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Dok-Nr. 109521

SUMMARY

With reference to the General Circular on Road Construction No. 04/2013 on alkali reactivity, many traffic areas in the municipal sector are assigned to moisture class WS on account of being allocated to load classes Bk1.8 to Bk100. The suitability of aggregates or concrete mixes for moisture class WS can be verified by subjecting the concrete to WS aggregate testing or an ASR performance test. A lack of appropriate verification in many regions means that ready-mixed concrete can often not be supplied. The WS classification was selected for motorways (high dynamic loads and external alkali supply). On account of the lower speeds involved, the dynamic traffic load is however not as high in municipal areas. An additional aspect is that de-icing agents are often not used in urban areas, so that there is less likelihood of alkali supply and a lower risk of deleterious ASR here than in the case of motorways. Moisture class WA or a comparable classification may therefore be sufficient. Drill cores from the municipal road construction sector and laboratory concretes were therefore tested with the methods developed for moisture classes WS and WA in a research project. The test results were taken as a basis for drawing up criteria for alkali reactivity assessment and for the practical assignment of concrete moisture classes in the municipal road construction sector.

ZUSAMMENFASSUNG

Viele Verkehrsflächen im kommunalen Bereich werden unter Bezug auf das Allgemeine Rundschreiben Straßenbau Nr. 04/2013 zur Alkaliempfindlichkeit aufgrund der Einordnung in die Belastungsklassen Bk1,8 bis Bk100 der Feuchtigkeitsklasse WS zugeordnet. Die Eignung von Gesteinskörnungen bzw. Betonen für die Feuchtigkeitsklasse WS kann durch eine WS-Grundprüfung oder eine AKR-Performance-Prüfung des Betons nachgewiesen werden. Da in vielen Regionen keine entsprechenden Nachweise vorliegen, ist oftmals kein Transportbeton lieferbar. Die Einstufung WS wurde für Autobahnen (hohe dynamische Belastung und Alkalizufuhr von außen) gewählt. Bei kommunalen Flächen ist aber infolge der geringeren Geschwindigkeit die dynamische Verkehrsbelastung nicht so hoch. Zudem werden im innerstädtischen Bereich oft keine Taumittel eingesetzt, so dass die Alkalizufuhr und das Risiko einer schädigenden AKR im Vergleich zum Autobahnbau geringer ausfallen dürften. Möglicherweise ist die Feuchtigkeitsklasse WA oder eine vergleichbare Zuordnung ausreichend. In einem Forschungsvorhaben wurden daher Bohrkerne aus Flächen des kommunalen Straßenbaus und Laborbetone mit den für die Feuchtigkeitsklassen WS bzw. WA entwickelten Prüfverfahren geprüft. Aus den Versuchsergebnissen wurden Kriterien erarbeitet, um die Alkaliempfindlichkeit und eine praxisgerechte Zuordnung der Feuchtigkeitsklasse von Betonen im Bereich des kommunalen Straßenbaus zu beurteilen.

(English text supplied by the authors)

Alkali-silica reaction in municipal road construction

Alkali-Kieselsäure-Reaktion im kommunalen Straßenbau

1 Introduction and aim of the investigation

Damage to concrete pavements on federal motorways in Germany arising from alkali-silica reaction (ASR) led to the development of ASR performance test methods [1–5]. The General Circular on Road Construction No. 04/2013 on the topic of alkali reactivity and corresponding testing procedures was published with a view to avoiding damage on motorways and trunk roads [6]. In this, the moisture classes WA (concrete which is often moist, or moist for lengthy periods, and is often exposed, or exposed for lengthy periods, to an external supply of alkalis) and WS (concrete, which in addition to the action effect associated with class WA is subject to a high dynamic load level) are assigned on the basis of the construction or load class [7] derived from the Directives for the standardisation of the superstructures of trafficked surfaces (RStO) (➧ Table 1). The suitability of aggregates or concrete mixes for class WS can be verified by subjecting the concrete to WS aggregate testing or an ASR performance test. Many traffic areas in the municipal sector are assigned to load classes Bk1.8 to Bk100 and thus, by analogy, to moisture class WS in accordance with the circular. These include bus stops, parking areas or types of roads based on the Directives for Urban Road Design (RASt) [8] in the urban sector (➧ Table 2), for example.

The WS classification was selected for federal motorways (external alkali supply and high dynamic load). On account of the lower speeds involved, the dynamic traffic load is probably not as high in municipal areas. In addition, gritting agents tend to be used rather than de-icing agents, thus reducing the alkali supply and the risk of deleterious ASR. Moisture class WA or a comparable classification may therefore be sufficient. The stipulations of the Alkali Guidelines of the German Committee for Structural Concrete (DAfStb) [9] would be applicable to moisture class WA.

Many applications in the field of municipal road construction involve smaller construction jobs than in the case of motorways and so do not warrant setting up an on-site mixing plant. The concrete therefore tends to be supplied by ready-mixed concrete companies. Practical experience since the introduction of the ARS has shown that problems are encountered with smaller building projects in particular, because moisture class WS is now demanded on the basis of the load class. As neither WS aggregate testing nor performance tests are available in many regions, it is often not possible to use concrete construction methods in urban areas. Ready-mixed concrete with the necessary verification cannot be supplied. The aim of the current research project was to provide the municipal traffic area sector with findings as a basis for practicable moisture class assignment and corresponding evaluation of the concrete by way of performance tests, for example. Practice-oriented selection of the moisture class and evaluation by way of a suitable test method help to guard against incorrect usage associated with deleterious ASR and permit the use of regionally available starting materials. The durability and cost-effectiveness of concrete construction are thus enhanced.

