Materialprüfanstalt Hannover
Bauwesen und Produktionstechnik

Test report no. 201019

1st copy of 10 September 2020

Ordering party:	Ha-Be Betonchemie GmbH Stüvestraße 39 31785 Hameln
Date of commission:	28.05.2020 / Mr Husmann
Subject of commission:	Tests regarding the efficiency of water resisting admixture for concrete Product: DURAHIT® Crystal Ad 2000 (DM)

The test report contains 17 pages.

The testing material is used up.

The test report shall be published unabridged. Any partial publishing requires written allowance by the testing institute. The test results refer only to the tested material.

Materialprüfanstalt für das Bauwesen und Produktionstechnik
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Niedersachsen

1. General

The ordering party has assigned MPA HANNOVER to perform tests regarding the efficiency of water resisting admixture for concrete in comparison to a reference concrete. The scope of the tests to be carried out has been determined by the ordering party and is set out in section 3. This test report states the results of the tests.

2. Delivery of samples

On 26.06.20, 01.07.2020 and 15.07.20 were delivered by an employee of the ordering party:

9 pcs.	Concrete cubes, L x B x H = 150 x 150 x 150 mm³	
2 pcs.	Concrete plates, L x B x H = 200 x 200 x 120 mm³	
3 pcs.	Concrete cylinders, D x H = 100 x 150 mm²	
5 pcs.	Concrete cubes, L x B x H = 150 x 150 x 70 mm³	
1 pcs.	Concrete plate, L x B x H = 400 x 400 x 120 mm³	
	with following information:	
	Date of production	24.06.2020
	Mixture no.	Reference

and:

9 pcs.	Concrete cubes, L x B x H = 150 x 150 x 150 mm³	
2 pcs.	Concrete plates, L x B x H = 200 x 200 x 120 mm³	
3 pcs.	Concrete cylinders, D x H = 100 x 150 mm²	
5 pcs.	Concrete cubes, L x B x H = 150 x 150 x 70 mm³	
1 pcs.	Concrete plate, L x B x H = 400 x 400 x 120 mm³	
	with following information:	
	Date of production	24.06.2020
	Mixture no.	Ad 2000

3. Scope

The scope of performed tests listed in Table 1. The tests were performed each at the Reference concrete (Reference) and at the concrete produced with the water resisting admixture DURAHIT® Crystal Ad 2000 (DM).

Table 1: Scope of testing

Test ID	Type of test	Age of sample	No. of samples
1	Flow table test DIN EN 12350-5:2019-09	5 min, 30 min	1 each
2	Bulk density DIN EN 12350-6:2019-09	20 min	1
3	Air content DIN EN 12350-7:2019-09	20 min	1
4	Compressive strength and bulk density DIN EN 12390-3:2009-07	2, 7 and 28 d	3
5	Depth of penetration of water under pressure DIN EN 12390-8:2009-07	28 d	2
6	Determination of capillary adsorption DIN EN 13057:2002	> 28 d	3
7	Freeze-thaw-salt resistance BAW-Merkblatt „Frostprüfung von Beton“, 2012	28 d	5
8	Chloride migration resistance BAW-Merkblatt „Chlorideindringwiderstand von Beton (MCL)“, 2004	56 d	3

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4. Results

4.1 Manufacture of samples

The samples were produced according to DIN EN 12390-2:2009-08 in the laboratory of Ha-Be Betonchemie GmbH, Hameln by witness of a representative of MPA HANNOVER. A forced mixer Zyklos ZK 50 was used for the mixing. The mixing time was 2 min after water addition. The water resisting admixture and the superplasticizer were added separately. The water content of the admixtures was taken into account with 70 M.-% for the calculation. The compositions of mixtures are listed in Table 2. All test specimens as well as the fresh grout tests were prepared from three mixtures each.

Table 2: Composition of mixtures

		Reference		Ad 2000	
Raw material		Quantity	Mass kg/m³	Quantity	Mass kg/m³
Cement	-	-	350	-	350
Water	-	-	175	-	166
w/c-ratio	-	-	0.50	-	0.48
Sand 0-2 mm	M.-% of aggregate	35	679	35	679
Gravel 2-8 mm		30	566	30	566
Gravel 8-16 mm		35	673	35	673
DURAHIT® Crystal Ad 2000 (DM)	M.-% of water	-	-	2.50	4.15
PANTARHIT® RC683 (FM)	M.-% of cement	0.30	1.05	0.50	1.75

4.2 Bulk density of fresh concrete, air content and flow table test

The properties of fresh concrete were determined according to DIN EN 12350-5 (flow table test), DIN EN 12350-6 (bulk density) and 12350-7 (air content). The results are listed in Table 3.

