Standard approach to assessing Alkali – Aggregate Reactions (AAR)

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EXAMPLE 2

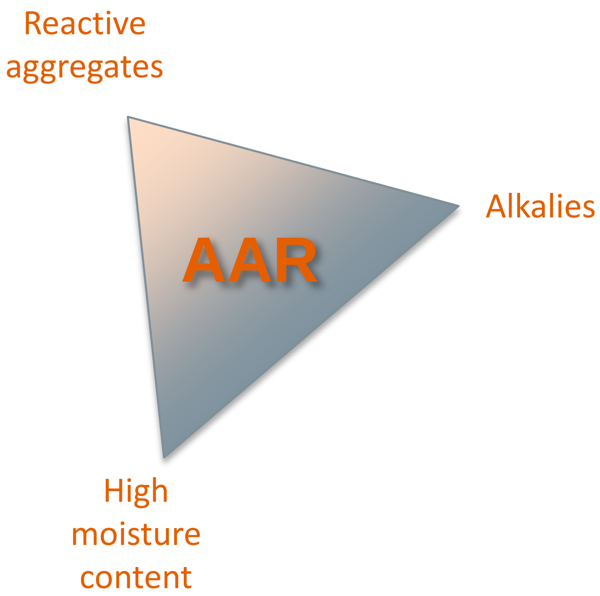
EXAMPLE 1

(Vahanen Oy)

1. What are alkali–aggregate reactions

- **Alkalies producing a silica-gel by dissolving soluble SiO_2 (e.g. Quartz) in the aggregate**
  - Gel has hygroscopic properties, leading to expansion under moist conditions
  - 5-50 years, depending on the type of aggregate and environmental conditions

- **Consequences for concrete structures:**
  - Expansion and (map) cracking
  - Reduction of constraining forces capacity
  - Influence on material properties
  - Initialize other deterioration mechanisms (frost damage and reinforcement corrosion)

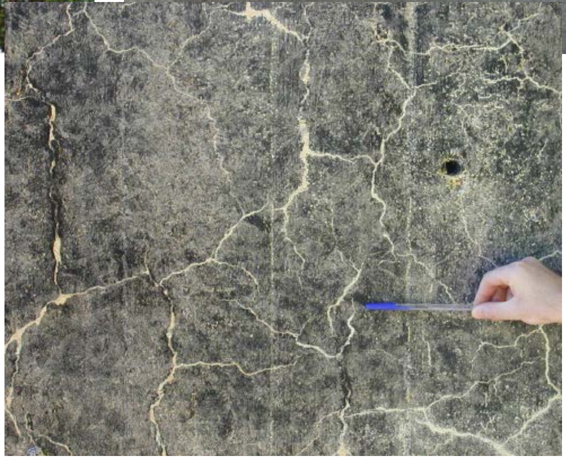


1. What are alkali–aggregate reactions

Orivesi (Huura Oy)

Ounasjoki (Huura Oy)

Tampere (Rakennuslehti)



2. Objective of study

- **Review internationally available guidelines for the management of alkali-aggregate reactions**

  Based on VTT Research Report *VTT-R-04798-18*

- **Recommendations for controlling AAR in new structures in Finland**

  Based on VTT Research Report *VTT-R-04799-18*

3. Adopted approach

- **Review of national and international guidelines and normative approaches adopted in several countries and by technical entities:**
    - CEN standards, RILEM* guidelines, and normative/guidance documents in Finland, Sweden, Portugal, Norway, USA and Canada

- **Review of tests and specifications for the assessment of aggregate reactivity, with guidance on interpretation of tests result where available:**
    - Both deem-to-satisfy and performance based approaches

- **Generic look at the assessment of structures affected, or potentially affected, with AAR**
    - Laboratory investigation used to support such assessment
    - Broad guidance on repair consideration for a structures affected by AAR

* RILEM - International Union of Laboratories & Experts in Construction Materials, Systems and Structures

