ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ
Satbayev University

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
КАЗАХСТАН
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N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
Satbayev University

SERIES

OF GEOLOGY AND TECHNICAL SCIENCES

4 (454)

JULY – AUGUST 2022

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

«Известия НАН РК. Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.

Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*

Periodicity: 6 times a year.

Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19

http://www.geolog-technical.kz/index.php/en/

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS *of the National Academy of Sciences of the Republic of Kazakhstan*
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 4, Number 454 (2022), 44-54
https://doi.org/10.32014/2022.2518-170X.199

UDK 693.542.4

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FINE-GRAINED CONCRETE USING MINERAL AND CHEMICAL ADDITIVES

Abstract. The formation of market relations in the economy of Kazakhstan predetermined the creation of a new concept for the production of basic types of building materials. Based on the current problems of the construction complex, the creation of new and improvement of existing technological processes should be aimed at the development and production of efficient and competitive building materials using local and non-traditional raw materials that have high operational properties. To implement these tasks, it is necessary to use innovative technologies in the production of concrete. This material has been used for many centuries, is being improved and developed. Currently, specialists from different countries are developing high–strength concrete of a particularly dense structure - fine-grained concrete with high strength indicators. Fine-grained concrete belongs to the category of heavy concrete, its advantages are a high coefficient of strength in the process of bending and stretching, frost resistance and water resistance. Due to these properties, the mixture is often used in the repair of seams, cracks, in the sealing of various deformations, as well as for the creation of reinforced structures and products in the production of thin-walled structures with thick or complex reinforcement. The use of chemical additives in concrete technology began in the 1940s and is widely used in many countries. Currently, chemicalization has become one of the directions in the development of concrete technology.

Key words: fine-grained concrete, mineral additives, superplasticizers, zeolite rocks, concrete mixtures, structure, strength.

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МИНЕРАЛДЫ ЖӘНЕ ХИМИЯЛЫҚ ҚОСПАЛАРДЫ ҚОЛДАНАТЫН ҰСАҚ ТҮЙІРШІКТІ БЕТОН

Аннотация. Қазақстан экономикасында нарықтық қатынастардың қалыптасуымен қатар құрылыс материалдарының негізгі түрлерін өндірудің тапшылығы айқындалды. Құрылыс кешенінің ағымдағы проблемаларын негізге ала отырып құрылыс технологиялары, жаңа технологиялық процестерді құру және қолданыстағыларын жетілдіру жоғары пайдалану қасиеттері бар жергілікті және дәстүрлі емес шикізатты пайдалана отырып, тиімді және бәсекеге қабілетті құрылыс материалдарын әзірлеуге және өндіруге бағытталуы тиіс. Осы міндеттерді іске асыру үшін бетон өндірісінде инновациялық технологияларды пайдалану қажет. Бұл материал ғасырлар бойы қолданылып келеді, уақытымен жетілдіріліп және үздіксіз дамып келеді. Қазіргі уақытта әртүрлі елдердің мамандары аса тығыз құрылымдағы аса берік бетон – беріктігі жоғары көрсеткіштері бар ұсақ түйіршікті бетон әзірлеуде. Ұсақ түйіршікті бетон ауыр бетон санатына жатады, оның артықшылықтары иілу және созылу процесінде жоғары беріктік коэффициенті, аязға төзімділігі және суға төзімді қасиеті жоғары. Осы қасиеттерге байланысты қоспасы көбінесе тігістерді, жарықтарды жөндеуде, әртүрлі деформацияларды өңдеуде, сондай-ақ қалың немесе күрделі арматурасы бар жұқа қабырғалы конструкцияларды өндіруде арматураланған құрылымдар мен өнімдерді жасау үшін қолданылады. Бетон технологиясында химиялық қоспаларды қолдану 1940 жылдары басталды және көптеген елдерде кеңінен қолданылады. Қазіргі уақытта химияландыру бетон технологиясын дамытудағы негізгі бағыттардың біріне айналды.

