EFFECTIVENESS OF THE ACCCELERATED MORTAR BAR METHOD, ASTM C-9 PROPOSAL P 214 OR NBRI, FOR ASSESSING POTENTIAL AAR IN QUÉBEC (CANADA)

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In this method, mortar bars are placed in NaOH at 80°C for two weeks, with length measurement made periodically. The method was applied to 142 aggregates of various compositions. For sands and gravels, a 14-day, 0.20% expansion limit criterion was used to differentiate deleterious or potentially deleterious aggregates from innocuous ones, and a 0.10% criterion is suggested for quarried silicate and carbonate aggregates. The test detected all known deleterious aggregates in Québec, except one (Potsdam sandstone), but was severe for many aggregates with good field record, a number of which expanded even more than 0.25% at 14 days, particularly sands and gravels. Consequently the test should not be used for aggregate rejection unless petrographic examination strongly confirms that the aggregate tested is petrographically similar to well known reactive aggregates.

INTRODUCTION

Since first proposed by Oberholster and Davies (1), the NBRI Accelerated Mortar Bar Method has been applied to a large number of aggregates in several countries and is now the most popular rapid test method used in Canada for assessing potential alkali-reactivity of concrete aggregates. Mortar bars for this test are made in accordance with ASTM C 227, but with a fixed water/cement of 0.50 (0.44 for uncrushed sands), and immersed in water at 23°C after demoulding, with the containers immediately placed in an oven at 80°C. The zero reading is taken the next day, and the bars are immersed in a 1N NaOH solution at 80°C for two weeks (12 days in the original NBRI method), and measured hot each working day. As reported by Fournier and Bérubé (2), several workers observed that expansion of mortar bars generally increased when increasing the water/cement. For this reason, the equivalent method ASTM C-9 Proposal P 214 recommends using a fixed w/c of 0.50 for coarse aggregates and manufactured sands, and 0.44 for uncrushed sands. The cement type and the alkali content of the cement used do not induce significant effect on expansion values, provided that the cement does not contain mineral admixtures (2, Hooton (3)). The precision of the test method has been assessed by a few researchers with very satisfactory results that are summarized in (2) and (3). Moreover, Davies and Oberholster (4), Shayan and Quick (5) and Fournier and Bérubé (6) observed that the reaction products formed during the test were similar to those found in ASR affected field concrete.

There is a general agreement that aggregates which expand less than 0.10% after 14 days be considered innocuous. Up until now, only a few deleteriously reactive aggregates were found to satisfy this value: alkali-carbonate reactive rocks from Ontario (Grattan-Bellew (7)), some (Potsdam) sandstones from Québec (Bérubé and Fournier (8)), and a phyllite from Australia (Shayan et al. (9)). A number of granitic aggregates from the U.S.A., which are suspected to be reactive in the field, are also not detected (Hooton (10)). Furthermore, Davies and Oberholster (11) suggested that slowly expansive siliceous rocks expand between 0.10% and 0.25% (after 12 days), while proposing a limit of 0.25% for rapidly expansive siliceous aggregates. Based on Canadian experience (8), many aggregates with good field performance produced expansion between 0.10% and 0.25% in the accelerated test, calling for further testing. Moreover, Grattan-Bellew (7) mentioned that it may be necessary to consider different acceptance criteria according to the type of aggregate tested, suggesting 0.10% at 14 days for siliceous limestones, 0.20% for greywackes and argillites, and 0.15% for the other aggregate types, while stressing the importance of petrographic examination prior to testing. Since 1987, the Accelerated Mortar Bar Method has been extensively used in Québec. This paper summarizes and discusses the results obtained at Laval University for 142 aggregates with various compositions.

TABLE 1 - Results for quarried carbonate aggregates.