4. Review normative approach – CEN Standards

- **The guidance for ASR testing has been compiled from the following CEN standards and Technical Reports:**
  - SFS-EN 12620:2008 Aggregates for concrete
  - SFS-EN 13055:2016 Lightweight aggregates for concrete
  - SFS-EN 206:2014 + A1:2016 Concrete. Specification, performance, production and conformity
  - SFS-EN 13670:2010 Execution of concrete structures
  - SFS-EN 13369:2018 Common rules for precast concrete products
  - CEN/TR 16349:2010 Framework for a specification on the avoidance of a damaging Alkali-Silica Reaction (ASR) in concrete

- Too premature to have European level harmonised classes and provisions for avoiding ASR on **due to the very specific local factors such as aggregate lithology, cement types and environmental exposure conditions**
- EN Standards refer to **guidance from provision valid in place of use** (national standards or guidelines)

4. Review normative approach – Finland

- **Finland has national standards (SFS) and Concrete Association code documents (BY), that provide further guidance on many aspects. Documents reviewed with regards to ASR were:**
  - SFS 7022 Betoni. Standardin SFS-EN 206:2014 käyttö Suomessa (Concrete. Application of standard SFS-EN 206:2014 in Finland)
  - SFS 5975 Betonirakenteiden toteutus. Standardin SFS-EN 13670 käyttö Suomessa (Concrete. Execution of concrete structures. Application of standard SFS-EN 13670 in Finland)
  - SFS 7003 Betonikiviaineksilta eri käyttökohteissa vaadittavat ominaisuudet ja niille asetetut vaatimustasot (Characteristics and requirement levels of aggregates for concrete in different applications)
  - BY 65/2016 Betoninormit 2016 (Concrete Code 2016)
  - BY 43/2018 Betonin Kiviainekset 2018 (Aggregates for concrete 2018)

- In Finland there is **NO GUIDANCE for addressing ASR**. Aggregate code (BY 43) provides some insight into the interpretation of petrographic analyses

4. Review normative approach – RILEM

- **List of RILEM Recommendations:**
  - AAR-0 Outline guide to the use of RILEM methods in assessments of alkali-reactivity potential of aggregates
  - AAR-1.1 Detection of potential alkali-reactivity – Petrographic examination method
  - AAR-1.2 Petrographic Atlas
  - AAR-2 Detection of potential alkali-reactivity – Accelerated mortar-bar test method for aggregates
  - AAR-3 Detection of potential alkali-reactivity – 38°C test method for aggregate combinations using concrete prisms
  - AAR-4.1 Detection of potential alkali-reactivity – 60°C test method for aggregate combinations using concrete prisms
  - AAR-5 Rapid preliminary screening test for carbonate aggregates
  - …
- RILEM provides **clear guidance for performance-based testing with well-defined requirements, and detailed guidance on mitigation measures**

4. Review normative approach – Sweden

- **Sweden's National Application document for the SS-EN 206 is where the "provisions valid in the place of use" concerning AAR are specified.**
    - SS 137003:2015 Betong. Användning av SS-EN 206 i Sverige (Concrete. Application of SS EN 206 in Sweden)

- Sweden's approach is **based on RILEM Recommendations**, where clear guidance for performance-based testing with well-defined requirements, and guidance on mitigation measures
- **Updated guidelines are in preparation and expected to be published in 2019**

- Two technical committees active addressing the testing for AAR and mitigation measure of sturctures affected with AAR
- *"The Swedish concrete industry has realised the need to have a good reputation, and that to sell concrete as a safe product, precautions need to be taken" – CBI/RISE*

