Ha-Be
Making good concrete better

ACID RESISTANT CONCRETE

Overview of Test Results

Content

Ha-Be
Making good concrete better

Content

Ha-Be
Making good concrete better

1. Requirements

Ha-Be
Making good concrete better

1. Requirements

Ha-Be
Making good concrete better

OBJECTIVE Development of a highly acid resistant concrete that exceeds the requirements for concrete in chemically highly aggressive environment

- Comparing the highly acid resistant concrete to comparison concrete by
  - Determination of damage of concrete due to different attacking media on basis of German DAfStb-Guideline „Concrete construction with water polluting substances“
  - Additional test of chloride migration coefficient on basis of German BAW-Guideline “Chloride migration resistance of concrete”

2. Mix design

Ha-Be
Making good concrete better

2. Mix design

2.1 SWB1

- CEM II 42,5 N/A-M-SLV from Israel
- Aggregates from Israel
- Superplasticizer PANTARHIT® RC683 (FM)
- Meets the requirements of XA2/ XA3 concrete (for concrete in chemically moderate/ highly aggressive environment)

ACID RESISTANT CONCRETE ACC. TO DIN EN 206-1 AND DIN 1045-2

2. Mix design

2.2 SWB2

- CEM III/B 42,5 N-SR from Israel
- Highly acid resistant aggregates from Israel
- Superplasticizer PANTARHIT® RC683 (FM)
- Stabilizer PANTARHEO® SB40 (ST)
- Additive MOWILITH® / CELVOLIT® LDM 6880*

HIGHLY ACID RESISTANT CONCRETE

** MOWILITH® LDM 6880 is a registered word mark of Celanese Emulsions GmbH. Outside Europe the additive is sold as CELVOLIT® LDM 6880.*

