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ҚАЙЫРЫМДЫЛЫҚ ҚОРЫ
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«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

# ХАБАРЛАРЫ

# ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

# NEWS

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*NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.*

*Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.*

*НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.*

**ЧФ «ХАЛЫҚ»**

В 2016 году для развития и улучшения качества жизни казахстанцев был создан частный Благотворительный фонд «Халык». За годы своей деятельности на реализацию благотворительных проектов в областях образования и науки, социальной защиты, культуры, здравоохранения и спорта, Фонд выделил более 45 миллиардов тенге.

Особое внимание Благотворительный фонд «Халык» уделяет образовательным программам, считая это направление одним из ключевых в своей деятельности. Оказывая поддержку отечественному образованию, Фонд вносит свой посильный вклад в развитие качественного образования в Казахстане. Тем самым способствуя росту числа людей, способных менять жизнь в стране к лучшему – профессионалов в различных сферах, потенциальных лидеров и «великих умов». Одной из значимых инициатив фонда «Халык» в образовательной сфере стал проект Ozgeris powered by Halyk Fund – первый в стране бизнес-инкубатор для учащихся 9-11 классов, который помогает развивать необходимые в современном мире предпринимательские навыки. Так, на содействие малому бизнесу школьников было выделено более 200 грантов. Для поддержки талантливых и мотивированных детей Фонд неоднократно выделял гранты на обучение в Международной школе «Мирас» и в Astana IT University, а также помог казахстанским школьникам принять участие в престижном конкурсе «USTEM Robotics» в США. Авторские работы в рамках проекта «Тәлімгер», которому Фонд оказал поддержку, легли в основу учебной программы, учебников и учебно-методических книг по предмету «Основы предпринимательства и бизнеса», преподаваемого в 10-11 классах казахстанских школ и колледжей.

Помимо помощи школьникам, учащимся колледжей и студентам Фонд считает важным внести свой вклад в повышение квалификации педагогов, совершенствование их знаний и навыков, поскольку именно они являются проводниками знаний будущих поколений казахстанцев. При поддержке Фонда «Халык» в южной столице был организован ежегодный городской конкурс педагогов «Almaty Digital Ustaz.

Важной инициативой стал реализуемый проект по обучению основам финансовой грамотности преподавателей из восьми областей Казахстана, что должно оказать существенное влияние на воспитание финансовой грамотности и предпринимательского мышления у нового поколения граждан страны.

Необходимую помощь Фонд «Халык» оказывает и тем, кто особенно остро в ней нуждается. В рамках социальной защиты населения активно проводится работа по поддержке детей, оставшихся без родителей, детей и взрослых из социально уязвимых слоев населения, людей с ограниченными возможностями, а также обеспечению нуждающихся социальным жильем, строительству социально важных объектов, таких как детские сады, детские площадки и физкультурно-оздоровительные комплексы.

В копилку добрых дел Фонда «Халык» можно добавить оказание помощи детскому спорту, куда относится поддержка в развитии детского футбола и карате в нашей стране. Жизненно важную помощь Благотворительный фонд «Халык» оказал нашим соотечественникам во время недавней пандемии COVID-19. Тогда, в разгар тяжелой борьбы с коронавирусной инфекцией Фонд выделил свыше 11 миллиардов тенге на приобретение необходимого медицинского оборудования и дорогостоящих медицинских препаратов, автомобилей скорой медицинской помощи и средств защиты, адресную материальную помощь социально уязвимым слоям населения и денежные выплаты медицинским работникам.

В 2023 году наряду с другими проектами, нацеленными на повышение благосостояния казахстанских граждан Фонд решил уделить особое внимание науке, поскольку она является частью общественной культуры, а уровень ее развития определяет уровень развития государства.

Поддержка Фондом выпуска журналов Национальной Академии наук Республики Казахстан, которые входят в международные фонды Scopus и Wos и в которых публикуются статьи отечественных ученых, докторантов и магистрантов, а также научных сотрудников высших учебных заведений и научно-исследовательских институтов нашей страны является не менее значимым вкладом Фонда в развитие казахстанского общества.

