

RILEM Recommended Test Method: AAR-0—Outline Guide to the Use of RILEM Methods in the Assessment of the Alkali-Reactivity Potential of Aggregates

1 Introduction

AAR-0 provides guidance on the integrated use of the assessment procedures described in AAR-1.1 & 1.2, AAR-2, AAR-3, AAR-4.1 and AAR-5 including preliminary advice on the interpretation of their findings. The principles are illustrated by the flow chart given in Fig. 1. Guidance on the specialised assessment of carbonate rock aggregates for alkali-reactivity potential is given in Annex A. Information on reference materials and testing accessories is given in Annex B.

2 Aggregate Assessment

Aggregates from both new and existing sources frequently require to be assessed for their suitability for use in concrete. The investigation of AAR potential is one essential part of the assessment, but it should be recognised that, in many or most cases, other properties will have a more important potential influence on the performance and durability of aggregates. Therefore, the evaluation of AAR potential should not be carried out in isolation, but rather as a specialised extension to the routine assessment of the suitability of an aggregate.

Consideration of AAR potential is complicated by the so-called ‘pessimism’ behaviour of some aggregates, whereby expansion of concrete is maximised at a certain level of reactive constituent in the aggregate and progressively reduced for both greater and lesser levels. It is consequently important for AAR assessment to consider the total combination of coarse and fine aggregates, rather than only the individual materials.

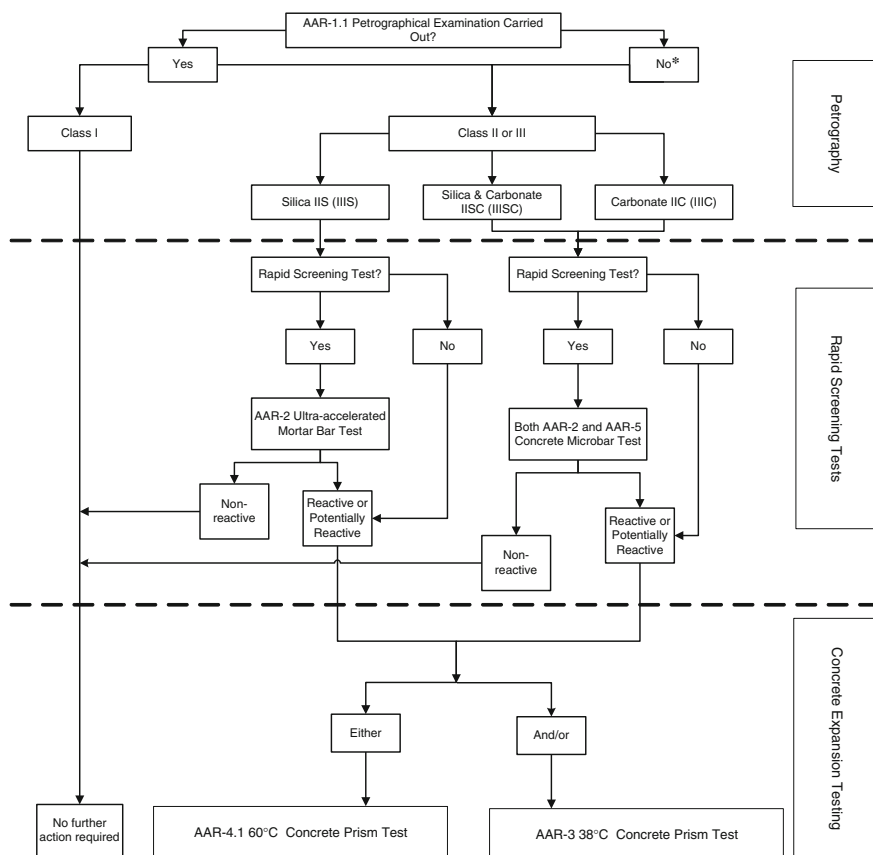


Fig. 1 Integrated assessment scheme. * If no petrographical examination has been carried out, assume Class II (or III)

Any expansion exceeding the criteria given for the tests used in the assessment of AAR potential are taken possibly to be caused by ASR and/or by reactions involving carbonates. However, it is recommended that post-test petrographical examination of specimens should be carried out to confirm that any expansion was caused by a form of AAR.

In addition to inherent reactivity, some aggregates, irrespective of whether they are themselves reactive or non-reactive, can influence the reactivity potential of a concrete mix by releasing alkalis that are additional to those derived primarily from the cement. The AAR-8 procedure for determining any content of releasable alkalis in aggregates is still under development and so is not part of the assessment scheme, but when it is available it should be carried out as part of an estimation of reactive alkali content in a particular concrete mix.

3 Principle

Any assessment of an aggregate combination for AAR potential should ideally commence with petrographical examinations of the component aggregates, which establishes their individual and combined compositions and identifies the types and concentrations of any potentially reactive constituents. This usually allows an aggregate combination to be assigned to one of three categories, as follows:

Class I—very unlikely to be alkali-reactive

Class II—potentially alkali-reactive or alkali-reactivity uncertain

Class III—very likely to be alkali-reactive

In the case of new aggregate sources, Class II is common and further testing will be required. For existing aggregate sources, when experience of use can be taken into account for local applications, Classes I or III are more often possibilities. Class III is exceptional for new aggregates and essentially limited to those found to contain opal or opaline silica.

When petrography indicates Class II (or Class III), it becomes necessary to decide on the most appropriate further tests. Aggregates which are either mainly siliceous, or carbonates with a potentially reactive silica content, are designated Class II-S or III-S and may be subjected to the RILEM expansion tests (AAR-2, AAR-3 or AAR-4.1).

Aggregates which are either mainly carbonate, or mixtures including potentially reactive types of carbonate, are designated Class II-C or III-C and may be subjected to the specialised procedures for aggregates comprising or containing carbonate materials, especially if the carbonate includes the mineral dolomite (calcium-magnesium carbonate). Some aggregates of mixed composition might be designated Class II-SC or III-SC and should thus be subjected to the procedures described for carbonate aggregates (AAR-5, but also see the guidance provided in Annex A).

The proportion of silica that can lead to the most damaging reaction will depend on the reactivity of the silica. A small amount of highly reactive silica in the aggregate will be most damaging, whereas, if the aggregate contains a high proportion of such highly reactive silica, there may be little damage. If aggregate containing highly reactive silica is mixed with a non-reactive aggregate, the behaviour of the mix will vary from very damaging to not damaging at all, depending on the proportions of the mix. This feature is known as the ‘pessimum’ effect. Conversely, in aggregates containing low reactivity forms of silica or where the silica is not easily exposed to the alkaline pore solution, the worst damage may occur when the greatest amount of silica is present.

Because of this it is important that the whole aggregate combination is assessed as amounts of reactive silica that are innocuous in either the fine or coarse aggregate alone may be damaging in the combined aggregate. Conversely, apparently reactive fine or coarse aggregates may be safe when used in combination. Both AAR-3 and AAR-4.1 are suitable for assessing the combined aggregate.

In the case of the RILEM expansion tests, the AAR-3 concrete prism method has previously been regarded as the reference test, on the basis of accumulated experience of its use in various forms. However, AAR-3 requires a lengthy period, up to 12 months or more, for reliable results to be obtained and even AAR-4.1 requires up to 4 months. Consequently, the accelerated mortar-bar (AAR-2) and concrete-bar (AAR-5) tests have been developed for the optional provision of an earlier indication of the outcome.

At present, following petrographic assessment, it is considered unwise to rely solely on the results of the accelerated screening tests and the preliminary indications from those methods should always be confirmed by one of the concrete prism tests. Also, practical experience has suggested that the accelerated mortar-bar test (AAR-2) might be unreliable for Class II-S aggregates containing porous flint (a type of chert) as a potentially reactive constituent. Greater experience with the accelerated mortar-bar test may, in due course, enable this advice to be modified.

It is hoped that AAR-3, or a variant of it, might eventually also be usable for assessing the reactivity performance of particular concrete mixes and the RILEM committee is actively developing such a performance test. However, although preliminary indications are encouraging, a definite correlation between the short-term results of this test method and long-term field performance has not yet been demonstrated, so that guidance on its use in practice cannot be provided at present. It is hoped that further development and international trials might, in due course, enable the performance variant of this method to be used for acceptance testing on a project-by-project basis.

