Wet curing of blended cement concrete is considered to be necessary to achieve optimum cement behaviour because the hydration reactions of both fly ash and granulated blast furnace slag are relatively slow compared with those of portland clinker compounds. Provided the amount of fly ash admixture is not excessively high, it is most unlikely that the drying shrinkage of blended cement concretes will be significantly greater than those of comparable straight portland cement concretes.

CONCLUDING REMARKS

Fly ash has been and will continue to be used successfully and advantageously as a partial cement replacement in concrete provided certain precautions are taken such as, (a) selection of suitably reactive fly ash, (b) control of fly ash uniformity and quality, (c) control of the fineness of blended cement during its production, (d) effective use of chemical admixtures and, (e) adaptation of constructional practices to the requirements and performances of blended cement in concrete.

The quantity of portland cement that can be replaced by fly ash should be carefully considered. For economic reasons large replacements (approximately 20%) would be considered desirable while for technical reasons it would appear that the replacement quantity should be kept within a 12-15% range. The actual replacement quantity will depend on a wide variety of factors. Increments in fly ash replacement above this suggested level may increase the number of defects in the cement paste. These defects increase the tendency for strength to decline and more importantly could reduce the long term durability of concrete exposed to natural weathering conditions.

Fly ash admixtures can also be used as pozzolanic inhibitors of reactive aggregate expansion. For this purpose fly ash must be readily reacted by alkalis, contain negligible amounts of alkalis, and have a fine particle size (preferably all particles should be 40 microns). Inhibition of aggregate expansion requires a high level (approximately 40%) of portland cement replacement by fly ash. Lesser cement replacements are likely to reduce but not completely inhibit reactive aggregate expansion.

Damage of concrete cylinders with REACTIVE SAND AND NON-REACTIVE, COARSE AGGREGATES

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The purpose of the present investigation has been to provide an introductory evaluation of a model for estimation of the expansion of concrete when knowing the expansion of the mortar and the amount of non-reactive, coarse aggregates used in the concrete.

The tests were carried out in co-operation with the Danish Engineering Academy, Section of Structural Mechanics, and the Technological Institute, department of Building Technique.

1. BACKGROUND

In 1956 the present Committe on Alkali Reactions in Concrete commenced a series of laboratory experiments with 48 nos. of ordinary concrete bars, size 100 x 100 x 600 mm. These pilot tests did not show convincing relations between the expansion of mortar bars, size 25 x 25 x 125 mm, and the expansion of concrete bars even when the same source of reactive sand was used. As in the case of the mortar bars, the elongation (expansion) measured was used to express the advance of the alkali silica reactions. In the concrete bars commercial crused granite as well as pit aggregates and maritime aggregates were used as coarse aggregates. A three per cent solution of NaCl was added to two of the mixes for the concrete bar tests in order to simulate a maritime environment. This was not the case in the mortar bar tests.

Many hypotheses have been advanced in order to explain the lack of deteriorating expansion and cracking of the concrete bars used for these tests. However, non of the hypotheses have been accepted so far on a basis of new laboratory tests.

2. MIX PROPORTIONS

In the present investigation tests have been carried out involving 10 different concrete mixes using reactive sand and non-reactive coarse aggregates. Furthermore, tests were carried out with two blind mixes, i.e. using non-reactive aggregates, fine as well as coarse. In order to check the accuracy of the measurements two of the mixes were repeated.

The basis of the mix design was a concrete with the following recipe:

Cement	300	kg/m^3
Water	150	"
Fine aggregates	805	"
Coarse aggregates	1150	"

This corresponds to a mortar with the following recipe:

Cement	521	kg/m^3
Water	261	"
Fine aggregates	1399	"
Coarse aggregates	0	"