Table 3: Results of test on fresh concrete

		Reference	Ad 2000
Air temperature	°C	20	20
Flow table test A after water addition in mm	5 min	520	500
	30 min	420	400
Fresh concrete temperature	°C	24	25
Bulk density of fresh concrete	kg/dm³	2.30	2.29
Air content	Vol.- %	2.9	3.7

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4.3 Compressive strength and bulk density

The determination of compressive strength was carried out 24 h, 7 days and 28 days after casting according to DIN EN 12390-3 at 3 cubes each with 150 mm edge length. The mean of the results are shown in Table 4. Details of the tests are listed in Appendix A1.

Table 4: Results of test of compressive strength according to DIN EN 12390-3, mean values

		Reference		Ad 2000	
Samples no.	Age d	Bulk density kg/m³	Compressive strength $f_{c,cube}$ MPa	Bulk density kg/m³	Compressive strength $f_{c,cube}$ MPa
1-3	1	2330	42.4	2330	48.8
4-6	7	2330	51.9	2350	58.3
7-9	28	2320	57.5	2330	62.9

4.4 Depth of penetration of water under pressure

The depth of penetration of water under pressure was carried out according to DIN EN 12390-8 at 2 cubes each with the dimensions of 150 x 150 x 150 mm. The age of samples was 30 days at the begin of testing. The results of the tests are shown in Table 5. The spread of water at the cracking surfaces is shown in Appendix A2.

Table 5: Results of depth of penetration of water according to DIN EN 12390-8

	Reference	Ad 2000
Sample no.	maximal depth of penetration mm	maximal depth of penetration mm
1	17	12
2	12	15
Mean	**15**	**14**

4.5 Capillary adsorption

The resistance of capillary absorption was determined according to DIN EN 13057 on three samples each with a height of 50 mm and a diameter of 104 mm. The results are listed in Table 6. Details of the tests are listed in Appendix A3.

Table 6: Test results of resistance of capillary absorption, mean values

		Reference	Ad 2000
Water uptake after 24 h	kg/m²	3.03	2.48
Absorption coefficient S_{24h}	kg/m²*h$^{0.5}$	0.62	0.51
Resistance coefficient R_{2h}	h/m²	1800	2300

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4.6 Freeze-thaw-salt resistance

4.6.1 Preparation for testing

The test of the freeze-thaw resistance was carried out according to BAW-Merkblatt „Frostprüfung von Beton“, version 2012. The samples were sawn, measured and prepared for testing, approximately 7 days before the start of the test. The lateral faces were glued with an aluminium foil with butyl bonding. The specimens were stored in a climate chamber at a temperature of 20 °C and a relative humidity of 65 % until testing. The weights of the specimens were determined before and after sealing of the lateral faces.

4.6.2 Capillary suction

After preparing of the specimens and the pre-storage described above, the specimens were place into the test containers on spacers with a height of 10 mm with the test surface facing the bottom. Then a test solution consisting of 3-percent sodium chloride solution was filled into the containers up to a height of 15 mm so that the specimens were immersed 5 mm depth into the test solution. The increase in weight of the test specimens was measured after two, five and seven days of storage in the test solution.

4.6.3 Freeze-thaw testing

The test specimens together with the test containers and the present test liquid were placed into a temperature-controlled chest with liquid cooling bath and subjected to freeze-thaw testing according to the test specification mentioned in section 1. One freeze-thaw cycle lasts 12 hours. Beginning at + 20 °C, the temperature was lowered in 4 hours with a constant cooling rate to –20 °C. Then it was left to cool for 3 hours at this temperature and within 4 hour increased to +20 °C again and subsequently held for one hour. The specimens were taken from the chest in specific intervals and the water uptake, the surface scaling and the dynamic E-modulus were determined according to test specification. The results of the freeze-thaw test are compiled in Tables 6 as mean values. Details of the tests are listed in Appendix A4.

Table 6: Results of the test of Freeze-thaw-salt resistance, mean values

		Surface scaling in g/m²		rel. dyn. E-modulus in %	
		Reference	Ad 2000	Reference	Ad 2000
Frost-thaw cycle	0	0	0	100	100
	4	88	38	99	98
	10	660	296	98	98
	14	1185	633	98	97
	18	1691	952	97	97
	24	2370	1535	97	96
	28	2790	1942	97	96

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4.7 Chloride migration resistance

The determination of the chloride migration resistance was performed according to BAW-Merkblatt „Chlorideindringwiderstand von Beton“, version 2012. The cubes were continuously stored under water after manufacturing. Cylinders with a diameter of 100 mm were drilled out from the samples approx. 7 days before testing. A layer of 10 mm was removed from the upper edge by sawing. A test area parallel saw cut was made at a height of approx. 50 ± 5 mm measured from the test surface. The test specimens were stored in a water bath at 20 °C until testing and were installed and tested in migration cells at the start of the test. The chloride migration coefficients calculated from the test results are shown in Appendix A4 and Table 7. For comparison, the normatively required coefficients are given in Table 8.

