Robust flowable concrete with viscosity agents

S. Grünewald
Delft University of Technology, Delft (NL)
Ghent University, Ghent (B)

J.C. Walraven
Delft University of Technology, Delft (NL)

Dresden
17 September 2014

Technische Universiteit Delft

Outline presentation

- Robustness
- Experimental set-up
- Comparison of results
- Relative robustness
- Conclusions

Robustness

Robustness requirements

Viscosity				Segregation resistance/ passing ability
VS 2 VF 2	Ramps			Specify passing ability for SF1& 2
VS 1 or 2 VF 1 or 2 or a target value.		Walls and piles	Tall and slender	Specify SR for SF 3
VS 1 VF 1	Floors and slabs			Specify SR for SF 2 & 3
	SF 1	SF 2	SF 3	
	Slump-flow			

Other flowable mixtures?

TU Delft

Robustness

Flowable concrete and robustness

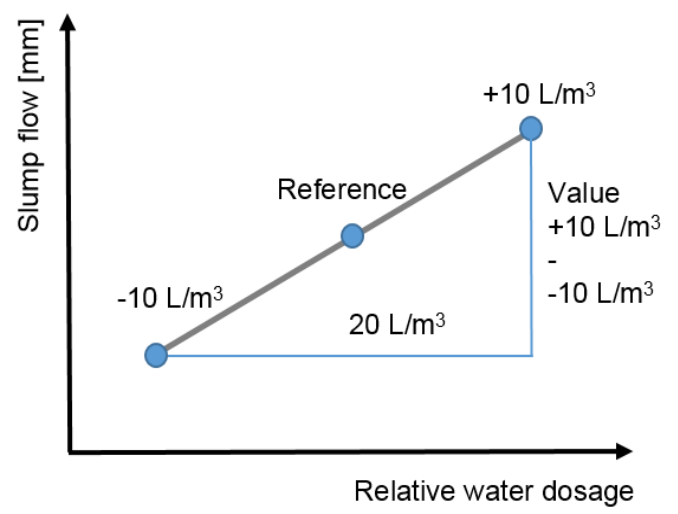
- No/little compaction energy
- Major design criterion
- Ready-mix producer: acceptance criteria
- Contractor / producer of prefabricated elements: quality of structure or products
- Time, quality concrete component, temperature, accuracy of instruments

Definition of robustness?

TU Delft

Robustness

Categories for robustness



Application
Architectural concrete
Risks

Category	Target range	Unit	C1 (> 8 l/m³)	C2 (5-8 l/m³)	C3 (< 5 l/m³)
Slump flow	100 mm	[mm/L/m³]	<6.2	6.2-10	>10
Sieve stability	10 %	[%/L/m³]	<0.62	0.62-1	>1
L-box ratio	0.20	[-/L/m³]	<0.012	0.012-0.02	>0.02

TU Delft

Experimental set-up

Seven reference mixtures

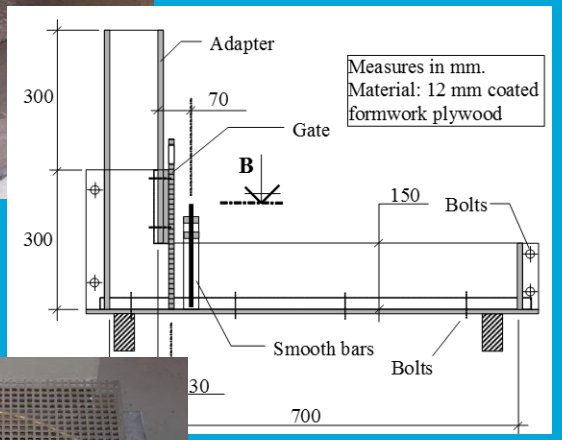
Mixture	A1	A2	A3	B1	B2	C1	C2
Mixture component	[kg/m³]	[kg/m³]	[kg/m³]	[kg/m³]	[kg/m³]	[kg/m³]	[kg/m³]
Slump flow [mm]	**753**	**688**	**768**	**713**	**678**	**743**	**723**
CEM I 52.5 R (ENCI Maastricht)	-	-	-	436	424	274	290
CEM III 42.5 N (ENCI Rotterdam)	373	373	373	-	-	-	-
Fly ash (SMZ)	125	125	125	138	135	101	100
Water	178	178	179	165	171	192	180
Fine sand (0.125-0.25 mm)	-	-	-		-	105	106
Sand (0.125-4 mm)	866	866	866	884	884	810	819
Coarse aggregates (4-16 mm)	762	762	762	716	716	804	813
Superplasticizer: Glenium 51	-	-	-	(3.87)	(3,76)	-	-
Superplasticizer: Glenium 27	(3,18)	(3,18)	(3.18)	-	-	(6.00)	(8.58)
VA: Foxcrete (Avebe)	-	-	-	-	-	(2.02)	-
VA: ST5 (Sika)	-	(0,76)	-	-	(0,84)	-	(1,00)
VA: Glenium Stream (BASF)	-	-	(1.27)	-	-	-	-
Water-binder ratio [6]	0.45	0.45	0.45	0.36	0.36	0.62	0.55
Water-powder ratio [by volume]	1.00	1.00	1.00	0.84	0.88	1.48	1.34
Paste content, excl. air [Vol.-%]	35.6	35.6	35.6	36.4	36.5	32.2	31.5

