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ASPECTS OF THE DIAGNOSIS OF ALKALI–SILICA REACTION

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1. INTRODUCTION

In 1976, mainland UK became generally aware that it had an ASR problem. The early cases have been described in papers to previous conferences and elsewhere [1] [2] [3].

Since then the UK has produced important recommendations for minimising the risk of damage from ASR [4], for diagnosing ASR [5], and for appraising existing structures [6].

This paper can only deal with general aspects of diagnosis, more detail is given in the report mentioned above [5].

2. THE NEED FOR RECOMMENDATIONS ON DIAGNOSIS

With an increase in the suspected cases of ASR in any country, more organisations will offer diagnostic services. This inevitably leads to varying views on diagnostic techniques and on the analysis of observations and test results.

The UK report was written to encourage a greater degree of uniformity and reliability in diagnosis. Some of the report relates only to the UK, but the general recommendations should be applicable anywhere.

Why do we need accurate diagnosis?

Most investigations are undertaken because of visible cracking or other damage to the concrete. If there is a positive diagnosis of ASR, the next questions will be 'What do we do about it, should we repair, and if so how?' Remedial works will differ, depending on whether the distress is caused by ASR, structural overstress, frost, sulphate attack, or one of many other causes. Accurate diagnoses are essential if inappropriate remedial actions, leading to possible waste of both time and money, are to be avoided.

There is, however, another important reason for requiring accurate diagnoses. Much money and effort is spent in reducing the risk of damage from ASR in new structures. The success of these measures depends on a reliable understanding of which materials and environmental conditions encourage damage from ASR. This understanding will only be acquired if we can rely on the diagnoses of the causes of damage.

3. THE PROCESS OF DIAGNOSIS

An investigation of a damaged structure should always be approached with an open mind. The first question should always be, 'What has caused the damage?' It should never be, 'Is this a case of ASR?' Only by this means will the true cause of the problem be determined.

Site inspection, examination of documentary evidence and consideration of the environmental and other history of the structure, will normally only serve to reduce the number of possible causes of the damage. The resulting list of possible causes might include ASR, and in some cases it might be possible to conclude that ASR is the most likely cause of damage. But a positive diagnosis of ASR cannot be made from a site inspection alone. It is essential to take samples of the concrete for examination in the laboratory.

These laboratory tests can only provide positive information about the samples of concrete in the laboratory. Reliable conclusions about the concrete in the structure can only be drawn if sampling is carefully planned to ensure that the samples are sufficiently representative of the concrete in the structure.

When investigating a concrete structure which shows signs of distress, and where ASR is suspected, two questions should be asked:

1) Has ASR occurred in the concrete?

The occurrence of ASR is identified by the presence of alkali-silica gel. Only if gel is positively identified can it be concluded that ASR has occurred in the concrete; without this observation no such conclusion can be reached. It is normally accepted that the best means of positively identifying gel is by the petrographic examinations of thin sections.

2) If alkali-silica gel is present, has ASR caused the damage?

Damage does not automatically follow when ASR occurs. The observation of gel, by itself, is not sufficiently diagnostic of damage from ASR. Alkali-silica gel can occur in many concretes without causing damage. It may be present only in very small amounts, or in voids or cracks caused by other phenomena. It follows that gel sometimes may be seen when the cause of damage is some phenomenon other than ASR, such as frost or sulphate attack, shrinkage, or thermal movements.

All too often, it is feared, the mere observation of gel, in thin sections or elsewhere, leads to the automatic conclusion that ASR has caused the damage. This should not be accepted. Much more investigation is needed before this conclusion may be reached with any certainty. It is only by observing 'sites of expansive reaction', where the formation and swelling of gel has obviously caused expansion, that we can begin to be confident that ASR has been the cause of damage.

The thin section work may be supported by a number of other tests and investigative techniques, each more or less useful in diagnosis. Many laboratory tests and techniques are available. These include examination of broken surfaces for evidence of reaction products in cracks and voids, or reaction rings on aggregates; examination of polished surfaces; observation of microcracking under ultra-violet light after impregnation by fluorescent dyes; and chemical analyses. Some of these are given in Table 1, which also gives an indication of their applicability.