4. Review normative approach – North America

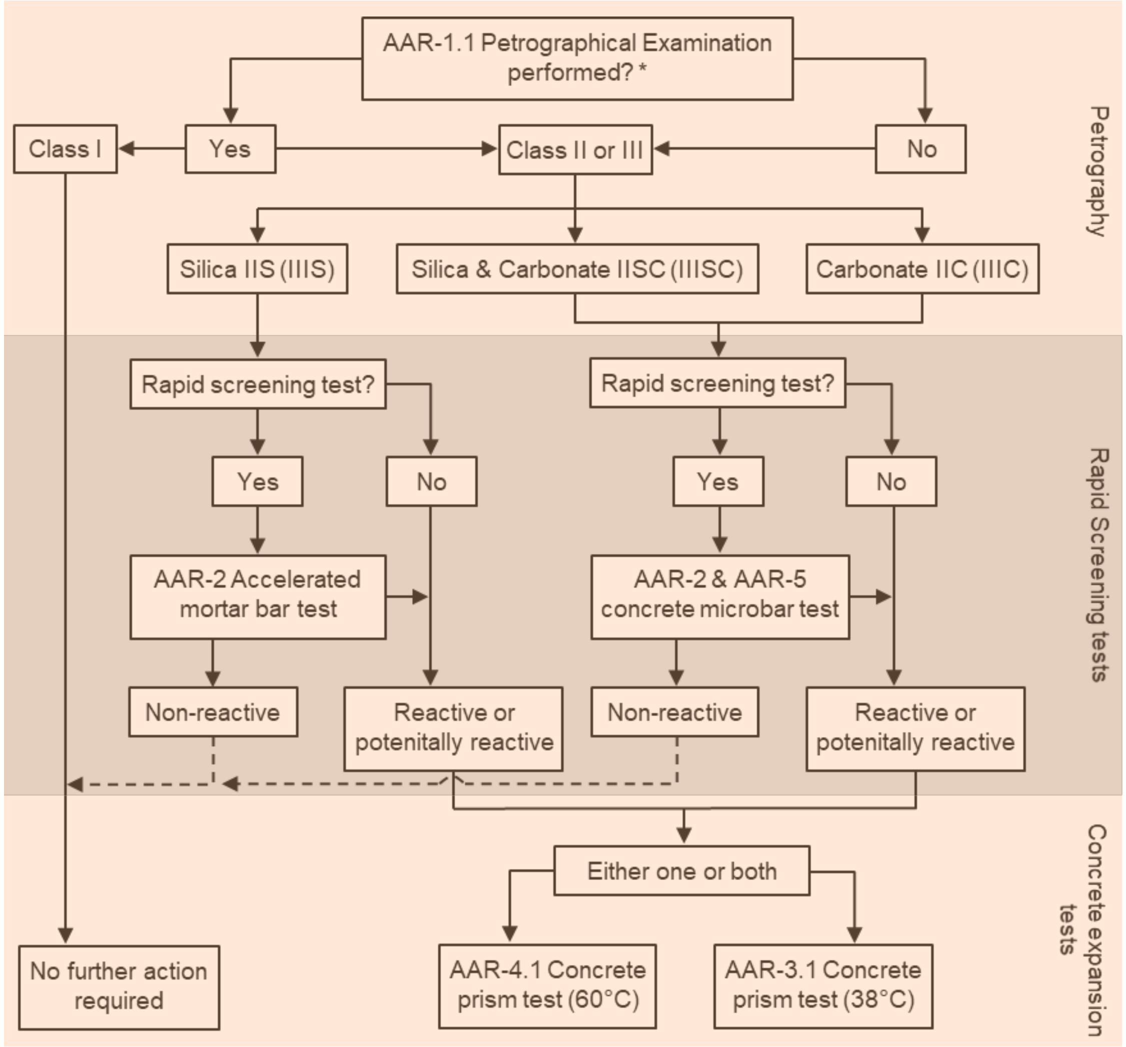
- **Current practice to prevent AAR in new concretes in the USA is established through the AASHTO R 80-17 and the ASTM C 1778-16 (Standard Guide form Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete)**
    - Both standards essentially the same: provide procedures, guidelines, and testing methods to assess aggregate reactivity as well as to select appropriate mitigation measures when reactive aggregates are used in new concretes
- **In Canada, specifications for minimizing the risk of ASR (including test methods) are covered by national standards (CSA A23.1/A23.2) and the general framework is provided in CSA A23.2-27A**
    - The standards offer two approaches to ASR risk management: a performance-based and a prescriptive-based approach. This differs from the direction that RILEM is taking, which is primarily focused on the performance-based testing.

