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High water-cement ratio SCC robustness with novel cellulose based admixture

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ABSTRACT

Novel cellulose based admixture (NCBA) grades were used to enhance medium strength SCC (w/c 0.60) robustness. Comparison was made with the use of limestone powder and a commercial stabilizer. Robustness was evaluated by measuring the effect of water content variation on slump-flow, viscosity by t_{500}-time, sieve segregation and water bleeding. Hardened concrete segregation and strength was also evaluated. Robustness assessment was based on selected limiting values for both workability and stability properties. Novel cellulose based admixture was an effective way in SCC robustness enhancement. Robustness evaluation was possible by common SCC testing.

Key words: Self compacting concrete (SCC), robustness, stability, novel cellulose based admixture

1 INTRODUCTION

There are several well known advantages in the use of self compacting concrete (SCC), but it may be difficult to produce robust SCC with a relatively high water-cement ratio (w/c), e.g. with w/c 0.50 – 0.60. The use of extra fine powder material is not always desired and availability of good filler may also be a problem. It would also be an advantage to be able to spare natural filler material resources when producing medium strength concrete.

In this study two grades of a novel cellulose based admixture (NCBA) were used. The effect of NCBA on the robustness of a SCC with w/c 0.60 was studied. Measurement of compressive strength was included. Comparison was made with a SCC with limestone powder (LP) and a SCC with commercial viscosity modifying stabilizer (S). This study is related to rheological studies with cement pastes, mortars and concretes presented here elsewhere [Vehmas 2011] and studies on the effect of NCBA on microstructure and hydration. Applicability of NCBA for other cement based products such as injection grouts and foam concrete are also underway and have already confirmed the effects of NCBA on cement based materials rheological properties and robustness.

The action of NCBA in SCC is based on the fact that it forms a stable gel-like structure with water. Only a low dry material content is needed for the reaction (dry material < 1 % in water). This gel has a high yield stress but low viscosity with a thixotropic nature.

2 EXPERIMENTS

2.1 Methods

The main idea was to first make basic SCC-mixes (4 basic mixes with w/c 0.60) with as optimal properties as possible by using two DCBA grades, limestone (GL) and a commercial stabilizer (S). The basic SCC slump-flow was 660 – 690 mm and t_{500}-time was 2.0 – 3.2 seconds. After that all the mixes were reproduced, but now with 5 % lower and 5 % higher total effective water content (±10.5 litres/m^3), i.e. with w/c 0.57 and w/c 0.63. The robustness of all the mixes was evaluated by the same measurable ways. Robustness checking is commonly recognized as an important step in the SCC mixture design process.

2.2 Materials and mixing

Cement CEM II/A-M(S-LL) 42.5 N (Yleissementti from Finnsementti Oy) was used in all the mixes. Natural Finnish aggregates and filler were used. Ground limestone SB63 (from Nordkalk OyAb) was used in powder type for the SCC mixes (GL). The superplasticizer was Glenium 51 from BASF. In one mix (S) commercial melamine sulphonate based stabilizer was used (dry material content 3 %). The novel cellulose based admixture grades, designated here as NCBA-1 and NCBA-2, were from UPM-Kymmene Corporation. Mixing was performed with a normal laboratory concrete mixer. NCBA and S were added last, with 3 min mixing time after adding.

2.3 Mixes

Mix designs for the basic SCC-mixes with w/c 0.60 are presented in Table 1. Each mix was repeated two times but then with the total effective water content either 5 % lower or higher (w/c was 0.57 or 0.63, see Table 2).

Table 1. Mix designs for the basic SCC-mixes.

	Basic SCC			
	NCBA-1	NCBA-2	S	GL
Cement [kg/m^3]	350	350	350	350
Aggregates [kg/m^3]	1785	1785	1785	1474
Ground Limestone (GL) [kg/m^3]	0	0	0	311
Effective water [kg/m^3]	210	210	210	210
Water/Cement ratio (w/c)	0.60	0.60	0.60	0.60
Plasticizer Glenium 51 (17.5 %) [% of cement]	1.60	1.60	1.60	1.40
Dry NCBA [% of cement]	0.080	0.220	0	0
Stabilizer, S [% of cement]	0	0	1.00	0

2.4 Fresh and hardened concrete testing

Fresh concrete testing was performed soon after mixing. Workability testing was done first, including slump-flow [EN 12350-8] and t_{500} time measurement. After that was sieve segregation testing [EN 12350-11] and measurement of water bleeding. For bleeding a container with a volume of 2 litres was used and these container-specimens were split vertically after hardening to detect concrete homogeneity and possible aggregate settlement. 150 mm cubes were made from the basic SCC mix (w/c 0.60) for the measurement of compressive strength at 1 d, 7 d and 28 d.

