

Using the Miniature Concrete Prism Test (MCPT) to evaluate ASR preventive measures

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Abstract

To determine the reactivity of aggregates, as well as the efficacy of preventive measures, the Accelerated Mortar Bar Test (AMBT) and the Concrete Prism Test (CPT) are common Alkali-Silica Reaction (ASR) performance tests used. But both of these methods have their performance issues. Alkali leaching and unrealistic high temperature are some of the shortcomings of CPT and AMBT respectively that lead to excessive false-positive and false-negative results. The Miniature Concrete Prism Test (MCPT) was developed to address some of the shortcomings related to the CPT and AMBT. The MCPT has been used to determine the reactivity of a wide variety of aggregates, but very limited studies have been conducted on its ability to evaluate ASR mitigation measures. In this paper, combinations of different reactive aggregates and supplementary cementitious materials (SCM) were tested. Field performance, the CPT and the AMBT data were already available for the selected mixes of this study. Comparing the results of the MCPT and other performance tests, as well as field data and establishing a correlation between them show how reliable the MCPT would be in the evaluation of ASR preventive measures. The results of this study showed that a better correlation was observed between the MCPT and field data compared to that of the CPT and the AMBT. Also, depending on the timeframe used for the MCPT, the correlation between this method and concrete at exposure sites significantly changes.

Keywords: alkali-silica reaction; accelerated mortar bar test; concrete prism test; miniature concrete prism test; outdoor exposure site

1. INTRODUCTION

The first report on the deleterious reaction between alkalis of cement and reactive silica in aggregate was published in 1940 by Stanton [1]. In that paper, Stanton not only showed that the sufficient quantity of alkalis of cement and reactive silica in aggregate are required to initiate and sustain alkali-silica reaction (ASR), but also it was demonstrated that using pozzolanic cement can reduce the expansion and the effect was shown to be beyond merely cement dilution. Stanton also demonstrated that using low-alkali cement (below 0.6% Na₂O_{eq}) can control ASR expansion. In the last 80 years since these findings were published, there have been hundreds of studies on ASR preventive measures. The findings of these studies show that most, if not all, SCM reduce deleterious expansion of ASR provided

that they are used in sufficient quantity. The amount of SCM required to control ASR depends on the chemical composition of the SCM, the reactivity level of the aggregate and the amount of alkalis provided by cement and other components of concrete [2,3].

To determine the required amount of SCM in a mix to control ASR performance tests are performed. There are numerous ASR performance tests, but various issues are associated with these tests.

The Mortar bar test (ASTM C227) [4] was developed based on the methodology described by Stanton [1]. The test involves making mortar bars and storing the specimens in a moist room for 24 hours after which the initial measurement is taken. Then the specimens are placed in a container where they stand on an end over, but not in contact with water. The containers are placed at 38° C for 14 days after which another length reading will be taken. There are a number of problems associated with this test method including alkali leaching and failure to correctly test the reactivity of aggregates [3,5]. Due to the unsuitability of the test method to determine the reactivity of aggregates and evaluate the efficiency of preventive measures, ASTM C227 was withdrawn in 2018.

The Pyrex mortar bar test [6] was developed to evaluate the effect of pozzolans on ASR. The testing procedure is the same as ASTM C227 except that borosilicate (Pyrex) glass is used as reactive aggregate. Various problems are associated with the test including high alkali content of Pyrex which can be released into the pore solution, variability of reactivity of Pyrex glass which may result in different expansions and extremely severe expansion limits which leads to the overestimation of the amount of SCM required [3].

The Accelerated Mortar Bar Test (AMBT) was developed by Oberholster and Davies [7]. 25×25×285 mm mortar bars are made and demoulded after 24 hours. This is followed by keeping the bars in water for one day after which initial length reading is taken. Then the bars are immersed into 1N NaOH solution and length measurements are performed periodically to determine the length change from the reference initial reading. The expansion after 14 days is usually used as the outcome of the test although some agencies use the 28-days expansion data. The main purpose of developing such a rapid test was to identify reactive aggregates but soon after the development of the test it was reported that the test can also be used to evaluate the efficiency of SCM in controlling ASR [8,9]. Short duration of the test makes it attractive for industrial purposes but there are various issues related to this test. Unrealistic high storage temperature (80° C) does not represent the ambient conditions that concrete structures encounter in the field [10]. Immersing samples in 1 N NaOH provides an “inexhaustible” source of alkalis which eventually invade the sample and leads to the expansion regardless of the type and amount of SCM used [11]. Also, one of the requirements of the test is that the reactive aggregate must be crushed if it is coarse. The manipulation of aggregate size further decreases the reliability of the test [11]. The test has been standardized as ASTM C1260 [12]. A modified version of the test is available as ASTM C1567 [13] to evaluate the efficiency of SCM to control ASR.