Түйін сөздер: ұсақ түйіршікті бетон, минералды қоспалар, суперпластификаторлар, цеолит жыныстары, бетон қоспалары, құрылым, беріктік.

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МЕЛКОЗЕРНИСТЫЙ БЕТОН С ИСПОЛЬЗОВАНИЕМ МИНЕРАЛЬНЫХ И ХИМИЧЕСКИХ ДОБАВОК

Аннотация. Становление рыночных отношений в экономике Казахстана предопределило создание новой концепции производства основных видов строительных материалов. Исходя из текущих проблем строительного комплекса, создание новых и совершенствование существующих технологических процессов должно быть направлено на разработку и производство эффективных и конкурентоспособных строительных материалов с использованием местного и нетрадиционного сырья, обладающих высокими эксплуатационными свойствами. Для реализации этих задач необходимо использовать инновационные технологии в производстве бетона. Этот материал используется уже много веков, совершенствуется и развивается. В настоящее время специалисты из разных стран разрабатывают высокопрочный бетон особо плотной структуры – мелкозернистый бетон с высокими прочностными показателями. Мелкозернистый бетон относится к категории тяжелых бетонов, его преимуществами являются высокий коэффициент прочности в процессе изгиба и растяжения, морозостойкость и водонепроницаемость. Благодаря этим свойствам смесь часто используется при ремонте швов, трещин, при заделке различных деформаций, а также для создания армированных конструкций и изделий при производстве тонкостенных конструкций с толстым или сложным армированием. Использование химических добавок в технологии бетона началось в 1940-х годах и широко используется во многих странах. В настоящее время химизация стала одним из направлений в развитии технологии бетона.

Ключевые слова: мелкозернистый бетон, минеральные добавки, суперпластификаторы, цеолитовые породы, бетонные смеси, структура, прочность.

Introduction. It is worth mentioning the efforts of many authors, in which they paid attention to the development of compositions, the study of properties and the development of fine-grained concrete in the construction industry. The possibility of economic efficiency of using fine-grained concrete for the construction of buildings and structures in areas with a shortage of coarse aggregate was been proved. Currently, fine-grained concrete is the most common type of building materials used in the construction of load-bearing and enclosing structures, in thermal insulation and as a protective lining layer of structures to protect against the effects of aggressive environments (Bazhenov et al., 2010).

At present, multicomponent fine-grained concrete is actively use in various construction industries. Previously, their widespread use was impossible due to some features of the properties and structure. The use of concrete structure modifiers has significantly improved the performance characteristics of such concretes. Today, this has become possible thanks to the transition to multicomponent concrete with various additives, such as superplasticizers and small mineral additives of various types. The multicomponent structure has a number of advantages. Firstly, it allows you to manage efficiently the formation of the structure at different stages of the technological process. Secondly, it allows you to obtain various materials with specified properties.

The aim of the study is to optimize the composition of fine-grained concrete using high-quality aggregates, mineral additives and superplasticizers.

The increase in porosity of fine-grained concrete is due to the fact that the aggregate has a high specific surface area, which significantly increases the water demand of the concrete mixture, which, when vibrated, contributes to the involvement of air in it within 5%. In addition, the absolute volume of cement paste in fine-grained concrete should always be greater than in coarse-grained concrete; therefore, the overall porosity of concrete has affected by interstitial voids that form when there is insufficient amount of it. The development of products based on them using natural zeolites is a new direction in the research of both zeolite raw materials and in chemistry and technology of building materials. Experts from all over the world have been actively engaged in the problems of studying and rational use of natural zeolites for the past thirty years, in Kazakhstan zeolites have been recognized as an independent type of mineral only in the last decade. Natural zeolites are inferior in their properties to synthetic ones, but they are cheaper. This makes the use of natural zeolites preferable in some cases. Deposits of high-siliceous zeolites are of industrial importance (Bazhenov et al., 2021).

