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PROPERTIES OF STRUCTURAL LIGHTWEIGHT EXPANDED CLAY CONCRETE WITH DIFFERENT TYPES OF POROUS SANDS

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Abstract. In this work, the strength, water tightness and average density of modified expanded clay lightweight on different types of sands were investigated. Quartz sand, expanded clay sand and sand from granulated foam glass were used. It is shown that structural lightweight expanded clay concrete on light sand from granular foam glass is effective for thin-walled structures of hydraulic structures, if necessary, to reduce their weight. It was established that the average density of lightweight expanded clay concrete on a mixture of quartz sand and granulated foam glass is 1400-1440 kg/m^3, water tightness is W10-W12, compressive strength up to 21 MPa, tensile strength in bending up to 5 MPa. Interstitial partitions of foam glass have an amorphous vitreous structure. The lightweight expanded clay concrete with sand of granulated foam glass has a high-water resistance and sufficient strength for thin-walled structures.

Keywords: *concrete, density, expanded clay, foam glass, sand, water tightness.*

Introduction

Structural expanded clay concrete and other lightweight concrete on artificial porous aggregates are often used in construction, including for thin-walled structures of hydraulic structures. Expanded clay lightweight concretes are the most promising materials for floating hydraulic structures, as they allow to increase the carrying capacity of these structures and have high durability [1]. The development of building technologies makes it possible to additionally increase the efficiency of expanded clay concrete and makes relevant research on the use of modern modifiers and new types of porous sands in their composition. In particular, granular foam glass [2, 3] is a promising porous filler. This aggregate has a low average density and at the same time practically does not permeable to water.

Problem formulation

The experience of using lightweight expanded clay concrete and light concrete similar to them showed high efficiency of these materials in civil, industrial and hydraulic engineering. Due to the low average density of concrete, the load on the foundations and supports is reduced. For constructions that work in bending, the use of lightweight concrete reduces the mass of the full load, thereby allowing an increase in the length of the spans. For example, in Norway, in 1999, a "Stolmabridge" with a main span of 148 m was built from lightweight concrete of class LC-55 with an average density of 1900..1950 kg/m^3 [4].

In reinforced concrete shipbuilding, lightweight concrete has shown high durability in the construction of oil and gas production platforms, floating docks, houses and hotels. These structures are operated in waters containing sulphates and chlorides, as well as exposed to freezing and thawing [1, 5]. Also, lightweight concrete allows you to increase the carrying capacity of reinforced concrete floating structures. In 1995, the International Federation for Structural Concrete (fib) recommended using only high-strength lightweight concrete in the construction of floating oil and gas platforms [6].

For the construction of reinforced concrete floating structures mainly lightweight concrete is used on ceramic aggregates with quartz sand. The average density of such lightweight expanded clay concrete and their analogs is usually from 1800 to 2000 kg/m^3. But recently, the first time for the marine floating structure tripping complex MPU Heavy Lifter was used lightweight concrete, which included part of the light sand. The class of this concrete is LC 35/38, its average density is less than 1600 kg/m^3 [7].

One of the relatively new types of light sand for lightweight expanded clay concrete is granulated foam glass [8]. Foam glass contains more than 90% of glass phase. Foam glass granules include small evenly distributed closed pores, separated by thin partitions. This type of aggregate is practically not permeable to water, therefore it is a promising component for light concrete of hydraulic structures, including floating reinforced concrete. When using a rational amount of granulated foam glass as a fine aggregate, lightweight expanded clay concrete with sufficient strength and durability can be obtained with a reduced average density.

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 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.