Geological group (Number of samples)	Trenton (43)		Black River (11)		Chazy (9)	Beek. (8)	Total (71)	
CSA Concrete Prism Test	R	NR	R	NR	NR	NR	R	NR
Expansion limit criterion = 0.04% at 6 months	32 (74%)	11 (26%)	3 (27%)	8 (73%)	9 (100%)	8 (100%)	35 (49%)	36 (51%)
Accelerated Mortar Bar Test[1]								
R+: samples showing exp. >0.25% at 14 d:	16 (50%)	1 (9%)	2 (67%)	- -	- -	- -	18 (51%)	1 (3%)
R-: samples showing exp. 0.1-0.25% at 14 d:	16 (50%)	- -	1 (33%)	3 (37%)	2 (22%)	2 (25%)	17 (49%)	7 (19%)
NR: samples showing exp. <0.10% at 14 d:	- -	10 (91%)	- -	5 (63%)	7 (78%)	6 (75%)	- -	28 (78%)
Overall effectiveness:	42/43 98%		8/11 73%		7/9 78%	6/8 75%	63/71 89%	

1: Aggregate classification in the accelerated mortar bar method: exp. at 14 days: >0.25% = rapidly reactive (R+); 0.10-0.25% = slowly reactive (R-); <0.10% = non reactive (NR).

APPLICATION TO QUARRIED CARBONATE AGGREGATES

Accelerated mortar bar tests were performed by Fournier and Bérubé (6) on 71 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 with 350 kg/m^3 of cement rather than 310 kg/m^3. A 6-month, 0.04% expansion limit was used to distinguish reactive or potentially reactive samples 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 350 kg/m^3 of cement), was in good agreement with the known field performance of 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 up until now any AAR related problems, except for a particular dolostone in a few dams (Bérubé et al. (12)).

The results are presented in Table 1 and on Figure 1. A 14-day, 0.10% expansion limit criterion is needed to recognize the potential reactivity of 100% [35/35] of the samples which expanded more than 0.04% in the concrete test (at 6 months), while allowing 78% [28/36] of the non-expansive samples (in concrete) to be correctly evaluated. The percentage of correctly evaluated non-reactive aggregates is 91, 63, 78 and 75%, for the Trenton, Black River, Chazy and Beekmantown geological groups, respectively. The overall effectiveness of the test, e.g. the percentage of all samples that were correctly evaluated, was 89% [63/71], varying from 73% to 98% from one geological group to another. Only one non expansive sample in concrete expanded more than 0.25% in the accelerated test; it corresponds to a clay-rich Trenton limestone (Fournier and Bérubé (6,13)). This sample expanded by only 0.026% at 6 months in concrete, and satisfied the 0.04% criterion used. However, it significantly expanded afterwards (0.108% at 1 year). Another sample from the same source expanded marginally at 6 months (0.046%), while presenting the highest expansion in the accelerated test (0.412%) (Figure 1). Finally, based on field inspection, these aggregates proved to be sligthly reactive in the field. According to the above results, for carbonate aggregates from Québec, a 14-day, 0.10% expansion limit is proposed for aggregate acceptance, while >0.25% strongly suggests that the aggregate tested is potentially reactive in the field. Materials producing expansions between 0.10% and 0.25%, however, should not be rejected and call for further testing. Indeed, 22% of the 36 non-reactive samples expanded >0.10% at 14 days in the accelerated test.

