INVESTIGATIONS ON ICELANDIC POZZOLANS

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SUMMARY

The pozzolanicity of various Icelandic natural pozzolans is discussed. The main groups of minerals tested were tuffs, ignimbrites and rhyolites. As the raw materials readily available for cement production in Iceland are high in alkalis the production of pozzolan cement seem a natural solution to the problem of counteracting harmful concrete expansions considering the potential reactivity of some Icelandic aggregates.

It is concluded that many of the pozzolans studied have sufficient pozzolanic activity to be used in pozzolan cement.

In Iceland many minerals of volcanic origin are found which are high in silica and alumina content. Previous tests performed by the author at the Building Research Institute show that some of these minerals possess pozzolanic properties. Materials like rhyolite, diatomite and pumice, finely ground and mixed with cement may reduce alkali aggregate expansions to such an extent that the risk of damage due to alkali aggregate reaction for most reactive materials in this country is greatly diminished.

Test results have indicated that of the three minerals mentioned the diatomite has the greatest pozzolanic activity and rhyolite the least.

Rhyolite has been used for some years for the production of pozzolanic cement in the Icelandic Cement Factory. Because of the better pozzolanic properties of pumice and diatomite the possibility of using them was considered. Unfortunately none of these materials are found in sufficient quantity near the factory and their use is therefore not economically possible.

For the common concrete producer who wishes to produce pozzolanic concrete the use of pozzolanic cement is the easiest way.

In this country reactive concrete materials are found but most of them have a low reactivity compared to known cases elsewhere. This fact and the relatively low temperature level should greatly reduce the danger of alkali aggregate reactions in Icelandic structures. The great importance of hydraulic structures in this country however, the wet climate, and the extremely high alkali content of the cement produced in Iceland will aggravate the situation.

As the raw materials available for cement production are very high in alkalis the production of pozzolan cement seems to be the most natural solution to the problem of counteracting harmful expansions. For the present production of pozzolan cement, the rhyolite selected on the basis of a previous investigation is used (1). As the use of pumice and diatomite was not of interest the possibility of other materials found in the vicinity of the cement factory was considered. It was known that in this area minerals are found with chemical and mineralogical composition of natural pozzolans. In order to find better pozzolans for the manufacture of pozzolan cement, and also to investigate the natur and properties of these materials, a search was made for such materials in this area and the area surrounding Reykjavík (2).

Fifteen samples were brought in for investigation. They were all finely ground and attempted to obtain a specific surface of ca. 8000 cm^2/g measured by the Blaine method. The grindability of th various samples was very varied and generally lower than expected Thus ground with the available laboratory equipment the specific surface of the samples proved to be 4500-8000 cm^2/g.

After grinding the pozzolans were mixed with an Icelandic portland cement in the proportion of 1:3 by weight (i.e. 25% pozzolan replacement). The portland cement had a fineness of 3900 cm^2/g and an alkali content (Na_2O equivalent) of 1,5%. All tests in this investigation were made with preblended pozzolan cements.

Three different tests were made:

1. Pozzolanicity test for pozzolanic cements, ISO-Recomendation 863-1968(E).
2. Test on compressive strength according to the Rilem-Cembureau method.
3. Test on alkali aggregate reaction, mortar bar method (ASTM C227-71).

The results of the pozzolanicity test are shown on Diagram 1. Of the samples the numbers 1, 3, 7, 13 and 14 are various types of basaltic tuffs with a silica content of about 50%. The silica percentage referes to a material without bound water which varies considerably from one tuff to another, or from 5% to 20%. The alumina content of the tuffs was about 13-15%.

Samples number 4, 5, 6 and 9 consist of ignimbritic rock. The silica content of these varies from 58-74% and the alumina content from 13-16%. These samples also have quite varying bound water content or from 1% to 12%.

Three of the samples are rhyolites, no. 2, 11 and 15, no. 15 being the rhyolite presently used for the production of pozzolan cement in the cement factory. The rhyolite samples have a silica content of 70% to 76%, alumina content 12% to 15% and bound water content of 1% to 6%.

