EXPERIENCE FROM USING THE RILEM AAR-1 PETROGRAPHIC METHOD AMONG EUROPEAN PETROGRAPHERS – PART OF THE PARTNER PROJECT

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Abstract

This paper summarizes the results and experience of the use of the petrographic method, developed by RILEM as AAR-1, to assess the alkali reactivity of aggregates. This project is a part of the European research project PARTNER (2002-2006).

22 different European aggregates were selected for petrographic analysis. 13 laboratories participated, whereas six perform such analysis regularly. In total 123 single analyses were performed.

The overall experience from the testing program is that the spread in results between the laboratories for about half of the aggregate types is very high. However, four of the most experienced laboratories presented results with rather low spread. Several parameters can influence the spread in results. The most important ones are most likely the lack of experience from analysing foreign aggregate types and too little co-ordination between the petrographers.

Eight laboratories were also involved in a precision trial. Also these results are presented in the paper.

Keywords: alkali-silica reactions, testing methods, petrographic analysis, precision trial

1 INTRODUCTION

This paper presents the results of an evaluation of the use of the petrographic method, developed by RILEM as AAR-1, to assess the alkali reactivity of European aggregates. It is one of a series of such evaluations, carried out under Work Package 3 (task 3.1) in the PARTNER programme /1/. The R&D programme has evaluated the tests developed by RILEM, and some regional tests, for their suitability for use with the wide variety of aggregate and geological types found across Europe and calibrated the results of these accelerated tests (9 in total) against behaviour in concrete in real structures and in field sites (cubes).

During the Partner Project precision trials were also carried out for four of the RILEM methods (Work Package 4, task 4.1). This paper also includes the main findings from the precision trial by use of the petrographic method.

2 METHOD

The petrographic method is a test method used as a "first step" to assess the reactivity of concrete aggregates. A detailed description of the RILEM AAR-1 Petrographic method was published in Materials and Structures in 2003 /2/.

The method is carried out by two mutually beneficial techniques; a standard petrographic examination of the aggregate particles and a detailed microscopical examination of thin-sections which may incorporate point-counting. An initial inspection of the aggregate material should be undertaken to assess which technique(s) should be employed.

This RILEM AAR-1 petrographic method allows for three different technique(s) / procedure(s) to determine the reactivity of a particular aggregate sample:

1. The hand separation technique by lithological characteristics of aggregate particles is most appropriate with coarser gravel aggregates where the different constituent of an aggregate are easily separated by eye, colour, density, physical characteristics etc (i.e. porous flints, or light coloured limestones and dark coloured basalt in the same gravel). In such circumstances it may

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not be necessary to study thin-sections of selected aggregates to enable fuller identification of the material. After separation selected particles can, if felt necessary, then be thin sectioned to determine the microscopical reactivity related characteristics. This procedure is named "Particle separation". The procedure is regarded to be attended with uncertainty and is not suited for unfamiliar or "complex" aggregate types.

2. For aggregates in which individual particle lithologies cannot be determined easily or there is clear variability of reactivity between the different parts of the aggregate particles at a microscopical scale, the point counting technique should be employed. This procedure is named "Point count analysis" and is in most cases the most accurate method for identification of the different rock types. An exception may be when the hardness of the different rock types in the aggregate is very different. If so, a crushing process may enrich weak rock types in the finest fractions, and an examination of the small fractions can give a false result compared with the content of the different rock types in the coarse fractions.

3. If a crushed rock aggregate has uniform characteristics for determination of its reactivity, for example a silicified limestone, greywacke, or a coarse holocrystalline granite, then a thin section of the total aggregate particles can be produced to determine lithological characteristics. This procedure is named "Whole rock petro".

All of these procedures are useful in establishing the reactivity of an aggregate, and none should be discounted as a technique of determining reactivity. The technique selected should be based on an initial macro-examination of the aggregate sample received. In reference to the RILEM AAR-1 method it is not compulsory to have to use only one of these specified techniques.

