A SIMPLE AUTOCLAVE MORTAR BAR METHOD FOR ASSESSING POTENTIAL ALKALI-AGGREGATE REACTIVITY IN CONCRETE

M.-A. Bérubé*, B. Fournier**, N. Dupont*, P. Mongeau* and J. Frenette*
* Départment de Géologie, Université Laval, Québec City, Québec, Canada, G1K 7P4.
** CANMET-EMR, Resource Utilization Laboratory, Ottawa, Ontario, Canada, K1A 0G1.

Mortar bars are made in accordance with ASTM C 227, but with a constant w/c of 0.50 and an alkali content of 3.5% (Na_2O eq.) of the cement mass (NaOH addition to the mixture water). The bars are placed in an autoclave commonly used for testing hydraulic cement, under 0.17 MPa (≈130°C) for 5 hours. The test was applied to more than one hundred aggregates of various compositions. For sands, gravels and carbonate aggregates, a 0.15% expansion limit criterion was used to differentiate deleterious or potentially deleterious aggregates from innocuous ones, and a 0.10% criterion was used for quarried silicate aggregates. The Autoclave Mortar Bar Method was better than the Accelerated Mortar Bar Method ASTM C-9 Proposal P 214 (or NBRI), in properly identifying reactive and non-reactive aggregates, particularly for sands and quarried silicate aggregates.

INTRODUCTION

A number of authors have proposed testing methods for potential alkali-aggregate reactivity which involve steam curing or boiling mortar or concrete specimens in water or alkaline solutions under relatively high temperatures and pressures. The dimensions of the samples tested, as well as the mixture proportions used and the procedure adopted, vary from one author to another but they generally consist of modified versions of original methods proposed by Tang et al. (1), Tamura et al. (2) or Nishibayashi et al. (3). The potential alkali-reactivity of the investigated aggregates is determined by measurement of length change (Tang & Nishibayashi methods), or by visual inspection of surface cracking and measurements of internal degradation (loss in dynamic modulus of elasticity and ultrasonic velocity) (Tamura Method). These methods generally gave reliable results, at least for the limited number of aggregates investigated. They were recently reviewed by Hobbs (4), Grattan-Bellew (5), Fournier et al. (6) and Bérubé and Fournier (7). Since 1987, a new autoclave method has been investigated at Laval University (Québec City, Canada). Up until now, more than one hundred aggregates of various compositions have been tested. This paper recalls the test procedure used and summarizes the results obtained so far.

PRELIMINARY WORK

The main objective of this research was to develop a simple test, using existing and commonly used laboratory equipment and procedures. The following conditions were first established: [1], test specimens consisting of mortar bars made according to ASTM C 227; [2], test procedure following ASTM C 151 (Autoclave expansion of Portland cement), and [3], test performable in one working day (excluding preparation and precuring of the mortar bars). The influence of various parameters, such as alkali content of the mortar mixture (1.0-3.5% Na_2O eq. of the cement mass), type of cement, water/cement (0.45-0.60), pressure-temperature conditions (0.1-1.0 MPa), and steam curing time (4-8 hours) in the autoclave, was then evaluated on a number of reactive and non-reactive carbonate and silicate aggregates. The results of this preliminary work on carbonate aggregates are detailed in (6). Let us recall that:

- A very high alkali content (3.5% Na_2O eq. of the cement mass) was needed for better differentiating innocuous and deleterious samples.
- The various ASTM type I cements tested produced no significant effect in mortar bar expansion, provided the total alkali content was controlled to 3.5% (Na_2O eq.) by adding NaOH.
- In general, expansion decreased with increasing the w/c, as observed in other tests performed at 100% RH on mortar (ASTM C 227) or concrete specimens (CAN/CSA A23.2-14A) (7).
- Non reactive aggregates expanded significantly at temperatures ≥150°C (≥0.34 MPa).
- For reactive aggregates, the expansion progressively increased when increasing the alkali content of the mixtures from 1.0 to 3.5% Na_2O eq., as well as the duration and the pressure-temperature of the steam curing, while these parameters had no significant effect on non-reactive aggregates.