The Concrete Prism Test (CPT) is regarded as the best indicator of the field-performance of concrete. The current version of the test was published in 1995 as ASTM C1293 [14]. In this test method the cement content is fixed at 420 kg/m³. The alkali content of the cement is boosted to 1.25% by adding NaOH to mixing water. Concrete prisms with a cross section of 75×75 mm and a length of 285 mm are made and stored over water at 38°C. The expansion limit is 0.04% at one year to determine the reactivity of aggregates. The same expansion limit is used at 2 years to evaluate ASR preventive measures. Although the CPT is considered as the most reliable ASR performance test, there are several shortcomings related to it. The problem of alkali leaching was first reported by Blanks and Meissner [15] where they detected a build up of alkali ions in the water on the bottom of containers. Lindgård et al [16] reported that alkali leaching is the major shortcoming of the CPT that limits the reliability of the test. The alkali leaching issue of the CPT has been one of the purposes of the new RILEM test method (RILEM AAR-10) where larger prisms with the cross-sectional area of 100×100 mm and the length between 400-450 mm are cast [17]. Alkali boosting is regarded as another issue of CPT. In order to ensure that there are enough alkalis present to identify the reactive aggregate, the alkali of the cement is boosted to 1.25%. Alkali boosting may accelerate the release of alkalis from certain aggregates [18]. It also changes the Na/K ratio which can affect the expansion of concrete [19]. CPT takes 1 year for determination of reactivity of aggregates and 2 years for evaluation of preventive measures. This long testing period is one of the most important disadvantages of this test method. Recently, there has been a growing concern over CPT's capability of evaluating the efficacy of SCM's in reducing ASR expansion [20].

Latifee and Rangaraju [21] outlined the proposed procedure for a new ASR performance test method called the Miniature Concrete Prism Test (MCPT). This method was adopted by the American

Association of State Highway and Transportation Officials (AASHTO) as AASHTO T 380 [22]. In this test method concrete prisms with a cross section of 50×50 mm and a length of 285 mm are made. The cement content is 420 kg/m³ and, similar to CPT, the alkali content of cement is boosted to 1.25%. This test is intended to be an accelerated laboratory method that can produce reliable results for determining the reactivity of aggregate and evaluating ASR mitigating measures. The main timeframe of the test is 56 days but under certain conditions an extended period of 84 days is chosen for the final expansion reading of concrete mixes. Similar to the AMBT, in the MCPT concrete prisms are immersed into 1N NaOH solution throughout the testing period which leads to an extreme severe environment for ASR; however, the temperature of the solution is maintained at 60°C in the MCPT rather than 80°C in the AMBT. Although not perfect, 60° C would provide a more realistic exposure condition compared to that of 80° C in AMBT. In addition, one important advantage of MCPT over AMBT is the aggregate gradation that is used in the tests. In AMBT, coarse aggregates must be crushed to sand size in order to be used. This can significantly change the expansion level of an aggregate [23]. On the other hand, coarse aggregate size between 4.75 mm to 12.5 mm is used in MCPT which minimizes aggregate manipulation and the effect it can have on the expansion level. Main advantages of MCPT over CPT are considerably shorter testing period and elimination of alkali leaching problem. A study was conducted by Rangaraju et al. [24] to assess the reactivity of 42 different types of coarse and fine aggregates with a wide range of reactivity from non-reactive to highly reactive with known field performance. The results of the study showed a good correlation with CPT but a weak correlation with AMBT. Although the reactivity of a wide range of aggregates has been tested in MCPT, only a few papers have focused on the test ability to evaluate ASR preventive measures. Tanesi et al. and Chopperla et al. [25,26] tested various mixes containing different types of SCMs in MCPT and obtained a 77% correlation with the same mixes exposed to ambient conditions in the field for 15 years. Table 1.1 shows a summary of the tests discussed here and indicates which one of the requirements for an ideal ASR performance test is met by each one of these tests. The question mark on the last row of the table shows the significance of this study: examining the reliability of MCPT in evaluating ASR preventive measures.

Table 1.1: Comparison of different test methods and criteria for an ideal performance test

	Rapid	Job aggregate	Unprocessed aggregate	Reliable	Job cement	All SCMs	Realistic temperature
CPT (ASTM C1293)	×	✓	✓	?	×	✓	✓
AMBT (ASTM C1260)	✓	✓	×	×	×	✓	×
PMBT* (ASTM C441)	✓	×	×	×	×	✓	✓
ASTM C227	✓	×	×	×	×	×	✓
MCPT (AASHTO T380)	✓	✓	×	?	×	✓	✓

*Pyrex Mortar Bar Test

2. MATERIALS AND EXPERIMENTAL METHODS

2.1 Materials

A high-alkali Type I Portland cement was used in this study. Different types of SCM including class F fly ash, class C fly ash, slag and silica fume were used as partial replacement for cement. Chemical composition and equivalent alkalis (Na₂O_{eq}) of cementing materials are shown in Table 2.1. All the cementing materials labelled I in the table were used at the University of New Brunswick, the cementing materials labelled II and class C fly ash were used at the Oregon State University.