2 Scope of the studies

The research project was conducted in three work packages. The first step was to study concrete sections from the municipal sector or comparable applications where good practical experience had been gained. A prerequisite was a service life of at least 10 years without any evidence of deleterious ASR. The sections were visually inspected for ASR-specific damage characteristics and the following data were recorded where available: Starting materials (cement type, alkali content, aggregates), concrete composition and other boundary conditions (year of construction, surface, use of de-icing agents). In order to establish the behaviour of the concretes in laboratory experiments, the second step involved taking drill core samples from the pavements and examining them with the testing procedures developed by VDZ for the moisture classes WA and WS [1 to 5]. Chloride profiles were also determined for selected concrete pave-

Table 1: Moisture classes of traffic areas (trunk roads) with application of the General Circular on Road Construction ARS No. 04/2013 [6]

RStO 01 Design-related load B[1)]	RStO 12 Dimensioning-related load B[1)]	RStO 01 Construction class	RStO 12 [7] Load class	Moisture class, trunk roads as per ARS [6]
> 32		SV	Bk100	WS
10 to 32		I	BK32	
3 to 10	3.2 to 10	II	BK10	
0.8 to 3	1.8 to 3.2	III	Bk3.2	
	1.0 to 1.8		Bk1.8	
0.3 to 0.8	0.3 to 1.0	IV	Bk1.0	WA
0.1 to 0.3	< 0.3	V	Bk0.3	
to 0.1		VI		

[1)] Equivalent 10 t standard axles in million

Table 2: Load classes and moisture class derived from these for typical design situations in the municipal road construction sector [8]

Typical design situation in accordance with [8]	Load class	Moisture class
Road without surrounding structures	Bk10 to Bk100	WS
Connecting road	Bk3.2/Bk10	
Industrial road	Bk3.2 to Bk100	
Commercial road	Bk1.8 to Bk100	
Main business road	Bk1.8 to Bk10	
Local business road	Bk1.8 to Bk10	
Local access road	Bk3.2/Bk10	
Village main road	Bk1.0 to Bk3.2	WA/WS
Access road	Bk1.0 to Bk3.2	
Distributor road	Bk1.0 to Bk3.2	
Residential road	Bk0.3/Bk1.0	WA
Residential street	Bk0.3	

ments and compared to the results from motorways (WS [9]). Finally, selected concretes were replicated in the laboratory. WS and WA performance testing was conducted on the basis of the information from the original initial test, and 40 °C fog chamber testing of the aggregates (crushed stone and gravel) was performed in accordance with the Alkali Guidelines [9].

3 Test results

3.1 Work package 1: Selection of areas

Examples for which good practical findings exist were selected to verify the suitability of concrete mixes for municipal traffic areas and their successful use in practice (❱ Table 3). A prerequisite was a service life of at least 10 years without any evidence of deleterious ASR. Certain potentially suitable areas could not be incorporated into the study, as their owners did not consent to drill core samples being taken when asked (e.g. a bus station and a lorry parking area). Instead of these areas, a section of motorway (no. 3) which had been produced with a concrete of the same composition as used in the region was included in the study. Three areas of

Table 3: Designation and year of construction of selected concrete areas

No.	Usage/type of traffic area	Year of construction
1	Road, left-turn lane	2003
2	Road	2002
3	Motorway hard shoulder with same concrete as other areas in the region in the municipal sector	2005
4	Bus station	2004/2005
5	B8n_I bypass (trunk road)	2002
6	B8n_II bypass (trunk road)	2002
7	Factory road	2004
8	Parking area	2007
9	Lorry parking area	1996

a cement plant with differing amounts of heavy traffic and de-icing agent application were selected (no. 7, 8 and 9). Two areas with different top-layer concretes from the B8n bypass in Duesseldorf (no. 5 and 6) were included. In addition, a bus station (no. 4) and two urban roads in Berlin (no. 1) and Wiesbaden (no. 2) were selected. The concrete used in the road area in Wiesbaden (no. 2) was also employed for the bus stops in the area of the road.

The selected areas were visually inspected for ASR-induced damage patterns [10]. This did not reveal any ASR-specific characteristics. Isolated fine near-surface shrinkage cracks were found.

The accessible data were recorded for each construction job (e.g. starting materials, concrete composition, construction/load class, year of construction, surface) (❱ Table 4). Information was also gathered on the placement method and treatment with de-icing agents, for example. With the exception of the B8n bypass (2-layer concrete), the concretes were placed in single layers. With regard to the traffic load, it can be assumed that at the time of construction areas 1 to 7 were assigned to construction classes SV and I to III and therefore formally comply with moisture class WS today. Area 8 is assigned to class WA and area 9 to class WS/WA. It was only possible to acquire qualitative information concerning the treatment with de-icing agents during gritting operations. Area no. 8 (parking area) was regularly treated with de-icing agent in winter. De-icing agent application was qualitatively classified as low, medium or high.

