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INVESTIGATION ON THE STRENGTH OF EXPANDED CLAY AGGREGATE CONCRETE SPECIMENS AFTER THERMAL EXPOSURE

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Abstract. The article describes the results of a laboratory study of the properties of expanded clay blocks. Expanded clay concrete modular blocks are used to install chimney stacks. The research aims to determine how the physical-mechanical properties of the material change when they are exposed to high temperatures. The question is raised about how much the strength of the structural material can decrease if it is exposed to higher temperatures. To broader and more objectively determine the material properties, materials with different fillers were chosen for the sample blocks. 24 expanded clay concrete blocks were formed for the study. The samples were hardened under uniform conditions in the laboratory. After the anticipated hardening time, the weight of the samples was determined, and they were weighed again after thermal exposure. Having adjusted the mass of expanded clay samples, their compressive strength properties were investigated. The research was carried out in the KUT Building Materials Laboratory following the requirements for compressive strength established in the normative documents.

After comparing the changes in the weight of expanded clay concrete sample blocks before and after thermal effects, the obtained results showed that the weight of the samples with coarse expanded clay filler and fibre decreased significantly after temperature exposure at 105 °C. After exposure of the same samples to temperatures of 300 °C and 600 °C, their mass decreased even more.

Before performing the compressive strength test of expanded clay concrete samples, all sample cubes were numbered and divided into three groups after thermal exposure. To compare the research results, control samples were separated from each group of foamed cubes with different fillings. The results of the compressive strength of the control samples were compared with the results of the thermally affected samples. The research revealed that the samples with fine-grained filler retained the highest strength after exposure to high temperatures, while the strength results of all other samples with coarse filler and coarse filler with fibre were low. The comparison of the results of the compressive strength of expanded clay concrete samples with coarse fillers suggests that the samples with fibre remained stronger after exposure to high temperature (600 °C) than the samples without additives.

To sum up the results of the laboratory test of expanded clay concrete samples, it can be assumed that their strength may decrease by up to 38 per cent when exposed to expanded clay concrete at high temperatures for a longer period.

Keywords: expanded clay concrete, blocks, thermal effects, strength

Introduction

A chimney is a structure for the exit of smoke or steam from ovens, fireplaces, fireplaces, stoves, and similar devices. For the functioning of this process, it is very important to ensure traction, i.e., continuous spontaneous air supply to the fuel. In some cases, a chimney can be a separate building.

Buildings with central heating and no wood-burning stoves usually have chimney-type structures that ensure passive ventilation of the premises. In such chimneys, self-draft is also created, which ensures air exchange in the rooms. Chimneys can be installed in buildings, part of their channels being intended for smoke and the other part for ensuring ventilation.

The main structural part of the chimney or smokestack can be assembled from expanded clay modular blocks. The installed supporting shell structure accommodates the inserts between the specially formed openings of the stack blocks. Chimney blocks are exposed to different effects of the combustion process and environmental climate.

The modern chimney is a three-layer chimney system designed for both modern solid and liquid fuel combinations, where there is an effect of exhaust gas condensation (the temperature of the exhaust gas is lower than 200 °C) and traditional heating devices for operation at high and low temperatures from 60 up to 600°C.

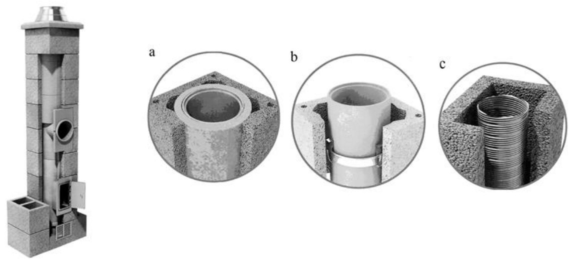

Fig. 1. Layered universal chimney system, a) a three-layer chimney system; b) a two-layer system intended for equipment with a closed combustion chamber; c) a chimney system intended for exhaust gas systems (https://www.schiedel.com/uk/commercial-chimney-systems-in-data-centres/)

The main goal of the research was to investigate the technical characteristics of expanded clay concrete and concrete with fibre filler intended for producing chimney blocks when extreme conditions typical of chimneys are created. When choosing the most sustainable building materials for structures, it is necessary to find out their physical and mechanical properties, and the most rational solution can be found by modelling the environment in which they will be used (Vaičukynienė et al., 2021). Compressive strength is the most important property of concrete because concrete can withstand great compressive stresses.

