Development of green self compacting concrete containing low clinker cement and calcareous fly ash

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Introduction

Green Concrete - concrete that has had extra steps taken in the mix design and placement to insure a sustainable structure and a long life cycle with a low maintenance surface. e.g. energy saving, CO_2 emissions, waste water.

optimized use of materials and mix design

enhanced workability in fresh state, best by the aim for obtaining self-compacting concrete (SCC).

enhanced durability and service life

The paper presents a concept of green self-compacting concrete (SCC), emphasizing mostly the minimization of the amount of clinker in concrete and obtainment of their low hardening temperature.

The main purpose of this SCC concrete are massive and semi-massive constructions, as well as the hot weather concreting

Self compacting concrete

SCC mixtures is designed for a combination of flowability, ability to pass through and around reinforcement without blockage, ability to remove air from the mix and resistance to segregation.

w/c < 0.50 (w/b < 0.4)
water - 160÷200 dm^3/m^3
fine fraction (0-0,125 mm) - 450÷600 kg/m^3
Segregation resistance, bleeding

Paste volume - 300÷400 dm^3/m^3
Segregation resistance, bleeding

Sand content - 40÷50% of total aggregate
Segregation resistance

Aggregate – coarse , max 16 mm
Segregation resistance

Effective superplasticizer
Flowability

Viscosity enhancing admixture
Segregation resistance, bleeding

Concrete for massive construction

Massive concrete composition is designed so that the amount of heat generated by cement hydration is minimized.

Constituents selection (cement, admixtures and additives)
low hardening temperaturę, low hydration heat

Low cement content, low content of finest fraction
Lower hardening temperaturę and sensibility of concrete for cracking

Low water content
Lower shrinkage, lower setting, lower concrete cracking

w/c > 0,5
reduced hardening temperature

Sand content 30 – 35%
Aggregate – max. 32 mm
Lower external stress, technology
Thermal conduction and thermal expansion coefficients

Green, low hydration SCC

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Lower shrinkage, lower setting, lower concrete cracking

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Aggregate – max. 32 mm
Lower external stress, technology
Thermal conduction and thermal expansion coefficients

w/c = 0.35 ÷ 0.60 (w/b = 0.35 ÷ 0.45)
water - 160÷200 dm^3/m^3
fine fraction (0-0,125 mm) - 450 kg/m^3

Paste volume - 300 dm^3/m^3

Low heat cement (CEM III/B)
+ mineral admixtures (CFA, quartz and limestone mill)

Aggregate – coarse , max 16 mm

Effective superplasticizer (retarding effect)

SCC proportioning

Ingredients [kg/m³]	B0	B1	B2	B3	B4
CEM I 52,5	451				
CEM III/B 42,5		306	238	250	253
CFA (ground)			104		
Quartz powder				135	
Limestone powder					125
Sand 0-4 mm	800	969	998	997	880
Coarse 4-11 mm	437	363	372	374	420
Coarse 8-16 mm	538	451	468	464	490
Water	171	193	151	158	160
SP	3.91	2.90	7.78	5.45	5.28
$w_{eff}/(c+a)$	0.38	0.63	0.44	0.41	0.42
w_{eff}/c	0.38	0.63	0.63	0.63	0.63
Cement paste volume, dm³	320	294	270	293	291
Clinker content in concrete	**428**	**77**	**60**	**62.5**	**63**