3.2 Work package 2: Drill core investigations

Drill core samples were taken from the nine areas. A sample of concrete was taken from the drill core of each area and thin sections of this were investigated for ASR-specific characteristics (cracks, gel). At the time of sampling there was no indication of deleterious ASR in any of the areas. Moreover, the chloride profile and the expansion in the 60 °C concrete test with alkali supply were determined.

3.2.1 Chloride profile

The chloride content of six selected concrete pavements was obtained via the cross-section to estimate the sodium chloride penetration behaviour in the concrete. The near-surface chloride profile determined was compared to data from drill cores from motorways (WS [11]). ❱ Fig. 1 shows the water-soluble chloride content of the concrete referenced to the proportion of hardened cement paste in relation to the dis-

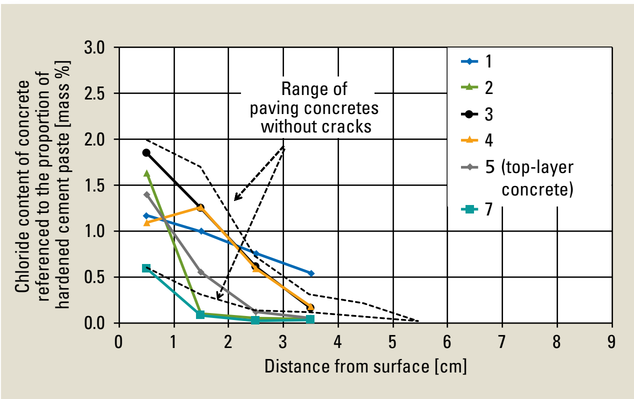

Figure 1: Water-soluble chloride content of drill cores from motorway concrete pavements (dashed lines [11]) and of drill cores from the municipal sector referenced to the proportion of hardened cement paste in relation to the distance from the surface

Table 4: Characteristic values of concrete pavements

No.	Concrete pavement construction method	Cement	kg/m³	Na_2O [mass %]	Age [years]	Classification in moisture class WS/WA	Use of de-icing agents in winter
1	Single-layer	CEM I 32,5 R	380	0.91	12	WS (Bkl I)	High
2		CEM I 42,5 R	370	0.82	13	WS (Bkl I)	Low
3		CEM I 32,5 R	350	0.58	10	WS (Bkl SV)	High
4		CEM II/B-T 42,5 N	355	0.79	9	WS (Bkl II)	High
5	Top-layer concrete I	CEM I 32,5 R	370	0.70	14	WS (Bkl SV)	High
6	Top-layer concrete II		375				
5/6	Bottom-layer concrete I/II		360				
7	Single-layer	CEM II/B-S 42,5 N	350	0.78	11	WS (Bkl III)	Low
8		CEM II/A-M (S-LL) 42,5 R	360	0.87	8	WA (Bkl V)	High
9		CEM I 32,5 R	340	0.85	19	WS/WA (Bkl III/IV)	Low

tance from the surface. The dashed lines outline the range of values obtained from motorway samples (WS). The soluble chloride content of the hardened cement paste decreased continuously down to a depth of around 5 cm. No systematic difference became apparent between the municipal areas and the motorways. With the exception of the factory road (area 7) which was not treated with de-icing agents, the other areas fell within the value range of the motorways (WS). The samples investigated could not confirm that lower chloride profiles generally occur in municipal road pavements as a result of a more sparing use of de-icing agents.

3.2.2 Drill core investigation in 60 °C concrete test with external alkali supply

Two drill cores from each of the nine areas were used for the tests. The drill cores were halved lengthways and measuring marks were placed at intervals of 20 cm. In the case of the two 2-layer concrete pavements (no. 5 and 6), the expansion of the approximately 5 cm to 7 cm thick top-layer concrete was separately recorded with additional 10 cm measurement sections on the top end face and on the inside of the lateral surface.

The residual expansion potential of the concrete was determined by way of the 60 °C concrete test with external alkali supply for the moisture classes WA (3 % NaCl solution) and WS (3 % and 10 % NaCl solution). If the expansion after ten cycles with 3 % alkali supply does not exceed a value of 0.50 mm/m, the concrete can be assigned to moisture class WA. For moisture class WS, values of 0.50 mm/m and 0.30 mm/m must not be exceeded with 10 % alkali supply and 3 % solution respectively. The test duration was extended from the normal ten cycles to a total of 15 cycles.

It became apparent that the short measurement section of 10 cm was not suitable for obtaining reproducible measured values. Only the bottom-layer concrete is therefore shown in the illustrations for the concretes B8n_I and B8n_II (no. 5 and 6). With one exception, no significant increase in expansion was found after ten cycles for a concentration of 3 % NaCl (➧ Fig. 2). The possible causes of the great expansion obtained with no. 8 must be investigated. As the expansion of the concretes is below a value of 0.50 mm/m, these can be assigned to moisture class WA. Based on the test results, the majority of the concretes would also be suitable for moisture class WS (≤ 0.30 mm/m).