In producing heat-resistant products and structures, Portland cement is suitable as a binding material. Expanded clay aggregate of different fractions can be used as coarse and fine aggregates in heat-resistant concrete. The strength of heat-resistant concrete depends on the temperature at which the product is used. Admixtures that improve the technological properties of the products are used in simple concrete or mortar mixes. Additives can improve the micro and macro structure of hardened materials, increase the density of binders, product strength, water and frost resistance, and improve appearance.

The research subject is the formed expanded clay concrete blocks with different fractions of expanded clay and the filler of some samples supplemented with fibre. The research was carried out in the Building Materials Laboratory of Kaunas University of Technology.

The purpose of the research was to determine how the compressive strength of expanded clay cubes will change when they have been exposed to high temperatures.

The objectives were to determine the strength of expanded clay samples that were exposed to high temperatures (fine-grained, coarse-grained and coarse-grained filler with fibre were used for the claydite concrete samples) and compare the mass change of expanded clay cubes before and after heating the samples.

Research methods included an experiment and laboratory research.

Brief description of research, workflow

For the study, different concrete mixes were made with expanded clay fillers of different fractions, and fibres were added to one part of the expanded clay concrete (Židanavičius et al., 2023; Statkauskas et al., 2022). Sample blocks were made from such mixtures. A total of 24 samples of expanded clay concrete were formed: 8 units with coarse expanded clay filler, 8 units with coarse expanded clay filler and fibre, and 8 units with fine expanded clay filler. The sample blocks were hardened in an air-dry environment in metal moulds for two days. Then, they were removed and placed in a water bath, where they remained for 34 days. The cubes were immersed in water to prevent the splitting of the samples during the hardening of the concrete until it reached the design strength. In this way, the samples had the same hardening conditions. The sample blocks were hardened in an air-dry environment in metal moulds, then removed and placed in a water bath. After soaking in water at room temperature, the samples were taken out and dried.

Four mixed groups were completed by taking two formed cubes with different fillings from each group of samples. Three groups of completed samples were exposed to high temperatures of varying degrees, and the fourth group was left as control samples only to determine the strength of the control group cubes and compare the obtained data.

The volumetric dimensions of the prepared samples are 75×75×75 mm.

Fig. 2. Expanded concrete blocks made for the study

Prepared sample cubes were divided into four separate groups before compression tests. One group of samples was placed in an oven and heated at a temperature of 300 °C for one hour, another part of the samples was heated at a temperature of 600 °C for an hour, and the third part of the samples was placed in a drying cabinet and kept at a temperature of 105 °C for one day.

After cooling all test samples and weighing them, the compressive strength of the cubes was tested, and control samples that were not exposed to high temperatures were compressed to compare the results. The results of tests of crushed cubes were processed using a computer program.

The properties of expanded clay concrete have been studied by scientists at Kaunas University of Technology. Their research included a wide range of studies on the physical, mechanical, and morphological properties of the materials. The results of the compressive strength of expanded clay concrete obtained in the research conducted by the KUT researchers are similar to the results of the control samples of this study (Augonis et al., 2022).

However, this study concentrates on determining the compressive strength properties of expanded clay concrete after exposure of samples to different high temperatures.

The choice of a research method was influenced by scientific research with lightweight aggregates, including expanded clay (Augonis et al., 2022; Bumanis et al., 2022).

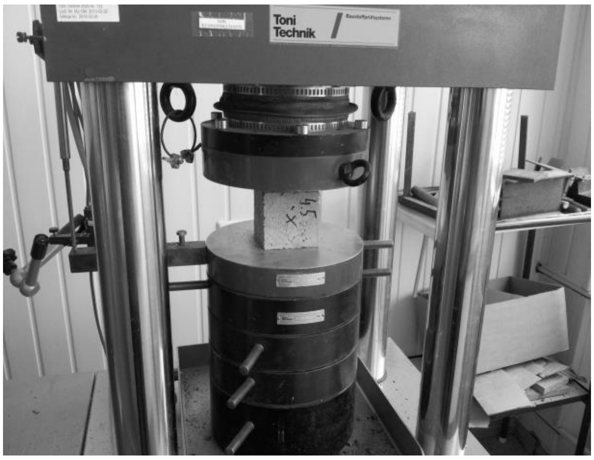

Fig. 3. Sample compression press

Materials used for samples

Cement CEM I 42.5 R was used to produce research samples. Coarse-grained expanded clay fractions of 2-8 mm and fine fractions of 0.2 mm expanded clay, fine-grained sand, water, and plasticiser Sika Visco CREEK D187W were used for the coarse aggregate mixture. One part of the coarse-grained aggregates that expanded clay concrete was supplemented with plastic fibre. All materials used met the requirements of LST EN 12620:2013.

