлены возможности изготовления стеновых блоков и облицовочных плит.

Ключевые слова: *строительство, энергоэффективные заполнители, шунгит, теплопроводность, пористость.*

1. INTRODUCTION:

The construction of energy-efficient, energy-saving houses involves using new design solutions, technologies, and thermal protection materials. The basis of construction is precast concrete, and in recent years it has undergone qualitative changes in the direction of weight reduction, thermal conductivity, and sound insulation. This is realized by introducing lightweight concrete based on porous natural and artificial aggregates. Modified structural lightweight concretes are produced in the same way as heavy concretes of similar structures, but the weight saving is 20-50%. Also, the heat transfers of buildings decrease, their level of thermal protection and vapor permeability increases, which leads to an increase in the comfort of living. One effective, lightweight aggregates for lightweight concrete is natural porous aggregates - volcanic tuffs, pumice, and others. In volcanic tuffs, porosity is in the range of 21.3-46.6%, their density ranges from 1400 to 1800 kg/m^3.

Moreover, the strength of volcanic tuffs is not inferior to, for example, marble. The bulk density of tuff sand is on average 1000 kg/m^3, crushed stone with a fraction of 5-10 mm - 970 kg/m^3, and crushed stone with a fraction of 10-20 - 950 kg/m^3. These indicators are much lower than that of construction sand and crushed stone based on granite, limestone, and other dense rocks. Therefore, based on tuff, it is possible to obtain lightweight structural concrete suitable for the manufacture of enclosing structures and piece wall products for the construction of energy-efficient housing.

To expand the raw material base and improve technical indicators, research is being carried out on the use of natural lightweight aggregates, particularly tuffs, to produce lightweight concrete based on them.

The authors (Silber A., 1994; Rube ́nLo ́pez-Doncel, 2012; Reference book on geology, 2017; Wedekind W., 2011; Stueck H., 2006; Siegesmund S., 2011; Trunov P. V., 2014) investigated the chemical and mineralogical compositions, as well as the structure of various tuffs.

According to (Silber A., 1994), volcanic tuff contains more than 90% volcanic material, from 50 to 90% is tuff-containing. If volcanic material content is less than half, the name is given for the predominant material of a different origin. Volcanic tuffs, depending on their composition, are liparite, trachytic, basaltic, and andesite. The chemical composition of tuffs varies widely: SiO_2 49-72%, Al_2O_3 10-24%, Fe_2O_3 2-6%, MgO 1-2,5% and others.

According to researchers from the Krakow Polytechnic Institute named after Tadeusz Kosciuszko (Silber A., 1994, tuff has a density of 0.8–1.5 g/cm^3 and a total porosity of 60–80%, depending on its origin and the screening (grinding) process. Tuff has a buffering capacity and can adsorb or release substances, especially during growth. They developed an artificial volcanic tuff stone that is solidified ash. They mixed tuff with other components - alkaline solutions and water glass. The resulting material (geopolymer) turned out to be as hard as granite.

Unlike other geopolymers, the new material can withstand high temperatures. When the temperature rises to 800-900 °C, it becomes even more robust and more reliable. These unique characteristics will make inorganic geopolymer an ideal building material; it will entirely replace expanded polystyrene in the usual thermal insulation of houses. Due to its unusual porous structure, the geopolymer breathes perfectly: it absorbs water, regulates the level of humidity in the room, and can even absorb unpleasant odors.

According to (Rube ́nLo ́pez-Doncel, 2012), tuff is a grayish-red to red volcanic rock with a characteristic porphyry tissue. Loseros (Mexico) tuff is a volcaniclastic rock with a rhyolite composition, consisting of very well-graded sand-sized crystals of fine to medium size and clastic rocks, enclosed in the ash-rich durable altered groundmass. Loseros (Mexico) tuff can have different color shades such as greenish, reddish, purple, and grayish, but the greenish variety is characteristic and most commonly used in construction (Rube ́nLo ́pez-Doncel, 2012).

In (Novi Asniar, 2019), it is shown that tuff has such geotechnical properties as 18-25 kN/m^3 specific gravity, 1.5-2.4 g/cm^3 bulk density, 2.29-2.64 g/cm^3 density particles, the compressive strength varies greatly depending on the degree of weathering, 0 - 1.45 MPa adhesion, friction angle = 24 ° - 45 ° and 4% - 42% porosity. The properties of tuff soil depend on the environment at the location of the deposit and the particle size.

The authors of (Wedekind W., 2011) studied the Habichtswald tuff and found that it contains a wide range of fragment grain sizes from a few millimeters to 5 cm. Its characteristic dark grayish, glassy or microcrystalline groundmass contains large amounts of montmorillonite. This tuff has a hypocrystalline structure with idiomorphic olivine-pyroxene crystals, and plagioclase, amphibole, and biotite can also be distinguished. Fragments of pre-existing basic rocks are also present in the form of glassy fragments.