3. Test set-up and performance

Ha-Be
Making good concrete better

3.1 Determination of damage of concrete due to different attacking media

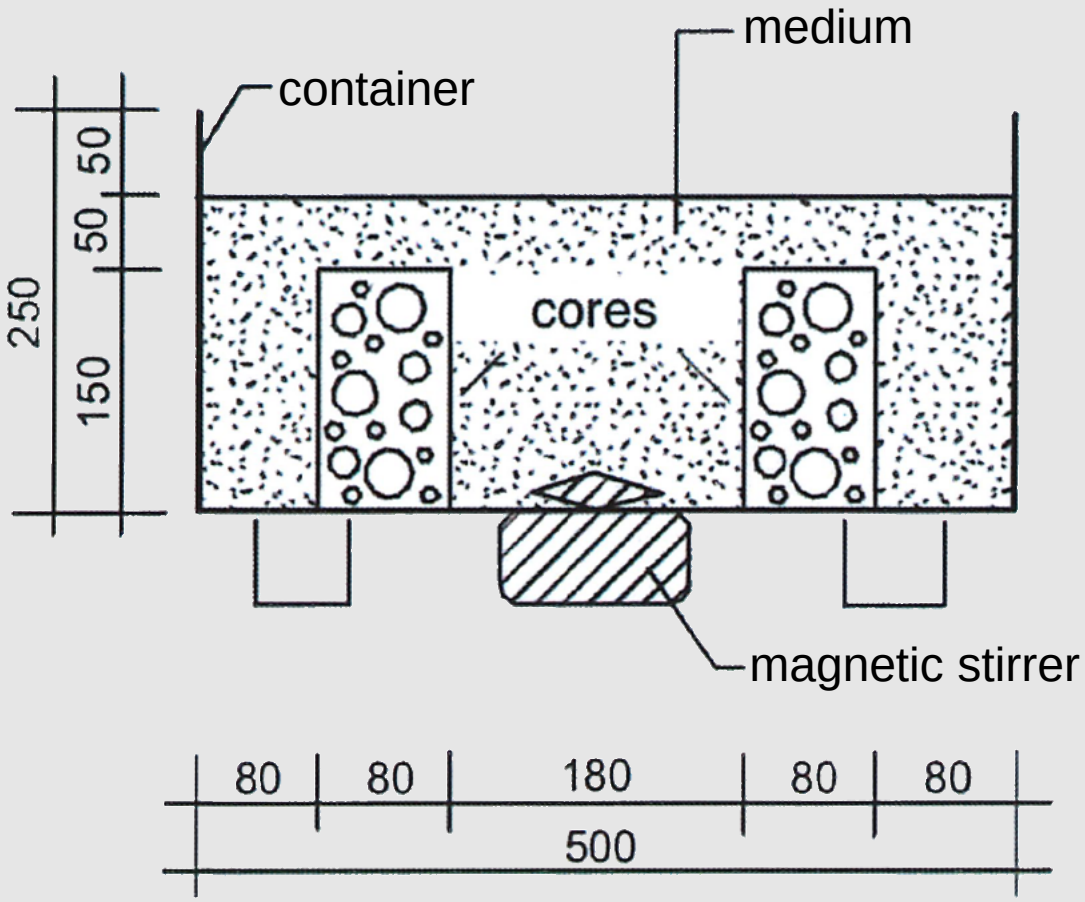
Ha-Be
Making good concrete better

3.1.1 USED TEST MEDIA

MEDIA	CONCENTRATION
Drinking water as reference	
Concentrated sulfuric adic H_2SO_4	96%
Hydrochloric acid HCl	30-33%
Phosphoric adic H_3PO_4	85 %
Nitric acid HNO_3	60%
Potassium hydroxide KOH	50%
Sodium hydroxide NaOH	50%
Saltwater like in the Dead Sea	Salt content 29%
Carnallit solution	
Deionised water	

