ALKALI REACTION TESTS WITH SOUND AGGREGATE

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ABSTRACT

Sound aggregates like sand and gravel of quartz without flint or opaline material have never been the cause of any trouble in normal concrete structures in Germany even if cements with high alkali contents were involved. On the other hand, this does not necessarily have to mean that each sound aggregate cannot react with the alkalies of the pore solution. Several experts have already indicated that nearly all aggregates can react, at least under extreme experimental conditions.

This phenomenon was investigated applying mortar tests with normal sound quartz aggregate. The extreme conditions were: High cement content, low w/c ratio, very high humidity, and a temperature of 40 °C. 13 cements with alkali contents from 0,5 to 1,2 wt % were tested over a period of 12 months.

The expansions of low alkali cements were very much lower than in Pyrex mortarbar tests. Portland cements with $\leq$ 0,6 % alkali (Na_2O-equivalents) caused only expansions $<$ 0,4 mm/m, Portland cements with $>$ 1,0 % alkali, however, produced expansions $>$ 1 mm/m. All the expansions of the slag cements with $>$ 40 % slag were $<$ 0,4 mm/m. The influence of the granulated slag was very nearly the same as in Pyrex mortarbar tests.

Introduction

It is a wellknown and fully accepted experience that in Germany destructive alkali silica reaction never occured in normal concrete structures if low alkali cements (PZ-NA or HOZ-NA) had been used or if the aggregate contained only sand and gravel of quartz without reactive flint and without opaline material (1).

On the other hand, it is also wellknown that in laboratory tests the expansion of low alkali cements can easily go up to 1,5 mm/m if pyrex glas aggregate is applied (2). Regarding the reactivity of different natural aggregates several experts have already indicated that almost all aggregates can react, at least under extreme experimental conditions (4,5,6).

For better understanding of these phenomena all the other parameters which are necessary for alkali silica reaktion or which increase its effect have to be taken into consideration, i. e. high relative humidity, elevated temperature, high cement content, low w/c ratio, pessimum grading of the aggregate.

The purpose of many laboratory investigations and especially of mortarbar tests is very often only to classify a cement, an additive, or an aggregate. In these cases all the remaining parameters are usually applied in extreme combinations which can never occur in a concrete structure - at least not in Germany. Under such very special experimental conditions even low alkali cements can expand distinctly with reactive aggregates, or high alkali cements can react with aggregates otherwise known as sound. That way it is even possible to force clean quartz aggregate to a weak but measurable alkali aggregate reaction.

Experimental Procedure

The expansion of mortarbars 4 x 4 x 16 cm with steel gage studs on each end was measured monthly over a period of 12 months. The prisms were demoulded after one day and then stored in closed moist boxes (> 95 % RH) at 40 °C. The reference length of the prisms was measured after three days ($\Delta = 0$).

The mix proportion in % by weight was

water/cement/aggregate = 0,43/1/2,25

i.e. a cement content of 600 kg/m^3. The aggregate grading was

mm	0/0,2	0,2/1	1/3	3/7	7/15
wt-%	10	30	20	20	20

The aggregate consisted of normal sound quartz material which passed the petrographic examination (ASTM C 295) and the quick chemical test (ASTM C 289) as nonreactive. 13 cements with contents of granulated blastfurnace slag from 0 to 70 wt-% and with alkali contents (Na_2O-equivalents) between 0,5 and 1,2 wt-% were tested.

Test Results

The characteristic cement data and the expansion test results after 12 months are given in Tab. 1.

TABLE 1

Results of Mortarbar-Expansion-Tests

N° of cement	blastfurnace-slag in wt-%	Na_2O-equivalents in wt-%	expansion in mm/m
1	0	1,20	1,66
2	0	1,11	1,19
3	0	0,48	0,21
4	13,0	1,12	0,94
5	39.0	1,08	0,47
6	41,3	0,84	0,24
7	47,6	0,78	0,23
8	48,2	0,99	0,32
9	49,0	1,08	0,31
10	59,0	1,08	0,21
11	65,3	1,06	0,21
12	68,5	0,75	0,20
13	69,5	0,87	0,15

This table shows distinct expansions up to more than 1 mm/m even though only quartz aggregate had been used. Moreover it provides another proof of the wellknown experience that blastfurnace slag in cements reduces the reaction to very low degrees even if the alkali content of the blastfurnace slag cement exceeds 1 wt-% (3,7,8).

