1981 ALKALI - AGGREGATE REACTION
ALKALI - AGGREGAATREAKSIE

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KEYNOTE ADDRESS

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Conference on alkali-aggregate reaction in concrete
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Konferensie oor alkali-aggregaatreaksie in beton
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1. INTRODUCTION

Since 1974, a series of international conferences have been held in Denmark, Iceland, England and the United States in an attempt to obtain a clearer understanding of the mechanism of the various forms of alkali-aggregate reaction. Although this conference is, strictly speaking, not one of the international series, it may be regarded as such since we are fortunate indeed to have 26 papers and 22 speakers from countries outside South Africa to add their knowledge and experience to our exchange of ideas on the problem. I would like to think that, apart from providing an opportunity for exchanging research findings, this conference will serve as a source of information for those who are responsible for specifying and building concrete structures – be they consulting engineers, architects, construction people, or those in Government Departments or local authorities.

For the benefit of overseas visitors I must explain at the outset that our major problem area is the Western Cape region in which the sources of coarse aggregate for concrete are predominantly vast deposits of a rock type which is largely indurated greywacke, siltstone and shale deriving from the Malmesbury Supergroup, and about which you will hear a great deal more in the next few days. Much of this rock is known to be reactive in combination with a high alkali concentration in the concrete.

Unfortunately, the very area in which our reactive rock type predominates also happens to be the part of South Africa where the raw materials that are exploited for cement manufacture tend to be relatively high in alkalis (see Figure 1). On the other hand, in the northern areas of South Africa where most of the rock types are innocuous as far as alkali-aggregate reaction is concerned, we find that in general few or no precautions are required to maintain alkali contents of cement at acceptable levels.

A little over 10 years ago when we first became aware that we had a problem which showed the signs and symptoms of expansion due to alkali-aggregate reaction, we took the obvious steps and examined the pioneering work that had been done in the United States during the 1930s and 1940s. But of course that noteworthy research achievement had been related to the classic alkali-silica reaction in which the amorphous or cryptocrystalline silica-bearing rock types bore little resemblance to our Malmesbury rocks. It was only later when the significance of another and distinctly different form of reaction became apparent that we realised what we were up against. We look forward to showing you during our inspection tour of concrete structures and paving on Tuesday, the symptoms of a reaction which, in our opinion, is similar to that occurring in Nova Scotia.

During the course of the next few days you will hear of the work being done by the National Building Research Institute (NBRI) and I think you will be impressed by the research progress made by this organisation which is carrying out its investigation under the guidance of a