TEST PROCEDURE, EXPERIMENTAL VARIABILITY AND REACTION PRODUCTS

In accordance with the results from the preliminary work, and the information found in the literature, the following test procedure was adopted (Figure 1):

1) Mortar bars are made according to ASTM C 227, but using a fixed water/cement of 0.50. The total alkali content of the mortar mixture is raised to 3.5% (Na_2O equivalent) of the cement mass by adding NaOH to the mixture water.
2) After 2 days of precuring at 23°C and 100% R.H., the bars are measured ("T0" reading).
3) The autoclave treatment follows the general procedure described in Section 10 of ASTM C 151 test method, with a few modifications. The period of steam curing is fixed at 5 hours, which represents the maximum time for the test to be completed in a single working day. The temperature (pressure) of curing is 130°C (25 PSI - 0.17 MPa).
4) The final measurement is taken after the bars have been progressively cooled to room temperature, as described in the ASTM C 151 test procedure (Figure 1).

The experimental variability of the method was evaluated by repeating the test 7 times over a 3 month period, with the same cement and the same aggregate, and by the same operator. The repeatability was very good, with a coefficient of variation of only 4.4% (6). Petrographic examination with the SEM of mortar bars containing reactive siliceous carbonate and silicate aggregates, and subjected to the autoclave test revealed the presence of usual ASR silico-calco-alkaline massive gels lining microcracks and pores of the cement paste. The classical well-formed rosette-like products were, however, not observed inside test mortar bars made with carbonate aggregates (6), thus suggesting that these are end-products, and that they are possibly not involved in the short term expansion produced by alkali-silica reaction.

APPLICATION TO QUARRIED CARBONATE AGGREGATES

Autoclave tests were performed by Fournier et al. (6) on 40 limestone and dolostone samples from the St.Lawrence Lowlands (Table 1). Reference concrete prisms were made in accordance with the Concrete Prism Method CAN/CSA-A23.2-14A, but using a cement content of 350 kg/m^3 rather than 310 kg/m^3. A limit of 0.04% expansion at 6 months was used to distinguish reactive or potentially reactive aggregates from non-reactive ones. An extensive field survey performed over the past five years in the St.Lawrence Lowlands indicated that such a limit (for CSA concrete made with a cement content of 350 kg/m^3) was in good agreement with the known field performance of the aggregates tested. In fact, the Trenton limestones are non-reactive to very reactive in concrete structures, a few Black River limestones are deleteriously reactive in the field, while the Chazy dolomitic/sandy limestones and the Beekmantown dolostones have not shown any AAR related problems up until now, except for a particular dolostone in a few dams (8). The results obtained are presented in Table 1 and on Figure 2. Using a 5-hour, 0.15% expansion limit criterion in autoclave, the potential reactivity of 100% [20/20] of the samples which significantly expanded in the concrete test (>0.04% at 6 months) is recognized, while 80% [16/20] of the non-expansive samples (in concrete) were properly classified. This percentage is similar for the four geological groups: 80, 80, 83 and 75% for Trenton, Black River, Chazy and Beekmantown, respectively. The overall effectiveness of the method, e.g. the percentage of all samples that were correctly evaluated, was 90% [36/40], varying from 75% to 96% from one geological group to another.

TABLE 1 - Results for quarried carbonate aggregates.

Geological group (Number of samples)	Trenton (23)		Black River (7)		Chazy (6)	Beek. (4)	Total (40)	
CSA Concrete Prism Test	R	NR	R	NR	NR	NR	R	NR
Expansion limit criterion = 0.04% at 6 months	18 (78%)	5 (22%)	2 (29%)	5 (71%)	6 (100%)	4 (100%)	20 (50%)	20 (50%)
Autoclave Mortar Bar Test								
Samples showing exp. >0.15% at 5 h	18 (100%)	1 (20%)	2 (100%)	1 (20%)	1 (17%)	1 (25%)	20 (100%)	4 (20%)
Samples showing exp. <0.15% at 5 h	0 (0%)	4 (80%)	0 (0%)	4 (80%)	5 (83%)	3 (75%)	0 (0%)	16 (80%)
Overall effectiveness	22/23 96%		6/7 86%		5/6 83%	3/4 75%	36/40 90%	

TABLE 2 - Results for quarried silicate aggregates.

