National Council for Cement and Building Materials

ALKALI-AGGREGATE REACTIONS IN CONCRETE : CAUSES, DIAGNOSIS AND PREVENTION

PART II

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NCB TECHNOLOGY DIGEST

ALKALI-AGGREGATE REACTION IN CONCRETE : CAUSES, DIAGNOSIS AND PREVENTION*

PART II

INTRODUCTION

THIS Technology Digest (Part II) covers the possible approaches to prevent alkali aggregate reaction with particular reference to the Indian sub-continent. Part I of the Technology Digest issued earlier describes the types of reactive rocks in concrete aggregates which are believed to be responsible for alkali aggregate reaction, and the diagnostic methods available.

PREVENTION

The different approaches to avoid the problem of deleterious alkali-silica reaction (ASR) in concrete are:

* Use of Non-reactive Aggregates from Alternate Sources
* Use of Low-Alkali Cement
* Reduction in Unit Cement Content in Concrete
* Use of Pozzolana, Slags and other Substitutes for Part Replacement of Cement
* Use of ASR-Inhibiting Salts
* Controls on Service Conditions.

Whenever the aggregates proposed to be used for a concrete construction are detected to be reactive, the first possibility is to avoid their use. If, however, aggregates from even alternate sources within economical distances also exhibit potential reactivity, then the solution may be alternate siting of the project itself.

Since siting of projects like dams are based on many other related considerations, changing the site is quite often not possible. Under such circumstances it is customary to use a cement with 'low' alkali-

*Reprint

content, the limit being 0·6% soda—equivalent (calculated as percentages of $Na_2O + 0{\cdot}658\ K_2O$ in the cement). This has been practised widely in USA and elsewhere where reactive aggregates are known to occur, eg, New Zealand, Canada, Iceland, Denmark and Turkey. Notwithstanding some examples to the contrary, this practice has in general, given satisfactory results.

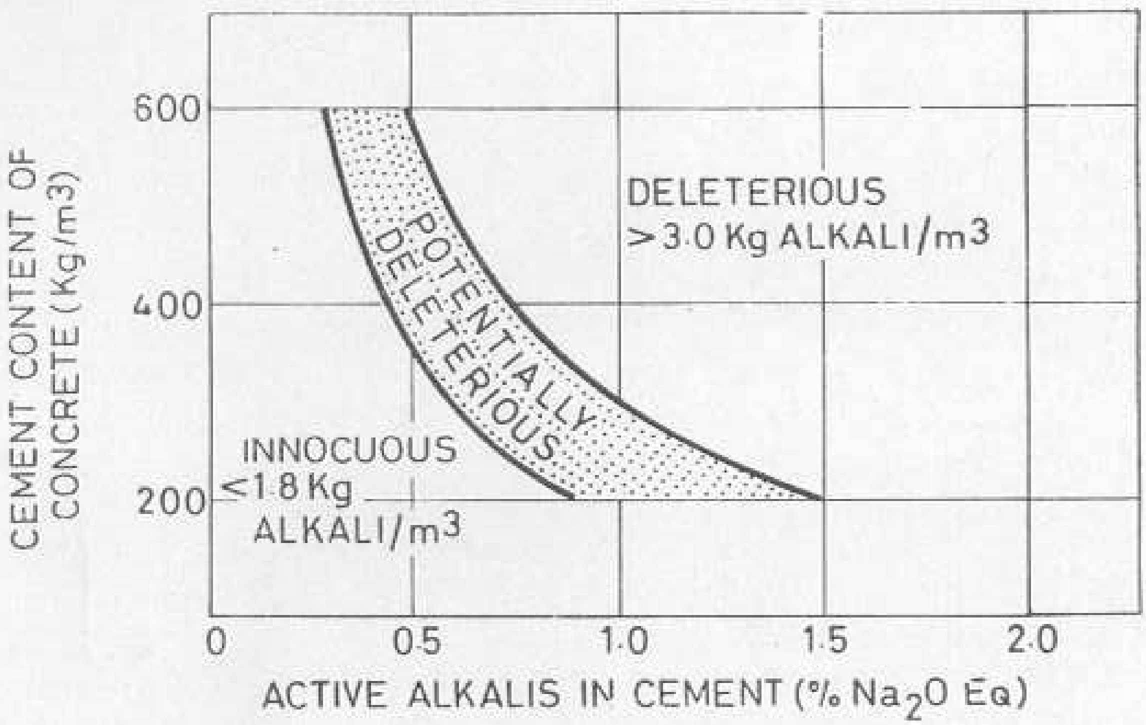

Fig 1 Schematic relationship between alkali content of cement and total cement content in concrete to prevent ASR

