MULTILABORATORY STUDY OF THE CONCRETE PRISM AND ACCELERATED MORTAR BAR EXPANSION TESTS WITH SPRATT AGGREGATE

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ABSTRACT : The main purpose of this study was to qualify a new stockpile of Spratt coarse aggregate used for ASR studies and for calibrating AAR test methods. Fifty seven laboratories volunteered to take part in this study. The new stockpile of Spratt aggregate (No. 3) gave similar expansion values in both accelerated mortar bar and concrete prism expansion tests (38°C) to those found with an earlier supply (Spratt 2) from the same source (established in 1992). This material should continue to be a reliable reactive aggregate to use for reference/research purposes. In the concrete prism expansion test at 38 and 60°C, the nature of the non-reactive sand used with the Spratt aggregate was found to have a significant impact on expansion.

Keywords: Accelerated mortar bar test, Alkali-silica reaction, , Concrete prism expansion test, Limestone, Multilaboratory study, Precision

1 INTRODUCTION

The Spratt aggregate is used in Canada and elsewhere as a reference aggregate for the calibration of alkali-silica reaction (ASR) test methods. Back in 1986, a first 100 tonne stockpile of the aggregate (*Spratt 1*) was established by the Ontario Ministry of Transportation (MTO), which made the material available free of charge for research purposes. The first stockpile was exhausted in 1991 when it was used for construction of an outdoor exposure site to evaluate long-term effectiveness of preventive measures [1]. A second stockpile (*Spratt 2*) produced from the same bench of the quarry was established in 1992. Results of studies into the expansion given by this second aggregate in multi-laboratory studies were published in 1996 [2-4]. By 2006, this stockpile was nearly exhausted and a third stockpile (*Spratt 3*) was established. Fournier and Rogers [5] gave details and presented the preliminary results of a study to qualify the new 100 tonne stockpile of *Spratt 3* coarse aggregate. The study also aimed at investigating the effect of a standard non-reactive fine aggregate on the precision of the Concrete Prism Test (CPT), and to look at the precision of an accelerated CPT (carried out at 60°C). The latter had been proposed by Ranc and Debray [6] in the early 1990s for evaluating, in a timely manner, the performance of job mix designs regarding their potential ASR. The test has since been proposed as RILEM test method AAR-4 [7].

The purpose of this paper it to present the final results of the multilaboratory study of the *Spratt 3* aggregate and to compare them to those of previous studies, thus providing a final statement on the validity of the new supply of Spratt aggregate to serve as a control material for ASR studies.

2 MATERIALS AND METHODS

2.1 Aggregates and Cement

The Spratt aggregate is a siliceous limestone from a quarry located in Stittsville near Ottawa, Canada. The geology and field performance is briefly described in a paper in this conference by Rogers and MacDonald. In 2005, a 100-tonne stockpile of 5-20 mm stone was produced from the same area of the

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quarry as used for previous supplies [5]. A 20 tonne supply of a fine aggregate, derived from Precambrian granites and high-grade metamorphic gneiss, was obtained from a natural sand deposit located in Wakefield, Quebec. This "control sand" gave a 14-day accelerated mortar bar expansion (CSA A23.2-25A) of 0.040%.

The participants in this study were asked to use a normal Portland cement and a non-reactive sand meeting the requirements of the CSA, ASTM or RILEM method used in their respective laboratories.

2.2 Sample Preparation

A large spinning riffler was used to prepare 30-kg bags of the Spratt aggregate and control sand samples [5]. Smaller size spinning rifflers are standard equipment in (accredited, geoscientific) laboratories to split particulate materials into representative subsamples suitable for further preparation and analysis. The bags were selected randomly for each laboratory so as to further reduce systematic sampling error.

2.3 Test Program and Methods

Participants in this multilaboratory study were invited to engage in one or several of the different parts that are summarized below and in Table 1. Part I of the test program consisted in performing comparative accelerated mortar bar testing (AMBT) of the "Spratt 2" and "Spratt 3" aggregate materials (both provided), and in accordance with either CSA A23.2-25A [8], ASTM C 1260 [9] or RILEM AAR-2 [10] test method. The expansion monitoring of the mortar bars was to be performed at regular intervals up to 28 days.

The Part II of the program consisted in making two concrete mixtures (in accordance with CSA A23.2-14A [11], ASTM C 1293 [12] or RILEM AAR-03 [13]) incorporating the "Spratt 3" aggregate, and control and local non-reactive sands. Expansion monitoring of the concrete prisms was to be performed at regular intervals up to one year. Additional amounts of "Spratt 3" material were sent to those interested in making larger mixtures (Part II) and cast 3 more prisms for running the CPT at 60°C (Part III), as described in [14]. Expansion monitoring of the test prisms was to be performed at regular intervals up to six months.

