

FHWA Workshop

Alkali-Aggregate Reaction

Session 04: ASR Test Methods



Presentation Outline

- ASR Test Methods
- Towards the Ideal ASR Test...

In this session, I will first describe the various standard test methods that have been used or are still being used to evaluate aggregate reactivity and preventive measures, such as SCMs and lithium-based admixtures. I will discuss the pros and cons of each test method.

It will be quite apparent from this session that we do not yet have the “ideal test method,” one that is rapid, reliable, reproducible, and related to field performance. Despite this shortcoming, it is still possible to use the currently available test methods to ensure that ASR will have only a minimal risk of occurring in a new concrete construction project.


ASR Test Methods

- ASTM C 295 - Standard Guide for Petrographic Examination of Aggregates for Concrete
- ASTM C 289 - Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)
- ASTM C 227 - Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
- ASTM C 441 - Standard Test Method for Effectiveness of Mineral Admixtures or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
- AASHTO T 303 (ASTM C 1260) - Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
- ASTM C 1567 - Standard Test Method for Determining the Potential Alkali-Silica Reactivity of Combinations of Cementitious Materials and Aggregate (Accelerated Mortar-Bar Method)
- ASTM C 1293 - Standard Test Method for Concrete Aggregates by Determination of Length Change of Concrete Due to Alkali-Silica Reaction


} Aggregate Tests

} Mortar Tests

} Concrete Test



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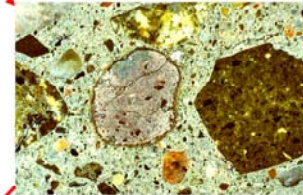
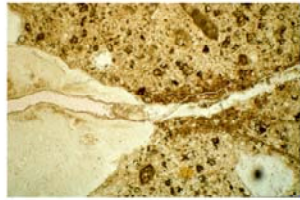
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There are various ASR test methods that have been standardized over the years. These range from tests that solely test the aggregate of interest to those that test mortar bars containing the aggregate to those that concrete prisms containing the aggregate.

Each of these tests will be briefly described, but the primary focus will be on those tests used the most and those recommended in AASHTO PP 65-11, specifically AASHTO T 303 (accelerated mortar bar test), ASTM C 1567 (accelerated mortar bar tests for evaluating SCMs) and ASTM C 1293 (concrete prism test).

ASTM C 295 - Standard Guide for Petrographic Examination of Aggregates for Concrete

A petrographic evaluation involves the microscopic analysis of aggregates (or concrete) using thin sections or polished surfaces.



Petrography is an important tool when assessing aggregate reactivity.

Petrographers can use polished and/or thin section analysis to characterize the mineralogy of a given aggregate, including an estimate of the percentage of reactive minerals present.

ASTM C 295 - Standard Guide for Petrographic Examination
of Aggregates for Concrete

Purpose of petrographic examination of aggregates:

- Identify most (but not all) potentially reactive minerals
 - Optically strained, microfractured, or microcrystalline quartz (5.0 % max.)
 - Chert or chalcedony (3.0 % max.)
 - Tridymite or cristobalite (1.0 % max.)
 - Opal (0.5 % max.)
 - Natural volcanic glass (3.0 % max.)
 - Track changes in source materials
 - Relate aggregate mineralogies/sources to field structures
- Note:
- Evaluation must be performed by trained petrographer.
 - Results should not be used solely to reject or accept aggregate source.

AASHTO,
PCA limits

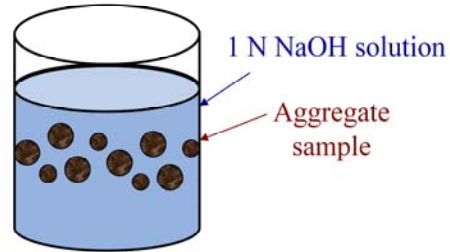
There are several important advantages of applying petrography to ASR.

An estimate of the amount of certain reactive minerals, such as chert, opal, or volcanic glass, can be achieved following ASTM C 295. However, it should be noted that some minerals are not detectable using petrographic examination, and caution is urged in accepting an aggregate based solely on the results of petrography.