Since it is the availability of total alkalies in the pore solutions of concrete in relation to the amount of deleterious constituents in the aggregates that control the extent of ASR, a recent approach has been to limit the total alkali-content in the concrete than in the cement *per se*. Accordingly, tolerable limits of alkalies per cubic metre of concrete have been suggested. It is held that total alkalies less than 1·8 kg/cubic metre of concrete would render it innocuous, whereas total alkalies exceeding 3·0 kg/cubic metre would render it potentially deleterious (Fig 1). It implies that even when only a high-alkali cement is available, it should be possible to use it with reactive aggregates, provided the total cement content in the concrete is kept low, so as not to exceed the threshold value of total alkalies in the concrete. It must be admitted that there are yet no concrete structures with reactive aggregates built on this concept, whose long-term performance can be checked. At the same time, the cement content in mass concrete constructions like dams is kept low by use of larger size aggregates etc, and any further reduction in cement content would be possible only with use of water-reducing admixtures or superplasticisers, without sacrificing other requirements of strength and serviceability.

The use of low-alkali cement as a counter-measure to reactive agregates was widely practised in the earlier decades, when such cements were produced and marketed, may be at some premium price. There are instances where some countries have imported such low-alkali cement in order to mitigate ASR in concrete constructions with reactive aggregates. With the modern practice of cement manufacture with preheater systems and where exhaust gases and dusts from the kilns are needed to be recycled, as dictated by the needs of the energy conservation and environmental control, it is quite likely that the total alkali content in the cement would be higher. In addition, it is reported that out of the total alkali content in cements, the proportion of water-soluble alkalies are generally higher (around 80%) in present day preheater plants and where volatiles are required to be recirculated than what was prevalent two or three decades ago (around 50%). This situation has focussed attention on another approach to tackle ASR problem, ie, use of pozzolans, slags and other industrial wastes as part replacement of cement. By such substitution the desirable result is achieved through means of:

a) reducing cement content in concrete mix and thereby the total alkali content;

b) consuming the alkalies of the cement in cementitious reaction with the pozzolana or slags before these can react with the aggregates;

c) reduction in $Ca(OH)_2$ in the hydrated cement system; and

d) general reduction in the porosity and permeability of concrete, thereby reducing the chances of ingress of moisture.

Ever since the detection of deleterious ASR in concrete, investigations on use of flyash and natural pozzolans have gone side by side and a large volume of research data have become available in the last four decades. Attention has recently been focussed on use of more reactive pozzolans like silica fume (by-product from the silicon and ferro-silicon alloys industries) and rice-husk ash. Notwithstanding such research efforts, there are only a few instances, in which such an admixture has been used in concrete containing known reactive aggregates and known high alkali cement, whereby a pozzolan has been solely relied upon to prevent the expected excessive expansion. This is partly due to the fact that till in the recent past, low alkali cements were available wherever required, In order that a pozzolan can prove effective in preventing the ASR, tests prescribed in ASTM C 441 have to be carried out.

There are a number of dams in USA where pozzolana has been used mainly to control the heat of hydration. However, in each of these cases, the cement used was again of low alkali content. As is expected, none of the structures have shown distress due to ASR.

A few considerations relating to use of cement substitutes to prevent ASR merit discussion. The first is that the level of cement substitution has to be relatively high, eg, around 25 to 30 % when flyash or calcined clay pozzolans are used and greater when slag (around 60 %) is used. In the context of manufacture of blended cements with prefixed quantity of pozzolans or slags interground in the cement, the flexibility to add larger dose of cement substitute becomes restricted. In India, the common pozzolana added in making pozzolana portland cement is generally not evaluated from the point of its potential for reducing ASR, as prescribed in ASTM C 441.

The second is the influence of alkalies contributed by the pozzolans or slags themselves in promoting ASR—a phenomenon which is not yet fully understood. Therefore, use of pozzolans, slags or other cement substitues in concrete where reactive aggregates are encountered, has to be approached in a very rational manner, taking into account the various technical parameters that may be involved, on a case-to-case basis.

There are research findings that certain barium and lithium salts @ 1% by weight of cement can prevent ASR. However, these have not yet been put to actual practice.

The other approach that has been thought of is to bring about changes in the operational conditions of the concrete structures, eg, to subject it to high compressive stresses to counteract tensile stresses or to prevent the ingress of moisture inside the concrete which causes swelling of the alkali-silica gel. In actual field-practice it is not easy to restrict the service conditions in such manners.

On the other hand, there are many differences between the actual service conditions of a structure and the laboratory conditions. It is, therefore, vitally necessary that practical solutions in a particular situation should take all contributory causes into account, make a proper and judicious evaluation of the concrete materials and service conditions, so as to arrive at the optimum preventive measures.

NCB EXPERTISE

NCB equipped as it is with all the available diagnostic facilities for simultaneously adopting these in structural investigations, and with its multi-disciplinary team of experts is in a unique position to take up such investigations including for other countries and suggest preventive measures.

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