In the study (Stueck H., 2006), most of the tuff structure grains are quartz, plagioclase, and fragments of volcanic rocks. Crystals are in the form of plagioclase from angular to subidiomorphic, angular quartz, and strongly altered biotite flakes. In thin sections, microlamination (plates) can be recognized due to variations in the frequency of fragments the size of sand. The difference is related to grain size and lime content. Inside the matrix can be found from 5% to over 20% calcite. The Eger-Damien tuff is grayish to light brown rock with fragments of various sizes. Fragments ranging in size from 1 to 30 mm are mainly elongated flattened fragments of pumice, in addition to which large plagioclase phenocrysts can be distinguished. Microcrystalline porphyry tissue with eutaxite or vitreous texture with flattened well-welded vitroclast can also be observed. The main constituents are idiomorphic to subiomorphic plagioclase crystals, which exhibit a very impressive zonal structure, together with plagioclase, subidiomorphic quartz, corroded hornblende, and altered biotite. Smectite occurs in relatively large quantities, about 10% by weight.

According to Siegesmund S. (2011), the studied tuff rocks have a low (up to 50%) or many micropores. According to Klopfer, microporosity is defined as pores from 0 to 0.01 mcm, capillary-active pores are from 0.01 to 10 mcm. For microprobes with pore diameters <0.1 mcm, water will condense below 99% relative humidity. Capillary absorption occurs in pores from 1 mcm to 1 mm. The microporosity of the studied rocks ranges from 13 to 97%.

According to Trunov P. V. (2014), the quality factor of volcanic tuff as a binder component compared to other sands of technogenic origin shows the quality factor K equal to 0.96. The microporosity of the studied rocks ranges from 13 to 97%. Volcanic tuff is characterized by a polydisperse distribution of particles with varying sizes from about 1 to 350 mcm (Trunov P.V., 2014).

The authors (Movsisyan M.S., 1993) proposed composition for obtaining a firing material, including 60-77% natural tuff, 20-30% glass powder, and 3-10% alkaline silicate solution. The mixture is stirred until a homogeneous mass is obtained, then it is poured into a metal mold, covered with a lid, and fired in a muffle furnace at a temperature of 800-890 °C for 10-15 minutes. After cooling, the product is removed and shaped, resulting in a lightweight, porous and durable material. The average density of the product is 700-900 kg/m^3, and the compressive strength is 50-100 kg/cm^2. The resulting material can produce facing and partition plates, blocks for industrial, civil, individual buildings, and housing construction.

To Gonchikov Z. M. (1998), the natural tuff of the Kamensk deposit of the Kabardino-Balkarian Autonomous Soviet Socialist Republic (KBASSR) was used to obtain a mixed binder as a pozzolanic additive together with SP S-3 (superplasticizer, grade S-3). Finely ground tuff is added in an amount of 40-60% to portland cement PC-D20 and PC-D0 (PC - portland cement). The tuff addition made it possible to reduce the thermal conductivity of dry cement stone from 0.537 to 0.4 W/m·°C. The optimal addition to PC-D0 cement is 40% tuff and 1% S-3 by weight of cement, which provides the grade of mixed binder M 400. Compositions of tuff concrete on aggregates and tuff using PC and MB (mixed binder) as binders have been developed. The resulting tuff concrete at the PC has an average density of 1340 kg/m^3 and compressive strength of 4.9 MPa, tuff concrete with a mixed binder (MB) has an average density of 1330 kg/m^3 and a compressive strength of 4 MPa. Porous tuff concretes were obtained at PC and MB with an average density of 1220 and 1250 kg/m^3 and compressive strength of 8.2 and 8.2 MPa.

Babayan G. G. (1992) has developed a concrete composition based on which a stone for masonry walls is made. The concrete composition contains, weight, %: portland cement 4-7; cement dust 9-18; tuff crushed stone 0.5-12; tuff sand 60-67.5 and water 10-12. The technology of manufacturing products is as follows: dosed components: cement, crushed tuff stone, and tuff sand are mixed at the beginning dry (1 min), and then water is added, and mixing is continued for 1.5 - 2 minutes, mixing time is 3-3.5 minutes. Then, samples are molded from the resulting mass at a pressure of 30-50 MPa and subjected to steaming according to the regime: raising the temperature for 2 hours, holding at a temperature of 90 °C for 6 hours, lowering the temperature for 2 hours (10 hours in total). Samples of products have an average density of 1655-1890 kg/m^3, compressive strength 15.6-23 MPa, softening coefficient after 25 cycles 0.8-0.92.