Testing methods

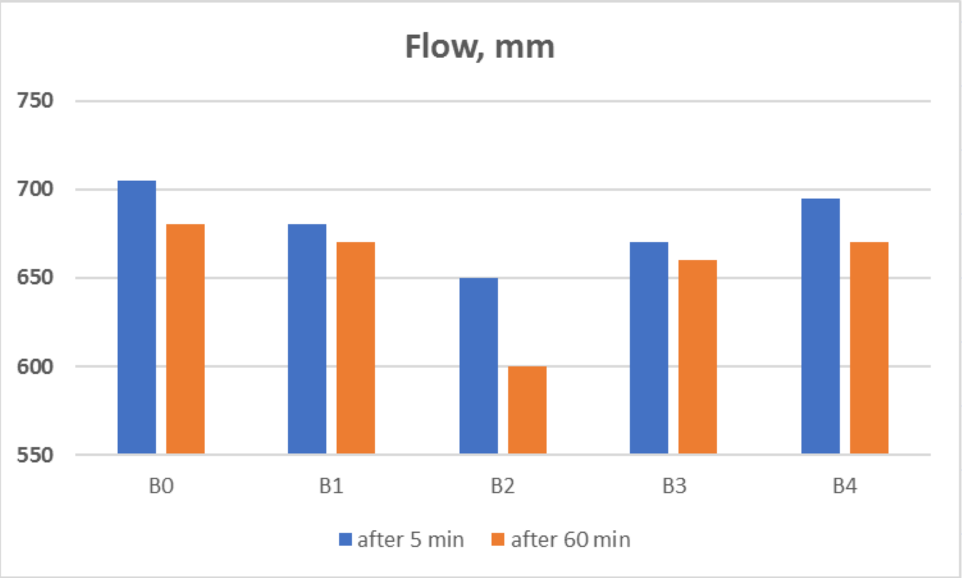
- Properties of fresh SCC - slump-flow - EN 12350-8. VSl Stability Index -ACI 237 R-07; 2007. Air content - EN 12350-7.
- Setting time of concrete - ultrasonic method - modified Schleibinger Vikasonik system.
- Development of concrete temperature - cubic samples 250 mm on a side insulated using styrofoam coating
- Early shrinkage – modified Schleibinger TLS apparatus on samples 10x10x50 cm during 24 hours from the moment of placement.
- Compressive strength after 2, 7 and 28 days - EN 12390-3.
- Hydration heat - for binders and admixtures used in tested concretes hydration head and hydration kinetics were measured using isomeric calorimeter TamAir produced by TA Instruments.