**С уважением,**
**Благотворительный Фонд «Халык»!**

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# STUDY OF THE INFLUENCE OF TECHNOLOGICAL FACTORS ON THE DENSITY AND STRENGTH OF ASH-GAS CONCRETE

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**Abstract.** *Study purpose* is to establish influence of technological factors of production on density and strength of ash-gas concrete. *Study object* is ash-gas concrete with density of 700, 800 and 900 kg/m$^3$ based on Portland cement CEM I 42.5 D0 and fly ash from Ekibastuz GRES-2. *Research methodology***.** Composition of ash-gas concretes with average density of 700, 800 and 900 kg/m$^3$ was developed in accordance with technical requirements of SN 277–80. Instructions for manufacture of products from cellular concrete. Dry mixtures with specific surface area of about 450 m$^2$/kg are obtained by joint grinding of ash and cement (with addition of 3...5 % gypsum). Grinding was carried out in a NOAH NQM-0.4 PLANETARY BALL MILL manufactured by YANGZHOU NUOYA MACHINERY CD., LTD.

Solution mixture was prepared as follows:

• in working capacity of mixer with a speed of 410 rpm was poured up to 95 % of required amount of water, then mixer impeller was turned on, after which ash, cement and bassanite (semi-aqueous gypsum) were sequentially fed;

• mixture was stirred for 3–4 minutes, and then, without stopping, required amount of aqueous suspension of aluminum powder was introduced, after which mixture was additionally stirred for 1–2 minutes.

In the work, influence of such technological factors as grinding, composition, water temperature and water-solid ratio on density and strength of gas-ash cement was studied. Influence of technological factors on density and strength of ash-gas concrete was studied on the base composition. It has been established that technological factors of production, such as dispersion and composition of mixture, water-to-solid ratio and mixing water temperatures, have a significant impact on density and strength of ash-gas concrete, therefore, optimization of these factors makes it possible to obtain ash-gas concrete with a given density and strength. *Novelty* lies in establishment of regular features of influence, depending on type of technological factors, on density and strength of ash-gas concrete with average density. *Practical significance* lies in production of ash-gas concretes with given density and strength by adjusting parameters of technological factors.

**Keywords:** *fly ash concrete, strength, density, dispersion composition, water-to-solid ratio, temperature*

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## ЗОЛОГАЗОБЕТОННЫҢ ТЫҒЫЗДЫҒЫ МЕН БЕРІКТІГІНЕ ТЕХНОЛОГИЯЛЫҚ ФАКТОРЛАРЫНЫҢ ӘСЕРІН ЗЕРТТЕУ

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**Аннотация.** *Зерттеудің мақсаты* — өндірістің технологиялық факторларының зологазобетонның тығыздығы мен беріктігіне әсерін анықтау. *Зерттеу* *нысаны* — тығыздығы 700, 800 және 900 кг/м3 Зологазобетон, ЦЕМ I 42,5 ДО ПОРТЛАНДЦЕМЕНТІ және Екібастұз ГРЭС-2 күлі. *Зерттеу әдістемесі.* Орташа тығыздығы 700, 800 және 900 кг/м3 зологазобетондардың құрамы СН 277-80 техникалық талаптарына сәйкес әзірленді. Ұялы бетоннан бұйымдар жасау жөніндегі Нұсқаулық. Меншікті беті шамамен 450 м2 / кг құрғақ қоспалар күл мен цементті бірге ұнтақтау арқылы алынады (3 гип 5 % гипс қоспасымен). Ұнтақтау Noah nqm-0,4 planetary BALL MILL планетарлық диірменінде, Yangzhou Nuoya MACHINERY CD өндірісінде жүзеге асырылды., LTD. Ерітінді қоспасы келесідей дайындалды:

– айналым саны 410 айн/мин Миксердің жұмыс сыйымдылығына дейін құйылды, қажетті су мөлшерінің 95 %, содан кейін араластырғыштың дөңгелегі кірді, содан кейін күл, цемент және бассанит (жартылай Сулы гипс)дәйекті түрде жеткізілді;

– қоспаны 3–4 минут араластырды, содан кейін тоқтатпай, алюминий ұнтағының суспензиясының қажетті мөлшерін енгізді, содан кейін қоспаны қосымша 1–2 минут араластырды.