Table 7: Chloride migration coefficients

Sample no.	Chloride migration coefficient x 10^{-12} [m²/s]	
	Reference	Ad 2000
1	13.5	13.4
2	14.5	13.3
3	12.3	11.8
Mean value D_{CL}	**13.5**	**12.9**
Max. individual value $D_{CL.max}$	14.5	13.4

Depending on the given exposure class, the mean values and maximum individual values of migration coefficients given in Table 8 must be complied in accordance with BAW-Merkblatt "Chlorideindringwiderstand von Beton“, version 2012.

Table 8: Mean values to be complied with and the maximum permissible individual values of the migration coefficients as a function of the exposure class

Given exposure class acc. DIN EN 206-1 /DIN 1045-2	Migration coeffizient	
	Mean value	*Max. individual value*
-	x 10^{-12} [m²/s]	x 10^{-12} [m²/s]
XS 1, XD 1	≤ 10.0	≤ 12.0
XS 2, XD 2		
XS 3, XD 3	≤ 5.0	≤ 7.0

Hanover, 10 September 2020

Head of Testing Institute

(ORR Dr.-Ing. H. Höveling)

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Contact

(Dipl.-Ing. A. Giese)

APPENDIX

Appendix A1: Test of compressive strength

Appendix A1-1: Results of test of compressive strength according to DIN EN 12390-3, Reference

Date of casting:									24.06.2020
Sample	Dimensions			Age	Mass	Bulk density	max. load F	Compressive strength	
	Length	Width	Height					$f_{c,dry}$	$f_{c,cube}$
no.	mm	mm	mm	d	kg	kg/m³	kN	N/mm²	
1	150	151	150		7.95	2330	965	-	42.5
2	150	151	150	2	7.94	2320	956	-	41.9
3	150	151	150		7.93	2340	966	-	42.7
Mean:						2330	-	-	42.4
4	150	151	150		7.90	2330	1199	-	53.0
5	150	152	150	7	7.95	2330	1198	-	52.7
6	150	151	150		7.85	2330	1125	-	49.9
Mean:						2330	-	-	51.9
7	150	151	150		7.85	2320	1416	62.6	57.6
8	150	152	150	28	7.93	2320	1407	61.7	56.8
9	150	151	150		7.94	2320	1437	63.2	58.1
Mean:						2320	-	62.5	57.5

Appendix A1-2: Results of test of compressive strength according to DIN EN 12390-3, AD 2000

Date of casting:									24.06.2020
Sample	Dimensions			Age	Mass	Bulk density	max. load F	Compressive strength	
	Length	Width	Height					$f_{c,dry}$	$f_{c.cube}$
no.	mm	mm	mm	d	kg	kg/m³	kN	N/mm²	
1	150	152	150		7.99	2340	1134	-	49.8
2	150	152	150	2	7.99	2340	1101	-	48.2
3	150	152	150		7.91	2310	1104	-	48.5
Mean:						2330	-	-	48.8
4	150	152	150		8.04	2340	1316	-	57.5
5	150	152	150	7	8.04	2340	1324	-	57.9
6	150	151	150		8.06	2360	1354	-	59.6
Mean:						2350	-	-	58.3
7	150	152	150		7.99	2330	1559	68.4	62.9
8	151	151	150	28	7.96	2330	1597	70.2	64.5
9	151	152	150		7.97	2320	1520	66.6	61.3
Mean:						2330	-	68.4	62.9