Four types of reactive aggregates were used in this study at the University of New Brunswick. A silicious limestone (Spratt) from Ontario, Canada, a greywacke (Springhill) from New Brunswick, Canada, a greywacke (Conrad) from Nova Scotia, Canada, and a greywacke-argillite (Sudbury) from Ontario, Canada. All these reactive aggregates were paired with non-reactive sand (Natural sand). At the Oregon State University, four types of reactive aggregates including a mixed mineralogy gravel (Placitas), a natural sand containing quartz and lesser amounts of chert and chalcedony (Wright), a mixed sand composed of quartz and lesser amounts of volcanic rocks and chert and chalcedony (Jobe) and a silicious limestone (Spratt) were used. A non-reactive carbonate rock (Beckmann) and a manufactured

non-reactive sand (Beckmann) were used to pair the aforementioned reactive aggregates. It should be noted that the results of testing done at the Oregon State University are published before but are used here to get a better overview of the correlation between MCPT and field exposure data.

Table 2.1: Chemical composition of cementing materials (NA: Not available)

	PC I	PC II	F fly ash I	F fly ash II	C fly ash	Slag I	Slag II	Silica fume I	Silica fume II
SiO ₂ (%)	18.8	19.0	55.6	52.1	35.0	33.8	36.6	93.8	94.7
CaO (%)	61.3	60.3	4.4	12.8	26.6	37.5	38.3	0.9	0.6
Al ₂ O ₃ (%)	5.7	4.1	20.1	23.6	16.5	9.8	7.9	0.6	0.6
Fe ₂ O ₃ (%)	2.5	2.8	5.7	4.5	5.8	1.3	0.7	0.1	0.1
MgO (%)	3	3.7	NA	2.0	5.4	10.5	10.1	0.3	0.4
SO ₃ (%)	4.2	3.6	1.7	0.8	2.4	2.0	2.3	NA	0.1
L.O.I (%)	2.7	2.8	NA	0.9	0.9	1.4	NA	2.8	NA
Na ₂ O _{eq} (%)	1.01	0.9	1.6	0.8	2.0	0.4	0.5	0.5	0.6

2.2 Experimental Methods

Prior to mixing, coarse aggregates were sieved to meet the gradation requirement of AASHTO T 380. The aggregate was stored in an oven overnight and dry rodded unit weight (DRUW) was measured on the following day to determine the coarse aggregate content of each mix and to ensure that all the requirements of AASHTO T 380 are met.

According to AASHTO T 380 alkali content of the cement should be boosted to 1.25%. To increase the alkalis of the cement NaOH was added to the mixing water prior to mix.

Twenty-six mixtures were made in total with four types of reactive aggregates and different types and levels of replacement as shown in Table 2.2. The MCPT consists of making 50×50×285 mm prisms and keeping them in moulds for 24 hours. After that samples are demoulded and stored under water at 60° C for one day. Initial length reading is taken, and samples are immersed in 1 N NaOH solution and following length-change measurements are done up to 84 days.

In order to test the reliability of the MCPT results the 56-days and 84-days expansion of the samples were compared to the data available for the same mixtures of reactive aggregates and cementing materials at CANMET exposure site in Ottawa, Canada, where concrete blocks have been exposed to ambient environmental conditions and subjected to length measurement for more than 15 years. All the blocks have 420 kg/m³ of cementing materials. The CANMET blocks that were used for benchmarking purposes are not alkali boosted and were made with high-alkali cement (0.90%), however, the cement alkalis of UT blocks used in this study were boosted to 1.25%. One of the blocks containing Spratt aggregate and ternary cementing materials including 25% slag and 4% silica fume was selected from a previous study [27] and is not alkali boosted. CANMET blocks are 400×400×700 mm in size and UT blocks are 380×380×710 mm. The ternary block with Spratt is 600×600×2000 mm in dimensions. The CPT and AMBT results of the same mixes were also available and are compared to the expansion of the MCPT samples in this study [28].

In order to be able to benchmark the MCPT, the combination of aggregates and SCMs were selected from the exposure blocks data available from previous studies. All the mixtures of Table 2.2 were chosen from the block data obtained from CANMET exposure site in Ottawa and UT exposure site in University of Texas at Austin [26,28]. In addition to exposure block expansion, the CPT and AMBT results were also collected from the previous studies performed on these exposure sites. The correlation of the CPT and the AMBT with exposure blocks will be compared to the correlation between the MCPT and the blocks. The MCPT mixes were prepared at the Oregon State University (Spratt, Jobe, Wright and Placitas) and the University of New Brunswick (Spratt, Sudbury, Conrad and Springhill).

Table 2.2: Mix designs

	Spratt (Sp)	Springhill (SH)	Conrad (CN)	Sudbury (SB)	Wright (W)	Placitas (PT)	Jobe (J)
Control (Ctrl)	✓	✓	✓	✓	✓	✓	✓
20% F fly ash(20FA)	✓		✓		✓	✓	✓
30% F fly ash(30FA)	✓	✓	✓				
56% F fly ash (56FA)		✓	✓				
35% Slag (35SG)	✓			✓			
40% Slag (40SG)					✓		
50% Slag (50SG)	✓			✓			✓
7.5% Silica fume (7.5SF)		✓					
10% Silica fume (10SF)		✓		✓			
12.5% Silica fume(12.5SF)		✓		✓			
25% Slag + 4% Silica fume(25SG4SF)	✓						
40% C fly ash (40C)	✓				✓	✓	
100% LiNO3(100Li)						✓	✓
35% Slag + 5% silica fume(35SG5SF)					✓		
35% C fly ash + 5% silica fume(35C5SF)					✓		

