NEW MUDFLOW– AND EARTHQUAKE – RESISTANT HYDRAULIC CONCRETE WITH MODIFIED STRUCTURE, LOW- ANIZOTROPIC HIGH STRENGTH, INVESTIGATION OF FOR POSSIBILITY OF CREATION OF INNOVATIVE NANOTECHNOLOGIES

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Be received 17.11.2016

Development of innovative technologies for hydraulic concretes of new generation, with modified structure, high strength of low anisotropy, mudflow and earthquake resistant, on the basis of resources of Southern Caucasus. Like everywhere in the world, hydraulic structures in Georgia are built using concretes which are not stable against mudflows and seismic tremors. This instability results in the wear of the surface of hydro-engineering structures, their destruction by mudflows and crushing by seismic tremors. Hence the prevention of hydraulic concrete instability by the innovative combined micro- and self(nano)-reinforcement of the concrete structure is a topical goal.

Key words: ***Micro, selfnanoreinforcement, fiber, metakaolin, clinoptiloellite, ethringite, habit, acicular, fibrous, platy.***

Introduction

In the 21st century, at the building market there has arisen the necessity to build reliable, strong and stable structures. This demanded to introduce much stricter requirements for concrete strength, earthquake resistance, crack resistance, abrasive wear resistance, stability against sulfate-containing, sea water, underground and surface waters, and mud streams [1]. Georgia is situated in the zone of mountainous relief of Southern Caucasus, where there permanently exists a high risk of occurrence of 7-9 magnitude earthquakes and mudflows. At the construction market, power generating, water-retaining, water removing, wave breaking hydraulic structures are intensively built. It is required of these structures to meet the demands of stability against all of the above-listed factors.

According to the building code, hydraulic engineering structures must be built using low-exothermic and hydraulically stable cements/concretes [2]. In Georgia, like everywhere in the world, hydraulic engineering structures are built using concretes which contain 1-20% of $[CaO, Ca(OH)_2]_{free}$ and have no resistance to mud streams and seismic tremors because in the technological area there are no hydraulic cement concretes with high wear resistance and stability against earthquake tremors. This is quite an alarming fact. Because of the action of water waves, mudflows, frost, the surface of hydraulic engineering structures may get worn out or destroyed within a short time, and in the case of earthquakes may get completely destroyed/crushed, which entails an increase of the number of human casualties by crushed concrete pieces, which took place in various countries [4]. Therefore the prevention of instability of hydraulic concrete is a topical task.

At the end of the 20^{th} century, to increase the stability of structures high performance concrete (HPC) of new generation was created by means of nanotechnologies. 1 m^3 of HPC practically contains 25-40% of Portland cement with a particle size of 20-70 mk, coaese filler (grain size is 140-25000 mk) and 5-10% of microdisperse mineral filler – a modificator with a grain size of 140 mk. Concrete is thinned (S = 15-25 sm) by a plastificator in a quantity of 0.5-1.5% of the cement mass. The strength of such concrete is 15-25 mPa in 26 h and 60-115 mPA after 28 days of hardening, non-

permeability to water is W12. Water absorption is 1-2%, wear is 0.3-0.4 cm, the structure is very dense, microporous. However the practical application revealed problems [5-9]:

- structures made of HPC are easily subjected to surface crack formation;

- HPC is very brittle and sensitive to impact and mechanical forces of various direction. In particular, intensive impacts from mud streams cause strong wear of the surface, while seismic vibrations cause cracking/destruction/crushing of concrete. Crushed concrete pieces increase the number of earthquake human victims. Therefore it is necessary to take preventive measures;

- HPC is anisotropic when its strength is measured along axes in different directions. (the strength of HPC is anisotropic). Compression strength is nearly 10 times the bending (flexural) strength and nearly 20 times the tensile strength. Therefore it is necessary to reinforce structure more intensively, which increases the reinforcement bar consumption and the construction more expensive.