No.	Rock type	Performance in the field[1]	CSA Concrete Prism % exp.-1y	CSA Concrete Prism Classified[2]	Autoclave Mortar Bar % exp.-5h	Autoclave Mortar Bar Classified[3]
	Innocuous or presumably innocuous aggregates in concrete structures					
1	Andesite	Presumably good	0.010	NR	0.317	R
2	Anorthosite	Not used in concrete	0.019	NR	0.035	NR
3	Basalte	Presumably good	0.005	NR	0.050	NR
4	Charnockite	Presumably good	0.014	NR	0.060	NR
5	Hornfel I	Presumably good	0.018	NR	0.224	R
6	Diorite	Innocuous	0.015	NR	0.061	NR
7	Gabbro	Presumably good	0.017	NR	0.064	NR
8	Granitic gneiss I	Innocuous	0.029	NR	0.095	±NR
9	Granite	Innocuous	0.018	NR	0.053	NR
10	Greywacke I	Innocuous	0.016	NR	0.210	R
11	Phonolite I	Innocuous	0.014	NR	0.039	NR
12	Quartzite	Not used in concrete	0.015	NR	0.038	NR
13	Syenite	Innocuous	0.012	NR	0.038	NR
	Deleterious aggregates in concrete structures					
14	Potsdam sandst. I	Deleteriously reactive	0.069	R	0.102	±R
15	Chloritic schist	Deleteriously reactive	0.046	R	0.173	R
16	Siliceous shale	Deleteriously reactive	0.089	R	0.523	R
17	Rhyolitic tuff I	Deleteriously reactive	0.224	R	0.275	R

Performance evaluation of the autoclave test	Classified as non-reactive		Classified as reactive	
• Innocuous or presumably innocuous aggregates:	10/13	(77%)	3/13	(23%)
• Deleteriously reactive aggregates:	-	-	4/4	(100%)
• Overall effectiveness:	14/17 (82%)			

1: Presumably good: aggregates used in many structures with no reported AAR until now. Innocuous: aggregates with satisfactory field record.
2: Limit of 0.04% expansion at 1 year.
3: Limit of 0.1% expansion at 5 hours.

APPLICATION TO QUARRIED SILICATE AGGREGATES

In a second step, autoclave tests were performed on 17 quarried silicate aggregates from Québec (Table 2). Reference concrete prisms were made in accordance with the method CAN/CSA-A23.2-14A, but raising the alkali content to 1.17% (Na_2O equivalent) of the cement mass (rather than 1.25%). A 1-year, 0.04% expansion limit criterion was used to distinguish reactive or potentially reactive aggregates from non-reactive ones. Up until now, all aggregates which expanded less have not been reported until now to be deleteriously reactive in the field. The results are presented in Table 2 and on Figure 3. Using the same limit as above for aggregate acceptance, e.g. 0.15% expansion after 5 hours of autoclaving, one of the 4 deleterious silicate aggregates tested was not detected (Potsdam sandstone I), while 77% [10/13] of the innocuous or presumably innocuous samples were correctly classified, for an overall effectiveness of 76% [13/17]. In order to allow detection of all reactive silicate aggregates tested, the limit must be lowered to 0.1%, in which case the overall effectiveness increases to 82% [14/17].

TABLE 3 - Results for aggregates used in Canadian dams.

No.	Rock type	Provenance	CSA Concrete Prism[1] % exp.-6m	CSA Concrete Prism[1] Classified[2]	Autoclave Mortar Bar % exp.-5h	Autoclave Mortar Bar Classified[3]
Innocuous aggregates in dams						
1	Phonolite II[4]	Québec	0.020	NR	0.064	NR
2	Granitic gneiss II	Québec	0.014	NR	0.066	NR
Deleteriously reactive aggregates in dams						
3	Potsdam sandstone II	Québec	0.122	R	0.146	R
4	Rhyolitic tuff IV	Québec	0.192	R	0.407	R
5	Dolostone	Québec	0.063	R	0.125	R
6	Metagreywacke	Québec	0.086	R	0.171	R
7	Greywacke III	Nova Scotia	0.127	R	0.240	R
8	Greywacke IV	New Brunswick	0.164	R	0.365	R
9	Greywacke V	Ontario	0.100	R	0.279	R
10	Rhyolitic porphyry	Ontario	0.139	R	0.289	R
11	Lithic gravel	Alberta	0.092	R	0.287	R

Performance evaluation of the autoclave test	Classified as non-reactive		Classified as reactive	
• Innocuous aggregates in dams:	2/2	(100%)	0/2	(0%)
• Deleteriously reactive aggregates in dams:	0/9	(0%)	9/9	(100%)
• Overall effectiveness:	11/11 (100%)			

1: CSA prisms stored at 38°C in NaOH 1N. 2: Expansion limit of 0.04% at 6 months.
3: Expansion limit of 0.10% at 5 hours. 4: Non-reactive control; not used in dams.