For the "Point count technique" the following procedure is described: For the coarse fractions (> 4 mm) two thin sections of the fraction 2-4 mm (after crushing) should be prepared and analyzed. For the sand fractions (≤ 4 mm) two thin sections of the fraction 2-4 mm, one thin section of the 1-2 mm fraction and one thin section of the 0.063-1 mm fraction should be prepared and analyzed separately.

The point counting procedure is carried out by traverses in regular increments in two directions to form a virtual orthogonal grid. It is important that point-counting covers the whole thin-section. During the point-counting, the operator must identify and group all rocks and minerals (both the reactive and non-reactive ones) located under the cross hairs at each point on the grid. Suggestions for rock names are given in ANNEX 4 in the AAR-1-method /2/). Note that a minimum of 1000 points (excluding points falling on to resin) should be counted for all the counted fractions. Additionally the number of points may significantly exceed the number of particles, as several points may be counted across some larger particles.

During the point counting process there are two different "procedures" in use. In some countries it is common to determine the constituent and thus the reactivity assessment of the individual point which is directly under the crosshairs rather than a determination of the reactivity of the entire aggregate particle. An evaluation of the reactivity of the whole particle is, however, common to use in other countries, e. g in Norway. An example; all cross hair points placed within a sandstone particle is recorded as sandstone. However, when particles consist of more than one type of rock e.g. sandstone with quartz vein, the cross hair point falling on to the sandstone should be recorded as sandstone, and cross hair points falling on to quartz vein should be recorded as quartz vein material. To determine which procedure to be used, the experience with the aggregates within each country should be taken into account. The operator should report which procedure that was used, and report the reactivity of each rock type as class I, II and III, respectively.

Experience within some regions and with particular materials (i.e. highly metamorphic rocks) has shown that a determination of the quartz grain size within a particle is important in the assessment of the reactivity potential of that material. In such a rock (aggregate) the percentage of the material containing these varying sizes of quartz crystals are essential in the overall determination of the reactivity. However, at this stage the RILEM AAR-1 Petrographic method should primarily attempt to report the reactivity potential of such constituents based on the petrographer's own experience.

3 WORK PROGRAMME

3.1 Point counting analyses (WP 3)

The main goal of the testing programme in task 3.1 in PARTNER was to evaluate the suitability of the RILEM AAR-1 petrographic method to assess the alkali reactivity of the wide variety of aggregate and geological types found across Europe. As a basis for planning the testing programme for all the nine accelerated tests, included RILEM AAR-1, 22 different aggregate types from 10 different European countries were used. For 14 of these both the fine (F ; ≤ 4 mm) and the coarse (C ; > 4 mm) fraction were selected. Information about the field performance was given by the participants from the different countries.

During the petrographic analyses all the laboratories had information about the origin (country) of each aggregate. Most of the laboratories received bulk samples of the materials, and thus prepared their own thin section (if the thin section technique was applied).

In total 123 single petrographic analyses, either of a fine (F) or a coarse (C) aggregate type, were performed within the testing programme, i.e. most aggregates have been examined by more than one laboratory. Totally 13 laboratories performed the analyses, and 6 of them classified themselves as experienced. Most of the aggregates were tested according to the point counting technique (80 single tests in total), and only results from this type of analysis are present in this article.

3.2 Precision trials (WP 4)

8 laboratories were chosen to participate in the precision trial according to the RILEM AAR-1 petrographic method with the point counting technique. The criteria for participation were either experience with the method from routine commission work or, as a minimum, from the WP 3 testing. It is preferred to use at least 3 different types of material in a precision trial.

The samples selected for the AAR-1 precision trial were chosen to represent as big a variation as possible and to include as many different reactive components as possible, since the identification of reactive components and classification of them into different reactivity categories earlier had been identified as the main difficulty.

Three materials were chosen for the AAR-1 precision trials, two natural sands (from Sweden and Denmark, respectively) and one coarse aggregate (from Norway). The reason for the selection of these materials was that they are composed of various types of reactive rocks, and most of these are globally known as reactive. The petrographers did not know exactly the origin of the materials (except country), but the main rock types in each aggregate were given. The laboratories received fractioned aggregate samples (e. g. 2-4 mm), and prepared their own thin sections.