3 RESULTS AND DISCUSSION

A total of 57 laboratories participated in one or several parts of the study. Results were received from 54 laboratories for the AMBT, from 41 laboratories doing the CPT at 38°C, while a total of 27 participants reported data for Accelerated CPT at 60°C (ACPT).

A summary of the AMBT results is shown in Table 2 (Spratt 2) and Table 3 (Spratt 3); results are also illustrated in Figure 1, which is a scatter diagram. Such diagrams allow a graphical representation of the closeness of a pair of test data to the mean. Laboratory results that coincide perfectly well with the average values would plot on the intersection point of both lines; also, data that fall uniformly around the mean with equal points in each quadrant show a test with random variation and little systematic laboratory bias.

Tables 4 (Spratt 3, control sand) and 5 (Spratt 3, local sand) show the results for the conventional CPT (38°C). Results are also shown graphically in Figure 3. Tables 6 (Spratt 3, control sand) and 7 (Spratt 3, local sand) show the results for the accelerated CPT (60°C). Results are also shown graphically in Figure 4.

3.1 Accelerated Mortar Bar Test

Table 2 and Figure 1 show data for the AMBT carried out on the Spratt 2 and Spratt 3 aggregates. In each case, the results have been separated according to the test method used, i.e. CSA A23.2-15A, ASTM C 1260 or RILEM AAR-2. It can be seen that, for both Spratt 2 and Spratt 3 aggregates, the mean expansion for the mortar bars made in accordance with the CSA and the ASTM procedures resulted in very similar expansions, both at 14 days and 28 days. The two procedures differ only by the use of slightly different w/c (0.50 for crushed materials in CSA A23.2-25A vs 0.47 for all materials (natural sand and crushed materials) in

ASTM C 1260), as well as by a specified cement alkali content (0.90 ± 0.10% Na_2Oeq) in the CSA method. Despite that, the mean expansion values were similar, although slightly higher standard deviations (SDs) were obtained at 14 days for those using the ASTM method; identical SD's were however obtained at 28 days.

For the Spratt 2 aggregate, the mean 14-day expansion calculated for the 51 sets of bars tested by the various participants, either by the CSA or the ASTM procedure, was 0.394%, which is similar to the mean expansion of 0.416% obtained in 1996 (aggregate from the same stockpile); the SDs are also very close: 14% in 1996 versus 14.3% in this study [3]. It should be remembered that these two sets of data were reported by different laboratories using different technicians and cements. As mentioned before, the data obtained with the RILEM bars were not included in the calculations, because of the difference in bar sizes that likely resulted in the large observed differences in expansions, as reported by Jensen and Fournier [15].

Tables 2 and 3, as well as Figure 1, show that the new stockpile produced in 2005 (Spratt 3) gave 0.378% expansion at 14 days, which compares very well with that for Spratt 2 (0.394%; this study). This provides confidence that the new stockpile has similar levels of reactivity/expansivity to that of the earlier supplies, thus presenting a consistent and reliable reactive aggregate for research purposes as well as for use as a laboratory reference standard.

The multi-laboratory coefficient of variation for the 14-day AMBT data used in Figure 1 was calculated to be 11.4 % for Spratt 3 and 12.9 % for Spratt 2 aggregates. This is similar to the average values found in earlier studies [3,4] of 15.2 %. Also, the data tend to fall in the top right and lower left quadrants in a linear fashion, thus indicating a significant laboratory bias. The variability in the test results could not be clearly related to the MgO content or the alkali content of the cements used by the participants (Figure 2).

3.2 Concrete Prism Test (38°C)

Figure 3 is a scatter diagram of the 6-month (A) and 1-year (B) concrete prism expansions at 38°C comparing the use of the control sand and the locally available non-reactive sand. The diagram shows systematic laboratory bias as found with the AMBT (Figure 3); also, higher average expansions were obtained for concretes incorporating the control sand versus local non-reactive sands. Fournier et al. [16] showed that the type of non-reactive sand can induce significant differences in concrete prism expansion. With a 14-day expansion of only 0.04%, the control sand used in this study satisfied the 0.05% maximum requirement given for non-reactive reference aggregate in RILEM AAR-0 or 0.10% in CSA A23.2-14A and ASTM C 1293. However, Ideker et al. [17] showed that this control sand can contribute significant alkalis ($K+$, likely from feldspars and micas present in the sand) to the concrete pore solution, thus resulting in increased expansion of the test prisms incorporating a reactive aggregate such as the Spratt limestone by increasing the effective alkali content and compensating to some extent for the leaching of alkalis occurring during the test.