The brittleness, cracking and crushing of HPC are caused by

- high exothermicity of used cement and the presence of [CaO, $Ca(OH)_2]_{free}$ in it;

- delayed formation of expansive crystalline hydrate of ettrigite suring the cement hardening;

- premature dehydration due to wind, high temperature of the environment and the use of water absorbing fillers.

The above-listed factors cause the decrease of the volume and thereby promote the appearance of tensile forces which smaller than compressive forces, which results in concrete cracking.

The brittleness of HPC intensifies with the growth of strength especially when the cement consumption is 500-600 kg / m^3 of concrete.

The main cause of HPC brittleness, surface cracking and anisotropy lies in the conglomerate property of its structural composition, incompatibility of the components and low adhesion, which is intensified by an excessive number of micropores and [CaO, $Ca(OH)_2]_{free}$ content.

Conglomeration and anisotropy and porosity caused by it are prevented by

- addition of finely dispersed natural or synthesized puzzolan, e.g., microsilica. Its grain size does not exceed

100 nm (0.1 mk) and therefore it fills up the cavities between cement particles (20-70 mk) and also decreases the CaO, $Ca(OH)_2]_{free}$ content because it bunds then into calcium dilicates;

-reinforcement with metal bars of periodic profile (d=6000-40000 mk) or with wire nets (d=1000-5000 mk), which is insufficient because during hydration 25-45% of cement contained in 1м^3 of HPC form 20-40% of crystal hydrates of micro and nano dimension. Bending, impact and rupture forces acting on concrete cause its destruction in the following succession: nano level – micro level – macro level. Hence use was made of the so-called “dispersed 3d volumetric micro reinforcement” with fiber (d=200-300 mk; L=6000-48000 mk). But the fiber itself creates problems: metal fiber is subject to corrosion, while propylene fiber has low adhesion which decreases strength.

The above facts clearly imply that the prevention of instability of hydraulic concrete to mud streams and earthquakes by the innovative combined micro- and self-nano-reinforcement of its structure is a topical and timely task including

- modification of the HPC structural composition by volumetric 3d micro reinforcement – by admixing fibers of silicate origin, e.g., basal fiber;

- modificationof the HPC structural composition by admixing puzzolans containing crystals of fibrous-acicular—platy habit, which together with [CaO, $Ca(OH)_2]_{free}$ and ethringite may form stable fiber-like reinforcing compounds. It is these compounds that which will perform the volumetric 3d self-nano-reinforcement of the concrete structure. Such concrete will resist destructive loads starting even from the nano level thereby increasing its stability.

In the case of positive solution on the project financing, the project participants will investigate the possibility of creation of an innovative technology of mudflow- and earthquake-resistant concretes of new generation, with modified structure, high strength of low anisotropy by the hypothesis: concrete modification by silicates, by grainy basalt fiber at the micro level, and by puzzolans containing platy-acicular-fibrous crystalline hydrates will lead to their braiding with crystalline hydrates of an analogous habit formed during the cement hardening and to their concentration around single fiber grains. Silicate modification means a simultaneous 3d- and self-nano-reinforcement of the concrete structure, which will diminish conglomeration, porosity, strength anisotropy, water permeability, wear, crushability, will increase the bending/compression/rupture, elasticity strength.

Selection/analysis of information, thermodynamic calculations/establishment of laws of the influence of technological factors (kind, mineral composition, quantity/conditions of components treatment) on the properties of concrete; Development of the algorithm and recipes for production of mudflow- and earthquake-resistant hydraulic concretes of new generation;

Creation of laboratory model samples of mudflow- and earthquake-resistant hydraulic concretes of new generation; Preparation of scientific articles, submission of patent applications and conference theses; presentation of recommendations on the production of stable hydraulic concretes.