4 RESULTS

4.1 Point counting analysis (WP 3)

All results from the petrographic analyses are presented in a project report /3/, that may be downloaded for free. The report contains detailed information about all the aggregate types tested, included reactive rock- and mineral types and field performance. For the point counting analyses the rock names should be stated according to suggested rock names given in the AAR-1 method. For the "point count analysis" procedure also the thin section technique applied, i.e. either "whole particle analysis on what is under the cross hairs" or "actual constituent under the cross hairs", should be reported for all rock types detected.

As a basis for calculating the total percentage of "reactive/possible reactive" rock types in an aggregate, each of the rock types detected should be placed, based on the petrographers experience, in one of the three "reactivity classes";

I. very unlikely to be alkali-reactive
II. alkali-reactive uncertain
III. very likely to be alkali-reactive.

The petrographers should base their classification on the national experience in the countries supplying the actual aggregate types.

Results from examination of the fractions 2-4 mm, 1-2 mm and 0.063-1 mm should be reported separately.

SINTEF have collected the results from all the 123 single petrographic analyses. When receiving the results SINTEF performed a certain quality control of the data, i.e. evaluated if all the requested data were reported, in addition to make a preliminary evaluation whether the results seemed reasonable. To be able to handle all the results, all the data were manually put into an Excel worksheet.

Table 1 presents the results from all the point counting analyses performed by the 12 participating laboratories. The following results are presented for each of the aggregate samples:

- Origin (country)/name of sample
- Type of aggregate (i. e. main rock type(s))
- Fraction investigated (e.g. 4-8 mm)
- Sum of suspicious rock types, i. e. the "reactivity classes" II and III (volume percentage within the aggregate fraction) [on the web page /3/ the detailed results for each of the three "reactivity" classes are available]
- Field performance (i. e. damage due to ASR documented?)
- Results in agreement with field performance?

For fine aggregates (F; < 4 mm) results from point counting of each of the fractions 2-4 mm, 1-2 mm and 0.063-1 mm were (should be) reported separately. If other fractions were examined, results for these fractions are presented as well.

Some aggregates have been examined by up to eight different laboratories according to the same petrographic procedure.

4.2 Precision trials (WP 4)

All the detailed results from the precision trial according to the petrographic analysis are presented in /4/.

Table 2 shows the percentage of class II and III material from the participating laboratories. These results were the basis for the precision calculations. In the left column the "identification number" of the eight laboratories involved is given. In the upper row the identification of each aggregate sample is given. "S" is the sand from Sweden, and "2-4", "1-2" and "0.063-" are the fractions examined (mm). The sample marked "D" is the Danish sand, and "N" is the coarse gravel from Norway. The most experienced laboratories are shaded in the table.

5 DISCUSSION

5.1 Point counting analyses (WP 3)

Variation between laboratories with respect to evaluation of aggregate reactivity

13 laboratories, both experienced and inexperienced have performed petrographic analysis according to the AAR-1 method. Before the testing program started about one half of the petrographers had participated in one or two internal petrographic workshops in the PARTNER project, where selected European aggregate types were examined in microscope and "discussed". No other co-ordination was made between the laboratories.

In the further discussion focus is made on the variation between the laboratories with respect to the sum of rock types detected within the "reactivity classes" II+III (i.e. the suspicious rock types with respect to ASR).

The overall experience from the testing program is that the spread in results between the laboratories for about half of the aggregate types is very high, also between some of the six laboratories performing the test on a regular basis. For 8 of the 22 aggregates types (D1, D2, G1, G2, It1, It2, UK2 and P1) the number of rock types detected by the participating laboratories within the "reactivity classes" II+III varies from less than 15 % to more than 85 %. The rock names used also vary a lot.

However, for four of the six most experienced laboratories the majority of the reported results seem to be more reliable. The cases where also these laboratories from time to time deviate from the average/median results, are mainly connected to the aggregate types D1, D2, It1 and UK2. These aggregate types are not familiar for most of these experienced petrographers, thus the importance of local knowledge about the reactivity of different alkali reactive aggregates is obvious.