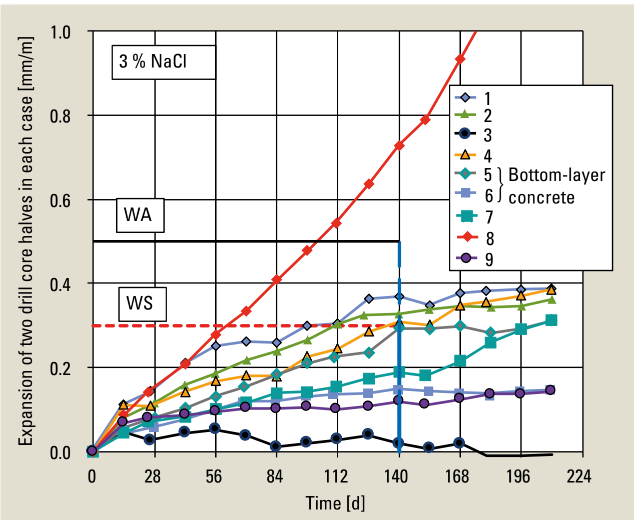

Figure 2: Expansion of drill core halves (mean value from two drill core halves) from the nine areas in the 60 °C concrete test with external alkali supply through a 3 % NaCl solution

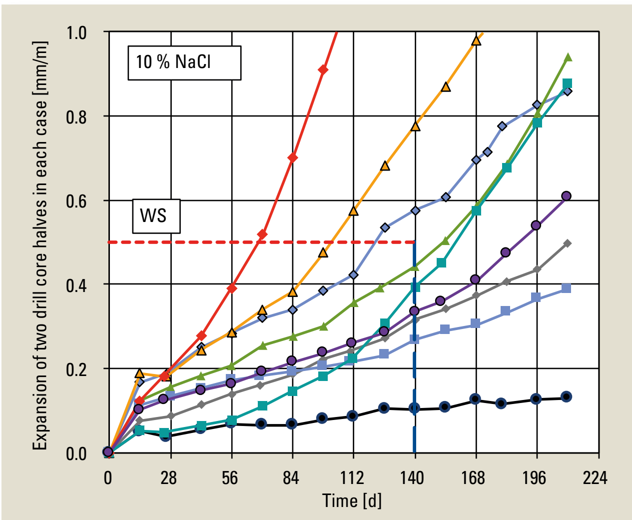

Figure 3: Expansion of drill core halves (mean value from two drill core halves) from the nine areas in the 60 °C concrete test with external alkali supply through a 10 % NaCl solution

Table 5: Concrete compositions in accordance with the applicable original initial test for the subsequent performance test

Characteristic value	Area			
	No. 1	No. 2	No. 3	No. 8
Cement	380 kg/m³ CEM I 42,5 N WS test cement	370 kg/m³ CEM I 42,5 N WS test cement	350 kg/m³ CEM I 42,5 N	360 kg/m³ CEM II/A-M (S-LL) 42,5 R
Na_2O equivalent	0.76 doped to 0.91 mass %	0.76 doped to 0.82 mass %	0.64 mass %	0.87 mass %
Water	168 kg/m³	173.9 kg/m³	140 kg/m³	153 kg/m³
w/c ratio	0.44	0.47	0.40	0.43
Air content	4.5 vol. %	4.5 vol. %	4.5 vol. %	4.5 vol. %
Aggregates	Values in vol. %, bulk density in kg/dm³			
Sand 0/2 mm	31 vol. %, 2.68	30 vol. %, 2.64	29 vol. %, 2.63	28 vol. %, 2.66
Gravel 2/8 mm	25 vol. %, 2.62	20 vol. %, 2.62	19 vol. %, 2.63	23 vol. %, 2.64
Gravel 8/16 mm	–	–	–	13 vol. %, 2.64
Crushed stone 8/11	–		14 vol. %, 2.70	–
Crushed stone 11/16	–		14 vol. %, 2.70	–
Crushed stone 8/16	44 vol. %, 2.76	50 vol. %, 2.80		36 vol. %, 2.65
Crushed stone 16/22	–	–	24 vol. %, 2.70	–

A far greater increase in expansion, even beyond the value for ten cycles, can be seen for a concentration of 10 % NaCl (➧ Fig. 3). Six of the nine types remained below the 0.50 mm/m assessment criterion after ten cycles for moisture class WS. Concrete 3 from the hard shoulder of a motorway, which was used in the same composition in several municipal areas in the region, exhibited very little expansion.

3.3 Work package 3: Production of laboratory concretes

3.3.1 General

Work package 3 involved obtaining the starting materials (cement, aggregates) of the concrete used to make the concrete pavements of samples no. 1, 2, 3 and 8 and then producing concretes from these in the laboratory. Based on the information from the original initial test, an ASR performance test was subsequently conducted by way of the 60 °C concrete test with a 3 % and 10 % NaCl solution. The concrete compositions for the performance tests are listed in ➧ Table 5.

As the cements originally used were no longer available in three cases, an ASR test cement was doped (no. 1 and no. 2) or use was made of a comparable cement (no. 3) (➧ Table 6). The alkali reactivity of the aggregate was also tested in accordance with the Alkali Guidelines with 40 °C fog chamber storage (four gravels and four crushed stones). The concrete compositions corresponded to the Alkali Guidelines (➧ Table 7).