Table 1: Laboratory tests used during investigation of ASR (From [5] with modification)

Laboratory test	Purpose	
	Diagnosis	Forecast of future expansion
Preliminary laboratory examination	***	***
Examination of sawn sections	**	
Examination of thin sections	***	*
Determination of alkali content	**	**
Determination of concrete mix proportions	*	**
Determination of alkali content	**	**
Expansion testing	**	**
Measurement of tensile/ compressive strength ratio	*	*
Alkali immersion test	*	

*** essential; ** do when possible; * may be helpful.

It probably is never possible to be completely certain that ASR is the cause of damage. In many cases, if not all, there will be an element of judgement by the investigator, who will reach a conclusion only after considering all the information available from an inspection of the site and the construction records, consideration of environmental factors and the results of laboratory investigations.

No positive rules can be laid down, but some guidance is given in Table 2. Here the observation, or otherwise, of 'reliably diagnostic' and 'indicative' features in the laboratory findings, are combined with a simple classification of site observations to produce a suggested assessment of the probability of ASR.

Table 2: Assessment of site observations and laboratory findings (From [5] with modifications)

Site observations	Laboratory findings		
Probability	Presence of reliably diagnostic features	Presence of possibly indicative features	Suggested ASR assessment
High	Yes	Yes	ASR probably main cause of damage.
High	None	Yes	ASR may be a minor cause of damage.
High	None	None	ASR has not occurred. Damage caused by other factors.
Low	Yes	Yes	ASR confirmed but may be non-expansive or a minor cause of damage
Low	None	Yes	ASR unlikely to have occurred but may be minor cause of damage
Low	None	None	ASR has not occurred.

4. FUTURE EXPANSION

A number of tests and investigations may assist in forecasting future expansion in the concrete. Some are included in Table 1, but the most directly indicative technique is the expansion test on cores cut from the concrete.

Cores for the expansion test are stored at a relative humidity of 100% (or as near to this as available methods permit). This is not easy to achieve, but a method of storage is given in Reference 5. Whatever the method of storage, the moisture uptake of the specimens during storage should be monitored by weighing them every time they are removed to measure their expansion. If the weight gain does not keep pace with the expansion, then there must be doubt about the efficiency of the storage regime in maintaining a relative humidity of 100%.

Most testing has been done at 38°C. This is the temperature used in the ASTM C227 test [7] for mortar bars and is the temperature about which most is known and for which most laboratories are equipped. A lower temperature of, say, 20°C might be better for simulating conditions in practice, but more information is needed on results obtained at lower temperatures.

Little is known about the reproducibility and repeatability of the expansion test. Whilst preparing its report, the BCA Working Party conducted inter-laboratory trials using the specification given in the published report, but these produced coefficents of reproducibility and repeatability too large for the test method to be positively recommended.

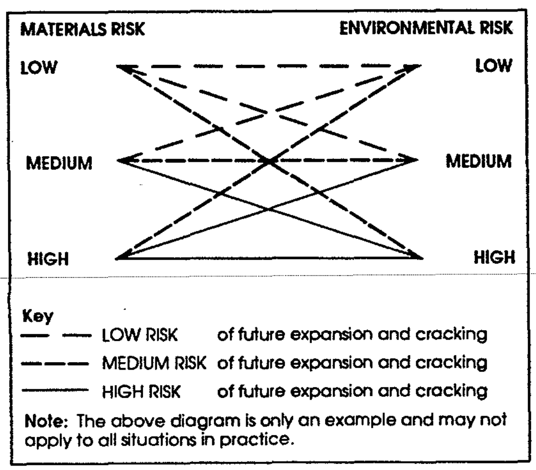
Further trials are being conducted using a tighter specification for the storage conditions, and with a mix having a more amenable expansion. It is hoped then to publish the results and produce a test of acceptable precision.

Although the expansion test is, perhaps, the most reliable single indicator of the potential for future unrestrained expansion, other information, such as the nature of the aggregates and the mix proportions, will help to produce a classification of the risk of future expansion arising from the materials in the concrete.

This may then be combined with the risk presented by the environment to which the structure is exposed, as shown in Figure 1, to produce a simple assessment of the risk of future expansion and cracking.

It should be remembered that the concrete in the core is unrestrained whilst being tested. Conditions in the structure are likely to be significantly different. There the concrete probably will be under stress and restrained by reinforcement and other parts of the structure. Restraint forces can make a significant difference to the expansion caused by ASR and this must be taken into account when interpreting the results of any expansion test to forecast possible expansion in the structure. Much more information on the longer term behaviour of structures suffering from ASR will be needed before the simple assessment in Figure 1 can be refined further.

Figure 1: Assessment of risk of future expansion and cracking [5]



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