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PROPERTIES OF SELF-COMPACTING CONCRETE WITH BASALT FIBER

A study of the rheological properties of self-compacting fiber reinforced concrete mixtures with additives of modifiers and microfillers and performance characteristics of concrete based on these mixtures has been carried out.

Key words: self-compacting fiber reinforced concrete, modifier, metakaolin, relative viscosity, strength, elasticity modulus.

Проведено дослідження реологічних властивостей фіброармованих само ущільню-вальних бетонних сумішей з добавками модифікаторів і мікронаповнювачів та експлуатаційних характеристик бетонів на їх основі.

Ключові слова: фіброармований самоущільнювальний бетон, модифікатор, метакаолін, умовна в’язкість, міцність, модуль пружності.

Introduction

The major demand to design and preparation of a new generation of concretes is to give them good workability during the concreting process. The abovementioned concretes are characterized by high content of mineral additives that modify certain properties (e.g. limestone flour, ash removal, thin grind granulated furnace slag, zeolite tuff et al.). Self-Compacting Concrete (SCC) is one of the most innovative materials in modern concrete technology. Using mineral additives in its composition provides change of the properties of concrete and provides significant economic benefits; moreover it is also an important element in the strategy of sustainable development.

Problem statement

Production and maintenance of concrete structures are accompanied by cracking, due to several reasons. Cracks, deformation or damage may be caused by shock, vibration and other dynamic loads; errors in calculations and reinforcement; use of substandard materials; disturbance of thermal processing and assembly technology; heterogeneity of strength, elasticity and stiffness of the materials used; and the loss of strength of the base. Each of these factors is most intensive at different stages of concrete hardening, and therefore their impact on the durability of concrete elements varies. The greatest role is played by deformations occurring in the hardened concrete, with the main part accounted for those that involve stretching or bending loads, internal pressure under cyclic freezing and thawing, the influence of the environment, and the corrosion process. The development of defects over time significantly affects the stress-deformed state of structural elements. It is possible to prevent all the above mentioned causes of cracking in concrete or to reduce the degree of their influence on material properties by use of self-compacting fiber reinforced concrete. Therefore, it is essential to study the influence of fibers on the rheological properties of self-compacting concrete mixtures and concretes based on them. The use of this composite will successfully resolve a number of specialized tasks: strengthening of bridge structures, runways, industrial concrete floors and others.

Analysis of recent research and publications

The increased use of concrete in construction and toughness of maintaining conditions of structures requires constant increase in its strength, crack toughness, resistance to shock and dynamic impact, abrasion, etc. Disperse reinforcement and reinforcement with continuous fibers provides increased resistance to cracking, flexural and tensile load, allows creating the necessary capacity margin, while maintaining the integrity of the design, even after the emergence of through-cracks [1].

The first attempts at concrete reinforcing with steel fibers were made by Jean Louis Lambeau. In 1855 he made a 3.5m boat with cement mortar reinforced with several layers of woven steel mesh. Later glassfibre concrete was used, consisting of specially arranged fiber glass mesh or fabric connected by cement mortar. Disperse-reinforced concrete was used in bridge construction in the Berlin Park (1988) for the reconstruction of the two-balk pedestrian bridge, and in a Japanese golf club (1992) for the construction of cable-stayed bridge. In Los Angeles and Santa Monica (USA), under the increasing seismic resistance of bridge structures programme, (1993) protective cladding of columns with fiber-reinforced concrete mats was used [2, 3].

The sharp increase in the price of conventional steel reinforcement in international markets causes the need to find solutions that would limit the use of steel. Fiber reinforcement can effectively replace a central armature in plate constructions of industrial flooring, coating of roads and bending elements. Market analysts point to a significant increase in steel consumption in China and India as an important factor in the rise in prices for steel products in international markets. An important argument in favor of synthetic disperse reinforcement is the simplicity of use [4].

Currently, the restraining factors in the process of implementation of reinforcement of concrete products with glass, polymeric, metallic fibers is low chemical resistance of these fibers in the environment of hardening cement paste, the high cost of synthetic fibers, with their low efficiency, and deficiency of metal fibers. All these flaws are completely absent in the basalt fiber. With widespread use of reinforced concrete, special attention should be paid to composites in which matrix is formed of cement stone, obtained on the basis of Portland cement and reinforced using as basalt fiber. Using basalt fiber allows to a large extent to offset the major disadvantages of concrete - low tensile strength and fragility. Use of basalt fibers increases frost resistance, heat resistance, abrasion resistance, moisture resistance of the material; and three-dimensional reinforcement is provided, shrinkage deformations are reduced, significantly increases the fracture toughness, impact strength et al. [5, 6].

