DEVELOPMENT OF AN ACCELERATED PERFORMANCE TEST ON CONCRETE FOR EVALUATING ITS RESISTANCE TO AAR.

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An expansion test, performed at 60°C and 100 % R.H., was developped and went through an interlaboratory study, in view of being included in the Recommandations for the prevention of the damage due to AAR of the French Ministry of Equipment.
This test constitutes a performance approach in a general decisionnal chart, to evaluate the ability of a given formulation of concrete to withstand the Alkali Aggregate Reaction.

INTRODUCTION

In France, the "Provisional Recommandations for the prevention of damage due to AAR", which were prepared under the aegis of the Ministry of Equipment, specify the required level of prevention for a concrete structure, depending on its nature and its environment, as well as the checking procedures for obtaining that level.
For most of the buildings and civil engineering works, one possibility consists in submitting the concrete to a performance test.
In this paper, we describe the performance test, which has been developped by the French Cement Industry.

PRINCIPLE OF THE TEST

The concrete is prepared in the laboratory as it is designed for the work, then it is casted in three 7x7x28 cm moulds with special inserts for length measurements. The specimens are then cured in a water-saturated atmosphere at 60°C and their lengths are periodically measured.

The main steps of the testing procedure are the following:

. The specimens remain in their moulds for 24 h at 20°C and a relative humidity greater than 90 %.
. After demoulding, the specimens are immersed for 30 mn in water at 20°C; their lengths are then measured (Lo).
. The specimens are then introduced in an airtight capped container with a 35 mm layer of water on the bottom. The container is put into a reactor generating steam at 60°C ± 2°C (Figure 1).

. Every two weeks, the container is taken out of the reactor and cooled in a 20°C and 100 % R.H. atmosphere, without removing the cap. After 24 h of cooling, the specimens are taken out of the container and their lengths are measured (Ln).
. After measuring, the specimens are put back into the container which is itself put back into the reactor for a new two-week period of time.

INTERLABORATORY STUDY

Coordinated by ATILH, a round robin test was settled between four laboratories: Ciments Français (CF), Ciments Lafarge (CL), Groupe Origny (GO) and Vicat (V). CEDEST was associated for further tests, which are not reported here.
The study was conducted as follows:
1) All the specimens of one concrete were made from the same batch, and were then dispatched to the four laboratories.
2) Three specimens of each concrete were tested in each laboratory.

Composition of tested concretes

Eighteen different concretes were designed from:

. Three potentially reactive ("PR") aggregates and three non-reactive ("NR") ones. The characteristics of the aggregates are given in figure 2.

. Three OPC cements with equivalent Na2O content of, respectively, 0.25 %, 0.75 %, and 1.05 %.

The composition of the eighteen concretes are given in figure 3.

. For all concretes, the cement content was fixed: 400 kg/m3.
. The alkali content of six concretes were increased by adding sodium hydroxide.
. In three concretes, a water-reducing agent was added to evaluate the influence of a water/cement ratio reduction on the expansion.

Results

Figures 5, 7, and 9 show the interlab mean values of expansion curves, for the three groups of concretes, respectively, "GPR1", "GPR2", and "SPR3".
Figures 4, 6, and 8 show the values of expansion obtained by the four laboratories, for the most expansive concrete in each group, respectively, N°6 ("GPR1"), N°11 ("GPR2"), and N°17 ("SPR3").

Comments on the results

1) The scattering of the results between the four laboratories is lower than the scattering of three single values (three specimens) obtained from one concrete, in one laboratory.

2) For all concretes, the expansion is nearly complete after 3 months (2 months for "GPR1" concretes).

3) The influence of the alkali content on the expansion is very "steep" for "GPR1" concretes (large gap between 4.2 and 5 kg/m3 curves), more gradual for "GPR2" concretes, and very "flat" for "SPR3" concretes.

4) The values of expansion are very low for "SPR3" concretes. These values were confirmed by preparing a new series of identical concretes and submitting them to the same interlaboratory study.

5) Alkalies from cement and alkalies from sodium hydroxide have more or less the same activity (comparison between concrete curves 5 and 6 in figure 5).

6) A greater compactness of the concrete, due to a water reduction, induces a greater expansion (comparison between concrete curves 1 and 2 in figure 5, and concrete curves 9 and 10 in figure 7).

PROPOSAL FOR A DECISIONAL CRITERIA OF THE TEST

To fix the critical threshold of expansion, a comparison has been made between the values obtained in the present test conditions (60°C, 100 % R.H.), and the values obtained on similar specimens, according to NF P 18-587 (test conditions: 38°C, 100 % R.H.) in which critical threshold is 0.04 % at 8 months.