3.3.2 ASR performance test

As, with a concentration of 3 % NaCl, the expansion of all the concrete mixes was below a value of 0.50 mm/m, these could be assigned to moisture class WA (➧ Figs. 4a to d). Based on the test results, three of the concrete mixes would also be suitable for moisture class WS (≤ 0.30 mm/m). The high level of drill core expansion exhibited by concrete no. 8 as compared to other areas was no longer found in the (subsequent) performance test (Fig. 4d). A far greater increase in expansion, even beyond the value for ten cycles, can be seen for a concentration of 10 % NaCl. Two types (no. 2 and no. 3, Figs. 4b and 4c) remained below the 0.50 mm/m assessment criterion after ten cycles for moisture class WS.

Table 6: Cements for performance tests with the 60 °C concrete test

Area	Cement on placement		Current cement		Cement for experimental programme
	Cement type	Na_2O [mass %]	Cement type	Na_2O [mass %]	
1	CEM I 32,5 R	0.91	CEM I 42,5 R	1.00	WS test cement CEM I 42,5 R Na_2O = 0.76 mass % doped to 0.91 mass %
2	CEM I 42,5 R	0.82	Clinker production discontinued	–	WS test cement CEM I 42,5 R Na_2O = 0.76 mass % doped to 0.82 mass %
3	CEM I 32,5 R	0.58	CEM I 52,5 N (so)	0.25	CEM I 42,5 N Na_2O = 0.64 mass %
8	CEM II/A-M (S-LL) 42,5 R	0.87	CEM II/A-M (S-LL) 42,5 R	0.87	Current cement

3.3.3 40 °C fog chamber storage

Five of the eight aggregates investigated (➧ Figs. 5a to h) met the requirements after 270 days: Cube crack width < 0.20 mm and prism expansion ≤ 0.60 mm/m. The following three aggregates failed to meet the requirements:

- Gravel from area no. 1: Expansion and crack width exceeded (Fig. 5 a),
- Crushed stone from area no. 3: Expansion and crack width exceeded (Fig. 5 f),
- Crushed stone from area no. 8: Crack width exceeded on last measurement date (Fig. 5 h).

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Table 7: Concrete compositions for testing in 40 °C fog chamber

Characteristic values of concrete compositions								
Cement	400 kg/m³ CEM I 32,5 R ASR test cement							
Na_2O	1.30 mass % (doped from 1.13 mass % with K_2SO_4)							
Water	w/c = 0.45: 180 kg/m³							
Air content	1.0 vol. %							
Sand 0/2	30 vol. % natural sand (VDZ standard sand)							
Aggregate [vol. %]								
Area	**1**		**2**		**3**		**8**	
Particle size group	0/16 mm		0/16 mm		0/22 mm		0/16 mm	
	Gravel	Crushed stone	Gravel	Crushed stone	Gravel	Crushed stone	Gravel	Crushed stone
2/8 mm	40	40	40	40	20	20	40	40
8/16 mm	30	30	30	30	20	20	30	30
16/22 mm	–	–	–	–	30	30	–	–

On the basis of these results, these three aggregates would be assigned to alkali reactivity class E III-S (alkali reactive). In accordance with the Alkali Guidelines they could then not be used for moisture class WA without taking other measures. A low-alkali cement has to be used in the case of cement contents up to and including 350 kg/m³. For cement contents > 350 kg/m³, the aggregate has to be replaced or the suitability of the concrete has to be verified in a performance test.

4 Summary

4.1 General

Damage from alkali-silica reaction can be avoided by using concretes with alkali reactivity low enough