The main task of modern concrete technology is traditionally to receive strong and durable composite and to reduce labor and energy costs in its production. For achieving high performance of modern concretes, high demands on materials for their preparation are placed. Of particular importance is self-compacting concrete reinforcement with basalt fiber that has high chemical resistance in alkaline environment of concrete. The basis of self-compacting fiber concrete technology is to improve the homogeneity of the concrete mixture by reducing the maximum size of coarse aggregate, use of microfillers for optimum density, the inclusion of concrete superplasticizers to improve thinning of concrete mixture and dispersion reinforcement of cement stone structures [6-8].

The aim of the work is to develop self-compacting concretes with the addition of modifiers, fillers and micro basalt fiber, optimizing their composition; research of the technological properties of concrete mixtures and operational characteristics of hardened concrete.

Research methods and materials

To produce self-compacting concretes the following were used: Portland cement CEM II/B-S 42.5 N, production of Volyn-Cement JSC with the following characteristics: specific surface $S_{пит}$ = 395 m^2/kg, rest on a sieve № 008 - 1.2 wt. %, beginning of hardening - 2 hours 35 minutes, the end - 4 hours 00 minutes, the boundary compressive strength after 2, 7 and 28 days - 18.5, 29.1 and 52.5 MPa, respectively. As the fine aggregate, silica sand from Zhovkivskyi deposits of Lviv Oblast with module size $M_{кр}$ = 1.77 was used. Quality parameters of silica sand meet the requirements of ДСТУ Б В.2.7-32-95 standard for heavy concrete. In order to provide concrete mixtures with high mobility performance and to maintain it over time, polycarboxylate superplasticizer based on Basf Glenium ACE 430 (PC) were added to their composition. As coarse aggregate for making concretes, the granite rubble from Virovsky deposits with fraction 5-20 mm, with a bulk density - 1480 kg/m^3,porosity - 43.5%, the true density - 2.62 g/cm^3, breakability Др = 8%, without clay and dusty impurities was used. The gravel from Virovsky deposits, which was used in research, meets ДСТУ Б В.2.7-74-98 standard according to granulometric composition and quality indicators for the preparation of heavy concrete.

As a mineral supplement, metakaolin with the following physical properties: bulk density, kg/m3 - 304.0 (before compacting), 447.0 (after compacting), rest on a sieve 0063 - 1.32 wt.%, loss on ignition - 1.2 wt.%, chemical composition, wt.%: Al_2O_3 - 43,8; SiO_2 - 53,42; Fe_2O_3 - 0,75; TiO_2 - 0,58; CaO - 0,4, was used.

The mixture was dispersedly reinforced with basalt fiber with diameter of 16 mcm, made of basalt roving according to ТУ У В.2.7-26.8-34323267-002:2009.

Tests of fluidity and viscosity of concrete mixture were implemented by FFB (Flieβmaβ –Flieβzeit – Bloker – Test)test method. Fluidity of concrete mixture was defined as the average value of flow index and viscosity value - as time of spreading of concrete mixture from the cone with obtaining 500 mm flow (t_{500}).

Results of the research

Mobility of the cement that meets the requirements for self-compaction (MC flow measured using Suttard cylinder is more than 300 mm) is achieved through the use of polycarboxylate type superplasticizer. To eliminate negative phenomena in Portland matrices with high mobility, growth of sedimentation stability and speed of hardening, it is necessary to use binders based on Portland cement composition using active mineral and complex chemical additives. Research of influence of polycarboxylate superplasticizer on fluidity of cement paste revealed that the introduction into the cement system at constant В/Ц=0.25 2 wt. % of PC provides 335 mm Suttard cylinder flow. It should be noted that the conditional viscosity of cement paste (В/Ц=0.25) with the introduction of 2wt.% polycarboxylate superplasticizer constitutes up to 250mmτ_{250}=4,5s time spreading. Compatible addition to Portland cement of polycarboxylate superplasticizer and metakaolin provides an increase in the viscosity of cement paste up to 250 τ = 5.6 s at high plasticity of cement paste (360 mm Suttard cylinder flow).

Research of polycarboxylate superplasticizers and metakaolin influence on the mechanical properties of Portland cement have shown (Table 1), that Portland stone with the addition of 1 wt.% superplasticizer of polycarboxylate type is characterized by slightly lower compressive strength and bending strength compared to stone without additives. Increasing the number of superplasticizer provides gain of compressive and bending strength of cement stone in all periods of hardening. Thus, the increase of compressive strength of cement stone with 2wt.% polycarboxylate superplasticizer after 2 days of hardening is ΔRct = 20%, after 7 days - ΔRct = 14%, after 28 days - ΔRct = 27%, and increase in bending strength ΔRzh=36% and $\Delta R_{зг}$=14% after 2 and 28 days of hardening. It should be noted that the joint introduction of superplasticizer and metakaolin causes a slight decrease in bending strength, but after 28 days of hardening with the introduction of 2wt.% and 10wt.% MK increase in bending strength of cement stone is ΔRzh = 25%, compression strength - ΔRct = 17%.