All sources of natural aggregates exhibit both systematic and random variations in composition and properties. Suitability assessments have therefore to be repeated periodically and this is particularly the case with evaluations of AAR potential.

4 Samples

Laboratory investigations are only reliable if the samples are representative. It is therefore important to ensure that the sample used for AAR assessment is properly representative of its source. In the case of an operating existing quarry, it is usually appropriate to take samples from the current stockpiles of processed aggregates, following the sampling procedures given in national and international standards for aggregate testing.

In the case of a new or prospective quarry, it might be more appropriate for an experienced geologist to take rock lump samples directly from natural outcrops and/or to drill cores from rock bodies to be extracted as quarrying for aggregates proceeds. Different rock types would be tested separately or in controlled combinations at the discretion of the field geologist: the test samples should endeavour to represent the aggregates which will be produced for actual use.

Guidance on the taking of representative samples is included in AAR-1.1 (petrographical examination).

RILEM have established some sources of suitable reference materials, including high-alkali Portland cement and both reactive and non-reactive natural aggregates (see Annex B).

5 Petrographical Examination: AAR-1.1 & 1.2

A procedure is given in AAR-1.1 & 1.2 for the petrographical examination and classification of aggregate samples for AAR potential. This procedure enables any potentially alkali-reactive constituents to be identified and, if necessary, quantified. The identification is based primarily upon basic petrological or mineralogical type (s), supported, whenever possible and appropriate, by local experience.

As explained earlier, petrographical examination will lead to one of three Classes: I, II or III. In the case of Class II (or Class III), it will also be necessary for the petrographical examination to determine whether the aggregate is wholly or partly siliceous (Class II-S or III-S), or wholly or partly carbonate (Class II-C or III-C), or possibly a combination containing significant proportions of both siliceous and carbonate materials (Class II-SC or III-SC). If petrography is not available or was inconclusive, the material being evaluated should be regarded as being Class II.

The procedure described in AAR-1.1 & 1.2 results in a petrographic analysis for the sample under investigation, whereby each particulate constituent has been petrologically (or mineralogically) identified, its relative proportion determined and its alkali-reactivity status (judged innocuous or potentially reactive) established. This information is then used to classify the aggregate sample, for the purposes of the AAR assessment, into one of the three categories I, II or III, suffixed -S, -C or -SC as appropriate.

Acceptance and experience with reactive constituents differ between countries, and thus, final assessment and classification should follow any national or regional experiences, recommendations and specifications. Therefore, it is recommended that, whenever possible, petrographers should apply local guidance and/or local experience to assist with this classification.

In the case of Class II and III aggregate samples, the material is additionally sub-classified according to the siliceous and/or carbonate nature of the potentially reactive constituents, using the following definitions:

Classes II-S & III-S aggregate samples contain particulate constituents judged to be potentially alkali-silica reactive (ASR).

Classes II-C & III-C aggregate samples contain particulate carbonate constituents judged to be potentially reactive.

Classes II-SC & III-SC aggregate samples contain both particulate constituents judged to be potentially alkali-silica reactive (ASR) and particulate carbonate constituents judged to be potentially reactive.

In the case of Class II-S or III-S materials, it is then appropriate to carry out the RILEM test methods for alkali-silica reactivity (ASR): the accelerated mortar-bar

test, AAR-2, for short-term screening purposes and the 38 °C concrete prism test, AAR-3, for any long-term confirmation. The 60 °C accelerated concrete prism test, AAR-4.1, may be considered as an alternative to AAR-3.

In the case of Class II-C, II-SC, III-C or III-SC materials, it is instead appropriate to carry out the AAR-5 short-term screening test procedures for aggregates comprising or containing carbonate aggregates. Again, any long-term confirmatory testing will involve either or both of the AAR-4.1 and AAR-3 methods. Additional information on the assessment of carbonate rock aggregates is given in Annex A.

Practical experience has indicated, however, that Class II-S or III-S aggregates containing more than 2 % by mass porous flint (chert) as a potentially reactive constituent cannot be reliably assessed using the AAR-2 accelerated mortar-bar test. Such aggregates are widely encountered, for example, in several northern European countries, including Belgium, Denmark, the Netherlands and the United Kingdom. Some porous flint (chert) aggregate combinations that have been established as being expansively reactive in actual structures were not detected as being expansive in the accelerated mortar-bar test. Class II-S or III-S aggregates found by petrography to contain more than 2 % porous flint (chert), therefore, should either be assessed using the AAR-3 or AAR-4.1 concrete prism tests or accepted as being potentially alkali-reactive and precautions taken to minimise the risk of ASR damage to any concrete in which the material is used.

6 Accelerated Mortar-Bar Testing: AAR-2

An accelerated screening test for ASR, using mortar-bar specimens, is given in AAR-2. The method is unsuitable for porous flint (chert) aggregates (see above).

Experience has shown that the test procedure is able to detect pessimum behaviour and it is therefore recommended that a series of tests is carried out, in which the test aggregate is mixed with a non-reactive material in a range of proportions. Guidance on this procedure is given in the annex to AAR-2. However, it is not certain that the pessimum proportion indicated by the test corresponds with that exhibited by a comparable concrete.

Criteria for the interpretation of the results of AAR-2 have not yet been finally agreed. However, on the basis of trials carried out by RILEM on aggregate combinations of known field performance from various parts of the world, it seems that results in the test (after the standard 16-days, using ‘long thin’ 25 × 25 × 250–300 mm specimens) of less than 0.10 % are likely to indicate non-expansive materials, whilst results exceeding 0.20 % are likely to indicate expansive materials. It is not currently possible to provide definitive interpretative guidance for results in the intermediate range 0.10–0.20 % and, for all practical purposes in the absence of additional local experience, aggregates yielding AAR-2 results in this range will need to be regarded as being potentially alkali-reactive.

These tentative criteria refer to the ‘long thin’ specimen size presently given in AAR-2, although it is probable that the ‘short fat’ (or ‘short thick’) specimen size

(40 × 40 × 160 mm) will become preferred in due course, particularly as this is the recommended specimen size in AAR-5. At present, optional versions of AAR-2 are available for both the long thin (AAR-2.1) and short fat (AAR-2.2) specimens. Based on the findings of the EU ‘PARTNER’ research programme, on average short fat specimens produce lower values than long thin specimens over the same time period; the mean ratio of expansion of short fat to long thin specimens is in the region of 0.75–0.80. However, this ratio may vary considerably; thus, for many aggregates it would give a misleading result if a fixed ratio is used to extrapolate from one type of specimen to the other.

It follows that, in the case of aggregate combinations producing AAR-2 results (after the standard 16-day test) of 0.10 % or higher for long thin specimens (AAR-2.1) or 0.08 % or higher for short fat specimens (AAR-2.2), precautions will probably need to be taken to minimise the risk of ASR damage to any concrete in which the material is used unless concrete prism testing or field performance indicates otherwise.

There is some evidence, for example from Argentina, Australia [1] and Canada [2], that some slowly reactive aggregates are not detected using the above criteria. In Australia, a limit of 0.10 % after 21 days of storage of long thin specimens in 1 M NaOH solution at 80 °C is used, and is found to correlate with the performance of slowly reactive aggregates in concrete structures; this would equate to 0.08 % at 14 days of storage.

It has been suggested that assessment of the rate of expansion might be an alternative method for interpreting the AAR-2 test, especially in the case of uncertain results, and tentative recommendations for this approach are given in the annex to the AAR-2 method (also see [3], for possible criteria).

7 38 °C Concrete Prism Testing: AAR-3

A 38 °C concrete prism test method for ASR is given in AAR-3. This test can be used in two ways: as a standard test for evaluating the alkali-reactivity of an aggregate combination (AAR-3.1) or as a test for establishing the ‘alkali threshold’ of a particular aggregate combination (AAR-3.2).

In AAR-3.1, coarse and fine test aggregates are tested together in a standard mix combination and, where pessimum behaviour is suspected (or where it is unknown whether a pessimum behaviour might be expected), repeat tests can be carried out in which the coarse and fine fractions are variously replaced by a non-reactive material. In some cases, it might be considered more desirable to conduct the tests using the actual aggregate combination planned for a particular project, although, in such cases, the usual interpretation criteria could be less applicable.

