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New Organic Expanding Admixtures for Reducing Shrinkage in Concrete

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ABSTRACT

Organic expanding admixtures (OEA) based on diethyleneglycol mono-tert-butyl ether have been synthesized and described, their influence on shrinkage deformations, concrete strength development, concrete pore structure, and durability was investigated. The possible mode of action of these admixtures is discussed. Use of OEA incorporating superplasticizers, microsilica and/or admixtures on the basis of sodium rhodanide and sodium thiosulphate is revealed to improve concrete performance and durability.

INTRODUCTION

Concrete shrinkage is one of the principal factors determining durability of concrete and reinforced concrete products and components. The techniques traditionally used to decrease shrinkage deformations require additional material and labor inputs are not always efficient [Kovler et al., 2005].

The attempts of active influence on the value and the nature of inherent concrete deformations are connected with the use of so called expansion agents (EA) presenting three basic groups: alumina-sulfate, alumina oxide and oxide agents [Titova, Bejlina, 2001].

The most widespread in building practice are expansion agents of the first type being as rule mixtures of aluminate and sulphate components [Berke et al., 1997]. The EA mechanism is associated with internal crystallization pressure and is governed by formation of calcium hydrosulphoaliminates in the trisulphate form during cement hardening. The evidence of the expanding effect supposes the presence of a liquid phase in concrete with a certain alkalinity being equivalent to the calcium oxide (CaO) content less than 0.027 g/l because with lower concentration the trisulphate form of hydrosulphoaliminate is unstable [Volzhensky et al., 1979]. Non-observance of these conditions, when introducing EA in a concrete mix, results in either weak evidence of the expanding effect (e.g. when cements with mineral admixtures are used and when calcium ions are bound by active silica in the course of hydration of these cements) or, vice-versa, leads to uncontrolled expansion capable to cause serious damage to concrete (e.g.

when using cements on the basis of high-alumina clinkers, with increased content of sulphates, etc.).

The increased formation of ettringite at earlier hydration stages often leads to rapid loss of concrete-mix consistency. Moreover, since moisture is required to start out the expansion reaction, ensuring the proper moisture conditions for concrete hardening becomes essential. At last, the concrete deformation restriction value (e.g. owing to forms, steel reinforcement, etc.) shall be carefully "designed" in order to reach the desired extent of expansion in structures. Thus, handling such cements requires special precautions: increased hardening periods, additional and precise placing of reinforcement in concrete, minimizing the number of re-entrant corners, side forms, etc. The above-said explains why cements with compensated shrinkage based on mineral expansion agents have not become a universal material in concrete technology [Bazhenov, 2007, Glekel' et al., 1986, Titova, Bejlina, 2001].

Thus, the existing methods, materials and techniques do not ensure guaranteed reduction of shrinkage deformations, since efficiency of their use requires consideration of a number of most important factors, which often are not subjected to control and regulation in real construction conditions. Efficiency of implementing these methods assumes the availability of data on chemical and mineralogical compositions of cements, kind of additives and expansion agents, this being always practicable. At the same time the unbalanced content of sulfate and alumina phases is fraught with inadequate manifestation of expansion strain or considerable uncontrolled internal stresses capable to bring serious structural damages.

Additional efforts required to handle cements with compensated shrinkage on the basis of non-organic expansion agents restrict, as mentioned above, their use in building practice; this has initiated the interest to organic origin agents. These shrinkage reducing agents (SRA) are used in the liquid or powdered form by their introduction both into cement and concrete mixes [Bentur et al., 2001, Bentz et al., 2001, Berke et al., 1997, Collepardi et al., 2005, Folliard, Berke, 1997, Rajabipour et al., 2008]. As a rule, the agents of this kind are hydroxyl oxyethylated or hydroxypropilated derivants of aliphatic alcohols and are produced in strictly controlled conditions, thus ensuring their constant chemical composition. The latter favorably compares organic expansion agents (OEA) with traditional expansion agents of the non-organic origin.