Higher concrete prism expansions were observed, on an average, for test prisms cast in accordance with CSA A23.2-14A compared to ASTM C 1293 methods. The trend seems to be more pronounced at 6 months than at one year, and was observed for both types of non-reactive sands (Figure 3). Both CSA and ASTM test methods are very similar, although the CSA method uses a fixed coarse-to-fine aggregate ratio of 60 : 40, while the ASTM method specifies a coarse aggregate oven-dryrodded unit volume of 0.70 ± 0.2%, which tends to result in a more "rocky" mixture [18]. The other test parameters (cement content, cement alkali content, w/c, concrete alkali content and storage conditions) are similar from one method to the other.

The data in Figure 3 also show that the highest concrete prism expansions were obtained from two European participants that used the RILEM AAR-03 method. This can likely be explained by the higher cement content of 440 kg/m^3 used in the RILEM method (compared to 420 kg/m^3 for the CSA and ASTM methods); since NaOH is added to the concrete mix water so as to increase the alkali content of the binder to 1.25% Na_2Oeq, it results in alkali contents of 5.50 kg/m^3 (RILEM) and 5.25 kg/m^3 (CSA/ASTM methods).

Also, the test prisms in the RILEM method are wrapped in damp cloth inside a plastic bag, which can reduce the leaching of alkalis from the test prisms during the test.

Although a direct comparison of the data is debatable, it should be noted that Fournier and Malhotra [2] reported similar average one-year concrete prism expansions of 0.170-0.176% for the concrete mixtures incorporating the Spratt 2 aggregate and the control sand (same source as that used in this study) or local sand sources. This compares to 0.204% for Spratt 3 and the control sand, and 0.178% for Spratt 3 and the local sand (values for *CSA + ASTM* in the Tables 4 and 5, respectively). The multi-laboratory coefficient of variation for the one-year concrete prism expansions ranges from about 24 to 25% for concretes incorporating the control or the local sand (Spratt 3, *CSA + ASTM*, Tables 4 and 5), which is identical to the values of about 25% for concretes incorporating Spratt 2 aggregate, local cements and non-reactive sands [2].

3.3 Accelerated Concrete Prism Test (60°C)

Figure 4 is a scatter diagram of the 13-week (A) and 18-week (B) concrete prism expansions at 60°C comparing the use of the control sand and the locally available non-reactive sand. The diagram shows systematic laboratory bias; also, there is a somewhat wider spread in the data than in the case of the AMBT and the CPT (38°C). This can be seen by multi-laboratory coefficients of variation that reach values higher that 30% and is most likely due to the lack of experience of some of the participants in performing this type of testing (since it is not a standard test procedure in North and South America) (Tables 6 and 7).

As observed for the sets of test prisms tested at 38°C, higher average expansions were obtained, at all ages, for concretes incorporating the control sand versus local non-reactive sands. Also, in the case of concretes incorporating the control sand, higher concrete prism expansions were observed, on an average, for test prisms cast in accordance with CSA A23.2-14A compared to ASTM C 1293 method (Table 6); the difference was however not observed for concretes incorporating the local non-reactive sands (Table 7).

Fournier et al. [16]reported that concrete prism expansion starts much faster at higher temperature (60°C) but levels off quite rapidly (i.e. after about 13 weeks) due to alkali leaching from the test prisms. The data obtained in this study show that the expansion reached after 26 weeks of testing at 60°C, which has basically levelled off, was inferior to that obtained after one year at 38°C (Figure 5).

4 CONCLUSIONS

The multi-laboratory variation of the AMBT at 14 days in solution was found to be about 11% (Spratt 3) and 13% (Spratt 2). This is similar to values found in earlier studies of about 15%.

The new stockpile of Spratt aggregate (No. 3) gave very similar expansion values and multi-laboratory coefficients of variation in both AMBT and CPT (38°C) to those found with a supply of the same aggregate established in 1992 and reported in multi-laboratory studies in 1996. This material should continue to be a reliable reactive aggregate to use for reference and research purposes. The multi-laboratory coefficients of variation was however somewhat higher for the CPT carried out at 60°C, which is most likely due to the lack of experience of some of the participants in performing this type of testing.