Petrography is also a useful tool in linking aggregate from a given source to field structures.

ASTM C 289 - Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)

- Accelerated aggregate test
- Sample placed in 1 N NaOH at 80 C for 24 hours
- Alkalinity and amount of dissolved silica measured at end of test



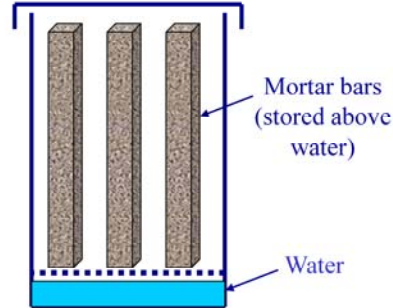
- Test shows poor reliability
- Very severe test -- many aggregates with good field performance “fail” test
- Not recommended, but sometimes still used...

ASTM C 289, or the “Quick Chemical Test” is a rapid test that measures the amount of silica that dissolves from an aggregate sample after 24 hours of immersion in 1 N NaOH solution at 80 °C.

Because of the severe conditions encountered in this test and the fact that a crushed aggregate sample is being evaluated (instead of mortar or concrete containing such an aggregate), there is generally a poor correlation between this test and the performance of aggregates in the field.

ASTM C 227 - Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)

- Mortar bar test (aggregate/cement = 2.25), intended to study cement-aggregate combinations.
- Specimens stored in high-humidity containers at 38 °C.
- Length change measurements made at 14 days, 1 month, 2 month, etc.



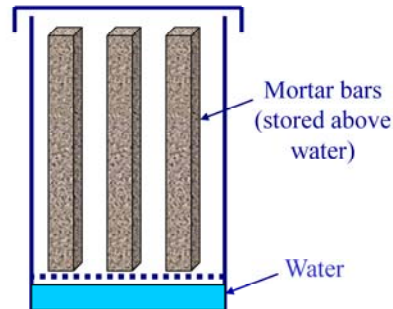
- Several reported problems with test, including excessive leaching of alkalis from specimens.
- Test not recommended but still used by some (also included in ASTM C 33 Appendix)

ASTM C 227 is essentially the test method developed by Stanton in the late 1930's. The test involves storing small mortar bars (25 mm x 25 mm cross section) over water at 38 °C.

Because of the small specimen size, leaching is quite significant in this test. For slower reacting aggregates, leaching can occur to a point where the alkali content of the bar drops below the alkali threshold for the given aggregate. This can cause an aggregate to be classified as non-reactive, when in fact, the aggregate shows to be reactive in more accurate test methods (such as ASTM C 1293) and in the field.

ASTM C 441 - Standard Test Method for Effectiveness of Mineral Admixtures or Slag in Preventing Excessive Expansion of Concrete Due to the ASR

- Mortar bar test, intended to assess effectiveness of SCM's in reducing ASR expansion.
- Uses high-alkali cement and pyrex glass.
- Specimens stored in high-humidity containers at 38 °C (similar set-up as ASTM C 227)



- Test not very reliable because of the use of pyrex glass, which is sensitive to test conditions and contains alkalis that may be released during the test.
- Test does not correlate well with data from concrete mixtures containing natural aggregates.

ASTM C 441 is similar to ASTM C 227 in terms of specimen size and storage conditions. However, this test uses crushed Pyrex glass as a “model aggregate,” and the test is used to evaluate how effective a given SCM is in reducing expansion triggered by the Pyrex glass. This test has no correlation to the performance of actual aggregates, and in addition, Pyrex can contain large and variable amounts of alkalis, which can be released during the test, adding variability to a test that already is flawed.