3.1 Determination of damage of concrete due to different attacking media

3.1.2 SET-UP

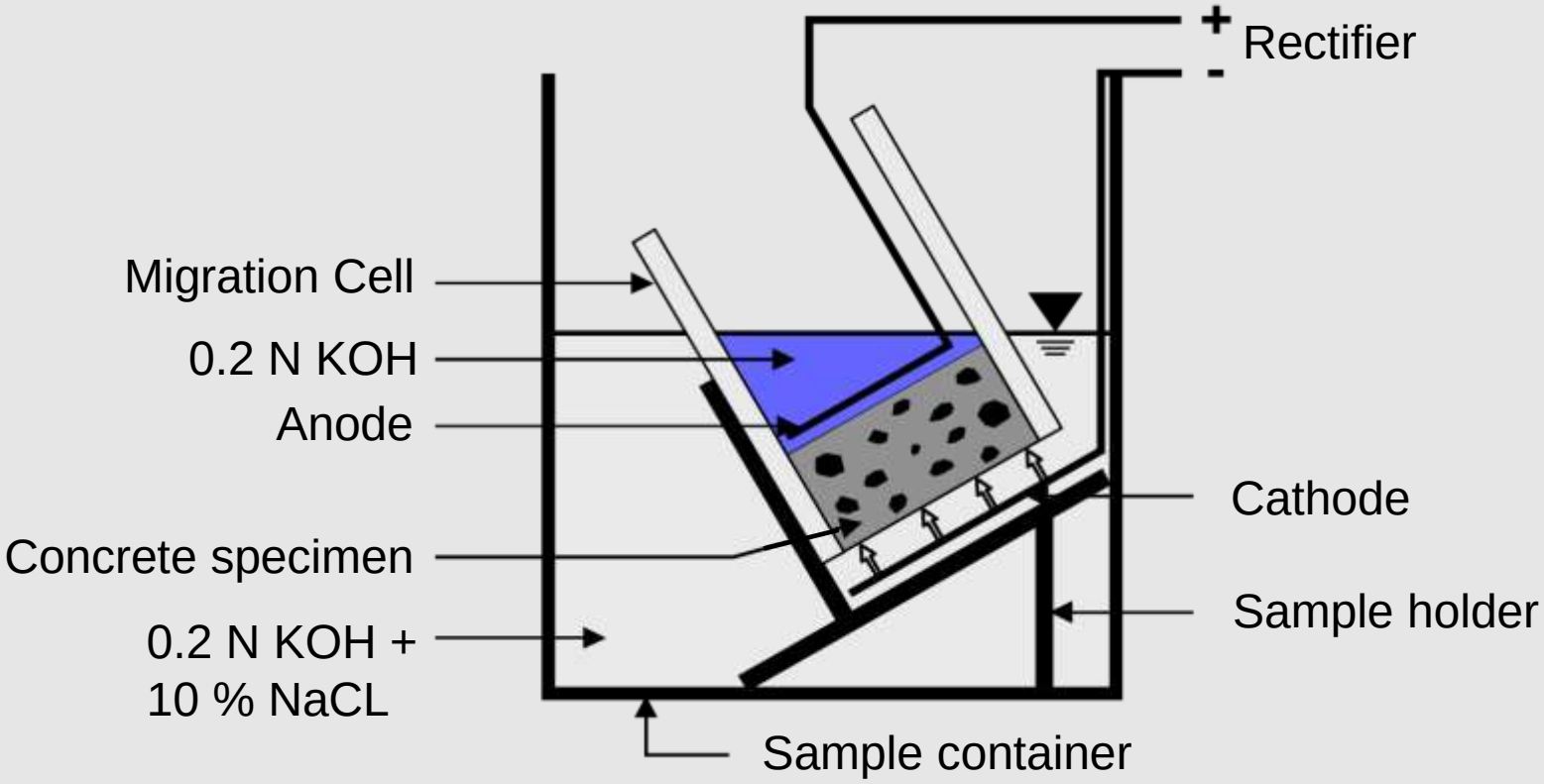


Exemplary test set up (dimensions in mm); source: DAfStb-Guideline

3.2 Test of chloride migration resistance

Ha-Be
Making good concrete better

3.2.1 SET-UP



Exemplary test set up chloride migration test; source: Bundesanstalt für Wasserbau (Hg.) (2012): BAWMerkblatt Chlorideindringwiderstand von Beton (MCL).

4. Test results

Ha-Be
Making good concrete better

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

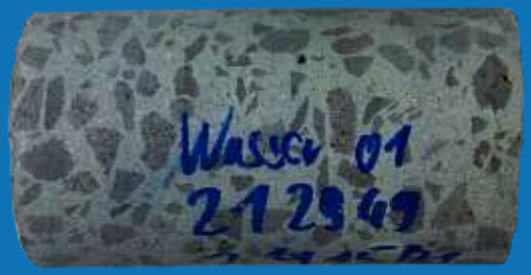
DRINKING WATER (REFERENCE)

	MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1 	57.6	0
SWB2 	53.8	0

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

DRINKING WATER (REFERENCE)

	BEFORE	AFTER
SWB1		
SWB2		

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

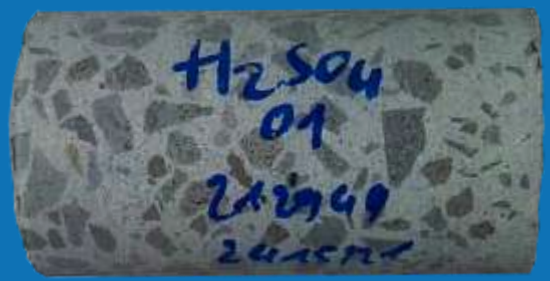
CONC. SULFURIC ACID

	MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1 	52.1	-9.6
SWB2 	52.2	-3.0

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

CONC. SULFURIC ACID

	BEFORE	AFTER
SWB1		
SWB2		

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

HYDROCHLORIC ACID

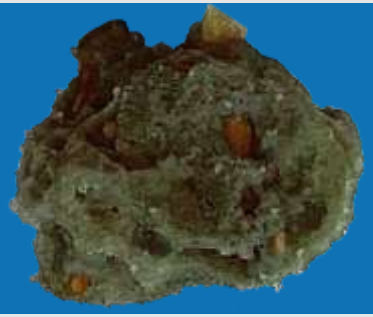
	MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1	---*	---*
SWB2	46.9	-12.9