The test should always be carried out using the cement and alkali contents stipulated in AAR-3.1, including the higher cement content permitted for certain types of aggregate combinations. The interpretation criteria suggested below for

AAR-3 would not be in any way applicable to concrete mixes with lower cement and/or alkali contents.

In AAR-3.2, the test is used as a means of establishing the alkali threshold at which a particular aggregate combination begins to exhibit a deleterious expansion. In this test, four concrete mixes with alkali levels in increments normally between 2 and 5 kg/m³ Na₂O eq. are tested. The alkali threshold is the alkali level at which there is a deleterious expansion (according to the criteria discussed below). This threshold is used to designate the aggregate reactivity class of the combination according to AAR-7.1 (the international specification for minimising the risk of ASR). It has been suggested that the leaching of alkalis from the relatively small concrete specimens used in this test can result in the alkali threshold determined by this method being higher than that found in field concretes. In using these AAR-3.2 results, therefore, it is recommended that a 'safety margin' is applied to the result to allow for the known differences between laboratory and field specimens, experimental uncertainty (e.g. from alkali leaching) and site batching variability. National specifications making use of such limits will need to decide on an appropriate safety margin from local experience [4].

Criteria for the interpretation of the results of AAR-3 have not yet been finally agreed. However, on the basis of trials carried out by RILEM on aggregate combinations of known field performance from various parts of the world, it seems that results in the test (usually after 12 months) of less than 0.05 % are likely to indicate non-expansive materials, whilst results exceeding 0.10 % indicate expansive materials. It is not currently possible to provide definitive interpretative guidance for results in the intermediate range 0.05–0.10 % and, for all practical purposes in the absence of additional local experience, aggregates yielding AAR-3 results in this range will need to be regarded as being potentially alkali-reactive. Since the RILEM interlaboratory trial, modifications to the method have been made on the basis of further experience and the results of the PARTNER programme. It is believed that these will have the effect of increasing expansions, especially at longer ages, so, if anything, these criteria will be even safer.

It follows that, in the case of aggregate combinations producing AAR-3 results of 0.05 % or higher (after 12 months), in the absence of local experience to the contrary, precautions should be taken to minimise the risk of ASR damage to any concrete in which the material is used. Again, there is some evidence that a lower criterion at 12 months (perhaps 0.04 or even 0.03 %) might be applicable for some slowly reactive aggregates.

In many cases, expansion will have ended or the rate of expansion become greatly reduced by the end of the standard 12-month test period. However, in some cases, expansion might still be occurring at 12 months, suggesting that the above criteria possibly could be exceeded during an extended period of testing. At present it is not possible to provide definitive guidance on the interpretation to be placed on such behaviour in the test, but it is suggested that, if time permits, testing may be continued until expansion ceases or it has become clear whether or not the criteria will be exceeded. If such continued testing is not practicable, a judgement will need to be made, from the inspection of the shape of the expansion curve up to

12 months, as to whether or not the criteria would be likely to be exceeded during further testing. In such a case, it is suggested that, in the absence of any relevant local experience, the result should be deemed to have exceeded the criteria if it is estimated that these criteria would be likely to be exceeded during an extension of testing to 24 months.

8 60 °C Concrete Prism Testing: AAR-4.1

A 60 °C concrete prism test method for ASR has been developed as AAR-4.1 and has been assessed by an international trial as an accelerated version of the AAR-3 test for evaluating the reactivity of an aggregate combination.

Criteria for the interpretation of the results of AAR-4.1 have not yet been finally agreed. However, on the basis of an initial assessment of the AAR-4.1 trials carried out by TC 191-ARP on aggregate combinations of known field performance from various parts of the world, it seems that a maximum expansion in the test of 0.03 % at 15 weeks indicates a non-reactive aggregate combination. It follows that, in the case of aggregate combinations producing AAR-4.1 results greater than 0.03 % at 15 weeks, in the absence of local experience to the contrary, precautions should be taken to minimise the risk of ASR damage to any concrete in which the material is used.

9 Carbonate Aggregate Testing: AAR-5

An accelerated screening test procedure for aggregates comprising or containing carbonate material has been developed as AAR-5 and has been assessed by an international trial. In this procedure, the aggregate material is subjected to testing using both the AAR-2 mortar-bar test and a new derivative test using ‘concrete-bar’ specimens, in which a 4/8 mm aggregate grading is used instead of the 0/4 mm grading used in AAR-2. In this application, both the AAR-2 and AAR-5 procedures employ ‘short fat’ specimens (nb the term ‘concrete-bar’ should not be confused with ‘concrete prism’).

Interpretation of the AAR-5 findings is based upon comparing the results of the two test methods. In typical ASR, the mortar-bar (AAR-2) method may be expected to produce greater expansion than the ‘concrete-bar’ (4/8 mm aggregate) method. However, investigations and trials have shown that expansion is greater in the ‘concrete-bar’ (4/8 mm aggregate) test in the case of carbonate aggregates (i.e., aggregates comprising crushed carbonate rock or natural aggregates containing a substantial proportion of carbonate rocks and minerals) that have been associated with carbonate-related expansion in concrete structures. Additionally, it has been found that these materials are not necessarily identified using the AAR-2 method alone. Therefore, in the AAR-5 procedure, if the ‘concrete-bars’ (4/8 mm aggregate)

expand more than the conventional AAR-2 mortar-bars (0/4 mm aggregate), the reactivity of the aggregate is probably not of the normal ASR type and further investigation using the longer-term AAR-4.1 or AAR-3 concrete prism tests will be required.

Interpretation of the comparison between the AAR-2 and AAR-5 results may be summarised as follows (in all cases referring to the ‘short-fat’ specimen option):

- AAR-2 > 0.08 %:
 - AAR-5 < AAR-2 = potential ASR
 - AAR-5 ≥ AAR-2 = possible combination of ASR & carbonate reaction
- AAR-2 < 0.08 %:
 - AAR-5 ≥ AAR-2 = possible carbonate reaction
 - AAR-5 < AAR-2 = no further testing

Further guidance on the specialised assessment of carbonate rocks and aggregates for reactivity potential is given in Annex A.

10 Precision of the RILEM Methods

The overall precisions of the three expansion RILEM methods were assessed in an inter-laboratory trial as part of the PARTNER Programme [5] following the procedure set out in ISO 5725-94 [6]. Eight laboratories took part in each assessment using three aggregates chosen to give a low, medium and high value in the particular test. The aggregate samples were prepared and distributed by the organizing laboratory. On the basis of this trial the details of the methods were improved so it can be expected that the present RILEM methods will have better precision.

The results of the trial are summarized below:*

Expected reactivity for aggregate in inter-laboratory trial	Low/medium	Medium	High
<i>AAR-2 (long thin bars, 14 days)</i>			
Measured mean expansion m (%)	0.133	0.420	0.375
Repeatability COV(sr) (%)	6.8	2.70	1.9
Reproducibility COV(sR) (%)	17.1	22.0	11.0
<i>AAR-3 (using wrapped prisms)</i>			
Measured mean expansion m (%)	0.059	0.181	0.260
Repeatability COV(sr) (%)	15.3	13.8	20.7
Reproducibility COV(sR) (%)	49.3	53.7	54.3
<i>AAR-4 (wrapping method)</i>			
Measured mean expansion m (%)	0.107	0.130	0.170

(continued)

(continued)

Expected reactivity for aggregate in inter-laboratory trial	Low/medium	Medium	High
Repeatability COV(sr) (%)	11.20	9.1	16.4
Reproducibility COV(sR) (%)	33.1	26.4	24.2

**General definitions:*

r = repeatability. This is a measure to determine the spread in results obtained between the individual prisms, tested at the same laboratory, same aggregate combinations and same concrete.

R = Reproducibility. This is a measure to compare the difference in the mean value obtained between the different laboratories.

COV(sR) = Coefficient of variation for the Reproducibility. By using the coefficient of variation (COV) one relates the spread to the actual expansion. The COV is the standard deviation divided by the mean value. The COV(sR) is thus used to compare the difference in the spread between the laboratories. Similarly, the COV(sr) is used to compare the spread within one single test carried out at one laboratory. In this case, the spread between the three prisms will determine whether it is correct to average their results or if the test has to be remade or only two of results should be averaged; all depending on the instructions in the test method.