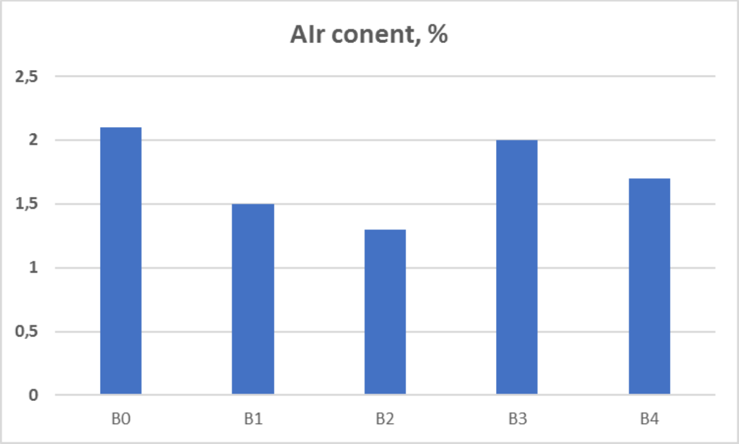
Test results

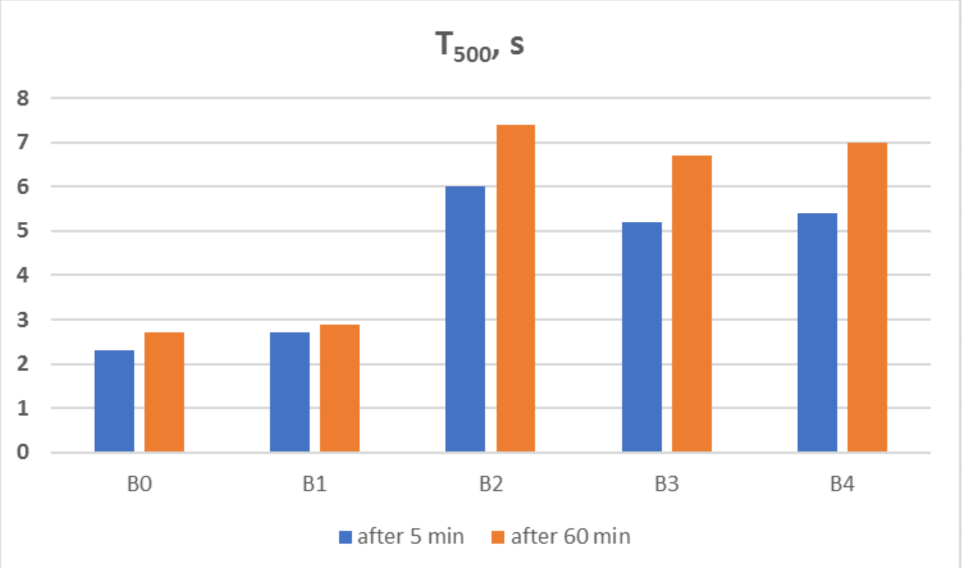
Property		B0	B1	B2	B3	B4
Flow, mm	after 5 min	705	680	650	670	695
	after 60 min	680	670	600	660	670
Flow time T_{500}, s	after 5 min	2.3	2.7	6.0	5.2	5.4
	after 60 min	2.7	2.9	7.4	6.7	7.0
Air content, %		2,1	1.5	1.3	2.0	1.7
Setting time of concrete, h:min		6:36	10:04	12:00	10:12	9:43
Shrinkage after 24 h, mm/m		0.93	1.03	1.39	1.36	1.22
Maximal temperature, °C		72.9	34.8	32.2	30.0	32.2
Time of maximal teperature, h:min		29:54	36:55	51:28	45:56	43:56
Compressive strength, MPa	after 1 day	34.3	2.27	4.9	1.2	1.98
	after 7 days	58.6	25.4	36.0	31.0	29.4
	after 28 days	77.8	41.4	48.3	44.8	42.5