When selecting and modelling the percentage ratio of the components of the expanded clay mixture, similar studies by other researchers were considered (Grynys et al., 2020).

Three different expanded clay mixes were produced, and the quantities of materials used and their ratios are provided in the tables (Tables 1, 2, 3).

Table 1. For the first group of samples, the amount of materials used for 8 litres of expanded clay mixture

Material	Marking	Quantity
Cement CEM I	C	3.2 kg
Coarse-grained expanded clay	K	5.12 kg
Fine-grained sand	Sm	2.448 kg
Water	V	1.535 kg
Plasticizer Sika Visco CREEK D 187 W		15 ml

Table 2. For the second group of samples, the amount of materials used for 8 litres of expanded clay mixture

Material	Marking	Quantity
Cement CEM I	C	3.2 kg
Coarse-grained expanded clay	K	5.712 kg
Fine-grained sand	Sm	2.448 kg
Water	V	1.535 kg
Plastic fibre	F_{ibra}	4.8 g
Plasticizer Sika Visco CREEK D 187 W		15 ml

Table 3. For the third group of samples, the amount of materials used for 8 litres of expanded clay mixture

Material	Marking	Quantity
Cement CEM I	C	3.2 kg
Coarse-grained expanded clay	K	3.264 kg
Fine-grained sand	Sm	4.96 kg
Water	V	1.535 kg

The prepared concrete mixture was shaken into forms and compacted by vibrating on a vibrating table. The following method of compaction of the sample cube mixture was chosen for this study (Villalon et al., 2021). All the cubes produced were hardened by changing the environmental conditions. First, the samples were cured for two days in an air-dry environment; then, they were unmoulded and placed in a water bath, remaining for 34 days. After that, the cubes were cut into samples of the same size with a circular saw. After drying the cubes at room temperature, they were weighed and numbered. Samples with coarse expanded clay concrete filler No. 1.1-1.6; samples with coarse expanded clay filler and fibre No. 2.1-2.6; samples with fine expanded clay filler No. 3.-3.6.

Determining the change in mass of the test cubes

All sample cubes with different fillers were weighed and divided into three groups before thermal exposure. Control samples were taken from each of the groups. Their strength characteristics will later be compared with other thermally treated samples. The first group of samples consisting of cubes with different fillings were placed in a heating cabinet and kept at a temperature of 105 °C for one day. Later, the samples were weighed again, and their weight change was recorded. The indicators are shown in Table 4:

Table 4. Mass change indicators of test cubes heated at 105 °C

Sample number	Mass of specimen before heating (g)	Mass of specimen after heating (g)	Exposure temperature, °C
1.5	365.00	337.7	105 °C
1.6	314.52	290.2	
2.5	382.57	350.4	
2.6	350.81	322.6	
3.5	723.38	684.8	
3.6	675.04	632.7	

After the samples were exposed to a temperature of 105 °C for a full day, the results showed that the cubes with coarse expanded clay concrete filling mass decreased on average by 7.6 per cent, the samples with expanded clay concrete and fibre filling mass decreased on average by 8.2 per cent; on average, fine-grained expanded clay samples got lighter by 5.8 per cent, and their content mass changed accordingly.

The second group of samples, which during the experiment was exposed to an even higher heating temperature of 300 °C for one hour, was also weighed after the experiment, and the change in the mass of the samples was estimated, which is shown in Table 5.

Table 5. Mass change indicators of test cubes heated at a temperature of 300 °C

Sample number	Mass of specimen before heating (g)	Mass of specimen after heating (g)	Exposure temperature, °C
1.1	362.35	334.5	300 °C
1.2	373.65	342.1	
2.1	368.80	339.0	
2.2	380.88	342.3	
3.1	672.90	619.8	
3.2	655.86	608.8	

The comparison of the results of changes in the mass of the samples after exposure to a temperature of 300 ^{0}C reveals that the cubes with a coarse expanded clay concrete filler got lighter on average by 8.1 per cent, the samples with expanded clay concrete and fibre filler got lighter on average by 9.1 per cent; samples of fine-grained expanded clay concrete lost on average 7.5 per cent of its mass.