The majority of the results reported from the two remaining experienced petrographers deviates much from the average/median results. For one of these laboratories the sum of aggregate types classified in the "reactivity classes" II or III is in many cases somewhat lower than reported from the other laboratories. For the second of these laboratories the percentage of aggregate types classified within the "reactivity classes" II or III is in most cases much higher than for all the other laboratories (also the unexperienced ones).

Other rock types that are placed in different "reactivity classes" by different laboratories are:

- Sandstone; class I by several laboratories, class II or III by other laboratories
- Siltstone; class I by one laboratory, class II or III by other laboratories
- Flint; different types of flint (often named chert by several laboratories) detected/named by different laboratories; the classification of reactivity also varies a lot - all three "reactivity classes" are used

Link to field performance

In the last column in Table 1 information about the field performance of the 22 "PARTNER aggregates" are given. The abbreviation "R" means that the actual aggregate type is proved to be alkali reactive based on field performance. "NR" means that no damage due to ASR is observed in real structures. As mentioned in the past the information is supplied by the participants from the different countries in the PARTNER project.

The results from the petrographic analyses of almost all the 22 aggregate types correlate very well with the reported field performance. The French aggregate F3 and the Spanish aggregate E1 are two exceptions. Both the performed petrographic analyses and the brief petrographic description states that the F3 aggregate contains many reactive rock types. Despite of this, the French partners were not aware of any deteriorated real concrete structures containing this aggregates type.

The situation for the E1 aggregates is opposite. Only a small content of reactive constituents are detected in the petrographic analyses performed, but serious damage is reported on a 30 years old precast concrete element. This aggregate type has also been discussed as a special case on one of the internal petrographic workshops in PARTNER, and several of the participating petrographers questioned whether E1 could lead to ASR.

In almost all known cases of Norwegian ASR-damaged structures, the damages are mainly caused by the coarse aggregate fractions (> 8-10 mm). For several of the other European aggregate types included, there is a lack of information about which fractions that have proved to give ASR-problems in real concrete structures - thus the abbreviation "R?" is included in Table 1. This lack of information makes the evaluation of several of the fine aggregates uncertain.

Variation between aggregate fractions examined?

Overall the content of suspicious rock types ("reactivity class" II+III) detected within the different fractions examined (i.e. > 4 mm, 2-4 mm and 1-2 mm) for a given aggregate type does not vary much compared to the variations revealed between the different laboratories participating (see above). The fraction 0.063-1 mm is tested for most fine aggregates. In particular, point counting of this small fraction did not give any complementary information about the reactivity of any of the aggregate types included in the test programme. For many of the aggregates types, e.g. N3 and N4, free minerals were also to a large extent detected within this fraction. Taking into account the time consuming examination of this small fraction, for most (all?) fine aggregate types one should consider to count the fractions 1-2 and 2-4 mm only, as has been done in Norway for the last 15 years /5, 6/.

Is the RILEM AAR-1 petrographic method a good tool to assess the alkali reactivity of aggregates?

The reported results from the testing programme within task 3.1 in PARTNER have detected large inter-laboratory variations between the participating laboratories, and revealed the following main issues to be dealt with and solved if the RILEM AAR-1 method aims to be a widely used and reliable testing method to assess the alkali reactivity of aggregates both within Europe and world wide:

- The importance of education and round robin testing
- The importance of experience, both with the method and with the actual local aggregates
- The importance of calibrating the results with other RILEM methods and with field experience to be able to establish critical limits for acceptable content of suspicious rock types in different aggregate types (e.g. as we successfully have been able to establish in Norway /7, 8/)
- The importance of accuracy, quality control and system for approval of laboratories and petrographers.

