MANTECH Publications

Journal of Ceramics and Concrete Technology
Volume 7 Issue 2
ISSN: 2457-0826 (Online)

# *The Effects of Using Various Types of Porous Sands on the Properties of Expanded Clay Concrete for Structural Purposes*

***Kavita Gupta[1], Rahul Shrivastava[2]***

*Students[1], Assistant Professor[2]*

*Department of Civil Engineering*

*Maharana Pratap Engineering College, Kanpur*

***Corresponding Author's Email: -*** *kgupta1@gmail.com[1]*

***Abstract***

*The strength, water tightness, and average density of modified expanded clay lightweight on several types of sands were explored in this study. Quartz sand, expanded clay sand, and granulated foam glass sand were all utilised. It is demonstrated that structural lightweight expanded clay concrete on light sand from granular foam glass is useful for reducing the weight of thin-walled hydraulic systems. The average density of lightweight expanded clay concrete on a mixture of quartz sand and granulated foam glass was determined to be 1400-1440 kg/m3, the water tightness is W10-W12, the compressive strength is up to 21 MPa, and the tensile strength in bending is up to 5 MPa. Foam glass interstitial barriers feature an amorphous vitreous structure. The lightweight expanded clay concrete with granulated foam glass sand is weather resistant and strong enough for thin-walled constructions.*

***Keywords:*** *Water Tightness, Expanded Clay, Concrete, Foam Glass, Sand*

## INTRODUCTION

In construction, structural expanded clay concrete and other lightweight concrete on artificial porous aggregates are frequently used, including for thin-walled hydraulic structures. Expanded clay lightweight concretes are the most promising materials for floating hydraulic constructions because they provide for increased carrying capacity and durability [1]. The advancement of construction technology allows for a rise in the efficiency of expanded clay concrete as well as research into the use of current modifiers and new


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types of porous sands in their composition. Granular foam glass [2, 3] in particular is potential porous filler. This aggregate has a low average density while being essentially impermeable to water.

**Problem formulation**

The use of lightweight expanded clay concrete and light concrete equivalent to it shown that these materials are highly efficient in civil, industrial, and hydraulic engineering. The load on the foundations and supports is decreased due to the low average density of concrete. The use of lightweight concrete in bending constructions decreases the bulk of the entire load, allowing for an increase in span length. In 1999, for example, a "Stolmabridge" with a main span of 148 m was erected in Norway using lightweight concrete of class LC-55 with an average density of 1900...1950 kg/m3.

Lightweight concrete has shown to be extremely durable in the construction of oil and gas production platforms, floating docks, residences, and hotels in reinforced concrete shipbuilding. These structures are used in sulphate and chloride-containing fluids, and they are subjected to freezing and thawing [1, 5]. Furthermore, lightweight concrete increases the carrying capacity of reinforced concrete floating structures. The International Federation for Structural Concrete (fib) suggested in 1995 that floating oil and gas platforms only be built using high-strength lightweight concrete.

Lightweight concrete on ceramic aggregates with quartz sand is primarily utilised in the building of reinforced concrete floating constructions. The typical density of lightweight expanded clay concrete and its analogues ranges between 1800 and 2000 kg/m3. However, lightweight concrete, which incorporated some light sand, was recently employed for the first time for the marine floating structure tripping complex MPU Heavy Lifter. This concrete is classified as LC 35/38, and its average density is less than 1600 kg/m3.

Granulated foam glass [8] is a relatively new form of light sand for lightweight expanded clay concrete. More than 90% of the glass phase is present in foam glass. Small equally distributed tight holes separated by narrow walls characterise foam glass grains. Because this form of aggregate is almost impermeable to water, it is a potential component for light concrete of hydraulic structures, particularly floating reinforced


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concrete. Lightweight expanded clay concrete with acceptable strength and durability may be generated with a lowered average density when a reasonable proportion of granulated foam glass is used as fine aggregate.

## RESEARCH METHODOLOGY

**For the manufacture of lightweight expanded clay concrete used:**

- expanded clay gravel of a fraction of 5-10 mm produced by the Odessa expanded clay factory with a bulk density of 500 kg/m$^3$;
- sulphate-resistant Portland cement CEM I 32.5 R/SR manufactured by Ivano- Frankivsk Cement Plant;
- polycarboxylate plasticizer Coral ExpertSuid-5.