2.5 Results

Fresh and hardened concrete measurement results are presented in Table 2 and Figure 1.

Table 2. Fresh and hardened concrete measurement results.

w/c	SCC	t_{500}-time [s]	Slump-flow [mm]	Bleeding (2 h) [vol.-%] 1)	Sieve segregation [w.-%]	Compressive strength [MPa] 1 d	7 d	28 d
0,57	NCBA-1 -5% water	8,0	540	0,2	0,6	-	-	-
0,60	NCBA-1	2,4	690	0,3	3,2	5,5	33,0	39,8
0,63	NCBA-1 +5% water	1,1	730	1,5	8,3	-	-	-
0,57	NCBA-2 -5% water	16,0	500	0,2	0,4	-	-	-
0,60	NCBA-2	3,2	660	1,3	3,2	5,5	30,6	36,1
0,63	NCBA-2 +5% water	2,5	675	1,8	7,2	-	-	-
0,57	S -5% water	3,0	610	0,8	2,4	-	-	-
0,60	S	2,9	690	2,7	10,4	5,3	31,9	37,5
0,63	S +5% water	2,5	630	2,8	16,7	-	-	-
0,57	GL -5% water	2,4	570	0,1	3,7	-	-	-
0,60	GL	2,0	670	0,1	5,4	11,1	37,3	43,4
0,63	GL +5% water	1,1	780	0,2	8,8	-	-	-

1) Vol. = 2 litres, h = ca. 160 mm, A = ca. 140 cm^2

Based on visual examination, there was no significant settlement of aggregates in any SCC.

3 ROBUSTNESS EVALUATION AND CONCLUSIONS

Robustness can be evaluated based on the testing results by finding out the range for permissible water content variation, and thus also for the corresponding w/c range. Based on the selected limiting values, several values for robustness could be calculated. The lower limiting value for w/c can be based on slump-flow or t_{500}-time and the higher value on sieve segregation or water bleeding. Two examples on robustness evaluation are presented in Figure 2. In Table 3 there are three robustness values based on limiting values: slump-flow 550 mm, t_{500}-time 7 s, sieve segregation 10 % and water bleeding 1.5 %. In some cases minor extrapolation was necessary for robustness evaluation and in some cases the lowest/highest value for w/c could not be measured as testing results were far ahead of the limiting value. In Table 3 there is also the minimum determined robustness value (minimum $\Delta(w/c)$), i.e. the lowest w/c range meeting all the limiting values.

The novel cellulose based admixture, and in this case especially NCBA-1, was effective in enhancing high w/c (0.60) SCC robustness. It was competent even compared with the powder type GL-SCC and e.g. robustness based on slump-flow and sieve segregation was even better with NCBA-1 than with a high content of limestone powder. For the basic NCBA-1, the t_{500}-time was about the same as for GL-SCC, but it decreased more than for GL-SCC with 5 % less water. Overall, the presented way for robustness evaluation was versatile and made it possible to select the most relevant limiting values for the actual case.