In the concrete prism expansion tests carried out at 38 and 60°C, the use of the same "control" non-reactive sand resulted in higher concrete prism expansions than for test prisms made with local non-reactive sands, and this despite the fact that the control non-reactive sand met the maximum requirement given for non-reactive reference aggregate in CSA, ASTM and RILEM test methods used. This has been attributed to the release of alkalis from alkali-bearing minerals present in the granitic-type control sand. Also, greater mean concrete prism expansion was obtained for participating laboratories using the CSA A23.2-14A method compared to the ASTM C 1293 method. Although the two methods are largely similar, the difference is possibly related to the difference in the coarse-to-fine aggregate ratios used in the above methods.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] Hooton, RD, Rogers, CA and Ramlochan, T (2006): The Kingston outdoor exposure site for ASR - after 14 years what have we learned ? Proc. of the M.A. Bérubé Symposium on AAR in concrete. 8th CANMET/ACI Int. Conf. on Recent Advances in Concrete Technology, Montréal, Canada, 171-193.

[2] Fournier, B and Malhotra, VM (1996): Interlaboratory study on the CSA A23.2-14A CPT for ASR in concrete. Proc. of the 10th Int. Conf. on AAR in Concrete, Melbourne, Australia, 302-309.

[3] Rogers, CA (1996): Multi-laboratory study of the accelerated mortar bar test for ASR. Proc. of the 10th Int. Conf. on AAR in Concrete, Melbourne, Australia, 362- 369.

[4] Rogers, CA (1999): Multi-laboratory study of the accelerated mortar bar test (ASTM C 1260) for alkali-silica reaction. Cement, Concrete and Aggregates [ASTM], (21):185-194.

[5] Fournier, B and Rogers, CA (2008): Multi-laboratory study of accelerated mortar bar and concrete prism tests (38° & 60°C). Proc. of the 13th Int. Conf. on AAR in Concrete, Trondheim, Norway, 10p.

[6] Ranc, R and Debray, L (1992): Reference tests methods and a performance criterion for concrete structures. Proc. of the 9th Int. Conf. on AAR in Concrete, London, United Kingdom, 824-830.

[7] Nixon, PJ, Lindgard, J, Borchers, I, Wigum, B. Schouenborg, J. (2008): The Eu Partner project – European standard tests to prevent alkali reactions in aggregates – final results and recommendations, Proc. of the 13th Int. Conf. on AAR in Concrete, Trondheim, Norway, 10p.

[8] Canadian Standards (2004): Test method for detection of alkali-silica reactive aggregate by accelerated expansion of mortar bars. Canadian Standards (CSA A23.2-25A): pp 6.

[9] ASTM Standards (2005): Standard test method for potential alkali reactivity of aggregates (Mortar-Bar Method). ASTM Standards Volume 04-02 (ASTM C 1260), 5p.

[10] RILEM (2000): AAR-2 - Detection of potential alkali-reactivity of aggregates - the ultra-accelerated mortar bar test. Materials & Structures, (33): 283-289.

[11] Canadian Standards (2004): Potential expansivity of aggregates (procedure for length change due to alkali-aggregate reaction in concrete prisms at 38°C). Canadian Standards (CSA A23.2-14A): pp 11.

[12] ASTM Standards (2005): Standard test method for determination of length change of concrete due to alkali-silica reaction. ASTM Standards Volume 04-02 (ASTM C 1293), 6p.

[13] RILEM AAR-03 (2000): Detection of potential alkali-reactivity - 38°C method for testing aggregate combinations using concrete prisms.

[14] Fournier, B, Chevrier, R, DeGrosbois, M, Lisella, R, Folliard, KJ, Ideker, J, Shehata, M, Thomas, MDA and Baxter, S. (2004): The accelerated CPT (60°C) : variability of the test method and proposed expansion limits, Proc. of the 12th Int. Conf. on AAR in Concrete, Beijing, China, 314-323.

[15] Jensen, V and Fournier, B (2000): Influence of different procedures on accelerated mortar bar and concrete prism tests: assessment of seven Norwegian alkali-reactive aggregates. Proc. of the 11th Int. Conf. on AAR in Concrete, Quebec City, Canada, 345-354.

[16] Fournier, B, Nkinamubanzi, PC, Lu, D, Thomas, MDA, Folliard, KJ and Ideker, JH. (2006): Evaluating Potential Alkali-Reactivity of Concrete Aggregates – How Reliable are the Current and new Test Methods ? Proc. of the M.A. Bérubé Symposium on AAR in concrete. 8th CANMET/ACI Int. Conf. on Recent Advances in Concrete Technology, Montréal, Canada, 21-44.

[17] Ideker, JH, East, BL, Folliard, KJ, Thomas, MDA. and Fournier, B. (2010): The current state of the accelerated concrete prism test. Cement and Concrete Research, (40): 550-555.

