ALKALI-SILICA REACTIVITY OF SANDS, COMPARISON OF VARIOUS TEST METHODS

NORDTEST PROJECT

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1. ABSTRACT

A number of Danish and Icelandic sands have been tested for alkali-silica reactivity by the following test methods:

1. ASTM C 227, mortar bar method

2. T.I. (NaCl) mortar bar method

3. ASTM C 289, quick chemical method, QCT

4. "Vorbeugende Massnahmen", chemical method

5. Petrographic examination.

The main observations were:

- The sodium-chloride mortar bar expansion method developed by the Teknologisk Institut, Byggeteknik (T.I.), Denmark, is excellent for measuring the alkali-silica reactivity of most sands in 20 weeks. 8 weeks in saturated, 50°C NaCl-solution is sufficient for the more reactive Danish sands.

- The QCT method with a new limit is excellent for Icelandic sands, and may be used for accepting Danish sands. In order to reject sands, additionally a petrographic examination is required.

2. INTRODUCTION

Extensive damage on concrete structures due to alkali-silica reactions has been observed in Denmark and Iceland. Such damage seems to be an increasing international problem including Norway and Sweden.

Different test methods have been used to classify the reactivity of aggregates. The methods considered most reliable are also the most time consuming ones, taking up to one year. Therefore, a definite need exists for a better correlation between the various test methods and for a comparison of results with known behavious in actual constructions.

In Sept. 1979 Nordtest-project 173-79 was started. The project was suggested by Rb (The Building Research Institute, Iceland) and T.I. (The Teknologisk Institut, Denmark), and the aim was to find a sound base for a fast, reliable method to measure the reactivity of sands. The project leader was Hákon Olafsson at Rb. (1).

3. TEST METHODS - TEST SAMPLES

The methods generally used for measuring alkali-silica reactivity of concrete can be divided into the following three types: - those based on chemical measurement of reactive silica, - those based on expansions of mortar bar prisms, and - those based on petrographic classification.

In this project the reactivity of a number of sands and sand-cement combinations was measured by the following methods:

1. ASTM C 227, mortar bar method
2. T.I. (NaCl), mortar bar method (2)
3. ASTM C 289, quick chemical method
4. "Vorbeugende Nassnahmen", chemical method (3)
5. Petrographic examination.

The materials used and the tests carried out are shown in Table 1.

TABLE 1 - Sands and test methods

SANDS I: Icelandic D: Danish S: Swedish	TEST METHODS				
	1) ASTM C 227	2) T.I.	ASTM C 289	V.M.	Petrogr. Exam.
I- 1, Hvalfjörður	x	x	x	x	x
I- 2, Saltvik	x	x	x	x	x
I- 3, Glæsibær, Ak.	x	x	x	x	x
I- 4. Isafj., Pollur	x	x	x	x	x
I- 5, Raudamelur	x	x	x	x	x
I- 6, Esjuberg	x	x	x	x	x
I- 7, Hraun, Olfusi	x	x	x	x	x
I- 8, Skorrholt	x	x	x	x	x
I- 9, Blönduós	x	-	x	-	-
I-10, Saudárkr., Borgars.	x	x	x	x	x
I-11, Glerá Ak.	x	x	x	x	x
I-13, Nesk., uppd.úr Reydaf.	x	x	x	x	x
I-14, Gáseyri	x	x	x	x	x
D- 1, Amager	x	x	x	x	x
D- 2, Nymølle	x	x	x	x	x
D- 3, Himmelev	x	x	x	x	x
D- 4, Løjtved	x	x	x	x	x
D- 5, Vorbadsbro	x	x	x	x	x
D- 6, Laen	x	x	x	x	x
D- 7, Reerslev	x	x	x	x	x
D- 8, Mogenstrup	x	x	x	x	x
D- 9, Kallerup	x	x	x	x	x
D-10, Ginnerup	x	x	x	x	x
D-11, Hinnerup	x	x	x	x	x
D-12, Tandskov	x	x	x	x	x
D-13, Røllum	x	x	x	x	x
D-14, Halk Hoved	x	x	x	x	x
D-15, Fragdrup	x	x	x	x	x
S- 1, Hassle Börrup	x	x	x	x	x

1) Tested with unblended Icelandic P.C. (Na_2O-eq = 1.55).
2) Tested with Danish reg. P.C. (Na_2O-eq = 0.70)

4. RESULTS - DISCUSSION

In Table 2 the sands have been classified by use of the different test methods. In this classification it was necessary to introduce two new methods, namely modified versions of T.I. and Q.C.T. The only modification of these methods is the change of classification criteria from the accepted methods. The following criteria for the various methods in this project were found suitable:

ASTM C 227		Reactivity index
1 year expansion	< 0.1%	1
1 " "	0.1-0.2%	2
1 " "	> 0.2%	3
T.I., 8 weeks		
8 weeks expansion	< 0.1%	1
8 " "	0.1-0.2%	2
8 " "	> 0.2%	3
T.I.- modified, 20 weeks		
20 weeks expansion	< 0.1%	1
20 " "	0.1-0.2%	2
20 " "	> 0.2%	3
Q.C.T. (ASTM C 289)		
non-reactive		1
reactive		3
Q.C.T.- modified		
Dissolved silica (mMole/litre)	< 100	1
" " " "	> 100	3
Vorbeugende Massnahmen		
Weight loss	< 0.5%	1
" "	0.5-1.5%	2
" "	> 1.5%	3
Petrography		
Vol.% reactive	< 2.0%	1
" % "	> 2.0%	3

In order to compare the different test methods, the following reactivity index is used:

Reactivity 1: not reactive
Reactivity 2: reactive
Reactivity 3: highly reactive.