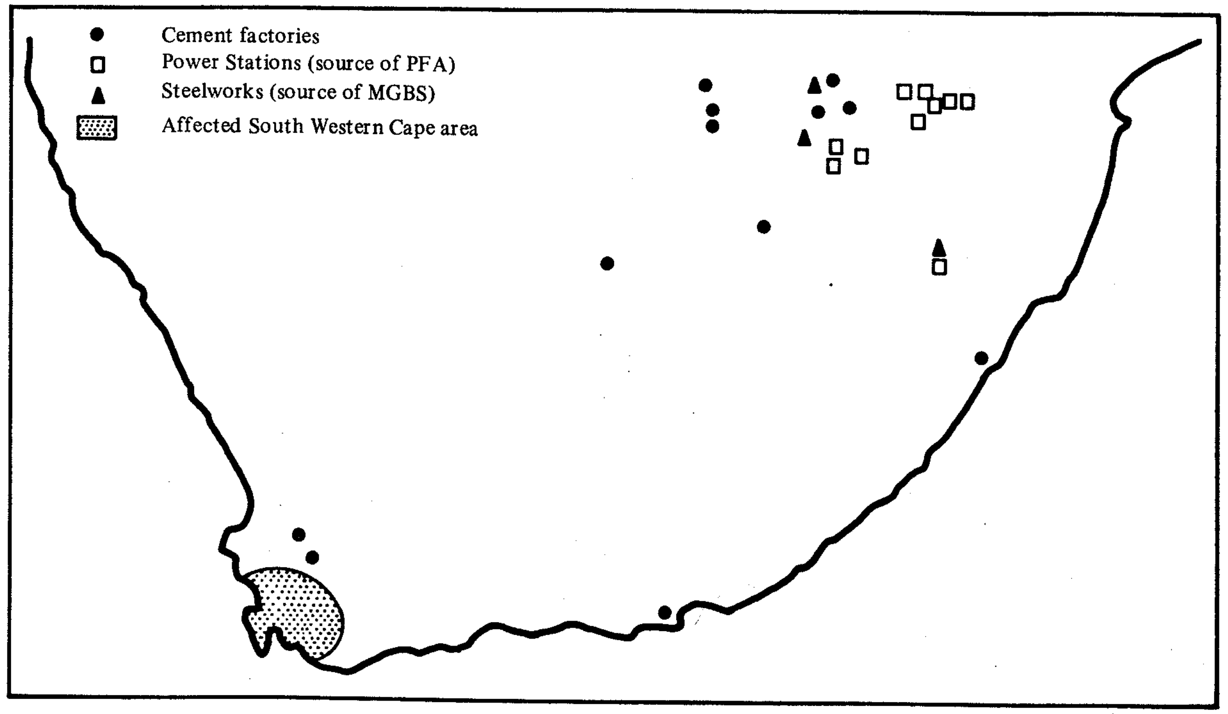

FIGURE 1: Location of the affected South Western Cape area, cement factories, sources of pulverised fuel ash (PFA) and milled granulated blastfurnace slag (MGBS)

Technical Steering Committee consisting of representatives from NBRI, the Portland Cement Institute (PCI), the cement industry, the producers of aggregates and certain public bodies.

With these brief remarks as background to the problem in South Africa, I would like now to touch on four factors which I believe to be of special importance in the approach we take towards solving, or at least alleviating, our problems.

We need

- a clearer understanding of the actual mechanism of the reaction;
- to establish a rapid, practical method of testing aggregate for reactivity;
- to make optimum use of admixtures that could possibly control the reaction and,
- to keep in mind that our approach to the problem must be practical.

2. MECHANISM OF THE REACTION

For the past three years the research team has been studying the various factors which influence the reaction. Although this research, together with valuable contributions obtained from overseas investigations, has yielded a wealth of fundamental knowledge and a great deal of useful information on the chemistry, physics and mineralogy of the reaction, the precise mechanism of the reaction is still obscure and an immense amount of research remains to be done before we can claim to have a clear understanding of the reaction.

Despite our assertion, for instance, that a major requirement for the reaction is that both reactive aggregates and high alkali content be present in the mix, many of us are aware of cases in which reactive aggregates used with high alkali cements have given rise to unexpectedly low expansion in the concrete – even when all other conditions have favoured the reaction. Similarly, we know of other anomalous instances where inexplicably large expansions have occurred for no apparent reason.

I firmly believe that there is an elusive factor involved in the reaction mechanism that has totally escaped us thusfar. Until we discover the key to this elusive detail, we shall continue to find ourselves baffled from time to time by unexplained expansion problems. Clearly, we need to delve deeper to identify the well hidden factor or factors involved before we will be able to predict more accurately the likely behaviour of concrete made with various materials.

3. TESTING PROCEDURES

A large number of tests have been devised by various authorities in an attempt to establish a basis for evaluating the potential reactivity of aggregates or of cement-aggregate combinations. Useful as these tests are as a guide, most of them are empirical and the interpretation of their results usually requires experience and careful judgement. With few exceptions (eg petrographic examination) the tests take a long time and when we finally conclude our investigations, we are often well aware that we have achieved little more than a guide and not a positive indication of the likely behaviour of the material in its proposed application.