Properties of SCC

B0 – CEM I
B1 – CEM III/B
B2 – CEM III/B + CFA
B3 – CEM III/B + Q
B4 – CEM III/B + L



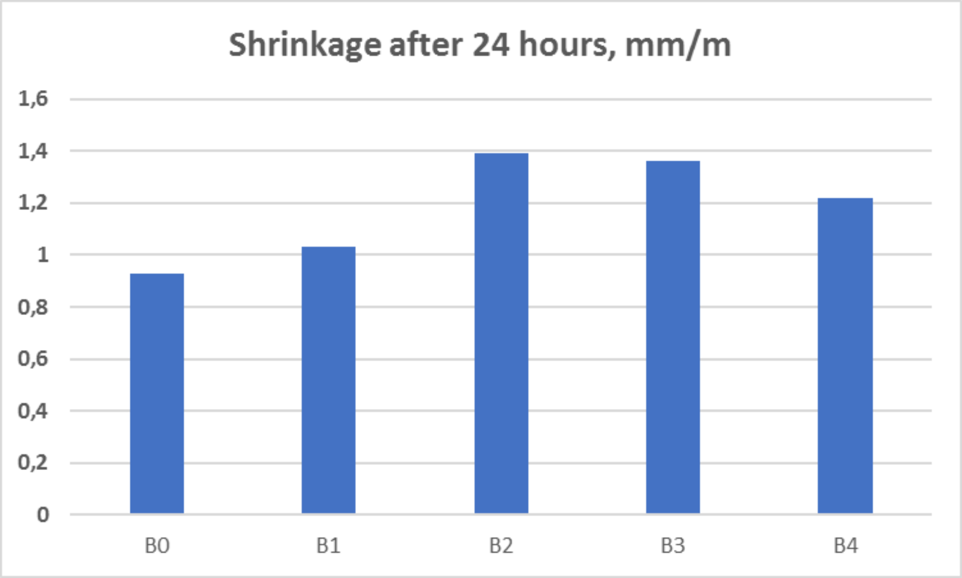




SP	**3.91**	**2.90**	**7.78**	**5.45**	**5.28**

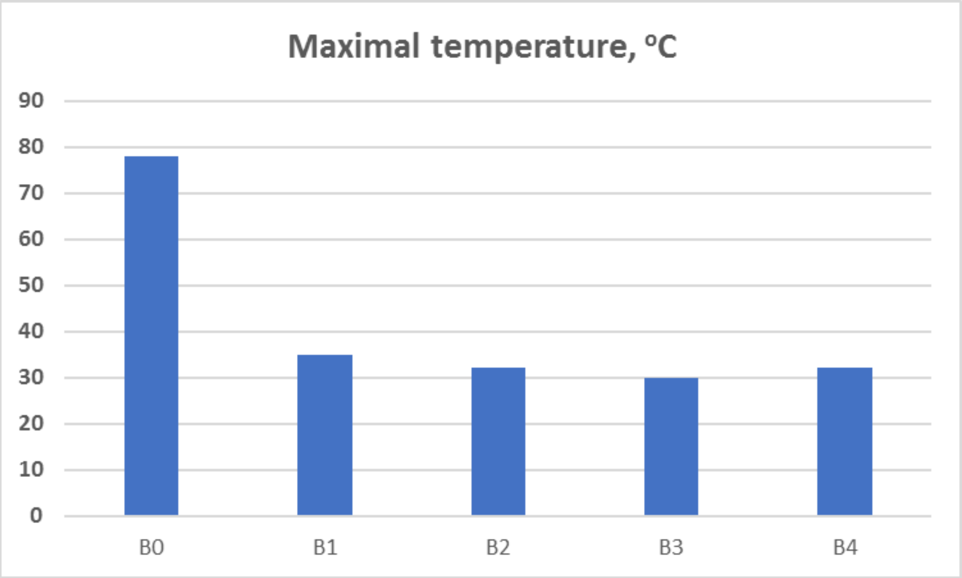
Settig time and shrinkage

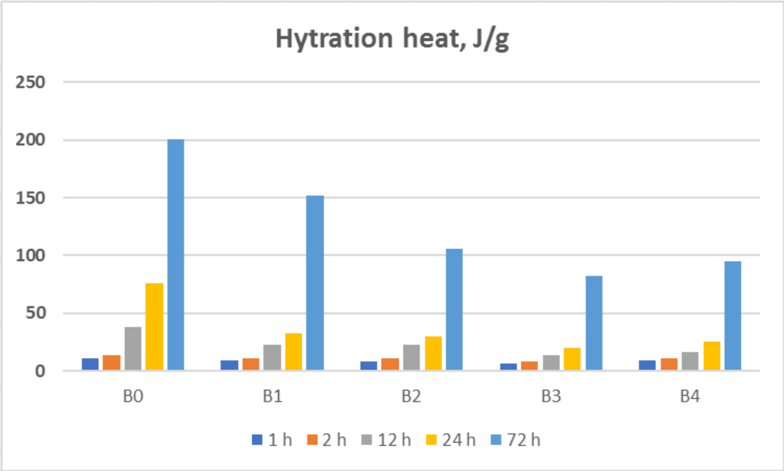
B0 – CEM I
B1 – CEM III/B
B2 – CEM III/B + CFA
B3 – CEM III/B + S
B4 – CEM III/B + L

