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ScienceDirect

Procedia Engineering 108 (2015) 608 – 615

Procedia Engineering

www.elsevier.com/locate/procedia

7th Scientific-Technical Conference Material Problems in Civil Engineering (MATBUD'2015)

Effect of lightweight aggregate on minimizing autogenous shrinkage in Self-Consolidating Concrete

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Abstract

Cracking is one of the main reasons for reduction of concrete durability, as it allows for penetration of water and aggressive chemicals leading to corrosion of rebars, deterioration and structural failure. Recently, rapid new developments in the new generation of concrete reveal the need for a better assessment of shrinkage and its effect on structural performance, as well as prevention and control of shrinkage. The shrinkage test methods that are codified in Poland (Graf-Kaufman and Amsler methods) allow for measurement of shrinkage deformation after removal of the forms, i.e. after 24 hours. In case of the new generation concrete with a low w/c ratio, the autogenous shrinkage is very important in the initial period of binding and hardening of concrete (up to 24 hours from casting). This paper presents the results of autogenous shrinkage tests for mortar and concrete. The autogenous shrinkage was tested using Auto-Shrink method. The crack resistance of concrete with regard to shrinkage deformations was tested using a ring-test method according to the ASTM Standard C 1698-09. Because autogenous shrinkage cannot be controlled by exterior curing procedures, the shrinkage tests were performed with light-weight aggregates saturated with water. Use of light-weight aggregates (LWA) allows for "interior curing" based on gradual release of water from presaturated LWA balancing interior moisture content. In addition, the effect of shrinkage reducing admixture on deformations of internally cured concrete was also tested. The test results confirmed the advantage of the considered internal curing for concrete. Internal curing can be successfully applied to concrete structures with low w/c ratio.

Peer-review under responsibility of organizing committee of the 7th Scientific-Technical Conference Material Problems in Civil Engineering

Keywords: lightweight aggregate; autogenous shrinkage; restrained shrinkage

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Peer-review under responsibility of organizing committee of the 7th Scientific-Technical Conference Material Problems in Civil Engineering
doi:10.1016/j.proeng.2015.06.186

1. Composition of mortar and concrete mix

The investigated mortars and concrete mixtures were prepared with Portland cement CEM I 42.5R (European Standard EN 197-1:2000), fly ash, silica fume, Sika Viscocrete 3 superplasticizer and lightweight aggregate Pollytag size of 0-4 mm and 4-8 mm, natural sand 0-2 mm (fine aggregate) and natural granite coarse aggregate size 2-8 mm. Pollytag is a lightweight aggregate obtained by sintering fly ash in temperature of 1000 °C – 1350 °C. Studied mortars had varying w/c ratio, thus different volume of natural fine aggregate and lower volume of superplasticizer. Recipes of mortars are presented in table 1.

Table 1. Composition of self-consolidating mortars.

Mortars	Cement [kg/m^3]	Additives [kg/m^3]		Water [kg/m^3]	SP [kg/m^3]	Fine Aggregate [kg/m^3]	w/c
		Fly ash	Silica Fume				
Z-1	450	72	38	113	20	735	0.25
Z-2	450	72	38	155	9	624	0.34
Z-3	450	72	38	180	4.5	557	0.40

The composition of lightweight concrete was based on modification of the SCC mix with natural aggregates, [6,7]. A constant amount of paste was assumed with a variable proportion of lightweight aggregate to natural aggregate. The w/c ratio assumed 0.34 and w/b ratio 0.28. Mixture proportions of the studied concrete mixtures are presented in table 2.

Table 2. Composition of self-consolidating concretes.

Mix	Cement [kg/m^3]	Additives [kg/m^3]		Water [kg/m^3]	SP [kg/m^3]	Aggregate [kg/m^3]			
						Natural		Pollytag	
		Fly ash	Silica Fume			0-2	2-8	0-2	4-8
M-1	450	72	38	155	11	624	1072	-	-
M-2	450	72	38	155	7.65	624	-	-	540
M-3	450	72	38	155	7.65	-	-	310	540

2. Rheology, density and strength properties of mortars and concretes

The slump flow of designed mortars was assumed to be between 24-26 cm. Mortars' rheology was tested with slump flow test and visual evaluation of segregation on the edge of the mix was performed. Results are presented in table 3. None of the studied mixes showed any signs of segregation, including bleeding.

Table 3. Rheology, density and strength properties of mortars.

Mortar		Z-1	Z-2	Z-3
Slump flow. D_{max}[cm]		24.5	24.0	25.5
V-funnel . t[s]		15.9	15.0	17.6
VSI				
Density after 28 [kg/m^3]		2210	2090	2030
Compressive strength $f_{c.4x4}$ [MPa]	28 days	87.24	70.73	70.22
Flexular strength f_{ctm} [MPa]	28 days	10.94	8.56	7.76