Five different types of sands were used as fine aggregate for lightweight expanded clay concrete, which were obtained by mixing different types of sands previously scattered in fractions [9]:

Composition number 1 (№1). Quartz sand with a fraction ratio (in mm): 0.16-0.315 - 10%, 0.315-0.63 - 25%, 0.63-1.25– 25%, 1.25-2.5– 25%, 2.5-5 - 15%. The bulk density of this sand was 1580 kg/m$^3$. Composition number 2 (№2). Sand in which 50% of the fractions of 2.5-5 mm and 1.25-2.5 mm (coarse fractions) were replaced with expanded clay sand of the same fractions (the producer of expanded clay sand is Odessa Expanded clay Plant).

The density of sand particles in the fraction 2.5-5 mm - 605 kg/m$^3$, in fractions 1.25- 2.5 mm - 700 kg/m$^3$. The bulk density of this artificial sand was 1430 kg/m$^3$.

Composition number 3 (№3). Sand, in which 100% of the fractions of 2.5-5 mm and 1.25-2.5 mm was replaced with expanded clay sand of the same fractions. The bulk density of this sand was 1290 kg/m$^3$.

Composition number 4 (№4). Sand, in which 50% of the fractions of 2.5-5 mm and 1.25-2.5 mm were replaced with granulated foam glass of the same fractions (foam glass manufacturer LLC «NPP Tekhnologiya», Shostka). The bulk density of granulated foam glass in the 2.5-5 mm fraction is 230 kg/m$^3$, in the 1.25-2.5 mm fraction it is 270 kg/m$^3$. The bulk density of this artificial sand was 1330 kg/m$^3$.

Composition number 5 (№5). Sand in which 100% of the fractions of 2.5-5 mm


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and 1.25-2.5 mm was replaced by granulated foam glass of the same fractions. The bulk density of this sand was 1080 kg/m$^3$.

Water absorption of expanded-clay granules per hour was about 16%, foam glass –5..6%.

Also in the concrete undergone, the amount of plasticizer Coral ExpertSuid-5 was varied in the range from 0.4 to 1% by weight of cement.

All mixtures had equal mobility P5. The amount of Portland cement in all investigated lightweight expanded clay concrete was 500 kg/m$^3$, the amount of expanded clay gravel was 675 l/m$^3$. The amount of sand in the concrete was adjusted depending on the amount of water in the mixture ranged from 460 to 470 l/m$^3$.

## RESULTS AND DISCUSSION

Equal mobility of mixtures was provided by changing the amount of water, respectively, the W/C of the mixtures depended on their composition. Figure 1 shows the graphs of the effect of the amount of Coral ExpertSuid-5 plasticizer and the type of sand on the W/C of expanded clay lightweight concrete mixtures. Analysis of the graphs shows that with an increase in the amount of the plasticizer Coral ExpertSuid-5 from 0.4 to 0.6% of the W/C mixtures on all types of sand, it sharply decreases – by 11-13%. A further increase in the amount of plasticizer also reduces the W/C of the mixture, but less significantly.

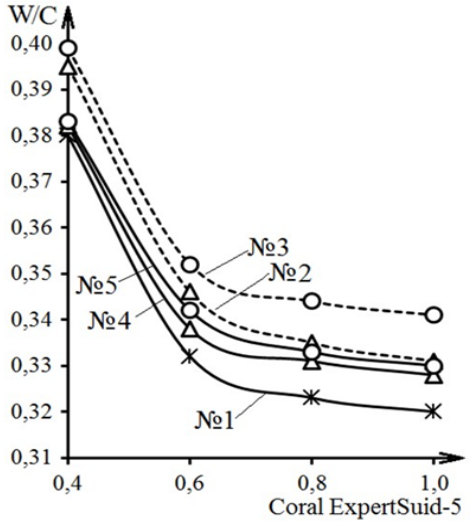



***Figure 1. The influence of the amount of plasticizer and the type of sand on the W/C expanded clay lightweight concrete mixtures of equal mobility***


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The smallest W/C are in mixtures on quartz sand (№ 1), the largest in expanded clay sand (№2, №3). Accordingly, when replacing 100% of the large fractions of quartz sand with light porous sand, the W/C grows more significantly than when replacing 50% of the fractions volume.

Mixes with fine aggregate of granulated foam glass (№4, №5) have higher-grade aggregate with higher amounts of silica sand, but lower than lightweight expanded clay concrete mixes with expanded clay sand. This results from the fact that the granulated foam glass has mainly closed porosity, respectively low water absorption.