The last two samples are sedimentary rock (no. 10) and pitchstone (no. 12).

The diagram shows that all the cement samples tested can be considered pozzolanic.

On Diagram 2 the compressive strength at 28 days is expressed against the fineness of the pozzolan cement. The bottom figures are the fineness of the pozzolan.

This diagram also expresses the grindability of the various samples. It shows that the tuffs no. 1 and 2, are very easily ground to a specific surface of 10 000 cm^2/g and more. The rhyolite presently used for pozzolan cement is rather easy to grind but most of the other samples were difficult to grind to higher fineness.

The test results show that the 28 day compressive strength of th pozzolan cements with a specific surface of 4200 to 5000 cm²/g reaches from 70% up to ca. 90% of that of the portland cement alone. The results also indicate, that the strength increases with greater specific surface of the pozzolans. Sample no. 2 has higher strength after 28 days than the basic portland cement Other samples showing good strength results are 4, 9 and 14 wher the two first are ignimbrites with high silica and alumina conte No. 14 is a tuff with low silica content, but no. 2 is a rhyolit with high silica content.

Diagram 3 shows the expansion of mortar bars made with the pozzolan cements against the fineness of the cements. The expansion of the portland cement alone is 0,122% after 6 months at 38°C. Most of the pozzolan samples show an expansion of 0,013-0,022% after 6 months, which is about one fifth or less of the expansion of the portland cement alone. In this connection it must be pointed out that the alkali content of mixes made with the pozzolanic cement is not the same as for those with portlan cement alone. The alkali content of the pozzolans is in most cases higher than that of the cement, but no relation could be determined between alkali content of a pozzolan and its effecti ness in counteracting expansion.

Diagram 4 shows more clearly the relations between the expansio of the different pozzolan cements.

The pozzolans most effective in counteracting expansion are the samples 6, 7 and 10 e.g. ignimbrite, tuff (pillow lava tuff) and sediment. As all these samples are rather coarsely ground, high fineness may not be absolutely necessary to reduce harmful expansions. The effect of the chemical composition is not quite clear. Comparing the strength test results and reduction of alkali aggregate expansions of the three main groups of materials used, tuffs, ignimbrite and rhyolites, the ignimbrites seem to have the strongest pozzolanic properties.

Finally it may be concluded that the above results show that many of the pozzolans included in this investigation have sufficient pozzolanic activity to be used in pozzolan cement. The different fineness of the pozzolans make an exact evaluation of the pozzolanic properties very difficult, since the relation between fineness and strength development and reduction in expansion is not known for these materials. Costa and Massazza (3) have stated that not only the specific surface affects the pozzolanic activity of natural pozzolans, but also the chemical and physical state, mainly the active silica and alumina content of the pozzolans.

The next step in this investigation will be to investigate these properties and how they will affect strength and expansion.