Жұмыста осындай технологиялық факторлардың әсері зерттелді, мысалы: ұнтақтау, құрамы, судың температурасы және судың қатты қатынасы газ-түз цементінің тығыздығы мен беріктігіне. Зологазобетонның тығыздығы мен беріктігіне технологиялық факторлардың әсері негізгі құрамда зерттелген. Өндірістің технологиялық факторлары, мысалы: қоспаның дисперсиясы мен құрамы, судың қатты қатынасы және қақпалы судың температурасы зологазобетонның тығыздығы мен беріктігіне айтарлықтай әсер ететіні анықталды, сондықтан осы факторларды оңтайландыру берілген тығыздығы мен беріктігі бар зологазобетон алуға мүмкіндік береді. Жаңалығы-орташа тығыздықтағы зологазобетонның тығыздығы мен беріктігіне технологиялық факторлардың түріне байланысты әсер етудің табиғи ерекшеліктерін белгілеу. Практикалық маңыздылығы-технологиялық факторлардың параметрлерін реттеу арқылы берілген тығыздығы мен беріктігі бар зологиялық бетондарды алу.

**Түйін сөздер:** *зологазобетон*, беріктігі, тығыздығы, дисперсия құрамы, судың қатты қатынасы, температура

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## ИССЛЕДОВАНИЕ ВЛИЯНИЯ ТЕХНОЛОГИЧЕСКИХ ФАКТОРОВ НА ПЛОТНОСТЬ И ПРОЧНОСТЬ ЗОЛОГАЗОБЕТОНА

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**Аннотация.** *Цель исследования* — установление влияния технологических факторов производства на плотность и прочность зологазобетона. *Объект исследования* — Зологазобетон с плотностью 700, 800 и 900 кг/м$^3$ на основе портландцемента ЦЕМ I 42,5 Д0 и золы-уноса Экибастузской ГРЭС-2. *Методика исследования***.** Состав зологазобетонов со средней плотностью 700, 800 и 900 кг/м3 разработан согласно техническим требованиям СН 277–80. Инструкция по изготовлению изделий из ячеистого бетона. Сухие смеси с удельной поверхностью около 450 м$^2$/кг получены путем совместного помола золы и цемента (с добавкой 3…5 % гипса). Помол осуществляли в планетарной мельнице NOAH NQM-0,4 PLANETARY BALL MILL, производство YANGZHOU NUOYA MACHINERY CD., LTD.

Растворную смесь готовили следующим образом:

в рабочую емкость миксера с числом оборотов 410 об/мин наливали до

95 % от требуемого количества воды, затем включали крыльчатку миксера, после чего последовательно подавали золу, цемент и бассанит (полуводный гипс);

смесь перемешивали в течение 3-4 мин, а затем, не останавливая, вводили требуемое количество водной суспензии алюминиевой пудры, после чего смесь дополнительно перемешали в течение 1–2 мин.

В работе исследовано влияние таких технологических факторов, как-то: измельчение, состав, температура воды и водотвердое отношение на плотность и прочность газозолоцемента. Влияние технологических факторов на плотность и прочность зологазобетона исследовано на базовом составе. Установлено, что технологические факторы производства, такие как: дисперсность и состав смеси, водотвердое отношение и температуры воды затворения оказывают существенное влияние на плотность и прочность зологазобетона, поэтому оптимизация этих факторов позволяет получить зологазобетон с заданными плотностью и прочностью. *Новизна* заключается в установлении закономерных особенностей влияния в зависимости от вида технологических факторов на плотность и прочность зологазобетона со средней плотностью. *Практическая значимость* заключается в получении зологазобетонов с заданной плотностью и прочностью путем регулирования параметров технологических факторов.

***Ключевые слова****: зологазобетон, прочность, плотность, состав дисперсности, водотвердое отношение, температура*

**Introduction**

At present, small-piece block products from gas and foam concrete with average density of 700, 800 and 900 kg/m$^3$ are developing at a good pace in Kazakhstan. Their undeniable advantages are:

– simplicity of production technology, which predetermines possibility (with help of small and medium-sized businesses, including private entrepreneurship) to organize their production in a short time, which contributes to rapid return of capital invested in them and to satisfy population's need for these products in a timely manner;

– wide base of raw materials, including technogenic materials, including fly ash; moreover, production of cellular products based on the latter individuals can be considered the most promising; this contributes to rational distribution of mineral resources, creation of waste-free technology and solution of ecological problem of environment.

*Task of the study is* to determine effect of dispersion and composition of ash-cement mixture, water mixing temperature and water-solid ratio on strength of ash-gas concrete, which are main technological factors.