APPLICATION TO AGGREGATES USED IN CANADIAN DAMS

The autoclave test was applied to a number of aggregates that were identified as deleteriously reactive in Canadian dams (8) (Table 3). The current Concrete Prism Method CAN/CSA A23.2-14A failed in detecting 4 of the 9 reactive aggregates tested. Other concrete test procedures were investigated in this study, all at 38°C: 1), CSA concrete in NaOH 1N; 2), CSA+ concrete at 100% R.H. (e.g. CSA concrete with a higher cement content of 410 kg/m^3); 3), mass concrete at 100% R.H.(mix design approaching those used in existing mass structures), and 4), mass concrete in NaOH 1N. Testing CSA or mass concrete in NaOH 1N was the only way to properly classify all the aggregates investigated (9 reactive and 2 non-reactive), according to a limit of 0.04% expansion at 6 months (CSA concrete) or 1 year (mass concrete). The accuracy of the autoclave mortar bar method was evaluated in accordance with the results obtained for the CSA concrete prisms immersed in NaOH. The results are presented in Table 3 and on Figure 3. Using the same limit as for the quarried silicate aggregates, e.g. 0.10% after 5 hours of autoclaving, all 11 aggregates tested were correctly evaluated. In fact, nine of the eleven aggregates tested in this project on mass concrete were also quarried silicate aggregates, and again a limit of 0.1% appears appropriate.

APPLICATION TO SANDS AND GRAVELS

Gravel samples from 19 sources currently producing concrete aggregates in Québec, sand samples from 18 of these sources, and one reactive gravel from Sudbury (Ontario, Canada) (Magni et al. (9)), used as a reference, were also tested with the autoclave method by Mongeau (10). They are grouped in Table 4 according to their geological association and provenance. All Grenville and Superior samples from Québec are mostly composed of granitic rock types (granitic gneiss, granite, diorite, syenite,...). Limestone is a major constituent in gravels from the eastern Appalachians (Gaspé Peninsula), except in one case (#12), while greywacke is the rock type leader in gravels from the western Appalachians. Despite no systematic survey of the concrete structures built with these aggregates, only a few at the most are thought to be deleteriously reactive in field concrete, apparently in three dams located in the Appalachians (8). Reference concrete prisms were made in accordance with the Concrete Prism Method CAN/CSA-A23.2-14A. However, the 1-year, 0.04% expansion limit criterion was extended to 1.5 years to allow time for the reference reactive gravel (Sudbury) to develop significant expansion (i.e. >0.04%). Only three among the 20 gravels tested expanded more than 0.04% at 1.5 years in concrete (#12, #13 and #20), including the Sudbury sample. One dam made with local natural aggregates and affected by ASR was located in each of the two areas represented by the two other expansive aggregates from Quebec. When lacking information concerning the field performance of the aggregates investigated, the above expansion limit (0.04% at 1.5 years in the CSA concrete test) was used to distinguish between reactive or potentially reactive aggregates and non-reactive ones. The accuracy of the autoclave mortar bar method was evaluated in accordance with this limit criterion. The results are presented in Table 4 and on Figure 4. Using a limit of 0.15% expansion after 5 hours in autoclave allows detection of all three expansive gravel aggregates (in concrete), while classifying as non-reactive 53% [9/17] of the non expansive samples, for an overall effectiveness of only 60% [12/20]. All granitic gravels from the Grenville and Superior geological provinces did not expand in concrete, while performing well in the autoclave method. The Sudbury gravel which belongs to the Superior province presents a different composition and expanded in both tests. The polygenic gravels from the Appalachians performed very badly in the autoclave test, which suggests that this test is very severe for this aggregate type. The sands were not tested in concrete but are assumed to perform like gravels from the same source; the two presumably reactive sands are classified as reactive with the autoclave test, while 69% [11/16] of the presumably non-reactive ones satisfy the limit of 0.15% at 5 hours, for an overall effectiveness of 72% [13/18] (Table 4), which is better than for parent gravels, possibly due to the severe reduction suffered by these coarser aggregates (crushing effect).