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]	Accelerated Mortar Bar % exp.-14d	Accelerated Mortar Bar Classified[3]
	Innocuous or presumably innocuous aggregates in concrete structures					
1	Andesite	Presumably good	0.010	NR	0.264	R+
2	Anorthosite	Not used in concrete	0.019	NR	0.008	NR
3	Basalte	Presumably good	0.005	NR	0.020	NR
4	Charnockite	Presumably good	0.014	NR	0.022	NR
5	Hornfel I	Presumably good	0.018	NR	0.226	R-
6	Hornfel II	Presumably innocuous	0.014	NR	0.231	R-
7	Diorite	Innocuous	0.015	NR	0.033	NR
8	Gabbro	Presumably good	0.017	NR	0.198	R-
9	Granitic gneiss I	Innocuous	0.029	NR	0.052	NR
10	Granite	Innocuous	0.018	NR	0.016	NR
11	Greywacke I	Innocuous	0.016	NR	0.190	R-
12	Greywacke II	Presumably innocuous	0.014	NR	0.197	R-
13	Phonolite I	Innocuous	0.014	NR	0.008	NR
14	Quartzite	Not used in concrete	0.015	NR	0.029	NR
15	Syenite	Innocuous	0.012	NR	0.012	NR
16	Calc. sandstone	Innocuous	0.020	NR	0.122	R-
	Deleterious aggregates in concrete structures					
17	Potsdam sandst. I	Deleteriously reactive	0.069	R	0.074	NR
18	Chloritic schist	Deleteriousy reactive	0.046	R	0.187	R-
19	Siliceous shale	Deleteriousy reactive	0.089	R	0.338	R+
20	Rhyolitic tuff I	Deleteriousy reactive	0.224	R	0.326	R+
21	Rhyolitic tuff II	Deleteriousy reactive	0.088	R	0.253	R+
22	Rhyolitic tuff III	Deleteriousy reactive	0.050	R	0.268	R+

Performance evaluation of the accelerated test	Classified as NR		Classified as R-		Classified as R+	
• Innocuous or presumably innocuous aggr.:	9/16	(56%)	6/16	(38%)	1/16	(6%)
• Deleteriously reactive aggregates:	1/6	(17%)	1/6	(16%)	4/6	(67%)
• Overall effectiveness:			14/22	(64%)		

1: Presumably good: aggregates used in many structures with no reported AAR until now; however, no systematic inspection of concrete structures has been done. Innocuous: aggregates with satisfactory field record.
2: Limit of 0.04% expansion at 1 year.
3: Exp. at 14 days: >0.25% = rapidly reactive (R+); 0.10-0.25% = slowly reactive (R-); <0.10% = non reactive (NR).

APPLICATION TO QUARRIED SILICATE AGGREGATES

Accelerated mortar bar tests were performed by Ouellet (14) on 22 quarried silicate aggregates from Québec (Table 2). Reference concrete prisms were made in accordance with CAN/CSA-A23.2-14A, but raising the alkali content to 1.17% (Na_2O eq.) 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, none of the aggregates which expanded less than the above limit have been reported to be deleteriously reactive in the field, but no systematic inspection of concrete structures has been done. The results are presented in Table 2 and on Figure 2. Even when using a severe criterion for aggregate acceptance, e.g. 0.10% at 14 days, one of the 6 deleterious aggregates tested still remained undetected (Potsdam sandstone I), while 56% [9/16] of the innocuous or presumably innocuous ones were correctly evaluated, for an overall effectiveness of 64% [14/22]. A large proportion (44%) of the 18 innocuous or presumably innocuous samples did not satisfy the criterion, with one even expanding >0.25%. The accelerated test is not significantly more accurate when using a criterion of 0.15% expansion at 14 days; only one more non-reactive aggregate is correctly classified, for an overall effectiveness of 68% [15/22]. For silicate aggregates from Québec, a 14-day, 0.10% expansion limit is proposed for aggregate acceptance, only some Potsdam sandstones remaining undetected, while expansion >0.25% strongly suggests that the aggregates are reactive in the field, since only one of the non-reactive aggregates tested exceeded this value. Again, materials expanding between 0.10% and 0.25%, which account for many innocuous or presumably innocuous aggregates, should not be rejected, unless petrographic examination strongly confirms that corresponding aggregates are petrographically similar to known reactive aggregates. The results obtained by other workers on other silicate aggregates from Canada (8), are in good agreement with the above results.

TABLE 3 - Results for aggregates used in Canadian dams.