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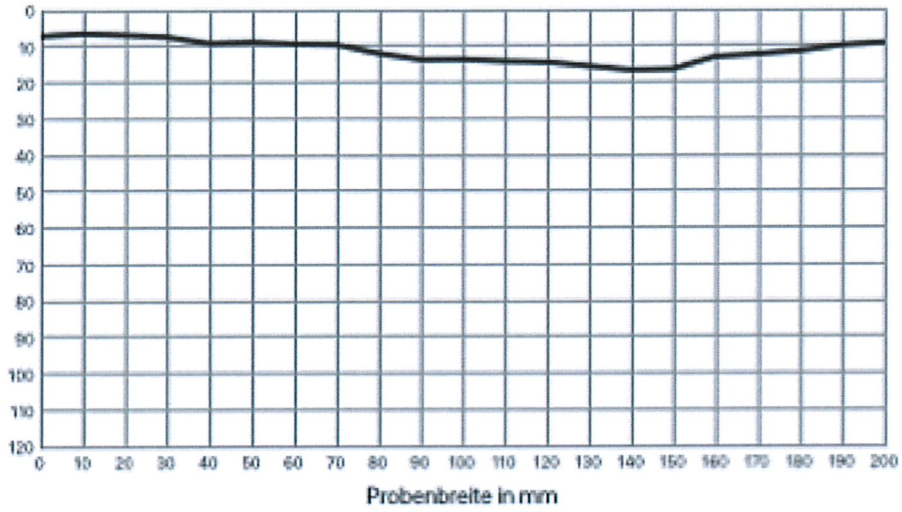
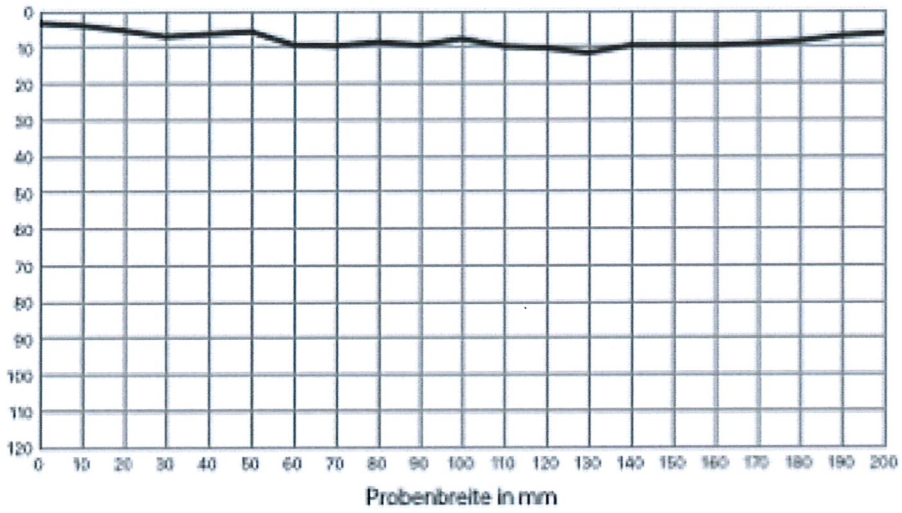
Appendix A2: Depth of penetration of water

Appendix A2-1: Depth of penetration of water, Reference: 1, max. depth of penetration t = 17 mm



Appendix A2-2: Depth of penetration of water, Reference: 2, max. depth of penetration t = 12 mm



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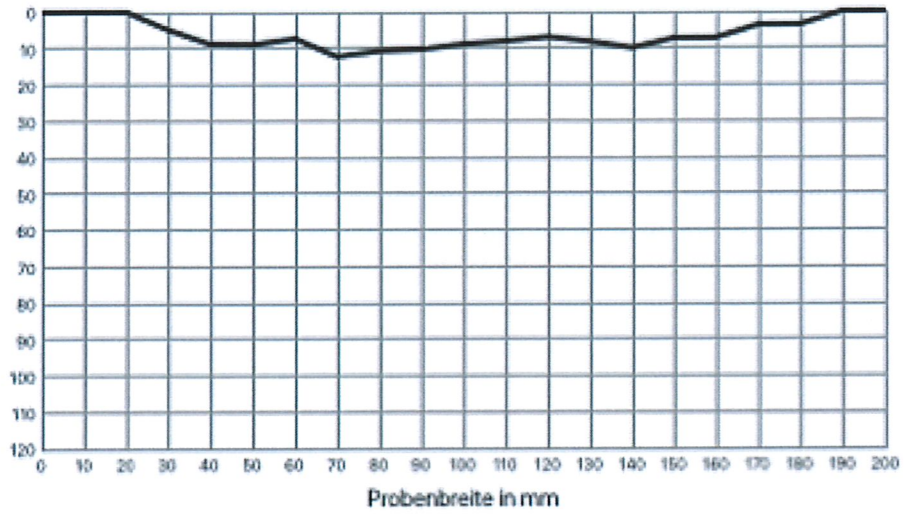
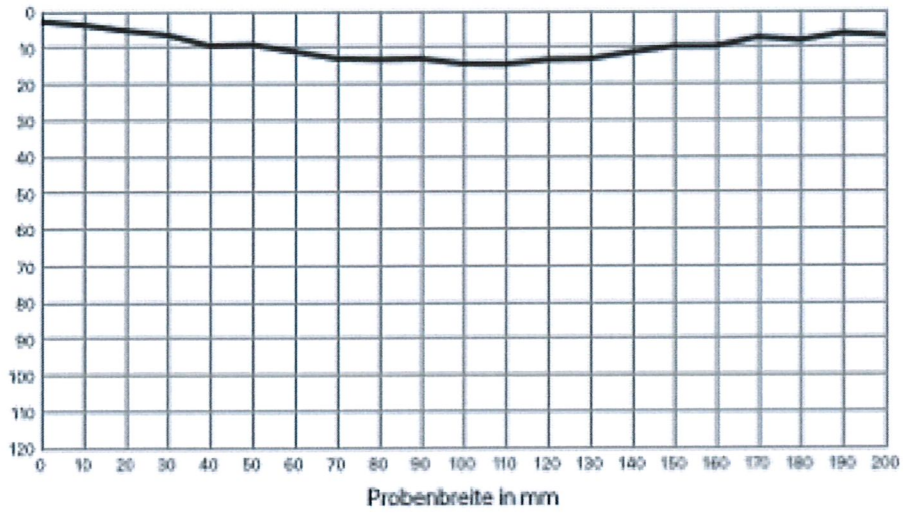
Appendix A2-3: Depth of penetration of water, AD 2000: 1, max. depth of penetration t = 12 mm