COMPARISON WITH MORTAR BAR METHOD ASTM C-9 PROPOSAL P 214 (OR NBRI)

The results of the 106 autoclave tests described above are compared in Table 5 and on Figure 5 with those obtained for the same samples in the Accelerated Mortar Bar Method ASTM C-9 Proposal P 214 (or NBRI) (6-8, 10, 11). The autoclave method performed as well as or better than the ASTM method for all types of aggregates, using in the ASTM test a 14-day, 0.1% expansion limit for quarried carbonate and silicate aggregates, and 0.2% for sands and gravels. In Figure 5, one can see that many non-reactive or presumably non-reactive aggregates, particularly sands and gravels (Figure 5C), expanded in the two accelerated methods, but more in the ASTM test. Using the limits suggested before for the different types of aggregates tested, e.g. <0.10% after 5 hours of autoclaving for quarried silicate aggregates, which includes the aggregates used in Canadian dams, <0.15% for quarried carbonate aggregates, and for sands and gravels, all 38 deleterious or presumably deleterious aggregates tested were detected, while 71% [48/68] of the

TABLE 4 - Results for sands and gravels.

No.	Petrographic composition (Principal rock types in %)	Concrete (gravels) % exp. (1.5 y)	Concrete (gravels) Classified as[1]	Autoclave (gravels) % exp. (5 h)	Autoclave (gravels) Classified as[2]	Autoclave (sands) % exp. (5 h)	Autoclave (sands) Classified as[2]
Gravels from the north shore of the St.Lawrence River (Grenville Geological Province)							
1	Granitic 67, diorite 18	0.013	NR	0.056	NR	0.050	NR
2	Granitic 52, diorite 31, quartzite 7	0.010	NR	0.045	NR	0.046	NR
3	Granitic 69, diorite 25	0.008	NR	0.052	NR	0.051	NR
4	Granitic 74, diorite 16, limestone 5	0.017	NR	0.064	NR	0.053	NR
5	Granitic 74, diorite 22	0.017	NR	0.039	NR	-	-
6	Granitic 44, anorthosite 25, syenite 23	0.011	NR	0.051	NR	0.048	NR
Gravels from the south-east ot the St.Lawrence River (Appalachians Geological Province)							
7	Limestone 86, schist 12	0.006	NR	0.197	R	0.154	±R
8	Limestone 50, greywacke 27, schist 18	0.014	NR	0.213	R	0.122	NR
9	Limestone 55, schist 30, greywacke 15	0.000	NR	0.191	R	0.156	±R
10	Limestone 36, greywacke 29, schist 22	0.012	NR	0.244	R	0.179	R
11	Limestone 85, greywacke 10, schist 10	0.009	NR	0.225	R	0.057	NR
12	Quartzite 21, limestone 16, schist 13, syenite 13, granitic 10, greywacke 9	0.051	R	0.208	R	0.228	R
Gravels from south-west of the St.Lawrence River (Appalachians Geological Province)							
13	Greywacke 33, schist 17, limestone 14, quartzite 14, granitic 11	0.041	±R	0.207	R	0.183	R
14	Greywacke 54, limestone 19, schist 18	0.000	NR	0.296	R	0.196	R
15	Greywacke 66, schist 18, quartzite 16	0.011	NR	0.197	R	0.181	R
16	Greywacke 48, quartzite 22, schist 20	0.009	NR	0.198	R	0.100	NR
Gravels from North-Western Québec and North-Eastern Ontario (Superior Geological Province)							
17	Granitic 50, diorite 20, greyw. 9, schist 8	0.027	NR	0.103	NR	0.129	NR
18	Diorite 40, granitic 31, andesite 10	0.025	NR	0.098	NR	0.089	NR
19	Diorite 62, granitic 22, andesite 16	0.036	NR	0.131	NR	0.121	NR
20[3]	Sandstone, greywacke, arkose, argillite	0.058	R	0.182	R	-	-

Performance of the autoclave test for gravels	Classified as non-reactive	Classified as reactive
• Innocuous or presumably innocuous:	9/17 (53%)	8/17 (47%)
• Deleteriously reactive or presumably so:	- -	3/3 (100%)
• Overall effectiveness:	12/20 (60%)	

