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Summary report

Accelerated Test for AAR of German Concrete Aggregates

1. Purpose

The aim of this research is to examine, if an existing internationally used of accelerated test for AAR might be applicable for the diagnosis of German aggregates. The integration in the Alkali Code of practice of the DAfStB (German Committee for Reinforced Concrete) would be convenient then. Part 3 of the Alkali Code of Practice is to examine Greywackes and other suspicious aggregates with expansion measurings of concrete prisms and observations of cracking on 30 cm cubes in a 9 months fog chamber test procedure. Due to the long duration of the storage, an accelerated test procedure would be a convenient alternative or completion of the existing test procedure in Part 3. However, the accelerated test has its usefulness only, if the evaluations of the results are similar to the now used, 9-month taken procedure. Important for an accelerated test is a simple handling without any special instruments. If such circumstances were all worked out, this accelerated test procedure could be used not only for the external quality control but for the internal quality control in the gravel pits as well.

2. Accomplishment of the Examinations

The examined accelerated test is based on the procedures of NBRI, ASTM-C-1260 and Rilem. It is internationally used and known as the (ultra) accelerated Mortar Bar Test. The duration of this test takes 14 days maximum. The formed prisms consist of fractured aggregates, and will be stored in 80 °C hot sodium hydroxide solution. The expansions are be measured for 14 days. The exceeding of the expansion with 1 per mille in this measured period is internationally the common value for detecting an alkali reactive aggregate.
The intention was to check the possibility of transferring this test procedure to German circumstances. Would this procedure combined with German suspicious aggregates lead to any definite results?
The following 9 rocks respectively aggregate compositions, together with a Portland cement (CEM I) with a Na_2O-equivalent of 1,3 % has been verified with the accelerated testing procedure.

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Tab.: 1 Compositions

No	CEM I (Na_2O-Equivalent 1.3%)	CEM I (Na_2O-Equivalent < 0.6%)
1	Greywacke Lausitz I	Greywacke Lausitz I
2	Greywacke Lausitz II	Greywacke Lausitz II
3	Greywacke Harz I	
4	Oberrhein-high grade chippings	
5	Glensanda- granite	
6	Glensanda- granite+ 2 % Opaline sandstone, ρ = 1.3-1.5 g/cm^3 (OSS-N)	Glensanda- granite+ 2 % Opaline sandstone, ρ = 1.3-1.5 g/cm^3 (OSS-N)
7	Glensanda- granite + 2 % Opaline sandstone, ρ = 1.7-1.9 g/cm^3 (OSS-H)	
8	Glensanda- granite + 2 % Opaline sandstone, ρ = 1.3-1.5 g/cm^3 + fine Aggregates (OSS- NF)	
9	Cement paste, no Aggregates	

The aggregates 1, 2 and 6 have also been tested with a Portland cement (CEM I) containing a Na_2O-equivalent of < 0,6 %.
In comparison of the rock No. 1 - 7 with the cement CEM I (1,3 % Na_2O-equiv.), concrete specimens were produced and tested in a fog chamber for 9 months according to Part 3 of the Alkali Code of practice in parallel.
In addition to both test procedures, the aggregates were characterized and described petrographically. The fabric of the used aggregates was examined with thin sections under the microscope in detail. After the expansion and storage experiments of both test procedures, the condition state of the concrete pieces were then documented photographically. Out of some tested concrete slices have been sawed out for producing larger thin sections. These have been investigated for describing the effect of the Alkali Aggregate Reaction in detail.

3. Summarized Representation of the Results

3.1 Characterization of the used Aggregates

In the following, thin sections of the used aggregates were represented. The following two photos (1 and 2) show the fabrics of the Greywackes Lausitz 2 and Harz 1.