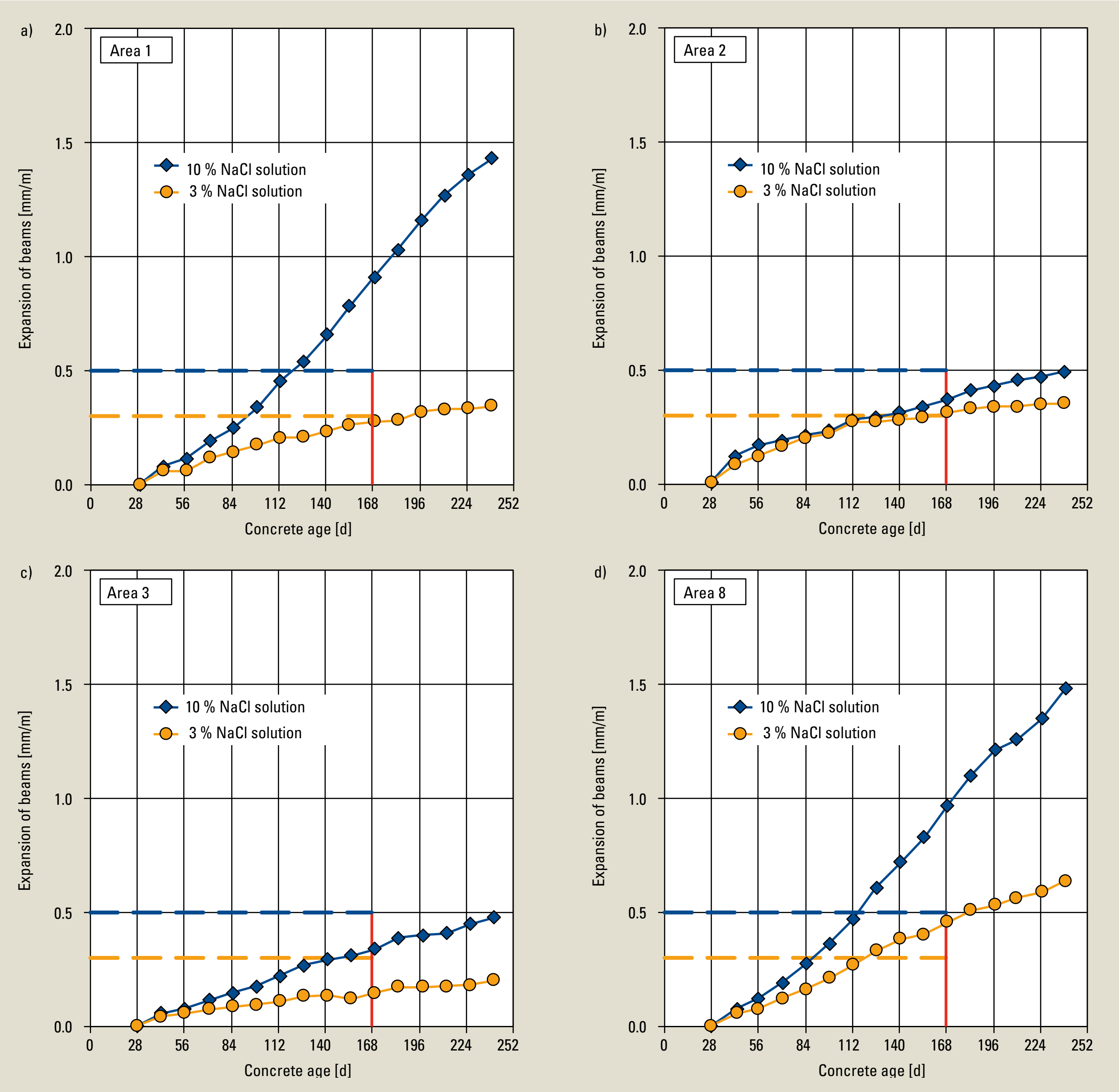

Figure 4: Expansion of concrete beams in the 60 °C concrete test with external alkali supply; a) Area 1; b) Area 2; c) Area 3; d) Area 8