10.1 Rilem AAR-2

The precision of this method was found to be quite good. At the proposed limiting value of 0.10 % for the long prisms the band of uncertainty is less than 0.025 % so, in precision terms, this method is well able to differentiate reactive from non-reactive materials.

10.2 Rilem AAR-3

The results concerning this method indicated that the repeatability is good, whereas the reproducibility is quite poor. The precision is, however, good enough to discriminate between non-reactive and reactive materials. The reproducibility is shown to be about half of the expansion value. At the level of 0.05 %, tentatively suggested as the limiting value to differentiate between reactive and non-reactive aggregate combinations when using AAR-3, there is therefore a band of uncertainty of 0.025 %, and the lowest result for a reactive aggregate should exceed 0.075 %. This was found to be the case for all the aggregates which react in normal time-scales and where their record of field reactivity is well established. However, the AAR-3 method is not so well suited to identifying “slowly” reactive aggregates unless the time period of the test is extended. It should be noted that in this trial a variation of the method in which the prisms were wrapped was used. This procedure is not now recommended.

10.3 RILEM AAR-4 (*Wrapped Prism Method*)

Testing according to the AAR-4 method resulted in a better overall precision than AAR-3, and was able to detect smaller differences in reactivity than the AAR-3 method. Like AAR-3, the precision of the AAR-4 Alternative method is sufficient to distinguish between non-reactive and reactive materials, but not between smaller differences of reactivity. At the tentatively proposed limiting value for differentiating reactive and non-reactive aggregates, 0.03 %, the band of uncertainty is less than 0.01 %.

11 Releasable Alkalis

Work is under way in RILEM to develop a standardised test method (AAR-8) for assessing the releasable alkali content of aggregates and this is at the stage of trials of the procedure in various specialist laboratories [7]. Various methods have been suggested and used previously, mostly based upon extraction by a calcium hydroxide solution, but none of these is considered adequately to replicate the possible release of alkalis within concrete. AAR-8 is based upon extraction using an alkali solution saturated with calcium hydroxide and early results suggest that the results may be regarded as meaningful. In due course, RILEM expects to be able to provide guidance on the interpretation and application of AAR-8 findings.

12 Conclusions

Petrographical examination (AAR-1.1 & 1.2) should be carried out in all cases. On some occasions this will lead directly to definitive outcomes, either Class I ‘unlikely to be alkali-reactive’, or Class III ‘very likely to be alkali-reactive’. In many cases, petrographical examination will lead to an indefinite outcome, Class II ‘potentially alkali-reactive’, and further testing will be required.

Siliceous aggregates (and carbonate aggregates with a significant siliceous content) may be further assessed for ASR, usually using first the short-term (2 or 3 weeks) screening test (AAR-2), then the 60 °C accelerated concrete prism test (AAR-4.1), which can be interpreted after 15 weeks. If required, the longer-term (12 months) 38 °C concrete prism test (AAR-3) may be carried out. The findings of the concrete prism tests should always take precedence. The AAR-2 test cannot be used for Class II aggregates containing porous flint (chert) as a potentially reactive constituent and the criteria for some slowly reactive aggregate types might need to be modified.

Carbonate aggregates (and siliceous aggregates with a significant carbonate content) may be further assessed using the AAR-5 short-term (2 or 3 weeks)

screening procedure, which will identify any aggregate reactivity that is probably not of the normal ASR type and indicate when further investigation using the longer-term AAR-4.1 or AAR-3 concrete prism tests will be required. Specific guidance on assessing carbonates is given in Annex A.

In addition to assessment of an aggregate combination for reactivity potential, the aggregates may be tested for releasable alkali content using the AAR-8 method that is being developed.

Annex A: Assessment of Carbonate Rock Aggregates for Reactivity Potential

A1 Scope

This Annex describes procedures for the assessment of potentially reactive carbonate rocks in concrete. The procedures include those in AAR-1.1 & 1.2, which does not include specific guidance on the assessment of carbonate rocks for reactivity in concrete. As a result of undergoing the procedures described in this Annex, carbonate rocks should be classified according to one of the following classes:

- Very unlikely to be alkali-reactive—Class I
- Alkali-reactivity uncertain—Class II
- Very likely to be alkali-reactive—Class III

It is very important that the petrographic analysis is carried out by a qualified geologist with experience of materials used for concrete and good local knowledge of alkali-reactive aggregates, minerals and in this case especially carbonate rocks.

A2 Definitions

A2.1 Alkali Carbonate Reaction (ACR)

Chemical-physical expansive reaction in concrete between certain impure coarse grain-sized dolomitic carbonate rocks and the cement paste. The reaction appears to be associated with dedolomitization and an associated swelling reaction, but is not yet fully understood and documented.

Note 1: *The reaction might occur concurrent with Alkali-Silica Reaction (ASR) caused by the same aggregate particle. Some researchers suggest that ASR is the only expansive reaction in reacted carbonate aggregates.*

A2.2 Carbonate Rock

A rock composed of more than 50 % by mass of carbonate minerals such as calcite or dolomite. They are sedimentary or metamorphic, and very rarely igneous (carbonatites) in origin.

A2.3 Carbonate Sedimentary Rocks

Calcareous rock is a rock containing an appreciable amount of calcium carbonate. It can be sedimentary limestone (e.g. chalk, tufa or calcarenite). Dolomitic limestone contains 10–50 % dolomite and 50–90 % calcite. Dolomite rock (dolomite) contains more than 50 % of the mineral dolomite. Dolomite occurs in crystalline and microcrystalline forms. The term “dolostone” is synonymous with dolomite rock, but has not gained universal acceptance.

Carbonate rock deposits can often contain intermixed layers of clay, shale, sandstone or siltstone. Silicification of carbonate rock deposits with dispersed crypto- and micro-crystalline quartz or opal is not uncommon.

A2.4 Metamorphic Carbonate Rocks

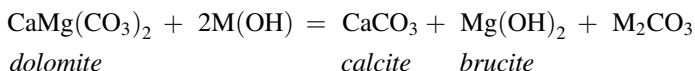
Metamorphic carbonate rock is termed marble. Dolomitic marble is composed mostly of the mineral dolomite.

A2.5 Dedolomitization

A process resulting from chemical weathering, diagenesis or metamorphism, wherein part or all of the magnesium component in a dolomite or dolomitic limestone is consumed in the formation of magnesium hydroxides and silicates (e.g. brucite, forsterite), resulting in an enrichment in the calcite content.

A2.6 Chemical Reaction of Dolomite in Concrete

Dolomite can be unstable in concrete under certain conditions. The instability and decomposition of dolomite in concretes produce more stable phases, such as calcite and brucite. It could be the result of the following reaction:



where *M* is an alkali metal.

It remains uncertain whether or not this dedolomitization process alone can sometimes cause damage to concrete.

A3 Principles

The AAR-1.1 & 1.2 petrographic examination method describes the visual recognition and quantification techniques for rocks and mineral constituents of aggregates sources with special emphasis on their potential for alkali reactivity. This Annex gives supplementary information and methods for assessing carbonate rocks for potential reactivity in concrete.

Thin-sections (optionally polished thin-sections) stained for carbonate rocks should be prepared and used to determine the types of carbonate rocks. The procedures for carbonate rocks are summarised in Fig. A.1. The procedure is generally used for aggregates originating from quarries dominated by carbonate rocks.

Note 2: *Crystalline carbonate rock without dolomite and impurities should be assessed unlikely to be reactive and further testing is not necessary. Carbonate aggregates intended to be used only as fines (sand) in concrete are unlikely to exhibit ACR but would still need to be assessed for ASR potential.*

The procedure allows for the additional use of 3 optional methods when carbonate rocks have been identified in thin section:

- (1) X-ray fluorescence analysis (XRF),
- (2) X-ray diffraction analysis (XRD),
- (3) Scanning Electron Microscopy (SEM) with Energy Dispersive X-ray analysis (EDX).