[18] Fournier, B, Ideker, JH, Folliard, KJ, Thomas, MDA, Nkinamubanzi, PC and Chevrier, R. (2009): Effect of environmental conditions on expansion in concrete due to alkali–silica reaction (ASR). Materials Characterization Journal, (60): 669-79.

TABLE 1: Test program for the interlaboratory study for the *Spratt 3* qualification

Part	Test methods		Coarse Aggregate	Sand	Cement	Expansion monitoring
I	Accelerated Mortar Bar Test	(CSA A23.2-25A, ASTM C 1260, **or** RILEM AAR-03)	Spratt 2	--	Local (general use)	Up to 28 days
			Spratt 3	--		
II	Concrete Prism Test (<u>38°C</u>)	(CSA A23.2-14A, ASTM C 1293 **or** RILEM AAR-03)	Spratt 3	Control (provided)	Local (general use)	Up to one year
			Spratt 3	Local		
III	Accelerated Concrete Prism Test (60°C)	• 3 additional prisms to be cast from Part II • Testing at 60°C as described in [14].	Spratt 3	Control (provided)	Local (general use)	Up to six months
			Spratt 3	Local		

TABLE 2: Summary of accelerated mortar bar test results, Spratt # 2

Age	Method	n	Mean (%)	Std Dev	Coef. Var. (%)	Min (%)	Max (%)
14 days	CSA [1]	26	0.395	0.044	11.2	0.305	0.467
	ASTM [1]	25	0.386	0.066	17.2	0.222	0.504
	CSA + ASTM [1]	51	0.391	0.056	14.3	0.222	0.504
	RILEM [1]	2	0.262	0.196	74.9	0.123	0.400
	Data Fig. 1[2]	50	0.394	0.051	12.9	0.272	0.504
28 days	CSA [1]	26	0.702	0.117	15.8	0.441	0.898
	ASTM [1]	25	0.681	0.108	15.8	0.481	0.886
	CSA + ASTM [1]	51	0.692	0.109	15.7	0.441	0.898
	RILEM [1]	2	0.519	0.363	70.0	0.262	0.775

[1] All data included for the statistical calculations
[2] All data included for the statistical calculations, but excluding the RILEM bars and one outlier (limited experience; using ASTM procedure).

TABLE 3: Summary of accelerated mortar bar test results, Spratt **#** 3

Age	Method	n	Mean (%)	Std Dev	Coef. Var. (%)	Min (%)	Max (%)
14 days	CSA [1]	26	0.375	0.043	11.6	0.307	0.486
	ASTM [1]	24	0.374	0.055	14.8	0.206	0.451
	CSA + ASTM [1]	50	0.375	0.049	13.1	0.206	0.486
	RILEM [1]	3	0.291	0.071	24.5	0.230	0.369
	Data Fig. 1[2]	49	0.378	0.043	11.4	0.276	0.486
28 days	CSA [1]	26	0.591	0.067	11.3	0.450	0.725
	ASTM [1]	24	0.571	0.064	11.2	0.470	0.700
	CSA + ASTM [1]	50	0.582	0.066	11.3	0.450	0.725
	RILEM [1]	3	0.547	0.065	11.9	0.500	0.621

[1] All data included for the statistical calculations
[2] All data included for the statistical calculations, but excluding the RILEM bars and one outlier (limited experience; using ASTM procedure).

TABLE 4: Summary of concrete prism test results, Spratt # 3, **control** sand, 38°C & R.H. > 95%

Age	Method	n	Mean (%)	Std Dev	Coef. Var. (%)	Min (%)	Max (%)
6 months	CSA	20	0.185	0.043	23.0	0.121	0.279
	ASTM	16	0.136	0.031	23.2	0.059	0.174
	CSA + ASTM	36	0.163	0.045	27.6	0.059	0.279
	RILEM	3	0.217	0.069	32.0	0.140	0.275
	CSA + ASTM + RILEM	39	0.167	0.048	28.9	0.059	0.279
1 year	CSA	19	0.226	0.051	22.5	0.149	0.334
	ASTM	16	0.177	0.035	19.9	0.128	0.241
	CSA + ASTM	35	0.204	0.050	24.7	0.128	0.334
	RILEM	3	0.274	0.082	29.9	0.184	0.344
	CSA + ASTM + RILEM	38	0.209	0.055	26.4	0.128	0.344

TABLE 5: Summary of concrete prism test results, Spratt # 3, **local** sand, 38°C & R.H. > 95%