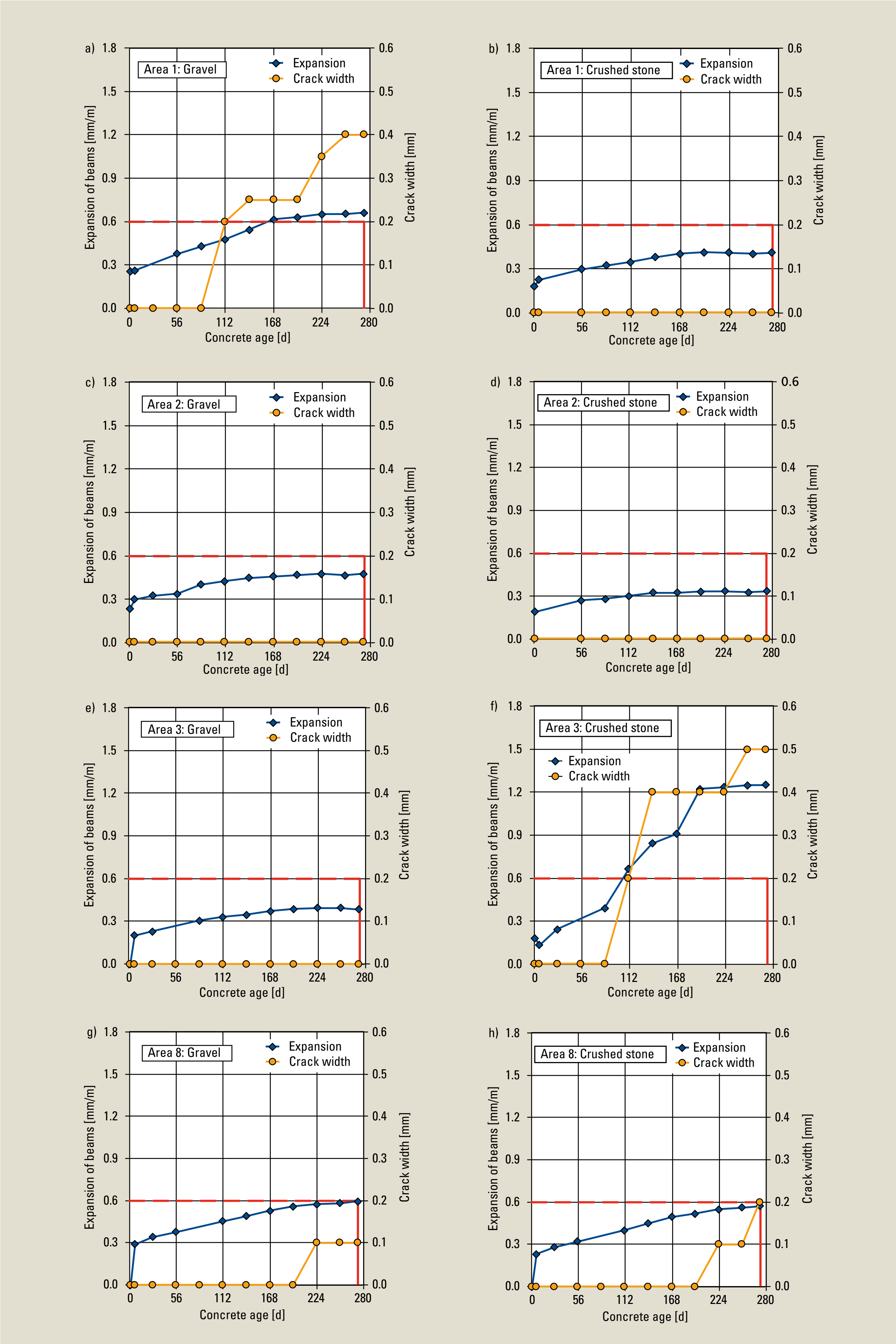

Figure 5: Expansion of concrete beams and crack width of concrete cubes in 40 °C fog chamber storage; a) and b) Area 1; c) and d) Area 2; e) and f) Area 3; g) and h) Area 8 (gravel on the left and crushed stone on the right in each case)

for the application concerned (= moisture class). Criteria to permit appropriate assessment of the alkali reactivity of concretes in the municipal road construction sector were drawn up in the IGF project IGF 18775 N. This involved using the 60 °C concrete test with various sodium chloride concentrations and 40 °C fog chamber storage.

4.2 Assessment of concretes with the test methods

All but one of the drill cores revealed expansion below the assessment criterion for moisture class WA in the 60 °C concrete test (➧ Fig. 6 on the left, 3 % NaCl). Expansion above the assessment criterion was found in one case (area no. 8). According to the sample provider, the area is ten years old and undamaged. On account of the assignment of the aggregate to class E III-S (alkali reactive) on the basis of fog chamber testing, the concrete would not correspond to the Alkali Guidelines in moisture class WA. In the case of area no. 3 from the hard shoulder of a motorway, the crushed stone is likewise assignable to E III-S, which means that, according to the Alkali Guidelines, it cannot be used in moisture class WA with a cement content > 350 kg/m^3. With a cement content up to 350 kg/m^3 the aggregate can be used with low-alkali cement. For the concrete of area 3 in the investigation, the content was 350 kg/m^3 and the cement used had low-alkali properties (s. Table 4).

Eight out of nine of the drill cores exhibited expansion below the assessment criterion for moisture class WA. The one concrete with expansion above the assessment criterion for moisture class WA would not have been suitable for WA on account of the fog chamber results for one of the aggregates used. All four of the laboratory concretes exhibited expansion below the assessment criterion for moisture class WA. Five out of nine drill cores also met the assessment criteria for moisture class WS (Fig. 6, on the left, 3 % NaCl). This likewise applied to two laboratory concretes.

4.3 Proposal for the assessment of concrete areas in the municipal sector

In the cases examined, application of the stipulations of the Alkali Guidelines for moisture class WA appears to be appropriate for road pavements. For concrete road pavements in the municipal sector up to and including load class Bk10, the recommendation is to base measures to prevent ASR on moisture class WA in the future (➧ Table 8). The concrete compositions and the starting materials must conform to the requirements of the Alkali Guidelines. The requirements for cements in accordance with the technical delivery terms for materials and material mixtures for base courses with hydraulic binders and concrete pavements (TL Beton-StB) would still apply irrespective of the moisture class if the invitation to tender makes reference to TL Beton-StB. In the event of classification in moisture class WA, the cement may additionally be subject to the requirements of DIN 1164-10 (low-alkali cement) in certain cases. Performance tests would then have to be conducted in the cases defined in the Alkali Guidelines or in case of doubt.

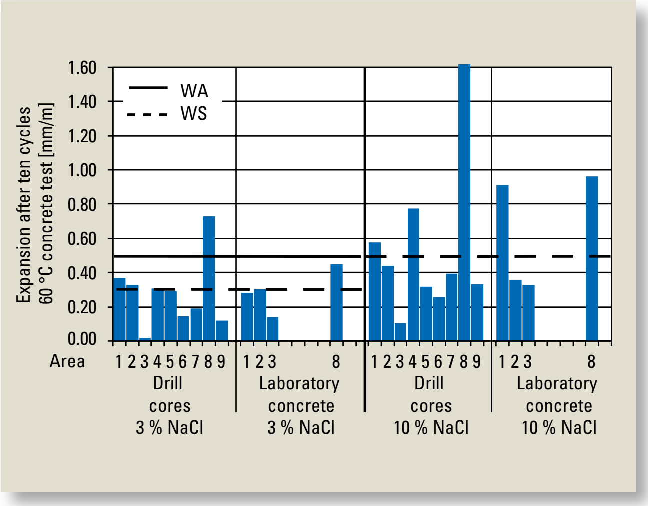

Figure 6: Expansion of drill core halves/concrete beams after ten cycles of alternating storage in the 60 °C concrete test with external alkali supply through a 3 and 10 % sodium chloride solution

Note on sponsorship

The IGF project IGF 18775 N of the research association VDZ gGmbH was sponsored by the Federation of Industrial Cooperative Research Associations within the framework of the scheme to promote Industrial Collective Research and Development (IGF) of the German Federal Ministry for Economic Affairs and Energy based on a resolution passed by the German Bundestag.