** test not possible*

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

HYDROCHLORIC ACID

	BEFORE	AFTER
SWB1		
SWB2		

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

PHOSPHORIC ACID

	MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1 	52.9	-8.2
SWB2 	59.0	9.5

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

PHOSPHORIC ACID

		BEFORE	AFTER
SWB1			
SWB2			

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

NITRIC ACID

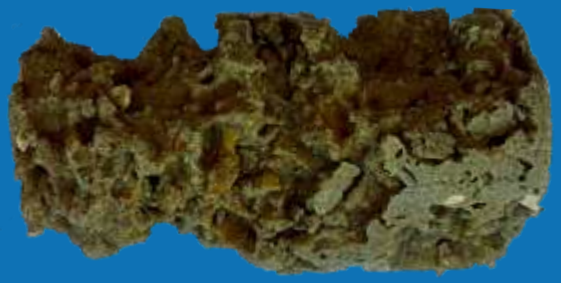
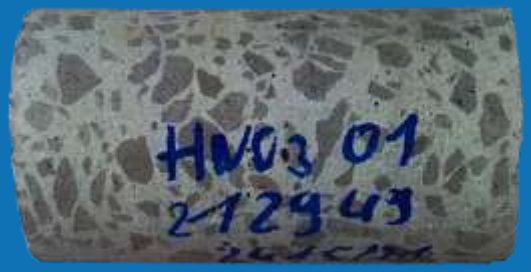
	MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1 	---*	---*
SWB2 	53.7	-0.2

** test not possible*

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

NITRIC ACID

	BEFORE	AFTER
SWB1			
SWB2			

4.1 Results of determination of damage of concrete due to different attacking media

POTASSIUM HYDROXIDE

	MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1 	54.4	-5.6
SWB2 	57.9	7.6

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

POTASSIUM HYDROXIDE

		BEFORE	AFTER
SWB1			
SWB2			

4.1 Results of determination of damage of concrete due to different attacking media

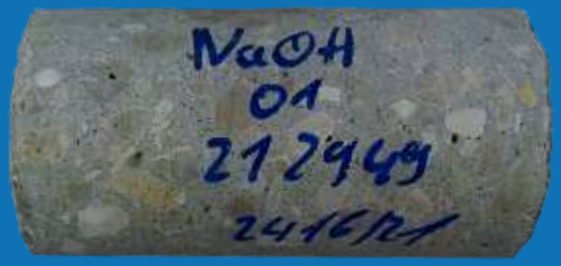
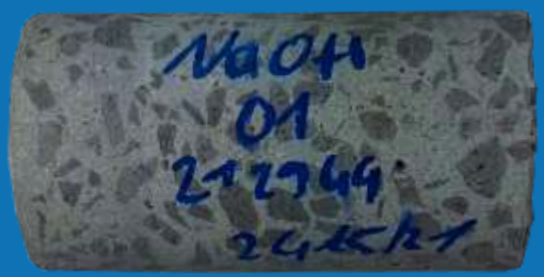
Ha-Be
Making good concrete better

SODIUM HYDROXIDE

		MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1		57.7	0.2
SWB2		57.5	6.8

4.1 Results of determination of damage of concrete due to different attacking media

SODIUM HYDROXIDE

	BEFORE	AFTER
SWB1		
SWB2		

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

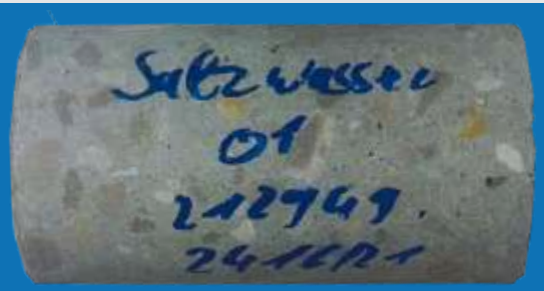
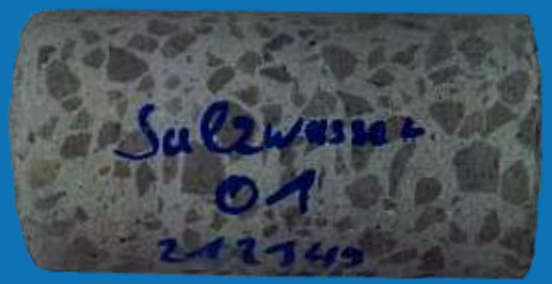
SALTWATER

		MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1		60.1	4.3
SWB2		56.7	5.3

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

SALTWATER

	BEFORE	AFTER
SWB1		
SWB2		

4.1 Results of determination of damage of concrete due to different attacking media

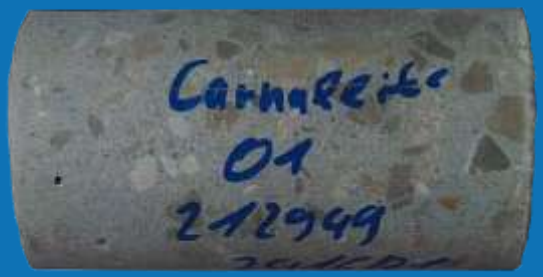
CARNALLIT SOLUTION

	MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1 	63.2	9.6
SWB2 	55.1	2.4

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

CARNALLIT SOLUTION

	BEFORE	AFTER
SWB1		
SWB2		

4.1 Results of determination of damage of concrete due to different attacking media

Ha-Be
Making good concrete better

DEIONISED WATER

	MEAN COMPRESSIVE STRENGTH [after storage – Mpa]	CHANGE IN STRENGTH [compared to reference - %]
SWB1 	57.7	0.1
SWB2 	55.1	2.4

4.1 Results of determination of damage of concrete due to different attacking media

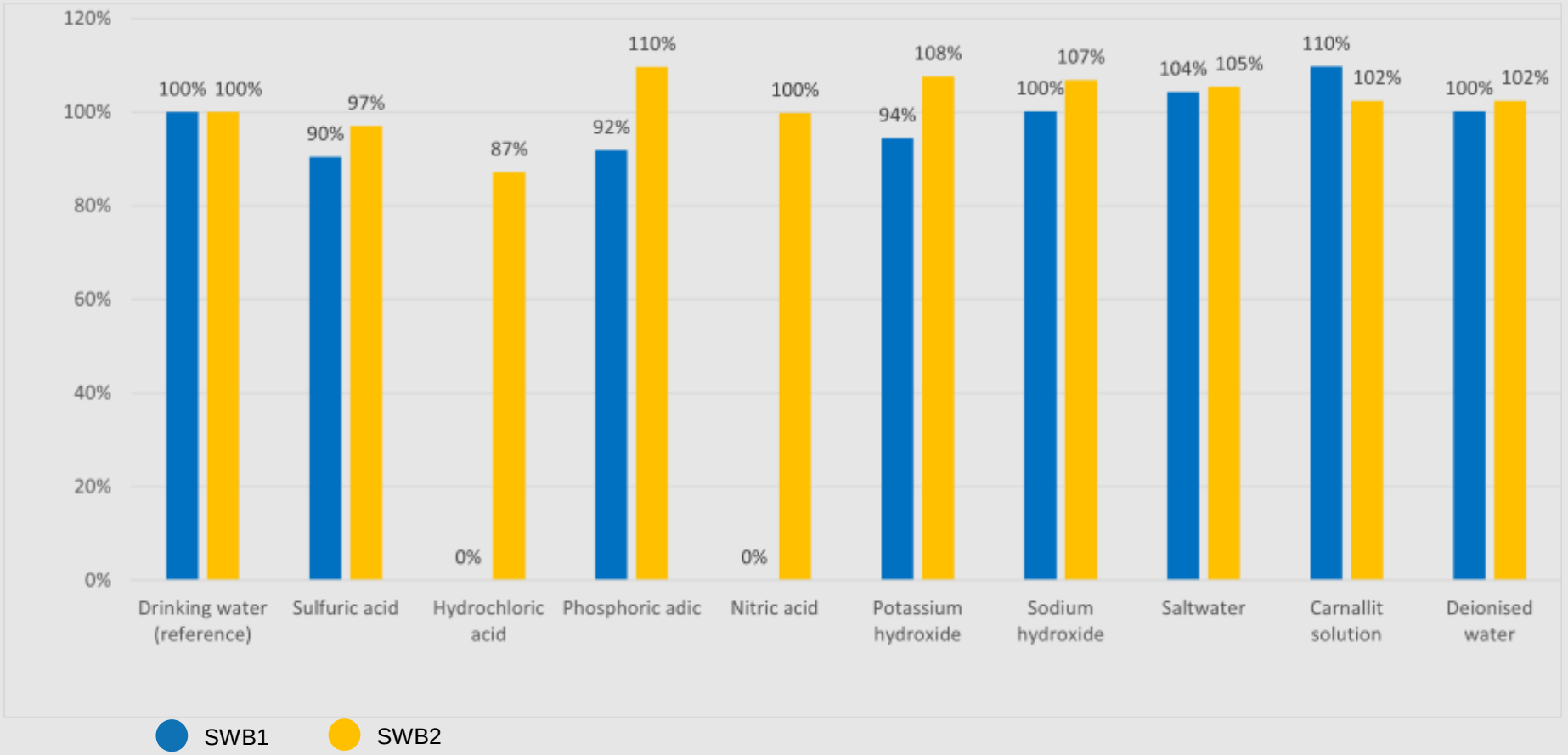
Ha-Be
Making good concrete better

DEIONISED WATER