Performance of the autoclave test for sands	Classified as non-reactive	Classified as reactive
• Innocuous or presumably innocuous[4]:	11/16 (69%)	5/16 (31%)
• Deleteriously reactive or presumably so[4]:	- -	2/2 (100%)
• Overall effectiveness:	13/18 (72%)	

1: Limit of 0.04% expansion at 1.5 years. 2: Limit of 0.15% expansion at 5 hours.
3: Gravel aggregate from Sudbury (Ontario) which is reactive in the field.
4: Assuming the same potential alkali-reactivity as for the gravel sample from the same source.

innocuous or presumably innocuous aggregates satisfied the proposed limit criteria, for an overall effectiveness of 81% [86/106]. With the ASTM C-9 Proposal P 214 (or NBRI) method, 62% [42/68] of the innocuous or presumably innocuous aggregates satisfied the proposed expansion limit criteria at 14 days, while one deleterious aggregate (Potsdam sandstone) was not detected (Figure 5B), for an overall effectiveness of 75% [79/106].

TABLE 5 - Comparison with the ASTM C-9 Proposal P 214 test method (or NBRI)

Aggregate type	Total tested	Reactivity[1] R (%)	Reactivity[1] NR (%)	ASTM C9-P214 Method[2] R (%)[4]	ASTM C9-P214 Method[2] NR (%)[5]	ASTM C9-P214 Method[2] Eff.(%)[6]	Autoclave Method[3] R (%)[4]	Autoclave Method[3] NR (%)[5]	Autoclave Method[3] Eff.(%)[6]
Carbonate	40	20 (50)	20 (50)	20 (100)	14 (70)	34 (85)	20 (100)	16 (80)	36 (90)
• Trenton	23	18 (78)	5(22)	18 (100)	4 (80)	22 (96)	18 (100)	4 (80)	22 (96)
• Black River	7	2 (29)	5 (71)	2 (100)	3 (60)	5 (71)	2 (100)	4 (80)	6 (86)
• Chazy	6	0 (0)	6 (100)	0 (100)	4 (67)	4 (67)	0 (100)	5 (83)	5 (83)
• Beekmantown	4	0 (0)	4 (100)	0 (100)	3 (75)	3 (75)	0 (100)	3 (75)	3 (75)
Quarried silicate	17	4 (24)	13 (76)	3 (75)	9 (69)	12 (71)	4 (100)	10 (77)	14 (82)
Used in dams	11	9 (82)	2 (18)	9 (100)	2 (100)	11 (100)	9 (100)	2 (100)	11 (100)
Sands / gravels	38	5 (13)	33 (87)	5 (100)	17 (52)	22 (58)	5 (100)	20 (61)	25 (66)
• Gravels	20	3 (15)	17 (85)	3 (100)	9 (53)	12 (60)	3 (100)	9 (53)	12 (60)
• Parent sands	18	2 (11)	16 (89)	2 (100)	8 (50)	10 (56)	2 (100)	11 (69)	13 (72)
All aggregates	106	38 (36)	68 (64)	37 (97)	42 (62)	79 (75)	38 (100)	48 (71)	86 (81)

1: Reactive (R) or non-reactive (NR), or presumably so, based on laboratory concrete testing and know field performance. The sands were not tested in concrete but assumed to perform like gravels from the same sources.
2: Expansion limit of 0.10% at 14 days; 0.2% for sands and gravels.
3: Expansion limit of 0.15% at 5 hours; 0.10% for silicate aggregates and those used in dams.
4: # and % of reactive or presumably reactive aggregates that were detected.
5: # and % of non-reactive or presumably non-reactive aggregates that satisfied the limit criteria.
6: # and % of all aggregates that were properly evaluated.