Appendix A2-4: Depth of penetration of water, AD 2000: 2, max. depth of penetration t = 15 mm



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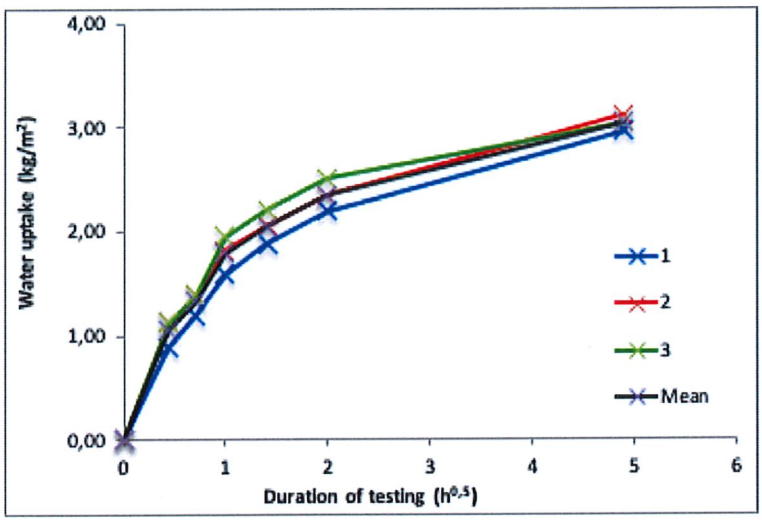
Appendix A3: Capillary adsorption

Appendix A3-1: Test results of capillary absorption, Reference
Production of samples: 24.06.2020
Time of testing: 19.08.2020 - 20.08.2020

Sample no.	Duration of testing (h)							absorption coefficient	resistance coefficient
	0	0.2	0.5	1	2	4	24	S_{24h}	R_{2h}
	Water uptake (kg/m^2)							$kg/m^2*h^{0.5}$	h/m^2
1	0.00	0.90	1.20	1.59	1.88	2.19	2.96	0.60	1800
2	0.00	1.13	1.39	1.83	2.05	2.34	3.11	0.63	1900
3	0.00	1.13	1.39	1.96	2.20	2.51	3.04	0.62	1700
Mean	**0.00**	**1.05**	**1.33**	**1.79**	**2.05**	**2.35**	**3.03**	**0.62**	**1800**

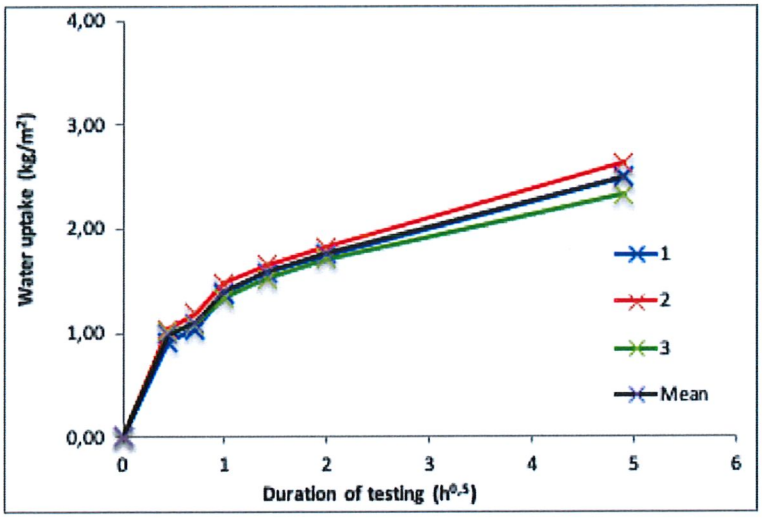
Appendix A3-2: Graph of the capillary absorption, Reference



Appendix A3-3: Test results of capillary absorption, Ad 2000
Production of samples: 24.06.2020
Time of testing: 19.08.2020 - 20.08.2020