**Analysis**. One of the promising direction for utilization of fly ash is production of cellular concrete on their basis, which is due to following circumstances (Avvakumov et al., 2009: 199; Yuai Yuan et al., 2014: 448; Hu Shuguang et al., 2016:304):

• high ash content (its content in composition of cellular concrete can reach 60…70 % by weight);

• it can be used in the composition of cellular concrete either as a silica component or as a component in composition of binders;

• content admissibility of unburned carbon in its composition in a larger amount (up to 15 %), which predetermines not to enrich it - the latest expensive technology in itself (for light and heavy concrete it is considered better when the coal content in the composition of fly ash is less than 3 % by weight);

• reducing cost of production of cellular concrete and promoting environmental protection;

• production of cellular concrete with specified physical and mechanical properties and durability, due to increased activity of fly ash compared to natural silica materials.

As for cellular concrete itself, now in Kazakhstan, as already mentioned, aerated concrete with a density of 700, 800 and 900 kg / m$^3$ of non-autoclave hardening is produced in large quantities - this is the most popular product, especially for civil engineering, although products from cellular concrete produced under conditions of autoclave hardening (Zbigniew, 2014: 189; Vladimirov et al., 2022: 10; Zhumadilova et al., 2022: 7).

It follows from foregoing: availability of raw materials, low fuel and energy consumption, simplicity and organization of production, low cost, relatively high physical and mechanical properties provide ash-gas concretes with great prospects.

**Materials and methods**

**Materials**

Following materials were used as starting materials**:**

− Portland cement CEM I 42.5 D0 (according to GOST 31108–2020), production AlaCem LLP, with the following rounded phase composition, %: alite ($3CaO{\cdot}SiO_2$-$C_3S$) – 58.7; belite ($2CaO{\cdot}SiO_2$-$C_2S$) - 17.54; felite ($3CaO{\cdot}Al_2O_3$-$C_3A$) -3.11; celite ($4CaO{\cdot}Al_2O_3{\cdot}$ $Fe_2O_3$-$C_4AF$) -15.4; gypsum ($CaSO_4{\cdot}2H_2O$) - 5.3;

− fly ash from Ekibastuz GRES-2 with the following chemical-mineralogical, granulometric and physical characteristics:

• chemical composition, %: $SiO_2$ – 56,7; $Al_2O_3$ – 28,6; ($Fe_2O_3$ + FeO) – 6,4; CaO – 1,1; MgO – 0,35; $SO_3$ – 1,3; $K_2O$ – 0,03; $Na_2O$ – 0,52; pricking loss – 3,0;

• phase composition (rounded), %: mullite (3Al2O3 · SiO2) – 38; α-quartz (SiO2)-32; sillimanite (Al2O3 SiO2) – 12; hematite (Fe2O3) - 5; glass phase–10; unburned carbon–3;

• granulometric composition, %: particles up to 0.5 mm - 0.14; 0.45 mm - 2.26; 0.25 mm - 3.6; 0.1 mm - 25.8; 0.09 mm - 0.84; 0.08 mm - 12.12; 0.06 mm - 4.5; 0.05 mm - 21.46; 0.045 mm - 21.38; 0.04 mm - 7.9; at the same time, unburned carbon is mainly in the composition of large fractions, glass phases are in small fractions, minerals are evenly present in all fractions;

• basicity modulus ($CaO+MgO/SiO_2{\cdot}Al_2O_3$) – about 0.02, activity modulus (Al2O3/SiO2) is 0.5; from which it follows that this fly ash is superacid; therefore, has the least activity;

• specific surface – 290 m2/kg; true density - 20 g/cm3, bulk density - 780 kg/m3;

• specific effective activity of radionuclides – 72 Bq/kg;

• this fly ash meets technical requirements of GOST 25818–2017;

− bassanite ($CaSO_4{\cdot}0,5H_2O$) – semi-aqueous gypsum grade not less than G-4 according to GOST 125-2018; its content in the composition of ash-gas concrete varied within 3 ... 5 % by weight;

− aluminum powder according to GOST 5494-2022.

Composition of ash-gas concretes with average density of 700, 800 and 900 kg/$m^3$ was developed in accordance with the technical requirements of SN 277–80. - Instructions for the manufacture of products from cellular concrete.