3. RESULTS AND DISCUSSION

3.1 Reactivity of aggregates

ASTM C1778 [29] classifies reactive aggregates based on their ultimate expansion in the CPT and AMBT. AASHTO T 380 follows a similar approach for the MCPT. Table 4 shows the expansion of the mixtures and their reactivity level based on ASTM C1778 (for CPT and AMBT) and AASHTO T 380 (for MCPT). While Spratt and Conrad are classified as “Highly reactive” in all laboratory tests, there are differences between the reactivity level of other aggregates. Sudbury is considered a “Highly reactive” aggregates according to MCPT and “Moderately reactive” according to AMBT and CPT. The difference can be attributed to the source of the aggregate. As mentioned earlier, CPT and AMBT results shown in this study have been obtained over 15 years ago and a different source has been used for those tests. Various quarries of the same aggregate could exhibit different expansions. Same rationale can explain the different reactivity classification of Springhill and Conrad presented in Table 3.1. Prescriptive approach to select a prevention method in ASMT C1778 depends on the reactivity level of the aggregate and the differences among the results of the laboratory tests can lead to determining a different prevention level. It is very likely that various reactivity classification of Springhill and Sudbury aggregates is because of the different sources used for the tests.

Table 3.1: Classification of aggregates reactivity

Aggregate	56-day MCPT expansion(%)	MCPT Reactivity level	1-year CPT expansion(%)	CPT Reactivity level	14-day AMBT expansion(%)	AMBT Reactivity level
Spratt	0.180	Highly reactive	0.180	Highly reactive	0.390	Highly reactive
Springhill	0.300	Very highly reactive	0.210	Highly reactive	0.460	Very highly reactive
Sudbury	0.200	Highly reactive	0.070	Moderately reactive	0.270	Moderately reactive
Conrad	0.240	Highly reactive	0.190	Highly reactive	0.410	Highly reactive
Jobe	0.643	Very highly reactive	0.583	Very highly reactive	0.820	Very highly reactive
Wright	0.382	Very highly reactive	0.207	Highly reactive	0.290	Moderately reactive
Placitas	0.169	Highly reactive	0.160	Highly reactive	0.640	Very highly reactive

3.2 Preventive measures

The expansion of the MCPT mixes containing different types and replacement levels of SCM is presented in Figure 3.1. Figure 3.1a shows the expansion of combination of Spratt aggregate and different SCMs at 56 and 84 days. The two dashed lines on the figure shows the “effective” and “uncertain” limit at 0.020% and 0.025% respectively. While all mixes have shown higher expansion than 0.025% after 84 days, 30% fly ash, 50% slag and a ternary blend of 25% slag and 4% silica fume have passed the test at 56 days.

Like Spratt, the expansion of Conrad aggregate could be controlled by the addition of 30% fly ash at 56 days (Figure 3.1b). But the mix failed after 84 days. 56% fly ash was sufficient to control expansion after 84 days.

Notable point about mixes containing Sudbury aggregate (Figure 3.1c) is the significant expansion between 56 days and 84 days. Although all mixes passed the test after 56 days, they have failed at 84 days. The mixture with 12.5% silica fume showed an expansion of 0.003% after 56 days, and in the next 28 days the expansion dramatically increased to 0.027%. The substantial increase in the last 28 days can be attributed to the idea that in the MCPT samples are submerged in 1 N NaOH solution. The solution provides an external source of alkalis which eventually can penetrate into the samples and mask the effect of SCMs. Increase in expansion was also considerable for the mixes with 50% slag and 10% silica fume.

None of the mixes with Placitas aggregate could reduce the expansion to below the threshold as shown in Figure 3.1d. The use of 100% LiNO₃ solution could not decrease the expansion very effectively.

Class F fly ash and a ternary blend of slag and silica fume were the most effective mixes in reducing the expansion of Wright aggregate as presented in Figure 3.1e. It should be mentioned that the expansion of the samples with 20% class F fly ash was at 0.021% after 56 days which is very close to the MCPT effective threshold (0.020%). This means that the mix lies in the uncertain zone defined by AASHTO T 380.

The expansion of Jobe aggregate which is has the highest reactivity among the aggregates used in this study according to Table 3.1, could not be controlled by the use of SCMs or LiNO₃.

Very high expansion of mixes containing Springhill aggregate and silica fume is the most notable point of Figure 3.1g. Even a concrete mixture with 12.5% silica fume failed in the test at 56 days. This can be attributed to the agglomeration of silica fume particles. When agglomerated, silica fume particles can act like a reactive aggregate and lead to higher expansion than was expected. It was observed that an

appropriate means of preventing ASR problems is to keep the silica fume agglomerates smaller than 150 μm [30].