Table 8: Proposal for the moisture class assessment of areas in the municipal sector as opposed to trunk roads in accordance with ARS

<table>
<tr><th rowspan="2">RStO 01 Design-related load B[1)]</th><th rowspan="2">RStO 12 Dimensioning-related load B[1)]</th><th rowspan="2">RStO 01 Construction class</th><th rowspan="2">RStO 12 [7] Load class</th><th colspan="2">Moisture class</th></tr>
<tr><th>Trunk roads as per ARS</th><th>Municipal sector (VDZ proposal)</th></tr>
<tr><td colspan="2">> 32</td><td>SV</td><td>Bk100</td><td rowspan="5">WS</td><td rowspan="2">WS</td></tr>
<tr><td colspan="2">10 to 32</td><td>I</td><td>Bk32</td></tr>
<tr><td>3 to 10</td><td>3.2 to 10</td><td>II</td><td>Bk10</td><td rowspan="6">WA
Extension up to Bk10</td></tr>
<tr><td rowspan="2">0.8 to 3</td><td>1.8 to 3.2</td><td rowspan="2">III</td><td>Bk3.2</td></tr>
<tr><td>1.0 to 1.8</td><td>Bk1.8</td></tr>
<tr><td>0.3 to 0.8</td><td>0.3 to 1.0</td><td>IV</td><td>Bk1.0</td><td rowspan="3">WA</td></tr>
<tr><td>0.1 to 0.3</td><td rowspan="2">< 0.3</td><td>V</td><td rowspan="2">Bk0.3</td></tr>
<tr><td>to 0.1</td><td>VI</td></tr>
</table>

[1)] Equivalent 10 t standard axles in million

LITERATURE

[1] Siebel, E.; Böhm, M.; Borchers, I.; Müller, C.; Bokern, J.; Schäfer, E.: AKR-Prüfverfahren: Vergleichbarkeit und Praxis-Relevanz. beton 56 (2006) No. 12, pp. 599–604; 57 (2007) No. 1–2, pp. 63–71.

[2] Müller, C.; Borchers, I.; Eickschen, E.: AKR-Prüfverfahren: Auf dem Weg zur Performance-Prüfung. Beton- und Stahlbetonbau 102 (2007) No. 8, pp. 528–538.

[3] Müller, C.; Borchers, I.; Eickschen, E.: Erfahrungen mit AKR-Prüfverfahren – Hinweise zur Ableitung praxisgerechter Bewertungskriterien für Performance und WS-Grundprüfungen. beton 62 (2012) No. 10, pp. 397–406.

[4] Müller, C.; Borchers, I.: AKR-Performance-Prüfungen: Erweiterung der Datenbasis mit dem 60 °C-Betonversuch unter besonderer Berücksichtigung von Zementen mit mehreren Hauptbestandteilen: AiF-Forschungsvorhaben Nr. 16569 N, VDZ gGmbH, Duesseldorf 2014.

[5] Borchers, I.; Müller, C.: Bewertung der Alkaliempfindlichkeit von Betonen für die Feuchtigkeitsklassen WF und WA. 18. Internationale Baustofftagung ibausil, Tagungsbericht Bd. 2, Weimar 2012, pp. 327–336.

[6] Allgemeines Rundschreiben Straßenbau Nr. 04/2013 – Sachgebiet 06.1: Straßenbaustoffe; Anforderungen, Eigenschaften – 04.4: Straßenbefestigung, Bauweisen – Vermeidung von Schäden an Fahrbahndecken aus Beton in Folge von Alkali-Kieselsäure-Reaktion (AKR).

[7] Richtlinien für die Standardisierung des Oberbaus von Verkehrsflächen RStO 12, Forschungsgesellschaft für Straßen- und Verkehrswesen, Arbeitsgruppe Infrastrukturmanagement, Ausgabe 2012, FGSV Verlag, Köln 2012.

[8] Richtlinien für die Anlage von Stadtstraßen, RASt 06, Forschungsgesellschaft für Straßen- und Verkehrswesen, Arbeitsgruppe Straßenentwurf, Ausgabe 2006, FGSV Verlag, Köln 2006.

[9] Vorbeugende Maßnahmen gegen schädigende Alkalireaktion im Beton: Alkali-Richtlinie. Deutscher Ausschuss für Stahlbeton, Berlin 2013.

[10] Empfehlungen für die Schadensdiagnose und die bauliche Erhaltung von AKR-geschädigten Fahrbahndecken aus Beton. Fortschreibung April 2012.

[11] Auswirkungen der Alkalizufuhr durch Taumittel auf Bindemittel für Beton mit alkalireaktiven Gesteinskörnungen: Schlussbericht zu Vorhaben Nr. 15977 N. Verein Deutscher Zementwerke, Bundesanstalt für Materialforschung und -prüfung, Duesseldorf, Berlin 2011.