Note 3: *Detection of dolomite and the potential degree of dedolomitization (and reaction products) can be made using the following techniques:*

1. *XRD, using an internal standard of very well known d-spacing to determine the d-spacing of dolomite.*
2. *Petrography, using alizarin-red dye, to determine zoning, crystal shape, partial dedolomitization or iron oxides stains as well as EMPA, SEM/EDX.*

Rather than proceeding with XRF analysis, XRD analysis and/or SEM/EDX (or WDX, see A6) analysis, this procedure also includes direct application of screening tests according to AAR-5 or even the longer-term AAR-3 or AAR-4.1 concrete expansion tests.

A4 Assessment Using XRF Analysis (Optional Method)

When carbonate minerals are identified by thin-section, an X-ray fluorescence (XRF) analysis on the bulk sample might be carried out. Minimum elements to be

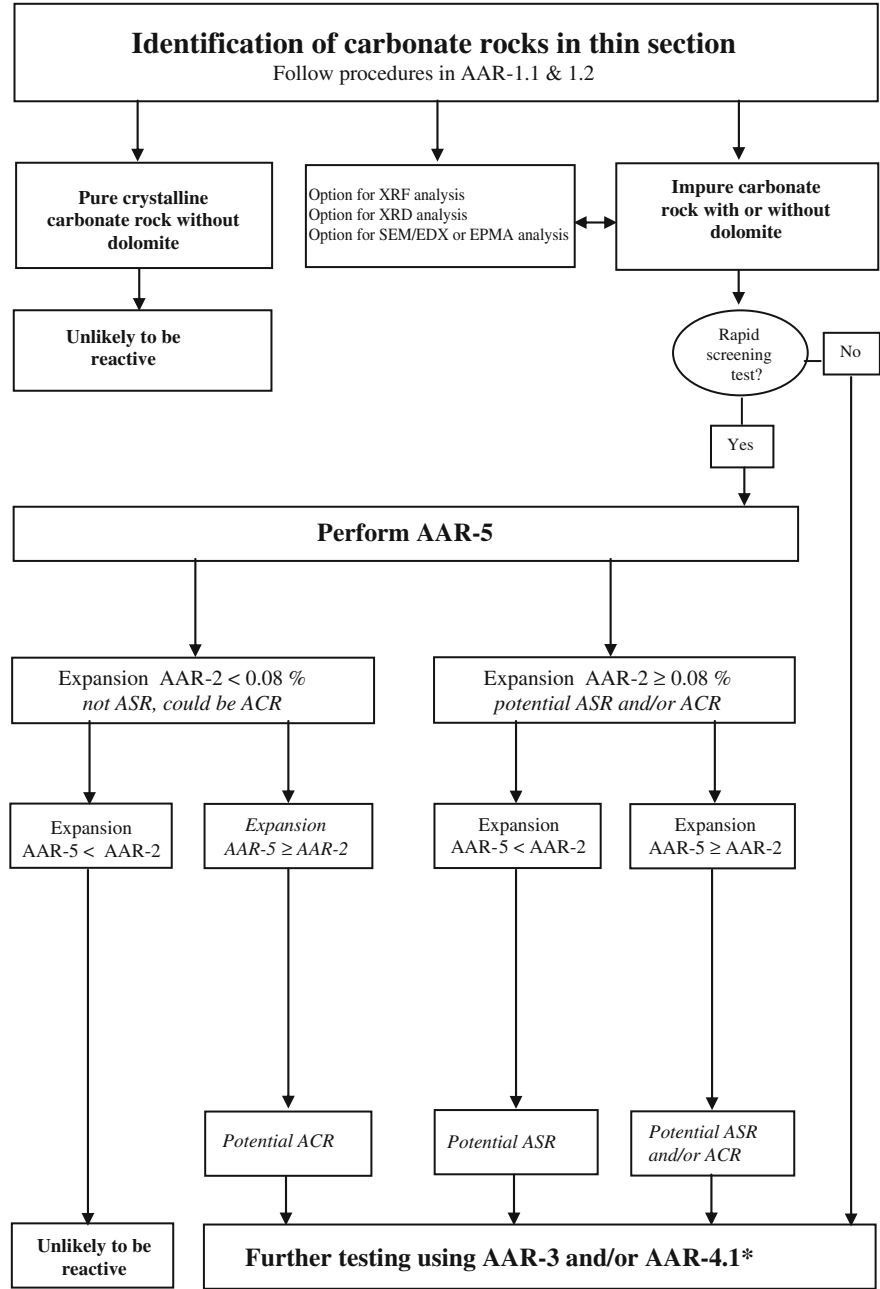


Fig. A.1 Flow chart for AAR assessment of carbonate rocks. * There is limited experience in using AAR 4.1 for carbonate rocks/aggregates

analysed are calcium and magnesium to indicate the carbonate minerals (calcite and dolomite), and aluminium to indicate the possible presence of clay minerals (see also Note 5 below).

For the assessment of reactivity, the calcium/magnesium oxide ratio should be calculated and the ratio plotted in Fig. A.2 against the aluminium oxide content. Two possibilities will result, based upon empirical observations in Canada, namely to be “considered potentially expansive” or “considered non-expansive”. Because of limited experience with the method outside Canada, a further assessment of possible expansion should be carried out according to AAR-5.

A5 Assessment Using XRD Analysis (Optional Method)

When carbonate minerals are identified by thin-section (see AAR-1.1 & 1.2), an X-ray diffraction (XRD) analysis on a bulk sample might be carried out. Generally the major (>5 %) and minor minerals (<5 %) are analysed and reported. Normally XRD analysis is used for qualitative identification of crystalline minerals (Note 4), but can also be used for semi-quantitative measurements.

The carbonate minerals magnesite, dolomite, ferroan dolomite and calcitic dolomite are considered indicative of potentially ACR reactive material. At present, the identification of any detectable quantity of these phases should classify the aggregate sample as “potentially expansive” and further testing according to AAR-5 should then be performed (see Fig. A.1).

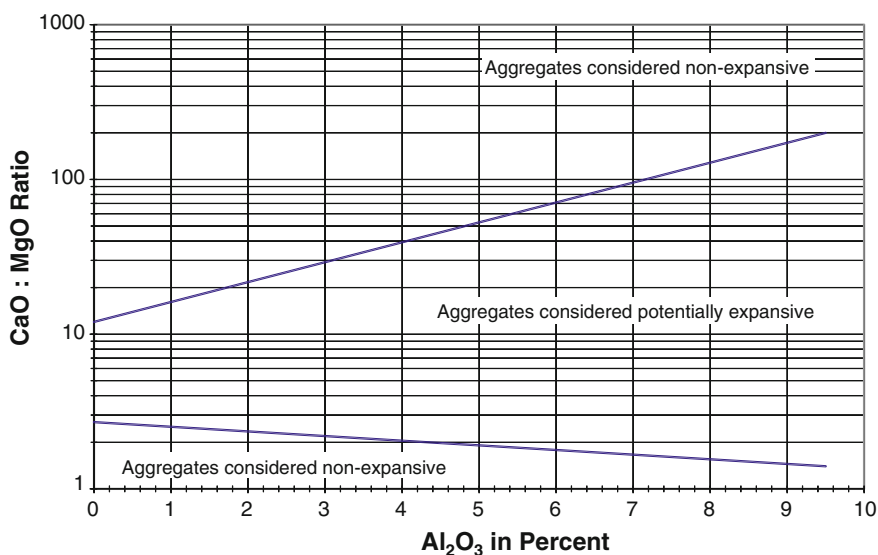


Fig. A.2 Suggested interpretation of XRF analysis findings. Figure modified from C.A. Rogers [8]

If ACR indicative minerals have not been identified by the XRD analysis, ACR is unlikely to occur, but ASR is still possible. In that case testing according to AAR-2 and/or AAR-3 and/or AAR-4.1 could be performed (see Fig. [A.1](#)).

Note 4: *XRD analysis, which identifies only crystalline materials, will not be able to characterize amorphous constituents (e.g. opal-A, glass, or other non crystalline constituents).*

Note 5: *In some carbonate rocks, clay minerals can occur that might also cause problems and non-AAR expansion in concrete. When necessary, clay minerals can be characterised using specialised XRD. In sedimentary carbonate rocks, the total alumina content is also a useful indicator of the amount of clay minerals, since alumina is normally only derived from clay minerals in the absence of feldspars (authigenic or detrital); clay mineral content is approximately 3 x the content of alumina (Al_2O_3).*

A6 Assessment Using SEM/EPMA Analysis (Optional Method)

When carbonate minerals are identified by thin-section analysis (see AAR-1.1 & 1.2), examination by use of Scanning Electron Microscopy (SEM) and/or Electron Probe Micro Analyser (EPMA) can be carried out. This examination should be carried out by qualified personnel with knowledge of these techniques. It is recommended to use polished thin-sections or polished samples. Elements can be detected and quantified by use of Energy Dispersive X-ray (EDX) analyses and minerals by use of Wavelength Diffraction X-ray (WDX) analysis.