To achieve the aim of the article it is planned to modify the concrete structure in order to diminish wear, to increase endurance against seismic tremors, bending and elasticity strength. The authors have worked out the innovative method of volumetric dispersed 3d reinforcement [10 - 16] which will be used for the solution of the following tasks:

1.Modification of the concrete structure by micro-reinforcement by silicate fibers. This task has two subtasks: selection of fiber (type, quantity, length); tests of the properties (compression, bending, tension, elasticity) of prepared concretes;

2. Modification of the concrete structure by self-nano-reinforcement by puzzolanas. This task has two subtasks: selection of type and quantity of puzzolana and a method of its activation; tests of the properties (compression, bending, tension, elasticity, heat release) of prepared concretes;

3. Tests of the properties of model samples of hydraulic concrete of new generation. This task has 6 subtasks: determination of heat release, water permeability, wear resistance, frost resistance, strength (bending, compression, tension) tests.

GTU personnel who will take part in the project have long-term experience in the cement and concrete technology area, they are doctors of science, authors of many published works (over 100) and patents (10), former military servicemen and participants in research under the top secret stamp.

The result of the fulfillment of the article, which belongs to the Applied Research category of new technologies development, will be the study of the possibility of producing mudflow- and earthquake-resistant hydraulic concrete of new generation on the basis of cements produced in Georgia and the existing puzzolan materials. In Georgia and everywhere in the world, hydraulic structures are built using concretes which contain 1-20% of $[CaO, Ca(OH)_2]_{free}$ and have no resistance to mud streams and seismic tremors because in the engineering area there are no hydraulic cement concretes with low wearability and stability against earthquake tremors. This is quite an alarming fact. Because of the action of water waves, mudflows, frost, the surface of hydraulic structures may get prematurely worn out or completely destroyed/crushed as a result of earthquakes, which entails an increase in the number of human casualties by crushed concrete pieces, which had already taken place in various countries [4].

Therefore the prevention of instability of hydraulic concrete by creation of mudflow- and earthquake-resistant concrete of new generation on the basis of cements produced in Georgia and the existing puzzolan materials is a topical task. In the framework of the project, an attempt will be made to produce, instead of concrete of anisotropic strength, hydraulicconcrete of less anisotropic strength, which will increase the stability and durability of hydraulic structures of any kind and

application. In the first stage the following work will be carried out: selection/analysis of information; calculation/determination of technological factors influencing the concrete properties; elaboration of an algorithm and recipes of investigated concretes of new generation; modification of the concrete structure by its micro reinforcement with fibers and selection of a fiber and tests of its properties when used in concrete. Also, on the basis of the obtained results, 2 scientific articles and 1 summary report for an international conference will be prepared. In the 2nd stage, work on the modification of concrete by self nano reinforcement by puzzolans will be carried out, including selection of puzzolan type and quantity and the technique of its activation, tests of the properties of the prepared concrete. On the basis of the obtained results, 2 scientific articles will be prepared, 1 patent application will be submitted and 1 summary report will be prepared for an international scientific conference.

In the 3rd stage, the model samples of investigated concrete of new generation will be subjected to (heat release, water permeability, wear resistance, frost resistance, compression/bending, tension and elasticity) tests. Also, 2 scientific articles will be prepared for publication, 2 patent applications will be submitted, 1 summary report will be prepared for an international conference and the presentation of recommendations on the production of stable hydraulic concrete will be held. The results will have a positive influence on the development of the national economy and infrastructure, will promote the population employment and stable progress of the young Georgian state.

The principal novelty of the research will consist in the increase of the stability of hydraulic concrete by the following hypothesis: modification of concrete by silicates: at the microlevel by grainy basalt fiber (D = 200-300 mk) made of basalt fiber (d = 0.7 – 1.0 mk = 70 -100 нм) and at the nano-level by puzzolans (more exactly, by activated zeolite tufa containing crystalline hydrates – platy clinoptiloellite (Fig. 1), fibrous mordenite (Fig. 2), acicular natrolite (Fig. 3), or by activated clay shale containing crystalline hydrate – platy metakaolin (Fig.4) will lead to their braiding with crystalline hydrates of analogous habit thet were formed during the cement hardening (platy-acicular tobermorite (fig. 5), acicular prismatic ettringite (Fig. 6) and their concentration around around single fiber grains (Figs. 7 and 8). Due to silicate modification, the simultaneous 3d micro and self-nano-reinforcement of concrete structure will take place, which will decrease conglomeration, porosity, water permeability, and increase the bending/compression, breaking/elasticity strength, wear resisistance (to mudflows), crush resistance (to earthquake shocks).

