

## COMMENTS

A broad discussion of contributions to the seminar presented on May 20th was held on Tuesday May 21st.

The discussion began with a brief reference to the importance of research on alkali-silica reaction from new angles. In connexion with the wish for a classification of coarse aggregates, it was proposed that cement and aggregates each be classified in three or more groups according to reactivity. The combination aggregates - cement could then be selected under given conditions (environment, particle size, ratio between opal and flint, etc.).

The rupture mechanism in concrete affected by alkali-silica reaction was discussed. It was pointed out that knowledge was lacking in this field and that closer cooperation with physical-chemical specialists might be useful. It was mentioned that cracking could be caused by expansion of the gravel material itself, and that the cracks propagated from the reactive particles, creating a network of cracks throughout the concrete. The participants went on to discuss the magnitude of the forces in alkali-silica reactions in relation, inter alia, to frost damage. A simple model for describing the relation between expansion and pressure was discussed. In this connexion, the question was raised of the degree to which external pressure affects the chemical reaction itself, in that it is known that external pressure can impede expansion.

Another topic dealt with was the investigation of structures with alkali-silica damage. A word of warning was given regarding the fact that alkali-silica reactions can occur after a specimen has been drilled from a structure, due to the addition of water.

The influence of the load on alkali-silica reaction and the relationship between the rupture mechanism and the particle size and distribution were also touched upon.

The reaction mechanism was discussed. It was agreed that the first step in the process was a diffusion of sodium, potassium, calcium and hydroxyl ions to the inner surface, together with water. This diffusion is followed by chemical reactions on the inner surface of the reactive particles. However, there was some disagreement on the details. There was a certain lack of clarity regarding the expansion resulting from the reaction.

In connexion with the discussion on methods of testing the reactivity of cement, a pyrex mortar-bar-test was presented, which should make it possible to compare results from different laboratories. On the basis of results with two standard cements (high and low alkali content) from a certain number of laboratories, a master curve is formed for expansion as a function of alkali-content. The experimental data from different laboratories is transferred by linear transformation to points corresponding to the master curve, thereby permitting direct comparison. The method requires the inclusion of standard cements in expansion measurements, and the assumption of a linear relationship between expansion and alkali content. A warning was given against the use of pyrex glass because of its alkali-content and because of the differences in the microstructure of opal and glass. It was emphasized that opal could not be used as an alternative standard aggregate because sufficient quantities of uniform character could not be procured. A proposal mentioned that it would be desirable to be able to distribute a large quantity of alkali-free glass that was well-characterized and that could therefore be used at different laboratories. ASTM has looked into the possibility of using glass balls.

An interesting and vital problem was brought up by a representative of the cement industry. He stressed that it was important to know where the alkali was located in the cement clinker and what

effect it had on the development of alkali-silica reactions because it might be possible to alter these factors during the production process. It was established that the reactivity of a cement is not only a function of the alkali-content.

The discussion showed what was needed in continued research on alkali-silica reactions: basic research to clarify the kinetics of reaction and to describe where and how the reactions develop and how silica gel causes cracks and rupture. The discussion also showed the need for simple and reliable methods of measuring the reactivity of cement and aggregates. In recognition of the fact that more high alkali cements are to be expected, it was pointed out that further research was required to find methods and means of preventing alkali-silica reactions.