The situation in Norway after more than 15 years of experience with use of the petrographic method, is that the method is regarded as a very reliable tool to assess the alkali reactivity of our Norwegian aggregates. Since the mid 90'ties the petrographic method has been the overall dominating method in use. The main reasons for this success is that we from the early 90'ties have focused on the above mentioned issues and implemented the results and experience into the "Norwegian approval system for handling the ASR problem" /9, 10/. Today, only three Norwegian laboratories are approved to perform petrographic analysis of concrete aggregates on a commercial basis.

Final remarks

Both the internal workshops and the testing within task 3.1 in the PARTNER project have shown that geological evaluations across the frontiers are difficult. Both the European petrographic atlas developed within the PARTNER project /11/ and any national petrographic atlases will hopefully give rise to reduce the spread in the future. For instance has such a national petrographic atlas been used successfully in Norway for almost a decade /12/.

The PARTNER project and in particular the internal workshops have established a very good network of contacts between several experienced and inexperienced petrographers that may be helpful in the future to an informal education and "flow of experience" across the frontiers.

5.2 Precision trial (WP 4)

The precision trial according to the RILEM AAR-1 (point counting procedure) showed a large spread between the different laboratories. Every laboratory identified the rocks and minerals similar, but the classification of the degree of alkali silica reactivity varied (i. e. class I, II or III). This is probably due to the regional experience and inexperience of the different reactive rocks. Only porous/opaline flint and mylonite/cataclasite have been classified as reactive by all laboratories. However, the spread between the four most experienced laboratories were rather low (see the shaded rows in Table 2).

6 CONCLUSIONS

This paper describes the results of an evaluation performed within the PARTNER programme of the use of the petrographic method, developed by RILEM as AAR-1, to assess the alkali reactivity of European aggregates.

In total 22 aggregate types across Europe were selected for testing by petrographic examination within WP 3 according to one or more of the three alternative procedures named "Whole rock petro", "Particle separation" and "Point count analysis", respectively.

SINTEF have collected the results from all the 123 single petrographic analyses performed, hence 80 point counting analyses.

The overall experience from the testing program is that the spread in results between the laboratories for about half of the aggregate types tested was very high, also between some of the six laboratories performing the test on a regular basis. However, for four of the most experienced laboratories the majority of the reported results seemed to be more reliable.

With two exceptions the average results from the petrographic analyses of the 22 aggregate types correlated very well with the reported field performance.

The PARTNER project and in particular the internal workshops in special have established a very good network of contacts between several experienced and inexperienced petrographers that may be helpful in the future to an informal education across the frontiers.

The results from the point counting in the precision trial (WP 4) also showed a large spread between the different laboratories, in particular in the classification of the alkali silica reactivity of the aggregates (i. e. class I, II or III). However, the results from the four most experienced laboratories harmonized better.

Overall, the results confirm the necessity of education and round robin testing. Petrographers need to get acquainted with the potentially reactive components in aggregates from different countries in order to use the most appropriate analytical techniques and to make a relevant assessment. Education, in combination with proficiency trials of individual laboratories, is therefore the way forward for future constructive development in this area. An improvement of the common understanding between petrographers really calls for extensive and repeated workshops.

7 REFERENCES

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TABLE 1: Summary results of all the point counting analyses performed by the 12 participating laboratories.