The same authors (Babayan G. G., Mikhaelyan V. G., 1992) proposed concrete using tuff. The composition includes weight, %: cement dust 38-42, tuff crushed stone 0.5-1.2, tuff sand 33-44, lime 0.5-2.0, gypsum 1-3, water 3-9, wastewater of asbestos-cement production 3-9. Concrete is used for the manufacture of autoclave-free building products. Building products is carried out in several production operations: preparation of a binder from furnace dust, lime, and gypsum. Dosage of dry binder, tuff sand, crushed stone, dry mixing of components, the dosage of asbestos-cement production wastewater and water, wet mixing of components, and molding of products at a pressure of 25-50 MPa. Steaming products according to the regime: raising the temperature to 90 °C for 2 hours, holding at a temperature of 90 °C for 6 hours, lowering the temperature for 2 hours (10 hours in total). Samples of products have an average density of 1600-1950 kg/m^3, compressive strength 18-25 MPa, water absorption 8.5-9.5%.

The authors Babayan G. G., and

Dashtoyan S. A. (1992) proposed a composition including cement dust 35.5-38.0%, tuff crushed stone 1-2.5%, tuff sand 33-40%, lime 0.5-2%, gypsum 0.5 -3%, water 9-10%, carbonate sludge, formed when cutting carbonate rocks 10-15%. The composition is used for the manufacture of partition plates, blocks, bricks, and others. The manufacturing technology of products is similar to that described above. Samples of products have an average density of 1645-2020 kg/m^3, compressive strength 16-23 MPa, water absorption 7.0-7.9%.

In the study (Gukosyan S. Zh., 1997) to obtain highly filled composites, wastes from the production of tuff stone and emulsion polyvinyl chloride, as well as polyvinyl butyral, were used. Wastes from the tuff stone production were sieved through sieves before use, and fractions <100mcm<200 mcm<300 mcm were selected for research. In the composition of the composites, the content of tuff powder varied within 70–90%. Mixing and ingredients (filler and polymer powders) were carried out in a mixer with a horizontal rotating chamber. Studies have shown that the optimal mixing time is 1.5-2 hours; the structure of the pressed samples judged the homogeneity of the composition. Samples for testing composites were prepared by compression pressing. The obtained samples were tested for strength in compression and bending, for water absorption for 24 hours at 20 °C. Testing composite samples showed that the most optimal additive is the tuff powder of fraction <200 mcm in an amount of 80%. The flexural strength of the composite is 27.8 MPa, and water absorption is 12.1%. Composites can be used for the production of PVC and linoleum boards.

In the study of Zagoyruko T. V. (2011), the composition of heat-resistant concrete was developed using expanded shungite as a filler. Expanded shungite possesses high heat resistance, strength, non-toxic, does not rot, prevents the spread of mold, has high-temperature resistance, fire resistance, and reflectivity. Based on optimization, the compositions of heat-resistant concrete with the addition of shungite with the specified properties were selected: strength 10 MPa, density 1500 kg/m^3. Tests were carried out on samples of heat-resistant concrete with the addition of shungite and without shungite (reference concrete). Comparative tests of the samples showed that the composition of heat-resistant concrete with the addition of shungite makes it possible to increase the heat resistance of concrete at 900 °C by 12 times and at 1100 °C by six times.

The authors of (Jehad Al-Zou'by, 2014) found that the use of zeolite filler in the manufacture of concrete, in the amount of 5, 10, and 15%, leads to an increase in its compressive strength. Simultaneously, with an increase in the amount of zeolite, the strength of concrete increases accordingly. The authors also investigated the strength of concrete on a volcanic tuff filler. It has been established that concrete containing 30% of a volcanic tuff aggregate has a strength of 28% lower than that of ordinary concrete on a limestone aggregate (R_c = 300 kg/cm^2) after 28 days of hardening. In concrete manufacture, aggregates with a maximum particle size of 10, 20, and 40 mm were used, which have a noticeable effect on concrete strength. The dependence of concrete strength on the size of aggregate fractions has been established. Tests have shown that with an increase in the aggregate fraction, the strength of concrete on a limestone aggregate by 0.2; 5 and 14%, respectively, higher than on volcanic tuff. The same pattern is shown in the study of high-strength concrete (R_c = 800 kg/cm^2) on limestone and volcanic tuff aggregate. Concrete made with limestone aggregate has a compressive strength of 4, 6, and 7% higher than concrete with a volcanic tuff aggregate of the same fractions.

Al Dwairi (2007), volcanic tuff in Jordan is present in the northeastern, central, and southern parts of the country. Volcanic tuffs in Jordan are studied for mineralogy, petrology, and their ecological, industrial, and agricultural applications. Volcanic tuff (detrital) differs depending on location and depending on the rate of weathering and zeolitization processes, reflecting the mineral content and the amount of secondary minerals associated with volcanic tuff zeolites being the most important.