TABLE 2 - Reactivity of sands classified by different test methods

Test specimen	CLASSIFICATION OF SANDS BY DIFFERENT METHODS							
	ASTM C 227	T.I. 8 W.	T.I. 20 W	Q.C.T. C 289	Q.C.T. Modif.	V.M.	Petro.	Field Exper.
I - 1	3	2	3	1	3	1	-	3
I - 2	1	1	1	1	1	1	1	-
I - 3	3	3	3	3	3	1	3	2
I - 4	3	1	1*	3	3	2	1	-
I - 5	1	1	1	1	1	2	1	1
I - 6	1	1	1	1	1	2	3	1
I - 7	3	1	1**	1	3	1	3	3
I - 8	3	3	3	1	3	1	3	-
I - 9	3	-	-	3	3	-	-	-
I - 10	3	1	3	1	3	1	3	3
I - 11	2	3	3	1	3	2	3	2
I - 13	1	1	1	1	1	2	3	-
I - 14	3	3	3	3	3	1	3	3
D - 1	3	1	2*	3	3	1	3	1
D - 2	3	3	3	3	3	3	3	2
D - 3	3	2	3	3	3	1	3	-
D - 4	2	1	2	3	3	2	3	2
D - 5	(1)	1	1	1	1	1	1	1
D - 6	(1)	1	1	3	1	2	3	-
D - 7	(1)	2	-	3	1	3	3	-
D - 8	(1)	3	3	3	3	3	3	2
D - 9	(1)	1	3	3	3	3	3	-
D - 10	(1)	3	3	3	3	3	3	-
D - 11	(1)	1	2	3	1	3	3	-
D - 12	(1)	1	1	3	1	2	1	-
D - 13	(1)	1	2	3	1	2	3	-
D - 14	(1)	3	3	3	3	2	3	-
D - 15	(2)	3	3	3	3	3	3	-
S - 1	2	1	1	1	1	2	1	-

Comment: ( ) tested with Danish cement (not high alkali).
*) index 3 after 40 weeks
**) index 2 after 40 weeks

By comparing the registered results from various methods, it can be seen from Table 2 that the best correlation exists between ASTM C 227 when used with high alkali cement, and modified versions of the T.I. and Q.C.T. methods.

The main purpose of this project was to provide a correlation between the test methods which could lead to a recommendation of a fast, reliable Nordtest method. In view of the obtained test results, the following observations have been made:

ASTM C 227 MORTAR BAR METHOD

This method has been a standard method in Iceland and is the best established method available. It gives reliable information of sands reactivity when used with high alkali cement. It also gives information of the reactivity of reactive sand used with different types of cement.

T.I. MORTAR BAR METHOD (8 weeks criteria)

After 8 weeks most Icelandic sands and some Danish sands are still expanding. The 8 weeks criteria is therefore, in many cases, unsuitable.

MODIFIED T.I. MORTAR BAR METHOD (20 weeks criteria)

Even though some sands are still expanding after 20 weeks a good correlation is obtained with ASTM C 227 and Q.C.T. modified.

This method with the 20 weeks criteria can hardly be classified as fast, taking up to 6 months. A great many sands with high reactivity can be classified considerably faster (8 weeks).

ASTM C 289 QUICK CHEMICAL TEST

This method with the reactivity criteria given in ASTM and shown in Fig. 1 gives limited practical information and is therefore not suitable.

ASTM C 289 (Q.C.T.) - MODIFIED

By modifying the reactivity criteria this method gives an excellent correlation to ASTM C 228 mortar bar method and also to the modified T.I. method.

The modified criteria are based on the amount of soluble silica, but not on reduction in alkalinity.

In the present investigation the best classification was obtained by using 100 mMole dissolved silica per litre as criteria.

VORBEUGENDE MASSNAHMEN

This method proved not to be reliable to judge the reactivity of sands.

PETROGRAPHIC ANALYSIS

This method gives good results in Denmark where the reactive aggregate types are well known and easily recognizable. In Iceland, where the reactive aggregates are not that well known, it is often difficult to distinguish between reactive and non-reactive basalt by petrographic means.

5. CONCLUSIONS

Comparison of 5 different test methods for evaluation of the alkali-silica reactivity of sands was performed on 14 Icelandic, 15 Danish, and 1 Swedish sand.

Generally a good agreement was found between the different methods. After modification of the exposure time for the T.I.-mortar bar expansion method to 20 weeks and modification of the borderline between reactive and non-reactive aggregates in the Quick Chemical Test, excellent agreement was found.

