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ESEARCH OF THE PROPERTIES OF THE SELF-COMPACTED CONCRETE OVER TIME

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Abstract. *Concrete mixture is examined as a complex multicomponent system that becomes a single unit and can be studied as a physical unity with certain rheological, physical and mechanical properties. Studying the change of properties of self-compacted concrete over time, as well as the effect of two-phasic introduction of super-plasticizer on properties of concrete mixture are presented in this article.*

Key words: *viscosity, friction coefficient, self-compacting concrete mixture, obstacle crossing ability, time of flowing through a V-shaped funnel, columns, building.*

ДОСЛІДЖЕННЯ ВЛАСТИВОСТЕЙ БЕТОНУ, ЗДАТНОГО ДО САМОУЩІЛЬНЕННЯ, В ЧАСІ

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Анотація. *Проведено дослідження зміни властивостей бетону, здатного до самоущільнення в часі, а також впливу двостадійного введення добавки суперпластифікатора на властивості бетонної суміші.*

Ключові слова: *суперпластифікатор, бетон, здатний до самоущільнення, бетонна суміш, в'язкість, коефіцієнт тертя.*

ИССЛЕДОВАНИЕ СВОЙСТВ САМОУПЛОТНЯЮЩЕГОСЯ БЕТОНА ВО ВРЕМЕНИ

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Аннотация. *Проведено исследование изменения свойств самоуплотняющегося бетона во времени, а также влияния двухстадийного введения добавки суперпластификатора на свойства бетонной смеси.*

Ключевые слова: *суперпластификатор, самоуплотняющийся бетон, бетонная смесь, вязкость, коэффициент трения.*

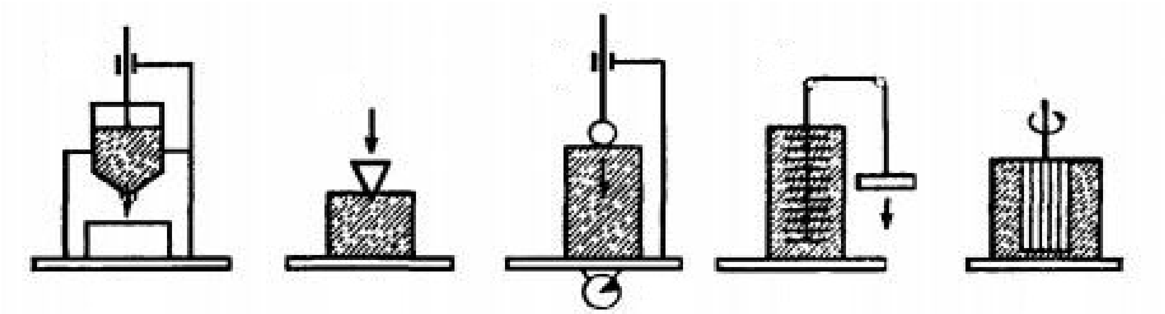
Introduction

The most essential property of concrete mixture is the ability of concrete mixture to spread and to accept the set form, keeping at the same time its monolithic nature and homogeneity (easy placement). Easy placement is determined by mobility (by fluidity) of concrete mixture in the moment of fill-out and plasticity, its ability to become deformed without a break of wholeness. For the complete estimation of concrete mixture and correct organization of concreting of monolithic reinforced-concrete constructions it is necessary to know other properties of mixture, as well: its compaction properties, homogeneity, layerability, change of volume in the process of consolidation, air-entraining, primitive durability (for the conclusion of concrete mixture by the method of shortcreting). The feature of concrete mixture is practically a permanent change of its properties, from the beginning of preparation to consolidation, that is stipulated by difficult physical and chemical processes that take place in concrete mixture and concrete. Concrete mixture is the complex multicomponent system that becomes associated and can be studied as the physical unity with certain reological, physical and mechanical properties.

Review of publications

For description of behavior of concrete mixture in different conditions various reological descriptions of it are used: maximal tension of slope, viscidity and period of relaxation [1]. For determination of these properties special devices or viscometer-stirrers are applied (Fig. 1). Such tests are executed mainly in research laboratories.