The quantitative statistical evaluation of the results received in this special experiment leads to the formula

$$\Delta_Q = 0{,}826 \cdot \left[A \cdot (1 - H/100) \right]^3 + 0{,}165 \qquad (1)$$

Δ_Q: expansion after 12 months in mm/m

A : Na_2O-equivalents in wt-%

H : content of granulated blastfurnace slag of the cements in wt-%

The coefficient of correlation of equ. (1) is r^2 = 99,0 %. That means that an exact calculation of the influences of alkali and blastfurnace slag is possible. Tab. 2 shows the results of this calculation

TABLE 2

Calculated Expansion of Mortarbars with Quartz Aggregate in mm/m

Na_2O-equivalent (A) in wt-%	content of granulated slag (H) in wt-%			
	0	25	50	75
0,0	0,17	0,17	0,17	0,17
0,3	0,19	0,17	0,17	0,17
0,6	0,34	0,24	0,19	0,17
0,9	0,77	0,42	0,24	0,17
1,2	1,59	0,77	0,34	0,19
1,5	2,95	1,34	0,51	0,21

Tab. 2 is valid only for this special mortarbar experiment. It is likely that the term + 0,165 mm/m in equ. (1) is only an experimental constant which is not due to alkali silica reaction. That would mean that all the calculated values of Tab. 2 should be diminuished by 0,17mm/m if the alkali reaction only shall be taken into consideration. In this case low alkali cements would create alkali expansions of $\leq$ 0,2 mm/m and high alkali cements would produce alkali expansions up to more than 1 mm/m under these experimental conditions.

In any case the influence of the granulated slag is very nearly the same as in pyrex mortarbar tests: Blastfurnace slag cements with 50 wt-% slag and 1,2 wt-% alkali react like portland cements with 0,6 wt-% alkali, and blastfurnace slag cements with 75 wt-% slag create little if any expansion.

Conclusion

If the experimental conditions of accelerated laboratory tests are powerful and sophisticated enough, it is likely that almost all SiO_2 containing aggregates can be forced to a reaction with concentrated alkali solutions even those which would never be harmfull to a concrete. When such laboratory tests are applied, it is therefore necessary to compare the results of an unknown material with the results of a familiar reference material that was tested exactly the same way. As far as the northern part of Europe is concerned a comprehensive research work on natural aggregates has been done in Denmark and in Germany (1,9) and the difference between harmful and innocuous material of this area is wellknown. After all, if the unknown aggregate behaves like quartz it cannot possibly be classified as deleterious.

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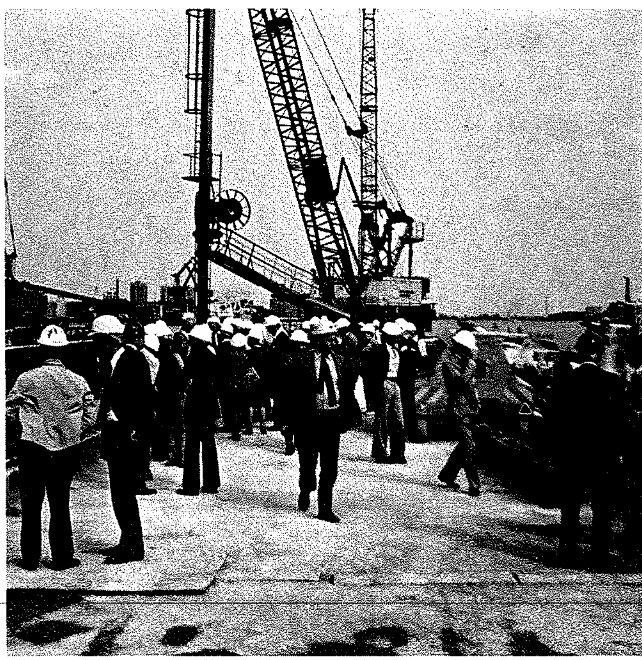
CONTRIBUTIONS TO DISCUSSION

Dr. P. Grattan-Bellew

The point that almost all aggregates can be made to expand under accelerated laboratory test conditions, stated by Dr. Smokzyk, is well made. Under such laboratory conditions it is essential to run parallel tests on reference aggregates with known expansion characteristics in concrete, so that "accelerated normal expansions" are not misinterpreted as being deleterious.

Mrs. K. Mather

I would suggest to Dr. Gratton-Bellew that a fine grained pure dense limestone is a good control aggregate for alkali-silica reaction mortar bars.



The Thames Barrage Site