

SPECIAL DISCUSSION SESSION
Thursday afternoon

Chairman: Prof S Diamond, Purdue University, USA

CONTRIBUTION FROM HARALDUR ASGEIRSSON
Director, The Building Research Institute, Reykjavik, Iceland

(Communicated by Dr G Idorn, Denmark, September 1978)

Dr Idorn, in introducing the contribution from Iceland said he had visited that country for the first time to investigate the alkali-silica reaction in 1967. Reykjavik, which was the capital of Iceland had about 100 000 inhabitants, and most of the houses were built of solid concrete. At that time he had found no evidence of deleterious alkali-silica reaction which was somewhat surprising since the Icelandic cements had one of the highest alkali contents in the world. Deleterious expansion had been observed in mortar bar tests with their aggregates and as a result they had used low alkali cement in some large dam projects in order to avoid the risk of deleterious expansion. When he had visited Iceland again in 1977 Dr Idorn said he had found plenty of examples of deleterious alkali-silica reaction in ordinary houses built by private citizens. He stressed that in such a situation the consequences of the alkali-silica reaction came down hard on ordinary people who had invested their money in housing particularly as the inflation rate in that country was about 50 per cent per annum. He explained that their conclusion in 1967 that there was no deleterious alkali-silica reaction in the houses had been based among other things on the fact that Iceland had a very low annual temperature. This had been prior to the discovery of the alkali-silica reaction in Nova Scotia, Canada and with that as background he then read the following contribution from Iceland.

'Since the Purdue meeting (September 1978) we have resorted entirely to the use of pozzolan or fumed silica condensate blended cements, and legalised a building code in which it is specified that mortar bar expansion in one year shall be within 0,1 per cent. This appears not to cause any difficulty if cement is replaced by 5 per cent of fumed silica condensate as is now general practice, though a 7½ per cent replacement is aimed at.

'The use of fumed silica condensate from a ferro-silicon plant here has provided definite relief for the concrete industry in this country, since it both cures alkali-silica expansion and improves cement strength. Because of this achievement our effort is now geared more towards the repair of existing damage.

'Some of our research endeavours in this direction are as follows.

1. We have calculated condensation risks and the possibility of the accumulation of moisture in various types of insulated exterior concrete walls. In some types condensation may occur and hence tight surface films may be harmful.

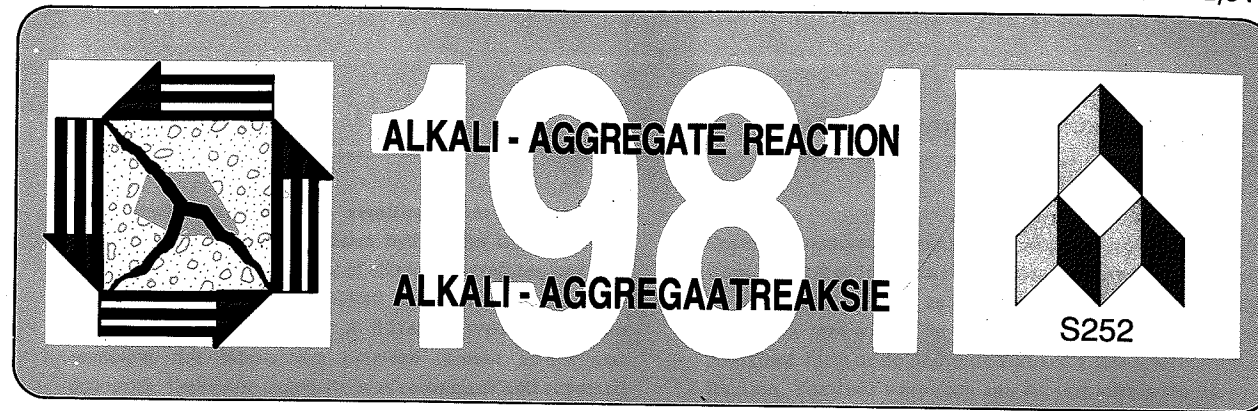
2. The drying out of exterior walls behind experimental claddings is being studied. The gel reaction product and in some cases CaCl_2 may be sufficiently hygroscopic to sustain continued expansion. Results to date however have not confirmed this and proper cladding is considered a definite cure.
3. Field and laboratory studies of insulating pads placed beneath various types of rendering are planned.
4. Laboratory studies are being attempted to measure driving rain resistance in terms of the ease of diffusion of water vapour through stuccoes and renderings of organic binders.
5. Some chemicals may retard the deterioration process. Thus small molecule hydrophobic silanes dissolved in light fluids may penetrate the microcracks, the silanes bond to the concrete and make it permanently water-repellent.
6. In some cases the demolition of deteriorated concrete and its replacement with sound concrete may be considered.
7. Finally some surface films that are relatively tight, yet open to diffusion will be tested to determine their value as preventive measures.

