RILEM TECHNICAL COMMITTEES (TCs) – PAST AND PRESENT. TC 258-AAA: AVOIDING ALKALI AGGREGATE REACTION (AAR) IN CONCRETE – PERFORMANCE BASED CONCEPT (2014 – 2019)

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Abstract

Since 1988, RILEM Technical Committees (TCs) have been seeking to establish universally applicable test methods for assessing the alkali-reactivity potential of aggregates, and later for concrete mixes. The "TC 106" (1988 – 2001) focused on accelerated aggregate tests, and presented the findings at the International Conferences on Alkali Aggregate Reaction (ICAAR) in Kyoto (1989), London (1992), Melbourne (1996) and Quebec (2000). The successor committee "TC 191-ARP" (2001 – 2006) also included work on Diagnosis/Appraisal & Specification, and presented the findings at the ICAAR in Beijing (2004). The "TC 219-ACS" (2006 – 2014) introduced work on Performance testing & Modelling, and presented findings at the ICAARs in Trondheim (2008) and in Austin (2012). The major recommendations from the last TC were published as a RILEM State-of-the-Art Report in 2015. The 4th RILEM TC on AAR, the "TC 258-AAA" was established 2014, scheduling to finish the work on performance-based assessment in 2019. The work in this TC is concentrated in the three Work Packages (WPs) dealing with: Accelerated performance testing in laboratory (WP1), laboratory testing vs. field exposure sites (WP2), and assessment of alkali inventory in concrete (WP3).

Keywords: Alkali Aggregate Reaction, RILEM, Regulations, Performance testing

1 BACKGROUND AND HISTORY

Alkali Aggregate Reaction (AAR) in concrete can be defined as chemical reactions (Alkali Silica Reactions, ASR and Alkali Carbonate Reaction, ACR) between the alkali hydroxides (sodium and potassium) in the pore solution of concrete and certain minerals in the aggregate. The product of the ASR is typically a hygroscopic gel that expands when absorbing water. This may introduce expansion and cracking in the surrounding hardened concrete, thereby affecting the mechanical properties of concrete and structure service-life and increasing cost for society. The incubation time needed before AAR damage starts ranges from a few months to several decades, depending heavily on aggregate type, binder type and exposure conditions.

Development and assessments of universally test methods, in order to avoid deleterious AAR in concrete, have been the focus of the RILEM[1] Technical Committees (TC) for more than 25 years. The first TC regarding AAR was established in 1988 as "TC 106", with Dr Philip Nixon from the Building Research Establishment (BRE) in the UK as the Chairman, and Dr Ian Sims from Sandberg, UK (now with RSK Environment Ltd) as the secretary. The TC had been proposed by Micheline Regourd-Moranville in France. The formation of this TC was reported at the 8th International Conference on Alkali Aggregate Reaction (ICAAR) in Kyoto, where the 2nd and 3rd meetings of the TC were held immediately before and during the conference. The primary objective of the TC was to develop tests for aggregate reactivity that could form the basis for internationally agreed methods and progress, as presented by Nixon & Sims (1992) [1].

In addition, some extra tasks were taken on, in particular a survey of national specifications for avoidance of AAR damage, and carrying out an assessment of reports of damage to structures made with low alkali cement or which contained fly ash or ground granulated blastfurnace slag. In 1993, an

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interim report was presented on the progress of the "TC-106" in developing tests for aggregate reactivity which could form the basis for internationally agreed methods (Nixon & Sims, 1993) [2]. In 1996, "TC 106" had members from 21 countries including virtually all those, which, at that time, were regarded as having significant AAR problems. The TC conducted a survey of test methods in use in the participating countries, presented by Nixon & Sims (1996) [3]. Following trials to demonstrate effectiveness in differentiating reactive and non-reactive aggregate combinations worldwide, "TC-106" finalised two expansion test series in 2000, presented by Nixon and Sims (2000) [4] at the 11th ICAAR in Québec. A concrete prism test (CPT) was considered reliable for most aggregate combinations, and an accelerated mortar-bar test was usually found suitable for predicting behaviour in the concrete test.