Age	Method	n	Mean (%)	Std Dev	Coef. Var. (%)	Min (%)	Max (%)
6 months	CSA	22	0.154	0.036	23.6	0.086	0.225
	ASTM	16	0.125	0.031	24.7	0.082	0.181
	CSA + ASTM	38	0.141	0.037	25.9	0.082	0.225
	RILEM	3	0.222	0.037	16.7	0.180	0.249
	CSA + ASTM + RILEM	41	0.147	0.042	28.5	0.082	0.249
1 year	CSA	20	0.191	0.044	22.8	0.113	0.289
	ASTM	16	0.161	0.035	21.9	0.104	0.220
	CSA + ASTM	37	0.178	0.042	23.8	0.104	0.289
	RILEM	3	0.275	0.056	20.4	0.210	0.308
	CSA + ASTM + RILEM	40	0.185	0.050	26.9	0.104	0.308

TABLE 6: Summary of concrete prism test results, Spratt # 3, **control** sand, 60°C & R.H. > 95%

Age	Method	n	Mean (%)	Std Dev	Coef. Var. (%)	Min (%)	Max (%)
13 weeks	CSA	11	0.166	0.032	19.4	0.129	0.217
	ASTM	9	0.125	0.039	31.5	0.056	0.168
	CSA + ASTM	20	0.147	0.040	27.5	0.056	0.217
	RILEM	3	0.172	0.022	13.0	0.146	0.187
	CSA + ASTM + RILEM	23	0.150	0.039	26.0	0.056	0.217
18 weeks	CSA	12	0.176	0.028	15.9	0.130	0.223
	ASTM	7	0.143	0.041	28.7	0.086	0.191
	CSA + ASTM	19	0.164	0.036	22.1	0.086	0.223
	RILEM	3	0.184	0.024	13.2	0.156	0.200
	CSA + ASTM + RILEM	22	0.167	0.035	21.1	0.086	0.223
26 weeks	CSA	12	0.183	0.028	15.4	0.139	0.231
	ASTM	9	0.142	0.047	32.8	0.075	0.204
	CSA + ASTM	21	0.165	0.042	25.1	0.075	0.231
	RILEM	3	0.192	0.017	8.8	0.173	0.204
	CSA + ASTM + RILEM	24	0.169	0.040	23.7	0.075	0.231

TABLE 7: Summary of concrete prism test results, Spratt # 3, **local** sand, 60^{o}C & R.H. > 95%

Age	Method	n	Mean (%)	Std Dev	Coef. Var. (%)	Min (%)	Max (%)
13 weeks	CSA	13	0.113	0.026	23.4	0.064	0.156
	ASTM	9	0.114	0.049	43.2	0.053	0.204
	CSA + ASTM	22	0.113	0.036	32.1	0.053	0.204
	RILEM	3	0.170	0.025	14.7	0.144	0.194
	CSA + ASTM + RILEM	25	0.120	0.040	32.9	0.053	0.204
18 weeks	CSA	14	0.124	0.025	20.1	0.067	0.161
	ASTM	7	0.139	0.049	35.1	0.074	0.216
	CSA + ASTM	21	0.129	0.034	26.5	0.067	0.216
	RILEM	3	0.180	0.025	14.0	0.153	0.203
	CSA + ASTM + RILEM	24	0.136	0.037	27.4	0.067	0.216
26 weeks	CSA	14	0.127	0.028	22.0	0.072	0.168
	ASTM	9	0.127	0.058	45.4	0.064	0.230
	CSA + ASTM	23	0.127	0.041	32.2	0.064	0.230
	RILEM	3	0.189	0.022	11.8	0.169	0.213
	CSA + ASTM + RILEM	26	0.134	0.044	32.6	0.064	0.230