OEA adding with 2-5% of mixing water by weight to a concrete mix results in considerable reduction of total shrinkage. [Nmai et al., 1998] reported on 50-60% shrinkage reduction on the 28^{th} day of hardening and 40-50% - in 12 weeks. In the light of the above said the present paper has investigated the effect of OEA proportion on processing characteristics of concrete mixes, concrete hardening rate and strength as well as characteristics of its pore structure.

EXPERIMENTAL DETAILS

Materials and test methods

As an OEA mono-tert-butyl ether of diethylene glycol (hereinafter – OEA-3) was synthesized. This composition of the agent was established in variation of both the nature of aliphatic alcohol and the degree of its hydroxyethylation in the course of further shrinkage compensation tests of the appropriate concretes. The OEA-3 agent production process comprises a stage of hydroxyethylation of tert-butyl alcohol by ethylene oxide under gage pressure ~2 atm and at 110-120°C.

The experimental proof of efficiency of the OEA-3 was carried out by comparative assessment of shrinkage deformations using cement mortar specimens according to GOST 11052-74 procedure (mortar formula 1:3, flow in tests according to GOST 310.4-81 – 150-170 mm) and concrete specimens according to GOST 24544-81 (1987). As efficiency criterion the extent of shrinkage deformation reduction was assumed for formulas with OEA-3 agent compared with the reference formula.
Fresh concretes were tested according to GOST 10181-2000, and hardened concretes – according to GOST 12730.0 – 12730.5. Compressive strength, bending tensile (flexure) strength, and tensile splitting strength of hardened concretes were determined in accordance with GOST 10180-90. Impermeability to water for series of concrete samples was estimated according to GOST 12730.5 by maximal water pressure, at which on four of six cylindrical samples the water percolation was not observed.

The Portland cement PC500-D0 (CEM I 42.5) from Staryi Oskol and Belgorod Cement Works (Table 1), and standard sand according to GOST 6139-91 were used in the tests.

Table 1. Cement Composition

Cement	C_3S	C_2S	C_3A	C_4AF	R_20
Belgorod PC500-D0	61,55	17,15	5,85	13,45	0,51
Stary Oskol PC500-D0	62,84	12,31	8,5	12,5	0,63

Washed crushed granite of 5-20 mm fraction in accordance with GOST 8267-93 was used as coarse aggregate.

The organic compound agents were introduced into mortars and concrete with mixing water proportion amounting to 2, 4 and 6% by cement weight. During the first day after casting the specimens were stored in a normal hardening chamber ($t = 20 \pm 2^oC$, $\varphi = 95 \pm 5\%$), after stripping and all through the tests – in air-dry conditions ($t = 20\text{-}25^oC$, $\varphi = 60\text{-}70\%$). The shrinkage deformations were determined starting from the 1-day age (zero reading). To assess the OEA impact on mortar and concrete hardening rates and strengths, the appropriate tests were conducted at the age of 1, 2, 3, 7, 14, 28 and 56 days.

RESULTS AND DISCUSSION

Fresh and hardened concrete

The specimen strength tests in the course of air-dry storage have shown that the presence of OEA-3 agent in the concrete mix causes reduction of the mortar hardening rate and strength; the greater the higher is the agent proportion. The most noticeable effect of strength reduction is manifested at the early age (1 day) and with 2-6% proportion it reaches 35-53%. At the 28-day age the strength values largely become proximate while the mortar strength reduction with OEA-

3 agent proportion in the above range does not exceed 8-22% with regard to the strength of the reference specimen without this agent.

Due to strength reduction in specimens with OEA-3 agent a possibility of using the agent together with other additives have been investigated with a view to recover the modified concrete strengths up to the level of the reference mortar strength. The studies were conducted with practically proven and available admixtures, such as a superplasticizer based on polymethylene-polynaphtalene sulfonates (PNS) and condensed silica fume (SF), as well as a hardening accelerator on the basis of industrial salt mixtures comprising sodium rhodanite, thiosulfate and sulfate. The admixtures were introduced at the stage of concrete mixing. The superplasticizer dosage was 0.6, that of silica fume – 10%, that of hardening accelerator – 2.5% by cement weight.