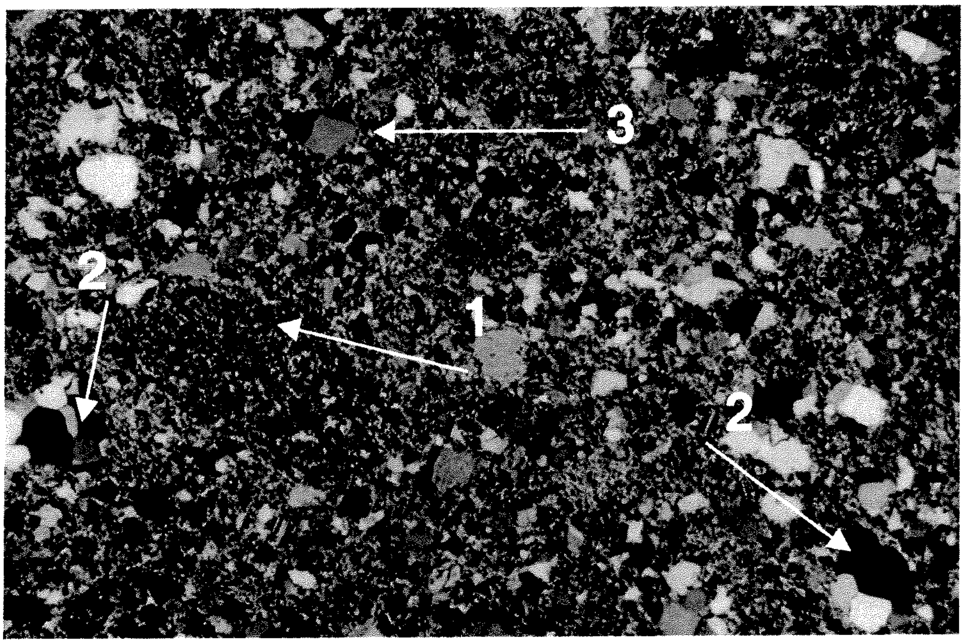


Photo 1 Greywacke Lausitz II, crossed Polarizers, Magnification 50-time, Image width ca. 4 mm, 1) cryptocrystalline Quartz, 2) intercrystallized Quartz grains, 3) detrial Quartz grain

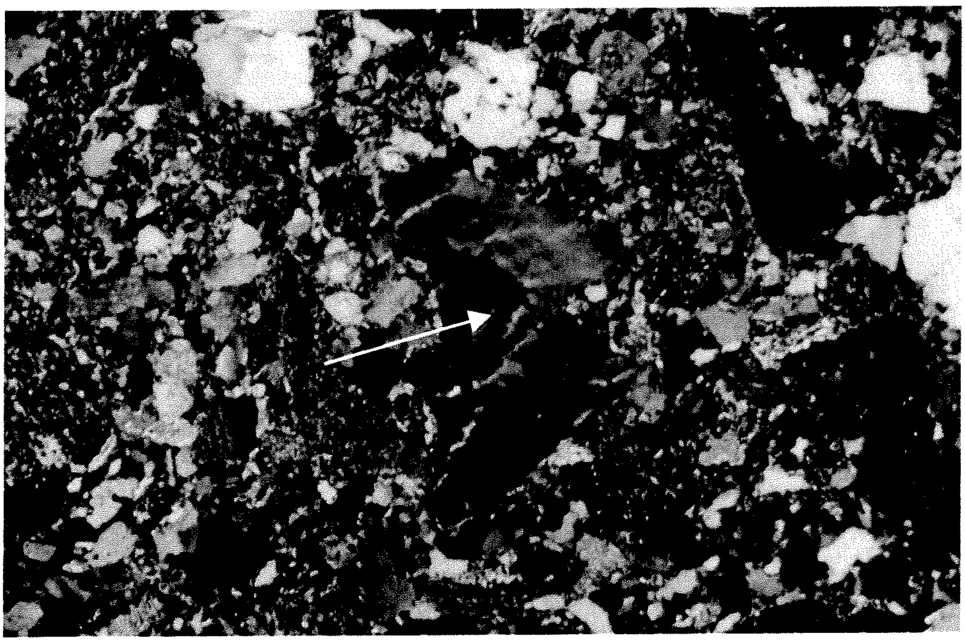


Photo 2 Greywacke Harz I, crossed Polarizers, Magnification 50-time, Image width ca. 4 mm, strong undulatory Quartz grain (Arrow)

Under the microscope crypto crystalline quartz accumulates and strong undulatory quartz grains could be identified quite often. These are responsible for the concluded Alkali Aggregate Reaction in all probability. The further exemplarily shown photos 3+4 display thin sections of the chert part which is found in the examined Oberrhein- high grade chippings in a worth mentioning way. Especially biogenic sponge needles are to be mentioned as alkali reactive.