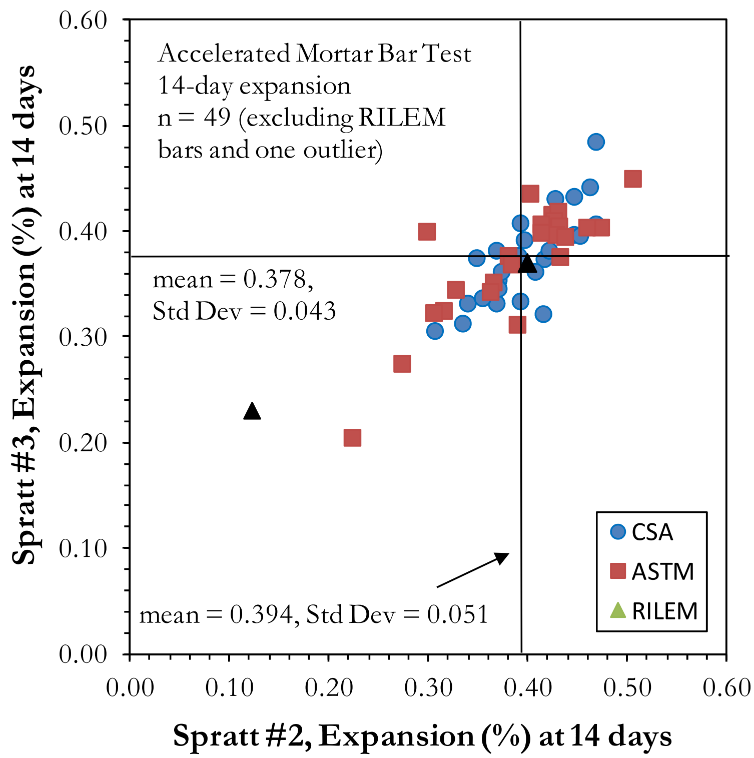

FIGURE 1 : Scatter diagram for accelerated mortar bar expansion test at 14 days.

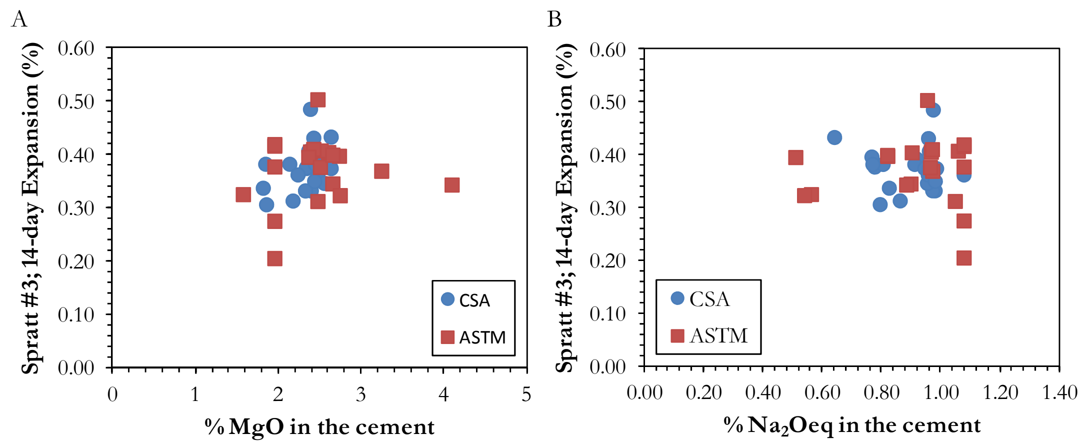

FIGURE 2 : A. Accelerated mortar bar expansions, carried out in accordance with the CSA A23.2-25A or the ASTM C 1260 methods compared with the chemical composition of the cements used. A. MgO content. B. Alkali content (Na_2Oeq).

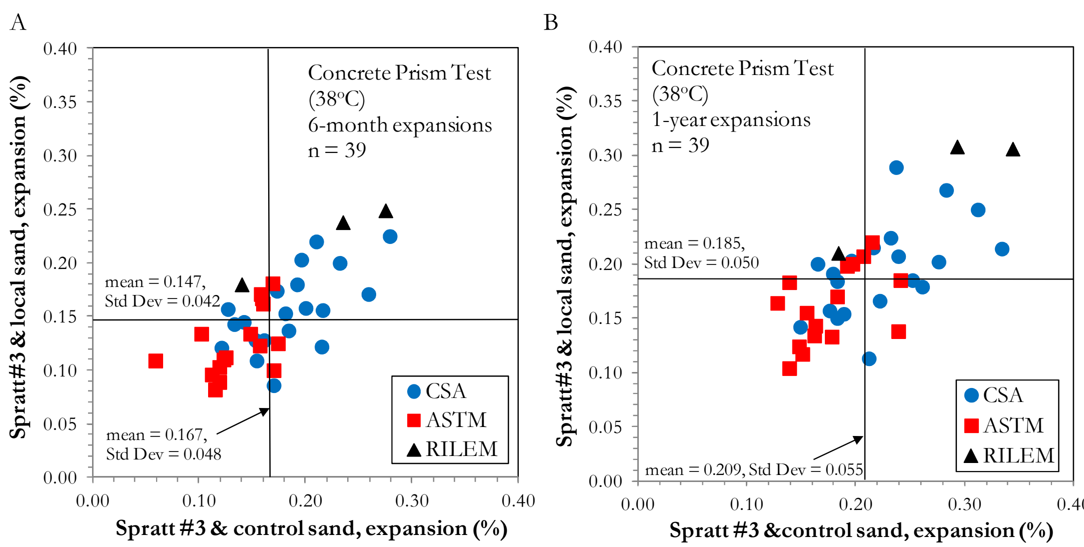

FIGURE 3 : Scatter diagram comparing concrete prism expansions for mixtures made with the Spratt 3 reactive aggregate in combination with either the local sand or the control sand, after 6 months (A) and one year (B) of testing a 38°C (RH > 95%).