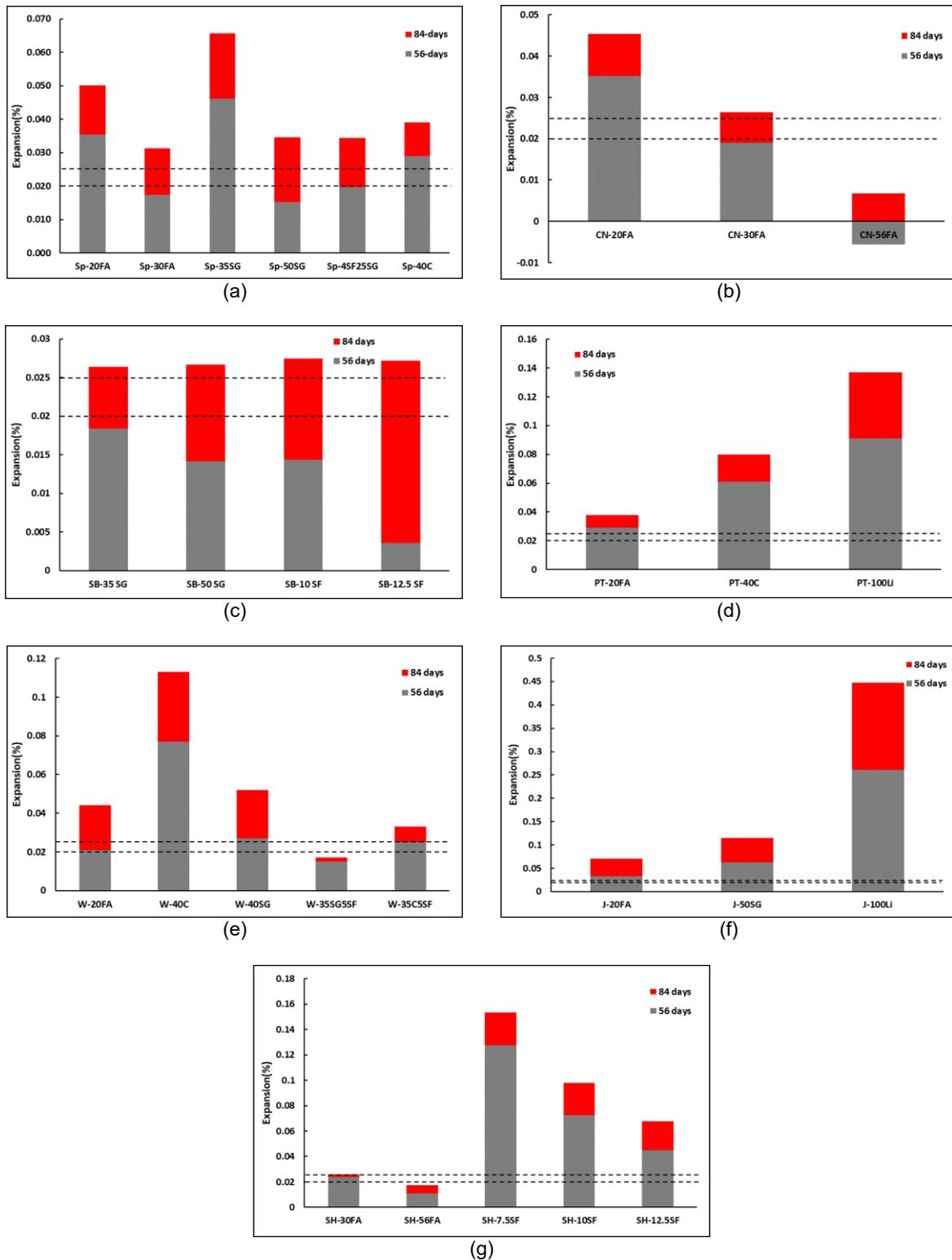


Figure 3.1: MCPT expansions of (a) Spratt (b) Conrad (c) Sudbury (d) Placitas (e) Wright (f) Jobe (g) Springhill

Reviewing Figure 1 indicates that the use of ternary blends of slag and silica fume can be one of the most efficient ways to control ASR expansion. The use of LiNO_3 in MCPT could not successfully reduce the expansion. This should be noted that all samples including the mixes with LiNO_3 were submerged in 1 N NaOH solution and no adjustment was made to the soak solution alkalinity of the mixes containing lithium.

In Figure 3.2 the expansion of MCPT samples at 56 days has been plotted against the expansion of the same combination of aggregate and SCMs in the field. This type of fail-pass plots can easily illustrate how well MCPT and field expansion of concrete mixtures are correlated. In Figure 3.2 vertical and horizontal dashed lines show the expansion limit for the exposure blocks and the laboratory testing respectively. The red dots show the mixtures that have inconsistent results in the field and in MCPT meaning that the mix failed in the former and passed the latter or the other way around. Out of 29 mixtures containing SCMs and lithium, 7 mixes showed inconsistent results in MCPT and exposure sites which means a correlation of 76%.