The third group of samples was heated for one hour at an even higher temperature of 600 °C, and the change in mass of all samples was also estimated, which is shown in Table 6.

Table 6. Mass change indicators of test cubes heated at a temperature of 600 °C

Sample number	Mass of specimen before heating (g)	Mass of specimen after heating (g)	Exposure temperature, °C
1.3	376.99	338.8	600 °C
1.4	369.77	329.5	
2.3	393.07	346.6	
2.4	348.90	314.5	
3.3	657.63	589.4	
3.4	609.65	545.5	

After the samples were exposed to a temperature of 600 °C, the following results were obtained: cubes with a coarse expanded clay concrete filler got lighter on average by 10.5 per cent, samples with expanded clay concrete and fibre filler got lighter on average by 10.8 per cent; samples of fine-grained expanded clay concrete got lighter on average by 10.4 per cent.

The percentage change in mass of all sample groups after they were exposed to high temperatures is shown in Fig. 4.

Fig. 4. Changes in the mass of the samples after exposure to high temperatures: the first group of samples heated at 105 °C, the second group of samples heated at 300 °C, the third group of samples heated at 600 °C, 1) samples with coarse-grained filler, 2) samples with fibre additive, 3) samples with fine-grained filler

Results of testing the compressive strength of test cubes

At the final stage of the study, all the sample cubes were subjected to a compression test. Such a test method is used to determine the physical-mechanical properties of similar building materials (Tamošaitis et al., 2023). The compressive strength of concrete is determined following the valid standards set out in LST EN 12390-2 and LST EN 12390-3.

The sample cubes exposed to high temperatures were tested in compression, and the compression results were compared with the control results of the samples of the same aggregate type not exposed to high temperatures. The results obtained from the crushing strength tests are shown in Fig. 5.

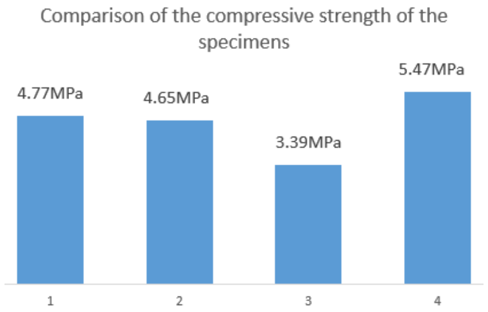

Fig. 5. Changes in the compressive strength of the samples with coarse expanded clay filler: 1) the average compressive strength of the samples after being exposed to a temperature of 105 °C; 2) the average compressive strength of the samples after being exposed to a temperature of 300 °C; 3) the average compressive strength of the samples after being exposed to a temperature of 600 °C; 4) compressive strength of control samples

The compressive examination of the expanded clay concrete samples with coarse filler showed that the more they were heated, the lower their strength. High temperatures reduced their strength even more.

The compressive strength results of the second group of expanded clay concrete samples with coarse aggregate and fibre addition are shown in Fig. 6.

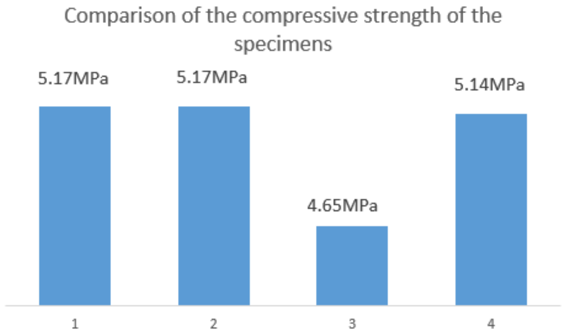

Fig. 6. Changes in the compressive strength of the samples with coarse expanded clay filler and plastic fibre: 1) the average compressive strength of the samples after being exposed to a temperature of 105 °C; 2) the average compressive strength of the samples after being exposed to a temperature of 300 °C; 3) the average compressive strength of the samples after being exposed to a temperature of 600 °C; 4) compressive strength of control samples

The compression results of the average values of the strength of expanded clay with fibre cubes did not differ much. The results obtained show that when the samples are exposed to moderately high temperatures, their strength increases slightly. However, after higher exposure to a temperature of 600 °C, the strength decreases.

The cubes of the third group of specimens with fine expanded clay filler were also exposed to high temperatures, and the averages of their compressive strength results are shown in Fig. 7.