No.	Rock type	Provenance	CSA Concrete Prism[1] % exp.-6m	Classified[2]	Accelerated Mortar Bar % exp.-14d	Classified[3]
Innocuous aggregates in dams						
1	Phonolite II[4]	Québec	0.020	NR	0.056	NR
2	Granitic gneiss II	Québec	0.014	NR	0.090	NR
Deleteriously reactive aggregates in dams						
3	Pots. sandstone II	Québec	0.122	R	0.181	R-
4	Rhyolitic tuff IV	Québec	0.192	R	0.422	R+
5	Dolostone	Québec	0.063	R	0.109	R-
6	Metagreywacke	Québec	0.086	R	0.239	R-
7	Greywacke III	Nova Scotia	0.127	R	0.334	R+
8	Greywacke IV	New Brunswick	0.164	R	0.395	R+
9	Greywacke V	Ontario	0.100	R	0.294	R+
10	Rhyolitic porphyry	Ontario	0.139	R	0.367	R+
11	Lithic gravel	Alberta	0.092	R	0.228	R-

Performance evaluation of the accelerated test	Classified as NR		Classified as R-		Classified as R+	
• Innocuous aggregates in dams:	2/2	(100%)	-	-	-	-
• Deleteriously reactive aggregates in dams:	-	-	4/9	(44%)	5/9	(56%)
• 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: Exp. at 14 days: >0.25% = rapidly reactive (R+); 0.10-0.25% = slowly reactive (R-); <0.10% = non reactive (NR).
4: Non-reactive control; not used in dams.

APPLICATION TO AGGREGATES USED IN CANADIAN DAMS

The accelerated test was applied to a number of aggregates that were identified as deleteriously reactive in Canadian dams (12) (Table 3). The current Concrete Prism Method CAN/CSA A23.2-14A failed in detecting 4 of the 9 reactive aggregates tested. Other concrete tests procedures were investigated in this study on mass concrete (12), 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 0.04% expansion limit criterion, at 6 months for CSA concrete and 1 year for mass concrete. The accuracy of the accelerated 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 2. The same limit as for the quarried silicate aggregates, e.g. 0.10% at 14 days, is necessary for detecting all deleteriously expansive aggregates in dams, while the two non-reactive aggregates are correctly evaluated. Four of the 9 reactive aggregates were slowly expansive in the accelerated test (e.g. 14-day expansion between 0.1 and 0.25%). In this particular study on mass concrete, 9 of the 11 aggregates tested 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), used as a reference, were also tested with the accelerated method by Mongeau (15). They are grouped in Table 4 according to their geological association and geographical 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. Reference concrete prisms were made in accordance with the Concrete Prism Method CAN/CSA-A23.2-14A, e.g. with 310 kg/m^3 of cement. However, the usual 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 (e.g. >0.04%). Only three among the 20 gravels tested expanded more than 0.04% at 1.5 years in CSA concrete (#12, #13 and #20), which include the Sudbury sample. Concrete prisms were also made with more cement (410 kg/m^3) for samples nos. 2, 5, 6, 10-15 and 18, which is recommended in order to detect slowly reactive aggregates such as the Sudbury gravel and many greywacke and argillite type aggregates (7). In addition to the #12 (0.044%) and #13 (0.044%) gravels, three other samples expanded more than 0.04% <u>at 1 year</u>: #10 (0.050%), #14 (0.086%) and #18 (0.069%). However, despite no systematic inspection of concrete structures built with the gravel aggregates tested, only a few at the most are thought to be deleteriously reactive in field concrete, apparently in only three dams located in the Appalachians (12). One dam made with local natural aggregates and showing signs of AAR is located in each of the two areas represented by the two aggregates #12 and #13, the only ones from Quebec which expanded in normal CSA concrete. When lacking information concerning the field performance of the aggregates investigated, the above expansion limit of 0.04% at 1.5 years in the CSA concrete test was used to distinguish reactive or potentially reactive aggregates from non-reactive ones. The accuracy of the accelerated mortar bar method was evaluated in accordance with this criterion.