Concrete Prism Test (CPT) ASTM C 1293

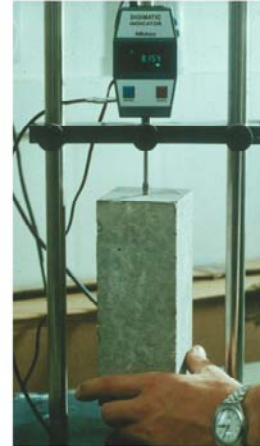
708 lb/yd³ cementitious material

NaOH added to yield 1.25%
Na₂O_e by mass of Portland
cement

$$0.42 \leq W/CM \leq 0.45$$

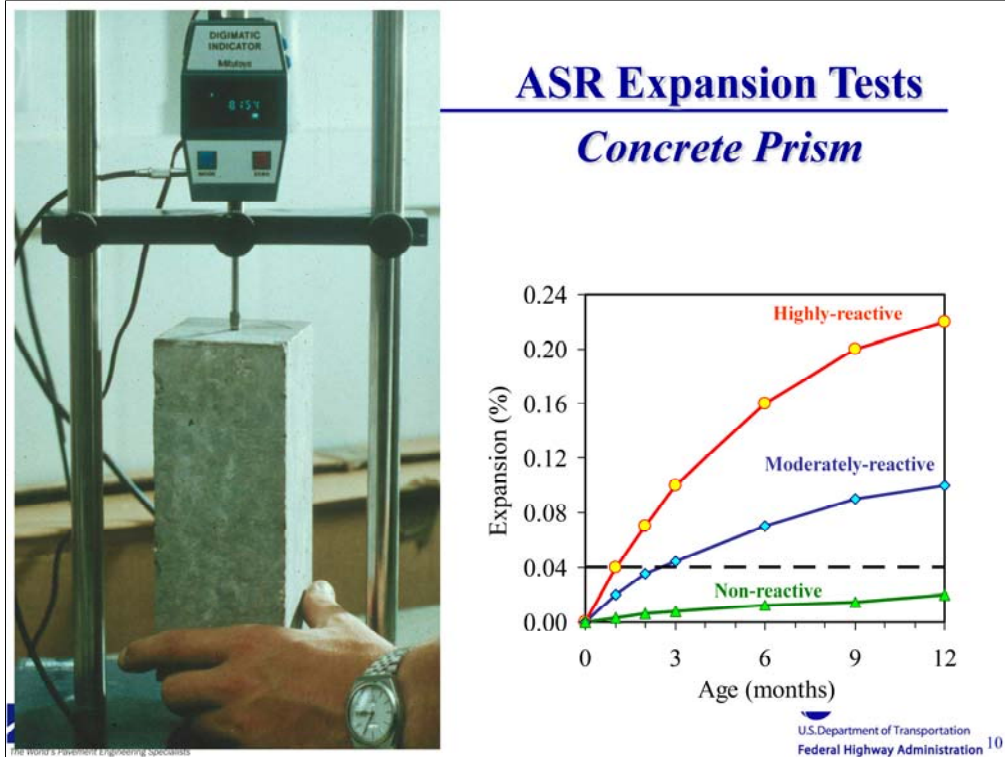
Concrete prisms
3 x 3 x 10 (min) inch

Stored over water at 100°F
(and nominally 100% RH)
for 1 year to test aggregates or
for 2 years to evaluate preventive
measures.



The concrete prism test, ASTM C 1293, was originally developed in Canada. The test involves storing concrete prisms (75 mm x 75 mm) over water at 38 °C. Because the specimen size is considerably larger than mortar bars used in ASTM C 227 and ASTM C 441, the effects of leaching are not as significant (albeit leaching is still important, as discussed later in this presentation).

The test takes one year to test aggregates and two years to test preventive measures, such as SCMs and lithium-based admixtures. It is this long duration (1-2 years) that is its largest impediment to more widespread use.



The expansion limit for ASTM C 1293 is 0.04 percent (at one year for aggregates, two years for preventive measures).

In Canadian standards (CSA), the reactivity of an aggregate is classified based on expansion at one year, with expansions between 0.04 and 0.12 percent considered moderately reactive, and expansions greater than 0.12 percent considered highly reactive.