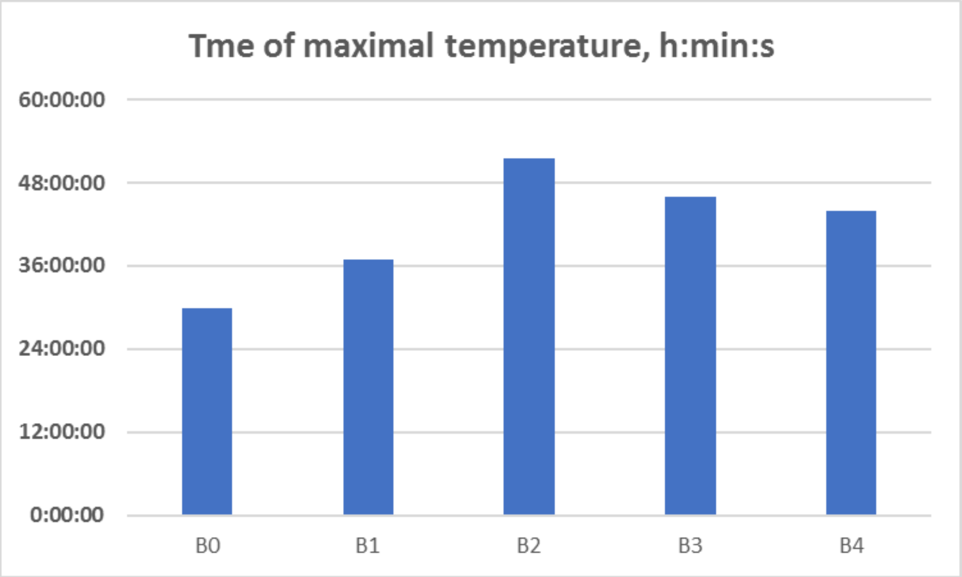


Temperature kinetics

B0 – CEM I
B1 – CEM III/B
B2 – CEM III/B + CFA
B3 – CEM III/B + S
B4 – CEM III/B + L

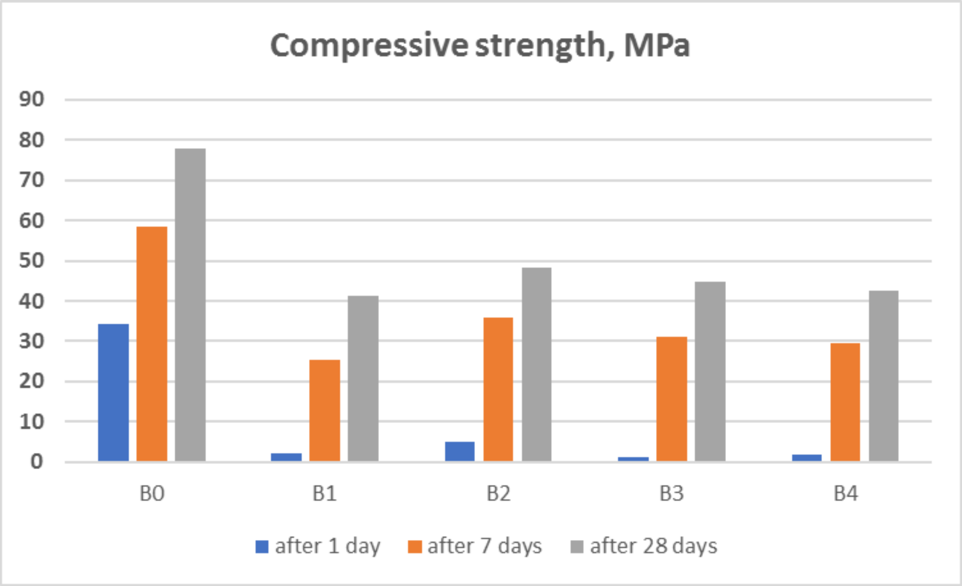






Compressive strength

B0 – CEM I
B1 – CEM III/B
B2 – CEM III/B + CFA
B3 – CEM III/B + S
B4 – CEM III/B + L



Summary

It was demonstrate that by optimizing materials and mix composition green SCC, characterized by low hardening heat can be obtained.

SCC are characterized by the low content of clinker, amounting from 60 to 77 kg/m^3 and good strength properties. It can be also assumed that those concretes, due to the high content of blast-furnace slag, will be characterized by the adequate durability, however it requires further experimental verification.

Ground calcerous fly ash can be used for self-compacting concrete, without negatively affecting its properties after hardening.