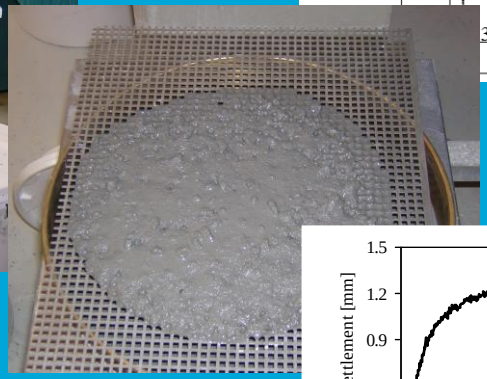
TU Delft

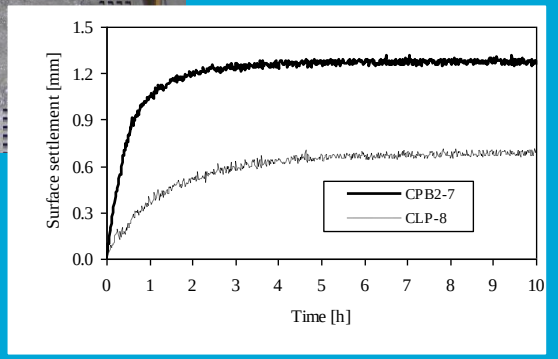
Experimental set-up

Test methods

- Slump flow / Flow-time T50
- L-Box
- Sieve segregation
- Penetration depth
- Surface settlement