ASTM C 1293 – PROS AND CONS

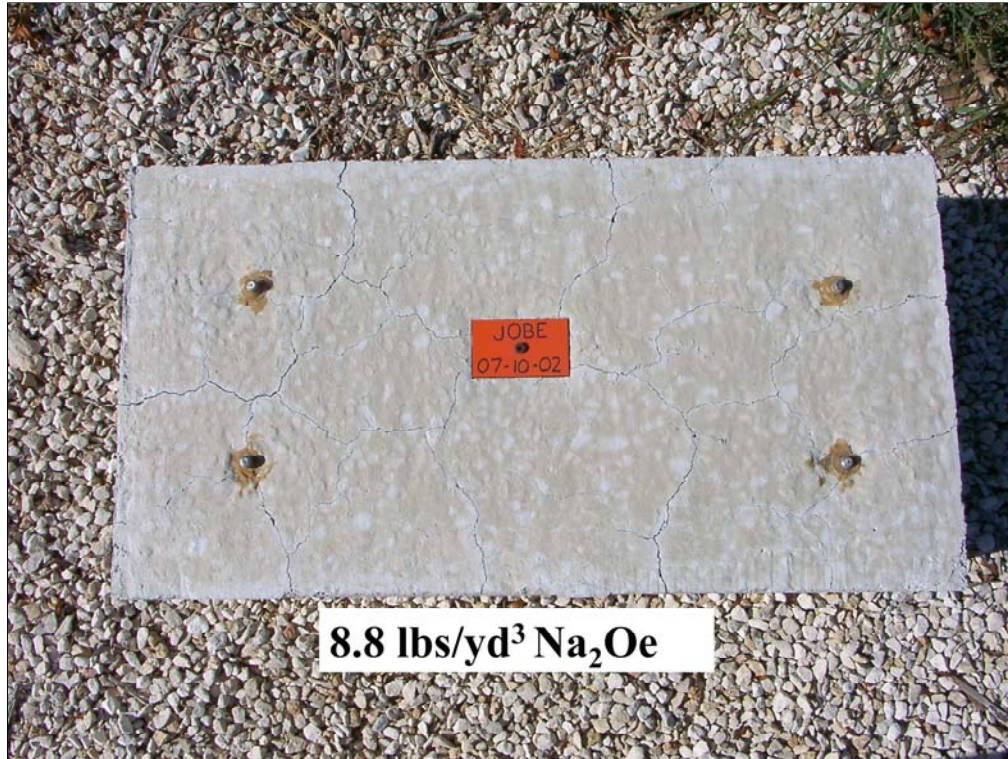
PROS

- Best predictor of aggregate reactivity (no known cases where aggregate expands in field but passes ASTM C 1293)
- Suitable for assessing supplementary cementing materials (SCMs) and lithium admixtures.
- Can test “real” concrete with realistic aggregate sizes (no need to crush coarse aggregates)

CONS

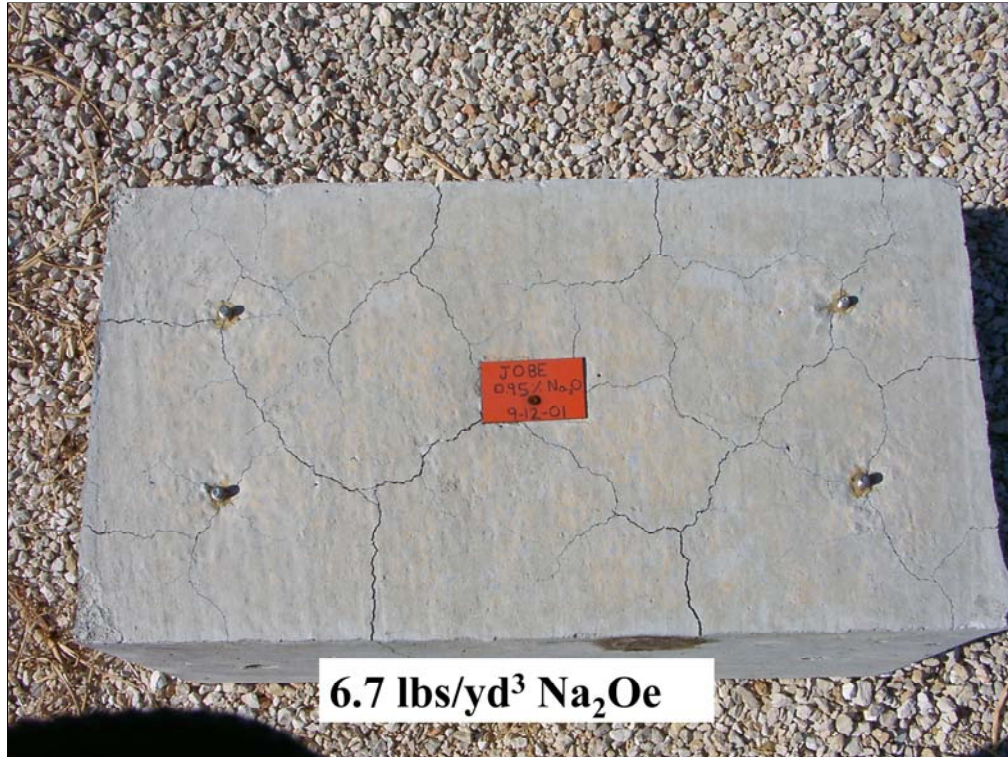
- Alkalies leach from prisms during course of test, making it impossible to evaluate alkali thresholds.
- The test takes too long (one year for aggregates, two years for preventive measures)!!!