Figure 2 shows graphs of the effect of the amount of plasticizer and the type of sand on the strength of the lightweight expanded clay concrete was studied. Analysis of the graphs shows that the amount of plasticizer Coral ExpertSuid-5 significantly affects the strength of expanded clay concrete under compression (Figure 2, a), but less significantly on the tensile strength under bending (Figure 2, b). The strongest are lightweight expanded clay concrete with the amount of plasticizer Coral ExpertSuid-5 0.8% by weight of cement.

The type of sand has a more noticeable effect on the compressive strength of lightweight expanded clay concrete than on the tensile strength in bending.

Compressive strength of light concrete with expanded clay sand in large fractions (№ 2, №3) is 3-10% lower than the strength of expanded clay concrete with quartz sand (№1). The tensile strength in bending of expanded clay lightweight concrete data is 4-9% lower than the strength of expanded clay concrete with quartz sand.

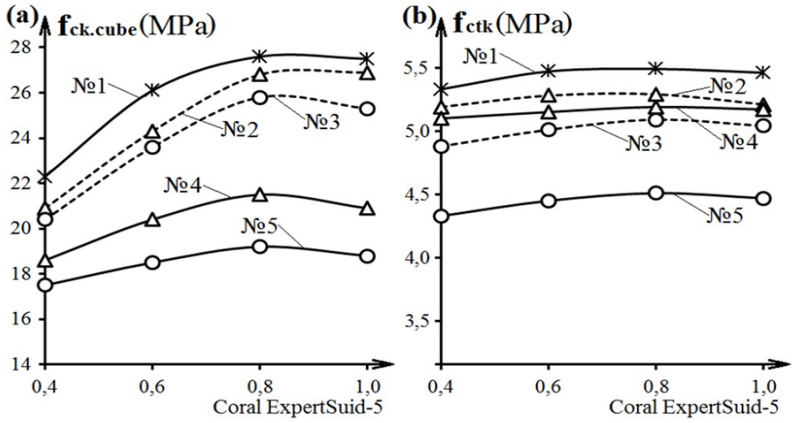



***Figure 2. The effect of the amount of plasticizer and the type of sand on the strength of expanded clay lightweight concrete: a) in compression; b) tension in bending.***


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During the use of granulated foam glass as a fine aggregate (№4, №5), the strength of lightweight expanded clay concrete under compression decreases by 17-32% compared to concrete on quartz sand (№ 1), and the tension in bending increases by 5-19%.

One of the most important quality indicators for concrete hydraulic structures is water tightness. It largely determines the durability of the material in thin-walled structures that are operated in contact with water. Accordingly, in the framework of this work, the water tightness of lightweight expanded clay concrete was investigated. Figure 3 shows the effect of the amount of plasticizer and the type of sand on the water tightness of the expanded clay concrete was studied.

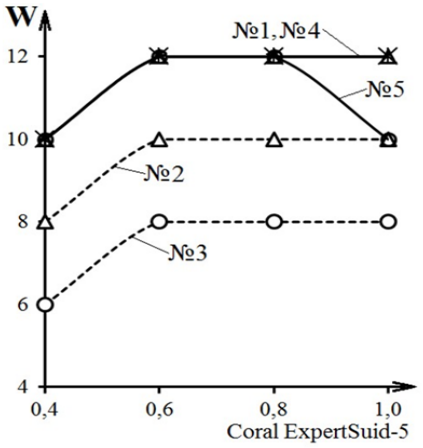



***Figure 3.The effect of the amount of plasticizer and the type of sand on the water tightness of lightweight expanded clay concrete.***

Analysis of the graphs shows that lightweight expanded clay concrete with foamed glass in large fractions of sand (№4, №5) are water tightness at virtually the level of expanded clay concrete on quartz sand. The water tightness of lightweight concrete with expanded clay sand in large fractions, respectively, is one (for №2) and two (for №3) grades lower than similar lightweight expanded clay concrete on quartz sand. This is due to the ability of this porous sand to pass water under hydrostatic pressure. By increasing the dosage of the Coral ExpertSuid-5 additive to 0.6-1.0%, the water tightness of the lightweight expanded clay concrete is increased by about the mark. As noted above, the main purpose of the application of light sand in lightweight expanded clay concrete is to reduce their average density. The effect of the amount of plasticizer and the type of sand on the average density of expanded clay concrete is shown in Figure4.