Sample no.	Duration of testing (h)							absorption coefficient	resistance coefficient
	0	0.2	0.5	1	2	4	24	S_{24h}	R_{2h}
	Water uptake (kg/m^2)							$kg/m^2*h^{0.5}$	h/m^2
1	0.00	0.92	1.04	1.38	1.58	1.75	2.50	0.51	2400
2	0.00	1.04	1.19	1.48	1.65	1.83	2.63	0.54	2300
3	0.00	1.00	1.07	1.34	1.52	1.71	2.32	0.47	2200
Mean	**0.00**	**0.99**	**1.10**	**1.40**	**1.58**	**1.76**	**2.48**	**0.51**	**2300**

Appendix A3-4: Graph of the capillary absorption, Ad 2000



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Appendix A4: Freeze-thaw-salt testing

Appendix A4-1: Dimensions and mass for specimen preparation. Reference

Specimen			1	2	3	4	5
Weight	without belt	g	2892	2837	2838	2879	2926
	with belt		2952	2896	2898	2938	2985
Dimensions w/o sealing	Length	mm	151	151	150	151	150
	Width		114	114	113	113	113
	Height		73	71	71	73	74

Appendix A4-2: Water uptake. Reference

Begin of test:									22.07.2020
Probe	after d		1	2	3	4	5	Mean	Standard deviation
Capillary suction in d	-7	M.- %	-0.22	-0.22	-0.24	-0.24	-0.21	-0.23	0.02
	-5		-0.06	-0.05	-0.06	-0.05	-0.04	-0.05	0.01
	-2		-0.01	-0.01	-0.02	-0.01	-0.01	-0.01	0.00
	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frost-thaw cycle	4		0.13	0.15	0.10	0.14	0.11	0.13	0.02
	10		0.23	0.27	0.20	0.27	0.22	0.24	0.03
	14		0.25	0.32	0.23	0.31	0.24	0.27	0.03
	18		0.30	0.33	0.27	0.37	0.29	0.31	0.03
	24		0.36	0.39	0.39	0.43	0.35	0.38	0.03
	28		0.40	0.42	0.41	0.48	0.38	0.42	0.03

Appendix A4-3: Relative dynamic E-modulus of the specimens, Reference

Frost-thaw cycle	Relative dynamic E-modulus in %						
	1	2	3	4	5	Mean	Standard deviation
0	100	100	100	100	100	100	0.0
4	99	99	99	100	98	99	0.6
10	98	98	99	99	98	98	0.8
14	98	98	98	99	97	98	0.6
18	97	97	98	98	97	97	0.7
24	96	96	98	98	96	97	1.0
28	95	96	97	98	96	97	1.2

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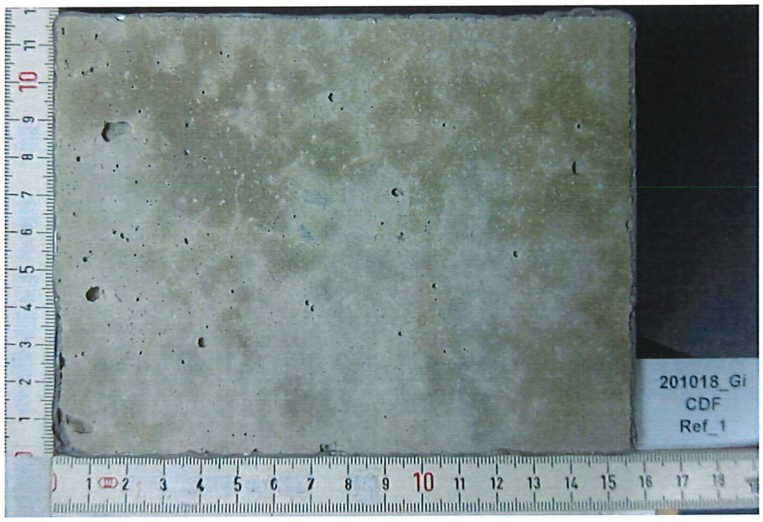
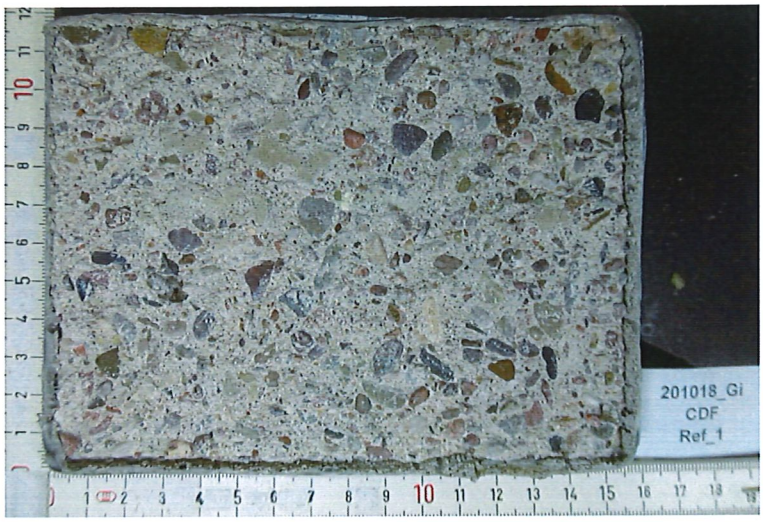
Appendix A4-4: Surface scaling of the specimens by weathering, Reference