- In North America, there is **clear guidance for performance-based and deem-to-satisfy approach, with well-defined requirements, and clear guidance on mitigation measures**.

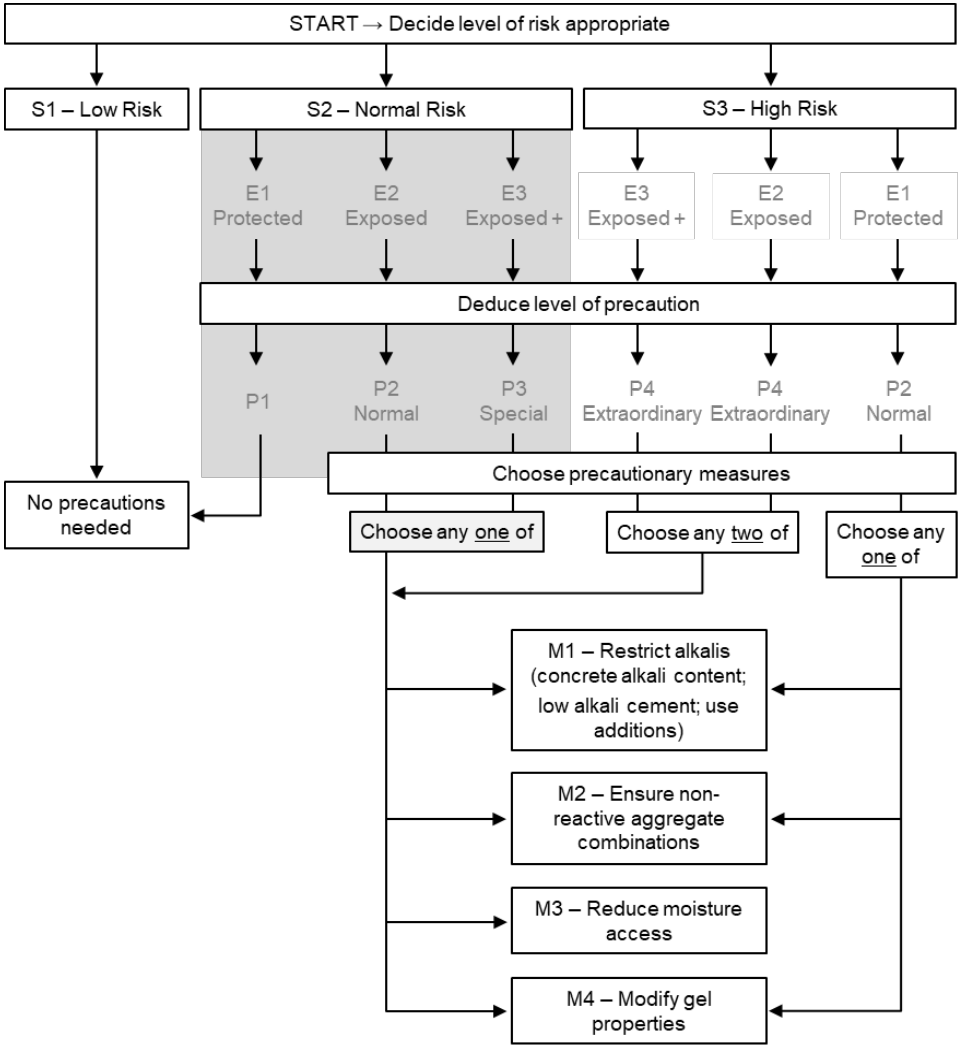
4. Review normative approach – Schematic view