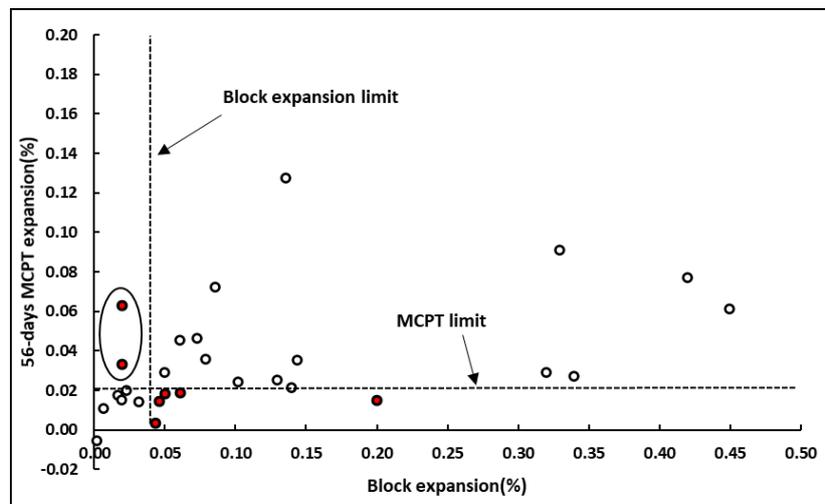


Figure 3.2: Correlation between 56-days MCPT results and block expansion

Figure 3.3 presents the correlation between 84-days MCPT results and block expansion. Again 7 mixtures have shown inconsistent results in MCPT and exposure sites. Thus the identical correlation value is obtained for 84-days MCPT expansion. The difference is that 6 of those 7 mixes have shown good performance in the field but failed in laboratory, which might be a sign of excessively harsh environment of MCPT when 84 days is chosen as the timeframe. One of the advantages of 56-days MCPT over 84-days MCPT can be the ability to identify the mixes that do not show expansion on the field. Looking at the pass-pass region of the Figure 3.2 (small area on the bottom left), there are 6 mixes that have passed the laboratory test and field exposure, but there are only 2 mixes that have not crossed the 84-days MCPT expansion limit in Figure 3.3. Those are the mixes with very high fly ash contents (56%). No difference was observed in the correlation value when different timeframes were used in MCPT. In both figures there are two mixtures circled in black, these are two mixes with Jobe aggregate that have not shown deleterious expansion in the field, but it should be noted that the time of exposure has been only 5 years. So, there is a possibility that the expansive behavior of these concrete blocks change in the future.

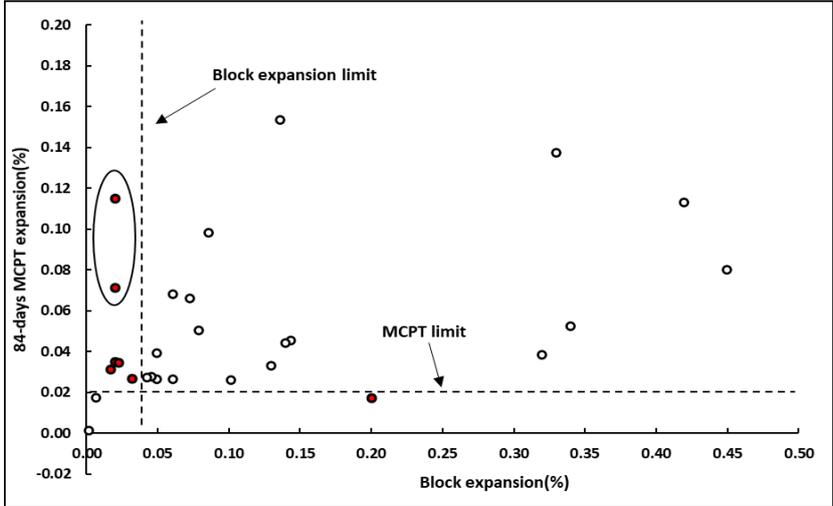


Figure 3.3: Correlation between 84-days MCPT results and block expansion

As shown in Figure 3.4 a considerable number of the mixes have shown false-negative results in CPT. 14-days AMBT expansion is also showing some false-negative results as presented in Figure 3.5. The level of false negativity of Figure 3.4 is significant. Among 21 mixes that showed expansion in the field, only 2 have exhibited deleterious expansion in CPT. Eight mixes have performed satisfactory in the field and the same mixes have shown low expansion in CPT (<0.04%). 14 mixes have failed in the field as shown in Figure 3.5 and only 6 of them has also expanded more than the AMBT limit. Only 5 mixes have shown desired performance in both exposure sites and AMBT.

Originally, an expansion limit of 0.020% was used as the limit for CPT [29], but the test was calibrated continuously against the field exposure block and the expansion of 0.040% was considered the indicator of deleterious expansion in the CPT. As shown in Figure 3.2, for the mixes of this study, an expansion limit of 0.040% provides a weak correlation of only 34.4%. Reducing the CPT expansion limit to 0.020% substantially increases the correlation to 58.6% as illustrated in Figure 3.6.