Table 2 shows the effect of OEA-3 agent on properties of concrete with the superplasticizer.
One may infer that the use of this agent in combination with the superplasticizer considerably improves the concrete properties. In particular, reduction of concrete mix water demand, density rise and reduction of entrained air volume are observed.

Table 2. Properties of Fresh and Hardened Concrete with OAE and PNS

Admixture	-	OEA	OEA + PNS
Dosage, % (by mass of cement)	-	6	6 + 0,6
Concrete mix proportions			
Cement, kg/m^3	471	466	462
Sand, kg/m^3	638	648	668
Coarse aggregate, kg/m^3	1075	1104	1137
Water, kg/m^3	193	191	134
W/C	0,41	0,41	0,29
Fresh concrete properties			
Slump, cm	12,5	14,0	14,0
Density, kg/m^3	2377	2437	2429
Concrete strength, MPa, after 28 days of hardening in a normal hardening chamber			
Flexure	5,8	5,6	6,9
Split	3,7	3,3	3,5
Compressive strength (cube)	52,7	43,2	53,2
Compressive strength (prism)	38,5	33,7	44,2
Modulus of elasticity, GPa			
Measured value	36,4	33,0	37,0
Normative (according SNiP 2.03.01-84)	36,0	32,5	36,0
Concrete strength, MPa, after 28 days of hardening in air-dry conditions			
Flexure	4,0	4,7	6,0
Split	2,5	2,6	3,5
Compressive strength (cube)	44,8	38,9	50,0

Compressive strength (prism)	35,1	26,1	36,0
Modulus of elasticity, GPa			
Measured value	34,9	30,8	35,8
Normative (according SNiP 2.03.01-84)	36,0	32,5	36,0

To a still greater extent the strength of concrete with OEA-3 agent is ensured by its use together with the superplasticizer and the hardening accelerator or the superplasticizer and silica fume (Table3). With the specified strength modification and hardening rates the concretes with similar admixtures are not only inferior to, but exceed the similar reference concretes.

Shrinkage

As is seen from Figure 1, OEA-3 agent ensures considerable shrinkage deformation reduction. For example, with 2% proportion by cement weight at 28-day age the shrinkage deformation reduction is 28%. With the agent proportion growth the shrinkage deformation

Table 3. Effect of OEA on the Rate of Hardening and Concrete Strength

Admixture	-	OEA-3	OEA-3 + PNS	OEA-3 + PNS + Accelerator	OEA-3 + PNS + SF
Dosage, % (by mass of cement)	-	6	6 + 0.6	6 + 0,6 + 2,5	6 + 0,6 + 10
Concrete mix proportions					
Cement, kg/m^3	352	348	356	352	353
Sand, kg/m^3	750	758	778	757	745
Coarse aggregate, kg/m^3	1125	1137	1167	1136	1117
Water, kg/m^3	182	181	135	147	161
W/C	0,52	0,52	0,38	0,42	0,46
Fresh concrete properties					
Slump, cm	2,5	2,0	2,5	3,5	3,0
Density, kg/m^3	2409	2445	2460	2424	2435
Compressive strength*					
1 day	11,3/28 100	5,4/17 48	8,8/22 78	12,1/29 107	11,6/28 103
2 days	21,4/53 100	14,1/44 66	20,8/51 97	23,1/56 108	21,2/51 99
3 days	25,9/64 100	17,9/55 69	25,4/62 98	27,2/66 105	25,4/62 98
7 days	32,7/81 100	24,5/76 75	33,4/82 102	34,0/83 104	33,0/80 101
28 days	40,4/100 100	32,3/100 80	40,8/100 101	41,2/100 102	41,2/100 102

* $\frac{R_j / \% R_{28}}{\% R^0_j}$, where R_j – compressive strength of concrete at the age of (j) days, MPa
R^0_j - compressive strength of reference concrete at the age of (j) days, MPa

reduction degree due to OEA-3 addition increases and for the specimen with OEA-3 6% addition is 64%.