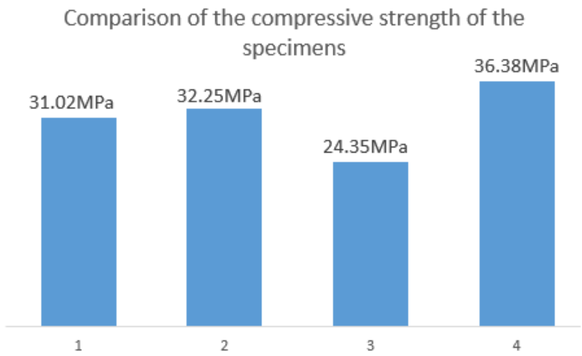

Fig. 7. Changes in the compressive strength of samples with fine-grained filler: 1) the average compressive strength of the samples after being exposed to a temperature of 105 °C; 2) the average compressive strength of the samples after being exposed to a temperature of 300 °C; 3) the average compressive strength of the samples after being exposed to a temperature of 600 °C; 4) compressive strength of control samples

The compression results show that the strength of the samples with fine-grained expanded clay fillers significantly decreased when they were exposed to a temperature of 600 °C. After exposure to lower temperatures, the performance of the samples decreased less significantly.

The study conducted was not large-scale. The formulated research objectives were associated only with the trends of possible changes in the properties of expanded clay concrete. When comparing the results of the study, statistical research methods were not employed due to the small number of available samples, and only average values of available samples were compared.

Conclusions

1. The formed expanded clay concrete cubes were weighed at the beginning, and after the thermal exposure, they were weighed again. It has been found that after heating the samples, the samples with fine-grained expanded clay filler got lighter the most. Respectively, after 105 °C temperature, they got lighter by 8.2 per cent, after 300 °C temperature by 9.1 per cent, and after a temperature of 600 °C by 10.8 per cent.
2. After researching the compressive strength of expanded clay concrete cubes, it has been found that when comparing the strength of the samples with the control samples after their exposure to a temperature of 600 °C, the samples with fine-grained filler remained the strongest. When the samples were exposed to lower temperatures (105 °C and 300 °C), the highest strength was also determined for cubes with fine-grained expanded clay fillers.
3. When determining the strength of the cubes, which was compared with the control samples, based on the obtained results, it can be stated that the temperature effect does not increase the strength of the expanded clay concrete cubes. Respectively, the strength of the cubes with coarse expanded clay filler decreased by 38 per cent, the strength of the cubes with coarse-grained filler and fibre decreased by 9.6 per cent, and the strength of samples with fine-grained filler decreased by 33 per cent.

References

1. Augonis, A., Ivanauskas, E., Bocullo, V., Kantautas, A., Vaičiukynienė, D. (2022). The influence of expanded glass and expanded clay on lightweight aggregate shotcrete properties. https://doi.org/10.3390/ma15051674
2. Židanavičius, D., Augonis, M., Adamukaitis, N., Villalon F, I. (2023). Concrete shrinkage analysis with quicklime, microfibers, and SRA admixtures. https://doi.org/10.3390/ma16052061
3. Villalon F, I., Dorosevas, V., Vaičiukyniene, D., Nizeviciene, D. (2021). The investigation of phosphogypsum specimens processed by press-forming method. https://doi.org/10.1007/s12649-020-01067-5
4. Tamošaitis, G., Vaičiukynienė, D., Jaskaudas, T., Mockiene, J., Pupeikis, D. (2023). Development of alkali-activated porous concrete composition from slag waste. https://doi.org/10.3390/ma16041360
5. Vaičiukynienė, D., Kantautas, A., Tučkutė, S., Manhanga, F., Janavičius, E., Ivanauskas, E., Rudžionis, Ž., Gaudutis, A. (2021). The using of concrete wash water from ready mixed concrete plants in cement systems. https://doi.org/10.3390/ma14102483
6. Lietuvos standartizacijos departamentas. [LST EN 12390-3:2009], Betono bandymas. 3 dalis. Bandinių stipris gniuždant. Vilnius: Lietuvos standartizacijos departamentas. https://standards.iteh.ai/catalog/standards/cen/d1d94876-958b-4941-ade0-780076fc330a/en-12390-3-2009
7. Lietuvos standartizacijos departamentas. [LST EN 12620:2013], Betono užpildai. Vilnius: Lietuvos standartizacijos departamentas. https://hdl.handle.net/20.500.12259/191629
8. Grinys, A., Augonis, A., Daukšys, M., Pupeikis, D. (2020). Mechanical properties and durability of rubberised and SBR latex modified rubberised concrete. https://doi.org/10.1016/j.conbuildmat.2020.118584
9. Bumanis, G., Vaičiukynienė, D. (2022). Lightweight porous geopolymers from waste red brick precursor and synthetic foaming admixture // Journal of physics: conference series: 5th international conference: innovative materials, structures and technologies 2022.09.28-2022.09.30 Riga, Latvia. https://epubl.ktu.edu/object/elaba:156391367/
10. Statkauskas, M., Grinys, A., Vaičiukynienė, D. (2022). Investigation of concrete shrinkage reducing additives https://doi.org/10.3390/ma15093407
11. Schiedel svetainė (n.d.). Prieiga (2023-09-20) per internetą: https://www.schiedel.com/uk/commercial-chimney-systems-in-data-centres/.com/uk/commercial-chimney-systems-in-data-centres/