Photo 3 Oberrhein- high grade chippings, Chert, crossed Polarizers, Magnification 50-time, Image width ca. 4 mm,1) spherical Chalzedon-Aggregates, 2) cryptocrystalline Quartz

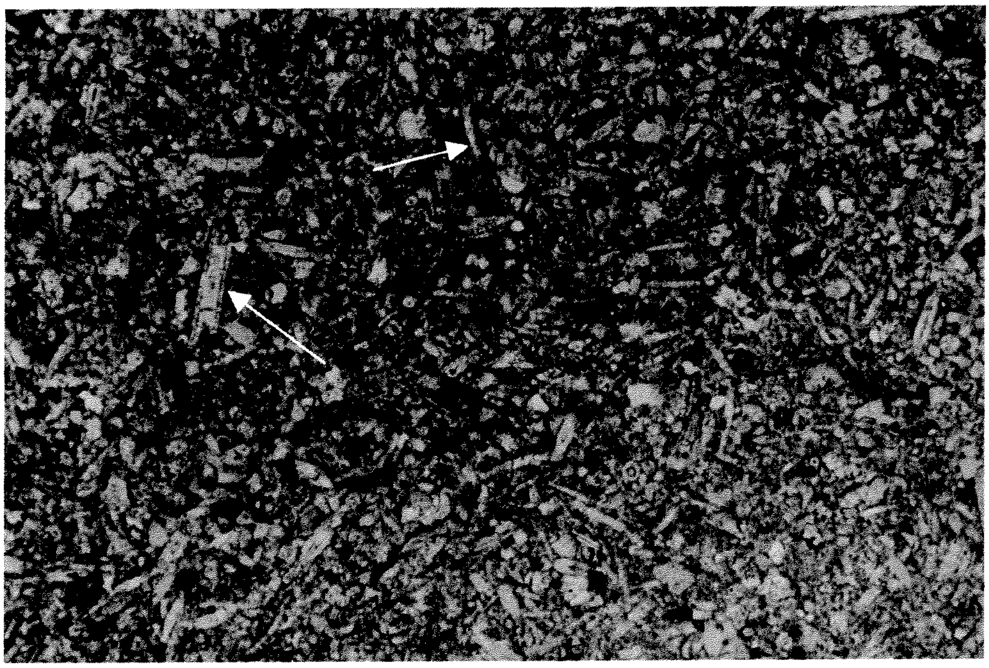


Photo 4 Oberrhein- high grade chippings, Chert, linear Polarizers, Magnification 100-times, Image width ca. 2 mm, biogenic Sediment with Sponge needles (Arrows)

Thin section photos of the remaining aggregates are not shown in this place. Only the strong alkali reactive biogenic sponge needles of the Opaline sandstone are remarkable.

Characterizing rock types also includes the measuring of the pore volume and therefore the density versus the water inhibition value. The following table shows not only the evaluated densities but also the pore volume of the aggregates.

Tab.: 2 Results of the Mercury Intrusion Porosimeter

Samplezeichnung	ρ_{bulk} [g/ml]	ρ_{rein} [g/ml]	V_P [Vol.-%]
Greywacke Lausitz I	2,6490	2,6618	0,48
Greywacke Lausitz II	2,6960	2,7170	0,77
Greywacke Harz I	2,7195	2,7316	0,44
Oberrhein-high grade chippings	2,6080	2,6168	0,34
Oberrhein-high grade chippings (Chert)	2,6151	2,6514	1,37
Glensanda- Granite	2,5710	2,5827	0,45
Opaline sandstone 1,3-1,5 g/cm³	1,4862	2,3429	36,56
Opaline sandstone 1,3-1,5 g/cm	1,4945	2,3138	35,41
Opaline sandstone 1,7-1,9 g/cm³	1,6917	2,1568	21,57

The results show that the Greywackes, the Granite and considerable parts of the Oberrhein-Material feature extremely low porosities of about 0,5 Vol.-%. This explains the slow reactivity of these rocks. In contrast, the porosity of dense Opaline sandstone is about 22 Vol.-%, and the Opaline sandstone with low density about 36 Vol.-%. On one hand, these porosities give reasons for the definitely faster reaction of this aggregate. On the other hand, they also explain the much lesser concrete damaging of the Opaline sandstone with low density compared to the one with higher density.