The current stage of research of zeolite rocks for their use in one of the most resource-intensive industries - the construction industry - is very relevant and promising, creating the prerequisites for the industrial development of deposits of various technological directions of building binders. The application of the results of these studies will make it possible to develop scientifically sound recommendations for expanding the raw material base and involving non-traditional types of local raw materials in the production process, reducing the cost of materials and products widely used in construction practice.

J.V. Smith (Smith, 1980) suggests calling zeolite "alum inosilicates with a skeleton structure, in which there are cavities occupied by large ions and water molecules, both of which are characterized by significant mobility, which provides the possibility of ion exchange and reversible dehydration."

From the point of view of other researchers characterizes zeolites as "crystalline aqueous alum inosilicates of a framework structure, from which water can be reversibly removed by moderate heating without destroying the silicon-aluminum-oxygen framework; at the same time, a system of regular channels and cavities is formed in the framework, accessible for the adsorption of small molecules" (Smith, 1980; Huynh et al., 2020). However, these definitions do not reflect the complexity and variability of the physicochemical properties of zeolite group minerals.

Modern science defines zeolites as aqueous alum inosilicates with a frame structure in which there are cavities occupied by large ions, more often alkaline and alkaline earth metals, and water molecules characterized by high mobility (Kastornykh et al., 2005).

Fine-grained concrete mix has a more homogeneous structure due to the absence of a large aggregate, and easier to handle various technological alterations. This will make it possible to obtain products and structures of various types with different operational properties that are not obtained using a large filler. To obtain special fine-grained concretes, liquid glass, polymers, phosphate binders, alumina and high-alumina cements are also used in the composition (Smith, 1980; Kastornykh et al., 2005).

Research Material and methods. The introduction of super- and hyperactive plasticizers, complex chemical additives and finely dispersed mineral fillers (ash, micro silica, finely ground slags, etc.) into the concrete mixture improves the strength characteristics of fine-grained concrete. For all fine-grained concretes, in order to improve their properties, it is useful to introduce a small addition of silica. Micro silicon compacts the structure of concrete by interacting with calcium hydroxide, promotes the formation of low-base hydra of calcium silicates, which makes it possible to obtain high-strength concretes and increases the service life of the structure of fine-grained concrete.

In addition, the use of silica reduces the consumption of binder. The introduction of micro silicon together with superplasticizers is optimal, since the increased content of micro-silica negatively affects the rheological properties of the latter.

The use of superplasticizers also makes it possible to solve a number of problems, for example, different conditions of concrete use in the regions. Therefore, additives based on chemical additives applied in such a way as to ensure equal performance characteristics for each region. These additives allow to increase the shelf life of the concrete mixture (the mixture remains liquid longer or does not settle), contributes to an increase in strength in the early stages of hardening, without additional air attraction.

Master Rheobuild 1000 K has used for the manufacture of cast concrete mixes with high plasticity. The superplasticizer makes it possible to obtain highly mobile concrete mixtures, reduce labor costs for processing and laying concrete reduces the amount of water in the concrete mixture, increases the degree of cement reaction, strength and durability of concrete products. It has recommended for concreting foundations, walls, ceilings, floors, screeds, paving slabs, cinder blocks, etc. This makes it possible to obtain cast concrete mixtures without delamination and separation of water. The composition of the additive is adapted to domestic aggregates and cements. (Lesovik et al., 2014; Morozova et al., 2018).

The mechanism of action of Master Rheobuild 1000 K and the distribution of raw material particles by size is shown in Figure 1.