As can be seen in the graphs, with an increase in the dosage of the plasticizer due to a decrease in the W/C of the mixture, the average density of lightweight expanded clay concrete does not significantly increase. During the application of 50% (№2) and 100% (№3)


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of expanded clay sand in large fractions, the average density of lightweight concrete decreases, respectively, from 4-5% and 6-7% compared to expanded clay concrete on quartz sand.

Sand granulated foam glass has a lower bulk density, respectively, during the application of 50% (№4) and 100% (№5) of foam glass in large fractions, the average density of lightweight expanded clay concrete decreases by 7-8% and 13-14% compared to expanded clay concrete on quartz sand (№1).At the same time, the average density of lightweight expanded clay concrete with 100% sand from granulated foam glass in large fractions (№5) does not exceed 1440 kg/m$^3$.

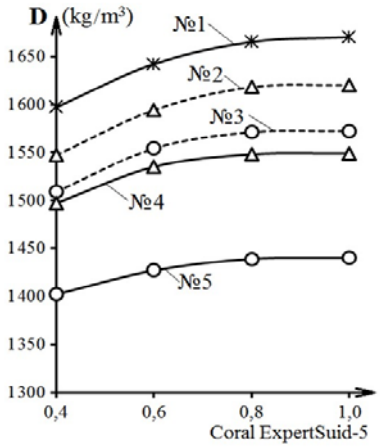



***Figure 4. The effect of the amount of plasticizer and the type of sand on the average density of lightweight expanded clay concrete***

Figure 5 shows the photographs of the structure of the contact zone of the granules of foam glass and the cement-sand matrix, taken with an electron microscope at 5000×1 magnification. Interstitial partitions of foam glass have an amorphous vitreous structure, respectively, in the photo they look like solid.

As a conclusion, the cement-sand matrix has close contact with the foam glass granules, which is explained, in particular, by the low water absorption of these granules and, accordingly, by small deformations of the aggregate during wetting and drying.

The above features of the structure of expanded clay concrete with granulated foam glass as part of fine aggregate explain the high water tightness of these materials at their low density and confirm the prospects of using porous sand based on granular foam glass in lightweight concrete for thin-walled structures of hydraulic structures.


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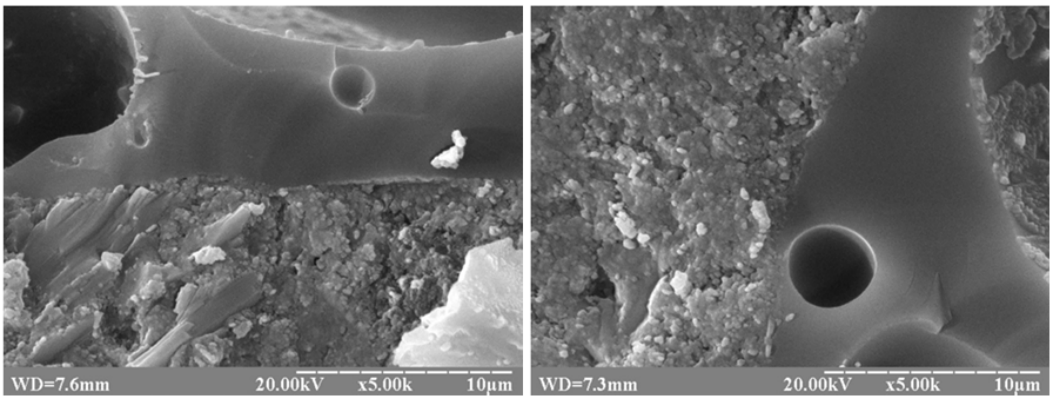



***Figure5. The structure of the contact zone of foam glass granules and cement- sand matrix, an increase of 5000×1***

## CONCLUSIONS

Modified lightweight expanded clay concrete with light sand of granulated foam glass is an excellent material for thin-walled constructions, which is vital to minimise weight while maintaining the material's required strength and high water tightness. This sort of lightweight concrete, in particular, may be utilised in reinforced concrete shipbuilding to boost the carrying capacity of floating structures.

The average density of lightweight expanded clay concrete on a mixture of quartz sand and granulated foam glass is 1400-1440 kg/m3, water tightness is W10-W12, compressive strength up to 21 MPa, tensile strength in bending up to 5 MPa. That is, lightweight expanded clay concrete with sand of granulated foam glass has a high water resistance and sufficient strength for many thin-walled structures.

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