Gradstein, F. M. (2012), the volcanic tuff from Al-Khala-1, Jordan is strongly changed in zeolite from brown to gray. The thickness of the colored cut is more than 50 m. The volcanic tuff from Al-Khala-2 is a fresh black slag. Tuff in both places is of Paleocene and Neogene age.

The authors Reyad A. Al Dwairi (2018) investigated the possibility of using volcanic tuff as lightweight structural concrete, for this two samples were subjected to the following laboratory tests: determination of specific gravity and water absorption, average density and porosity, which was determined following ASTM C29/C29M - 17a., and the abrasion of the tuff in the abrasion machine. The analyses were carried out in the Civil Engineering Department of the Tafil Technical University laboratories in Southern

Jordan.

Thus, natural tuff and waste from the production of tuff stone are widely used to manufacture building materials for various purposes. In Kazakhstan, there is practically no research and development on the use of natural tuff and waste from the production of tuff stone in the technology of concretes, binders, and other materials.

Research on the use of tuff and its waste in technology is carried out in Armenia, Russia, and Poland. In Poland, based on tuff, a fire-resistant geopolymer was obtained that replaces expanded polystyrene and absorbs unpleasant odors. In Armenia, based on natural tuff and waste from the production of tuff stone, compositions and raw mixtures have been developed to manufacture of wall stones, partition plates, blocks, and bricks. Also obtained are polymer composite materials, where finely ground tuff powders are used as fillers. A mixed binder and porous tuff concrete products were obtained in KBASSR using tuff and Portland cement.

2. MATERIALS AND METHODS:

*2.*1 Materials.

As the main raw material, overburden volcanic rocks are used, formed during volcanic tuff extraction (Chundzha village, Uygur district of Almaty region, Kazakhstan) represent volcanic tuff of a lower quality, not suitable for the manufacture of piece goods. For research, we used pieces of overburden volcanic rocks with dimensions of 50-150 mm. The overburden was crushed in a jaw crusher and screened through a set of standard sieves to make aggregates. As a result, aggregates were obtained from tuff fractions: 0.16-5 mm, 5-10 mm, and 10-20 mm. The first fraction corresponds to the fine aggregate - sand, the second and third fractions - to the coarse aggregate - crushed stone. Figure 1 shows photographs of crushed tuff stone. For the manufacture of lightweight structural concrete, Portland cement CEM I 32.5 N (GOST 31108-2003) was used as a binder.

2.2 Methods

The crushing capacity of crushed stone was determined by the degree of destruction of the grains during compression (crushing) in the cylinder with the size 150 mm (GOST 8269.0-97, 2018).

The calculation of the composition of tuff concrete was carried out according to the method described in the DBC (Departmental building codes) (Departmental building codes, 1992).

2.2.1 Determination of the bulk density of aggregates.

According to GOST 9758-86 (GOST – Governmental standard), the bulk density of aggregates obtained from tuff was determined. Porous inorganic aggregates for construction work. It was used: a set of graduated cylindrical vessels, an electric drying cabinet, a metal ruler. The aggregate dried to constant weight was poured into a pre-weighed measuring vessel from a height of 100 mm above its upper edge until a cone formed above the top of the vessel, which was removed with a metal ruler flush with the edges of the vessel (without compaction) and weighed. The porous sand was poured through a funnel. The size of the measuring vessel and the volume of the test sample depends on the aggregate size.

2.2.2 Determination of the average density of tuff concrete.

According to GOST 27005-2014, the average density of lightweight concrete was determined. Lightweight and cellular concrete. Average density control rules. It was used laboratory scales and a drying cabinet. For a unit value of concrete density, the average density of a series of samples made from one sample of a concrete mixture or the average density of a series of selected samples is taken. Concrete samples hardened under normal conditions for 28 days were weighed on an electronic laboratory balance. The average density of the three samples was determined by arithmetic.

2.2.3 Determination of the strength of aggregates when pressed in a cylinder.

The strength of the tuff aggregate under compression in the cylinder was determined by the load corresponding to the immersion of the punch by 20 mm into the layer of the aggregate test sample. Were used: hydraulic press, steel composite cylinder with a diameter of 150 mm, drying cabinet. The punch was pressed in without skewing at a speed of 0.5-1.0 mm/s. The sample dried to constant weight was placed in a cylinder and installed in a hydraulic press. Strength is determined according to GOST 9758-2012 Porous inorganic fillers for construction work. Test methods. The strength of the aggregate of an individual fraction under compression in the cylinder was calculated for each aggregate fraction as the arithmetic means of the results of two parallel tests of this fraction.