The results are presented in Table 4 and on Figure 3. A criterion of 0.2% expansion at 14 days allowed detection of all three expansive gravel aggregates (in concrete), all classified as rapidly expansive (R+) in the accelerated test (exp. >0.25% at 14 days); in the meantime, only 53% [9/17] of the non expansive samples (in concrete) were correctly evaluated, for an overall effectiveness of only 60% [12/20]. Furthermore, 41% of the non-expansive samples (in concrete) were rapidly expansive in the accelerated test (exp. >0.25% at 14 days). All granitic gravels from the Grenville and Superior geological provinces did not expand in concrete, while most of them

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]	Accelerat. (gravels) % exp. (14 d)	Accelerat. (gravels) Classified as[2]	Accelerat. (sands) % exp. (14 d)	Accelerat. (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	0.064	NR	0.055	NR
2	Granitic 52, diorite 31, quartzite 7	0.010	NR	0.061	NR	0.025	NR
3	Granitic 69, diorite 25	0.008	NR	0.064	NR	0.063	NR
4	Granitic 74, diorite 16, limestone 5	0.017	NR	0.062	NR	0.047	NR
5	Granitic 74, diorite 22	0.017	NR	0.054	NR	-	-
6	Granitic 44, anorthosite 25, syenite 23	0.011	NR	0.109	NR	0.050	NR
Gravels from the south-east ot the St.Lawrence River (Appalachians Geological Province)							
7	Limestone 86, schist 12	0.006	NR	0.151	NR	0.101	NR
8	Limestone 50, greywacke 27, schist 18	0.014	NR	0.389	R+	0.223	R-
9	Limestone 55, schist 30, greywacke 15	0.000	NR	0.313	R+	0.259	R+
10	Limestone 36, greywacke 29, schist 22	0.012	NR	0.378	R+	0.268	R+
11	Limestone 85, greywacke 10, schist 10	0.009	NR	0.274	R+	0.143	NR
12	Quartzite 21, limestone 16, schist 13, syenite 13, granitic 10, greywacke 9	0.051	R	0.331	R+	0.417	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	0.391	R+	0.292	R+
14	Greywacke 54, limestone 19, schist 18	0.000	NR	0.486	R+	0.313	R+
15	Greywacke 66, schist 18, quartzite 16	0.011	NR	0.367	R+	0.408	R+
16	Greywacke 48, quartzite 22, schist 20	0.009	NR	0.374	R+	0.260	R+
Gravels from North-Western Québec and North-Eastern Ontario (Superior Geological Province)							
17	Granitic 50, diorite 20, greyw. 9, schist 8	0.027	NR	0.169	NR	0.156	NR
18	Diorite 40, granitic 31, andesite 10	0.025	NR	0.182	NR	0.204	R-
19	Diorite 62, granitic 22, andesite 16	0.036	NR	0.221	R-	0.269	R+
20[3]	Sandstone, greywacke, arkose, argillite	0.058	R	0.344	R+	-	-

Performance of the accelerated test for gravels	Classified as NR		Classified as R-		Classified as R+	
• Innocuous or presumably innocuous:	9/17	(53%)	1/17	(6%)	7/17	(41%)
• Deleteriously reactive or presumably so:	-	-	-	-	3/3	(100%)
• Overall effectiveness:			12/20	(60%)		

Performance of the accelerated test for sands[4]	Classified as NR		Classified as R-		Classified as R+	
• Innocuous or presumably innocuous:	8/16	(50%)	2/16	(13%)	6/16	(37%)
• Deleteriously reactive or presumably so:	-	-	-	-	2/2	(100%)
• Overall effectiveness:			10/18	(56%)		

1: Limit of 0.04% expansion at 1.5 years for CSA concrete prisms containing 310 kg/m^3 of cement. For 10 gravels, samples were also made with 410 kg/m^3 of cement (refer to the text).
2: Exp. at 14 days: >0.25% = rapidly reactive (R+); 0.2-0.25% = slowly reactive (R-); <0.2% = non reactive (NR).
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.