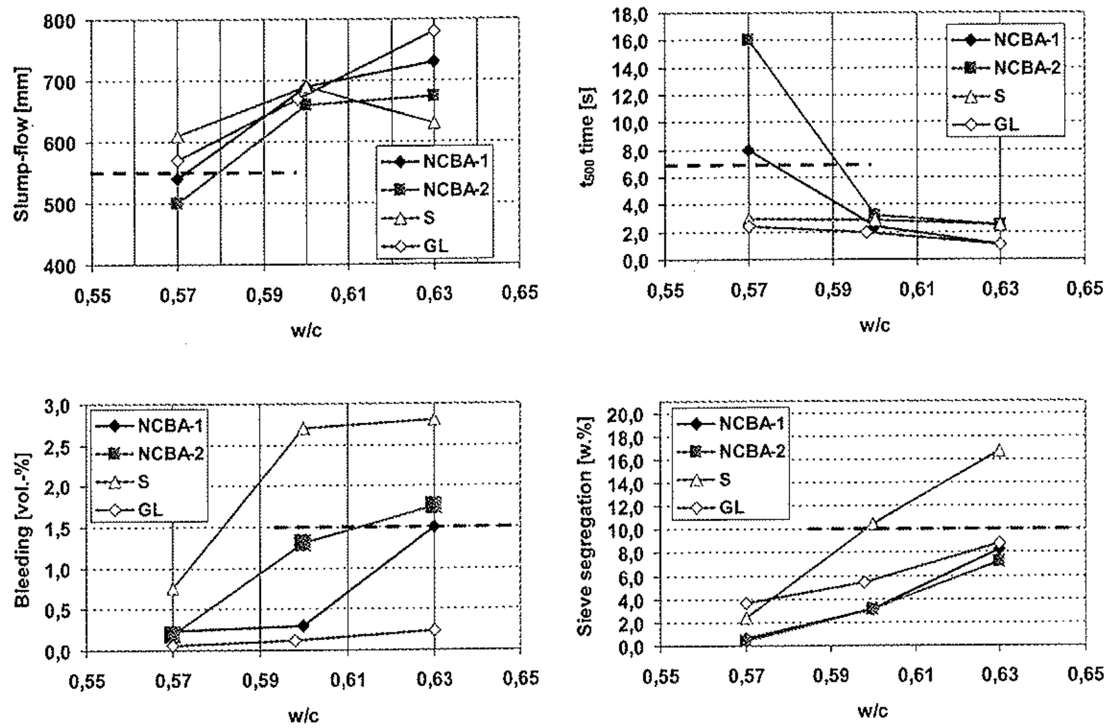

Figure 1. Fresh SCC measurement results as function of w/c.

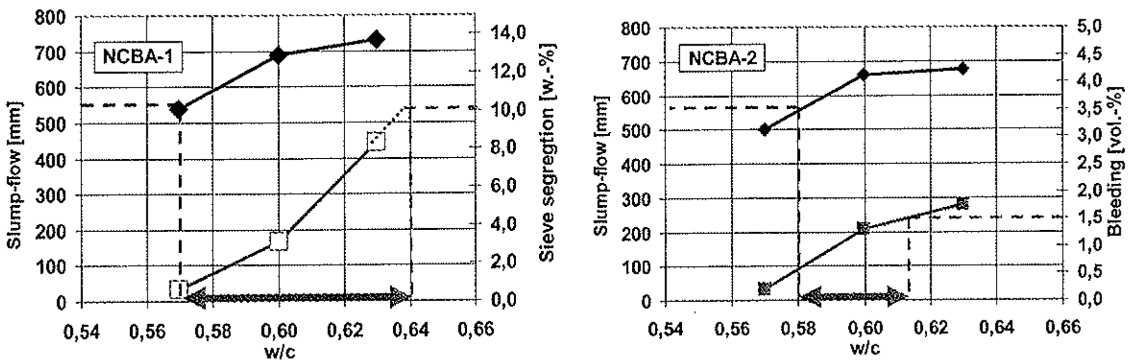

Figure 2. Example of robustness evaluation. Allowable w/c-range for slump-flow >550 mm and sieve segregation <10 %.

Table 3. Determined limiting w/c values for robustness representing slump-flow >550 mm, t_{500}-time >7 s, sieve segregation <10 % and water bleeding <1.5 %.

SCC	Limiting w/c-values for robustness evaluation						Minimum Robust-ness [Δ(w/c)]
	Slump-flow and Bleeding		Slump-flow and Sieve-segregation		t_{500}-time and Sieve segregation		
NCBA-1	0,575	0,630	0,568	0,638	0,576	0,636	0,055
NCBA-2	0,580	0,615	0,577	0,647	0,592	0,648	0,035
S	0,553	0,583	0,548	0,596	*0,570* 2)	0,597	0,030
GL	0,566	*0,630* 1)	0,562	0,636	*0,570* 2)	0,636	0,074

1) The real value is much higher, but could not be estimated
2) The real value is much lower, but could not be estimated