Table 4 and Figure 2 show the results of concrete shrinkage deformation tests and OEA-3 agent introduction efficiency under different hardening conditions. The tests were conducted according to GOST 24544 procedure. With account of the above data on OEA-3 efficiency this agent was added to concrete mixes together with the superlasticizer. Naturally hardening specimens during the first day after casting were stored under normal conditions (temperature 20-25^{o}C, relative air humidity 95-100%). Some specimens after casting were steam cured according to the mode 2+3+6+2 (precuring + temperature rise + isothermal heating + cool-down) at the isothermal heating temperature 80-85^{o}C. These tests used fine-grained concrete on the basis of the Staryi Oskol Portland cement and the quartz sand with fineness modulus M_f = 2.37 as aggregates.

The results obtained show that throughout the tests the shrinkage deformations with OEA-3 agent are considerably lower than those of the reference concrete, with the shrinkage reduction extent being proportional to the agent amount. It has been established that for concretes after steam curing the above mentioned relationships are retained. Indeed, already at the early age shrinkage of concretes with OEA-3 is 2-4 times less than the reference concrete shrinkage. At the 56-day age of air-dry storage the reference concrete shrinkage deformations were 30.3x10^{-5} m/m, while for the concrete with OEA-3 agent their values did not exceed 14.4x10^{-5} m/m. The shrinkage deformation reduction in relation to the reference concrete was 52% in this case.

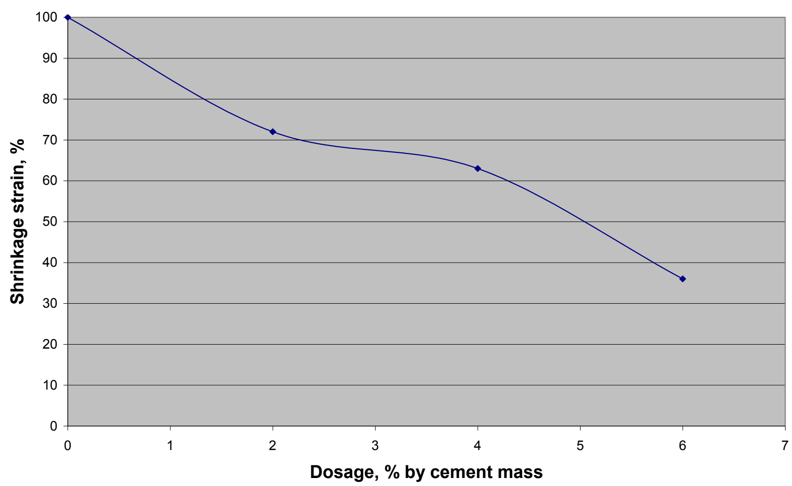

Fig. 1. Effect of OEA-3 on Relative Shrinkage Deformations of Mortar Specimens (28 days of air-dry storage)

Table 4. Effect of OEA on Shrinkage Deformation Value (10^{-5} m/m) for Fine-grained Concretes

Admixture	-	OEA + PNS		
Dosage, % cement mass.	-	2 + 0,6	4 + 0,6	6 + 0,6
Cement, kg/m^3	478	482	478	480
Sand, kg/m^3	1433	1524	1520	1442
Water, kg/m^3	252	189	190	189
W/C	0,53	0,39	0,40	0,39
Slump, cm	12,0	11,0	12,5	13,0
Density, kg/m^3	2163	2205	2210	2198
Shrinkage strain, $\varepsilon_{shr}\cdot10^5$ m/m / shrinkage reduction, %				
Normal curing				
2 days	4,5/0	4,3/4	4,0/11	2,2/51
7 days	14,1/0	7,7/45	7,2/49	6,3/55
14 days	26,0/0	16,4/37	14,9/43	7,6/71
21 days	33,5/0	21,1/37	19,5/42	10,6/68
28 days	40,8/0	28,8/29	24,0/41	13,3/67
56 days	49,0/0	35,5/26	28,8/40	18,0/63
After steam curing				
2 days	0,8/0	-	-	0,15/77
7 days	7,7/0	-	-	3,3/57
14 days	13,0/0	-	-	6,1/53
21 days	18,9/0	-	-	10,5/44
28 days	21,7/0	-	-	12,5/42
56 days	30,3/0	-	-	14,4/52