'Unfortunately this program is somewhat too extensive and will have to be limited in several ways. Certainly it will extend over a long period, but since we now know how much is at stake, we are anxious to speed the work up as much as possible.'

Dr P E Grattan-Bellew (NRC, Ottawa, Canada) asked how old the concrete was by the time it started to show cracks.

Dr G Idorn replied that in some cases it was as little as one year old. The cracks appearing now were confined to recently built houses, and he thought that the increased cement content played a part. He also thought that a recent practice of dredging aggregates from the fjords might be a contributing factor. Another possibility was the higher thermogradients that came with a higher cement content.

Dr R E Oberholster (NBRI, SA) said that when the alkali-aggregate reaction involved carbonate rocks it was called the alkali-carbonate rock reaction, but when siliceous minerals were involved it could be called the alkali-silica reaction, the alkali-silicate reaction or



ALKALI-CARBONATE REACTIONS IN CONCRETE

by Dr A B Poole*

SYNOPSIS

Certain types of carbonate aggregate will react with alkalis from the cement paste in concretes. At least three types of reaction have been identified. One, which involves fine grained dolomitic limestone aggregate, has been shown to cause deleterious expansion in concrete. Detailed experimental studies using electron probe micro-analysis show how ion concentration maxima develop and migrate through the reacting zones with time. The modification of ionic concentrations in the cement paste pore fluids have also been investigated by this technique to show how changes in Na^+ and OH^- ions modify the reaction rate. Scanning electron microscopy has been used to study the solution and crystallisation of phases in the reacting zones and to investigate the role of the interstitial clay in producing the expansive and disruptive features of the reaction.

SAMEVATTING

Sekere tipes karbonaat-aggregaat sal met alkalië uit die sementbry in beton reageer. Minstens drie tipes reaksie is geïdentifiseer. Een, waarby fynkorrelrige dolomitiese kalksteen betrokke is, is uitgewys as die oorsaak van vernietigende uitsetting in beton. Gedetailleerde eksperimentele ondersoek, waarin van mikrosonde ontleding gebruik gemaak is, toon hoe ionkonsentrasie ontwikkel en met verloop van tyd deur die reaktiewe sones beweeg. Die wysiging van ionkonsentrasie in die sementbryporievloeistowwe is ook dmv hierdie tegniek ondersoek om aan te toon hoe veranderinge in Na^+ en OH^- ione die reaksietempo wysig. Aftaselektronmikroskopie is gebruik om die oplossing en kristallisering van fases in die reaksiesones te bestudeer en die rol van die tussenruimtelike klei te ondersoek wat die uitset- en verbrokkelingskenmerke van die reaksie veroorsaak.

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Conference on alkali-aggregate reaction in concrete
Cape Town - South Africa
March 30 - April 3, 1981

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Konferensie oor alkali-aggregaatreaksie in beton
Kaapstad - Suid-Afrika
30 Maart - 3 April, 1981

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the alkali-siliceous rock reaction, seemingly to indicate different types of reaction mechanism. He asked Prof Gillott whether he still believed it was the phyllosilicates that caused expansion with rock types such as greywackes, hornfelses and phyllites, and whether he would use the term alkali-silicate reaction specifically for this mechanism. If so he asked would this signify a different reaction to the one for which Dr Grattan-Bellew used the term alkali-siliceous rock reaction in his papers. He added that in their work on the Malmesbury Group of rocks NBRI researchers had been unable to prove that it was the phyllosilicates that caused the expansion in concrete.

