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LIGHT-WEIGHT SELF-COMPACTING FIBRE-REINFORCED CONCRETE

Rudolf Hela [1], Lenka Bodnárová [2]

Abstract

The article deals with self-compacting concrete mix-design with light-weight aggregate Liapor for strength class LC 25/28, D 1.6 and mix-design with light-weight aggregate Liapor combined with natural aggregate for class LC 40/44, D 1.8. These mix-designs were tested with synthetic fibres Chryso Fibre S50 in the amount of 1, 4 and 8 kg/m^3 and steel fibres 20 mm in the amount of 25 kg/m^3. Rheological properties were experimentally tested by means of Slump test, Orimet, J-Ring and L-Box immediately after mixing and at time intervals of 60 and 90 minutes after mixing. Volumetric changes including development of temperature of fresh concrete were measured for 7 days from the time of placing. Physico-mechanical properties of hardened concrete were observed - compressive strength after 7 and 28 days, tensile bending strength after 28 days, static and dynamic elastic modules, frost resistance, surface resistance to water and defrosting chemicals.

Keywords: Light-weight self-compacting fibre-reinforced concrete; self-compacting concrete; light-weight aggregate; rheological properties; physico-mechanical properties;

1 Introduction

Self-Compacting Light-Weight Concrete (SCLC) is a special type of concrete representing the latest trends of concrete technology. It combines advantages of light-weight and self-compacting concrete. It has several strong points - excellent heat-insulating properties, low volume weight with sufficient compressive strength and good workability enabling simple placing with no risk of poor vibrating. These properties enable this concrete to be used in wide range of applications of contemporary building industry, in particularly for renovation of older buildings, construction of heat-insulating floors and production of prefabricated structural elements. The crucial condition of SCLC production is application of natural or manufactured light-weight aggregate.

2 Special characteristics of SCLC design

Design and manufacture of light-weight concrete and particularly SCLC has specific problems related to high water-absorbing capacity of light-weight aggregate under both

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1) Brno University of Technology, Faculty of Civil Engineering, Institute of Technology of Building Materials and Components, Veveří 95, 662 37 Brno, Czech Rep., hela.r@fce.vutbr.cz

2) Brno University of Technology, Faculty of Civil Engineering, Institute of Technology of Building Materials and Components, Veveří 95, 662 37 Brno, Czech Rep. bodnarova.l@fce.vutbr.cz

normal and high pressure, to which SCLC can be subjected during pumping. Liapor can be used dry; however additional water has to be added to saturate it. This batch of water does not contribute to mastic cement; therefore it is not included in w/c ratio.

The other option is to saturate Liapor in advance. Experiments [1] with SCLC proved that it is expedient to soak the aggregate beforehand, for at least 24 hours in laboratory conditions to make sure the pores are saturated. The tests proved the results of mix-design with additional water are worse than the results of the mix-design with saturated aggregate. This holds true for both fresh and hardened concrete (rheological properties, compressive strength and freeze resistance). Yet, if we chose the mix-design with added water, it is essential to check water absorbing capacity of the aggregate used, maximal size of grain, way of transport and method of placing. In case of ready-mix concrete it is necessary to increase the volume of added water by the amount absorbed during transport and placing.

2.1 Special characteristics of design and manufacture of SCLC that have to be taken into account

- poor flowability and self-compacting capacity due to low volume weight of aggregate
- propensity of light-weight aggregate to segregate and rise to the top
- high porosity of aggregate causing higher absorption of mixing water into grains, hence poor hydration of cement, lost of workability in time and poor rheological properties of SCC.

3 Concrete with dispersed fibre reinforcement

Fibre-reinforced concrete is a special type of structural concrete containing fibres in addition to usual components. Even dispersion of fibres in concrete can considerably influence those properties which are usually considered to be weaknesses of concrete - resistance to tensile stress, brittle character of rupture and volumetric changes.

3.1 Types of fibres used

- Synthetic fibres Chryso Fibre S50, made from mix of polypropylene and polyethylene. Length of fibre is 50 mm, tensile strength 650 n/mm^2, Young's module of elasticity 5GPa and real specific gravity 920 kg/m^3. Dosing recommended by manufacturer is 4kg/m^3 of concrete.
- Straight steel fibres made by the Krampe Company. The fibres are made from steel wire with tensile strength over 1,100 N/mm^2, diameter is 0,5 mm, length 20 mm.
- Crimped steel fibres made by the Krampe Company. The fibres are made from steel wire with tensile strength over 1,100 N/mm^2, diameter 0.5 m and length 20 mm.
- Polypropylene fibres Fibrin 323 made by the Krampe Company. The fibres are monofilament with diameter 32 μm and length 12 mm. Recommended dosage is 0.91 kg/m^3. One cube meter of concrete than contains 1,200 million fibres.