Devices based on determination of speed of flow of cement dough or concrete mixture through a capillary, tube or opening of certain form and size (Fig. 1, a). It can perform testing under the certain pressure. These devices are widely used for the estimation of reological properties of concrete mixtures that are considered self-compacting. Devices based on bathymetry of penetration in cement dough or concrete mixture of cone or other body. The most exact results are received at the test of cement dough (Fig. 1, b).



a b c d e

Fig. 1. Schemes of devices for determination of reological properties of cement dough and concrete mixture [1]: a – after measuring speed of flow of mixture through opening; b – after bathymetry of penetration of cone; c – after speed of immersion of sphere; d – after strenth of pulling out; e – after strenth of rotation of coaxial cylinders

Devices based on determination of speed of immersion or emerging of sphere of certain mass and sizes (Desov device etc.). Tests are usually conducted during a vibration of mixture (fig. 1, c). Devices, based on measuring the strength of pulling fluted plastins, bars or cylinders out from mixture (fig. 1, d). Devices, based on the rotation of coakcial cylinders between which there are 6 tonns of mixture. Thus either internal, or external cylinder can be revolved. At the test frequency of rotation and strength, necessary for overcoming of resistance of concrete mixture are measured (fig. 1, e).

At determining reological properties of concrete mixture oscillation influences are often used. Viscometer-stirrers are set onto oscillation devices, or in their construction there is possibility of creation of oscillation influence, often with the wide changes of parameters (frequencies and amplitudes of vibrations). Exactness and correctness of determination of reological properties of concrete mixture depend on her structure and composition. The higher homogeneity is, the more correct test result are taken [1]. With the increase of content of filler especially large, the role of friction and casual factors rises, variation of results of tests grows. The volumes of tested concrete mixture and working sizes of devices, that in the operating crossing must be in 3–4 times more maximum size of large filler, must increase with the increase of the scale of the filler [1].

On a site area mobility (fluidity) of mixture is mostly controlled, for which devices that allow quickly and in a comparatively simple way to get necessary description of concrete mixture (sinking of cone, sprea of the cone and others like that) are applied, and all of them characterize behavior of mixture under certain conditions and serve for the benchmark estimate of ability of mixture to the placement, compacting or self-compacting. Advantage of technical methods of determination of mobility of concrete mixture must be the speed of the test and comparative simplicity in usage of devices accessible for any building laboratory. However on the basis of these tests it is impossible to get complete reological curve of concrete mixture and according to complete data about its reological properties, especially when on the site area concrete mixture by means of pipelines is given to the place of compaction via a concrete pump.

Aim of the research and its tasks

The primary aim of work is researching properties of self-compacted concrete mixture in time, and also solving the problem of maintening basic properties of concrete mixture.

Researching the properties of self-compacted concrete mixture

In foreign practice renovation of SSC properties at its application as custom concrete is provided by additional introduction of 0,2 % superplasticizer additive from mass of cement on a site area [2]. In Ukraine the innovative method of construction is offered with concrete mixture under the conditions of the protracted transporting and temperature increase, namely – twophasic use of additives [3].

Additives of different types (plasticizers, superplasticizers, moderator-coolants, accelerators) are combined and added separately on different stages, depending on the season, the patterns of organization of concrete work, distance to the site area, taking into account the cost of transportations and other factors. It also allows not to enter the extra (unaccounted at the stage of planning composition of concrete) amount of water to a concrete-mixer, to turn the consistency of concrete mixture lost in the process of transporting, and not to decrease the class of durability of concrete in a construction. We offer the improvement to the method of two-staged use of additives by using only superplasticizers for maintenance of properties of self-compacted concrete mixture without using extra additives retarding and accelerating. According to the standart [4] for self-compacting concretes (SSC), operating in Ukraine, the following data are determined:

– the class according to spread (diameter of the cone spread);
– the class of viscidity (spreading time to the diameter of 500 mm and time of flowing concrete mixture from V-shape funnel);
– the class of practicability (determination of movability of concrete mixture with the help of L-shaped basket and diameter of cone spread through armature framework shaped as a ring).

In the course of lab testing the possibility of separate introduction of superplasticizers (SP) was checked up for providing the maintenance of properties of self-compacting concrete mixture while transporting by mixing machines from a mixing plant to the place of compaction (table. 1, 2).