- **Independent of standard or guideline, procedure are in essence identical:**
  1. **Petrographic analysis**
  2. **Rapid screening test (mortar prisms)**
     - Accelerated – 80°C (for 2 - 4 weeks)
  3. **Concrete expansion test (concrete prisms)**
     - *“Normally”* accelerated – 38°C (for > 12 months)
     - *“Very”* accelerated – 60°C (for 3 - 5 months)

  (4. Testing of precautionary/mitigation measures)
     - Usually on concrete prism test


AAR-1.1 Petrographical Examination performed? *
Yes
No
Class I
Class II or III
Silica IIS (IIIS)
Silica & Carbonate IISC (IIISC)
Carbonate IIC (IIIC)
Petrography
Rapid screening test?
Yes
No
AAR-2 Accelerated mortar bar test
Non-reactive
Reactive or potentially reactive
Rapid screening test?
Yes
No
AAR-2 & AAR-5 concrete microbar test
Non-reactive
Reactive or potentially reactive
Rapid Screening tests
Either one or both
No further action required
AAR-4.1 Concrete prism test (60°C)
AAR-3.1 Concrete prism test (38°C)
Concrete expansion tests

VTT


START → Decide level of risk appropriate
S1 – Low Risk
S2 – Normal Risk
S3 – High Risk
E1 Protected
E2 Exposed
E3 Exposed +
E3 Exposed +
E2 Exposed
E1 Protected
Deduce level of precaution
P1
P2 Normal
P3 Special
P4 Extraordinary
P4 Extraordinary
P2 Normal
Choose precautionary measures
No precautions needed
Choose any one of
Choose any two of
Choose any one of
M1 – Restrict alkalis (concrete alkali content; low alkali cement; use additions)
M2 – Ensure non-reactive aggregate combinations
M3 – Reduce moisture access
M4 – Modify gel properties

VTT

5. Test and specifications for aggregate reactivity

Table 21. Summary table of standards for mortar bar tests

Test method	Procedure	Sample	Assessment criteria	Pros and Cons
Mortar bar test: ASTM C227, (has been withdrawn) NP 1381	Mortar specimens stored in a saturated environment at 38 °C for 6 months to 1-year. Implementation of expansion measures at defined ages.	2 to 4 mortar bars of dimensions 25 x 25 x 285 mm.	Reactive if after 6 months expansion > 0.10%	Slow test; Dependent on the test conditions: cement alkali content, water/cement ratio, etc.; Considered as a mild test, with tendency to classify some aggregates as non-reactive aggregates that despite in reality being reactive.
Accelerated mortar bar test: ASTM C 1260, RILEM AAR-2.1/2.2	Mortar specimens, stored in 1N NaOH solution at 80 ° C for 14 days. Measurement of expansion at defined ages.	3 bars (prisms) of mortar of dimensions 25x25x285 mm, or 40x40x160 mm (AAR-2.2). Aggregate size 0.15-4.75 mm or 0.125-4 mm).	Non reactive if expansion <0.10% at 14 days; Inconclusive if 0.10% < Expansion <0.20%.at 14 days; Reactive if expansion > 0.20%.at 14 days	Rapid test (14 days); It allows to evaluate the effectiveness of mineral additions; Does not detect the reactivity of slow and delayed reactivity aggregates; Considered a severe test, it tends to classify reactive aggregates with good performance on site.
Accelerated mortar bar test: Performance assessment for SCM´s: ASTM C1567	Mortar specimens stored in t 1N NaOH, at 80 °C for 14 days. Measurement of expansion at defined ages.	Mortar bars of dimensions 25 x 25 x 285 mm.	Combinations of cement, SCM and aggregate with expansion < 0.10 % at 14 days - likely to produce acceptable expansions when tested in concrete and low risk of deleterious expansion under field conditions	Rapid test (14 days); Dependent on mix design under study. Is a performance test to assess mix design.
Accelerated mortar bar test: NT BUILD 295	Mortar specimens, stored in saturated NaCl solution at 50 °C for 20 weeks. Measurement of expansion at defined ages.	3 bars (prisms) of mortar of dimensions 40x40x160 mm. Aggregate size < 4.75 mm		Slow test; Use to classify potential reactive aggregates based on performance testing assessment.
Accelerated mortar bar test for carbonate aggregates: RILEM AAR-5	Mortar specimens stored in 1N NaOH solution at 80 °C for 14 days. Expansion measurements at defined ages. Must be performed in conjunction with the accelerated mortar bar test.	3 mortar prisms of dimensions 40x40x160 mm. Aggregate with dimension 4-8 mm.	If RILEM AAR-2 > 0,08% and: AAR-5 < AAR-2 = ASR; AAR-5 > AAR2 = combination Of ASR and ACR; If RILEM AAR-2 < 0,08% and: AAR-5 > AAR-2 = ACR; AAR-5 < AAR-2 = non-reactive	Rapid test (14 days); Completes ASTM C 1260 / RILEM AAR-2 in assessing reactivity of carbonate aggregates; Exclusive for carbonate aggregates; Considered a severe test, not representative of the conditions found on site.