4 Mix designs

Mix-designs were based on the equation of absolute volumes. Proportions of aggregate were determined by way of experiment in a set of tests aiming at optimal proportions of individual fractions. The amount of cement was always 370 kg/m^3. Fly ash from Detmarovice was used for all of the mix-designs, dosage for the mix design with solely light-weight aggregate Liapor was 50% of the dose of cement, for mix designs with combination of light-weight and natural aggregate 40% of volume of cement. Dosing of stabilizer SPT and superplasticizer Stachement 2000 was determined by way of experiment as well as the amount of mixing water - w/c ratio was between 0.29 and 0.47. Fibres were dosed according to recommendation of manufacturers. All of the mix designs used aggregate soaked in water for at least 24 hours. All four most common methods were used to test consistency of fresh SCC - Slump test, Orimet + J-Ring and L-box. Volumetric changes of fresh concrete were tested as well. Properties observed were compressive strength, tensile bending strength, splitting tensile strength - Brazilian test, dynamic modulus, static modulus, frost-resistance and resistance to water and CHRL.

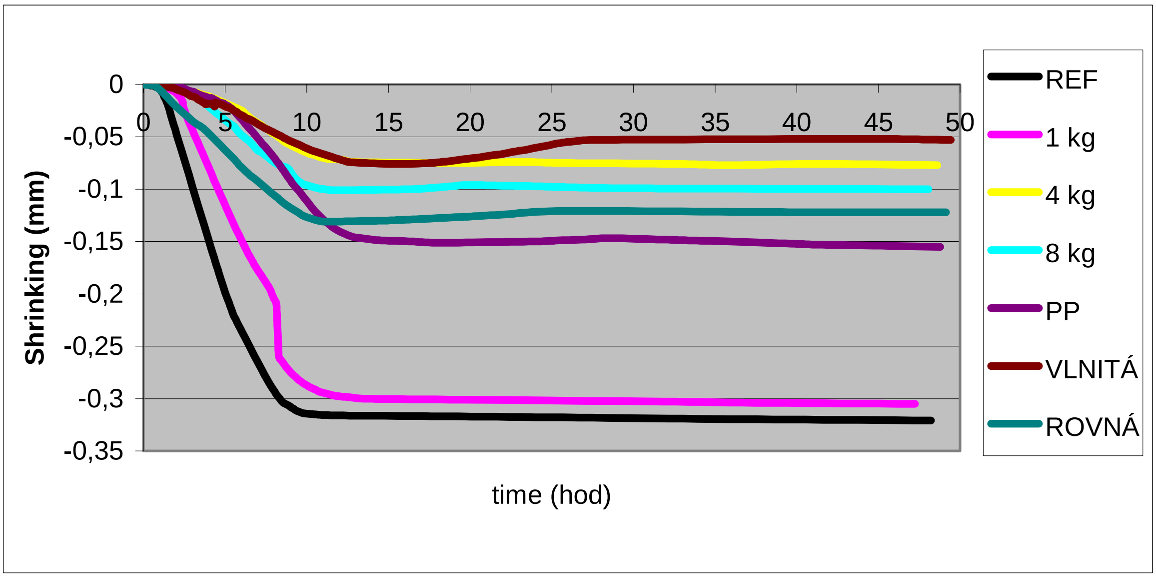

Fig. 1 Volumetric changes of concrete after mixing (note: values of shrinking are for the casting bed 375.55 mm long)