Table1

Influence of polycarboxylate superplasticizer and metakaolin on the properties of Portland cement

№	type and amount of additives	W/B	Compression/bending strength, MPa, after, days		
			2	7	28
1	v/a	0.25	60.7/7,5	76.4/9.1	80.3/12.2
2	1%SP	0.25	58.0/4,3	73.27/8.9	75.1/11.1
3	2% SP	0.25	72.8/10,2	87.2/8.1	102.1/13.9
4	1% SP +10% МК	0.25	54.3/6,9	67.2/9.8	73.3/12.2
5	2% SP +10% МК	0.25	60.0/4,5	76.7/12.9	93.7/15.3

Thus, the use of polycarboxylate superplasticizer type and metakaolin provides obtaining of cement compositions satisfying the requirements for self-compacting on the viscosity and plasticity.

The main function of fiber in the concrete is to reduce the stress concentration there. Investigation of the influence of basalt fiber length on properties of cement paste determined that introduction of basalt fibers causes reduced mobility of cement paste from 335 mm to 320 mm at fiber length 12 mm, at fiber length 24 mm - up to 310 mm, at fiber length 36 mm - to 300 mm. With increasing length of the fibers increases the viscosity of the cement paste (Fig. 1). Thus, with the introduction of fibers length of 12 mm conditional viscosity of cement paste increases from 4.5 s to 6.4 s, with increasing fibers length up to 36 mm viscosity of cement paste increases to 15.8 s.

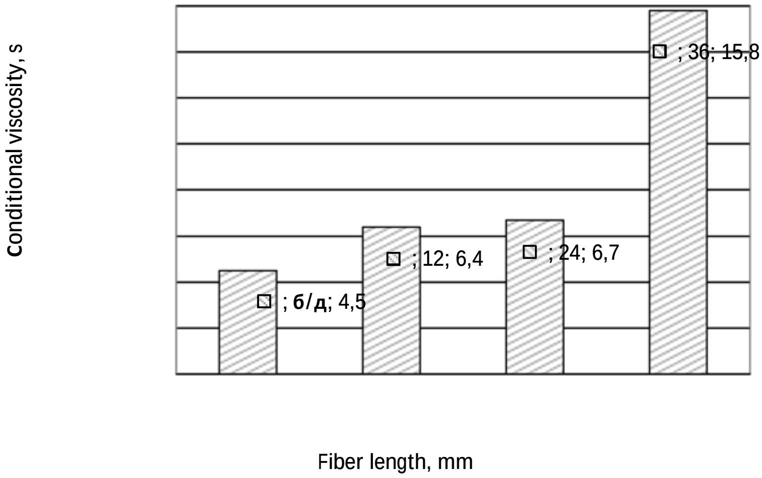

Fig. 1. Influence of fiber length on the conditional viscosity of cement paste

Investigation of basalt fibers influence on fine concrete properties found that the use of basalt fibers provides increase of bending strength at all periods of hardening. Thus, the bending strength of fine-grained concrete without fibers after 28 days of hardening under normal conditions is 10.2 MPa, when adding 1.5 wt.% bending strength of fine-grained concrete increases to 13 MPa (technical effect ΔRzh28 = 28%).

The carried out research of influence of fiber on the properties of self-compacting concrete found that introduction fibers in its composition does not cause are duction in plasticity of concrete mixture (Fig. 2). Thus, cone flow of self-compacting concrete mixture was 780 mm with conditional viscosity t_{500}=6s with water-cement (В/Ц=0,3), with the introduction of basalt fibers cone flow is 790 mm, and viscosity t_{500}=5 s.

Fig. 2. Plasticity of self-compacting fiber reinforced concrete mixture

Fig. 3. Breaking capacity of self-compacting fiber reinforced concrete mixture

Self-compacting concretes are used for concreting highly reinforced constructions, so the filler capacity of prepared self-compacting fiber reinforced concrete mixtures was determined in the work in terms of fluidity and visual J-ring method. Determination of the capacity for self-compacting according to J-ring method showed excellent ability of self-compacting fiber reinforced concrete mixtures obstacles to overcome closely set reinforcing rods without blocking (Fig. 3). It has been found that the obtained self-compacting concrete mixtures reinforced with basalt fiber, are characterized by high density (average density of concrete mixture is 2400-2425 kg/m3) and low air consumption (0.35%).