3.2. Results of the comparative investigations to the accelerated test and estimation

According to the instructions of the Alkali Code of practice Part 3, concrete prisms and cubes with particle size groups of 0-2, 2-8 and 8-16 were produced. The testing aggregates include particle size groups 2-16 mm and come to 70 % of the total aggregate, while the particle size group 0-2 maintain 30 % consisting non-reactive sand.
The prisms of the accelerated test containing the testing aggregate only. The aggregates were crushed and consist of different particle size groups. The maximum particle size was 4 mm.

The measured expansion of the concrete prisms for all tested aggregates (fog chamber samples) were shown on the following diagram.

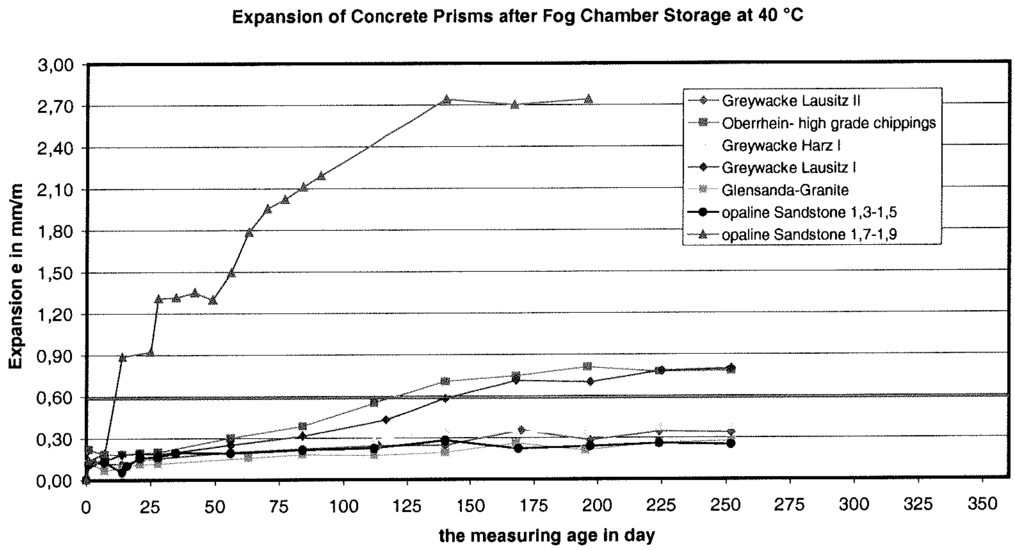
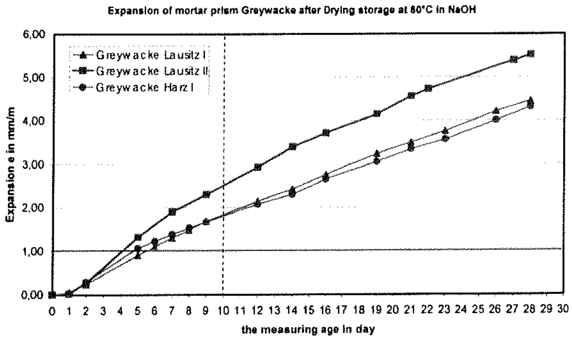


Diagram 1: Comparison of all mean average values

It is clearly seen that the mixture with dense opaline sandstone shows the fastest reaction and the highest expansion during 9 months storage time. The Greywacke Lausitz 1 and the Oberrhein material exceed the non-reactive expansion limit of 0,6 mm/m according to part 3 of the guideline as well. All other aggregates i.e. Greywackes Lausitz 2 and Harz 1, the Glensanda granite and the mixture with the opaline sandstone of low density reach the expansion limit by no mean. Considering the expansion results of the concrete prisms according to the guideline part 3 only, the evaluation would lead to a misinterpretation, because the simultaneous examined, quite sizeable cubes, especially Greywackes Lausitz 2 and Harz 1 show noticeable crackings during the storage time. Therefore, the prescription in part 3 of the guideline is a reliable estimation. Only the combination of the expansion results as well as the cracking of the cube according to part 3 of the guideline permits a reliable estimation of aggregates.

The next diagrams show the results of the accelerated test confronted with the concrete prisms and cube results according to part 3 of the guideline. The latter are drawn as coloured bars with the belonging limit values.