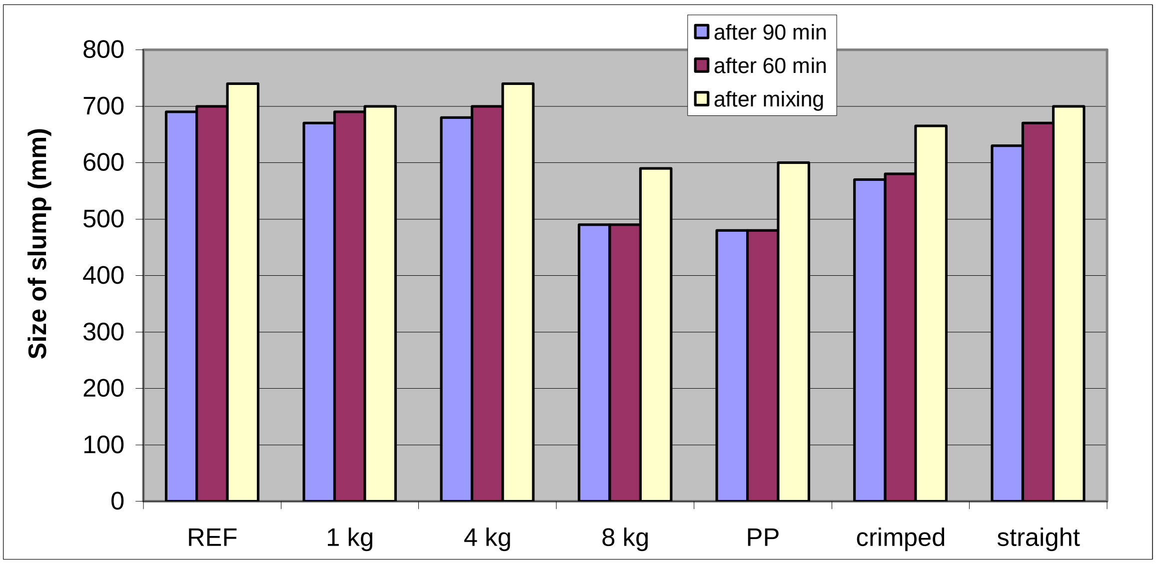

Fig. 2 Size of slump as a function of time (after mixing, after 60 min and 90 min)

Table 1: Results of tested properties Liapor and natural aggregate [2]

Mix-designs			REF.	REC I 1kg	REC I 4kg	REC I8 kg	REC I PP	REC I straight	REC I crimped
Volume weight of concrete[kg/m^3]	Fresh		1780	1780	1780	1790	1780	1820	1840
	hardened		1740	1740	1740	1740	1730	1750	1750
Test	time	recommended range							
Abrams T_{50} [s]	0	2 - 5	2,6	2,4	2,5	6,4	5,5	3,8	3,2
	60		4,0	4,1	4,2	-	-	8,2	4,4
	90		5,5	6,5	5,4	-	-	9,3	5,9
Abrams- slump [mm]	0	650 - 800	740	700	740	590	600	665	700
	60		700	690	700	490	480	580	670
	90		690	670	680	490	480	570	630
Orimet- flow time [s]	0	1 - 5	4,5	3,1	3,5	7,0	8,3	5,9	4,0
	60		7,3	4,8	4,8	9,1	13,4	12,1	7,2
	90		8,1	4,3	6,3	10,8	15,1	13,8	8,3
Orimet + J Ring - blocking [mm]	0	max 10	7	26	79	85	-	8	4
	60		9	39	-	-	-	20	8
	90		9	44	-	-	-	20	11
Orimet + J Ring - slump [mm]	0		650	680	490	-	500	620	680
	60		630	620	-	-	470	520	630
	90		630	650	-	-	470	500	630
L Box T40cm [s]	0		2,5	6,1	-	-	4,5	3,8	3,3
	60		3,9	9,8	-	-	9	5,9	4,6
	90		4,5	10,1	-	-	-	6,2	6,2
L Box total[s]	0		4,2	9,2	-	-	10	6	4,2
	60		7,6	13,4	-	-	28	12,3	5,9
	90		8,5	16,5	-	-	-	14,0	7,3
L Box h_2/h_1	0	0,8 - 1	1	0,92	-	-	0,74	0,89	0,95
	60		0,91	0,75	-	-	0,48	0,74	0,83
	90		0,84	0,63	-	-	-	0,63	0,75
Shrinking of fresh concrete[mm/m]			-0,855	-0,815	-0,205	-0,266	-0,155	-0,144	-0,328
Shrinking after 28 days– lab. conditions [mm/m]			-0,717	-0,617	-0,68	-0,87	-0,833	-0,799	-1,016
Shrinking after 28 days– in water[mm/m]			-0,083	0,113	0,44	0,167	0,053	0,133	0,08
CHRL 100 cycles [g/m^2]			R	22455	2323	11484	841	3806	3324
Coefficient of frost resistance[%]			97	97	96	91	94	93	96
Tensile bending strength [MPa]			2,5	3,2	3,3	3,2	3,0	2,6	2,5
Compressive strength [MPa]	7 days		29	29,5	32	36	28	36,5	33
	28 days		40	39,5	45,5	44	41	46,5	41,5
Splitting tensile strength [MPa] (Brazilian test)	limit of first crack		2,9	3,7	3,4	3,1	2,9	3,1	2,9
	Failure limit		3,9	4	5,3	5,5	4,2	4,4	4,5
Static modulus			17,4	17,2	21,3	20,5	21,2	22,2	20,4
Dynamic elasticity modulus- 28 days [GPa]			24,0	24,7	24,9	24,4	23,4	24,9	23,8
Volume weight class			D 1,8	D 1,8	D 1,8	D 1,8	D 1,8	D 1,8	D 1,8
Concrete strength class			LC 35/38	LC 35/38	LC 40/44	LC 35/38	LC 35/38	LC 40/44	LC 35/38