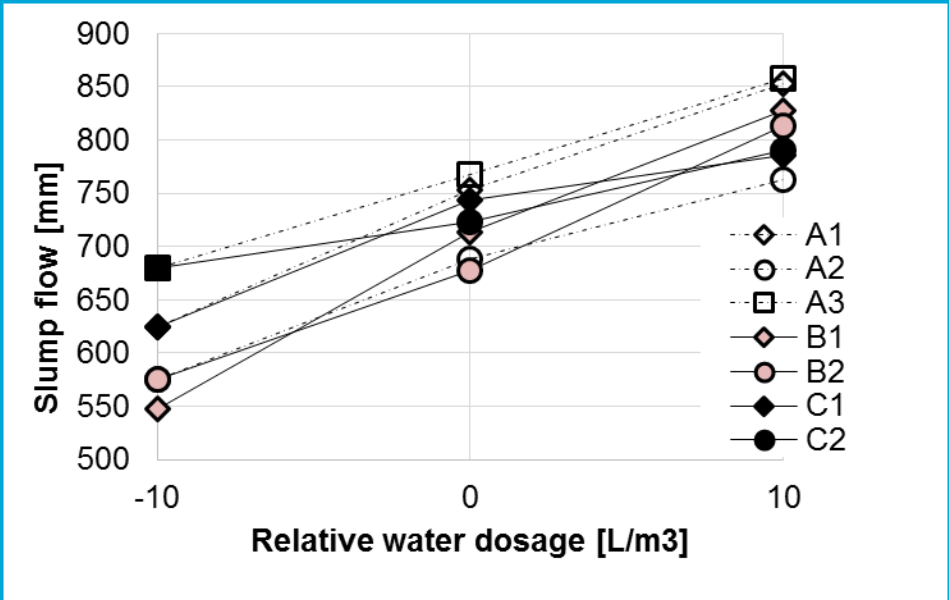


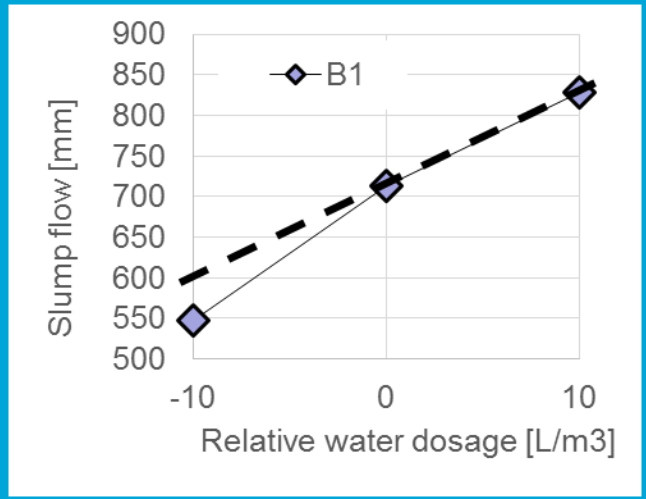


TU Delft

Comparison of results

Slump flow





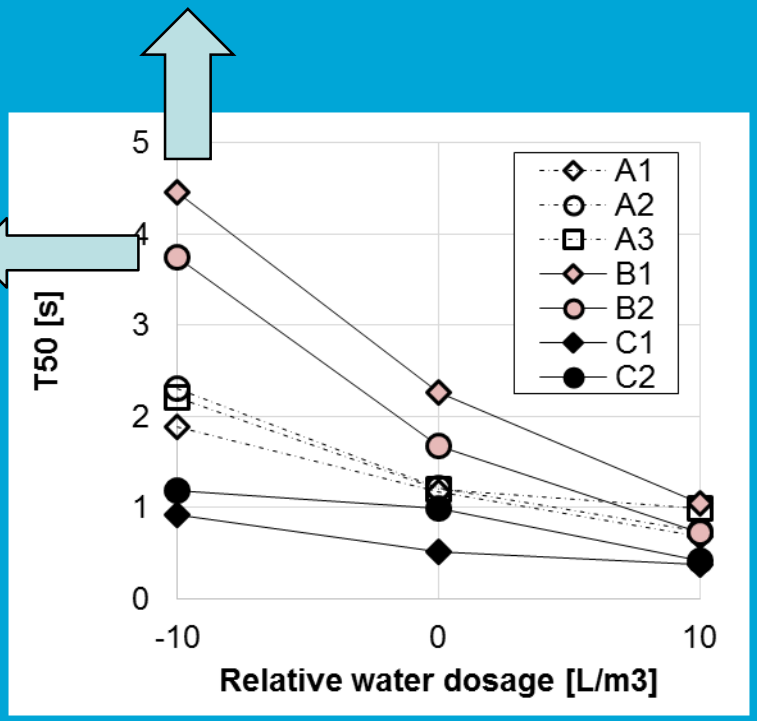
TU Delft

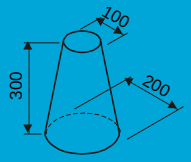
Comparison of results

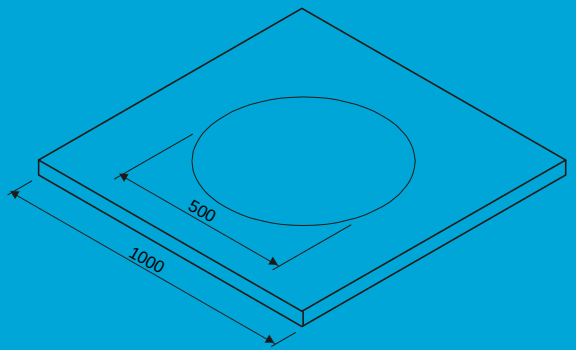
Flow-time T50

Slump flow:
575 mm

Slump flow:
548 mm



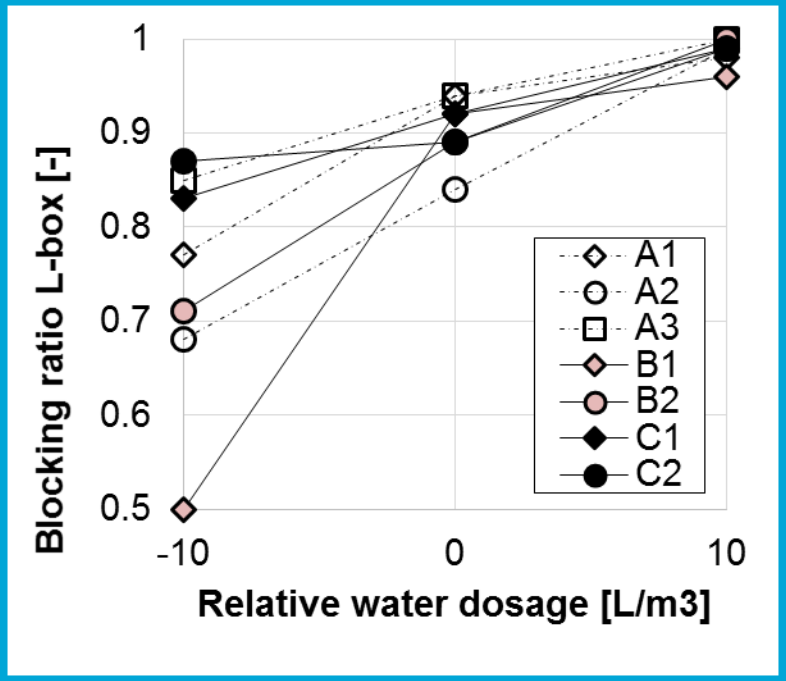


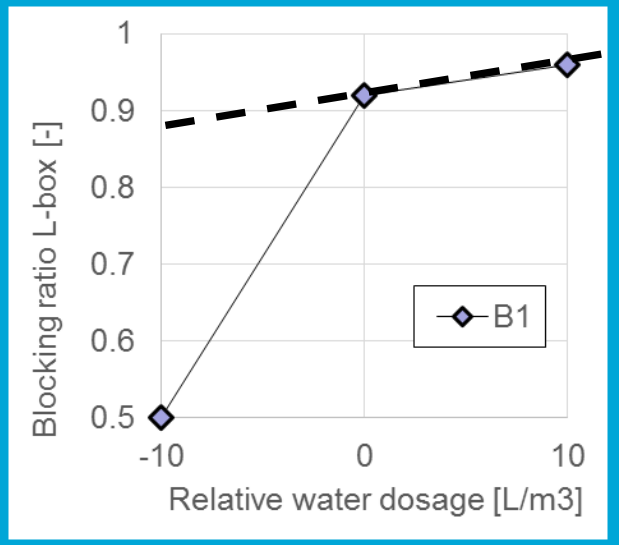


TU Delft

Comparison of results

L-box

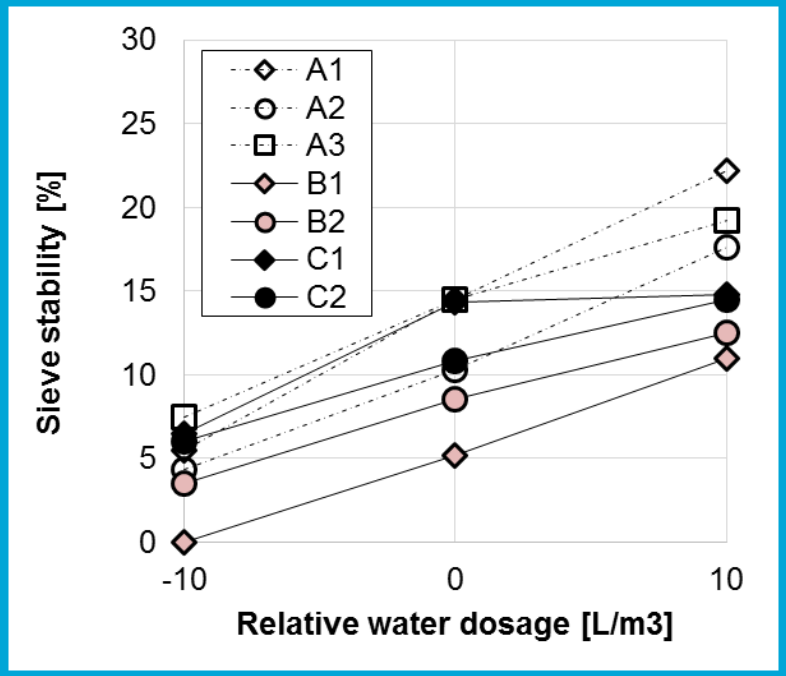




TU Delft

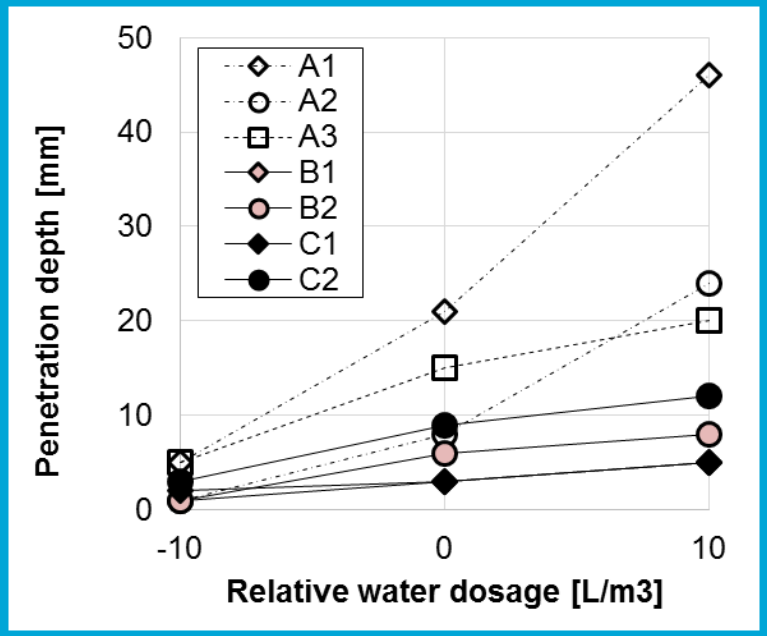
Comparison of results