[8/9] performed well in the accelerated mortar bar method. The Sudbury gravel which belongs to the Superior province presents a different composition and expanded in both tests. Most polygenic gravels from the Appalachians performed very badly in the accelerated test, which suggests that this test is very severe for this type of aggregate; indeed, as mentioned previously, only a few of these natural aggregates at the most are deleteriously reactive in the field. Assuming that each of the 18 sands tested in the accelerated test presents a potential for ASR in concrete that is similar to the one of the gravel from the same source, then the two presumably reactive sands (#12 and #13) are classified as reactive in the accelerated test, while 50% [8/16] of the presumably non-reactive ones satisfy the criterion of 0.20% at 14 days, for an overall effectiveness of 56% [10/18] (Table 4); this is not better than for gravels. For sands and gravels from Québec, a 14-day, 0.20% and possibly 0.25% expansion limit could be used for aggregate acceptance. It is important to recall that sands and gravels expanding more than 0.20% at 14 days should not be rejected, but call for further testing.

DISCUSSION

The results obtained in this study confirm that the expansion limit criterion used for aggregate acceptance should vary with the type of materials, as suggested by other workers (7). For Québec aggregates, a 14-day, 0.1% expansion limit criterion is proposed for quarried silicate and carbonate aggregates, and 0.2% for sands and gravels. Let us recall that 0.2% was also previously proposed for greywacke and argillite aggregates (7), while greywacke particles are abundant in most natural sands and gravels from the Québec Appalachians (Table 4). It is also clear from past experience and from the results presented in this study that many aggregates with good field performance produce expansion between 0.10% and 0.25% in the ASTM C-9 Proposal P 214 or the NBRI methods, and even more than 0.25%, therefore call for further testing on concrete specimens. Globally, the accelerated mortar bar method was able to detect 98% [54/55] of the deleterious or presumably deleterious aggregates reported in this study, while correctly classifying 64% [56/87] of the innocuous or presumably innocuous ones, for an overall effectiveness of 77% (110 aggregates correctly evaluated on a total of 142).

Among the 142 aggregates described in this paper, 106 (38 reactive; 68 non-reactive or presumably non-reactive) were tested with the autoclave mortar bar method proposed by Fournier et al. (16). As reported elsewhere (Bérubé and Fournier (17)), this method performed as well and even better than the Accelerated Mortar Bar Method (AMBT) for all types of aggregates: it properly classified 100% of the reactive aggregates tested (97% for the AMBT), 71% of the non-reactive or presumably non-reactive ones (62% for the AMBT), for an overall efficiency of 81% (75% for the AMBT). The autoclave method has the advantage to take only 3 days.

EVALUATION OF THE EFFECTIVENESS OF MINERAL ADMIXTURES IN SUPPRESSING EXPANSION DUE TO AAR

The Accelerated Mortar Bar Method ASTM C-9 Proposal P 214 (or NBRI) was also used for determining the effectiveness of mineral admixtures such as condensed silica fume, pulverized fly ash and granulated blast furnace slag in the presence of alkali-silica reactive aggregates (Davies and Oberholster (18), Bérubé and Duchesne (19), Duchesne and Bérubé (20)). In Québec, the method is currently used to evaluate the performance of silica fume blended cements in presence of potentially reactive aggregates. In a particular study involving two very alkali-silica reactive aggregates from Canada (20), the accelerated mortar bar test appeared satisfactory for testing pulverized fly ash and granulated blast furnace slag, using a 14-day, 0.1% expansion limit criterion, but is apparently not severe enough for condensed silica fume. On the other hand, the autoclave method just mentioned, also used for evaluating the effectiveness of mineral admixtures in suppressing ASR expansion, looked appropriate for silica fume and slag, but a little too severe for fly ash, using a 5-hour, 0.1% expansion limit criterion (20).

CONCLUSION

The Accelerated Mortar Bar Method ASTM C-9 Proposal P 214 (or NBRI) should be used for rejecting aggregates, unless petrographic examination strongly confirms that the aggregate tested is petrographically similar to well known reactive aggregates. Indeed, many innocuous aggregates that performed well in the field or in other laboratory tests on mortar or concrete specimens, failed the test when using the proposed 14-day, 0.10% expansion limit criterion for quarried silicate and carbonate aggregates, or 0.20% for sands and gravels. The test is particularly severe for innocuous natural aggregates of which about 40% expanded even more than 0.25% at 14 days. Further testing should then be performed for aggregates expanding more than the above proposed acceptance limit criteria.

