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Production Technology of Modified Expanded Clay Lightweight Concrete for Floating Structures

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Abstract. Concrete ships (floating docks, hotels, houses, marinas, oil platforms) are being built in many countries around the world. For such ships previously used mainly heavy concrete. Recently, for concrete floating structures often use lightweight aggregate concrete. Using expanded clay lightweight concretes reduces the weight of the construction. At reducing the weight load lifting of the floating structure is increased. The use of lightweight concrete improves people's occupation and equipment on a reinforced concrete ship.

Influence of composition expanded clay concrete on its properties has been found. At the first stage, were investigated lightweight concrete based on the processed by hydrophobisator gravel. In the second phase were investigated concretes with silica fume. Planned three-factor experiment was conducted. Such concrete composition were varied: the amount of cement (500-600 kg/m^3), silica fume (0-50 kg/m^3) and superplasticizer S-3 (0.5-1%). Concretes were made from equal mixtures mobility P2 (4-6 cm). It is found that the compressive strength of concrete is in the range of 32 to 43 MPa. By increasing the amount of cement strength increases, but this increase is not linear type. Tensile strength of concrete was in the range of 5.6 to 7.0 MPa. Water-resistant concrete was in the range of W4 to W12. When administered to 30-35 kg/m^3 silica fume of about 2 MPa increases compressive strength expanded clay lightweight concrete and 0.3 MPa the tensile strength increases with bending. By increasing the amount of additive S-3 is significantly increased compressive strength concrete. However, the introduction of additives increases tensile strength is less when bending. Due to the introduction of the optimal amount of silica fume and S-3 water resistance of concrete is increased by about 40-50%.

Thus, the modified expanded clay lightweight concrete has a relatively low bulk density with high strength. They can be used in thin-walled construction of hydraulic structures, in particular floating docks, houses and hotels.

Keywords: shipbuilding reinforced concrete, expanded clay lightweight concrete, silica fume, plasticizer, experimental and statistical modeling.

کورته:

پاپۆڕە کۆنکریتیەکان (سەکۆکانی لێوار دەریا، ئوتێلەکان، خانووەکان، مارینەکان، پلاتفۆڕمی نەوت) هەموو پێشتر دروست کراون لە کۆنکرێتی قورس، بەڵام ئێستا ئەو پێکهاتانە لە کۆنکرێتی چەوی سوک دروست دەکرێت. بەکارهێنانی فراوانی سووکە چڕیە کۆنکرێتیەکان قورسایی پێکهاتە کۆنکرێتیەکان کەم دەکاتەوە. بە کەم کردنەوەی قورسایەکان بەرزکردنەوەی پێکهاتەکان زیاد دەکات. بەکار هێنانی کۆنکرێتی سوک دەبێتە هۆی پێشکەوتنی پیشەی خەڵک و ئەو ئامێرانەی لە کۆنکرێتی پێکهاتە شیشدا بەکار دەهێنرێ.

کاریگەری پێکهاتەکانی کۆنکریت لەسەر سیفاتەکانی دۆزراوەتەوە. لە هەنگاوی یەکەمدا پشکنین بۆ کۆنکریتە سوکەکە دەکرێت لە سەر بنچینەی شێی تێکەڵەکە. لە ڕووی دووەمدا پشکنین بۆ سلیکای کۆنکرێتەکە دەکرێت. پلانی سێ فاکتەری تەجروبەکە کرا. پێکهاتەی کۆنکرێتەکە جۆراوجۆرە: ڕێژەیچیمەنتۆ (٥٠٠ – ٦٠٠ کغم/م٣)، سلیکا (٠- ٥٠ کغم/م٣) لەگەڵ پلاستەری سوپەر س-٣ (٠،٥ – ١%). کۆنکرێت وەرگیراوە لە تێکڵاوی یەکسان پ ٢ (٤-٦ سم). دۆزراوەتەوە کە هێزی کۆنکرێت لە نێوان ٣٢ – ٤٣ مێگا پاسکاڵدایە. بە هۆی زیاد کردنی ڕێژەی چیمەنتۆ بەهێزییەکە زیاد دەکات. بەڵام ئەم زیاد کرنە هێڵی نیە. هێزی بەرگری کشان ڕێکخرا لە نێوان ٥.٦ -٧.٠ میگا پاسکاڵ. بەرگری ئاو لە نێوان ٤ -١٢ . کاتێکی بەکار هێنانی ٣٠ – ٣٥ کگم/ م٣ لە سلیکا ٢ مێگا پاسکاڵ هێزی کۆنکرێتە سوکەکە زیاد دەکات وە ٠.٣ هێزی بەرگری کشان زیاد دەکات لەگەڵ چەمانەوە. بهۆی زیاد کردنی ڕێژەی زیادەی س-٣ بە بەرچاوی هێزی کۆنکرێت زیاد دەکات. لەگەڵ ئەوەشا پێشکەش کردنی زیادەکان هێزی زیاد بوونی کشان کەم دەکاتەوە لە کاتی چەمانەوەدا. بەهۆی پێشکەش کردنی زۆرترین ڕێژەی سلیکا لەگەڵ س-٣ بەرگری ئاوی کۆنکرێت زیاد دەکات بە ڕێژەی ٤٠ – ٥٠ %.