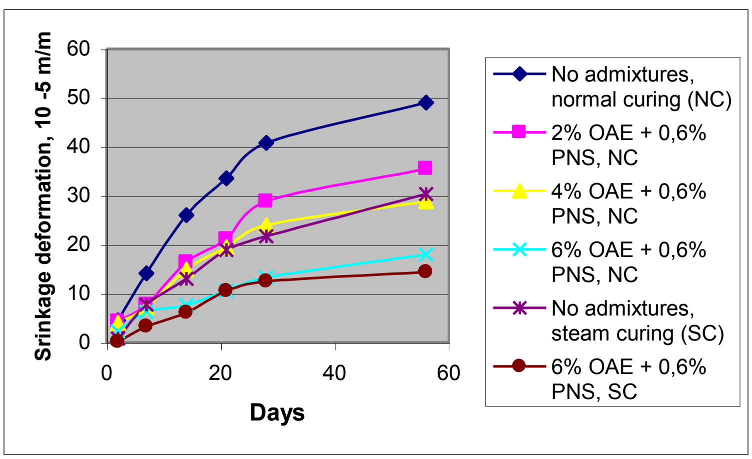

Fig. 2. Shrinkage Deformations of Fine-grained Concrete.

Table 5 and Figure 3 present the test results for concretes with OEA-3 agent and the use the Belgorod Portland cement PC500-D0 (CEM I 42.5) and aggregates having the following characteristics: washed crushed granite of 5-20 mm fraction and quartz sand of fineness M_f = 2.3 complying to GOST 26633 requirements. It has been established that with account of the reduction of concrete shrinkage deformations as compared to that of fine-grained one, the results obtained are in agreement with the above data. In all periods of hardening OEA-3 agent manifests high efficiency. At the 56-day age this agent particularly ensures (with 6% proportion by cement weight) reduction of shrinkage deformations by 57% in relation to the reference concrete.

Table 5. Shrinkage Deformations of Concretes with OEA

Admixture	-	OEA			OEA + PNS		
Dosage, % (by mass of cement)	-	2	4	6	2 + 0,6	4 + 0,6	6 + 0,6
Concrete mix proportions							
Cement, kg/m^3	471	475	468	475	483	477	462
Sand, kg/m^3	638	637	632	628	645	653	668
Coarse aggregate, kg/m^3	1075	1084	1076	1069	1098	1112	1137
Water, kg/m^3	193	190	192	190	151	143	134
W/C	0,41	0,40	0,41	0,40	0,32	0,30	0,29
Fresh concrete properties							
Slump, cm	12,5	13,5	15,0	13,0	12,5	15,0	14,0
Density, kg/m^3	2377	2395	2387	2390	2406	2413	2429
Shrinkage strain, $\varepsilon_{shr} \cdot 10^5$ m/m / shrinkage reduction, %							
2 days	4,5/0	4,0/11	3,7/18	2,8/38	3,3/27	2,8/38	1,5/67
7 days	9,3/0	8,8/5	7,5/19	6,6/29	7,0/25	6,4/31	4,9/47
14 days	14,7/0	14,0/5	12,2/17	10,5/29	11,6/21	9,5/35	7,4/50
21 days	17,9/0	17,0/5	15,9/11	13,0/27	16,0/11	13,6/24	8,1/55
28 days	20,4/0	18,3/10	16,8/18	14,2/30	17,1/16	15,1/26	9,5/53
56 days	23,8/0	20,2/15	18,1/24	16,5/31	18,4/23	15,6/34	10,2/57

Thus, the tests have shown that OEA-3 agent on the basis of mono-tert-butyl ether of diethylene glycol is an efficient means of reducing shrinkage deformations in different concretes irrespective of the hardening conditions (natural hardening or steam curing). Adding of OEA-3 agent to concrete mixes together with the superplasticizer and silica fume increases its efficiency.