Country	Aggregate	Aggregate type	Fraction[1] (mm)	Statistics[2]	Point counting (%) TS 2-4 mm[5] Sum II+III	TS 2-4 mm[5] Comments	TS 1-2 mm[5] Sum II+III	TS 1-2 mm[5] Comments	TS 0.063-1 mm[5] Sum II+III	TS 0.063-1 mm[5] Comments	Field performance[6]	Results in agreement with field performance?
Belgium	B1(F)	Silicified limestone	0-2	"average"					97	1 result (TS 0.125-2 mm)	R?	YES
	B1(C)		4-20/ "coarse"	"average"	100	1 result (1 lab., 1 frac.)[4]			100	1 result (TS 0.063-2 mm)	R	YES
Denmark	D1 (F)	Gravel with opaline flint	0-4	average Median minimum maximum	36? 16? 6 85	7 results (7 lab., 1 frac.)	39 44 7 87	5 results (5 lab., 1 frac.)	48 35 28 81	3 results (3 lab., 1 frac.)	R (pessimum behavior)	YES
	D2 (F)	Sea gravel semi-dense flint	0-4	average median minimum maximum	38 28 2 100	5 results (5 lab., 1 frac.)	50 40 9 100	3 results (3 lab., 1 frac.)	53 -- 6 100	2 results (2 lab., 1 frac.)	R	YES
	D3 (F)	Non reactive silicious sand	0-2	average median minimum maximum			2 -- 0 3	2 results (2 lab., 1 frac.)			NR	YES
France	F1 (C)	Gravel with flint	6-20	"average" median minimum maximum	96 -- -- --	1 result (1 lab., 1 frac.)	96 -- -- --	1 result (1 lab., 1 frac.)	86 -- -- --	1 result (0-1 mm)	R (pessimum behavior)	YES
	F2(F)	Non reactive limestone	0-5	"average"	0	1 result (1 lab., 1 frac.)	0	1 result (1 lab., 1 frac.)	0	1 result (1 lab., 1 frac.)	NR	YES
	F3(F)	Silicious gravel	0-4	average median minimum maximum	53? 42 37 94	5 results (5 lab., 1 frac.)	54 35/70 30 82	4 results (4 lab., 1 frac.)	60 76 25 78	3 results (3 lab., 1 frac.)	NR?	NO
	F3(C)		4-20	"average" median minimum maximum	26? -- -- --	1 result (1 lab., 1 frac.) (TS > 4 mm)					NR?	NO
Germany	G1 (C)	Gravel with silicified limestone and chert	"4-22"	"average" median minimum maximum	46 -- -- --	1 result (1 lab., 1 frac.)	44 -- -- --	1 result (1 lab., 1 frac.)	33 -- -- --	1 result (1 lab., 1 frac.)	R	YES
	G2 (C)	Gravel with opaline sandstone and flint	"2-8"	average median minimum maximum	50? 43 14? 92	3 results (3 lab., 2 frac.)					R	YES
Italy	It1(F)	Gravel with limestone, chert and flint	0-5	average median minimum maximum	32? 10 8 100	4 results (4 lab., 1 frac.)	61 -- 21 100	2 results (2 lab., 1 frac.)	55 -- 10 100	2 results (2 lab., 1 frac.)	R	YES
	It1(C)		"5-30"	"average" median minimum maximum	10? -- -- --	1 result (1 lab., 1 frac.?)					R	YES
	It2(F)	Gravel with quartzite and gneiss	0-5	average median minimum maximum	51? 24?/81 14 100	5 results (5 lab., 1 frac.)	82 86 60 100	3 results (3 lab., 1 frac.)			R?	YES