CONCLUSION

The autoclave mortar bar method under development at Laval University since 1987 and firstly published by Fournier et al. (6) is of great interest for the following reasons:

1. Test bars are made in accordance with the well-known ASTM C227 Mortar Bar Method.
2. The equipment needed (autoclave) is commonly used for testing cements.
3. The test procedure is very simple.
4. The test can be performed in one working day and the results can be obtained in only three days, including sample preparation and curing.
5. The experimental results obtained so far indicated that the test is more reliable than the Accelerated Mortar Bar Method ASTM C-9 Proposal P 214, which is similar to the corresponding NBRI method, in particular for sands and quarried silicate aggregates.
6. The ASR reaction products formed during the test are identical to those found in laboratory tests performed at lower temperature as well as in field concrete affected by ASR, which suggests that the reaction mechanisms are similar to those prevailing in less severe conditions.
7. The method was used with success in the evaluation of the effectiveness of mineral admixtures in suppressing expansion due to ASR, which is discussed by Duchesne & Bérubé (12).

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Mix Characteristics

Cement: High alkali type 10
Aggregates: Washed; grading according to ASTM C227
C/A: 1 : 2.25
W/C: 0.50 (Distilled water)
Alkali Content: Raised to 3.5% (Na_2O equivalent) with NaOH
Mix Procedure: According to ASTM C227
Size of Test Specimens (bars): 25 x 25 x 285 mm

2 days precuring

- 1 day in the molds
- 1 day in moist cabinet (23°C)

Measurement To (23°C)

Autoclave Treatment

Procedure: According to ASTM C151 (Autoclave Expansion of Portland Cement)
Amount of distilled water in the autoclave: 500 ml
Pressure used: 25 PSI (0.172 MPa) (Corresponding temperature: 130°C)
Curing time: 5 hours

Measurement T_{Final} (23°C)
% Expansion: $(T_{Final} - To)/ To * 100$

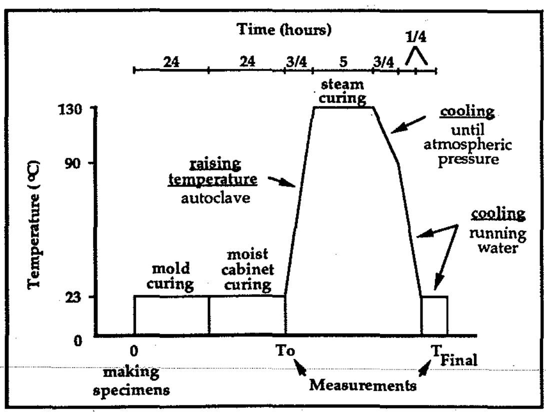
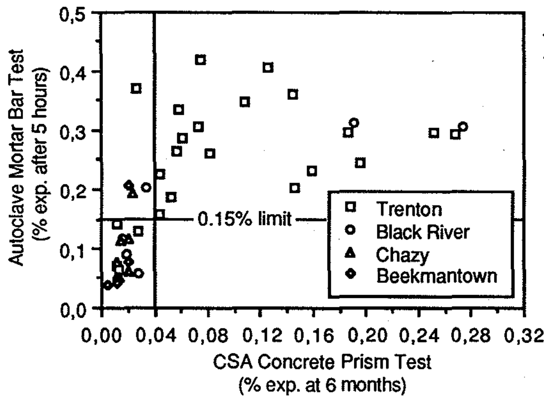
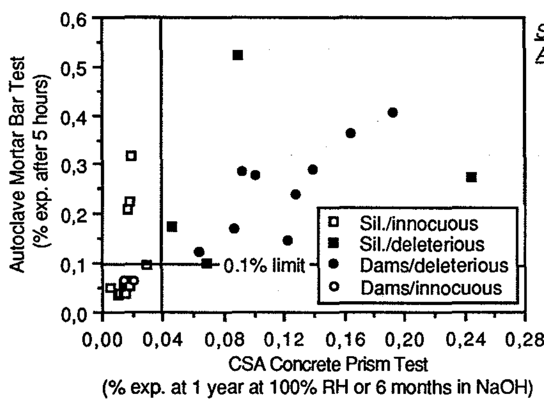


Figure 1: Test procedure used in the Autoclave Method.