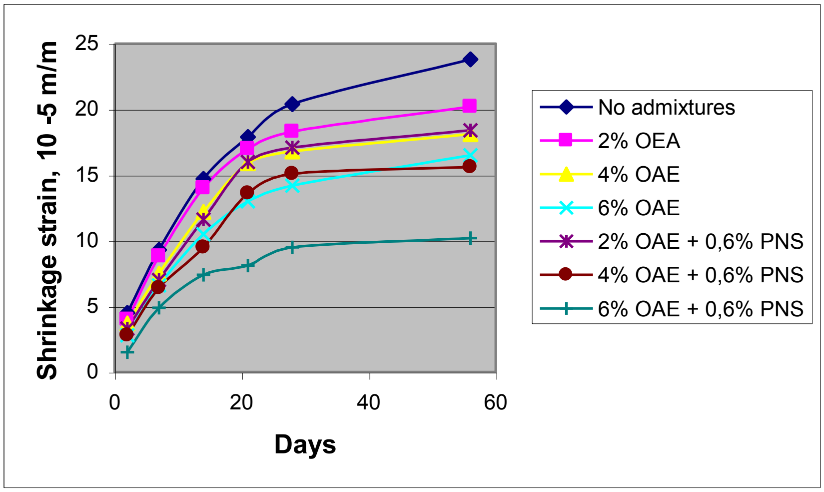

Fig. 3. Shrinkage Deformations of Concrete

In conclusion of consideration of OEA-3 modified concrete structural properties let us mention two more circumstances. First of all it should be emphasized that actually this agent in the studied proportion range (2-6% by cement weight) does not affect workability and storability of concrete mixes. Use of OEA-3 facilitates essential reduction of concrete mix air-entrainment and their density increase. It has been established that as a result of density rise and reduction of structural damage of concretes using OEA-3 the considerable (by 1.3-1.7 times) increase of concrete water-impermeability and frost-resistance is ensured due to shrinkage deformation reduction.

Void structure and durability

To predict properties of modified concrete the integrated studies in the void structure characteristics of concrete with organic expansion agents were conducted with regard to their type, proportion and hardening conditions. The effect of OEA-3 on the concrete void structure characteristics was explored studying the kinetics of their water absorption in conformance with the methods in GOST 12730.4. It was established that irrespective of hardening conditions the OEA introduction ensured reduction of volumetric water absorption that characterizes the volume of integrated effective porosity of concrete and reduction of the prevailing void diameter. Thus, OEA-3 together with PNS superplasticizer ensures considerable reduction of volumetric water absorption by concrete when hardened both in atmospheric and normal conditions – from 15.2 down to 12.9% and from 11.1 to 8.3%, respectively. The value of the average void size (λ_2 = 0.37) allows to refer [Sheikin et al., 1979] the normally hardened concrete with OEA-3 in combination with C-3 superplasticizer to materials with a micro porous structure (λ_2 = 0.51). Thus, one may state that the presence of OEA-3 in concrete maximally eliminates the negative effect of concrete curing in unfavorable conditions, probably, due to reduction of moisture loss and shrinkage strains.

The data on the nature of changes in cement system porosity are supported by the optical microscopy results. Parameters of the specimen porous structure were studied by the optical method using Gallery software. It is established that compared to the concrete of the reference composition without agents, the concrete with OEA have reduced porosity, with a less number of voids in the polished specimen plane, a lower total area of voids and their total perimeter as well as the lower coefficient of three-dimensional interval (distance factor).

The relative void content with the radius less than 1000 Å, when using OEA-3, increases from 29.3% for the reference composition to 35.9-37.1%, this being a factor enhancing the material water impermeability and durability [Powers, 1945]. At the same time the optical microscopy data and the results of determining kinetics of cement stone and grout water absorption evidence about the increase in cement systems with OEA of the relative volume of conditionally closed air voids, this being a factor of frost-resistance improvement.