**Solution preparation**

Composition of ash-gas concretes with average density of 700, 800 and 900 kg/$m^3$ was developed in accordance with the technical requirements of SN 277–80. - Instructions for the manufacture of products from cellular concrete. Dry mixtures with a specific surface area of about 450 $m^2$/kg are obtained by joint grinding of ash and cement (with the addition of 3...5 % gypsum). Grinding was carried out in a NOAH NQM-0.4 PLANETARY BALL MILL manufactured by YANGZHOU NUOYA MACHINERY CD., LTD.

Solution mixture was prepared as follows:

• in the working capacity of the mixer with a speed of 410 rpm was poured up to 95 % of the required amount of water, then the mixer impeller was turned on, after which ash, cement and bassanite (semi-aqueous gypsum) were sequentially fed;

• mixture was stirred for 3–4 minutes, and then, without stopping, required amount of aqueous suspension of aluminum powder was introduced, after which mixture was additionally stirred for 1–2 minutes.

**Sample preparation**

At the end of mixing, cellular mixture was poured into molds 10x10x10 cm in size for 30 seconds. Molds are filled with solution in one step. Filling height of mold with mortar was 9.0…9.5 cm. Molds with cellular concrete mixture are kept at pouring posts at room temperature (20…22°C) during swelling. After filling form with ash-gas-concrete mixture and its swelling, resulting "hump" is cut after 2 hours. After 3 hours, samples with mold are placed in the steam chamber and steamed according to the 3 + 8 + 3 hour mode (raising temperature to 85 ° C + isothermal exposure to this temperature + descent)

**Methods for studying physical and mechanical properties of samples**

Determination of physical and mechanical properties of cellular concrete was carried out in accordance with technical requirements of relevant standards. At the same time, compressive strength is translated through coefficient to strength of a reference sample with a size of 15x15x15 cm (GOST 10180-2012).

In the work, influence of such technological factors as grinding, composition, water temperature and water-solid ratio on density and strength of gas-ash cement was studied.

Influence of technological factors on density and strength of ash-gas concrete was studied on the base composition given in Table 1, from which it can be seen that strength of samples with average density of 700 kg/m$^3$ reaches 3.5 MPa, and with average density of 800 and 900 kg/m$^3$ - 5.1 and 7.6 MPa, respectively. These indicators confirm: samples obtained from mechanically activated ash-cement binder according to the technical requirements of GOST 25485-2019 in appearance belong to structural and heat-insulating cellular concrete, have the corresponding grade (class) - M 35 (B 2.5); M 50 (B 3.5) and M 75 (B 5.0).

Table 1 - Designed and updated basic composition of ash-gas concrete

| Specified average density | Specific surface m$^2$/kg | Composition, kg/m$^2$ | | | | | Compressive strength, MPa |
|---|---|---|---|---|---|---|---|
| | | Ash | Cement | Gypsum | Water | Powder | |
| 700 | 450 | 273 | 363 | 3,2 | 368 | 0,318 | 3,5 |
| 800 | 430 | 337 | 450 | 3,2 | 456 | 0,360 | 5,1 |
| 900 | 420 | 351 | 467 | 4,1 | 474 | 0,4 | 7,6 |

**Results and discussion.**

**Influence of grinding**

Degree of physico-chemical processes occurring during hydration of ash-cement mixture and hardening of ash-gas concrete with acquisition of certain density and strength is significantly affected by the above factors. We will consider them separately.

. Ash used, as mentioned above, is super-acid, therefore, inactive. One way to increase its activity is to grind it separately or as part of mixtures. At the same time, specific surface of both ash and cement increases, which contributes to increase in their activity (Kuldeyev et al., 2023: 8; Kuldeyev et al., 2023: 5; Bek et al., 2022: 5).

Determination of dispersion influence of ash-cement mixture on strength of ash-gas concrete was carried out as follows.

Ash-gas concrete with average density of 700, 800 and 900 kg/m$^3$ obtained:

• without grinding original ash-cement mixture with a specific surface area of about 280 m$^2$/kg;

• with grinding of this mixture to a specific surface of 420…450 m$^2$/kg.

Results are shown in table. 2 and in Fig. 1, from which it can be seen:

• that samples strength from mechanically activated binder is higher by 1.5…3.4 MPa than from non-activated binder;

• that mechanical activation of gold-cement binder has a more favorable effect on increasing strength of more dense cellular concrete than less dense - in the first case, increase in samples strength reaches 1.5 MPa, and in the second - 3.4 MPa.