Some of the tests play an essential part in our investigations and I am not suggesting that we abandon these, but I should like to propose two points for consideration during our conference.

(a) Since it is difficult enough to classify aggregates – good or bad – in a laboratory test, we must clearly recognise the inadequacies and limitations of these tests and place greater emphasis on the importance of past history and service records. Structures that have stood the test of time provide the most valuable guide to the use of cement and aggregate types, especially when we have been wise enough to make and keep a clear record of the nature of the materials we have used in their construction.

(b) We should direct some of our thoughts and subsequent research efforts towards finding a rapid means of identifying potentially troublesome materials. In seeking this rapid test, we should be thoroughly pragmatic and not spend years striving for perfection because even the long term test is only a laboratory guide and not a positive prediction of the actual behaviour of concrete in the structure.

In aiming at our rapid testing techniques, we might consider as one of our targets, for instance, the further development of special parameters for petrographic examination in which we place greater emphasis on overall mineralogy and on factors such as the presence of undulatory extinction and sutured margins of quartz grains. Highly subjective though the petrographic technique may be, it can provide useful guidance in a matter of days rather than months.

4. USE OF MINERAL ADMIXTURES

It is very much in our national interest to explore the utilization of admixtures as a means of counteracting alkali-aggregate expansion. Apart from providing a practical solution, admixtures can have economic and energy saving benefits.

We have already examined the overall suitability of a number of admixtures. South Africa is well known for her knowledge and understanding of the use of milled granulated blastfurnace slag (MGBS) in concrete and is presently examining and experimenting with pulverised fuel ash (PFA) concretes. We know, for instance, that the substitution of not less than 35 per cent MGBS or about 20 per cent good quality PFA, by mass, of cement, will go a

long way towards counteracting the disruptive expansion of concrete. As far as PFA is concerned, we accept that it is necessary to control strictly the quality and uniformity of the product, but we are inhibited at this stage by warnings of a possible lack of long term durability. While I do not dispute the validity of this warning, I would like to learn more about the nature and mechanism of this possible deterioration of PFA concrete and I sincerely hope that this point will be aired during our conference.

Admixtures have an influence on the economics of our construction activities that goes far beyond the inhibition of alkali-aggregate expansion of concretes. We are all conscious today of the very real need for conservation of energy, of material resources and of the environment. While the raw materials for making portland cement are relatively abundant, one of the limiting features of future cement production will be the conservation of our energy resources. Major savings in energy can be achieved by the utilisation in cement of suitable industrial waste products such as MGBS and pozzolanic materials like PFA. A report by the NATO Committee on Challenges of Modern Society[1] refers to the blending of cement with MGBS and with PFA and estimates that this has reduced energy consumption in the cement industries in France and the Netherlands by as much as 40 per cent.

Future developments in the cement industry will almost certainly include greater use of industrial waste products not only as an important energy conservation measure but as a means of reducing the capital content of future plant per ton output. To demonstrate the importance of this capital cost factor, it can be mentioned that in the past ten years the average cost of building a new cement plant on a greenfield site has escalated approximately five-fold in terms of cost per annual ton of cement produced[2]. The greater use of blended cements in the future will provide us with the additional benefits of conserving our raw material resources substantially to the benefit of the environment.

These potential savings in energy and resources add weight to our need to examine the use of admixtures as a means of counteracting alkali-aggregate expansion. We simply cannot ignore the fact that it is very much in our national interest to explore the utilisation of admixtures for this purpose.

Finally, on the matter of admixtures, I must point out for the benefit of our overseas visitors another unfortunate geographic or geological circumstance in South Africa. Figure 1 shows that the sources of MGBS and PFA are situated far from the area which may benefit most from their use. These large distances impose logistic difficulties that must be balanced against the cost of other solutions to the problem.