Interpretation of results obtained by EDX is the same as given in Fig. [A.2](#). Interpretation of results obtained by WDX analysis is the same as given above for XRD.

A7 Assessment of Reactivity According to AAR-5

An accelerated screening test procedure for aggregates comprising or containing carbonate material has been developed as AAR-5 and has been assessed by an international trial.

In this procedure, the aggregate material is subjected to testing using both the RILEM AAR-2 mortar-bar test and a new derivative test using ‘concrete-bar’ specimens, in which a 4/8 mm aggregate grading is used instead of the 0/4 mm grading used in AAR-2. In this application, both the AAR-2 and AAR-5 procedures employ ‘short fat’ prism specimens (40 × 40 × 160 mm).

The interpretation of the AAR-5 findings is based upon comparing the results of these two test methods. In typical ASR, the mortar-bar (AAR-2) method may be expected to produce greater expansion than the ‘concrete-bar’ method. However, investigations and trials have shown that expansion is greater in the ‘concrete-bar’ test in the case of carbonate aggregates that have been associated with expansion in concrete structures, and also that these materials are not necessarily identified using the AAR-2 method alone. Therefore, in the AAR-5 procedure, if the concrete-bars expand more than the mortar-bars, the reactivity of the aggregate is probably not that of the normal ASR type and further investigation using the longer-term AAR-4.1 and/or AAR-3 concrete prism tests will be required.

Interpretation of the comparison between the AAR-2 and AAR-5 results (both using the ‘short-fat’ specimen option) may be summarised as follows (where appropriate, the 0.08 % expansion criterion shown may be replaced by a locally determined value):

- RILEM AAR-2 \geq 0.08 % and:
 - AAR-5 < AAR-2 = potential ASR
 - AAR-5 \geq AAR-2 = possible combination of ASR and ACR
- RILEM AAR-2 < 0.08 % and:
 - AAR-5 \geq AAR-2 = possible ACR
 - AAR-5 < AAR-2 = unlikely to be reactive (no further testing necessary)

A8 Assessment of Reactivity Using AAR-3 and/or AAR-4.1

If potential ASR and/or potential ACR are detected, the longer-term (at least 12 months) 38 °C concrete prism test (AAR-3) may be carried out. Concrete test prisms are prepared from the aggregate combination and are stored in warm, humid conditions for 12 months to promote any alkali-silica reaction or alkali-carbonate reaction. The findings of the concrete prism tests should always take precedence over the results of AAR-2 or AAR-5.

Alternatively, aggregates may be assessed for ASR or ACR using the 60 °C concrete prism test AAR-4.1, which can be interpreted after 15 weeks. It is envisaged that the AAR-4.1 method might be used as an accelerated version of the AAR-3 test. However, at present there is only limited experience of using the 60 °C concrete prism method for ACR detection.

A9 Limitations and Need for Research

The suggested test procedures are based on the present knowledge of ACR. The optional XRF method (see Fig. A.2) is based primarily on Canadian experience and

some rarer cases internationally. Therefore, experience and testing of carbonate rocks other than Canadian materials are needed to validate or revise the Canadian procedures and criteria.

The mechanism of ACR is not fully understood and more research is needed on this issue. Carbonate rocks are internationally important and widely used aggregate types for concrete. The guidance given in this Annex will hopefully be a step forward in producing durable concrete with carbonate rocks, but will need to be reviewed periodically and updated as appropriate.

Annex B: Guide to Reference Materials

B1 Preamble

This guide is intended to provide assistance to any laboratories undertaking the RILEM expansion tests, using either mortar-bar or concrete-bar specimens (AAR-2 & AAR-5) or concrete prism specimens (AAR-3 & AAR-4.1). It includes information on the use of reference cement or aggregate materials and various accessories required for conducting the tests.

B2 Introduction

The use of reference cement and aggregate materials is not mandatory in the AAR-2, AAR-3, AAR-4.1 and AAR-5 test methods. However, in any testing, the use of reference materials, with known and constant properties or behaviour, may be useful, or stipulated, in certain circumstances, including the following:

- to establish the reliability and accuracy of a new test procedure;
- to assess the competence of a laboratory or the testing personnel;
- to provide reassurance in the case of tests yielding variable results;
- to provide controls for direct comparison with material under evaluation.

In particular relation to the three TC 219-ACS expansion tests for alkali-aggregate reaction, reference materials may be specifically used as follows:

- **Reference High-Alkali Cement:** to minimise any variations arising from using cements of different sources, compositions and properties;
- **Reference Reactive Aggregate:** to provide reassurance to laboratories undertaking tests for the first time, to enable routine checking of testing facilities or their personnel and for use in inter-laboratory precision experiments;
- **Reference Non-Reactive Aggregate:** to enable a baseline movement to be established for testing facilities and for use in programmes for identifying any pessimum behaviour.

B3 Selected Reference Materials

B3.1 High-Alkali Cement

A source of suitable high-alkali Portland cement has been selected, as follows:

- **Norcem, Norway:**
Cite reference: RILEM reference cement
Contact: Dr Knut Kjellsen,
Norcem AS, R&D Department,
3950 Brevik, Norway
Telephone: +47 35 57 20 00
Fax: +47 35 57 04 00
E-mail: knut.kjellsen@norcem.no
Minimum quantity: 25 kg (& supplied in multiples of 25 kg)

Property data for this cement are given in Table [B.1](#).

B3.2 Reactive Aggregates—ASR

Many ‘reactive’ aggregates have been used in experimental research into ASR, variously using natural and synthetic materials. RILEM recommends that a natural aggregate should be selected and that the preferred material should have exhibited a sensibly uniform behaviour in various test methods. After reviewing the options, a crushed siliceous limestone from Spratt’s Quarry, near Ottawa in Canada, has been selected.

A stockpile of material from the appropriate strata at Spratt’s Quarry has been established by the Ontario Ministry of Transportation, who are prepared to supply modest amounts, as follows:

- **Ontario Ministry of Transportation:**
Cite: 20–5 mm crushed Spratt’s aggregate
Contact: Mrs Carole Anne MacDonald, Petrographer, Soils and Aggregates Section
Building C, Room 220, 1201 Wilson Avenue, Downsview, Ontario, M3 M 1J8, Canada
Telephone: +1 416 235 3738
Fax: +1 416 235 4101
E-mail: caroleanne.macdonald@ontario.ca
Minimum quantity: 25 kg

Table B.1 Property data—
reference high-Alkali
Cement*

Source	Norcem A/S, Norway
Type	CEM I 42.5 R
Description/sample	Quality declaration
Date (day/month/year)	08/2/2010
CHEMICAL ANALYSIS	% by mass
Loss on ignition	1.1
Insoluble residue	na
Silica, SiO ₂	19.8
Alumina, Al ₂ O ₃	5.2
Ferric oxide, Fe ₂ O ₃	3.5
Lime, CaO	61.7
Magnesia, MgO	2.7
Sulfur trioxide, SO ₃	3.7
Potash, K ₂ O	1.16
Soda, Na ₂ O	0.52
Chloride, Cl	0.05
Phosphorous pentoxide, P ₂ O ₅	na
Chromium, Cr ⁶⁺	0.00 mg/kg
Free lime	1.4
Total alkali, Na ₂ O eq.	1.28
Lime saturation factor	na
C ₃ S	na
C ₂ S	na
C ₃ A	na
C ₄ AF	na
Gypsum	na
Limestone	0.9
PHYSICAL PROPERTIES	EN 196
Fineness, Blaine, m ² /kg	573
Sieve analysis: >90 µm, % by mass	0
Soundness, Le Chatelier, mm	0
Soundness, autoclave, %	na
Setting times, min: initial final	105 na
Compressive strength, MPa: 1 day 2 days 3 days 7 days 28 days	31 37 na 48 54

*These data are summarised from a certificate supplied to RILEM TC 219-ACS by the manufacturer. Data for presently available batches should be obtained from the manufacturer
na = not available

Geological information, together with some analytical and test data, is given in Figs. B.1, B.2 and Tables B.2, B.3.