کەواتە، گۆڕین و فراوان کردنی کۆنریتی سووک چری کەم دەکات و هێز زیاد دەکات. ئەتوانرێ بەکاربهێنرێ لە پێکهاتەی دیواری تەنکدا بۆ بیناو پێکهاتە هایدرۆلیکیەکان، بە تایبەتی لە سەکۆی ئاوی و خانوو ئوتێلدا.

الملخص:

يجري بناء سفن خرسانية (أرصفة عائمة، وفنادق، ومنازل، ومراسي، ومنصات نفطية) في العديد من البلدان في جميع أنحاء العالم. وتستخدم سابقا الخرسانة الثقيلة أساسا. في الآونة الأخيرة، للهياكل العائمة ملموسة غالبا ما تستخدم خرسانة الوزن الخفيف. باستخدام الخرسانة الطين خفيفة الوزن يقلل من وزن البناء. في الحد من رفع الوزن و رفع هيكل العائمة . استخدام الخرسانة خفيفة الوزن يحسن الاستغلال الانسب للمكان والمعدات على سفينة الخرسانة المسلحة.
تم التحقيق من الخرسانة خفيفة الوزن على أساس معالجتها من قبل الحصى. في المرحلة الثانية تم فحص الخرسانة مع الدخان السيليكا. وأجريت تجربة ثلاثة عوامل مخطط لها. وتفاوتت هذه التركيبة الخرسانية: كمية الاسمنت (500-600 كغ / م 3)، ودخان السيليكا (0-50 كغم / م 3) والملدن الفائق 1-0.5 (S-3٪). مصنوعة من الخرسانة من خليط متساوية التنقل 6-4 (P2 سم). وقد وجد أن مقاومة الانضغاط للخرسانة تتراوح بين 32 و 43 ميجا باسكال. من خلال زيادة كمية قوة الأسمنت يزيد، ولكن هذه الزيادة ليست الخطية. وكانت قوة الشد من الخرسانة في نطاق 5 ، 6 حتى 7.0 ميغاباسكال. وكانت الخرسانة المقاومة للماء في نطاق W4 إلى W12. عندما تدار إلى 30-35 كغ / m3 يزيد من قوة توسيع الخرسانة الطين خفيفة الوزن وعند 0.3 ميغاباسكال تزيد قوة الشد مع الانحناء.
وهكذا، فإن الخرسانة المعدلة خفيفة الوزن لديها كثافة منخفضة نسبيا ويمكن استخدامها في بناء الجدران الرفيعة، ولا سيما الأرصفة العائمة والمنازل والفنادق.

Introduction:

Expanded clay lightweight concrete is a well-known material. This concrete has high strength at relatively low average density. The reinforced concrete shipbuilding except heavy concrete used high-strength expanded clay concrete. Lightweight concretes reduce the weight the ship, respectively, increase its capacity. The use of lightweight concrete also helps to improve the comfort of people staying in the rooms of concrete ship.

Now used only modified concrete (heavy and lightweight) to provide the necessary mechanical properties and durability of the material constructions of floating structures. The main types of modifiers for shipbuilding concrete is a plasticizers and colmataging additives. Also, studies of many scientists show that the silica fume have an effective modifier for cement-based materials. This modifier is a waste of ferroalloy production and relatively cheap. Therefore relevant is the study of the effect of silica fume and other modifiers on properties of modified concrete shipbuilding.

Many years of experience with the shipbuilding expanded clay lightweight concrete proved its effectiveness. The first lightweight aggregate concrete tanker ship SS «Selma» was built in 1919. Casing of this ship remained satisfactorily to this day in the partially flooded state [1]. A total of 12 ships, totaling 60,000 tons were built for reinforced lightweight concrete during the First World War [2]. Mass concrete construction of ships becomes during the Second World War. During the Second World War was launched 104 concrete ships [3].