ASTM C 1293 is generally considered the most accurate test for evaluating aggregate reactivity. The test can also be used to evaluate preventive measures, but the test takes two years. Leaching is still a significant factor in ASTM C 1293, and the test is not suitable for establishing the alkali threshold for a given aggregate, as illustrated in the following slides.



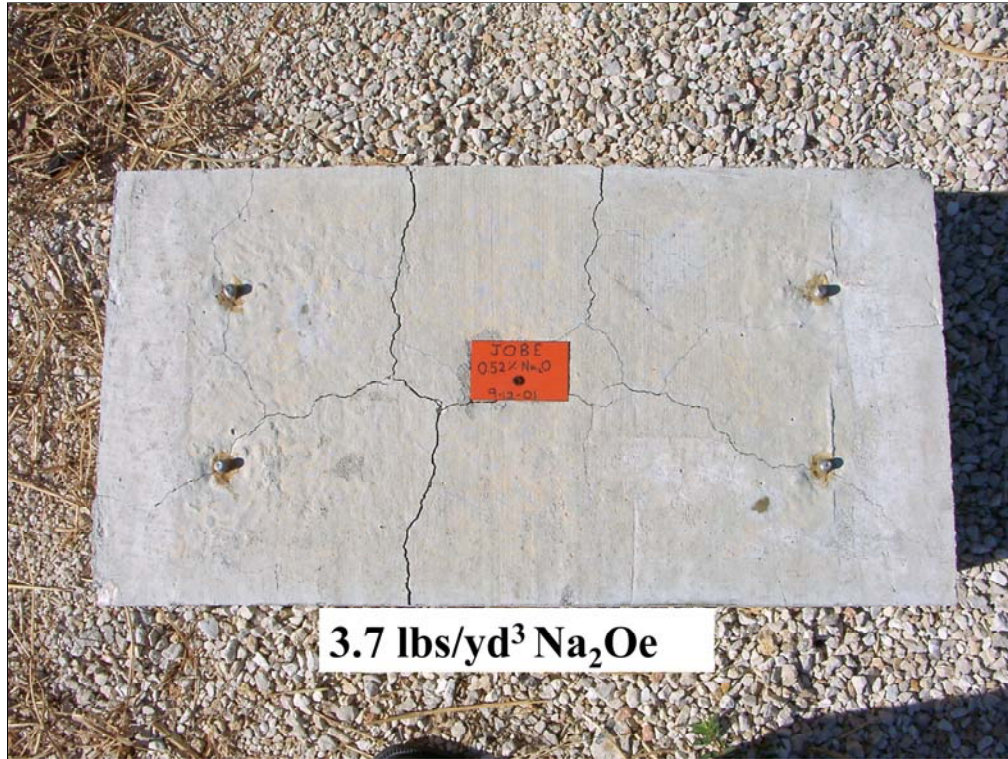
This exposure block (Austin, TX) contained a highly-reactive sand from El Paso, TX, a high-alkali cement with additional alkalis added to achieve a Na_2O_e content of 1.25 percent. With a cement content of 708 lbs/yd³, this block had an alkali loading of 8.8 lbs/yd³.

