ALKALI-AGGREGATE REACTION IN THE WESTERN CAPE REGION OF SOUTH AFRICA - A REVIEW

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This paper reviews the current situation in the Western Cape Province of South Africa where damage to structures from alkali-silica reaction has been cause for concern for a number of years. Developments in specifications, the use of mineral admixtures and in cement composition are described. The results of tests carried out on numerous aggregates from the area are presented.

INTRODUCTION

The fifth International Conference on Alkali-Aggregate-Reaction in concrete was held in Cape Town in 1981.
In view of the closure in 1991 of the M1 motorway in Johannesburg for repairs and the subsequent Press articles on "Concrete Cancer" it is perhaps timely to review the situation 11 years on. In this period a number of new "cases" have come to light, a survey of major bridges in the Cape Town Municipal area has been carried out and a comprehensive aggregate testing programme has been carried out by the Portland Cement Institute on behalf of the Cape Provincial Administration, Materials Testing Division.

HISTORY OF AAR IN THE WESTERN CAPE

The first known structure to suffer alkali aggregate reaction damage was the raised section of Steenbras dam, one of Cape Town's main water storage facilities, constructed in 1960, although at the time the damage was not attributed to the effects of AAR. In the early 1970's a number of reports were received of similar cracking but it was not until 1976 that an expansive alkali-aggregate reaction of some kind was positively identified (1).
The "classic cases" which appeared at the time included the Pirow Street road-over-rail bridge, the N2 freeway from the airport to Somerset West and a number of bridges crossing the N1 freeway to Paarl.
Of these cases the only serviceability failure to date has been the N2 freeway which had to be patched at the transverse joints and overlaid after some 14 years service.
Since 1981 numerous other affected structure have been identified in the Western Cape.

A contract survey of concrete structures in the Cape Town area was carried out by the NBRI in 1977 and reported at the fifth International Conference in 1981. (2)

It identified numerous cases of ASR, but many of the structures listed as uncracked and built between 1969 and 1976 have since cracked. Typical examples are some of the road bridges over the Blue Route and some bridges over Kromboom Parkway, both major urban freeways.

A further survey, carried out by the Roads Branch of the City Engineers Dept between December 1985 and Feb.1986 identified 34 cases of ASR in bridges in the Municipal area alone. This survey was by no means exhaustive and many structures were not examined (3). Lack of resources has prevented any follow-up surveys since.

Other cases that have been noticed personally are:

Muldersvlei Sub Station bases.

Civic Centre (parts only).

Good Hope Centre (anchor blocks & main arches).

Foreshore Freeways (particularly balustrades).

Receiver of Revenue Building (one corner).

One wing wall of incrementally launched bridge over the N1.

Steenbras Pumped Storage Scheme Turbine House.

Voëlvlei Water Pipeline.

Two cases may even predate Steenbras Dam:

Columns in an air-conditioning water tank in an old building in the centre of Cape Town showed suspicious cracks when inspected during a refurbishment contract. Examination of cores showed all the classic signs of AAR.

In March this year a very interesting case was identified at B - Berth in the Cape Town docks. This structure was erected in 1959 and is affected by ASR in the pile caps and columns below floor level. There are no indications of ASR above floor level.

This structure was built in 1959 and is relatively well documented.

DEVELOPMENTS IN CEMENTITIOUS BINDERS SINCE 1981

Once the problem had been recognised the local cement company considered producing a low-alkali cement, and a guaranteed low-alkali cement became available in January 1984.
Sulphate Resisting Cement, which happened to be a low alkali cement, had been available prior to this date but at a fairly high cost premium.
The low alkali cement was priced between OPC and SRC and the Na_2O equivalent content never exceeded 0,4 %. This cement was taken off the market in December 1990 and replaced by a Low Alkali Sulphate Resisting Cement (LASRC) in order to rationalise production at the two local factories.

From 1982 to date the equivalent Na_2O content of both available OPC's was kept at or below 0,6%.