The specialists were surveyed casing lightweight aggregate concrete four ships at the age of 55 to 80 years. These surveys have shown a high durability of the material in an aggressive marine environment. Lightweight concrete has strength in range of 34 to 60 MPa, carbonation depth of 5 mm, and most designs was defects associated with impaired protective layer [4]. Lightweight aggregate structures also have high durability and good maintainability. Also lightweights concrete ships improve the safety of dry cargo [3]. This fact is due to the condensation of moisture on the lower hull of lightweight concrete as compared with metal casing.

High porous ceramic filler used for the production of concrete in the construction of floating oil platforms [5,6]. In particular, light concrete class LC-60 constructed “Heidun” floating oil platform. The platform operates in the Norwegian sector of the North Sea [7]. Concrete with porous aggregates have shown excellent durability in the harsh operating conditions in waters with sulfates and chlorides. Also concrete with porous aggregates have a high frost resistance [8].

There is a positive experience in the construction of lightweight aggregate concrete floating docks in Ukraine factory of reinforced concrete shipbuilding Kherson State Plant "Palada" (Kherson) [9] (Figure 1). In particular, the floating hotel "Baccara" was built in Kherson (Figure 2). This hotel is built on a reinforced concrete pontoon.

Figure 1: Construction technology of concrete floating structures at the Kherson State Plant "Palada" (Kherson, Ukraine).

Figure 2: Floating hotel «Bakkara» (Kyiv, Ukraine). This hotel is built in the Kherson State Plant "Palada" (Kherson, Ukraine)

Materials and methods. We used following materials: sulfate-resistant Portland cement M400, expanded clay gravel fractions 5-10 mm, quartz sand with fineness modulus 2.7, superplasticizer S-3, bridging agent Penetron Admix, silicon organic liquid 136-157M, polypropylene fiber Baucon (fiber diameter of 18.7 micron, fiber length - 12 mm) and silica fume.

Studies of the shipbuilding expanded clay concrete properties were conducted using experimental design techniques [10]. In the first stage 5-factors experiment was conducted by 27 point optimal plan [11].

The following factors had varied compositions: X_1 – sulfate-resistant Portland cement, from 400 to 600 kg/m^3; X_2 – concentration of the silicone fluid in the emulsion during processing of gravel, from 0 to 1.6%; X_3 – bridging the addition of Penetron

Admix, 0 to 2% of cement weight; X_4 – additive superplasticizer S-3, from 0.5 to 0.9% of cement weight; X_5 – polypropylene fibers Baucon, from 0 to 1.2 kg/m^3.

Hydrophobization gravel was carried out by dipping into the emulsion silicone fluid. All expanded clay lightweight concrete mixes have mobility equal 2 ± 0.5 cm.

In the second stage 3-factors experiment was conducted by 15 point optimal plan. The following factors had varied compositions: X_1 – sulfate-resistant Portland cement, from 500 to 600 kg/m^3; X_2 – silica fume, from 0 to 50 kg/m^3; X_3 – additive superplasticizer S-3, from 0.5 to 1% of cement weight. All expanded clay lightweight concrete mixes have mobility equal 3 ± 1 cm, which is almost similar to the first stage.

Results. It was found (the first stage of studies) that the introduction of Penetron Admix and fiber has little effect on the compressive strength of expanded clay lightweight concrete shipbuilding. Effect of amount of Portland cement, superplasticizer C-3 and the concentration of the silicone fluid in the processing gravel shown in Fig.3. The diagram shows that the strongest there is concrete, which was introduced in 0.7-0.8% superplasticizer S-3. Hydrophobization gravel at a concentration of 0.7-0.8% silicone fluid insignificantly increases the strength expanded clay lightweight concrete. Increasing the concentration of silicone fluids is more negatively affected by 0.8% since filler deteriorates adhesion to the matrix.