The work of "TC 106" culminated in 2000 in an integrated assessment scheme, presented by Sims & Nixon in 2001 [5]. After considering a wide range of methods for assessing aggregates for AAR, TC-106 concentrated on a three stage test procedure:

1) Petrographical examination (AAR-1), (RILEM 2003) [6]
2) Accelerated mortar-bar expansion test (AAR-2), (RILEM, 2000) [7]
3) Accelerated concrete prism expansion test (AAR-3), (RILEM 2000) [8]

The successor committee "TC 191-ARP" (*Alkali-Reactivity & Prevention – Assessment, Specification and Diagnosis*), formed in 2001, continued the work on an accelerated CPT (AAR-4) and specialised procedures for carbonate aggregates. This TC also had a widened scope to seek international consistency in approaches to diagnosis (AAR-6) and specification (AAR-7) and in assessment of alkali release from aggregates (AAR-8). The overall progress of "TC 191-ARP" was presented by Sims et al. (2004) [9] and Nixon et al. (2004) [10] at the 12th ICAAR in Beijing in 2004. Following discussions at the 11th and the 12th ICAAR conferences, "TC 191-ARP" developed the basis of a specification to avoid AAR damage to concrete worldwide (Sims & Nixon, 2006 [11] and Nixon & Sims, 2006) [12].

The 3rd "TC 219-ACS" (*Alkali Aggregate Reaction in Concrete Structures: Performance Testing and Appraisal*) was established in 2006, presenting findings at the ICAARs in Trondheim (2008) and in Austin (2012). The committee terminated its activities in early 2014, and concluded the 25 years' work of the three TCs chaired by Dr Nixon with Dr Sims as the secretary - see Figure 1. In recognition that damaging expansion involves interaction between all the main components of a concrete mix, TC 219-ACS also focused on the assessment of the effect of the cement/binder on AAR, i.e., performance testing. Several documents/recommendations were prepared in the TC: Lindgård et al. (2010, 2011 & 2012) [13], [14], [15] and Godart et al. (2013) [16]. The full set of RILEM Recommendations has now finally been published (Nixon & Sims, 2016) [17] – see Figure 2. This State-of-the-art Report contains five recommended test methods for aggregates (designated AAR-1 to AAR-5) and an overall recommendation that describes how these should be used to enable a comprehensive aggregate assessment (AAR-0). Additionally, the report includes two Recommended International Specifications for concrete (AAR-7.1 & 7.2) and a Preliminary International Specification for dams and other hydro structures (AAR-7.3), which describe how the aggregate assessment can be combined with other measures in the design of the concrete to produce a concrete with a minimised risk of developing damage from AAR. There has also been considerable effort in publishing a petrographic atlas by Fernandes et al. (2016) [18]. This RILEM AAR 1.2 Atlas is complementary to the petrographic method described in RILEM AAR 1.1. It is designed and intended to assist in the identification of alkali-reactive rock types in concrete aggregates by thin-section petrography.

2 ONGOING ACTIVITIES IN THE NEW "TC 258-AAA" (2014-2019)

The current, 4th RILEM "TC 258-AAA" (*Avoiding Alkali Aggregate Reaction in Concrete - Performance Based Concept*) was established in 2014, chaired by Professor Børge Johannes Wigum from Norcem (HeidelbergCement Group Northern Europe), in Norway, and Dr Jan Lindgård from SINTEF Building and Infrastructure, in Norway, as the secretary. The main purpose of this new TC is to develop and promote a performance based testing concept for the prevention of deleterious AAR. The issue of Alkali Carbonate Reaction (ACR) is not included in the work of this TC. Strong emphasis will be put on the implementation of the RILEM methods and recommendations as national- and international standards.

2.1 The Work Packages (WPs)

WP1 - Performance testing and accelerated testing in laboratory.