It should be noted that basalt fiber reinforcement of self-compacting concrete promotes the growth of compressive strength at all hardening periods (Fig. 4). Thus, the increase of compressive strength of self-compacting concrete reinforced with basalt fiber, after 2 days of hardening under normal conditions is $\Delta R_{ст}$=7,5 %, after 7 days – $\Delta R_{ст}$=18,5 %, after 28 days – $\Delta R_{ст}$=4 %. Water consumption of fiber reinforcement of self-compacting concrete is W_m=2,2%.

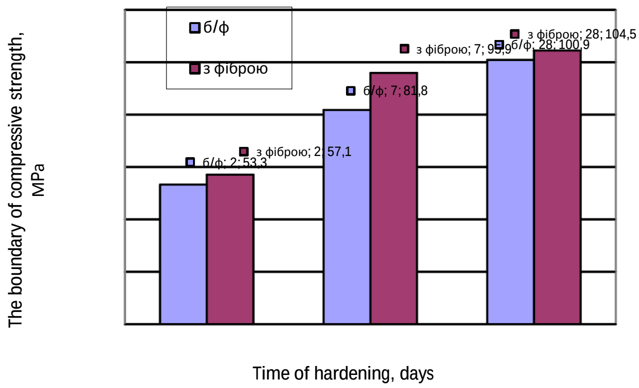

Fig. 4. Strength of self-compacting concrete reinforced with basalt fiber

Investigations of deformation properties of self-compacting fiber reinforced concrete found that within the measured strain there is almost no increase in the longitudinal and transversal strain of quick flow, which is typical for high quality concrete. Modulus of elasticity of self-compacting fiber reinforced concrete increases from 51.6 to 63.9 GPa and Poisson's ratio decreases from 0.19 to 0.17 compared to self-compacting concrete without fibers. Prism strength of self-compacting concrete is 71.7 MPa, whereas of self-compacting concretes, reinforced with basalt fiber - 96.2 MPa.

Conclusion. Researches of physical and mechanical characteristics of self-compacting fiber reinforced concrete showed that the optimal fiber length, that ensures maximum increase in bending strength length, is 24 mm. Use of polycarboxylate superplasticizer, metakaolin and basalt fibers ensures optimum concrete structure formation under normal conditions and ultimately leads to increase in its strength. Self-compacting fiber reinforced concretes are characterized by strength after 28 days of hardening under normal conditions of 104.5 MPa, strength modulus 63.9 GPa, Poisson's ratio of 0.17, the water absorption of 2.2%, which allows using them in a resource-saving building construction, in the construction of industrial floors, nuclear power plants, marine hydraulic structures, reservoirs, large prefabricated structures, construction of bridges and tunnels, monolithic and gathered monolithic special constructions, covering of airports, runways, monolithic structures for space launch complex systems, and other special projects.

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USE OF ZEOLITE OF THE SOKYRNYTSA DEPOSIT IN ENGINEERING OF ENVIRONMENT

In the given article the theoretical bases of adsorption of typical contaminations of wastewaters are grounded. The review of literary data in relation to application of the klynoptylolite of Sokirnitsa deposit in engineering of environment is carried out. Experimental data of adsorption capacity of natural klynoptylolite are resulted. A mechanism and features of processes of adsorption in static terms is described. Conformities to the law of change of adsorption capacity in accordance to the parameters of molecules of adsorbate were observed.

Key words: zeolite, adsorptin, wastewater, external diffusion.

Обґрунтовано теоретичні основи адсорбції типових забруднень стічних вод. Проведено огляд літературних даних стосовно застосування клиноптилоліту Сокирницького родовища в інженерії довкілля. Наведено експериментальні дані сорбційної ємності природного клиноптилоліту. Описано механізм та особливості процесів адсорбції в статичних умовах. Встановлено закономірності зміни сорбційної ємності відповідно до параметрів молекул адсорбату.

Ключові слова: цеоліт, адсорбція, стічні води, зовнішня дифузія.

Formulation of the problem and its copulas with the important scientific or practical tasks

The change of composition of natural waters as a result of the tehnogenic influence needs the search of new safe methods of industrial wastewaters treatment. The existent methods of industrial wastewaters treatment, that consist in application of chemical reagents or physical influence on water, allow to withdraw from it contaminating the matters, changing physical and chemical properties of water and violating the natural balance of dissolved in it salts.

However in nature takes place the smoothing of salt balance of filtration waters and withdrawal from them of dangerous admixtures by passing of water through a geochemical barrier, that has an enormous adsorption capacity in relation to ksenobyotyks.

The protective function of geochemical barrier consists in presence in it clay minerals, carbonates, aluminosilicates, in particular zeolites, etc. Application of such natural minerals-adsorbents for treatment of wastewaters and natural muddy waters on the stage of defending will allow to withdraw by adsorption without application of chemical reagents not only the dangerous contaminating matters of antropogenic origin, but also to improve a structure and mineral composition of water.