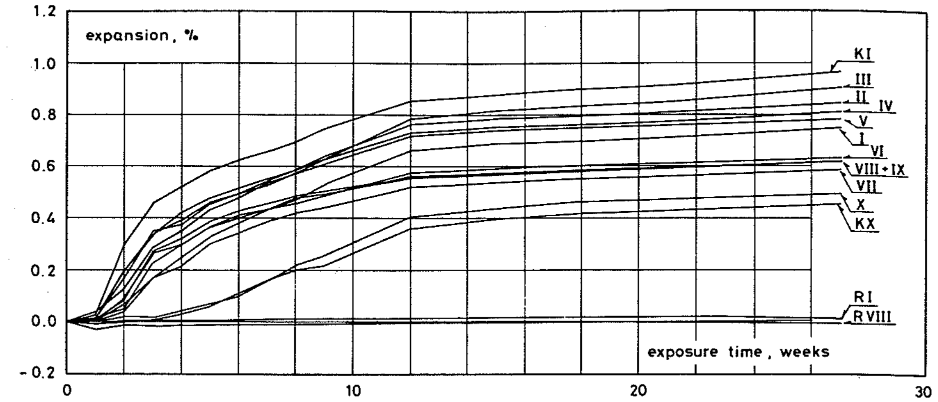

Figure 1: Expansion (%) of concrete cylinders in relation to the exposure time (weeks) for the different mix proportions used in the test. The amount of coarse, non-reactive aggregate used for the different mixes appears from figure 2.

Between these extremes mixes with different contents of coarse aggregates were used. An effort was made to keep the mortar composition of the concrete constant, i.e. the water/cement-ratio (0.50) and the ratio between cement and fine aggregates (2.68). The slump of the concrete was kept constant by means of applying super plasticizer as an adjusting agent.

3. TYPE OF AGGREGATES

As reactive "fine aggregates" a typical commercial product, "Farum Sand", was selected. As typical non-reactive coarse aggregates, also a widely used commercial product, crushed "Rønne Granit" was selected.

From mortar bar tests it is known that "Farum Sand" is reactive. It is also known that concrete structures made from "Farum Sand" and "Rønne Granit" have shown typical deterioration determined as alkali silica reactions by means of observation of thin sections of deteriorated concrete sampled from such structures.

4. TEST SPECIMEN

As tests specimens ordinary concrete cylinders, diameter 150 mm and height 300 mm, were used. These cylinders were used to check the compression strength, the splitting tensile strength, the weight change and the expansion during the storage period. In order to measure the elongation of the cylinders they were cut in two halves and supplied with stainless steel pins in the gavity center of the end sections. Thus the measurement length was 300 mm. An apparatus for measuring the length of the cut cylinders was designed in order to ensure that they could always be placed in the pins of the specimens and the measurement device of the apparatus were kept in the same position at all times.

5. STORAGE

The specimens were stored under water, saturated with NaCl, and at a temperature of 50°C. This environment is now a standard

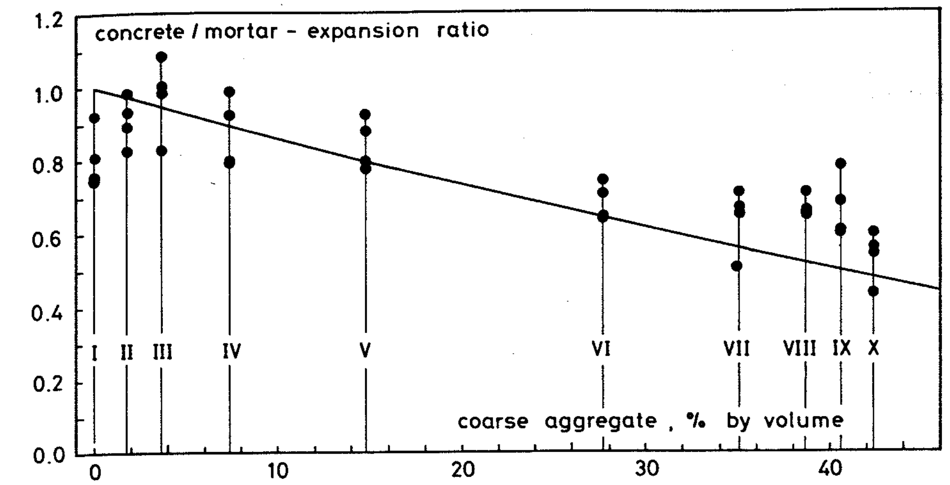

Figure 2: Ratio of concrete expansion to expansion of mortar at final stage of tests shown in relation to the contents of coarse, non-reactive aggregate as the percentage by volume of the concrete. The curve shown is the result of a theoretical model, applying the methods of continuum.

when testing mortar bars, size 40 x 40 x 160 mm, in Denmark. These storage conditions differ from those applied by the former Committee on Alkali Reactions. However, it is found more important to be in accordance with the new procedure for accelerated mortar bar tests in Denmark than to follow an abandoned procedure.

6. THEORY

When mortar which shows expansions due to alkali silica reaction is diluted with non-ractive coarse aggregates the over all expansions must decrease. By using the methods of continuum mechanics formulae are derived to estimate the expansion on basis of the expansion of the mortar itself and the amount of non-reactive coarse aggregates used in the concrete mix.