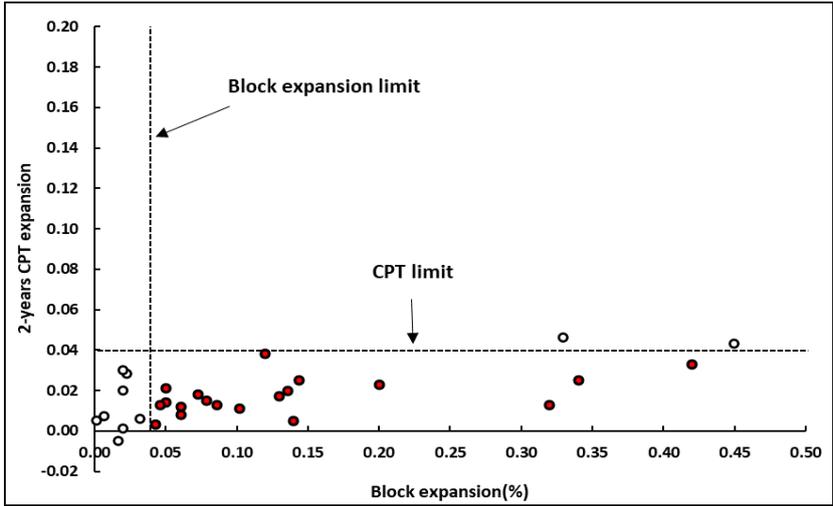


Figure 3.4: Correlation between CPT and exposure blocks

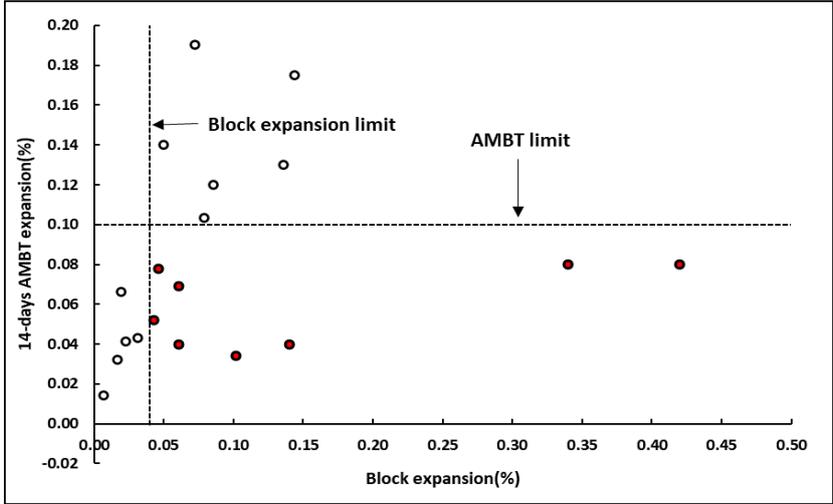


Figure 3.5: Correlation between AMBT and exposure blocks

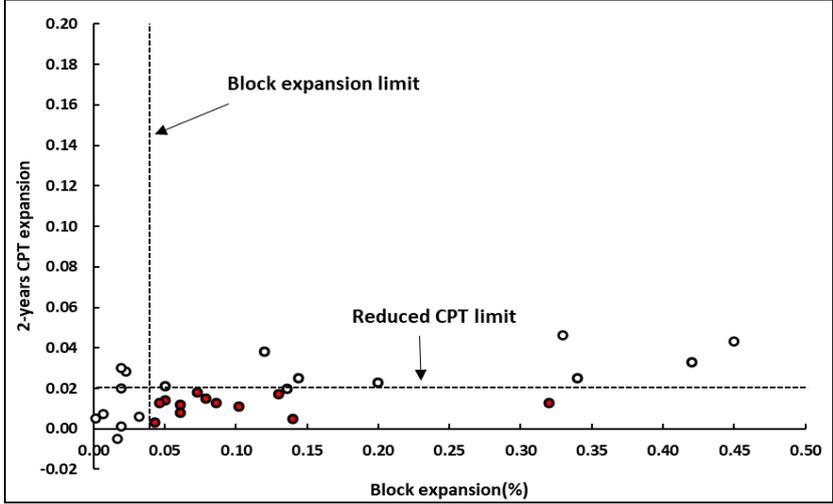


Figure 3.6: Correlation between CPT with reduced limit and exposure blocks

Table 3.2 presents the expansion of all SCM mixes in different laboratory tests as well as in the field. Cells highlighted in green show the mixes that have performed acceptable in the laboratory test or in the field. Red cells show the failure of a mixture and yellow cells show the mixes which had uncertain level of expansion in MCPT. Best correlation with the exposure blocks was observed in MCPT. 19 of 28 mixes showed consistent results in the field and 56-days MCPT which means a correlation of 67.8%. In addition, 3 mixes failed in the field but exhibited uncertain level of expansion in MCPT after 56 days. AASHTO T 380 recommendation for samples which show uncertain expansion is to increase the SCM replacement level. So, depending on the expansion threshold (0.020% or 0.025%) that is considered for MCPT, the correlation between the test and the exposure blocks can be 67.8% or 78.5%. It should also be noted that the field expansion data used in this study was taken when blocks containing Jobe sand and 20% fly ash and 50% slag were only 5 years old, which is significantly lower than other mixes as seen in Table 3.2, so there is still a possibility that these blocks develop ASR in the future.