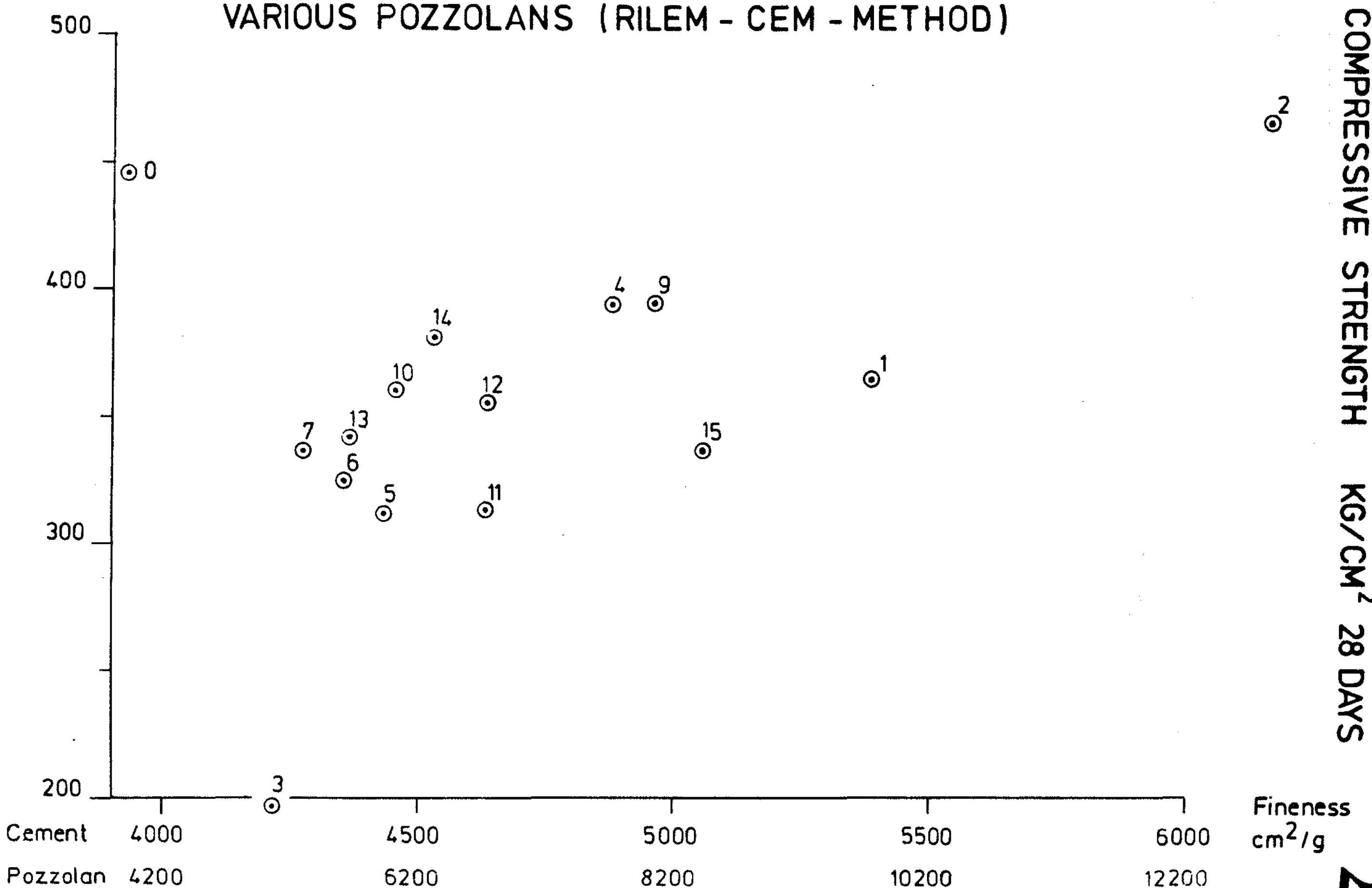
REFERENCES

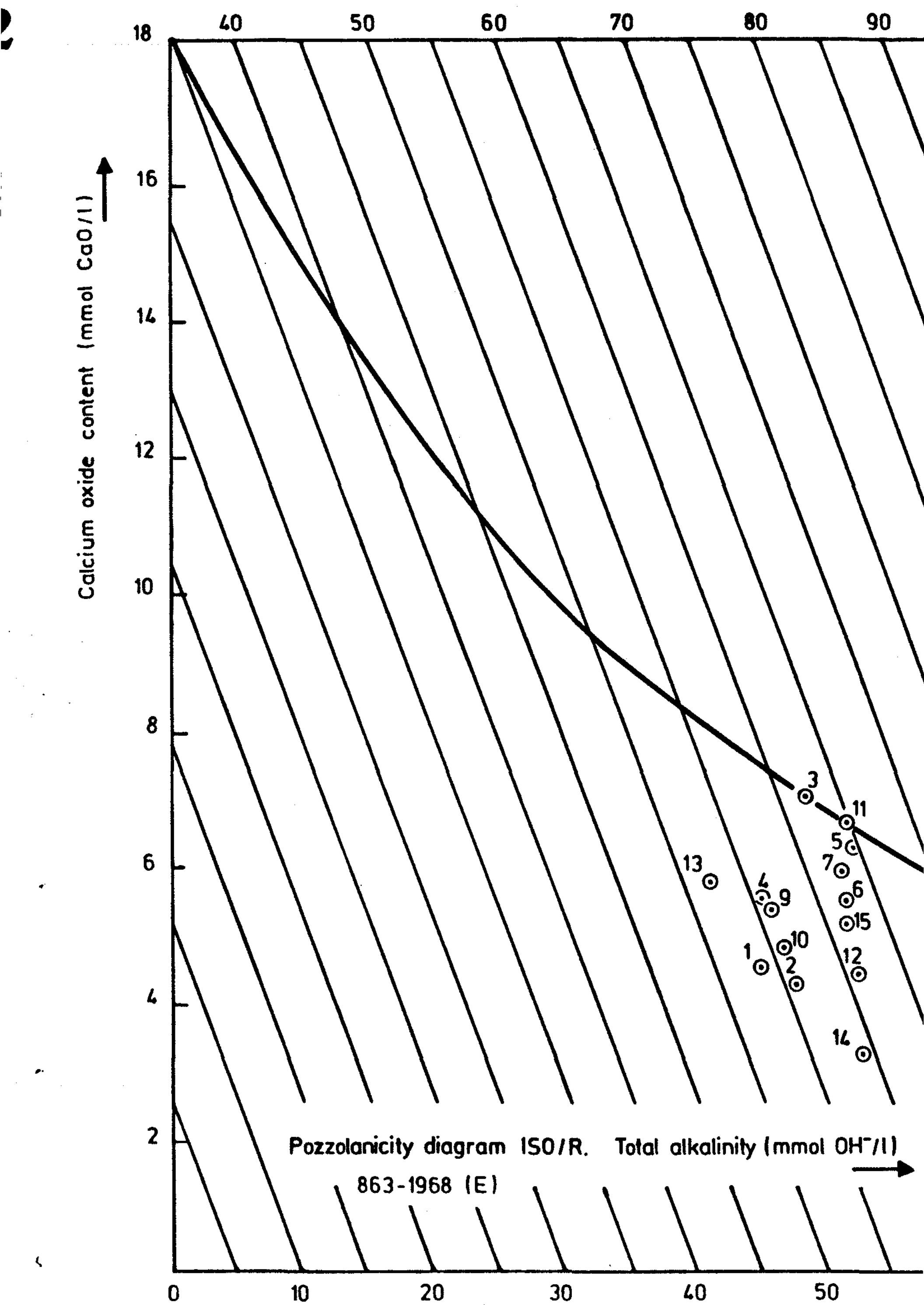
(1) Gudmundsson, G., and Ásgeirsson, H., Some Investigations on Alkali-Aggregate Reaction, Cement and Concrete Research 5, 211-220 (1975)

(2) Sæmundsson, K., Geological Prospecting for Pozzolanic Materials in Iceland, Reykjavik 1975.