The following analyses will be performed: chemical, petrographuc, X-ray-diffractometeric. Chromatographic, EN196/EN-1:2000. Eurostandard methods will be applied. Tesrs of concrete for porosity, density, water permeability, crack resistancem wear resistance, frost resistance, brittleness, compression-bending-tension tests will be carried out in conformity with the erurostandards EN196/EN-1:2000, using the equipment of CONTROLS, TESTING and MATEST companies, which meets the aims of the project to investigate the possibility of creation of the innovative nano-technology of hydraulic concrete of new generation, with modified structure, high strength, low anisotropy, resistant to mudflows and earthquakes.

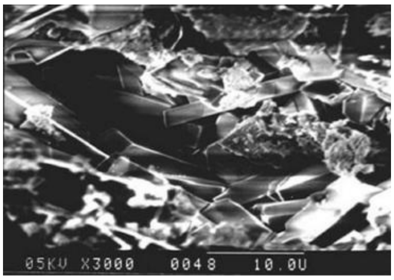

Fig. 1. Clinoptilolite

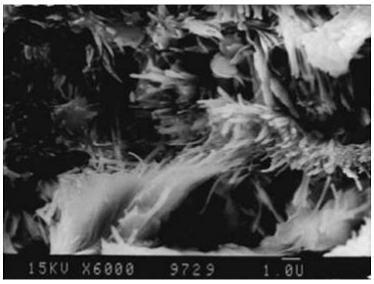

Fig. 2. Mordenite

Fig. 3. Natrolite

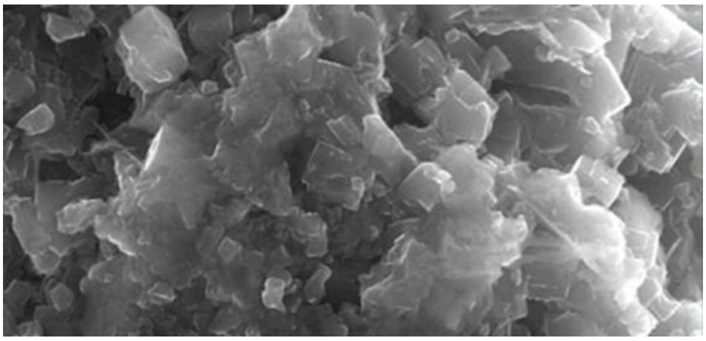

Fig. 4. Metacaoline

Fig. 5. Tobermorite

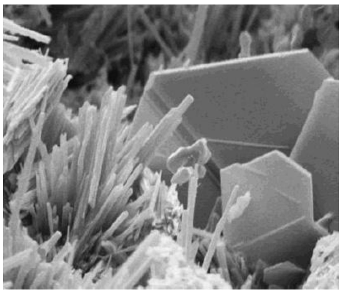

Fig. 6. Ettringite

Fig. 7. Basalt fiber

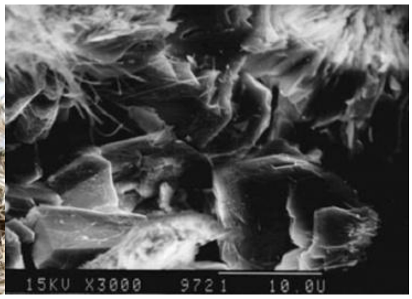

Fig. 8. Ettri.+clinopt.+bas.fiber

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