At the preparation of concrete mixture 60 and 70 % superplasticizers were added for necessary 88 % of water for premix, to get the slope of the cone of 20 cm for providing interfusion during transportation in automates mixing plant. Other part of water for premix (12 %) and superplasticizers (40 % and 30 % accordingly) were added in 1,0 and 1,5 hour for comparing of maintenance to the indexes of the mixture prepared at once on a concrete knot (control composition). Control mixture was put into the frame after 1,0 and 1,5 hour storage in a laboratory (temperature of storage 220 °C) and outside (temperature of storage 320 °C) accordingly, that imitated delivery to the site area at different temperature conditions (table 1, 2). Besides, measuring in time was conducted for basic indexes of self-compacted concrete mixture at the temperature of storage 220 °C (fig. 2).

Lab tests showed that for all three compositions of cone spread presented in 670–700 mm, spreading time to the diameter of 500 mm – 1,5–3,0 sec, ability to overcome an obstacle – 0,90–0,92, and time of flow from V- shape funnel is 4–5 secs. Maximal durability on compression at the age of 3 and 28 twenty-four hours showed composition with adding SP in 60 % and 40 % accordingly, and minimum is control composition at adding water for providing necessary placibility.

Table 1 Verification in change of mobility for concrete mixture (temperature of storage of 320 °C)

Components and indexes	Composition		
	control	60–40	70–30
1	2	3	4
Cement, kg	500		
Sand SF=1,6, kg	600		
Gran–screening, kg	200		
Breakstone fr. 5–10, kg	900		
Water (initial addition), l	250	215	215
Additive, % rom C (initial addition)	1% FK59	0,6% FK59	0,7% FK59
W/C (initial addition)	0,50	0,43	0,43
Placibility, sinking of cone , sm	–	20	22
Placiability, sprea of the cone, sm	70	–	–
Viscosity, t_{500}, sec	3,0	–	–
Viscosity, t_{cone}, sec	4,0	–	–
Ability to overcome the obsticle (with 3 rebars)	0,92	–	–
Kind of preservation	In a lab under the film	Outside under the film	Outside under the film
Storage temperature, °C	22	32	32
Placibility, sinking of cone , sm (in 60 min after mixing)	–	6	8
Placibility, sprea of the cone, sm (in 60 min after mixing)	68	–	–
Water (second addition in 60 min), l	–	21	36
Additive, % from C (second addition in 60 min)	–	0,4% FK59	0,3% FK59
W/C (second addition in 60 min)	–	0,47	0,50
Indexis after the second addition of the additive			
Placibility, sprea of the cone, sm	–	70	70
Viscosity, t_{500}, sec	–	1,5	2,0
Viscisity, t_{cone}, sec	–	4,0	5,0
Ability to overcome the obsticle (with 3 rebars)	–	0,9	0,9
$f_{cm,cube}$, MPa, (28 days)	41,7	41,3	38,6

Table 2 Verifications in change of mobility for concrete mixture (temperature of storage of 290 °C)

Components and indexes	Composition		
	control	60–40	70–30
Cement, kg	500		
Sand SF=1,6, kg	600		
Gran–screening, kg	200		
Breakstone fr. 5–10, kg	900		
Water (initial addition), l	250	215	215
Additive, % rom C (initial addition)	1% FK59	0,6% FK59	0,7% FK59
W/C (initial addition)	0,50	0,43	0,43
Placibility, sinking of cone , sm	–	20	21
Placiability, sprea of the cone, sm	68	–	–
Kind of preservation	Outside under the film		
Storage temperature, ^{0}C	29	29	29
Placibility, sinking of cone, sm (in 90 min after mixing)	–	7	10
Placibility, sprea of the cone , sm (in 90 min after mixing)	50	–	–
Water (second addition in 90 min), l	33	28,5	28,5
Additive, % from C (second addition in 90 min)	–	0,4% FK59	0,3% FK59
W/C (second addition in 90 min)	0,57	0,49	0,49
Indexis after the second addition of the additive			
Placibility, sprea of the cone, sm	63	67	68
$f_{cm,cube}$, MPa, (3 days)	12,5	17,3	16,7
$f_{cm,cube}$, MPa, (28 days)	32,4	37,5	35,3