Prof J Gillott (University of Calgary, Canada) replied that when he had suggested that the phyllosilicates were a significant factor in the expansion mechanism in Nova Scotia, much of the work had been quite new and he had felt then that the exfoliation that had been observed was probably significant in so far as the expansive mechanism was concerned. He still thought that it might be the case because he had observed this type of reaction in other rocks of this type, from other places, but had always to bear in mind that it was quite possible that it was the fine-grained quartz or other forms of silica in the rock that were the major factors in the mechanism of expansion. Nova Scotian rocks were metamorphic and the quartz might well show strain and certainly was fine-grained. All fine-grained silica was to some extent soluble in alkaline solution and so gel products might be formed and presumably could perform in much the same way as they did from more reactive forms of silica such as opal. He had suggested that the alkali-aggregate reaction should be subdivided into more than one category because he thought that in addition to the possibility that there was a different mechanism in rocks of this sort, there were significant differences between the way in which those rocks had behaved and what he had called the classical alkali-silica reaction. He felt it was convenient to have more than one 'general sack category' for alkali-aggregate reactions. As to whether the phyllosilicates contributed to expansion, he thought they did, but had always recognised the possibility that they were not the major cause. Possibly it was indeed the fine-grained quartz which was the principal cause of expansion, but either way he still thought it was useful to have more than one class of alkali-aggregate reaction and whether the term alkali-silicate was adopted for rocks of this kind or whether one referred merely to siliceous rock did not matter greatly. What did matter was that it was convenient to be able to categorise the reactions.

Dr L Dolar-Mantuani (Ontario, Canada) claimed that she was the originator of the term alkali-siliceous rock reaction, and said that she had introduced it because she needed a wider term than alkali-silica reaction (which she said referred to the reaction of alkalis with the metastable silica minerals and volcanic glasses) to include rocks such as quartzite, granite, granodiorite and gneiss. There was no doubt that with the greywackes and argillites of the Canadian shield, there was a silica reaction in which plenty of gel formed. The grey-

wackes that occurred in the Appalachians were different in that as a result of hydrothermal action vermiculite had been formed. However, despite the fact that the vermiculite may exfoliate, she could not see why there should be a different reaction with the cement alkalis.

Dr P E Grattan-Bellew (NRC, Ottawa, Canada) said he did not think that there was a fundamental difference in the mechanism of the classical alkali-silica reaction and the reaction mechanism of the slowly expanding siliceous rocks.

He was not entirely satisfied with the term 'siliceous' but it had been used by Dr L Dolar-Mantuani and he hesitated to coin yet another new definition.

He thought it would be much better to use the term 'slowly expanding silica reaction' in place of siliceous aggregate reaction.

The reason for needing a second definition at all was that the siliceous aggregates such as greywacke, some quartzites, quartz biotite and gneiss, which showed this reaction expanded much more slowly than the classical alkali-silica aggregates and this fact was very important in testing.

In the case of the classical alkali-silica reaction a test could be done in 36 days, or at most 3 months, but if one ran such a test on a slowly expanding silica aggregate for only 3 months one would conclude (incorrectly) that they were non-expansive.

He believed that in both reactions the mechanism was the same but that it showed up in different ways.

In the classical alkali-silica reaction

- the opal was first attacked by the alkali and swelled (expanded)
- the opal then started to dissolve and shrank
- the 'gel'-impregnated pores in the concrete absorbed water and swelled creating internal pressure which resulted in the expansion of the concrete.

In the slowly expanding silica aggregates (e.g. hornfels)

- the grain boundary region between the quartz grains where there was a high concentration of defects, and hence high free energy, was attacked by alkali and started to dissolve
- this resulted in the expansion of the aggregate either through the release of stress or through the 'gel' impregnating the pores in rock as for the classical reaction.

The expansion of concrete might be due to both the expansion of aggregate and to a mechanism similar to (c). The difference was that in this case only a small part of the SiO_2 that occurred around the grain boundaries was soluble and available to form 'gel'.