Avoidance of ASR in future structures is of great importance, and the ways to achieve this will be covered by the work programme within this TC. Development of performance test methods to examine the potential alkali reactivity of particular concrete mixes to be used in a project has already been focused on in the work programme of the previous "TC 219-ACS". In that work programme, it was taken into account the mitigating effect of supplementary materials such as fly ash or slag, etc., or the specification of low alkali levels in the mix. By using such mitigation measures, a much wider selection of aggregates can be used safely while increasing the sustainability of the concrete and aggregate industry. Although such draft performance tests have been under preparation in the former RILEM TC, there is still a necessity to finalize and validate these test methods, including arranging international inter-laboratory trials. As soon as the necessary validation is finished, it is the intention to publish these methods as RILEM Recommendations. WP1 is headed by Dr Terje F. Rønning, (HeidelbergCement Group Northern Europe, Norway).

Previous test procedures [17] included the testing of alkali-reactivity of aggregates and the determination of the alkali threshold of an aggregate combination *(Note: A remark is given in RILEM AAR-0 [17] regarding the latter application of the RILEM AAR-3 CPT: Due to alkali leaching from the relatively small concrete prisms, a "safety margin" should be applied to take into account for the known differences between accelerated laboratory testing and real field behaviour)*. In the new "TC 258-AAA", the main work in WP1 is concentrating on the performance testing concept using a 38°C CPT *(with larger prism size compared with RILEM AAR-3 to reduce the extent of alkali leaching)*. The testing concept includes the following applications for performance assessment of combinations of aggregates and cement/binders at various or specific alkali content:

- The determination of critical binder combination to enable the use of a specific, reactive aggregate (product) for non-reactive concrete mix design.
- The determination of a general (set of:) binder combination(s) to enable the use of a group or regional set of (worst case:) aggregates for non-reactive concrete mix design.
- The development of a well-performing job-mix, consisting of a combination of reactive aggregate(s) and binder(s), including mix design deviation limits.

WP2 - Performance testing and laboratory vs. field; Exposure site.

An important additional tool in validation of the performance testing concept is to make an assessment of the link between the accelerated results from the laboratory and behaviour of these concrete mixtures in real field structures. This will be carried out by compiling the main findings from exposure sites worldwide and preparing an overview of "lab-field correlation" from exposure sites and real concrete structures in services. One main objective is to establish a link between outdoor exposure sites dedicated to AAR investigations and located in different parts of the world, in order to generate an international database on the effect of environmental conditions on the kinetics of AAR. Ultimately, this will allow the development of new specifications for reducing the risk of deleterious expansion and cracking development in concrete structures due to AAR in different environments. WP2 is headed by Professor Benoît Fournier (Université Laval, Québec, Canada).

The initial work in WP2 has included casting of about 80 concrete cubes (300x300x300 mm) for outdoor storage at 10 different exposure sites in Europe and North America (Portugal, France, Norway, Iceland, Germany, Canada & USA). The concrete cubes were made with reactive aggregates from Europe and North America, along with control non-reactive aggregates. The concrete mixtures included ordinary Portland cement and addition of fly ash (20 and 30%), along with control mixtures. The expansion of the cubes will be measured at the various outdoor sites and the different conditions will be monitored (temperature and humidity; also internally in some of the concrete cubes).

WP3 - Performance testing; Assessment of detailed alkali inventory in concrete, including internal alkali release from aggregates, recycling of alkali and external alkali supply.

One of the important "missing links" in the international AAR research is how to measure the amount of potential alkalis to be released from various types of aggregates in the laboratory, under accelerated conditions. This is of particular importance for massive concrete structures aiming to have long-service life, e.g., dams, where the contribution of alkalis from aggregates in some cases is believed to contribute to damaging AAR despite the fact that the concrete has been designed to meet current specifications for avoidance of AAR. Various test methods have already been proposed, and it is the intention in WP3 to finalise and validate a test method for alkalis released by aggregates, including

compiling results from exposure sites and concrete structures worldwide in order to assess the "true" level of alkali released from various aggregates. As soon as the necessary validation is finished, it is the intention to publish this method as a RILEM Recommendation. It is also of importance to evaluate the potential internal alkali recycling in the concrete which in some instances has been reported, in addition to assess any alkali contribution from external sources. WP3 is headed by Dr Esperanza Menéndez Méndez (Institute of Construction Science, "Eduardo Torroja" (CSIC), Spain).