Increasing the duration of MCPT led to the failure of most mixes. Only mixes with high amount of class F fly ash (56%) and a ternary blend of 35% slag and 5% silica fume passed the test after 84 days. The correlation between 84-days MCPT and exposure blocks was 68.9%. One mix showed uncertain expansion after 84 days.

Regardless of the MCPT time frame, the test showed a significantly improved correlation with exposure blocks compared to CPT and AMBT. As shown in Table 3.2 there were several mixtures that CPT and AMBT could not correctly predict the exposure block performance, but MCPT could.

It seems that increasing the duration of the MCPT does not substantially affect its correlation with exposure blocks at least for the aggregates that were used in this study. All aggregates are categorized as highly or very highly reactive based on MCPT, so maybe the test time frame can play an important role when moderate and low reactive aggregates are studied. More research needs to be conducted on this matter.

Although MCPT has shown strong correlation with the field exposure blocks in this study, the test still suffers from a few drawbacks. Alkali boosting and submerging the samples in 1 N NaOH do not replicate the natural conditions. Modifications such as submerging the samples in modelled pore solution (similar alkalinity with a mix of KOH and NaOH) and not boosting the alkalis of cement could be considered to further develop the test method.

Table 3.2: Expansion of concrete mixtures in the field and various laboratory performance tests

Aggregate	Mix designation	Alkali level of the block	Age of the block (years)	Block (%)	56-days MCPT (%)	84-days MCPT (%)	CPT	AMBT
Spratt	Sp-20FA	0.9%	17.9	0.079	0.035	0.050	0.015	0.103
	Sp-30FA	0.9%	18.0	0.017	0.017	0.031	-0.005	0.032
	Sp-35SG	0.9%	18.1	0.073	0.046	0.066	0.018	0.190
	Sp-50SG	0.9%	18	0.020	0.015	0.035	0.001	0.066
	Sp-25SG4SF	0.9%	20.0	0.023	0.019	0.034	0.028	0.041
	Sp-40C	1.25%	16.0	0.050	0.029	0.039	0.014	---
Springhill	SH-30FA	0.9%	18.2	0.102	0.021	0.024	0.011	0.034
	SH-56FA	0.9%	18.2	0.007	0.010	0.017	0.007	0.014
	SH-7.5SF	0.9%	18.0	0.136	0.127	0.153	0.020	0.130
	SH-10SF	0.9%	18.0	0.086	0.072	0.098	0.013	0.120
	SH-12.5SF	0.9%	18.0	0.061	0.045	0.068	0.008	0.040
Conrad	SH-20FA	0.9%	16.1	0.144	0.035	0.045	0.025	0.175
	SH-30FA	0.9%	16.1	0.061	0.022	0.029	0.012	0.069
	SH-56FA	0.9%	16.1	0.002	-0.005	0.001	0.005	---
Sudbury	SB-10SF	0.9%	18.9	0.046	0.014	0.027	0.013	0.052
	SB-12.5SF	0.9%	18.9	0.043	0.003	0.027	0.003	0.078
	SB-35SG	0.9%	18.1	0.050	0.018	0.026	0.021	0.140
	SB-50SG	0.9%	18.1	0.032	0.014	0.027	0.006	0.043
Jobe	J-20FA	1.25%	5.0	0.020	0.033	0.071	0.020	0.020
	J-50SG	1.25%	5.0	0.020	0.063	0.115	0.030	---
	J-100Li	1.25%	18.0	0.120	0.261	0.447	0.038	---
Placitas	PT-20FA	1.25%	16.0	0.320	0.029	0.038	0.013	---
	PT-40C	1.25%	16.0	0.450	0.061	0.080	0.043	---
	PT-100Li	1.25%	16.0	0.330	0.091	0.137	0.046	---
Wright	W-20FA	1.25%	16.0	0.140	0.021	0.044	0.005	0.040
	W-40C	1.25%	16.0	0.420	0.077	0.113	0.033	0.080
	W-35SG5SF	1.25%	16.0	0.200	0.015	0.017	0.023	---
	W-35C5SF	1.25%	16.0	0.130	0.025	0.033	0.017	0.060

4. CONCLUSIONS

This study was conducted to assess the reliability of the MCPT (AASHTO T380) in evaluating ASR preventive measures and also to benchmark the results of MCPT against the data collected from exposure sites. Following conclusions are drawn from the results of this study:

- MCPT showed an improved correlation with field data compared to CPT and AMBT. 67.8% of MCPT results after 56 days were consistent with the expansion of exposure blocks. The value for 84-days MCPT was 68.9%. For the mixtures studied in this research a correlation of 35.7% and 42.8% were calculated for CPT and AMBT respectively.
- Changing the time frame of MCPT did not significantly affect the correlation of the test with field data.
- One of the advantages of choosing 56 days as the MCPT testing period was identifying the concrete mixtures that would not show deleterious expansion in the field. Increasing the testing time to 84 days leads to the failure of the most concrete mixtures, some of which may show desired performance in the field.
- A better understanding of the reliability of MCPT can be gained if the test is done on moderate and low/slowly reactive aggregates.
- For mixes with lithium, the same soak solution was chosen (1 N NaOH) in this study. A modification on the alkalinity and composition of the soak solution might be required when lithium is used in concrete mixtures.

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