The Effect of Relative Humidity and Temperature on Alkali Expansion of Mortar Bars

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ABSTRACT

In recent years considerable research and full scale experiments have been carried out in order to deminish deleterious expansion in exterior walls of concrete houses in Iceland. All attempts have primarily been aimed at reducing the moisture content of concrete. Too little is hitherto known of the effect of different moisture contents on the expansions.

This paper shows expansion of mortar bars stored at different RH levels, ranging from 73-100% at two different temperatures for up to two years. The bars are cast with high alkali cement (Na_2O-eq 1,5%) and natural aggregates known to have caused deleterious expansion in concrete.

The results are presented and discussed with special regard to both rate of expansion and total expansion.

INTRODUCTION

In the period 1961-1978 sea dredged alkali reactive aggregates were used to great extent in concrete homes in Reykjavik and vicinity. Shortly before or in 1958, the Icelandic Cement factory started production of Icelandic Cement which was high in alkalies, with Na_2O-eq appx. 1,5. This unfortunate combination lead to extensive map cracking and consequent freeze-thaw damage in exterior walls of many severly exposed houses built in this period.

At the 6th AAR conference held in Copenhagen 1983 the author presented a paper on Repair of Vulnerable Concrete, where full scale experiments of reducing moisture content in exterior walls, and thereby reducing or stopping the deteriorating processes were described and some results shown. Some such methods are now widely used in this country with favorable results.

The work which this paper is based upon was carried out in the last two years and is to be continued. It´s aim is to clarify the effect of relative humidity and temperature on alkali-aggregate expansion and therby provide a sounder basis for technical advice on measures for preventing, delaying or stopping deterioration from alkali-aggregate reactions and the consequent frost damage.

EXPERIMENTAL

For these experiments mortar bars and test methods specified by ASTM C227 were used. Washed Hvalfjordur sand was used as aggregate since this sand had caused deterioration of concrete. Unblended Icelandic Portland cement was used containing Na_2O eq = 1,5. Constant humidity was obtained by use of saturated salt solutions. The following solutions were used:

H_2O	giving	100%	RH
$KClO_3$	"	96-97%	"
KNO_3	"	90-92%	"
KCl	"	83-85%	"
$NaNO_3$	"	72-74%	"

The mortar bars were stored in sealed glass containers kept at 38°C and 23°C at the above mentioned RH levels. At fixed time intervals, 1-, 3-, 6-, 12-, 18- and 22 months, the length and weight of the mortar bars were measured and they were photographed. Their degree of cracking and visible signs of reactions were registered, see table 1. Two identical series were run simultaneously and the results presented are mean values from these two series.

RESULTS AND DISCUSSION

Total expansion of the mortar bars are shown in fig. 1 and 2. In fig. 1 it can be seen that at a temperature of 38°C expansion at the highest RH levels stops after 12 months while mortar bars at lower RH-levels are still expanding after 22 months. Total expansion is seemingly decreasing with decreasing RH under 95% although this difference is less when expansion is corrected for drying shrinkage at the lower RH levels. In fig. 2 it can be seen that at 23°C expansion is slower than at the 38°C level, and that difference in expansion between RH levels is obviously greater even after correction for drying shrinkage. Thus total expansions at 90% RH are less than 40% of the expansions at 100% RH and less than 30% of the expansions at 38°C and 100% RH.

The rates of expansion are plotted in fig. 3 and 4. It can clearly be seen that the max. expansion rate decreases rapidly with decreasing RH (under 95%) both at 38°C and 23°C. It can also be observed especially from the 38°C rates, that after expansion has culminated at the higher RH levels expansion at lower levels is still going on. By comparing these two figures one can clearly see the great effect of temperature on the rate of expansion; the max. rate at 23°C being only 1/3-1/5 of the max. rate at 38°C.

The effect of RH on expansions at 38°C and 23°C is shown in fig. 5. Even though expansions at the lowest RH levels are not completly finished it seems clear that by decreasing the RH level expansions can be reduced considerably.