Table 6 presents the test results for concretes with OEA-3 according to GOST 10060 and GOST 12730.5.

Table 6. Frost-resistance and Impermeability to Water of Concretes with OEA

Admixture	-	OEA			OEA + PNS		
Dosage, % (by mass of cement)	-	2	4	6	2 + 0,6	4 + 0,6	6 + 0,6
Concrete mix proportions							
Cement, kg/m^3	471	475	468	475	483	477	462
Sand, kg/m^3	638	637	632	628	645	653	668
Coarse aggregate, kg/m^3	1075	1084	1076	1069	1098	1112	1137
Water, kg/m^3	193	190	192	190	151	143	134
W/C	0,41	0,40	0,41	0,40	0,32	0,30	0,29
Fresh concrete properties							
Slump, cm	12,5	13,5	15,0	13,0	12,5	15,0	14,0
Density, kg/m^3	2377	2395	2387	2390	2406	2413	2429
Freeze-thaw resistance, R_c, MPa / k_{frost}, after cycles							
0	51,4	50,2	48,0	43,7	52,4	54,8	52,8
150	59,6/1,16	57,2/1,14	53,8/1,12	52,0/1,22	60,3/1,15	65,8/1,20	64,9/1,23
200	58,1/1,13	60,7/1,21	57,6/1.02	51,1/1,20	61,8/1,18	68,5/1,25	64,4/1.22
300	51,3/1,00	52,7/1,05	52,08/1,01	48,6/1,14	56,6/1,08	64,1/1,17	63,4/1,20
400	46,8/0,91	49,2/0,98	46,1/0,96	45,6/1,07	54,0/1,03	59,7/1,09	60,2/1,14
Impermeability to water in accordance with GOST 12730.5							
Mark	W8	W8	W10	W12	W10	W10	W14

OEA mode of action

Though consideration of the shrinkage deformation compensation mechanism for concretes with OEA is out of this presentation framework, we would like in brief dwell upon a number of experimental findings that may throw light on this mechanism. In literature there were repeated efforts to create an action model for these agents [Bentur et al., 2001, Bentz et al., 2001, Collepardi et al., 2005, Rajabipour et al., 2008], but until now the trustworthy OEA behavior pattern in concretes has been unavailable. In all papers devoted to studying the mechanism of shrinkage deformation reduction when similar organic compounds are introduced, the lead is gained by the experimentally observed considerable reduction of pore water surface tension in the OEA presence. This is accounted for by the dominating role of the capillary pressure in the shrinkage mechanism under concrete hardening at 45-90% of relative humidity. The capillary forces manifest themselves, when water starts evaporating from the capillaries about 350-530 Å in size. With further water removal the size of capillaries remained filled diminishes, thereby causing the rise of capillary pressure and compressive forces transferred to capillary walls, and resulting in compression of cement stone matrix – shrinkage. The value of capillary pressure that increases with water evaporation is proportional to the pore water surface tension. OEA drastically reduces the value of this parameter (down to ~40 dyne/cm) that may result in the noticeable reduction of shrinkage deformations under modified concrete hardening. It has been established that the surface tension of 1% OEA-3 water solution is 23.1 versus 72.7 dyne/cm for water. The surfactants of this agent are also proved by the analysis of surface tension concentration dependence for OEA-3 water solutions.

Further, if wetting ability of a cement clinker surface estimated by the value of cos Θ, is 0.76 (PC500-D0 Portland cement from the Staryi Oskol Cement Works), then for 1% OEA water solution the wetting ability reaches 0.89, i.e. OEA-3 agent markedly increases the wetting ability of cement clinker grain surface. Increasing water surface activity at the interface with air and solid phase owing to the use of this agent in conformance with generally accepted concepts shall increase the rate of binder hydration. As a matter of fact, OEA-3 reduces the strength gain rate during the first day of hardening. Thus, when introduced into a concrete mix, such agents act simultaneously according to several reaction mechanisms that may be opposite. It has been established that OEA-3 agent does not essentially affect the phase composition of hydration products. At the same time, adding this agent to a concrete mix is accompanied by slow-down of hydration processes, especially at the early hardening stage, this being expressed both in reduction of strength parameters and in increase of setting periods and slow-down of the plastic strength gain rate. To compensate the effect found, and accordingly, to reduce the structure-formation rate and strength characteristics one may recommend, as shown above, the procedures such as reduction of mixing water consumption owing to the use of efficient plasticizers or introduction of accelerating admixtures.