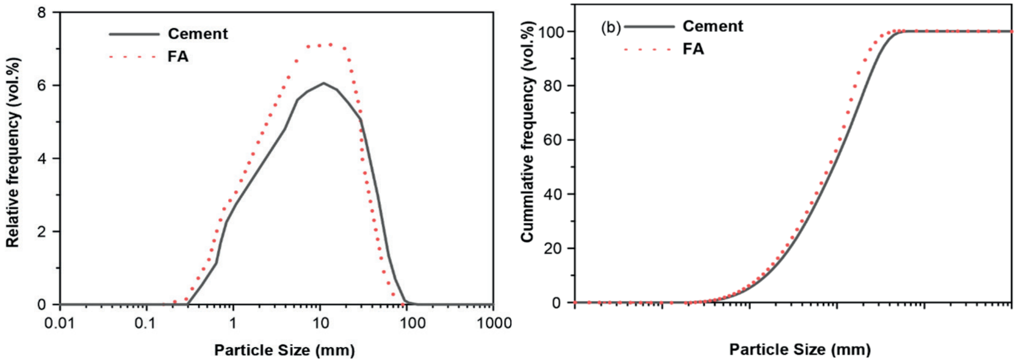

Figure 1. Particle size distribution of raw materials, (a) frequency distribution and (b) cumulative distribution

The main effect of “Master Rheobuild 1000 K” is that “plasticization is achieved by the action of a complex of multifunctional polymers with hydrophobic and hydrophilic surface-active properties that change the wetting of cement particles, thereby increasing the spreadability and subsequently the strength of concrete” (Perfilov, 2021; Tolypina et al., 2010).

Additional advantages of this additive has revealed: significantly saves cement; increases the workability of concrete and mortar mixtures from P1 to P5; increases the early (by 10-25%) and average (by 10-20%) strength of concrete (with constant workability); reduces the water consumption of concrete-mortar mixture by 10-20%; allows you to obtain mobile mixtures, stacked vibration-free; increases the survivability of the concrete mix up to 1.5-2 hours, depending on the quality of the materials used, the conditions of manufacture and transportation of the concrete mix; this makes it possible to obtain highly mobile concrete mixtures without delamination and slowing down the hardening of concrete in the early stages; increases the activity of the binder and the completeness of hydration due to the peptizing effect of the additive; increases durability by 2-3 times; prevents the appearance of cracks" (Gusenkov, 2009; Lukuttsova et al., 2010; Lukuttsova et al., 2018).

Results and discussion. A super plasticizing and super water-soluble additive has used - Master Air 200, designed for the production of high-quality concrete mixes and the production of concretes with high performance characteristics. Technical characteristics of Master Air 200: - base aqueous compositions of modified polycarboxylate esters.

Master Air 200 has used dissolved in water or added simultaneously with the addition of water to the mixture directly into the mixer. The introduction of a plasticizer into a dry concrete mix after the addition of water is unacceptable. In order to obtain a homogeneous structure of the concrete mixture, its mixing has carried out for at least 60 seconds.

The compositions of concrete mixtures of batches 1-6 are presented in Table 1.

Table 1. Composition of the concrete mix

Batch №	1	2	3	4	5
Unit of measurement, kg/m^3					
Cement	629	666	641	625	621
Kapchagai Sand	1258	-	-	1250 (фр. 0,315-0,63)	-
Crushed sand from zeolite	-	-	1283	-	-
Water	314	333	321	312	310
W/C	0,5	0,5	0,5	0,5	0,5
Density of concrete mix, kg/m^3	2201	2332	2245	2187	2172

Crushed sand has a high-water absorption (Volzhensky et al., 1989; Volodchenko et al., 2015; Wałach et al., 2019; Yin et al., 2011) due to the rough surface and cracks in the grain, as a result of which the concrete mixture on crushed sand is more rigid than on natural sands, the mobility of the concrete mixture decreases sharply compared to the mobility of mixtures on natural sands, the data are given in Table 2. Processing of the results of thermogravimetric analysis presented calculations of the mass loss of the sample of the studied zeolite rocks show that the removal of the main part of the zeolite water proceeds intensively in rocks up to 500-600^{0}C (Fig. 2).