Table 2 - Influence of dispersion of the ash-cement mixture on the strength of the ash-gas concrete

| Average density, kg/m$^3$ | Mixture condition | Composition, kg/m$^3$ | | | | | Compressive strength, MPa |
|---|---|---|---|---|---|---|---|
| | | Ash | Cement | Gypsum | Water | Powder | |
| 700 | without grinding | 273 | 363 | 3,2 | 368 | 0,318 | 2,0 |
| | With grinding | | | | | | 3,5 |
| 800 | without grinding | 337 | 450 | 3,2 | 456 | 0,360 | 3,1 |
| | With grinding | | | | | | 5,1 |
| 900 | without grinding | 351 | 467 | 4,1 | 474 | 0,4 | 4,2 |
| | With grinding | | | | | | 7,6 |

Based on the results obtained, influence of fineness of ash-cement mixture on strength of ash-gas concrete was obtained (Fig. 1).

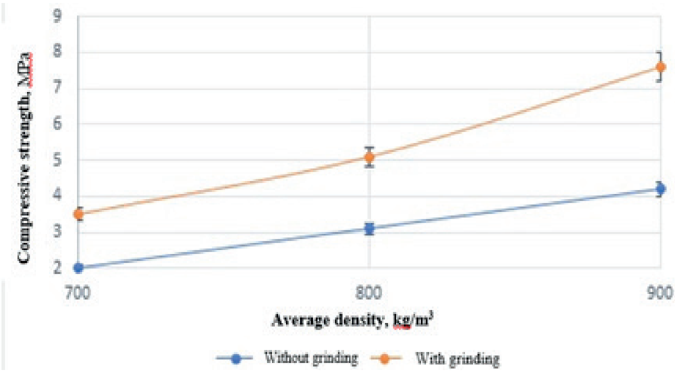


Fig.1 - Dispersion influence of ash-cement mixture on strength of ash-gas concrete

It follows from the foregoing: mechanic activation is one of the best ways to improve characteristics of ash-gas concrete, since this increases reactivity of mixture components and it is closely related to the well-known patterns of mechanic chemical processes of solids, since following physicochemical and technological factors are carried out (Kenzhina et al., 2023: 8):

• particles are dispersed, as a result of which chemical bonds in the crystalline level are broken;

• particles surface is amorphized;

• contact between particles increases, which contributes to increase in the density of their stacking;

• degree of particles with defects increases.

Mechanical activation of ash and cement particles in the hardened system interacts with water, forming cementing substances in a larger amount, which is accompanied by increase in strength of ash-gas concrete.

**Influence of composition**

Among main technological factors, composition of cellular concrete is decisive. Since its density, strength and durability mainly depend on the composition.

Table 3 and in fig. 2 shows composition effect on strength of ash-gas concrete. For each given density (700, 800 and 900 kg/m$^3$), three compositions were selected. Components content from base to lower side is reduced by 10 %, and to higher side is increased by 20 %. This combination significantly affects not only samples strength it also affects value of average density. We will show this on the example of samples with average density of 700 kg/m$^3$:

• when components are reduced by 10 % of their content in the base composition, average density decreases from 710 kg/m$^3$ to 690 kg/m$^3$, and the compressive strength from 3.5 MPa to 3.0 MPa;

• with an increase in components by 20 % of their content in base composition, average density increases from 710 kg/m$^3$ to 830 kg/m$^3$, and strength from 3.5 MPa to 4.2 MPa.

Table 3 - Composition influence of ash-gas concrete on its strength

| Target average density kg/m$^3$ | Composition, kg/m$^3$ | | | | | Average dry density, kg/m$^3$ | Compressive strength, MPa |
|---|---|---|---|---|---|---|---|
| | Ash | Cement | Gypsum | Water | Powder | | |
| 700 | 246 | 328 | 2,9 | 331 | 0,288 | 690 | 3,0 |
| | 273 | 363 | 3,2 | 368 | 0,318 | 710 | 3,5 |
| | 328 | 436 | 3,8 | 442 | 0,382 | 830 | 4,2 |
| 800 | 303 | 405 | 2,9 | 410 | 0,32 | 800 | 4,2 |
| | 337 | 450 | 3,2 | 456 | 0,360 | 815 | 5,1 |
| | 404 | 540 | 3,8 | 547 | 0,432 | 835 | 6,0 |
| 900 | 316 | 420 | 3,7 | 427 | 0,36 | 890 | 7,0 |
| | 351 | 467 | 4,1 | 474 | 0,4 | 920 | 7,6 |
| | 421 | 560 | 4,9 | 569 | 0,5 | 940 | 8,7 |