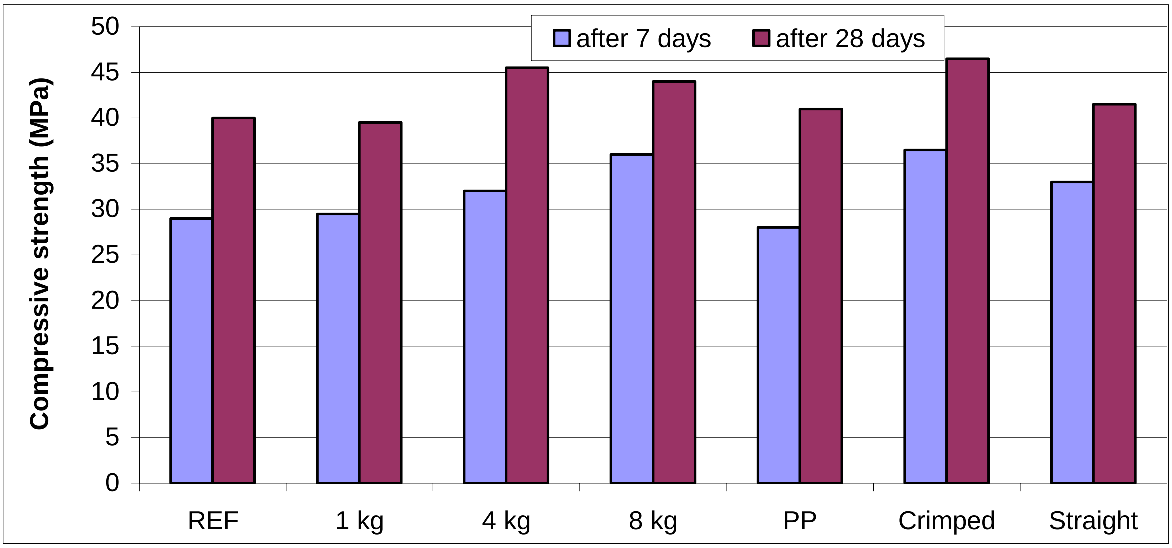

Fig. 3 Comparison of compressive strength after 7 and 28 days

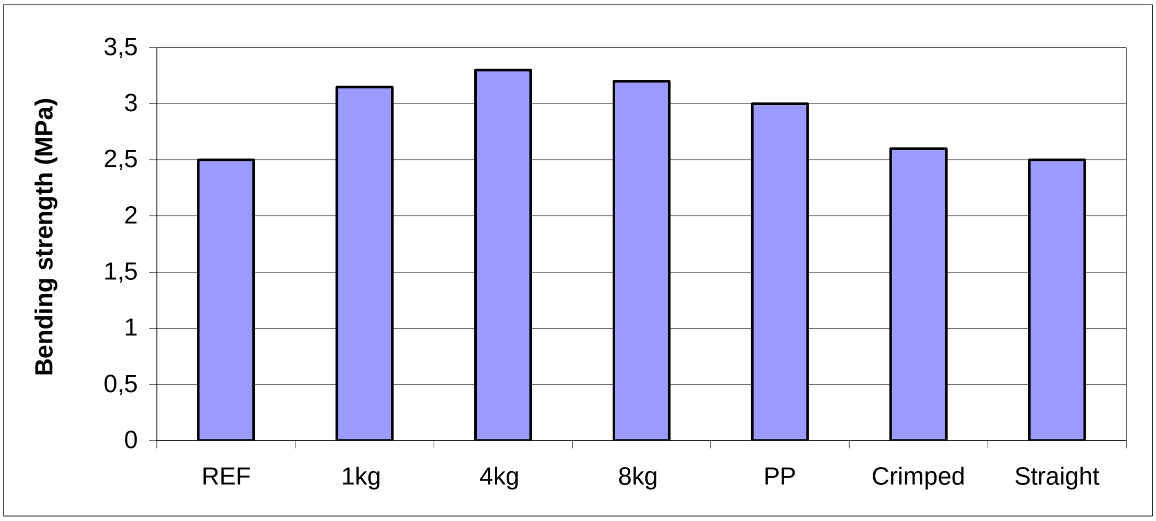

Fig. 4 Comparison of bending strength after 28 days

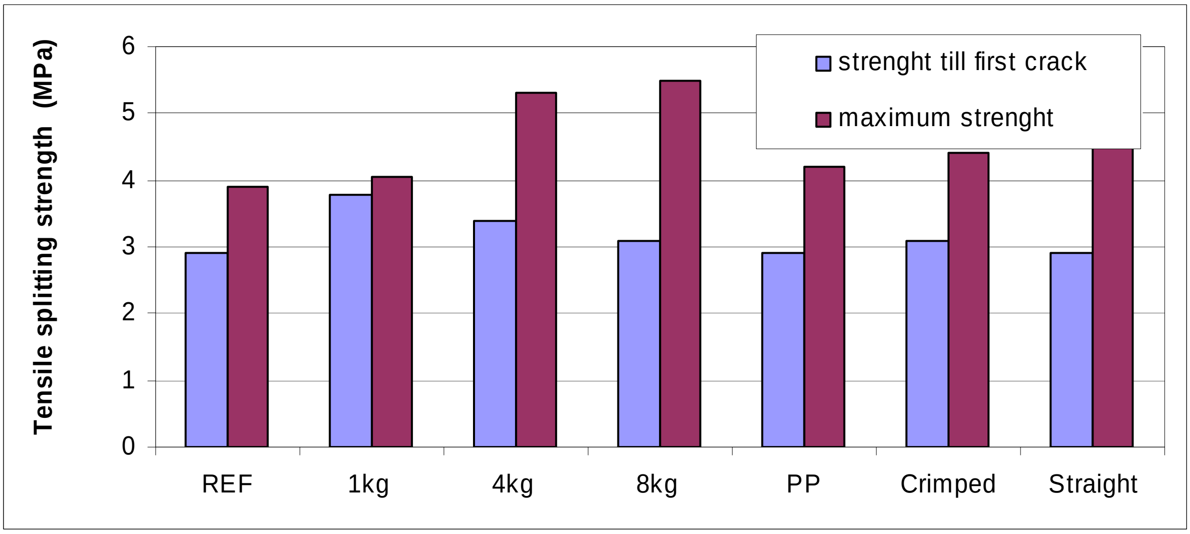

Fig. 5 Comparison of tensile splitting strength by Brazilian test after 28 days

5 Conclusions

Tested mix-design of LSCC showed good rheological and physico-mechanical properties. Adding synthetic fibres in greater amounts fundamentally changes rheological properties. The limit for synthetic fibres was 1 kg/m^3. The fibres tend to block on reinforcement of testing apparatus (like L-Box) and block passage of concrete. However, the fibres reduce shrinking of concrete. Synthetic fibres in the dose of 4 kg/m^3 and higher considerably increase tensile bending strength, compressive strength and in particular splitting tensile strength (Brazilian test). Brazilian test of mix-designs with steel and synthetic fibres gives two different outputs. The stressed specimen first shows a crack at the moment of matrix failure and then the stress is carried by dispersed fibres up to the moment of total failure. Another positive impact of fibres was proved by the CHRL test, where the fibres prevented disintegration of the concrete surface. If the concrete is exposed to adverse environment (dry conditions with no curing), it shows undesired shrinking. No influence of fibres on shrinking of hardened concrete in adverse environment regardless of the dosage of fibres was observed. Steel fibres partly worsened workability of fresh concrete, on the other hand the fibres improved volumetric changes and increased strengths of concrete - mix-design REC I. - Crimped showed the highest compressive strength and the highest static modulus of all tested mix-designs; this type of fibres also increased splitting tensile strength. In general we can say that the mix-design shows no resistance to CHRL. In most of the cases the tested surface disintegrated after 100 cycles and the loss was higher than 5,000 g/m^2. On the other hand, the mix-design is resistant to frost and the frost-resistance coefficient was higher than 90% after 100 freeze-thaw cycle.

Aknowledgements

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References

[1] Kolář, M.: *Lehké samozhutnitelné betony s kamenivem Liapor,* Diplomová práce 2004, VUT Brno, Fakulta stavební 2004

[2] Tesař, D.: *Lehké samozhutnitelné betony,* Diplomová práce 2006, VUT Brno, Fakulta stavební 2006

[3] Hela. R., Hubertová, M.: *Lightweight High Performance Conceret,* The second FIB congress Napless Italy 2006