Table 2. Concrete strength

Age of samples	Batch №				
	1	2	3	4	5
Compressive strength, R_{cs}, MPa					
7 day	30,3	30,3	40,8		

14 day	46	42,5	49,5		
28 day	47,8	47,2	51,5	51,5	52,9
120	53,1	52,4	57,2		
Bending strength, R_{bs}, MPa					
28 day				79,69	70,31

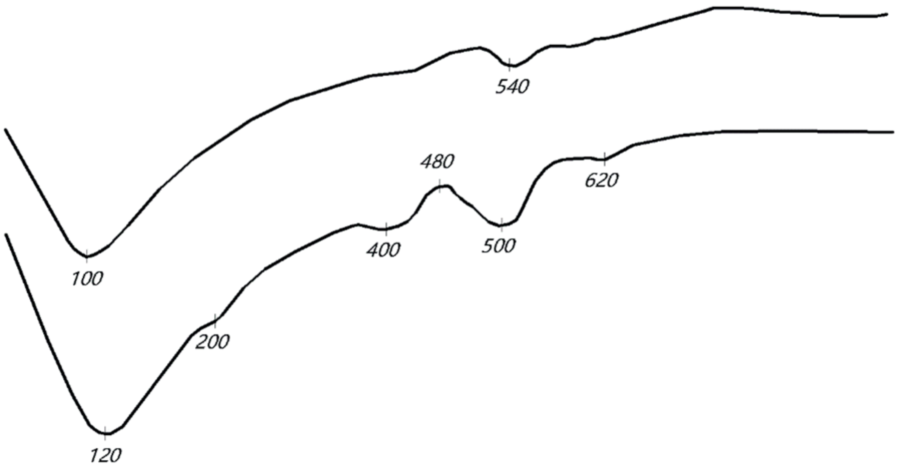

Figure 2. Curves of differential thermal analysis of zeolite rocks

Figure 3 shows the curves of differential thermal analysis of the studied rocks. Thermograms of zeolite rocks in the temperature range of 20-700^{0}C have a deep endothermic effect characteristic of clinoptilolite, corresponding to continuous processes of mineral dehydration, with a maximum at 100^{0}C, and the DTA curve in the area of this effect is smooth. Zeolite is dehydrated by 60% when heated to 300^{0}C, and at 700^{0}C it is almost completely dehydrated.

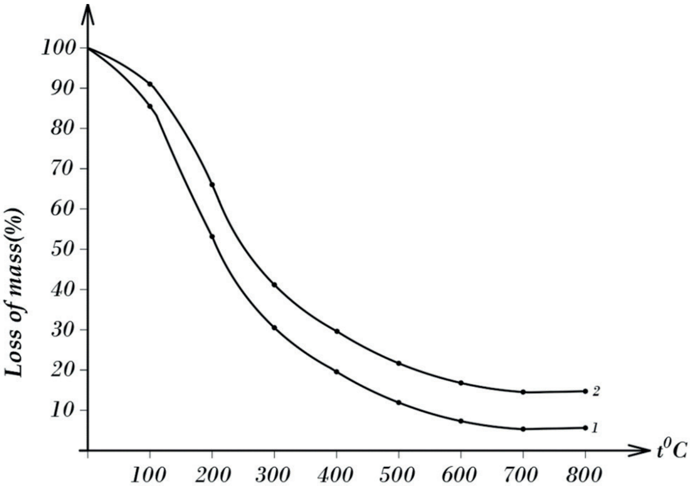

Figure 3. Mass loss of zeolite rocks during heating

In practice, the strength of concrete has reduced by using smaller fractions of sand as a filler. An increase in the strength of concrete made on sand of the 1.25-2.5 mm fraction has observed by 15%, on sand of the 2.5-5 mm fraction - by 30%, on crushed zeolite – by 40%, compared with the strength of concrete on the 0.63-1.25 mm fraction. Thus, one of the conditions for high strength of fine-grained concrete is the size of the grains of sand, consequently - an increase in the size of sand leads to an increase in the strength of fine-grained concrete.

The contact zone of the aggregate with the cement stone has examined using an electronic scanning desktop microscope JEOL 6000 at magnification from 20 to 1500 times.

The ratio of the size of the image on the monitor to the size of the growth on the sample determines the magnification of the microscope. The creation of a stable image of dielectric objects in the "low vacuum" mode has ensured by the intake of air into the sample chamber, because of which non-conductive objects can be observe without prior spraying of a conductive coating.