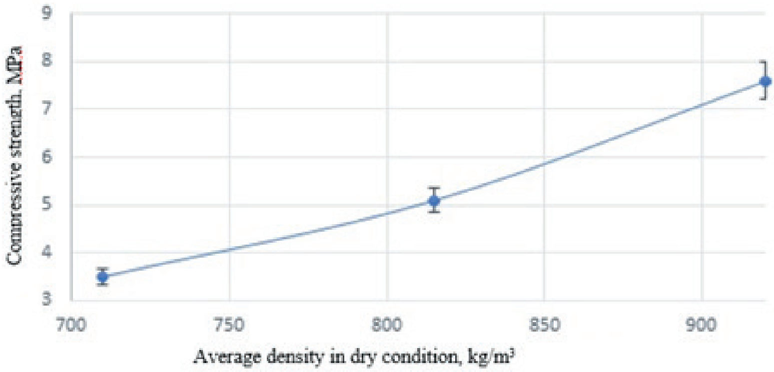


Fig. 2 - Influence of composition of ash-gas concrete on its strength

Analysis of these data shows that components content in composition of ash-gas concrete should be within no more than 10 % of specified value.

Thus, optimization regulation of composition of concrete products is one of the main methods in concrete science. This technique is especially important for cellular concrete, since it is not only necessary to monitor their strength, but also their density (Nurlybayev, 2022: 3352; Nurpeissova, 2023: 8; Utegulov et al., 2011: 3).

**Influence of water-solid ratio (W/T)**

Value of water-solid ratio plays significant role in obtaining cellular concrete with a given density and strength.

Effect of W/T on density and strength of ash-gas concrete was studied at its values of 0.52; 0.58 and 0.60. At the same time, the following changes occur in mixtures and ash-gas concretes (Table 4 and Fig. 3):

• with increase in the W/T value, as expected, mobility of mixture increases, and average density and strength decrease;

• at W/T=0.52, samples with density of 920 kg/m$^3$ become denser (980 kg/m$^3$) than samples with a density of 710 kg/m$^3$ (750 kg/m$^3$);

• at W/T=0.60, the decrease in density is greater for specimens with density 920 kg/m$^3$ than with a density of 710 kg/m$^3$.

Table 4 - Influence of water-solid ratio (W/T) on density and strength of ash-gas concrete

| Target average density kg/m$^3$ | water-solid ratio | Mass mobility according to Suttardt, sm | Average dry density, kg/m$^3$ | Dry strength, MPa |
|---|---|---|---|---|
| 700 | 0,52 | 15 | 750 | 3,9 |
| | 0,58 | 17 | 710 | 3,5 |
| | 0,60 | 20 | 690 | 3,0 |
| 800 | 0,52 | 14 | 870 | 5,9 |
| | 0,58 | 16 | 815 | 5,1 |
| | 0,60 | 17 | 785 | 4,7 |
| 900 | 0,52 | 13 | 980 | 8,3 |
| | 0,58 | 15 | 920 | 7,6 |
| | 0,60 | 16 | 881 | 7,0 |

From table 4 follows Fig. 3 - Influence of water-solid ratio (W/T) on density and strength of ash-gas concrete.

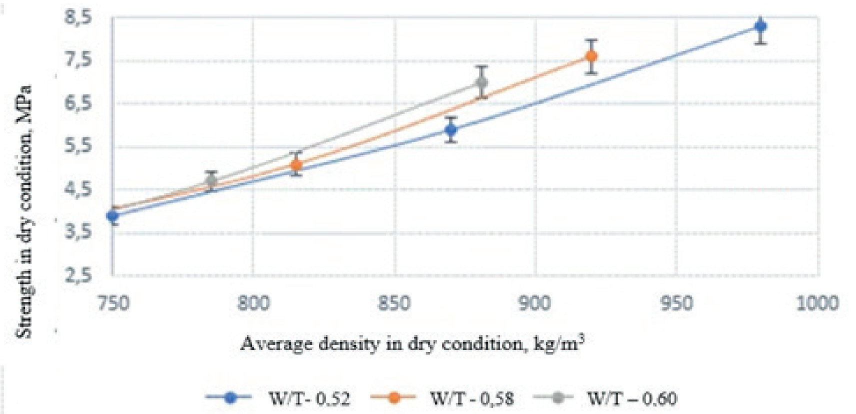


Fig. 3 - Influence of water-solid ratio (W/T) on density and strength of ash-gas concrete