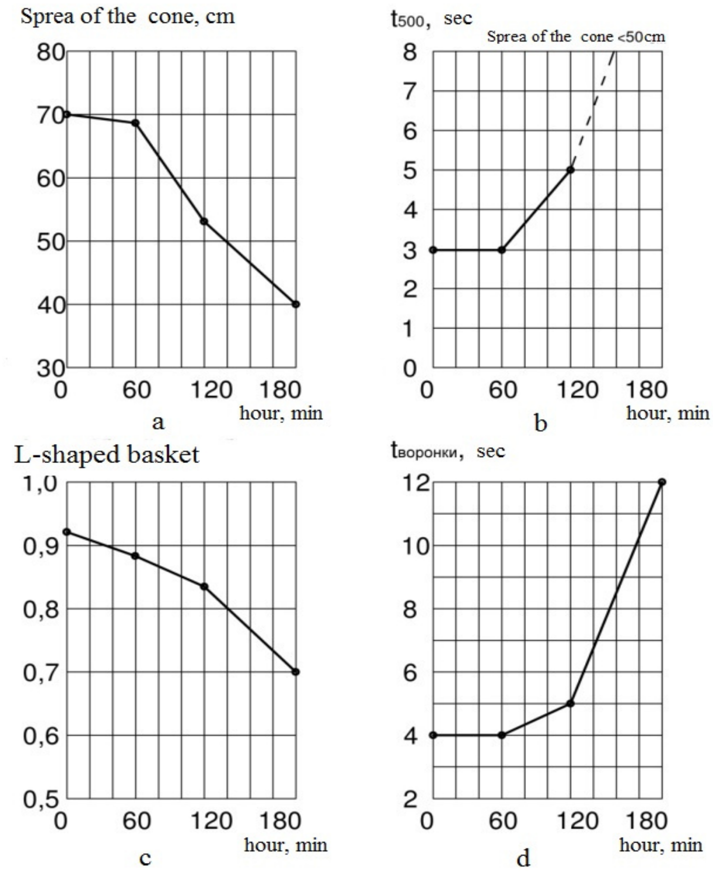


Figure 2. Schemes of change of basic indexes in self-compacted concrete mixture in time (at the temperature of storage 220 °C): a – spread of cone; b – spreading time to the diameter of 500 mm; c – ability to overcome an obstacle with three rebars; d – time of flowing of concrete mixture from V- shape funnel

Thus the amount of water of premix at 2-staged addition of SP did not exceed control composition, and even was less than on 3–5 %.

Dynamics of change of basic indexes SSC in time showed that without intensive transportation of concrete mixture in automated mixing plant to the cone spread began considerably to diminish already after 60 min from the moment of premix, other indexes change more slowly (fig. 2). The results received allowed to carry out concreting of reinforced columns on 1st floor of the 5-storeyed building. Thus 40 % additions of SP together with 12 % of water of premix were added directly to the mixing plant at the moment of its arriving at the site area with next interfusion of concrete mixture during 3-4 min. Concreting of reinforced columns on the 1st floor about 10 m high was made with the use of planking in two stages.

Average compression strength for SSC at the test of cubes (the size is a 15x15x15 sm) that was concreted at the same time with building construction, confirmed the necessity of applicating SP for concreting conditions, when the temperature of air is between 27–320 °C, and the conditions of transportating the self-compacted concrete mixture exceeds 1,5–2,0 hours (table 3).

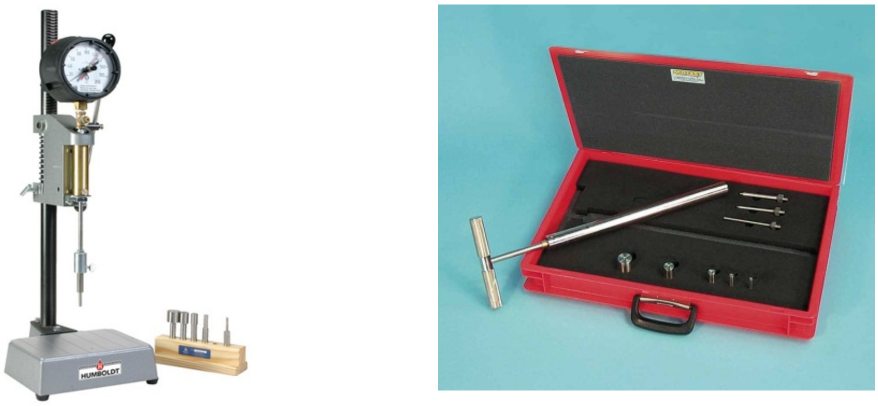
Table 3 Sizes of the average compression strength for SSC