The other chemical method ("Vorbeugende Massnahmen") was not suitable to test Icelandic sands and failed on some of the Danish sands, too.

6. REFERENCES

1) Olafsson, H. and Thaulow, N. - Nordtest Project 173-79, Final Report 1981

2) Chatterji, S. - Cement and Conc.Res. 8, 647, 1978

3) Vorbeugende Massnahmen gegen schädigende Alkalireaktion im Beton - Beton 24, 5, 179-185, 1974.

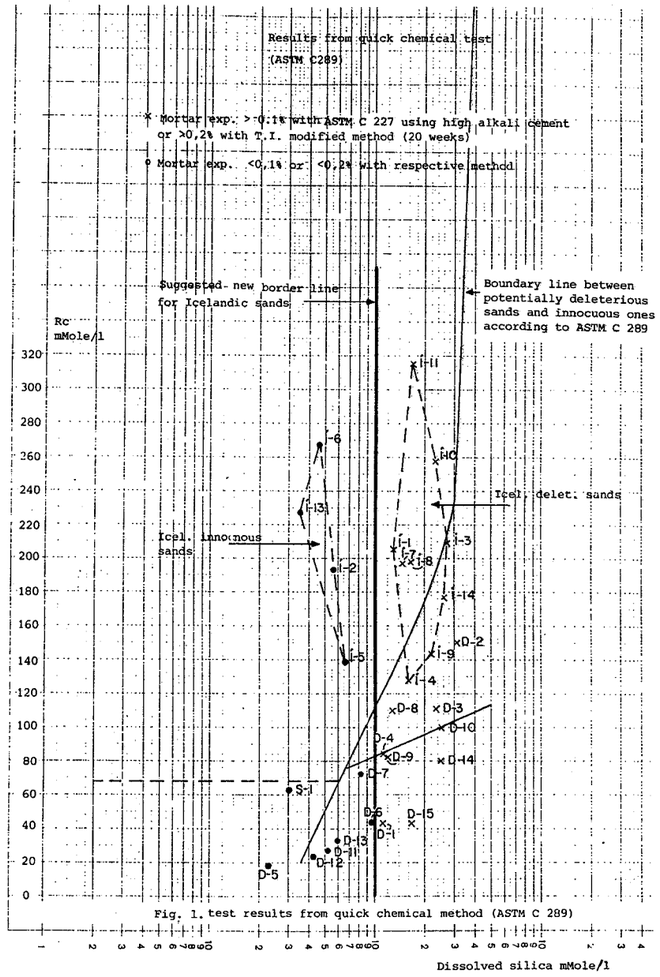

Fig. 1. test results from quick chemical method (ASTM C 289)

ASSESSMENT OF AGGREGATE REACTIVITY TESTS AND SIGNIFICANCE OF TEST RESULTS

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SUMMARY

There has been some continuing controversy about the validity of different test procedures, the significance of test data and the correctness of conclusions drawn from them. This paper examines the various objections levelled against the tests and explains the difficulties encountered in assessing the significance of the test data.

INTRODUCTION

Various qualitative tests have been devised to demonstrate aggregate reactivity. These tests generally show changes in the aggregate or in the hardened mortar. Observable changes in the aggregate and mortar must be assessed visually and somewhat subjectively by the operator. These tests can, however, yield very pertinent information about aggregate reactivity if properly evaluated by an experienced assessor.

Quantitative tests are of two different types, namely:

(a) A mortar bar expansion test, designated A.S.T.M. C-227, which was developed from the original studies of Stanton (1940) and
(b) A chemical reaction test, designated A.S.T.M. C-289, originally devised by Mielenz et al (1947).

Both tests yield numerical data which must be effectively evaluated. The validity, repeatability and correctness of the rapid chemical test results have been widely criticized. It is considered, however, that these criticisms are not soundly based and that, despite certain defects in the method, the chemical test yields data which permit a very rapid and reasonably accurate estimate of potential aggregate reactivity to be made. The rapid chemical test results can be confirmed by the slow developing expansions of cement-aggregate combinations in the mortar bar test. All the observable symptoms and the chemical and mortar bar test data must invariably be consistent and assessed with due allowances being made for anomalies in samples and sampling, for minor variations in test results and for the expected exposure conditions and working duty of the concrete.

THE MORTAR BAR EXPANSION TEST

The mortar bar expansion test permits performance studies on specific cement-aggregate combinations, the measurement of expansion of specimens and the observation of aggregate reaction and mortar or concrete damage when exposed to specified environmental conditions. The relatively long time required for significant aggregate reaction and mortar or concrete expansion to develop constitutes the major disadvantage of this test.

Various material and procedural factors, which can be varied arbitrarily, significantly affect the rates of aggregate reaction and mortar or concrete expansion. Such factors as amount of reactive component in the aggregate, size of reactive particles, mortar or concrete composition and compaction, cement alkali content, water/cement ratio, storage temperature of specimens, rate of drying etc., affect the test results. Consequently, accelerated test procedures,