This comparison was made in the laboratory of Ciments Lafarge, on:
. the 18 "interlab" concretes, described above,
. 27 "Lafarge" concretes, which characteristics are given in figure 10.

The expansion curves obtained at 38°C and 60°C for the 18 most expansive "Lafarge" concretes, are compared in figure 11.

In figure 12, the expansion values obtained at 60°C and 2 months, for both series of concretes, are plotted versus values obtained at 38°C and 8 months. Except for some very expansive concretes (L3, L5, L18), the correlation is quite good. According to the least squares line, the corresponding value for 0.04 % at 38°C is 0.024 % at 60°C.
This last value, which still needs to be confirmed, can be taken as a provisional threshold for the test interpretation.

CONCLUSION

More than 45 concretes were submitted to the expansion test which was developped in the laboratories of French cement industry.
Through a round robin test, its reproducibility could be evaluated: the scattering of the interlab mean values is lower than the scattering of the single values obtained from one concrete (3 specimens), in one laboratory.
From the comparison between the values of expansion obtained in the test conditions and those obtained according to NF P 18-587, a provisional threshold can be proposed for the test interpretation .

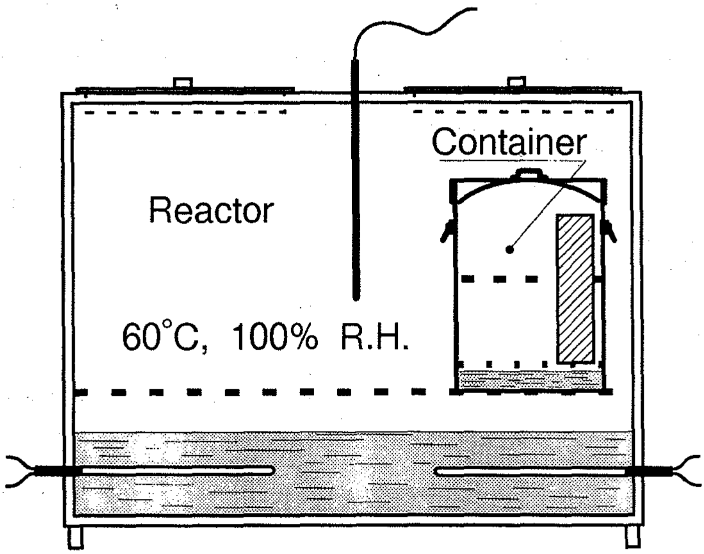

Figure 1: Reactor

	GRAVEL			SAND		
	GPR1	GPR2	GNR3	SNR1	SNR2	SPR3
L.O.I.	1.63	14.85	1.58	42.00	43.80	12.74
SiO2	97.43	55.00	64.30	3.52	0.00	59.00
Al2O3	0.35	5.01	12.55	0.40	0.06	7.32
Fe2O3	0.42	2.15	9.38	0.42	0.03	2.70
TiO2	0.04	0.26		0.02	0.00	
MnO	0.00	0.05		0.01	0.00	
CaO	0.22	19.11	6.56	52.85	55.49	14.80
MgO	0.00	1.06	0.00	0.42	0.45	0.86
SO3	0.07	0.05	0.00	0.17	0.05	0.00
K2O	0.11	0.86	2.55	0.10	0.00	1.36
Na2O	0.04	1.13	2.44	0.00	0.01	0.88
P2O5	0.02	0.11		0.01	0.01	
Calcite	x	x		xxxxx	xxxxx	24 %
Quartz	xx	x	xxxx	x		28 %
Orthose		x	xx			25 %
Plagioclases		x	xx			9 %
Micas		x	x			13 %
Dolomite				x	x	1 %
Crypto. SiO2	80 %					
Chlorite		x				
Cordiérite		x				

Figure 2: Characteristics of aggregates

INTERLAB CONCRETES	GRAVEL	SAND	eq.Na2O (kg/m3) Total(*)	NaOH	Water Reduc.
1	GPR1	SNR1	4,2	-	
2			4,2	-	x
3			1	-	
4			3	-	
5			5	4	
6			5	0,8	
7	GPR2	SNR2	1	-	
8			3	-	
9			4,2	-	
10			4,2	-	x
11			5	0,8	
12	GNR3	SPR3	3	-	
13			1	-	
14			7	6	
15			4,2	-	
16			4,2	-	x
17			5	0,8	
18	GNR3	SNR2	5	0,8	