Country	Agg-reg-ate	Aggregate type	Frac tion[1] (mm)	Statistics[2]	Point counting (%) TS 2-4 mm[5] Sum II+III	TS 2-4 mm[5] Comments	TS 1-2 mm[5] Sum II+III	TS 1-2 mm[5] Comments	TS 0.063-1 mm[5] Sum II+III	TS 0.063-1 mm[5] Comments	Field perfor-mance[6]	Results in agree-ment with field perfor-mance?
Norway	N1 (C)	Cataclasite	4-16	**average** median minimum maximum	**90?** 98 71? 100	3 results (3 lab., 1 frac.)					**R**	**YES**
Norway	N2 (C)	Sandstone	8-16	**"average"**	**100**	1 result (1 lab., 1 frac.)					**R**	**YES**
Norway	N3 (F)	Non-reactive granitic sand	0-4	**average** median minimum maximum	**2** 1 0 6	3 results (3 lab., 1 frac.)	**2** 1 0 6	3 results (3 lab., 1 frac.)	**2** -- 0 4	2 results (2 lab., 1 frac.)	**NR**	**YES**
Norway	N4 (F)	Gravel with sandstone and cataclastic rocks	0-7	**"average"** median minimum maximum	**27** -- 23 31	2 results (2 lab., 1 frac.)					**R?**	**YES**
Norway	N4 (C)	Gravel with sandstone and cataclastic rocks	7-16	**"average"** median minimum maximum	**25** -- 23 27	2 results (2 lab., 1 frac.)					**R**	**YES**
Norway	N5 (F)	Gravel with rhyolite and quartzite	0-8	**"average"**	**22**	1 result (1 lab., 1 frac.)	**17**	1 result (1 lab., 1 frac.)			**R?**	**YES**
Norway	N5 (C)	Gravel with rhyolite and quartzite	8-16	**"average"**	**22**	1 result (1 lab., 1 frac.)					**R**	**YES**
Norway	N6 (F)	Gravel/ sand with argillaceous rocks and sandstone	0-8	**"average"**	**37**	1 result (1 lab., 1 frac.)	**23**	1 result (1 lab., 1 frac.)			**R?**	**YES**
Norway	N6 (C)	Gravel/ sand with argillaceous rocks and sandstone	8-16	**"average"**	**33**	1 result (1 lab., 1 frac.)					**R**	**YES**
Sweden	S1(F)	Gravel with porphyritic rhyolite	0-8	**average** median minimum maximum	**52?** 44 35? 100	5 results (5 lab., 1 frac.)	**61** 45 37 100	3 results (3 lab., 1 frac.)			**R?**	**YES**
Sweden	S1(C)		4-16	**"average"** median minimum maximum	**43?** -- -- --	1 result (1 lab., 1 frac.) (TS > 4 mm)					**R?**	**YES?**
United Kingdom	UK1 (F)	Greywacke	0-5	**"average"**	**83**	1 result (1 lab., 1 frac.)	**66**	1 result (1 lab., 1 frac.)	**40**	1 result (1 lab., 1 frac.)	**R?**	**YES**
United Kingdom	UK2 (F)	Gravel with quartzite and chert	0-5	**average** median minimum maximum	**52** 54 15 89	5 results (5 lab., 1 frac.)	**27** 9 7 66	3 results (3 lab., 1 frac.)			**R**	**YES**
United Kingdom	UK2 (C)	Gravel with quartzite and chert	5-20	**average** median minimum maximum	**54** 48 15 98	3 results (3 lab., 1 frac.)					**R**	**YES**
Portugal	P1 (C)	Silicified limestone	4-19	**"average"**	**100**	1 result (1 lab., 1 frac.)					**R**	**YES**
Spain	E1 (F)	Silicified and clayed dolostone	0-4	**average** median minimum maximum	**3?** -- 0 8	3 results (3 lab., 1 frac.)	**3?** -- 0? 5	2 results (2 lab., 1 frac.)			**R?**	**NO**

1 The fraction investigated in the petrographic analyses
2 The **average** represents the mean results of all the investigated fractions at all laboratories. **"Average"** means less than three results available.
3 The numbers represent the sum of the "reactivity classes" II and III, i.e. the sum of all the rock suspicious.
4 Lab. = laboratories; frac. = fractions
5 TS = thin sections
6 R = proved to alkali reactive based on field performance ; NR = not observed damage due to ASR in real structures
(green) = something is not clear or uncertain
(orange) = OK results (i.e. checked and found reasonable)

TABLE 2: Results from the AAR-1 Precision trials. Percentage of recorded AAR class II and III from the participating laboratories.

Laboratory	S 2-4	S 1-2	S 0.063-1	D 2-4	D 1-2	D 0.063-1	N 2-4
Lab 2	99	94	71	80	66	86	30
Lab 3	12	16	7	38	29	16	13
Lab 4	44	34	18	52	33	4	25
Lab 5	53	39	29	43	26	4	20
Lab 8	99	99	88	76	74	65	100
Lab 9	57	54	26	52	32	3	25
Lab 15	30	26	14	16	11	2	21
Lab 22	42	38	27	48	32	9	32
Standard dev	30.8	30.7	28.8	20.5	21.2	32.8	27.6
Mean	55	50	35	51	38	24	33
Variance	57	61	82	40	56	139	83

Class II – alkali-reactivity uncertain

Class III – very likely to be alkali-reactive