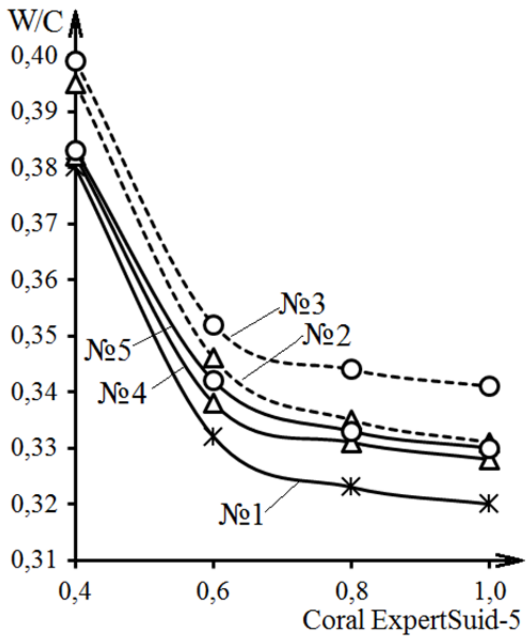

Figure 1. The influence of the amount of plasticizer and the type of sand on the W/C expanded clay lightweight concrete mixtures of equal mobility.

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.

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%.

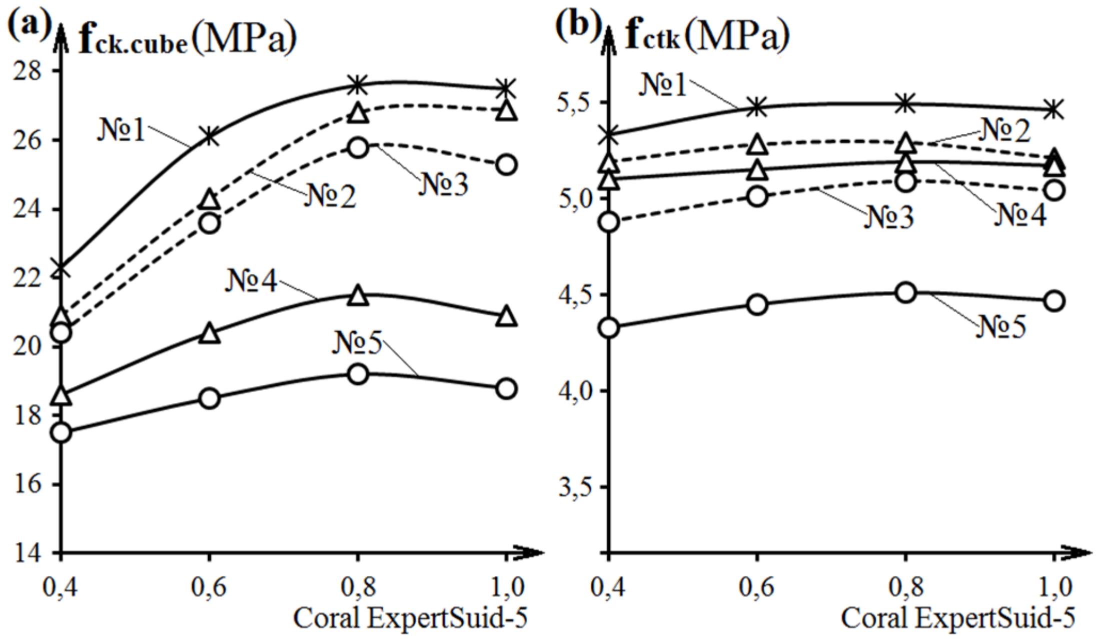

Figure 2. The effect of the amount of plasticizer and the type of sand on the strength of expanded clay lightweight concrete: a) in compression; b) tension in bending.

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.

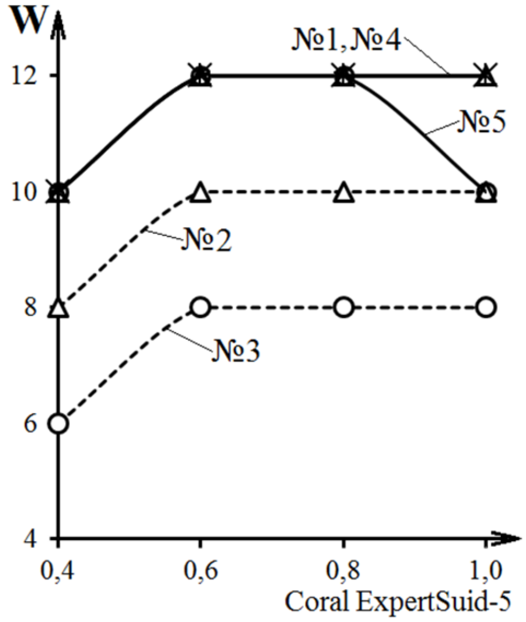

Figure 3. The effect of the amount of plasticizer and the type of sand on the water tightness of lightweight expanded clay concrete.