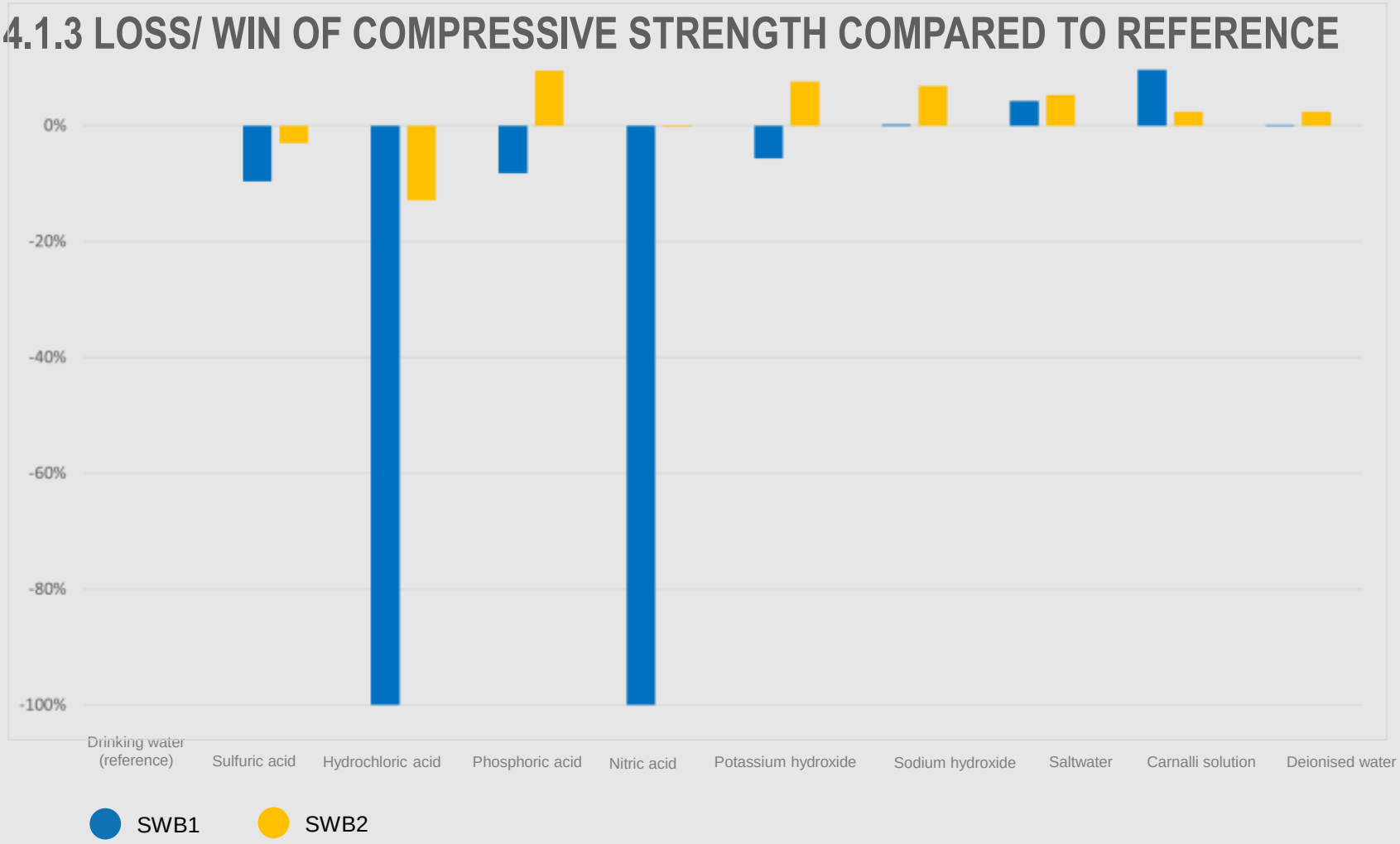
		BEFORE	AFTER
SWB1			
SWB2			

4.1 Results of determination of damage of concrete due to different attacking media

4.1.2 MEAN COMPRESSIVE STRENGTH COMPARED TO REFERENCE



4.1 Results of determination of damage of concrete due to different attacking media



4.2 Results of chloride migration resistance

Ha-Be
Making good concrete better

CHLORIDE MIGRATION COEFFICIENTS

SAMPLE NO.	CHLORIDE MIGRATION COEFFICIENT x 10^{-12} [m^2/s]	
	SWB1 	**SWB2** 
1	8.0	1.8
2	8.2	2.0
3	8.5	1.8
MEAN VALUE D_{CL}	**8.2**	**1.9**
MAX. INDIVIDUAL VALUE $D_{CL, max}$	8.5	2.0

MORE THAN 4 x LOWER AS SWB1

5. Evaluation

Ha-Be
Making good concrete better

5. Evaluation

5.1 DETERMINATION OF DAMAGE OF CONCRETE DUE TO DIFFERENT ATTACKING MEDIA

- Great differences between SWB1 and SWB2 are shown after storage in hydrochloric and nitric acid.
- Although SWB1 concrete is already acid-resistant according to DIN EN 206-1 and DIN 1045-2, it does not meet the requirements of hydrochloric acid or nitric acid

→ **SWB2 shows significantly better behavior regarding the attacking media**

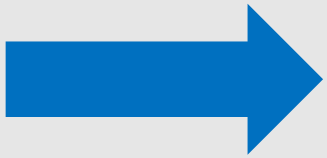
→ **SWB2 exceeds the requirements for class AX3**

5. Evaluation

Ha-Be
Making good concrete better

5.2 CHLORIDE MIGRATION RESISTANCE

- The coefficient for SWB2 is more than 4 times lower than for SWB1
- SWB1 fulfils the requirements of exposure classes XS2 (under water) and XD2 (wet, rarely dry)
- SWB2 fulfils the requirements of exposure classes XS3 (alternately wet and dry) and XD3 (tide, drippling and drizzling water belts)



SWB2 is having a very good behavior regarding the migration of chlorides

6. Statement on test results

Ha-Be
Making good concrete better

PROF. JÖRG REYMENDT, FRANKFURT UNIVERSITY OF APPLIED SCIENCES

Ha-Be
Making good concrete better

MAKING GOOD CONCRETE BETTER.

Not just a Slogan - a promise.

Tradition | Innovation | Quality | Know-how | Service | Experience