(*) except the contribution of aggregates

Figure 3: Composition of "interlab" concretes

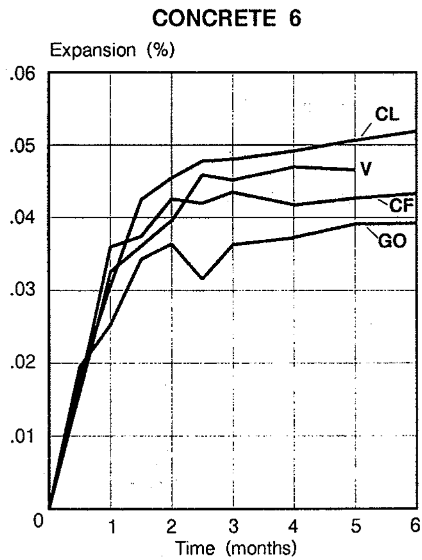

Figure 4: Expansion curves of concrete N°6

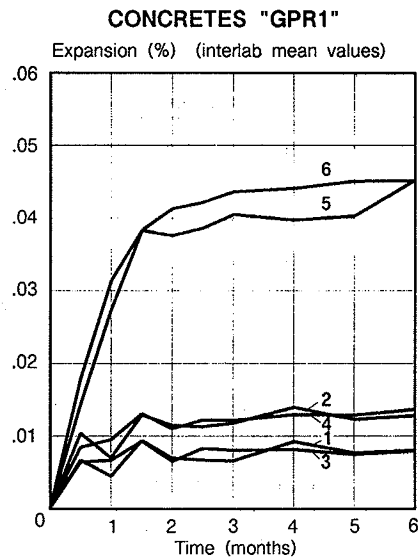

Figure 5: Expansion curves of "GPR1" concretes

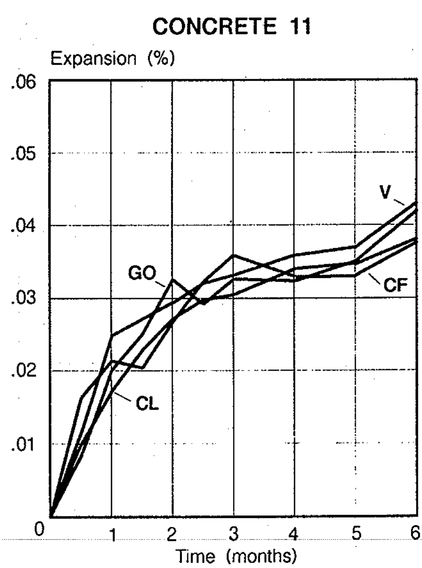

Figure 6: Expansion curves of concrete N°11

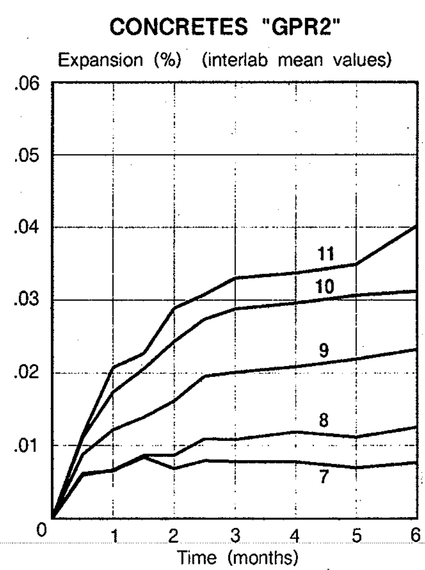

Figure 7: Expansion curves of "GPR2" concretes

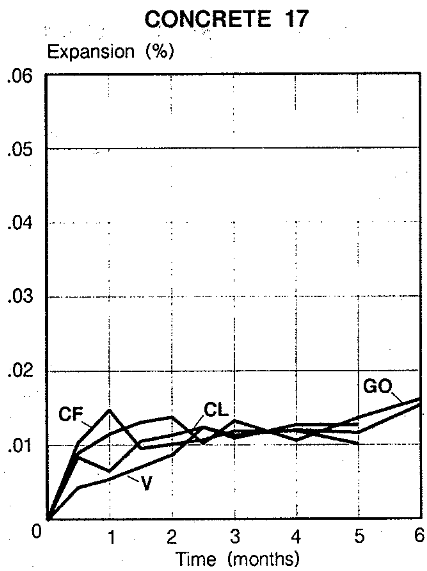

Figure 8: Expansion curves of concrete N°17

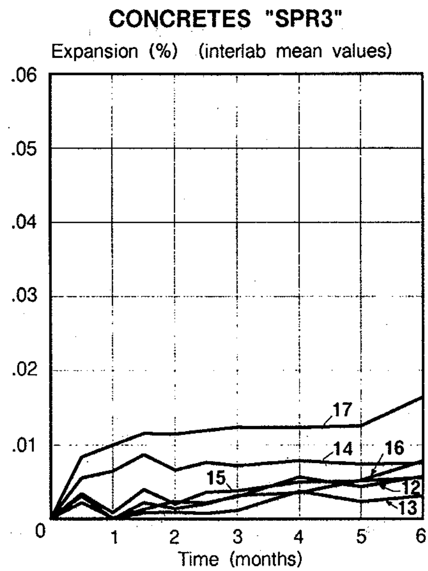