Frost-thaw cycle	Surface scaling in g/m²						
	1	2	3	4	5	Mean	Standard deviation
0	0	0	0	0	0	0	0
4	61	109	139	83	50	88	36
10	459	782	959	650	450	660	217
14	919	1323	1520	1208	956	1185	253
18	1395	1800	2041	1752	1464	1691	263
24	2110	2420	2727	2488	2102	2370	266
28	2511	2823	3135	2974	2504	2790	280
95 % - quantile after 28 frost-thaw cycles						3386	---

Appendix A4-5: Sample before testing, Reference



Appendix A4-6: Sample after testing, Reference



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Appendix A4-7: Dimensions and mass for specimen preparation, Ad 2000

Specimen			1	2	3	4	5
Weight	without belt	g	2840	2822	2856	2825	2888
	with belt		2899	2882	2915	2885	2948
Dimensions w/o sealing	Length	mm	151	151	152	151	152
	Width		113	114	114	114	113
	Height		72	71	72	72	72

Appendix A4-8: Water uptake. Ad 2000

Begin of test:									22.07.2020
Probe	after d		1	2	3	4	5	Mean	Standard deviation
Capillary suction in d	-7	M.- %	-0.30	-0.22	-0.24	-0.22	-0.23	-0.24	0.03
	-5		-0.07	-0.04	-0.05	-0.05	-0.06	-0.05	0.01
	-2		-0.02	-0.01	0.00	0.00	-0.01	-0.01	0.01
	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frost-thaw cycle	4		0.17	0.12	0.14	0.15	0.12	0.14	0.02
	10		0.27	0.20	0.27	0.22	0.20	0.23	0.03
	14		0.31	0.22	0.31	0.24	0.24	0.27	0.04
	18		0.34	0.25	0.35	0.24	0.26	0.29	0.05
	24		0.44	0.28	0.42	0.28	0.31	0.35	0.07
	28		0.45	0.30	0.40	0.34	0.29	0.36	0.06

Appendix A4-9: Relative dynamic E-modulus of the specimens, Ad 2000

Frost-thaw cycle	Relative dynamic E-modulus in %						
	1	2	3	4	5	Mean	Standard deviation
0	100	100	100	100	100	100	0.0
4	98	98	97	99	99	98	0.6
10	98	97	98	98	98	98	0.4
14	97	97	98	97	98	97	0.4
18	97	97	94	97	98	97	1.4
24	96	96	95	97	97	96	0.7
28	95	96	96	97	96	96	0.8

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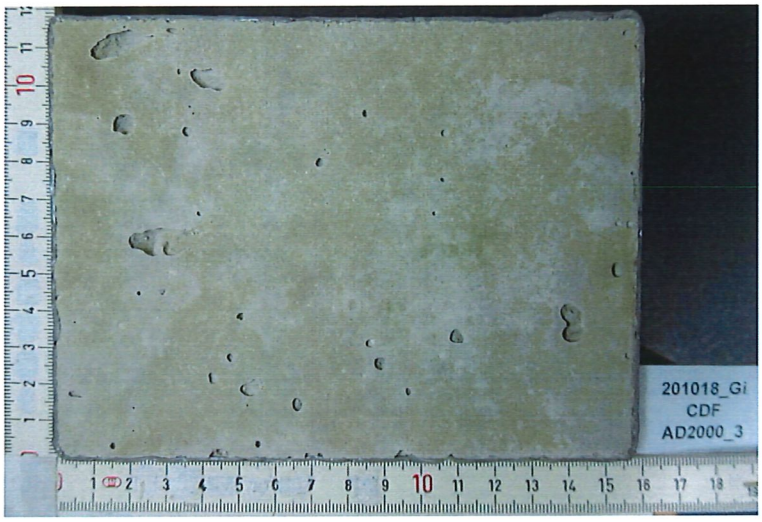
Appendix A4-10: Surface scaling of the specimens by weathering, Ad 2000