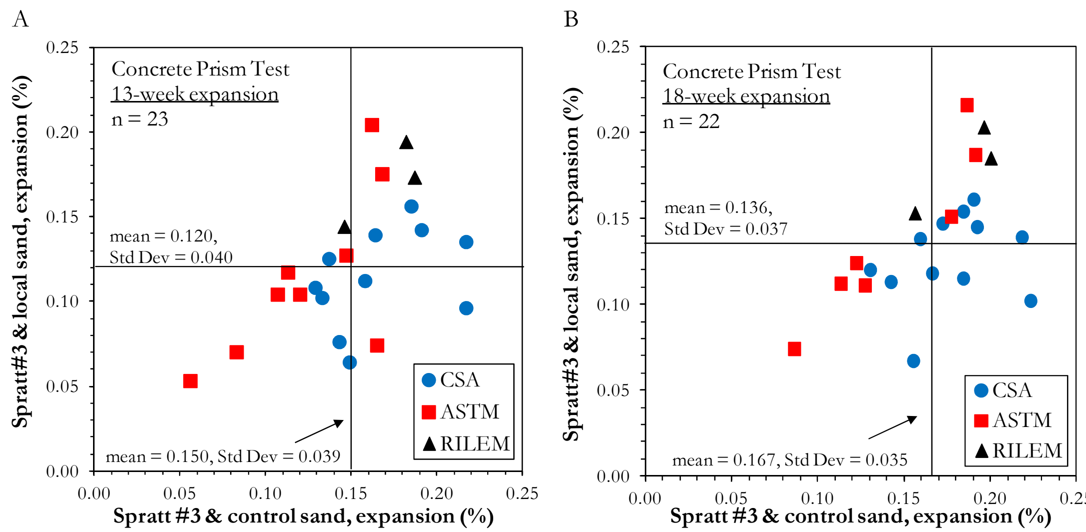

FIGURE 4: Scatter diagrams comparing concrete prism expansions for mixtures made with the Spratt 3 reactive aggregate in combination with either the local sand or the control sand, after 13 weeks (A) and 18 weeks (B) of testing at 60°C.

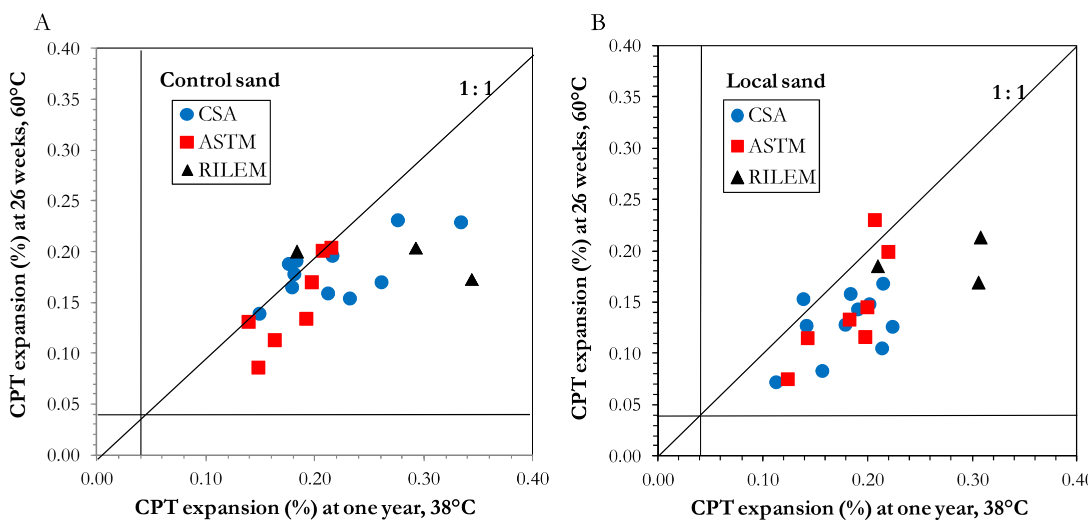

Figure 5: Scatter diagrams comparing concrete prism expansions after 26 weeks at 60°C (RH > 95%) and one year at 38°C (RH > 95%), for mixtures made with the control sand (A) and the local sand (B).