Microscopic examination of concrete samples on natural sands after strength testing shows that in most cases destruction occurs along the contact zone of aggregate – cement stone, as a result of which the grains of sand break out of the "nests" in the cement stone.

The contacts between the grains of natural aggregate and cement stone are mostly uneven, dense and strong, new formations of calcium oxide hydrate are visible. In some areas of the contact zone, there is insufficient adhesion of grains of sand with cement stone in the form of a narrow intermittent or continuous strip (Shadykanov, 2019). The effect of Master Rheobuild 1000 K and Master Air 200 on the compressive strength of cement dough are shown in Figure 4.

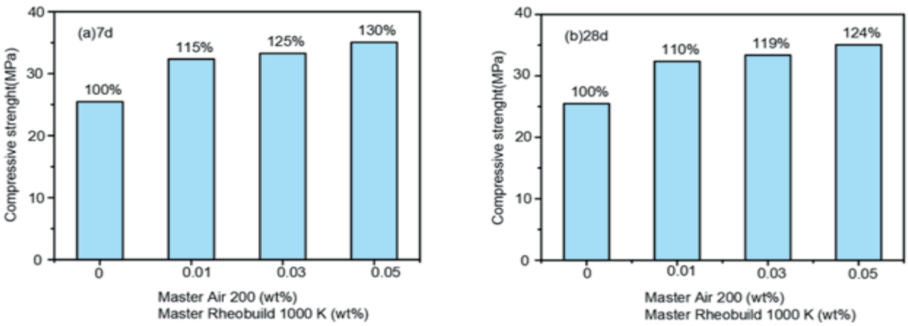

Figure 4. Compressive strength of cement dough at (a) 7 d and (b) 28 d.

The contacts of cement stone with grains of crushed sand from granites are good, dense. Cement stone penetrates into the irregularities of the grains of sand. Data on the composition of the concrete mixture is given in Table 3. The results of strength tests of samples are presented in Table 4.

Table 3. Composition of the concrete mix

Batch №	1	2	3	4	5
	C:S =1:1	C:S=1:2	C:S =1:3	C:S =1:1,5	C:S =1:2,5
Unit of measurement, kg/m^3					
Cement	1188	1188	1188	1188	1188
Kapchagai Sand	1188	2376	3564	1782	2970
Water	500	650	900	575	775
W/C	0,42	0,547	0,757	0,484	0,652
Density of concrete mix, kg/m^3	2143	2157	2128	2150	2150
Spread out on the shaking table, cm	20	21	21	20,5	21

Table 4. Concrete strength

Age of samples	Batch №				
	1	2	3	4	5
Compressive strength, R_{cs}, MPa					
7 day	40,2	33,5	14,7	36,9	24,1
14 day	51,6	40,2	23,6	45,9	31,9
28 day	56,7	42,5	27,1	49,6	34,8

Conclusion. Thanks to the use of fine aggregates like sand and zeolite, the uniformity of concrete increases. The above-mentioned high values up to 57.2 MPa of strength were achieved by increasing the uniformity, density of the material, by reducing the intermediate zone between the cement stone (matrix) and the filler, the number of voids was minimized, and the water-cement ratio was reduced. In addition, to improve the quality of fine-grained concrete, it is necessary to use Master Rheobuild 1000 K and Master Air 200 additives both to ensure mobility and reduce the amount of water. Replacing a large aggregate with sand reduces the size of microcracks in concrete, thereby increasing the compressive and tensile strength of concrete. Similarly, it became possible to use crushed sands from high-strength rocks as zeolite.

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ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Директор отдела издания научных журналов НАН РК *А. Ботанқызы*
Заместитель директор отдела издания научных журналов НАН РК *Р. Жәлиқызы*
Редакторы: *М.С. Ахметова, Д.С. Аленов*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 25.07.2022.
Формат 70x90$^{1}/_{16}$. Бумага офсетная. Печать – ризограф.
15,5 п.л. Тираж 300. Заказ 4.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-19