7. RESULTS

The specimens were exposed to a minimum of 26 weeks. The tests were continued until the expansion stopped. This has shown expansion above the acceptable for practical use and heavy cracking has appeared. A significant relationship between the expansion and weight change has been one of the results. The loss of the strength of the concrete, compression as well as tension has been determined and a remarkable drop has been the result.

The main result of the test however, is that the decrease of the expansion of the concrete specimens is in fair accordance with the theory put forward. It shows that the method of continuum mechanics may be of interest for further studies of the mechanism of alkali silica reactions of concrete. However, it

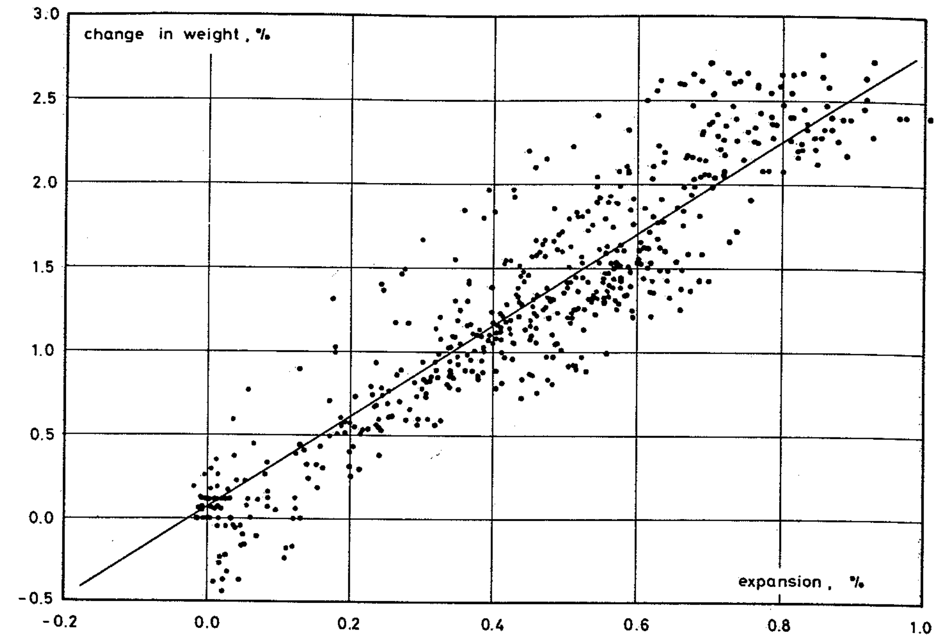

Figure 3: The change in weight of the concrete cylinders in relation to the corresponding expansion at any time measured. The straight line shown is found by regression analysis.

does not explain why reinforced concrete when reactive is showing less expansion in practice than found by the tests here carried out.

8. FUTURE TESTS

New tests are planned to give a follow-up and a better understanding of the mechanism of alkali silica reactions in concrete when non-reactive as well as reactive coarse aggregates are used. Furthermore, it is planned in the near future to study the effect of reinforcement on the expansion of concrete due to alkali silica reactions.

STUDIES OF ALKALI-SILICA REACTION WITH SPECIAL REFERENCE TO PREVENTION OF DAMAGE TO CONCRETE

A PRELIMINARY STUDY

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1. ABSTRACT

From petrographic studies of alkali-silica reaction damaged concrete specimens and other investigations it has been proposed that the presence of free $Ca(OH)_2$ is a necessary pre-requisite for the development of destructive alkali-silica reaction. It has also been proposed that a complete removal of free $Ca(OH)_2$, by reacting with an active pozzolana, will effectively stop the development of destructive alkali-silica reaction, even in the presence of an unlimited supply of alkali-salts. This paper describes work done to test the above hypothesis.

In this work ordinary Portland cement was mixed with different proportions of diatomaceous earth (moler). Using these cement-pozzolana mixtures, 1:3::"cement":sand, mortars were made with each of two known reactive sands and one nearly unreactive sand. 40x40x160 mm. prisms were made from above mortars. These prisms, after 27 days water curing, were tested for their expansivity by hot NaCl bath method.

The observations, to date, indicate that an addition of 20% diatomaceous earth seems to stop expansion due to alkali-silica reaction, even though the prisms were stored in a saturated NaCl bath. A petrographic examination of a thin section of each of the expansion tested prisms failed to reveal the presence of crystalline $Ca(OH)_2$ in bars made with "cement" containing 20% diatomaceous earth.