2.2.4 Determination of the strength of tuff concrete.

The compressive strength of tuff concrete samples was determined according to GOST 10180-2012 Concrete. Methods for determining the strength of control samples. It was used: testing machine, metal ruler. The concrete samples were installed in a testing machine (Hydraulic Press). The samples were loaded continuously at a constant rate of increase in the load until its destruction. The maximum force achieved during the test is taken as the breaking load.

2.2.5 Determination of thermal conductivity.

The thermal conductivity of tuff concrete was determined using an ITP-MG4 (250) thermal conductivity meter based on GOST 7076-99 (GOST 7076-99). Samples were made of tuff concrete with a size of 250x250x100 mm for the test equipment dimensions. The samples hardened under normal conditions for 28 days. During the test, the temperature difference between the face faces of the sample was set in the range of 10-30 K. The average temperature of the sample during testing must be specified in the regulatory document for a specific type of material or product. After reaching a stationary thermal regime, the thickness of the sample placed in the device is measured with a caliper with no more than 0.5% error. After the end of the test, determine the mass of the sample. The average arithmetic mean values of thermal resistance and effective thermal conductivity of all tested samples were taken as the test result.

X-ray diffractometric analysis was carried out on a DRON-3.0 diffractometer with $Cu_{K\alpha}$ - radiation, β - filter. Conditions for recording diffraction patterns: U = 35 kV; I = 20 mA; shooting θ-2θ; detector 2 deg/min. Semi-quantitative X-ray phase analysis was carried out based on the diffraction patterns of powder samples using equal portions and artificial mixtures. The quantitative ratios of the crystalline phases were determined. The interpretation of the diffractograms was carried out using ICDD card index data: the database of powder diffractometric data PDF2 (Powder Diffraction File) and diffractograms of minerals free of impurities.

3. RESULTS AND DISCUSSION:

The research results on the development of compositions and technological parameters of lightweight structural concrete based on overburden formed during volcanic tuff extraction. They are of particular interest for the production of lightweight structural concrete and facing tiles on its basis.

The chemical composition of the tuff was determined by X-ray spectral local analysis (RLA) using a JCTXA-733 electron probe microanalyzer. Table 1 shows the results of the chemical analysis of volcanic tuff.

Overburden tuff rock from the village Chundzha, Uygur District, Almaty Region, is yellowish to orange-brownish (hypercrystalline to aphanite texture) with various debris sizes.

Figure 2 shows a diffractogram of overburden volcanic tuff. All the given diffraction peaks belong only to the phases indicated above. The results of semi-quantitative X-ray phase analysis showed that the content of minerals in the tuff composition is: sanidine $(K_{0.831}Na_{0.169})(AlSi_3O_8)$ – 29,2 %; kaolinite $Al_2Si_2O_5(OH)_4$ – 24,4 %; zeolite (heulandite) $Na_{5.68}Ca_{1.52}(Al_{8.6}Si_{27.4}O_{72})(H_2O)_{21.4}$ – 23,3 %; kyanite $Al_2O(SiO_4)$ – 14,2 %; calcite $Ca(CO_3)$ – 7,3 %; micas $KAl_2(AlSi_3O_{10})(OH)_2$ – 1,5 %.

Fragments are mainly light brown to brownish-reddish poorly flattened pumice and other lithoclasts (basalts and other volcanic fragments), which can range in diameter from a few mm (the size of sand grains) to 5 cm, and sometimes more (Figure 3).

One of the main requirements for the suitability of the crushed stone for the manufacture of concrete is the value of the indicator of its crushing capacity. Depending on the index of crushing (Cr), crushed stone (gravel) is divided into the following grades: Cr8 (with a weight loss of up to 8%), Cr12 (with a weight loss of 8 to 12%), Cr16 (with a weight loss of 13 to 16%) and Cr24 (with a weight loss of 16 to 24%).

The crushing capacity of tuff crushed stone was determined in 2 fractions: 5-10 and 10-20 mm. The crushed tuff stone obtained by us corresponds to the Cr24 brand.

To calculate the composition of lightweight concrete on porous aggregates, it is necessary to determine the bulk density of the aggregates (ρ_{bulk}). The best ratio was established between fine and coarse aggregates on schedule. A binder was added to the resulting mixture of aggregates per 1 m^3 of the total volume of small and large aggregates. For each of the three compositions mentioned above, the optimal water consumption was determined. The output of concrete at given compaction would be the smallest, and therefore, the concrete would be the most workable and durable. Bulk densities were determined for aggregates obtained from two batches. Bulk densities of aggregates from the first batch of tuff (GOST 9758-2012):

- ρ_{bulk}, tuff sand – 970 kg/m^3;
- ρ_{bulk}, tuff crushed stone fractions 5-10 mm – 988 kg/m^3;
- $\rho_{bulk,}$ tuff crushed stone fractions 10-20 mm – 999,7 kg/m^3;
- $\rho_{bulk,}$ (average value of the sum of 2 fractions) – 995 kg/m^3.