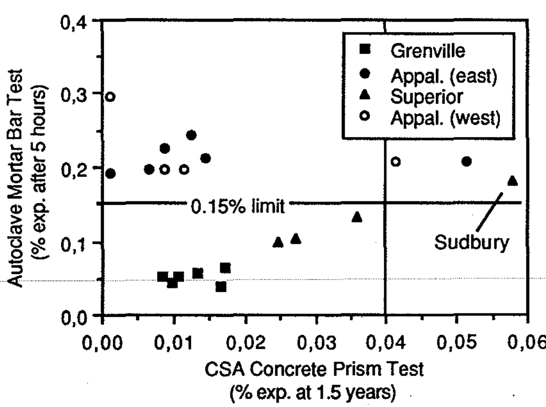
CARBONATE AGGREGATES

Figure 2: Results with the autoclave mortar bar method for quarried carbonate aggregates from Québec compared to those with the Concrete Prism Method CAN/CSA A23.2-14A (using 350 kg/m^3 of cement).



SILICATE AGGR. & AGGR. USED IN DAMS

Figure 3: Results with the autoclave mortar bar method for quarried silicate aggregates from Québec and a number of aggregates used in Canadian dams compared to those with the Concrete Prism Method CAN/CSA A23.2-14A (at 100% RH and 38°C for silicate aggregates; in NaOH 1N at 38°C for aggregates used in dams).



GRAVELS

Figure 4: Results with the autoclave mortar bar method for gravels from Québec compared to those with the Concrete Prism Method CAN/CSA A23.2-14A.

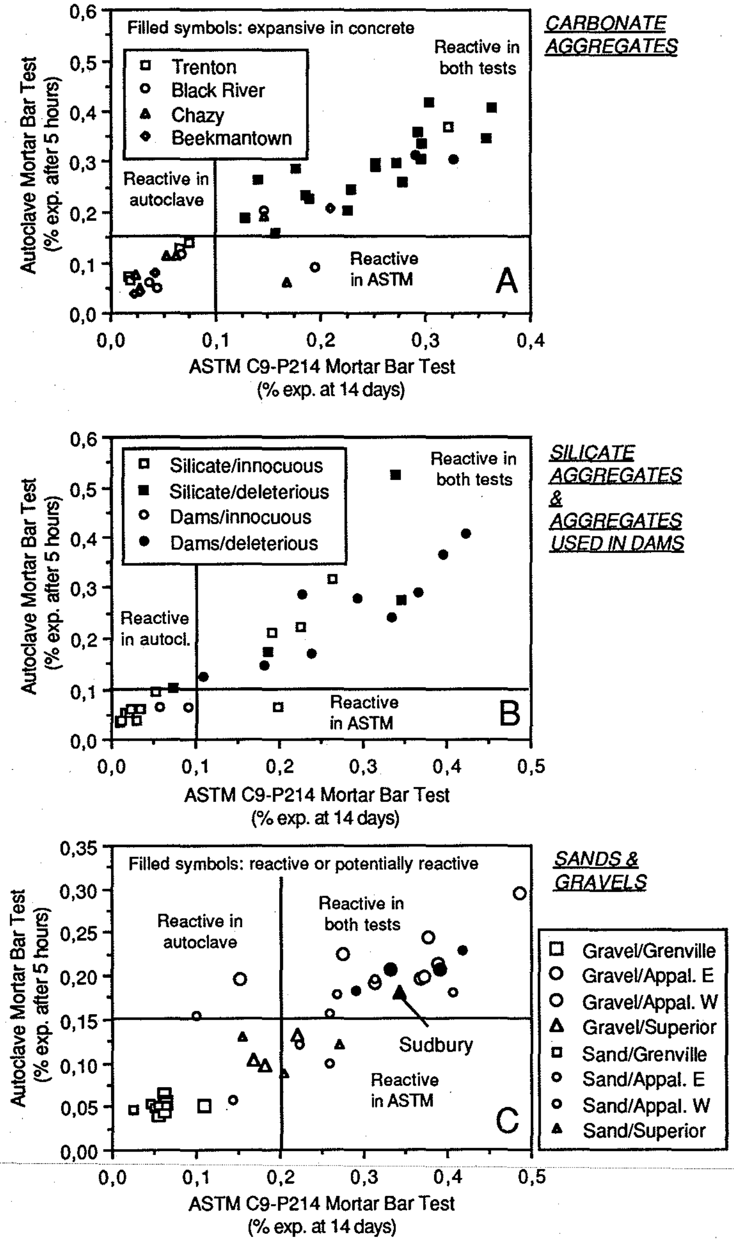


Figure 5: Comparison between results with the Autoclave Mortar Bar Method and the Accelerated Mortar Bar Method ASTM C-9 Proposal P 214 (or NBRI).