KERAMZITBETONIO BANDINIŲ STIPRIO TYRIMAS PO TERMINIO POVEIKIO

Santrauka

Straipsnyje aprašomi keramzitbetonio blokelių savybių laboratorinio tyrimo rezultatai. Keramzitbetonio moduliniai blokeliai naudojami dūmtraukių kaminams įrengti. Šiuo tyrimu norėta nustatyti, kaip pakinta medžiagos fizinės-mechaninės savybės, kai jos paveikiamos aukšta temperatūra. Keliamas kausimas, kiek gali sumažėti struktūrinės medžiagos stipris, jei medžiaga bus veikiama aukštesnių temperatūrų. Platesniam ir objektyvesniam medžiagų savybių nustatymui bandinių blokeliams buvo pasirinktos medžiagos su skirtingais užpildais. Bandiniai buvo kietinami vienodomis sąlygomis laboratorijoje, o po numatyto jų kietinimo laiko nustatyta bandinių masė, vėliau po terminio poveikio jie dar kartą pasverti. Patikslinus keramzitbetonio bandinių masę, jų stiprumo savybės tiriamos gniuždant. Tyrimas buvo atliktas Kauno Technologijos universiteto statybinių medžiagų laboratorijoje laikantis stiprumo gniuždant reikalavimų nustatytų norminiuose dokumentuose. Palyginus keramzitbetonio bandinių blokelių svorio pokyčius prieš terminį poveikį ir po jo, gauti rezultatai parodė, kad bandinių su stambiu keramzito užpildu ir fibra mase labiausiai sumažėjo paveikus 105 °C temperatūra (8,2 procento). Po tų pačių bandinių poveikio 300 °C temperatūra, masė pakito 9,1 procento, o po 600 °C temperatūros poveikio, jų masė sumažėjo 10,8 procento. Prieš atliekant keramzitbetonio bandinių stiprio gniuždant tyrimą, visi bandinių kubeliai po terminio poveikio buvo sunumeruoti ir suskirstyti į tris grupes. Tyrimo rezultatų palyginimui iš kiekvienos suformuotų kubelių su skirtingais užpildais grupių buvo atskirti kontroliniai bandiniai. Kontrolinių bandinių stiprumo gniuždant rezultatai palyginti su termiškai paveiktų bandinių stiprio rezultatais. Tyrimo metu nustatyta, kad paveikus aukšta temperatūra didžiausią stiprį išlaikė bandiniai su smulkiagrūdžiu užpildu: 105 °C temperatūra – 31,02 MPa; 300 °C temperatūra – 32,25 MPa; 600 °C temperatūra – 24,35 MPa. Visų kitų bandinių su stambaus užpildo ir stambaus užpildo su fibra gauti stiprio rezultatai buvo mažesni. Palyginus keramzitbetonio bandinių su stambiais užpildais stiprio gniuždant rezultatus galima daryti prielaidą, kad bandiniai su fibra, paveikus aukšta temperatūra (600 °C) išliko stipresni. Apibendrinant gautus keramzitbetonio bandinių tyrimo rezultatus galima daryti prielaidą, kad ilgesnį laiką veikiant keramzitbetonį aukštomis temperatūromis jų stipris gali sumažėti iki 38 proc.

Reikšminiai žodžiai: keramzitbetonis, blokeliai, terminis poveikis, stipris

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