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AAR PROBLEMS IN ICELAND—PRESENT STATE

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ABSTRACT

Alkali content in Icelandic cement is high and some aggregates are reactive. Therefore precautions were taken concerning all constructions other than housing. In housing concrete cast in the period 1960-1979 serious AAR problems occur. From 1979 no serious AAR cases have been found, thanks to preventive measures taken, silica fume replacement in cement being the most important one. Research on remedial measures for AAR damaged concrete is of high priority.

1. INTRODUCTION

Cement and concrete making in Iceland is unique in many ways. Geologically, the country is so young that calcareous raw materials are only to be found as off-shore sea-shell deposits, and for argillaceous material rhyolitic rock must be used. Because of this, Icelandic cement has a low silica content and is high in alkalies with an Na_2O equivalent of around 1,5%.

Being aware of the potential danger of alkali-aggregate reaction in structures subjected to a high degree of moisture such as harbors, dams and bridges precautions were taken, using inoccuous aggregates, imported low alkali cement or pozzolan cement. No serious damage caused by alkali aggregate reactions have been found in these constructions.

In house construction no such precautions were taken. This was partly due to the belief that such constructions were not vulnerable to alkali-aggregate reactions because of low moisture content, partly that no knowledge was of damages in such constructions anywere else and special precautions would have increased building cost.

Even though reactive aggregates are relatively common the ASR damage in Iceland is to a great extent due to one aggregate source, Hvalfjord sand. This is due to the fact that this material, seadredged and unwashed, was used increasingly for concrete making in the most populated area in the period 1962-1979. This area, Reykjavik and surroundings, happens to have the most unfavorable climate with frequent driving rain and numerous freeze - thaw cycles during wintertime, which is the ideal conditions for interplay between frost action and AAR damage in concrete. When use of these aggregates was started mortar bar tests carried out by the Icelandic Building Research Institute showed that they were reactive and the municipal authorities were warned of the potential danger. No direct actions were taken though.

In an extensive field study, carried out in 1977-1978 and published early in 1979, it was found that AAR damage was a major problem in housing concrete in the Reykjavik area [1].

2. PREVENTIVE MEASURES

Six months after the publication of the before mentioned report several preventive measures were taken. Of these the most important were:

- changing the criteria on reactive materials
- blending silica fume into the Icelandic Portland cement
- requesting washing of sea-dredged gravel materials
- limiting the use of the active gravel source.

As previously mentioned the principal test method used for evaluating alkali-silica reaction is the well-known ASTM-C227 mortar bar method. The ASTM 6-months criterion of 0,1% expansion was at first used for guidance. In 1979, however, the Icelandic building code demanded a stricter criterion or 0,05% in six months and 0,1% in 12 months. The reason for this can easily be seen in fig. 1. The 6 months expansion is not a good indicator of the total expansions of most Icelandic aggregates, while the expansion in 12 months is a far better one.

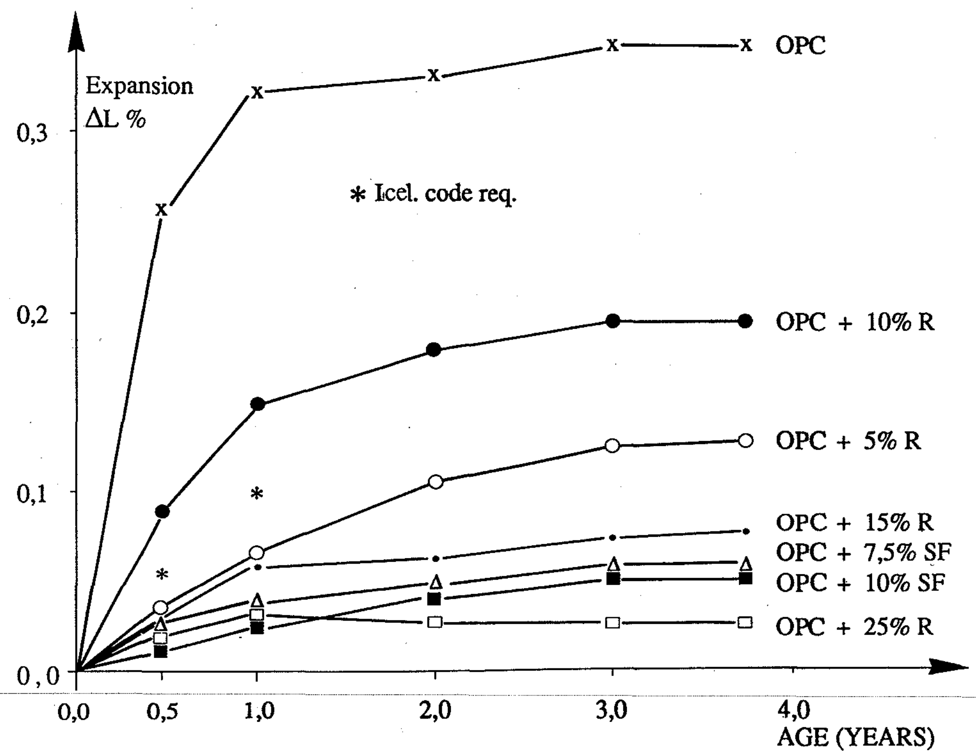

Fig. 1 Rhyolite (R) and silica fume (SF) vs. mortar bar expansion (Hvalfjord sand). [2]