As shown in the photo, this block exhibited significant cracking, with cracks evident in about a month of field exposure.



This block is identical to the previous slide, except for the fact that this block was “unboosted,” meaning additional NaOH was not added. Thus, the alkali content of the block was 0.95 percent, resulting in an alkali loading of 6.7 lbs/yd³.

As shown in the photo, this block also exhibited significant cracking, with cracks evident after about a year of field exposure.

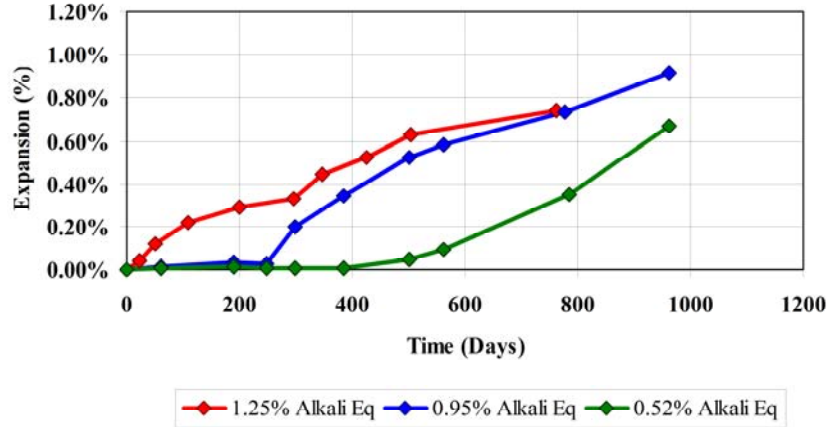


This block is identical to those shown in the last two slides, but it contained a low-alkali cement, producing an exposure blocks with an alkali loading of 3.7 lbs/yd³.

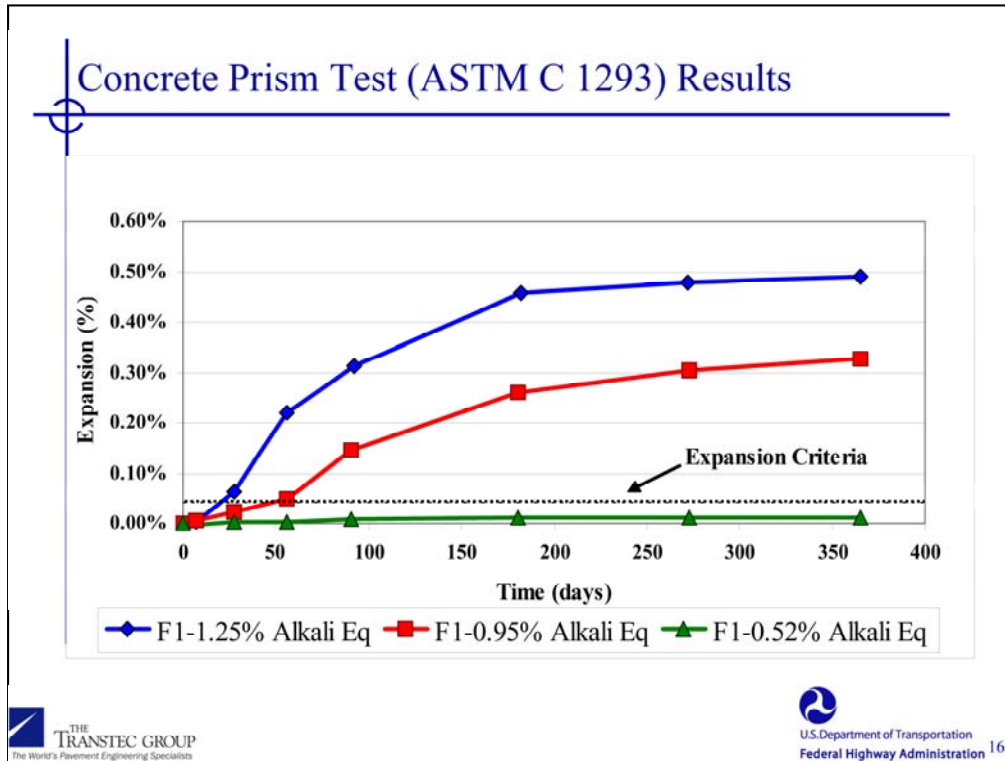
This block took over a year and a half or so to exhibit cracking, as shown in the photograph.