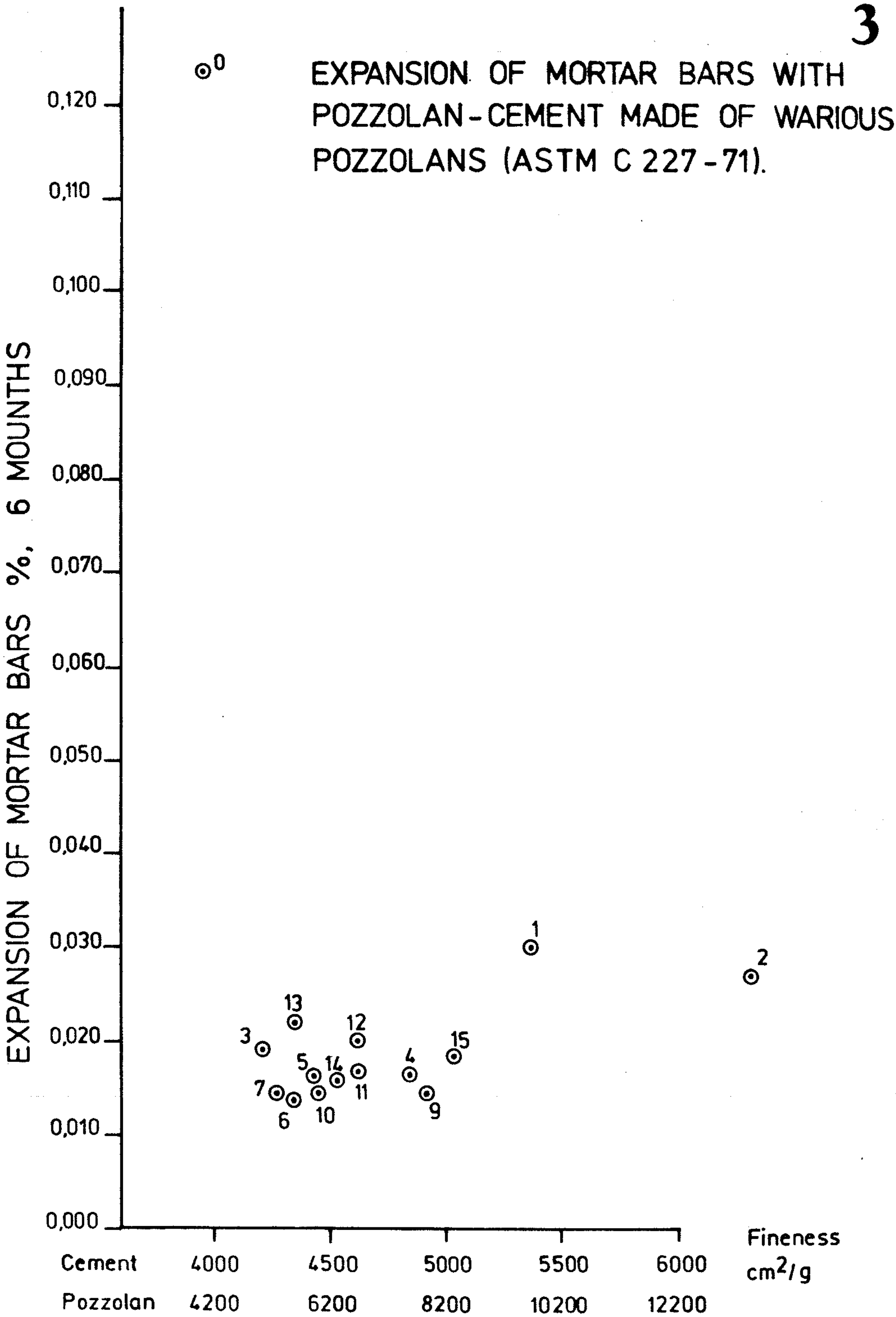
(3) Costa, U., and Massazza, F., Factors Affecting the Reaction with Lime of Italian Pozzolanas, Il cemento 3, 131 (1974).

COMPRESSIVE STRENGTH OF POZZOLAN - CEMENT WITH VARIOUS POZZOLANS (RILEM - CEM - METHOD)





Calcium oxide content (mmol CaO/l)
Pozzolanicity diagram ISO/R. 863-1968 (E)
Total alkalinity (mmol OH⁻/l)
18
16
14
12
10
8
6
4
2
0
10
20
30
40
50
40
50
60
70
80
90
1
2
3
4
5
6
7
9
10
11
12
13
14
15


EXPANSION OF MORTAR BARS WITH POZZOLAN-CEMENT MADE OF WARIOUS POZZOLANS (ASTM C 227-71).
EXPANSION OF MORTAR BARS %, 6 MOUNTHS
0,120
0,110
0,100
0,090
0,080
0,070
0,060
0,050
0,040
0,030
0,020
0,010
0,000
0
1
2
3
4
5
6
7
9
10
11
12
13
14
15
Fineness cm2/g
Cement
4000
4500
5000
5500
6000
Pozzolan
4200
6200
8200
10200
12200

EXPANSION OF MORTAR BARS WITH POZZOLAN-CEMENT MADE OF VARIOUS POZZOLANS (ASTM C 227-71).