CONCLUSION

The recent years of the world building practice are characterized with development and practical use of efficient organic expanding agents (OEA), among which, particularly, one can refer as an example admixtures on the basis of polyalkyleneglycol. According to findings this OEA type ensures the concrete shrinkage reduction by 20-40% for 8 weeks of hardening (more than 60% -

jointly with PNS). The physical and chemical essence of the concrete shrinkage compensation process per se, when concretes are modified with organic expansion agents, has not received an unambiguous interpretation until now. None of the mechanisms of such modification offered to date provide an opportunity to formulate scientific principles of "the molecular design" of new OEA and to predict their properties, thereby opening a wide field of further research.

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REFERENCES

Bazhenov Yu.M. (2007). "Concrete Technology." M., ASV Publishing, 528 p. (in Russian).

Bentur A., Berke N. S., Dallaire M. P., Durning T. A. (2001). "Crack mitigation effects of shrinkage reducing admixtures", *Design and Construction Practices to Mitigate Cracking*, ACI SP-204, 155-170.

Bentz D.P., Geiker M. R., Hansen K. K. (2001). "Shrinkage reducing admixtures and early age desiccation in cement pastes and mortars." *Cem. Concr. Res*., 31 (7), 1075-1085.

Berke N.S., Dallaire M.P., Hicks M.C., Kerkar A. (1997). "New developments in shrinkage reducing." *Proceedings of the Fifth CANMET/ACI International Conference on Superplasticizers and Other Chemical Admixtures in Concrete*, 1997, ACI SP-173, 971-998.

Collepardi M., Borsoi A., Collepardi S., Olagot J. J. O., Troli R. (2005). "Effects of shrinkage reducing admixture in shrinkage compensating concrete under non-wet curing conditions", *Cem. Concr. Comp.*, 27 (6), 704-708.

Folliard K.J., Berke N. S. (1997). "Properties of high-performance concrete containing shrinkage-reducing admixture." *Cem. Concr. Res.*, 27 (9), 1357-1364.

Glekel' F.L., Kopp R.Z., Akhmedov K.S. (1986). "Hydration structure formation control using surface-active substances." Tashkent, «FAN» Publishing, 224 p. (in Russian).

Kovler K., Jensen O.M., Falikman V.R. (2005) "New Methods for Moisture Control of High-Performance Concrete." *2nd International Conference "Concrete and Reinforced Concrete – Development Trends", Moscow, Russia*, 2005, vol.1, 257-266.

Nmai C. K., Tomita R., Hondo F., Buffenbarger J. (1998). "Shrinkage-reducing admixtures." *Concr. Int.*, 20 (4), 31-37.

Powers T.C. (1945). "A Working Hypothesis for Further Studies of Frost Resistance of Concrete." *J. Amer. Concrete Inst. Proc.*, vol. 45, 285-295.

Rajabipour F., Sant G., Weiss J. (2008). "Interactions between shrinkage reducing admixtures (SRA) and cement paste's pore solution." *Cem. Concr. Res.*, 38, 606-615.

Sheikin A.Ye., Chekhovsky Yu.V., Brusser M.I. (1979). "Structure and Properties of Cement Concrete." M., Stroyizdat, 343 p. (in Russian).

Titova L.A., Bejlina M.I. (2001). "Expanded Admixtures for Advanced Concrete." *Beton i Zhelezobeton (Concrete and Reinforced Concrete)*, № 4, 24-27 (in Russian).

Volzhensky A.V., Bourov Ju.S., Kolokol'nikov V.S. (1979). "Mineral Binders." M., Stroyizdat, 2nd Ed., 480 p. (in Russian).