5. Test and specifications for aggregate reactivity

Table 22. Summary table of standards for concrete prism tests

Test method	Procedure	Sample	Assessment criteria	Pros and Cons
Concrete prism expansion tests: ASTM C 1293, NF P 18-587, RILEM AAR-3.1 and AAR-3.2	Concrete test pieces kept in a saturated environment at 38 °C for 1 year (or more); Expansion measurements at defined ages.	3 prisms for expansion test with concrete prisms (75 x 75 x 250-mm gauge length). Aggregate with dimension 0-22 mm.	Non reactive if expansion < 0.05% after 1 year. Reactive if expansion > 0.05% after 1 year. Inconclusive if expansion > 0.03% at 1 year and 0.04 at 2 years. Test method considered by many to be the most reliable for identifying aggregate reactivity based on generally good correlation between test and field performance	Slow test; Dependent on the test conditions employed: cement alkali content, w/c ratio, etc.; High leaching of alkalis from prisms; Acceptance criterion is not yet definitely agreed; Best indicator of job performance in RAS; Test conditions closest to actual exposure conditions on site; Good to distinguish reactive aggregates from non-reactive ones; Allows to evaluate combinations of aggregates; It allows to evaluate the effectiveness of mineral additions.
Accelerated concrete prism test : RILEM AAR-4.1	Concrete specimens kept in a saturated environment at 60 ° C for 12 or 20 weeks; Implementation of expansion measures at defined ages.	3 concrete prisms with dimensions 75x75x285 mm. Aggregate with dimension 0-22.4 mm.	Not fully agreed: - Not reactive if at 12 or 15 weeks the expansion <0.02%; - Reactive if at 12 or 15 weeks the expansion > 0.02%. But still considering 0.03% at 15-20 weeks (depends on country)	Relatively fast test; Dependent on the test conditions employed: cement alkali content, w/c ratio, etc.; High leaching of alkalis from prisms; Acceptance criterion is not yet definitely agreed; Considered a severe test, not representative of the conditions found on site; Good to distinguish reactive aggregates from non-reactive ones; More consistent method, even to identify aggregates of slow reactivity; It allows to evaluate the effectiveness of mineral additions.

7. Conclusions

- **AAR is dependent on very specific local factors** such as aggregate lithology, cement types (own cement production) and environmental exposure conditions
  - Reason why there is **NO European regulation for AAR** – standards refer to guidance from provision valid in place of use (national standards or guidelines)
- There is currently **good support for performance-based testing of AAR**, with well-defined requirements and detailed guidance on mitigation measures (RILEM based)
- Since each country has their local factors, it is up to the national concrete industry to tackle the specific needs necessary to address AAR
  - **This should constitute a common goal for the concrete industry in Finland**
- A coordinated international effort has initiated to harmonise approaches advocated in RILEM and across Europe – Finland can benefit from this knowledge
- **"AAR standards" will have minimum impact on current "concreting" processes, but are needed so that WHEN there is suspicion of AAR, there is clear guidance how to proceed**

Kiitos