As you can see, water content mixture has very sensitive effect on density and strength of ash-gas concrete:

• reducing it increases the strength of cellular concrete (of course, favorable), but at the same time increases its density, which is highly undesirable;

• increasing it reduces both the strength and density of cellular concrete, value of which does not meet technical requirements of GOST 25485-89.

**Influence of water temperature**.

Table 5 and fig. 4 shows effect of water temperature on mobility, average density and strength of ash-gas concrete, which shows:

• with increase in water temperature from 20 to 50°C, mobility of mixture decreases, and average density and strength of ash-gas concrete increases;

• with increase in the given average density of ash-gas concrete, effect of elevated temperature has positive effect on increasing its strength, which is due to an increase in the reactivity of water at elevated temperatures, which contributes to formation of more cementing substances as a result of accelerating interaction between particles of cement and ash (Patent No. 4834, 2023; Patent No. 4856, 2023).

Table 5 - Influence of mixing water temperature on mixture mobility, density and strength of ash-gas concrete

| Target average density kg/m³ | Water temperature, °C | mixture mobility, cm | Average dry density, kg/m³ | Compressive strength, MPa |
|---|---|---|---|---|
| 700 | 20 | 17 | 710 | 3,5 |
| | 35 | 15 | 715 | 3,8 |
| | 50 | 13 | 730 | 4,5 |
| 800 | 20 | 16 | 815 | 5,1 |
| | 35 | 14 | 825 | 5,9 |
| | 50 | 11 | 836 | 6,8 |

| | | | | |
|---|---|---|---|---|
| 900 | 20 | 15 | 920 | 7,6 |
| | 35 | 12 | 930 | 8,3 |
| | 50 | 10 | 939 | 9,7 |

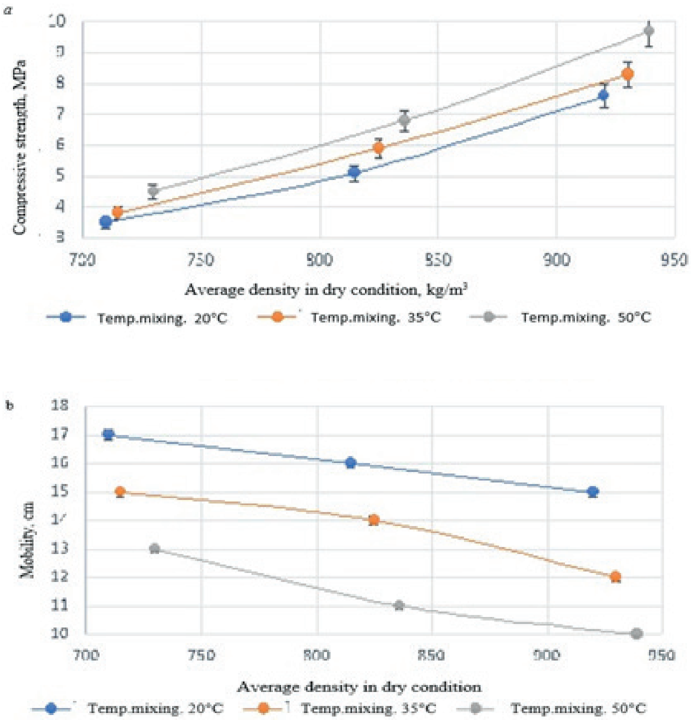


Fig. 4: *a* - Effect of mixing water Temperature on density and strength of ash-gas concrete;
b - Influence of mixing water temperature on mixture mobility

**Conclusions**

Physico-technical properties of raw materials, concrete mixtures and cellular concretes were studied using the ash of the Ekibastuz GRES-2 as a fine aggregate for sands of Kazakhstan deposits.

It has been established that technological factors of production, such as dispersion and mixture composition, water-to-solid ratio and mixing water temperatures, have significant impact on density and strength of ash-gas concrete, therefore, optimization of these factors makes it possible to obtain ash-gas concrete with a given density and strength**.**

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