Frost-thaw cycle	Surface scaling in g/m²						
	1	2	3	4	5	Mean	Standard deviation
0	0	0	0	0	0	0	0
4	25	29	22	74	40	38	21
10	167	382	145	567	221	296	177
14	400	884	360	1060	461	633	317
18	413	1397	661	1559	727	952	498
24	780	2137	1213	2267	1278	1535	640
28	1124	2599	1616	2710	1662	1942	685
95 % - quantile after 28 frost-thaw cycles						3402	---

Appendix A4-11: Sample before testing, Ad 2000



Appendix A4-12: Sample after testing, AD 2000

Appendix A5: Chloride migration

Appendix A5-1: Measured values of the test, Reference

Sample no.	Test start		Test end		Amperage start	Amperage end	Duration of test
	Date	Time	Date	Time	mA	mA	h
1	19.08.20	19:00	20.08.20	06:00	79.8	76.7	11.00
2	19.08.20	19:00	20.08.20	06:00	79.1	74.5	11.00
3	19.08.20	19:00	20.08.20	06:00	74.7	70.5	11.00

Sample no.	Test liquid		Test sample				
	Temperature		Height	Diameter	Mass after		Bulk density
	Start	End			Water storage	Testing	Water storage
	°C	°C	mm	mm	g	g	[kg/m³]
1	25.3	25.7	51.8	99.6		933.00	934.80
2	25.3	25.7	51.5	99.6		932.57	934.13
3	25.3	25.7	52.8	99.6		929.64	931.47

Penetration depths:

[mm]	Sample 1 half 1	Sample 1 half 2	Sample 2 half 1	Sample 2 half 2	Sample 3 half 1	Sample 3 half 2
Point 1	22.9	21.6	18.3	19.9	17.9	16.1
Point 2	18.0	15.9	17.0	13.3	12.0	11.0
Point 3	13.2	11.8	17.1	13.3	14.0	11.0
Point 4	14.8	9.8	14.2	16.9	12.8	14.2
Point 5	15.2	14.8	18.8	14.8	12.8	14.8
Point 6	12.1	14.9	17.1	12.5	10.0	13.1
Point 7	13.5	13.0	14.3	11.9	11.8	11.4
Point 8	12.0	13.1	12.5	13.5	12.7	13.5
Point 9	15.1	13.6	16.7	16.5	12.0	12.9
Point 10	15.1	18.0	13.1	15.2	15.9	12.9
Point 11	16.8	17.1	14.8	15.7	12.8	13.3
Mean value x_d	14.2	13.9	15.9	14.3	12.6	12.8
Max. value x_{max}	16.8	15.9	18.8	16.9	14.0	14.8

Remark: Blue values were not included in the evaluation!

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Appendix A5-2: Measured values of the test, AD 2000

Sample no.	Test start		Test end		Amperage start	Amperage end	Duration of test
	Date	Time	Date	Time	mA	mA	h
1	19.08.20	19:00	20.08.20	06:00	59.0	58.8	11.00
2	19.08.20	19:00	20.08.20	06:00	58.1	58.7	11.00
3	19.08.20	19:00	20.08.20	06:00	66.2	65.7	11.00

Sample no.	Test liquid		Test sample				
	Temperature		Height	Diameter	Mass after		Bulk density Water storage
	Start	End			Water storage	Testing	
	°C	°C	mm	mm	g	g	[kg/m³]
1	25.3	25.7	52.3	99.5		934.48	935.58
2	25.3	25.7	51.8	99.5		921.47	922.28
3	25.3	25.7	49.7	99.5		878.10	879.45

Penetration depths:

[mm]	Sample 1 half 1	Sample 1 half 2	Sample 2 half 1	Sample 2 half 2	Sample 3 half 1	Sample 3 half 2
Point 1	16.5	23.4	23.5	16.5	17.4	24.9
Point 2	13.0	17.7	14.9	14.1	14.8	16.1
Point 3	11.1	16.6	18.2	10.9	14.1	11.8
Point 4	12.2	15.1	13.1	12.0	12.6	12.7
Point 5	12.4	16.2	13.0	13.9	11.9	10.2
Point 6	10.3	15.4	10.5	12.0	12.9	10.3
Point 7	15.0	12.7	15.5	12.9	12.8	11.8
Point 8	13.7	13.3	13.2	13.8	12.8	12.3
Point 9	16.5	11.5	16.4	17.2	14.3	14.2
Point 10	13.7	12.1	11.7	15.9	16.8	16.8
Point 11	14.2	14.5	15.7	23.8	25.1	19.0
Mean value x_d	13.2	14.5	14.2	13.6	13.3	12.4
Max. value x_{max}	15.0	16.6	16.4	16.5	14.8	14.2

Remark: Blue values were not included in the evaluation!

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