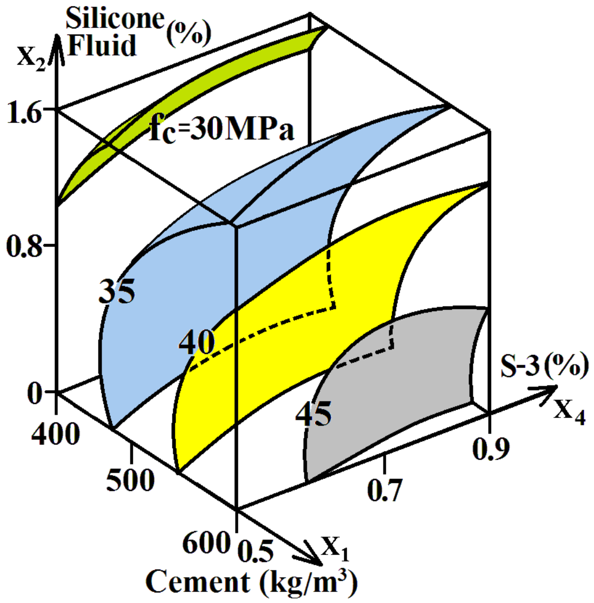

Figure 3: Effect of the amount of Portland cement, superplasticizer S-3 and the concentration of silicone fluid strength shipbuilding expanded clay lightweight concrete (the first stage experiment).

For of floating structures one of the main indicators of concretes quality is the water-resistance. In experimental statistical model diagram type "cubes on the square" is built. This diagram shows the influence of factors on the composition of the water-resistance is shown in Fig.4.The diagram shows that the amount of Portland cement is less than 500 kg/m^3 water-resistance expanded clay lightweight concrete is from W2 to W6. Such compositions may be used only in the pantoon baffles and interior of floating structures premises. Compositions with amounts of Portland cement 500 kg/m^3 at gravel processing hydrophobizator a concentration of about 0.8% are water-resistance below W6.

When the amount of cement is 600 kg/m^3, water-resistance of concrete is not less than W8. Compositions with the amount of superplasticizer S-3 0.7-0.8% have the maximum water-resistance, up to W10. The effectiveness of the introduction of additives Penetron Admix is approximately equal for all compositions. Introduction 2% Penetron Admix improves the water-resistance on approximately 2 atmospheres.