Interest in silica fume in Iceland dates back to 1972, when the first samples of the material were tested as early as a ferro-silicon plant was conceived in the country. Figure 1 shows what may be considered as primary results of our endeavour. In line with this the State Cement Works has since 1979 only produced cement with intermixed silica fume, first with 5% replacement but since 1983 with 7 1/2%. Research at BRI has shown that such a limited amount is highly effective to preventing deleterious expansion. There are no serious negative side effects such as higher water requirement or increased drying shrinkage, wereas a higher dosage has these side effects. [3,4,5,6]

Another building code restriction is that since 1979 unwashed sedredged aggregates are banned. The reason for this ban is easily read from Figure 2, and the explanation for this effect of sea water is that NaCl from the sea may exchange ions with Ca(0H) liberated during the cement hydration and form Na0H which increases the alkalinity of the concrete and its alkali reactivity.

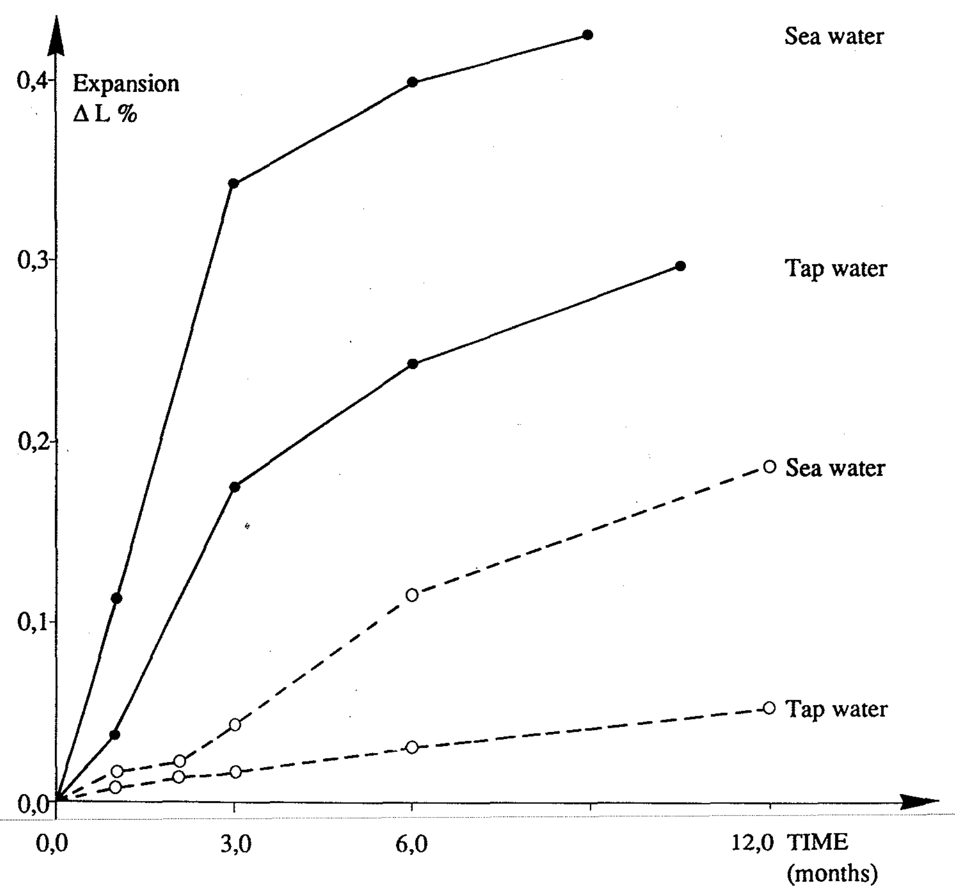

Fig. 2 The influence of sea water on mortar bar expansion due to alkali-silica reactions (Hvalfjord sand). [2]

3. CURRENT STATE

When this conference is held, precisely 10 years have passed since the before mentioned preventive measures were taken. This should be long enough a period to justify looking back and seeing what experience one has from these preventive actions. This can roughly be sumarised in the following way:

- No cases of concrete damage, due to AAR has been found. Every third year a field survey is undertaken on representative number of houses built after 1979. Cores are taken from all houses with map cracking for further examination in the laboratory. After visual inspection of cores and microscopey, these are stored in a chamber with temperature 38° C and 100% humidity for a year, and then examined again for gel, cracks and reaction rims in aggregates. Only minor traces of gel and reaction rims have been found in a few cores, contrary to earlier experience with the same type of concrete without silica fume were these AAR indicators were found in most cores. [7-11]

- Because of increased cement strength with added silica fume, the w/c ratio in the concrete went up and the amount of cement content down for a period of time, in cases were requirements were placed on strength and air entrainment. This has in some cases led to less durable concrete so direct criteria concerning these factors had to be put in the building code for different exposure classes.