A Round-Robin test has been initiated in WP3 in order to evaluate the draft test procedure for measuring potential amount of releasable alkalis from aggregates. In the test, the aggregates are submerged in two solutions for 52 weeks while being exposed to two temperatures (38°C and 60°C). A total of 6 laboratories participate with 5 types of aggregates, which have been prepared and distributed. The results will be ready during the summer of 2016. The results should later be linked to field behaviour in real concrete structures. In addition, initial work in WP3 includes the preparation of an outline of a literature review report regarding the alkali inventory in concrete.

2.2 Status of RILEM "TC 258-AAA" at the end of 2015

RILEM "TC 258-AAA" has a wide international membership which helps to promote the aims of the eventual international use of RILEM methods and recommendations. Physical meetings twice a year will still be the centre of its activities and wherever possible these will be co-ordinated with major relevant international conferences to facilitate attendance. Members around the world that are not able to travel to the meetings, will follow the discussions through the extended minutes of the meetings, and are able to provide input through electronic media. All relevant documents, including the minutes from the meetings, are available for members of this TC at the RILEM internal website. At the inaugural meeting in October 2014, in Oslo Norway, 27 delegates participated, where the majority were from Europe (20), but also from North America (5) and Asia (2). The second meeting was held in London in April 2015, with a total of 35 delegates participating; Europe (28), North America (5) and Asia (2). The third meeting was arranged in Toronto, Canada, in September 2015, with a total of 23 delegated participating; Europe (9), North America (13) and Asia (1). A meeting is also scheduled in July 2016 in São Paulo, Brazil, in connection with the 15th ICAAR conference.

3 CONCLUDING REMARKS

We have struggled to understand, control and prevent damage from AAR in the past 75 years since it was first reported in concrete. In addition to the ICAARs, which started in 1974, the continuing series of RILEM Technical Committees has helped to harness international cooperation in this struggle for the last nearly 30 years. The RILEM work has recently archived some significant milestones regarding recommendations to prevent damage by AAR in new concrete structures (Figure 2) [17].

The work in the current "TC 258-AAA" will continue for the years to come, until 2019, with particular focus on the performance based testing concept. It is our anticipation to increase the input from all parties all around the world, enabling the implementation of the RILEM methods and recommendations as national- and international standards.

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FIGURE 1: Honoured after 25 years of service in RILEM Technical Committees (TCs). Heading the three TCs since 1988; Dr Philip Nixon - Chairman (left), and Dr Ian Sims – Secretary (right). Professor Børge Johannes Wigum (middle) is the new Chairman of RILEM "TC 258-AAA".

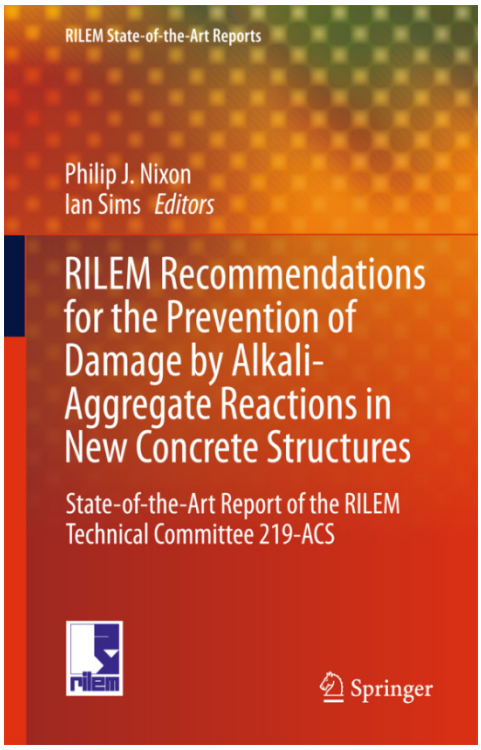

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FIGURE 2: Facsimile of the RILEM State-of-the-Art Report: RILEM Recommendations for the Prevention of Damage by Alkali-Aggregate Reactions in New Concrete Structures [17].