Fly Ash and GGBS were and are available in the Western Cape but because of transport costs offer no economic advantage.

Condensed Silica Fume became commercially available in the late 1980's, but again is relatively expensive in the Western Cape.

DEVELOPMENTS IN AGGREGATE KNOWLEDGE

Since 1981 most, if not all, crushed aggregate available in the Western and Southern Cape have been examined petrographically and tested for potential reactivity using the accelerated test method reported by Davies and Oberholster.(4)

Most of these tests were carried out at the Portland Cement Institute's Head Office laboratory.

Briefly the results can be summarized as follows:

Aggregate Type	Number of Sources (West Cape only)	Recommended Na_2O equivalent.(Max) (kg/m^3)
Greywacke	6	2.1
Dolomitic- greywacke	2	2.1
Granite		
Granite	3	No limit
Quartzite	1	2.8
Quartzite	1	2.1
Limestone	1	2.4
Quartzitic-	1	No limit
sandstone	5	2.8
Meta volcanic tuff		
	1	2.1

In other words, except for three sources of granite and one of limestone, all crushed stone aggregate in the Western Cape should be regarded with suspicion if the exposure conditions warrant it.

DEVELOPMENTS IN SPECIFICATIONS AND MIX DESIGN

In the South African context the following Specifications and Codes are relevant:

1. SABS 0100: The Structural Use of Concrete (currently under revision)

2. SABS 1200: Standardized Specification for Civil Engineering Construction, Part G: Concrete (Structural)
3. SABS 0120: Code of practice for use with standardized specification for Civil Engineering construction and Contract Documents.

4. SABS 1083: Aggregates from natural sources (Currently under revision)

Other codes in common use are:

5. BS 8007: Design of Concrete structures for retaining aqueous liquids.

6. BS 5400: Part 4: Code of practice for design of concrete bridges.

7. BS 8110: Structural use of concrete.

Less commonly used are:

8. BS 882: Aggregates from natural sources for concrete.

9. BS 5328 Part 1:Guide to specifying concrete

There are three references to AAR in the British Standards:

BS 882 Appendix B

BS 8110 Part 1: Clause 6.2.5.4

BS 5382 Part 1: Clause 4.2.4

Broadly speaking the recommendations made in these documents are as follows:

(i) measures to reduce the degree of saturation of the concrete;

(ii) the use of LAPC (Na_2O eq. < 0,6 %); or

(iii)limit the Na_2O equivalent content to a maximum of 3 kg/m^3.

(iv) use a blended cement containing at least 50% GGBS or 30 % Fly Ash (BS 8110)

Reference is also made to BRE digests 258 and 330 and Concrete Society Technical Report 30.

The South African Code, SABS 0100: Part II makes similar recommendations with different limits:

Na_2O max. 2.1kg/m^3
GGBS substitution min. 40%
Fly Ash substitution min. 20%

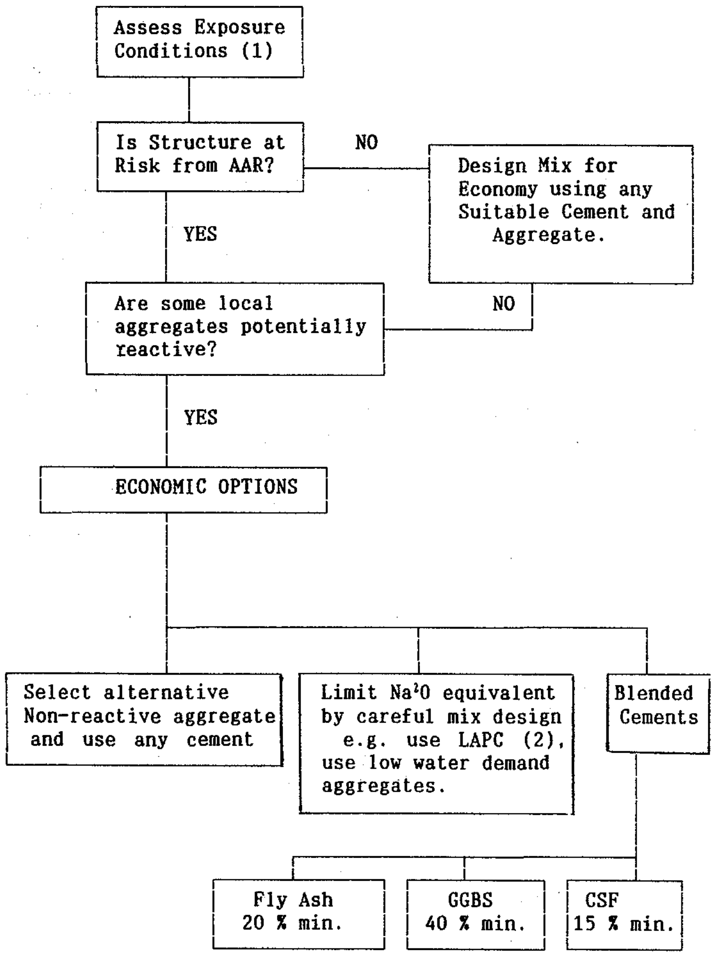
It also recommends the use of "any low-alkali portland cement" as an alternative.

SABS 1200 G refers the designer back to SABS 1083 which in its unrevised form contains a substantial section on AAR (Appendix C-15), but no guidance on preventive measures..

SABS 0120: Part 2 Section G gives special Project Specification clauses to cover AAR, but having been approved in 1982 the recommendations are now obsolete in terms of current knowledge.

It is the author's opinion that the Specification requirements outlined above are unnecessarily difficult to interpret.

The Portland Cement Institutes'current recommendations are shown in the following chart



(1) It must be borne in mind that simultaneous aggressive conditions may exist, e.g. sulphates in the ground water.

(2) The use of LAPC alone does not preclude the possible occurence of AAR if the cement content is high enough.

Because of the publicity given to AAR in the Western Cape, and elsewhere in South Africa, most if not all current project specifications contain provisions similar to those given in the flow chart above.

CONCLUSION

In the light of current knowledge there is no reason why any structure erected in South Africa in future should suffer from AAR deterioration. The problem is openly recognized by the cement producers, by the aggregate producers, by specifiers, clients and contractors.

One example of this open recognition is a publication by a major aggregate producer which lists 21 of their quarries country wide and, where relevant, indicates the relevant maximum Na_2O equivalent (5). This openness in communicating about the problem has had a major influence in arriving at suitable preventative measures.

On the repair side, however, there is no universal panacea. Each case must be considered on its own merits.

Serviceability failures have so far been rare. In the vast majority of cases the structures have functioned satisfactorily even though the cracking is extremely unsightly in many cases. The reason for this could very well be that exposure conditions in most of the Western Cape are relatively mild - frost and snow occur only in high lying areas remote from densely populated areas and there has therefore never been a need for the use of de-icing salts and damage to concrete due to freezing and thawing is unknown in the region.

REFERENCES

(1) Oberholster, R.E. - Alkali-Aggregate-Reaction in South Africa - A Review. Proc. 5th Int Conf on AAR.

(2) Semmelink, C.J.- Field Survey of the Extent of Cracking and Other Details of Concrete Structures Showing Deterioration Due to Alkali-Aggregate Reaction in the South Western Cape Province. Proc. 5th Int Conf on AAR.

(3) Private communication .

(4) Davies, G. and Oberholster, R.E. - An Inter-Laboratory Test Programme on the NBRI Accelerated Test to Determine the Alkali Reactivity of Aggregates.- BOU 92,1987, NBRI.

(5) Alkali-Aggregate-Reaction. Choosing the right aggregate and cement for concrete, 2nd Ed, Hippo Quarries, Sandton, 1991.