Nevertheless, this accelerated test remains a useful screening tool as it is able to recognize within two weeks most deleterious aggregates (except the alkali-carbonate reactive aggregates and a limited number of other aggregates, such as some Potsdam sandstones), while allowing the acceptance of a significant proportion of innocuous aggregates (64% in the present study). With the Petrographic Examination and the Concrete Prism Method CAN/CSA A23.2-14A, the AMBT is included in a decision chart currently used in Québec for assessing in the laboratory the potential alkali-reactivity of concrete aggregates. In this chart, which is presented elsewhere (8, 13), all aggregates can be submitted to the AMBT except the non-detectable alkali-carbonate reactive aggregates and the Potsdam type aggregates; so, petrographic examination has to be performed prior to testing. A relatively severe criterion of 0.1% expansion at 14 days in the AMBT is used for aggregate acceptance, while expansion in excess of 0.1% normally calls for further testing with the CSA concrete prism test. In some cases, aggregates expanding more than 0.25% at 14 days could be classified as potentially reactive, based on experience with similar types of aggregates. However, this remark does not hold for sands of gravels.

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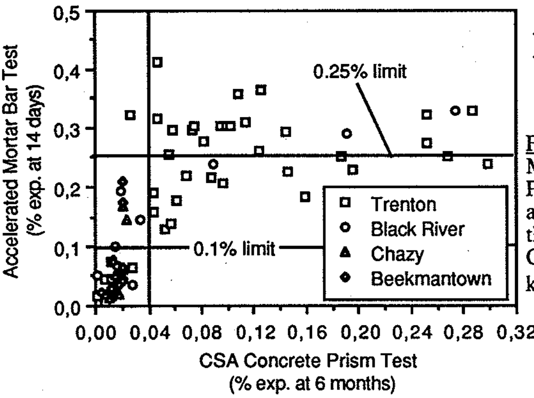
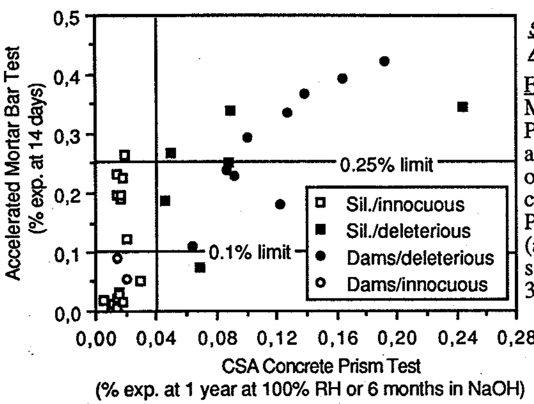


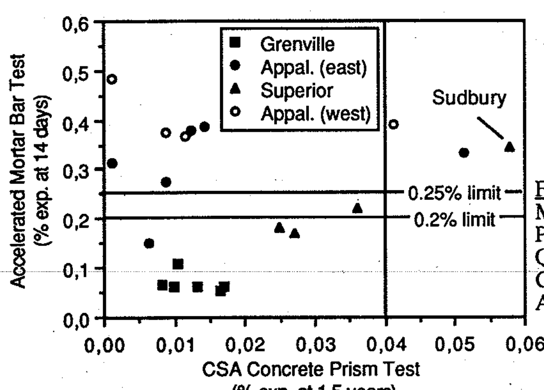
CARBONATE AGGREGATES

Figure 1: Results with the Accelerated Mortar Bar Method ASTM C-9 Proposal P 214 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 2: Results with the Accelerated Mortar Bar Method ASTM C-9 Proposal P 214 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 quarried silicate aggregates; in NaOH 1N at 38°C for aggregates used in dams).



GRAVELS

Figure 3: Results with the Accelerated Mortar Bar Method ASTM C-9 Proposal P 214 for gravels from Québec compared to those with the Concrete Prism Method CAN/CSA A23.2-14A.