5. THE NEED FOR A REALISTIC AND PRACTICAL APPROACH

My final point concerns the very real need for a calm and practical approach to solving our problems. In South Africa we are tending to over-react to the difficulties imposed by this physico-chemical reaction, and this is causing a number of unnecessarily expensive belt-and-braces solutions. For example, the NBRI Information Sheet[3] on alkali-aggregate reaction was produced as a guide and not as a specification, yet it has become apparent that it is being applied inappropriately in some instances. It must not be regarded as a substitute for the proper engineering evaluation of aggregates and cements. While it is undoubtedly true that certain highly critical applications of concrete may require the use of both low alkali cement and non-reactive aggregate, such applications probably amount to less than 5 per cent in the South Western Cape and certainly less than 1 per cent throughout South Africa. In many instances where the concrete is at risk, either a low alkali cement or a non-reactive aggregate and good design of the structure will suffice.

Larger still are the volumes of concrete used in benign environments where it is perfectly acceptable to use any cement and any aggregate. To make the best possible use of available aggregates and cements and to achieve economies for the construction industry we must appreciate that excessive caution in specifying the materials for concrete may be regarded in the same light as overdesigning the structure. We cannot afford the luxury and expense of overconservatism which is no substitute for sound engineering judgement.

This is not the first time that South Africa has been faced with a problem of disruptive dimensional changes in concrete. In 1954 Dr Niko Stutterheim of the NBRI demonstrated that certain natural aggregates in South Africa were responsible for excessive shrinkage cracking of concretes and mortars. The problem was widespread and serious and led to considerable research and investigation which was carried out over a period of some years by the NBRI.

That investigation bore several striking resemblances to the one we are discussing today:

(a) we needed to examine the mechanism of the shrinkage phenomenon;

(b) it was a matter of economic importance to the construction industry to make the best use of aggregates in certain areas where the availability of approved material was poor;

(c) this made it necessary to be able to define critical applications of concrete in the context of materials and the environment;

(d) and it was necessary to devise test procedures that would enable us to readily identify potentially harmful aggregate types. We soon discovered that there was no sharp line of demarcation between normal and shrinking aggregates.

You will notice the marked similarity between the shrinkage problem of 20 years ago and the alkali-aggregate problem of today. We resolved our shrinkage problem, firstly by getting to know something about the mechanism of shrinkage. Secondly, we learnt how to test for shrinkage and how to identify shrinking aggregates rapidly. Thirdly, we discovered to what extent and in what applications we could accept shrinking aggregates in our concrete without jeopardising unduly the life or serviceability of the structure. As testimony to the success of the sound engineering solution I can mention that over half the concrete stone used in Durban today is tillite from the Dwyka Group, vast quantities of sand from the Caledon River near Wepener have been successfully used in much of the concrete in Bloemfontein, and large quantities of sand from the Stormberg Formation of the Karroo were used in the concrete of our famous Orange-Fish tunnel. All these materials fall into the category of shrinking aggregates.

6. CONCLUSIONS

I don't think I am being over-optimistic in predicting that we will achieve the same success with our alkali-aggregate reaction problems as we have with our shrinkage problems, provided we adopt the same pragmatic approach and use the same sound engineering principles in relation to both specification and design of concrete and structures.

Indeed, I would make so bold as to suggest that we in South Africa can be proud of our record. Not only do we have well equipped research laboratories working towards understanding and providing practical solutions to our problems, but suppliers of materials have played a constructive role. For example, cement manufacturers and aggregate producers have arranged seminars on alkali-aggregate reactivity. The cement industry has done its utmost not only to ensure the quality of its product in general, but particularly in the South Western and Eastern Cape where alkali content has been on the high side in the past, every effort has been made to assist the construction industry by significantly reducing alkalis to acceptable levels. Similarly, the suppliers of aggregate have gone to great pains to select better sources of material and to improve the physical characteristics of the aggregate produced.

I have every confidence that the papers and discussions at this conference will stimulate our work on the problem of alkali-aggregate reactivity and bring us closer to a practical solution to the problem.

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