Accelerated Test Procedure

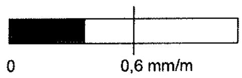


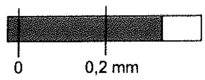
Code of Practice Part 3

Expansions of the concrete prisms after 9 months fog chamber storage

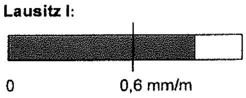
Cracking of the cube after 9 months fog chamber storage

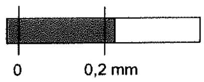
Lausitz II:



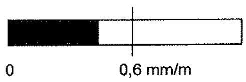


Lausitz I:





Harz I:



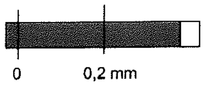
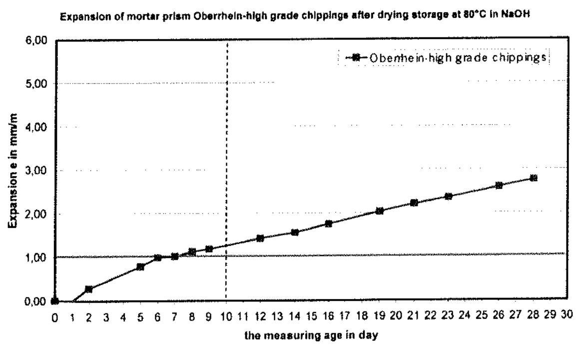


Figure 1

Accelerated Test Procedure

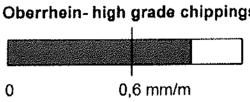


Code of Practice Part 3

Expansions of the concrete prisms after 9 months fog chamber storage

Cracking of the cube after 9 months fog chamber storage

Oberrhein- high grade chippings:



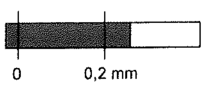
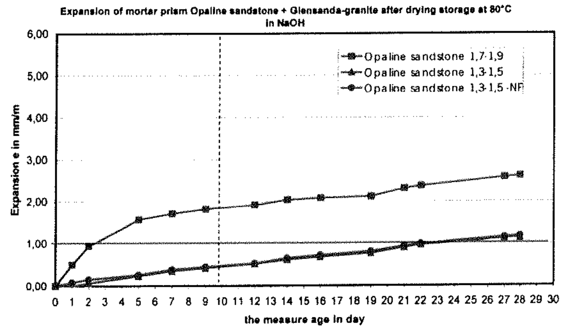


Figure 2

Accelerated Test Procedure

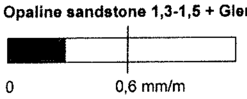


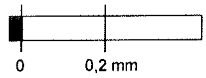
Code of practice Part 3

Expansions of the concrete prisms after 9 months fog chamber storage

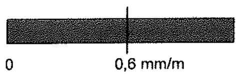
Cracking of the cube after 9 months fog chamber storage

Opaline sandstone 1,3-1,5 + Glensanda- granite:





Opaline sandstone 1,7-1,9 + Glensanda- granite:



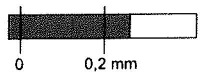
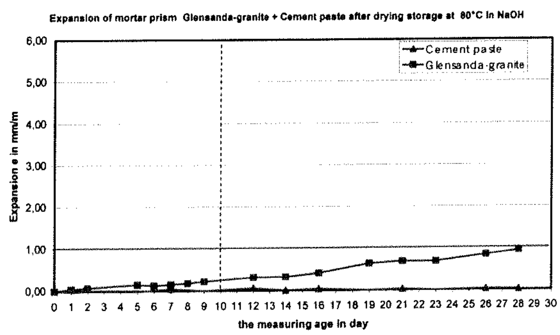


Figure 3

Accelerated Test Procedure

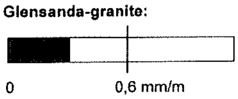


Code of Practice Part 3

Expansions of the concrete prisms after 9 months fog chamber storage

Cracking of the cube after 9 months fog chamber storage

Glensanda-granite:



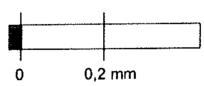
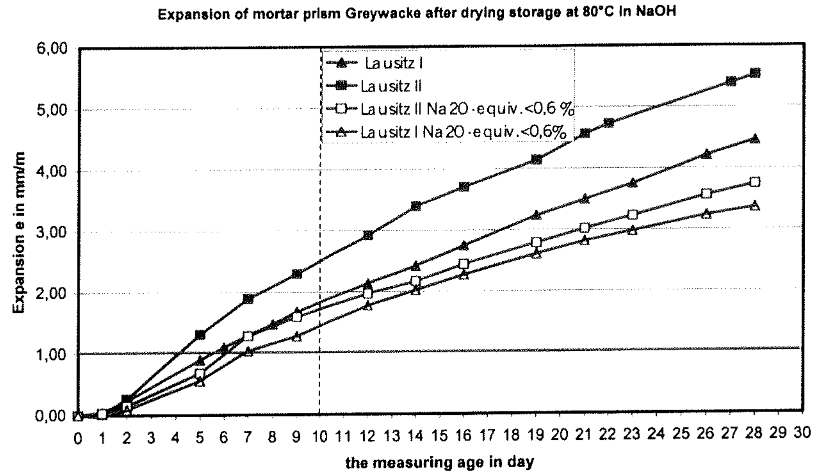


Figure 4

Accelerated Test Procedure



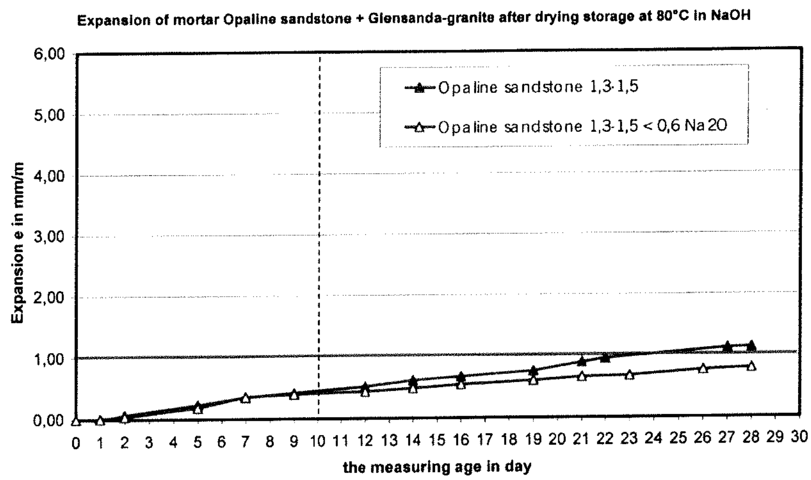


Figure 5

Figure 1 show the results of the tested Greywackes. All 3 Greywackes are classified as reactive with the accelerated test. Figure 2 shows the results for the Oberrhein-high grade chippings. Both examinations methods yield the same matching results. The following figure 3 contains the results for the mixture of the non-reactive granite and the Opaline sandstone with higher and lower density as well as with intimately disseminated Opaline sandstone of lower density. Then again corresponding with both methods the part of Opaline sandstone with high density 1,7 - 1,9 leads to a quick and clear reaction, whereas the part of Opaline sandstone of lower density according to part 3 of the guideline results in only low expansion and no cracks on the cube. Coincidently, there are also only slight expansions in the accelerated test procedure.
The following figure 4 contains the results of the checking of the non-reactive alkali parts of the Glendanda-granite as well as the one of the pure cement paste. The accelerate test classifies both as non reactive. Especially the cement paste does not show any expansion at all duration of the whole checking time. Even according to part

3 of the alkali guideline, there are neither cracks in the cube nor remarkable expansions received in the concrete prisms using Glensanda-granite.

Summarizing these comparing tests the accelerated test procedure and part 3 of the guideline lead to the same classification in all cases.

The examination of the expansion behaviour according to the accelerated test with an other cement type (low alkali) were implemented as well. It was accomplished on mixtures with Greywackes Lausitz 1 and Lausitz 2 and with Opaline sandstone with low density. As expected, the latter with the low alkali cement shows lower expansions comparing the high alkali cement. The Greywackes Lausitz 1 and Lausitz 2 with the low alkali cement show lower expansions as well, but the accelerated test procedure also exceeds the non-reactive limit value. These results were assuming that the usage of low alkali cement or cement paste point out a compensation due to external supply of alkalies other then the sodium hydroxide solution storage tank.

Obviously the accelerated test is suitable to distinguish reliably between reactive rock types and non reactive ones. However, it is recommended to carry out some further experiments with other sorts of rocks to secure this method.