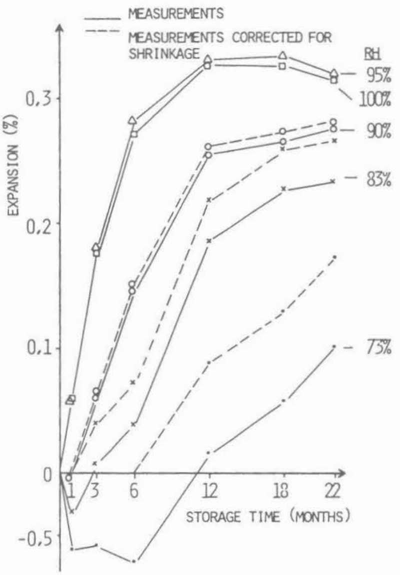


Fig. 1 - Expansion of mortar bars at temperature 38°C and RH 73-100%

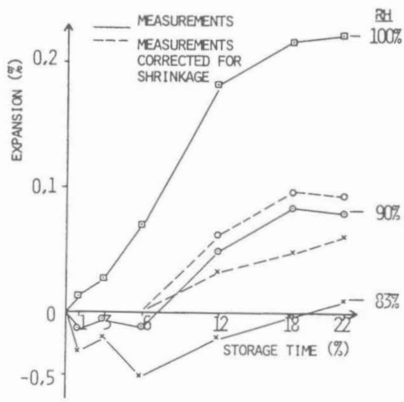


Fig. 2 - Expansion of mortar bars at temperature 23°C and RH levels 83-100%

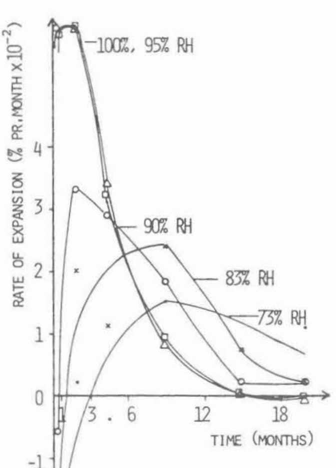


Fig. 3 - Rate of expansion of mortar bars at t = 38°C and RH = 73-100%

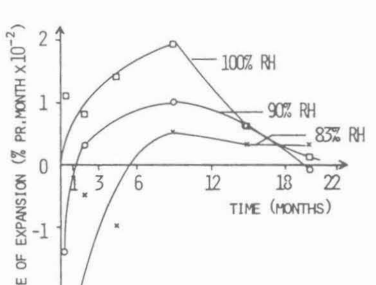


Fig. 4 - Rate of expansion of mortar bars at t = 23°C and RH = 83-100%

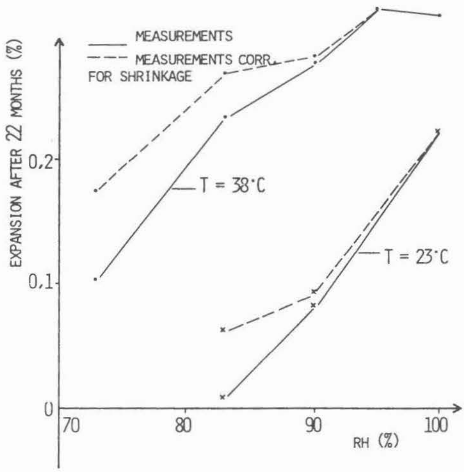


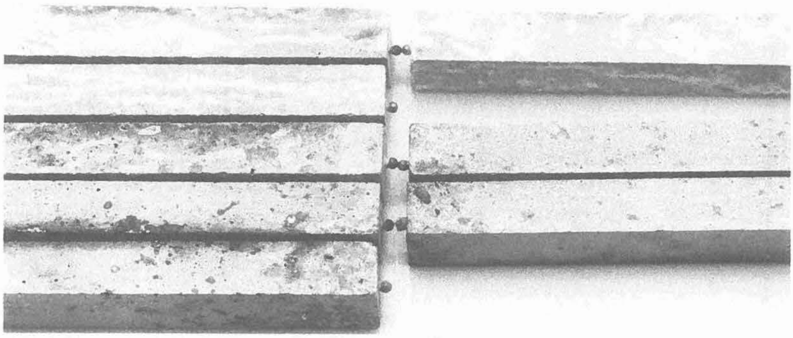
Fig. 5 - The effect of temperature on mortar bar expansion as function of relative humidity

In table 1 visual signs of AAR, such as reaction spots, gel and cracks are graded. In fig. 6 bars from the two series are shown after 2 years in storage jars. If visual signs of AAR are compared with measured expansions it seems to give a relativly good indication of the expansions.

Table 1 - grading of visual signs of AAR

Observations	Temp. (°C)	RH (%)	Storage time (months) 1	3	6	12	22
Visable signs of AAR on mortar bars	38	100	3	3	4	5	5
		95	3	3	4	5	5
		90	1	2	2	3	3
		83	0	1	1	1	2
		73	0	0	0	1	1
	23	100	1	2	2	3	4
		90	0	1	1	1	2
		83	0	0	0-1	0-1	1

Scale of grading: 0-5
0 = no signs, 5 = dominating signs (videly distributed reaction spots, gel and cracks).



a) b)

Fig. 6 - Mortar bars after 2 years in storage jars:
a) at 38°C and RH = 73, 83, 90, 95 and 100%.
b) at 23°C and RH = 83, 90 and 100%.

CONCLUSIONS

From the results presented in this paper the following conclusions can be drawn:

1. By reducing the relative humidity from 100% to below 90% the total expansion caused by alkali aggregate expansion can be reduced. The lower the RH the greater is the reduction in expansion. Decreased rate of expansion delays deterioration.

2. Expansion is a function of temperature. By preventing high temperatures in concrete, e.g. by using light colors on exterior walls instead of dark ones or by shielding them from the sunshine, expansions and rate of expansion is diminished.

REFERENCES

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