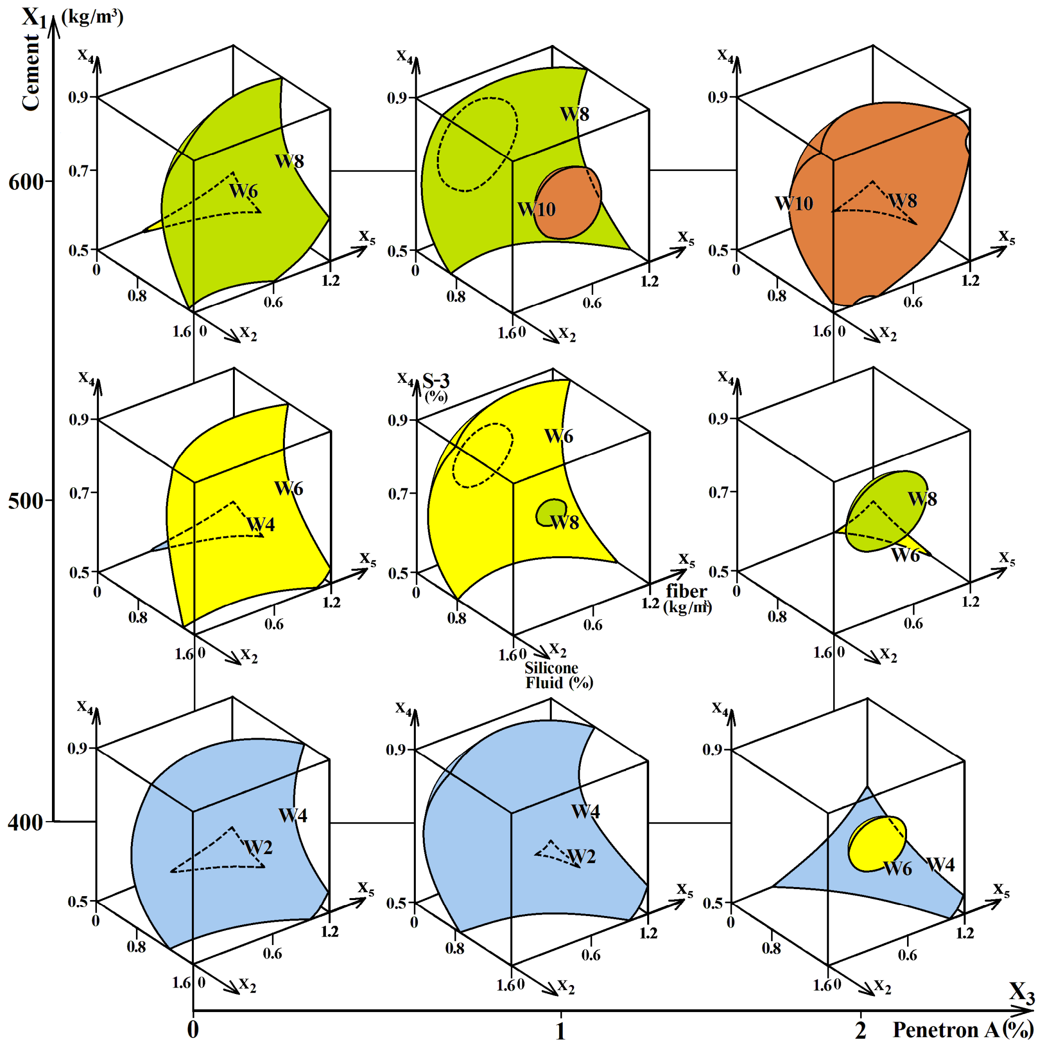

Figure 4: Influence of factors on the composition of water-resistance of the shipbuilding expanded clay lightweight concrete (the first stage experiment).

In the second phase we investigated the influence of silica fume on the properties of concrete shipbuilding. The use of silica fume is one of the promising areas for high-quality cement composite technology [12]. In particular, in the production of lightweight concrete Heidun Oil platform in its structure silica fume added in an amount of 20 kg/m^3 [7]. Silica fume reduces the volume changes in concrete, thereby reducing the number of micro-cracks [13].

The diagrams in the form of cubes were constructed in accordance with an experimental statistical models of the second phase of studies. These charts show the influence of factors on the strength of the concrete structure (Figure 5). On Figure 5.a shows the influence of factors on compressive strength of concrete, on the Figure.5.b shows the influence of factors on the strength of tensile bending.

Analysis of the diagrams shows that the composition of factors affect the compressive strength and tensile strength is similar. Compressive strength of concrete is in the range of 32 to 43 MPa, tensile strength was within the range of 5.6 to 7.0 MPa. By increasing the amount of Portland cement expanded clay lightweight concrete strength increases. Introduction of 30-35 kg/m^3 of silica fume increases the compressive strength of concrete at average of 2 MPa (5-7%) and the tensile strength of concrete increases to 0.3 MPa (6-8%). This effect is not significant, but the main goal was the introduction of silica fume increase water resistance and durability of concrete.

With increasing amount of additive S-3 to 0.8-1% by reducing the water/cement concrete compressive strength is increased by 2-2.5 MPa. However, the amount of superplasticizer has little effect on tensile strength of the concrete. Importantly, expanded clay lightweight concrete has high tensile strength compared with the heavy concrete compressive strength equal. This expanded clay lightweight concrete is effective for thin-walled structures.