A precision trial using an accelerated mortar-bar test [9] was carried out in North America in 1995 (Rogers et al. 1996). This indicated an average 14-day expansion of about 0.42 %, with all compliant laboratories yielding results greater than 0.30 %. A further study with new samples in 2007 produced a similar average 14-day expansion of 0.39 % [10].

In a concrete prism test (CSA method), using cement with an alkali content of 1.25 % (as Na_2O eq.) and 38 °C storage, expansion values with Spratt's coarse aggregate (and non-reactive sand) at 1 year have been reported in the range 0.08–0.16 %. An inter-laboratory concrete prism test study (CSA method), using mixtures of Spratt's coarse aggregate and non-reactive sand, produced average expansion values in the range 0.16–0.18 %, depending upon mix details and storage conditions [11].

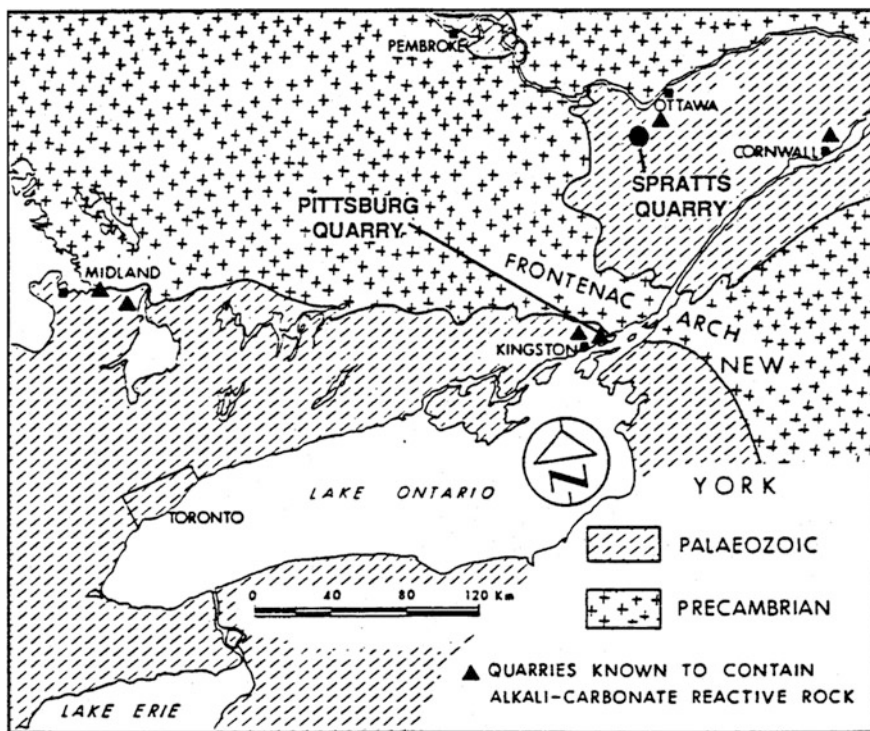


Fig. B.1 Geological map showing location of Spratt's and Pittsburg Quarries. *Reproduced by courtesy of the Ontario Ministry of transportation*

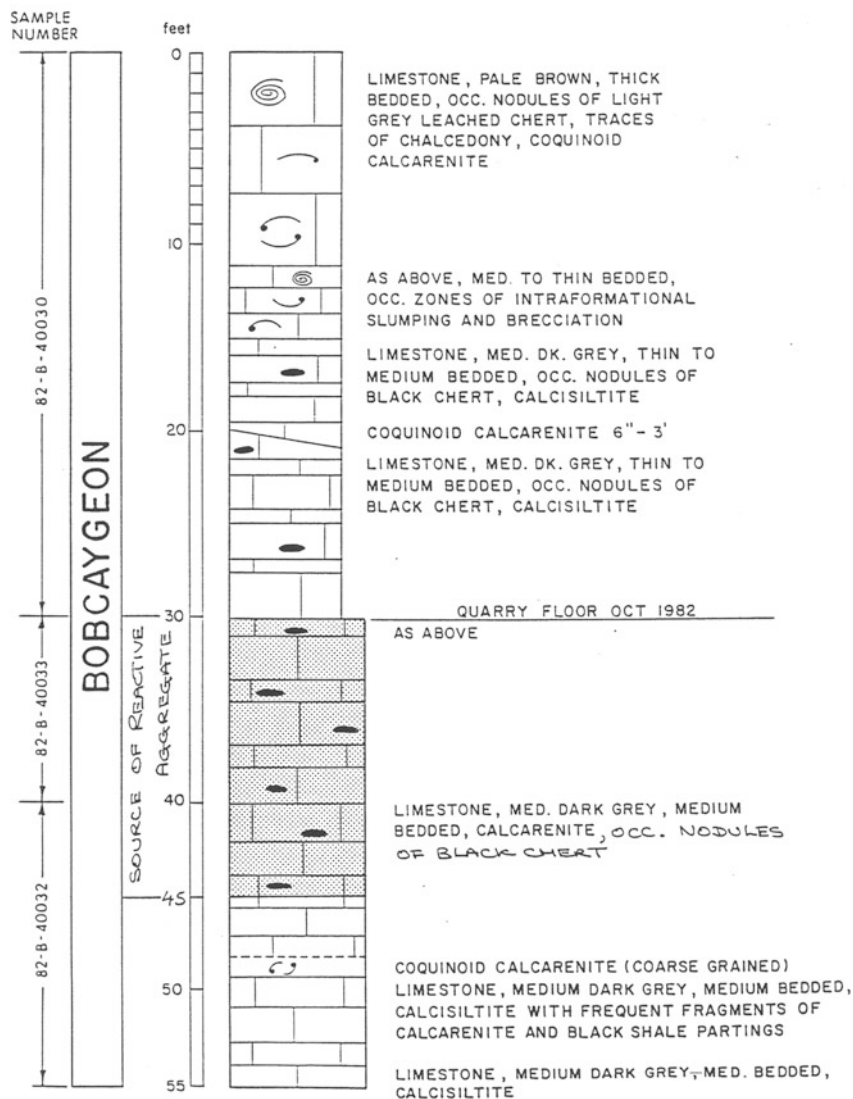


Fig. B.2 Stratigraphic column showing layers exposed in Spratt's Quarry. *Reproduced by courtesy of the Ontario Ministry of transportation*

B3.3 Reactive Aggregates—Carbonate

A stockpile of reactive carbonate aggregate material from the Pittsburg Quarry at Kingston, Ontario, Canada, has been established by the Ontario Ministry of Transportation, who are prepared to supply modest amounts, as follows:

- **Ontario Ministry of Transportation:**

Cite: 20–5 mm crushed Pittsburg Quarry aggregate

Contact: Mrs Carole Anne MacDonald, Petrographer, Soils and Aggregates Section

Building C, Room 220, 1201 Wilson Avenue, Downsview, Ontario, M3 M 1J8, Canada

Telephone: +1 416 235 3738

Fax: +1 416 235 4101

E-mail: caroleanne.macdonald@ontario.ca

Minimum quantity: 25 kg

The geological location of Pittsburg Quarry is shown in Fig. B.1 and some preliminary analytical and test data are given in Table B.4.