- The concrete producers as well as the workers are happy with the silica blended concrete.

4. PROTECTION OF AAR DAMAGED CONCRETE

The main task concerning AAR reactions in Iceland today is the maintenance of concrete houses previously damaged by AAR. A few research projects have been carried out showing close relationship between moisture content and AAR expansions on one hand and map cracking due to AAR and frost damage on the other hand [12]. This has led to the conclusion that by reducing the moisture content in concrete AAR damage can be reduced; and freeze-thaw damage as well, but in the most populated region in Iceland the climatic conditions are very severe in terms of freeze-thaw cycles and driving rain as previously mentioned.

Methods for decreasing moisture content in exteriour walls of concrete houses have been tested [13,14]. Favorable effects have been registerd by use of ventilated panels, with or without insulation, with impregnation of hydrophobing materials (silanes, siloxans and silicones) without or in combination with paints, and with high permeability renderings applied on insulation.

Due to theese results, hydrophobing materials are now widely used on houses with signs of AAR damages in the first fase, or potentially vulnerable for AAR damage. Tests have also shown a considerable benefici-al effect of silanes on freeze-thaw resistance of concrete with w/c-ratio over 0,55 and insufficient air entrainment [14]. For more severely damaged houses claddings or renderings are used.

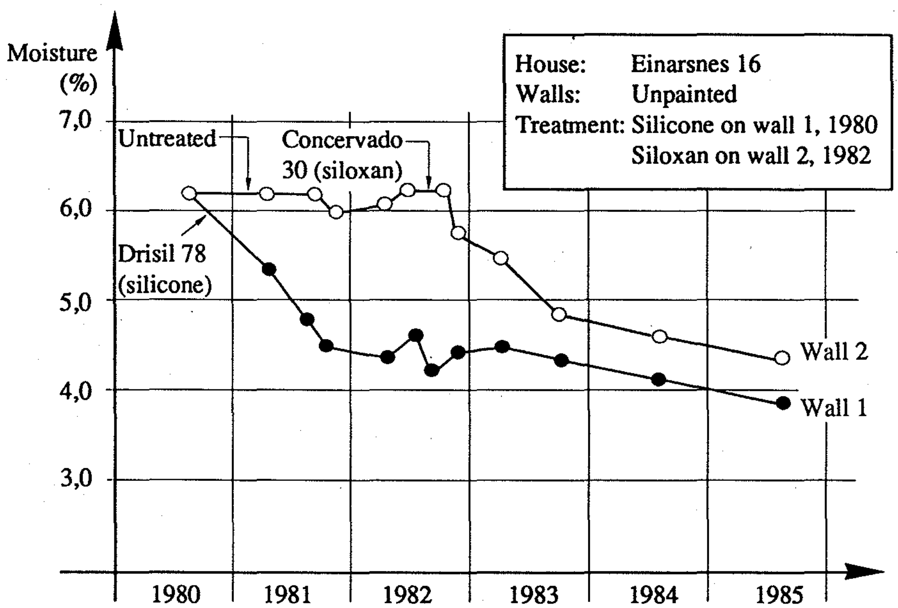

Fig. 3 Moisture development in concrete after imprgnation with silicone (Disil 78 and siloxan (Conservado 30). [14]

4. PROSPECTS

It is a general opinion, based on laboratory tests and practical experience, that ASR will not cause extensive damage in concrete produced after 1979. Isolated cases of ASR damage can not be totally excluded since the amount of silica fume in the cement is theoretically not enough to bind all the OH ions in the concrete, and traces of alkali-silica gel has been observed in a few cases. Also one has to bear in mind that silica fume as well as some other possolanas delay expansions as well as reduce them thus affecting the acceptence criteria of some standard test methods [6].

The activities concerning ASR in the near future will be focussed on the following main areas:

- field surveys. These will be continued, on excerpt of houses intended for information on the general quality of concrete as well as AAR. Also eventual cases of AAR damage will be studied.
- research. The current research project dealing with interacti-on between ASR and freeze-thaw resistance will be continued. Especially will frost actions in and around silica gel be studied. Further studies on the reactivity of Icelandic aggregates and classification of these by petrographic methods will be undertaken.
- remedial measures on ASR damaged concrete. Following up on the projects already reported as well as testing new methods and materials.

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