Sieve stability

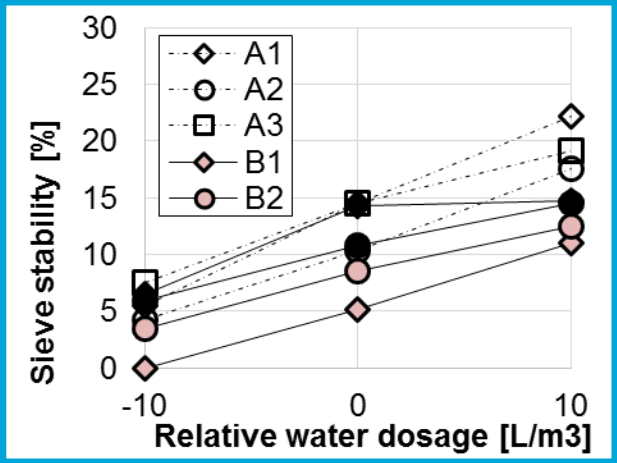


Comparison of results

Penetration depth



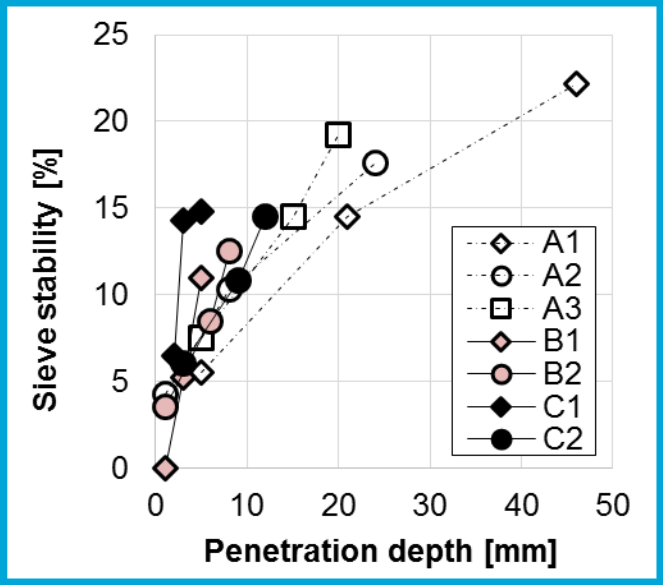
Sieve stability



TU Delft

Comparison of results

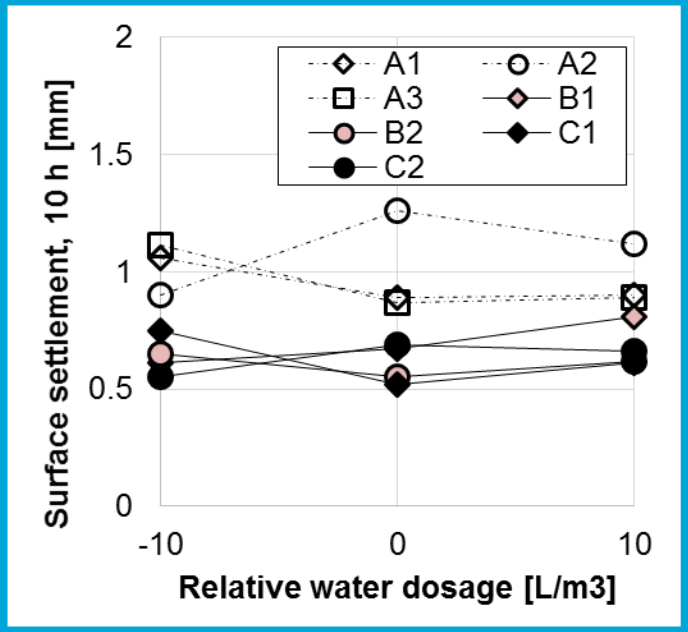
Penetration depth/sieve stability

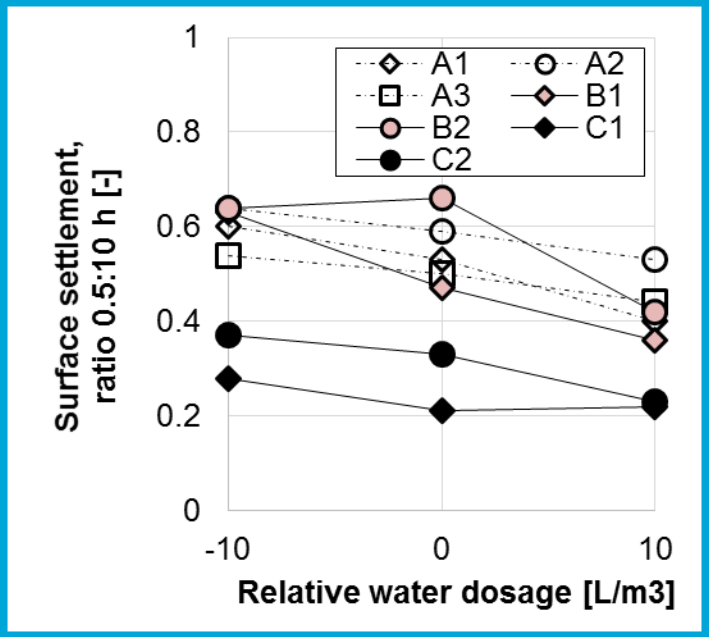


TU Delft

Comparison of results

Surface settlement





TU Delft

Relative robustness

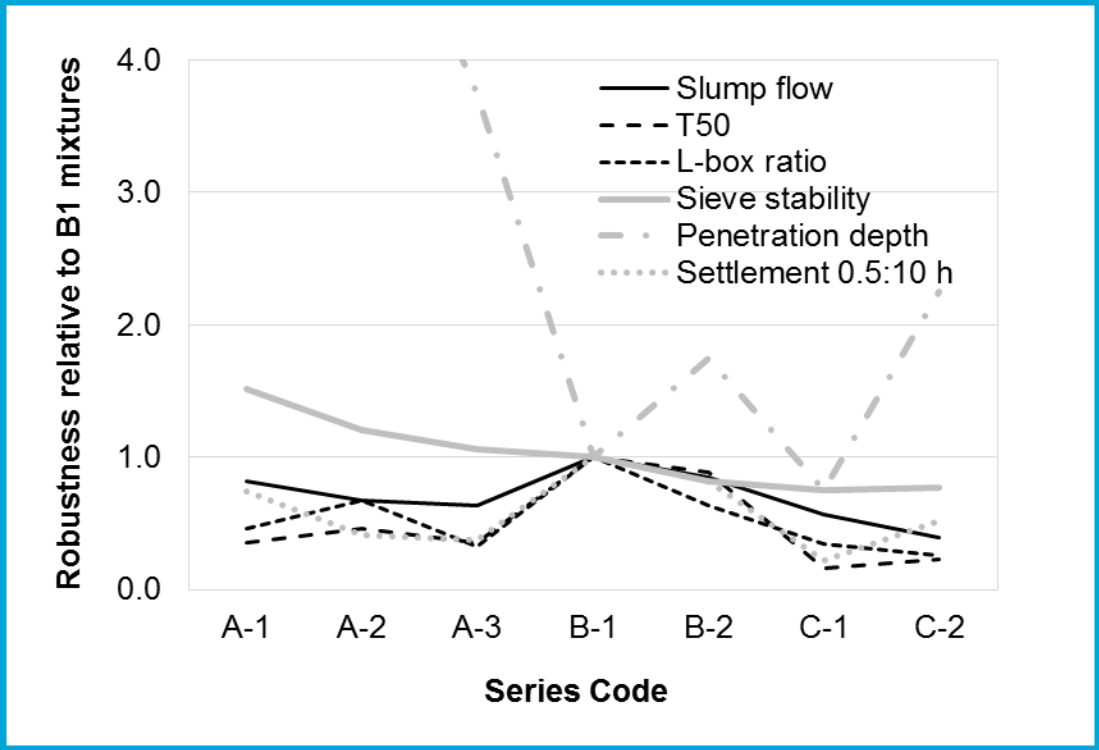
Data analysis

Mix	Value	Slump flow	T50	L-Box	Sieve stability	Penetration depth	Settlement, after 10 h	Settlement, 0.5:10 h