Table B.2 Information and data—reference reactive Spratt's aggregate*

CHEMICAL ANALYSIS¹	Whole rock	Acid insoluble portion
	% by mass	
Acid insoluble residue	10	100
Silica, SiO ₂	8.70	86.92
Alumina, Al ₂ O ₃	0.59	4.24
Titania, TiO ₂	0.04	0.21
Phosphate, P ₂ O ₅	0.29	0.45
Ferric oxide, Fe ₂ O ₃	0.58	1.28
Lime, CaO	48.47	0.26
Magnesia, MgO	1.67	0.78
Soda, Na ₂ O	0.04	0.08
Potash, K ₂ O	0.08	0.78
Sulfur, S	0.13	1.16
Loss @ 1050 °C	39.55	4.02
Total	100.14	100.18
MINERALOGY²	Whole rock	Acid insoluble portion
	phases detected and order	of concentration
Calcite	major	–
Quartz	minor	major
Dolomite	minor	–
Pyrite	nd	minor
Illite (clay mineral)	nd	minor

*These summary data are collated from detailed information held on file by RILEM TC 219-ACS

nd = not detected (below lower level of detection for method)

¹X-ray fluorescence, by Hung Chen, Canada Cement Lafarge Ltd, Montreal

²X-ray diffraction, by Hung Chen, Canada Cement Lafarge Ltd, Montreal

Table B.3 ASR test data—reference reactive Spratt's aggregate

ASTM C289 CHEMICAL METHOD¹	R_c/S_c millimoles/litre (classification)
300–150 µm (acid insoluble component)	36/307 (deleterious)
<150 µm (acid insoluble component)	52/391 (deleterious)
ASTM C227 MORTAR-BAR TEST²	% expansion, range (various storage types)
13 weeks (3 months)	<0.05–0.14
26 weeks (6 months)	<0.10–0.28
39 weeks (9 months)	<0.10–0.34
ACCELERATED MORTAR BAR TESTS³	
ASTM C1260 (number of labs = 23)	% expansion, range (mean), standard deviation
After immersion for 14 days	0.276–0.457 (0.389), 0.044
After immersion for 21 days	0.407–0.580 (0.495), 0.058
After immersion for 28 days	0.488–0.700 (0.584), 0.058
CSA A23.2-25 (2009) (number of labs = 28)	
After immersion for 14 days	0.307–0.486 (0.372), 0.042
After immersion for 21 days	0.383–0.592 (0.482), 0.052
After immersion for 28 days	0.450–0.725 (0.582), 0.068
RILEM AAR-2 (number of labs = 3)	
After immersion for 14 days	0.23–0.369 (0.291), ⁴
After immersion for 21 days	0.357–0.490 (0.410), ⁴
After immersion for 28 days	0.500–0.621 (0.547), ⁴
CONCRETE PRISM EXPANSION TESTS³	
CSA A23.2-14A and ASTM C 1293 (number of labs = 35 and 36)	% expansion, range (mean), standard deviation
Using control sand, 12 month expansion at 38 °C	0.128–0.334 (0.204), 0.050
Using local sand, 12 month expansion at 38 °C	0.104–0.268 (0.175), 0.039
RILEM AAR-3 (number of labs = 3)	
Using control sand, 12 month expansion at 38 °C	0.184–0.344 (0.274), ⁴
Using local sand, 12 month expansion at 38 °C	0.210–0.308 (0.275), ⁴
CSA A23.2-14A and ASTM C 1293 but tested at 60 °C (number of labs shown below)	
Using control sand, 13 week expansion (n = 19)	0.056–0.217 (0.146), 0.041
Using control sand, 26 week expansion (n = 21)	0.075–0.231 (0.165), 0.042
Using local sand, 13 week expansion (n = 22)	0.053–0.204 (0.113), 0.036
Using local sand, 26 week expansion (n = 23)	0.064–0.230 (0.127), 0.041

¹Grattan-Bellew, P E, July 1987 (whole rock testing gives 128/32, in the innocuous field)²Cement total alkali content 1.17 % as Na₂O eq., Ontario Hydro-MTC study³These data correspond to the results of an interlaboratory study that was carried out in 2007–2009. The study was organized by Chris Rogers (former MTO and now retired/consultant), Carole-Anne MacDonald (MTO) and Benoit Fournier (Laval University)⁴Number of laboratories was too few to enable a standard deviation to be calculated

Table B.4 Analytical and test data—reference reactive Pittsburg carbonate aggregate

ASTM C586 ROCK CYLINDER TEST¹	% Expansion
1 day	0.04
3 days	0.08
7 days	0.28
15 days	0.81
28 days	1.72
64 days	3.50
CSA CHEMICAL ANALYSIS	% by mass ²
CaO	40.9, 42.6, 43.2
MgO	6.29, 6.17, 8.31
Al ₂ O ₃	2.70, 2.08, 1.81
Classification by CaO/MgO Ratio vs. Al ₂ O ₃	Potentially expansive
PETROGRAPHY	Observations @ NRC & CANMET
Texture	Rhombic crystals of dolomite (20–50 µm) in a matrix of micrite and clay minerals
Study by XRD of effect of NaOH treatment	Formation of brucite (after 14 days) & progressive reductions in dolomite & quartz
CSA CONCRETE PRISM EXPANSION TEST^{3,4}	% expansion, range (mean %), standard deviation
One year stored at 23 °C in moist room	0.105–0.210 (0.153), 0.0294
Two years stored at 23 °C in moist room	0.158–0.250 (0.193), 0.0350
One year stored at 23 °C in moist room sealed in plastic bag	0.153–0.298 (0.235), 0.0404
Two years stored at 23 °C in moist room sealed in plastic bag	0.211–0.389 (0.295), 0.0476
One year stored in 5 % NaCl solution at 23 °C	0.116–0.292 (0.236), 0.0521
Two years stored in 5 % NaCl solution at 23 °C	0.199–0.399 (0.340), 0.0615
One year stored at 38 °C in sealed box with moisture	0.218–0.466 (0.307), 0.0716
Two years stored at 38 °C in sealed box with moisture	0.235–0.537 (0.375), 0.0862

¹Good samples are not available to conduct this test. Data will be found on expansion of rock cylinders from this quarry in Williams and Rogers [12] and Rogers [13]

²Second set of chemical data for Pittsburg aggregate is unpublished 1993 inter-laboratory (12 laboratories) data from the Ontario Ministry of Transportation, whilst the third set of data is from Shehata et al. [14]

³Source of data for concrete prism expansion testing is results of an unpublished report on work conducted in 1991–1992 from Chris Rogers (2011)

⁴CSA A23.2-14A 1986, with 310 kg/m³ high-alkali Portland cement boosted to 1.25 % Na₂O eq. Number of labs 15–17

B3.4 Non-reactive Aggregate

A suitable non-reactive aggregate is defined using an unusually demanding criterion of less than 0.05 % expansion in the AAR-2 accelerated mortar-bar test.

In the RILEM trials of the AAR-4.1 60 °C concrete prism test, a crushed limestone from Boulonnais in France has been identified for use as the non-reactive reference coarse and fine aggregates. Arrangements have been made for ex-Boulonnais coarse and/or fine aggregates to be stocked and supplied by the following organisation:

- **Carrières du Boulonnais** (<http://www.lesgranulatsdugroupecb.com>):

Cite: Coarse and/or Fine Boulonnais Aggregate

Contact: Ms Sophie Citerne (Export/Industry Sales Manager)

530 BD du Parc d'affaires Eurotunnel

62231 Coquelles

France

Mobile/Cell: +33 (0)6.08.33.57.76

E-mail: sciterne@groupecb.com

B4 Test Accessories

B4.1 Storage Containers for Concrete Prisms

The AAR-3 concrete prism test involves the storage of specimens in a suitable container, as defined in the method. One source of suitable containers is as follows:

- **LINPAC Ropak**

Cite: 5 gallon or 19 litre round container 10540 Talbert Avenue, Suite 200
Fountain Valley, CA 92708, USA

Tel: +1 (714) 845 2845

Web: www.linpac.com

E-mail: info@linpacpackaging.com

B4.2 Reactor Storage for Concrete Prisms

The recommended storage for concrete prisms in the AAR-4.1 test utilises the reactor system, which can also be used for the AAR-3 test. Information on this apparatus may be obtained from the following:

- **Chaudronnerie Mecanique Generale:**

27 rue de la Constellation

Parc St Christophe, BP 8262

95801 Cergy Ontoise Cedex, France

- **Espo-Sud:**
Quartier les Ramières, BP37
07350 Cruas
France

- **Schleibinger Geräte Teubert u Greim GmbH:**
Gewerbestr. 4
D-84428 Buchbach
Germany
Tel: +49 8086 94010
E-mail: schlei@schleibinger.com

- **Ratio TEC Prüfsysteme GmbH:**
In der Au 17
88515 Langenenslingen
Germany
Tel: +49 7376 9622-0
E-mail: ratio.tec@t-online.de

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RILEM Recommendations for the Prevention of Damage
by Alkali-Aggregate Reactions in New Concrete
Structures

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