Figure 9: Expansion curves of "SPR3" concretes

CONCRETES "LAFARGE"	AGGREGATES	eq.Na2O (kg/m3)
L1	SPRATT	5.1
L2	SUDBURY	
L3	PITTSBURG	
L4	CHAMBON	
L5	POSTDAM BEAUHARNOIS	
L6	POSTDAM LES CEDRES	
L7		
L8	WALLERS	
L9		
L10		
L11		
L12		
L13	OMYA	
L14		3.9
L15		5,1
L16		
L17		
L18	CALCINATED FLINT	
L19		3,9
L20		3,9
L21		1,2
L22		2
L23		1
L24		
L25		
L26		3,9
L27		3,9

Figure 10: Composition of "Lafarge" concretes

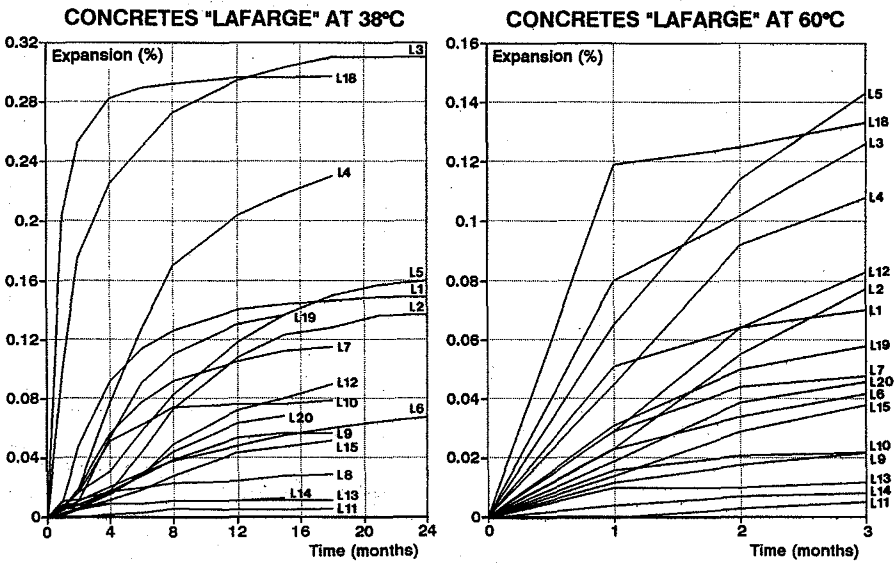

Figure 11: Expansion curves of "Lafarge" concretes

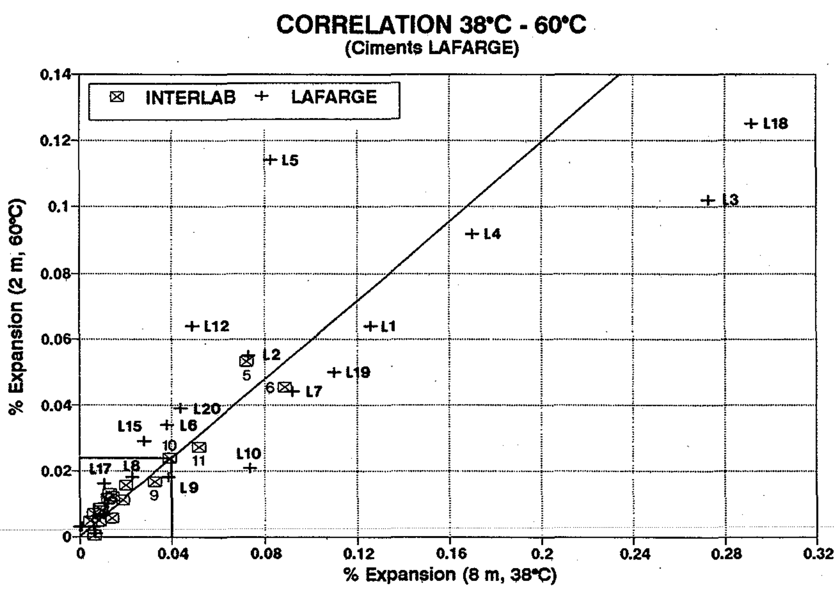

Figure 12: Correlation 38°C - 60°C