Bulk densities of aggregates from the second batch of tuff:

- ρ_{bulk}, tuff sand – 1040 kg/m^3;
- ρ_{bulk}, tuff crushed stone fractions 5-10 mm – 950,7 kg/m^3;
- ρ_{bulk}, tuff crushed stone fractions 10-20 mm – 961kg/m^3;
- $\rho_{bulk,}$ (average value of the sum of 2 fractions) – 956,4 kg/m^3.

The bulk densities of crushed stone and sand of the first and second batches differ markedly from each other, indicating an unstable (uneven) volcanic tuff density. This factor is associated with the different porosity of the volcanic rock, which depends on the cooling conditions of the volcanic lava.

After calculating the composition of tuff concrete, all raw materials: cement, aggregates, additives, and water are dosed and mixed. The concrete mix is placed in a mold and compacted by Vibro-compression on a vibrating table. To determine the properties of tuff concrete, sample cubes with dimensions of 100x100x100 mm were made. The hardening of concrete samples is carried out in moisture conditions for 7, 14, and 28 days and steaming in a steaming chamber for 12-16 hours. After hardening, the properties (strength, average density, thermal conductivity coefficient) of concrete samples were determined according to the above standard procedures. Table 2 shows the compositions and properties of concrete samples based on volcanic tuff.

Tuff concrete samples No. 6 and No. 7 were made from aggregates obtained from 2 batches of overburden tuff rocks.

As can be seen from the data in the table, the compressive strength of tuff concrete samples of compositions No. 6 and No.7 is lower than that of concretes obtained based on tuff from the first batch. Therefore, in the manufacture of tuff concrete products, each time after crushing tuff into the sand and crushed stone from a new batch, it is necessary to check their bulk density, crushing capacity, and strength of crushed stone.

The average density of tuff concrete is 1822-1910 kg/m^3, the grade of tuff concrete is in the range of 15.0-20.0 MPa. The thermal conductivity coefficient (λ) is within the range of 0.611-0.757 W/m·K, which is lower than the thermal conductivity of heavy cement concrete with a density of 2100-2500 kg/m^3 (0.9-1.3 W/m·K), (GOST 25820-2014).

The possibility of manufacturing finishing tiles from tuff concrete by grinding and polishing its surface has been established. Simultaneously, the structure of aggregates of various shades is exposed, giving it a decorative effect (Figure 4).

Based on tuff sand, with a grain size of less than 3 mm, a concrete stone with dimensions of 390x190x188mm with two technological voids was made by Vibro-compression (GOST 6133-99). The emptiness of stone is 51% of its total volume. The ratio of cement: tuff sand = 1:5. The concrete stone hardened at room temperature (18-20 °C) for 18 days after forming. Compressive strength tests of concrete stone were carried out. It was found that the compressive strength is 30.8 kg/cm^2 or 3.1 MPa, which corresponds to the M25 grade.

When transporting a wall block (stone) made of lightweight concrete of a low grade and laying walls, vertical cracks, chips, crumbling corners, and other types of defects are formed (Figure 5). Such a wall block can be used for individual construction of a one-story house in non-seismic areas. According to (GOST 6133-99), lightweight concrete wall stones are grades 100, 75, 50, 35, 25. By agreement with the consumer, the grade of the block on tuff sand can be increased to M50-M100.

4. CONCLUSIONS:

1. One of the main requirements of lightweight concrete manufacturing technology is the use of porous aggregates. Such aggregates were obtained by crushing porous volcanic tuff rocks. The porosity was in the range of 21.3-46.6% in volcanic tuffs; its density ranges from 1400 to 1800 kg/m^3.

2. In this work, overburden volcanic rock was used as the main raw material, which was formed during the extraction of volcanic tuff (Chundzha village, Uygur district of Almaty

region, Kazakhstan) and is a volcanic tuff of lower quality, not suitable for the manufacture of piece products.

3. The chemical composition of the overburden volcanic tuff was determined. The X-ray diffractometric and X-ray phase analyses were carried out on a semi-quantitative basis based on the diffractograms of powder samples. The main crystalline phases of overburden volcanic tuff were represented by kaolinite $Al_2Si_2O_5(OH)_4$, zeolite (heulandite) $Na_{5.68}Ca_{1.52}(Al_{8.6}Si_{27.4}O_{72})(H_2O)_{21.4}$, kyanite $Al_2O(SiO_4)$, calcite $CaCO_3$, and mica $KAl_2(AlSi_3O_{10})(OH)_2$.