		[mm]	[s]	[-]	[%]	[mm]	[mm]	[-]
A-1	Reference	753	1.17	0.94	14.50%	21	0.89	0.53
	(+10L)-(-10L)	228	-1.2	0.21	16.70%	41	-0.16	-0.2
	Slope (1 L/m^3)	11.4	-0.06	0.011	0.008	2.05	-0.008	-0.01
A-2	Reference	688	1.21	0.84	10.30%	8	1.26	0.59
	(+10L)-(-10L)	188	-1.56	0.31	13.30%	23	0.22	-0.11
	Slope (1 L/m^3)	9.4	-0.08	0.016	0.007	1.15	0.011	-0.0055
A-3	Reference	768	1.2	0.94	14.50%	15	0.87	0.5
	(+10L)-(-10L)	178	-1.22	0.15	11.70%	15	-0.22	-0.1
	Slope (1 L/m^3)	8.9	-0.06	0.008	0.006	0.75	-0.011	-0.005
B-1	Reference	713	2.27	0.92	5.20%	3	0.67	0.47
	(+10L)-(-10L)	280	-3.41	0.46	11.00%	4	0.2	-0.27
	Slope (1 L/m^3)	14	-0.17	0.023	0.006	0.2	0.01	-0.0135
B-2	Reference	678	1.68	0.89	8.50%	6	0.55	0.66
	(+10L)-(-10L)	238	-3.02	0.29	9.00%	7	-0.03	-0.22
	Slope (1 L/m^3)	11.9	-0.15	0.015	0.005	0.35	-0.0015	-0.011
C-1	Reference	743	0.52	0.92	14.30%	3	0.52	0.21
	(+10L)-(-10L)	160	-0.54	0.16	8.30%	3	-0.14	-0.06
	Slope (1 L/m^3)	8	-0.03	0.008	0.004	0.15	-0.007	-0.003
C-2	Reference	723	0.99	0.89	10.80%	9	0.69	0.33
	(+10L)-(-10L)	110	-0.77	0.12	8.50%	9	0.11	-0.14
	Slope (1 L/m^3)	5.5	-0.04	0.006	0.004	0.45	0.0055	-0.007

TU Delft

Relative robustness

Test methods and robustness



TU Delft

Conclusions

• Technical progress: Viscosity agents can significantly enhance the robustness of SCC; the effect of more or less water on the change of the slump flow of Mix C2 was only 39% compared to Mix B1 (adding a VA to a powder-type SCC enhanced the robustness by 15-22%).

• Definition: Robustness depends on the definition and chosen test method. The test method and related key characteristic(s) of SCC should be chosen dependent on the application.

• Interpretation: Results of test methods for segregation resistance are affected by different flow phenomena and are difficult to compare.