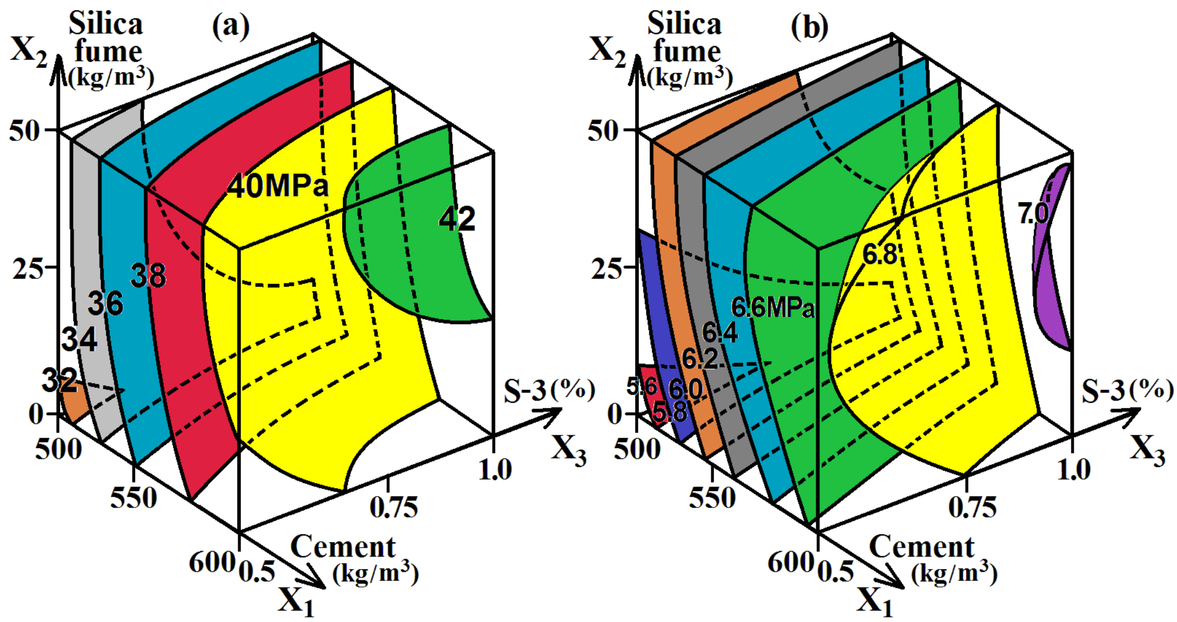

Figure 5: Influence of factors on the composition of strength shipbuilding expanded clay lightweight concrete (the second stage experiment). a) concrete compressive strength, b) tensile strength of concrete.

The second stage was also investigated water resistance of concrete. The diagram in Figure 6 shows the influence of factors on the composition of the water resistance of concrete with silica fume.

As can be seen from the diagram, the amount of Portland cement most significantly affects the level of water resistance concrete. When administered 30-35 kg/m^3 of silica fume concrete increases the water resistance of more than 2 atmosphere. By increasing the amount of superplasticizer S-3 with 0.5 to 0.9% increases the resistance of concrete almost 2 atmosphere. Maximum water resistance was higher than the W12.

On account of lightweight concrete use a reduction in the weight of concrete construction occurs. This increases load capacity of ships, including floating docks. The average density of expanded clay lightweight concrete after water saturation is from 1750 to 1900 kg/m^3. That density of concrete complies with the industry standard.

So, modified expanded clay lightweight concrete complies with Maritime Register and can be used for the construction of concrete floating structures. Optimal technological methods of manufacture and use of expanded clay lightweight concrete were developed for thin floating hydraulic structures. «Regulations on the preparation of modified shipbuilding technologies for the manufacture of thin-walled expanded clay lightweight concrete floating structures and floating docks» were developed and approved.

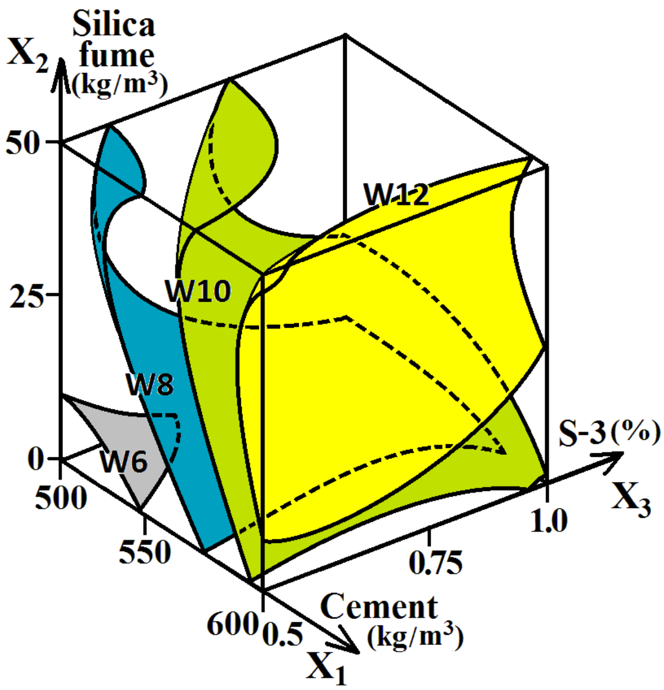

Figure 6: Influence of factors on the composition of water-resistance of the shipbuilding expanded clay lightweight concrete (the second stage experiment).

Conclusions. The compressive strength of shipbuilding expanded clay lightweight concrete is in the range of 32 to 43 MPa. Tensile strength of concrete was in the range of 5.6 to 7.0 MPa. Water resistance of modified concrete was in range of W6 to W12. So, modified expanded clay lightweight concrete complies with Maritime Register and can be used for the construction of floating docks, hotels, houses, marinas, oil platforms and other floating structures. By replacing heavy shipbuilding concrete to expanded clay lightweight concrete, increases load-carrying capacity of a ship, in particular a floating dock, and increase people's comfort and technological equipment.

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