4.Tuff sand with bulk density was obtained by crushing and sieving 970-1040 kg/m^3; tuff crushed stone 5-10 mm - 950.7-988 kg/m^3; tuff crushed stone fraction 10-20 mm - 961- 999.7 kg/m^3. The compositions were calculated, mixtures were compiled, and samples of tuff concrete were made. Moreover, the tuff content in the concrete was 80%.

5. It was established that the bulk densities of aggregates obtained from different volcanic tuff batches differ from each other; therefore, the compressive strength of tuff concrete specimens of compositions No. 6 and No.7 was lower than that of concretes obtained based on tuff from the first batch. Therefore, each time after crushing the tuff into the sand and crushed stone, it is necessary to check their bulk density, crushing capacity, and strength of the crushed stone from a new batch.

6. The obtained samples of tuff concrete have an average density of 1822-1910 kg/m^3, in terms of compressive strength, they correspond to B12.5-15 classes (GOST 25820-2014). The thermal conductivity of tuff concrete samples is in the range of 0.611-0.757 W/m·K. These indicators satisfy the requirements for lightweight structural concrete.

7. The possibility of making finishing tiles from tuff concrete by grinding and polishing its surface was established. Simultaneously, the structure of aggregates of various shades is exposed, giving it a decorative effect.

8. The possibility of manufacturing wall concrete blocks of the M 25-35 brand with dimensions of 390x190x188mm with two technological voids (GOST 6133-99) was established. The weight of the block is 17-18 kg, which is lighter than similar blocks on conventional aggregates, and, accordingly, it has lower thermal conductivity and higher thermal insulation properties.

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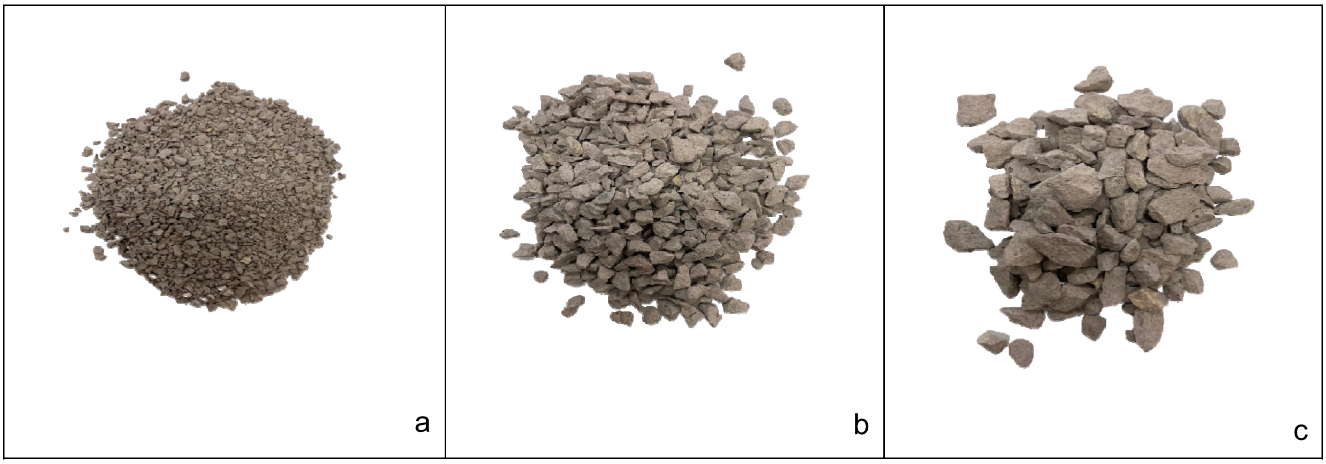

Figure 1. *Tuff rubble. Fraction 0.16-5 mm (a); fraction 5-10 mm (b); fraction 10-20 mm (c).*