Indexes	Elements of construction	
	Reinforcement of the overlap	Reinforcement of the column
Adding SP	One time, 100 % additive while preparing concrete mixture	Two time, 60 % additive while preparing concrete mixture and 40 % before placement into the construction
$f_{cm,cube}$, MPa, (28 day)	31,0–48,8	41,7–57,1

Duration of interval between the placement of contiguous layers of concrete mixture without formation of construction joits must not exceed the term of beginning the curring of concrete mixture of the previous layer. The conditions for beginning concrete curring must be determined by a construction laboratory according to the national standard of the USA [5] by means of penetrometer with a loading device (fig. 3).

According to the results of the tests (table. 4) the curve of dependence of penetration resistance is built on the time that characterizes speed of concrete mixture curring (fig. 4).

According to the curve time of beginning and end of curring are measured (290 and 377 min accordingly), when penetration resistance presents 4,0 and 24,0 MPa. The index of the curring beginning gives an opportunity to define a maximal interval from the beginning of premix of concrete mixture at the plant to the moment of placement it during the construction on the site area, as well as the interval between the compaction of contiguous layers of concrete mixture without formation of construction joints.



a b

Figure 3. Appliances for determination of size of penetration resistance for concrete mixture : a – for lab tests; b – for tests on the site area

Table 4 Measuring of penetrometer for determination of curring conditions of concrete mixture

Time, min	200	230	260	290	320	345	340	380
Penetration resistance	0,3	0,8	2,0	4,0	8,0	13,0	17,0	25,0

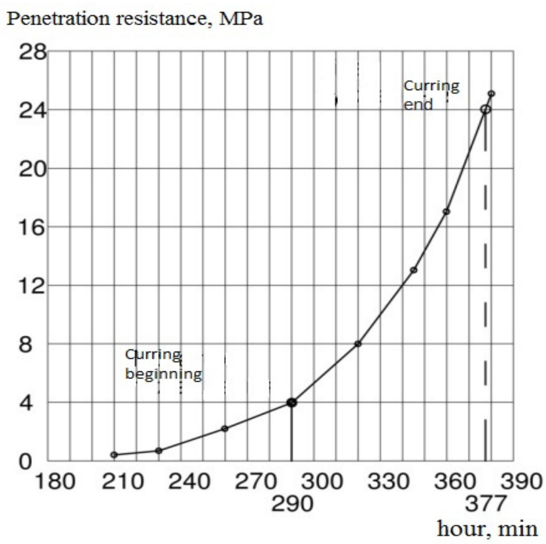


Figure 4. The curve of dependence of penetration resistance from time

For conducting the series of experiments studing dynamic viscidity and the coefficient of friction (reological descriptions) of concrete mixture and mortar, transported to the site area by automated mixing plant, special devices were worked out by the specialists of Kharkiv national university of Civil engineering and architecture (fig. 5).

At determination of dynamic viscidity the method of falling spherewas use, based on the speed of its free falling according to the method of Stocks [6, 7]

$$\mu = \frac{d^2(\rho - \rho_0)t}{18l}, \quad (1)$$

where d – the sphere diametre, mm; ρ – density of the sphere material, kg/m; ρ_0 – average density of the concrete mixture; l – distance between the measures on the device.

a

b

Figure 5. Devices for determination of reological descriptions of concrete mixture: a – to viscidity; b – coefficient of friction

For researches compositions of mortar with different mobility were taken [8]. Researches were conducted in gravitational mixing plant, because automates one is the gravitational machine.

Conclusions

It should be noted that the analysis of methodologies and equipment for determination of descriptions of concrete mixture qualities, as well as experimental studies undertaken before did not allow to get statistical data for self-compacting concrete mixtures to a full degree, but in their turn they will influence energy consumption for transporting and placement of these concrete mixtures with the help of concrete pumps and mortar-concrete pumps.

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