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 Figure 4.

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) 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.

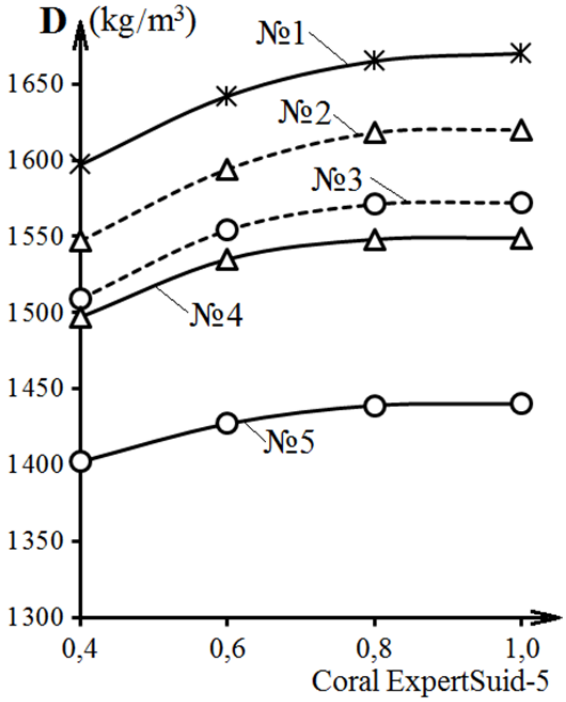

Figure 4. The effect of the amount of plasticizer and the type of sand on the average density of lightweight expanded clay concrete.

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.

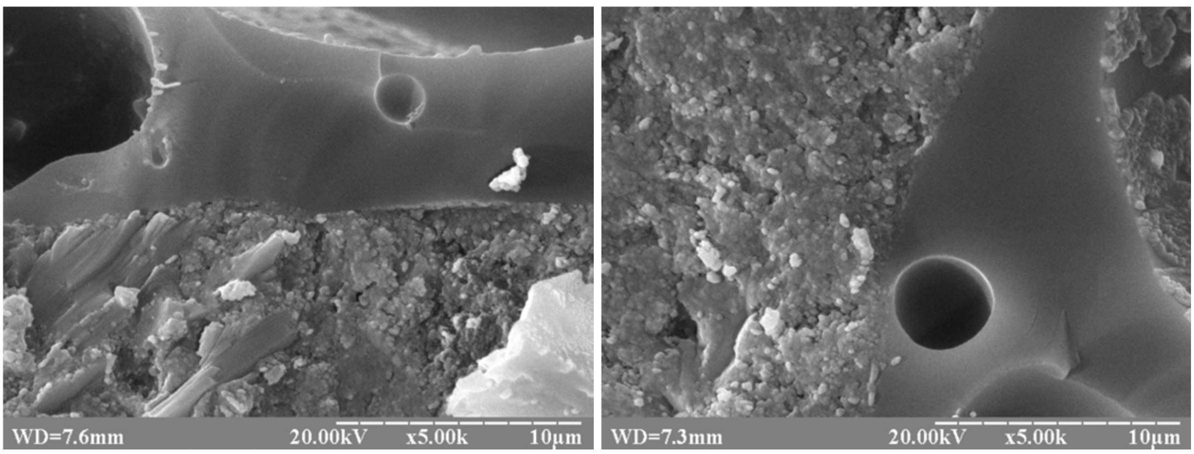

Figure5. The structure of the contact zone of foam glass granules and cement-sand matrix, an increase of 5000×1.

Conclusions

Modified lightweight expanded clay concrete with light sand of granulated foam glass is an effective material for thin-walled structures, which is important to reduce weight while providing the necessary strength and high water tightness of the material. In particular, this type of lightweight concrete can be used in reinforced concrete shipbuilding to further increase 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/m^3, 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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