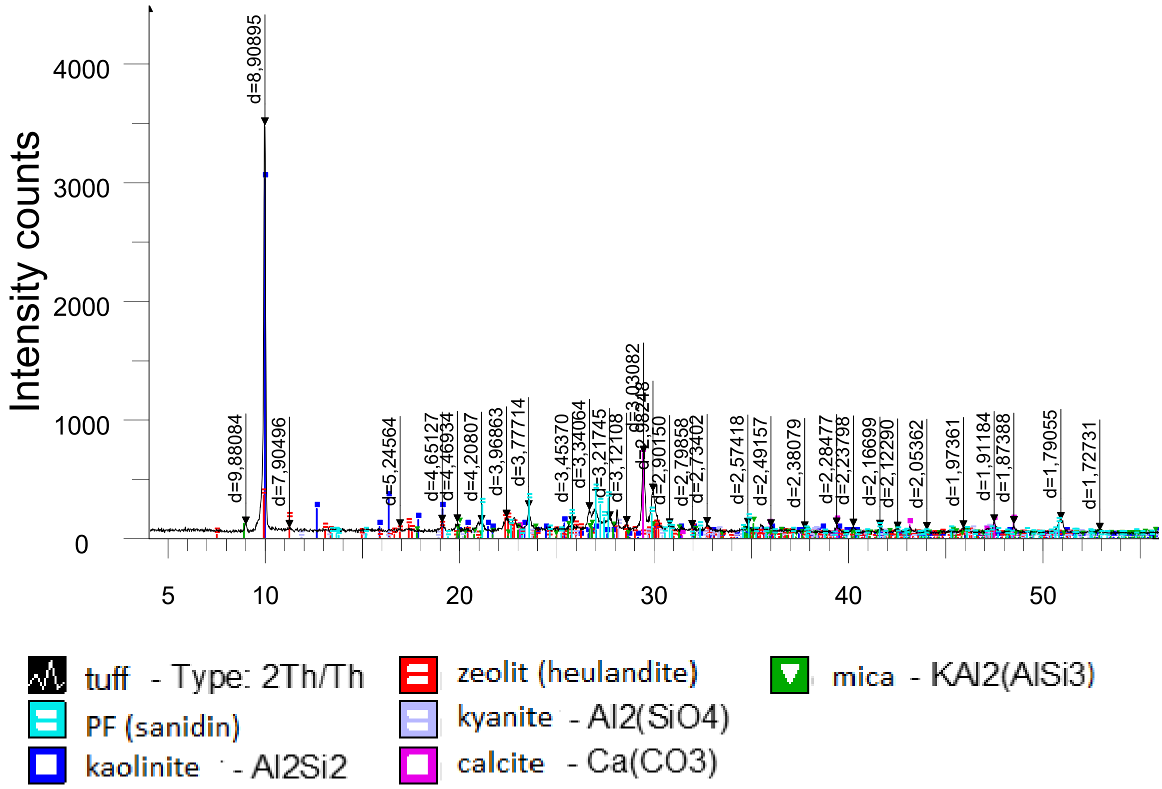

Figure 2. *Diffractogram of volcanic tuff*

Figure 3. *Overburden volcanic tuff structure*

Figure 4. *Decorative facing tiles made of tuff concrete*

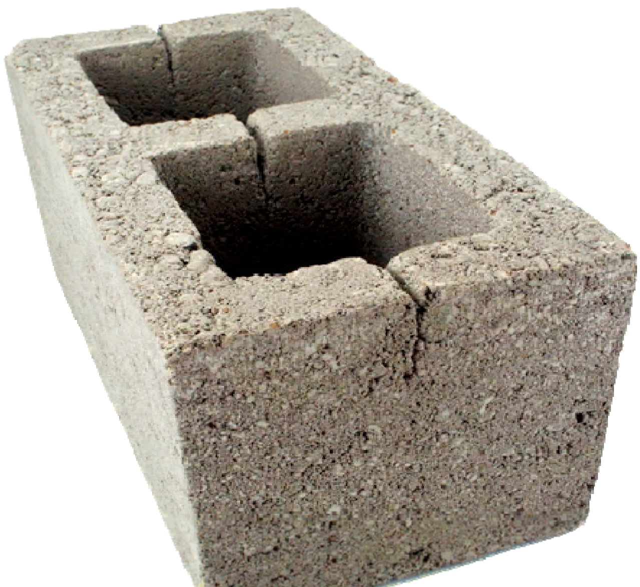

Figure 5. *Tuff concrete wall block*

***Table 1**. The chemical compound of volcanic tuff*

Compound, % by mass								
SiO_2	Al_2O_3	K_2O	Na_2O	CaO	FeO	MgO	TiO_2	MnO
72.36	14.04	5.14	3.54	2.36	1.47	0.67	0.16	0.26

***Table 2.** The Cement content and properties of tuff concrete samples*

No.	**Cement content in 1m^3 of concrete**	**Average density (ρ_{av}) of concrete, kg/m^3**		**Compressive strength, MPa**		**Concrete class**	**Thermal conductivity, λ, W/m·K**
		Estimated	**Factual**	**After heat treatment humidity (HTH)**	**After 28 days**		
1	380	1800	1910	14.3	20.0	B15	0.7545
2	350	1800	1900	12.3	17.5	B12.5	0.7490
3	350	1800	1880	11.5	16.4	B12.5	0.7230
4	350	1800	1822	13.1	20.0	B15	0.6651
5	350	1800	1843	13.7	21.08	B15	0.6742
6	350	1800	1918	10.2	14.6	B12.5	0.7557
7	350	1700	1879	12.4	17.7	B12.5	0.7430