In summary, all three of the blocks shown in these slides exhibited significant cracking when stored outdoors in Austin, TX, with the last block showing expansion and cracking at a relatively low alkali loading.

Exposure Block Expansion Results

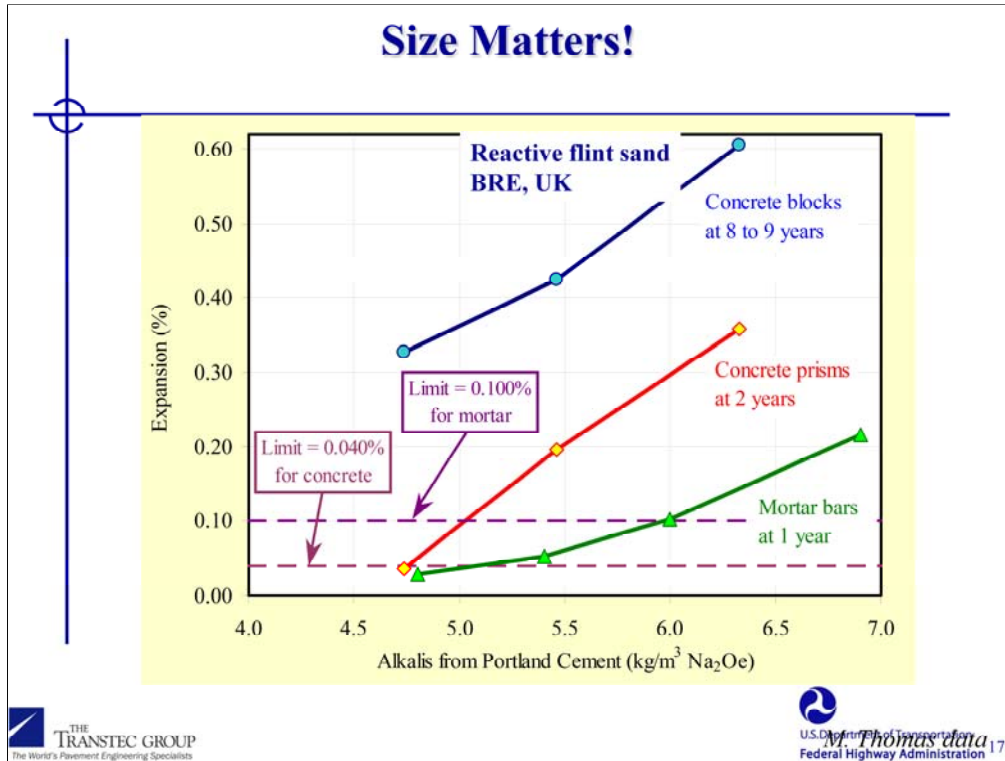


This graph shows the expansion of the three exposure blocks just discussed. Although the three blocks began to expand at different times, they all ultimately exhibited significant expansions, above 0.60 percent for all three blocks.



However, when prisms cast from the same concrete mixtures used in the three exposure blocks just discussed were tested using ASTM C 1293 storage conditions, only the two higher alkali mixtures expanded.


The lowest alkali mixture showed very little expansion, with expansion well below the 0.04 percent expansion limit after one year. It is assumed that leaching reduced the alkali loading of these low-alkali prisms below the alkali threshold for this highly-reactive sand. This example illustrates why ASTM C 1293 can not be used as a test for determining alkali thresholds for aggregates.



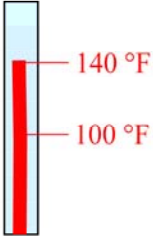
This graph illustrates the same point.


The data show that the larger the size of the specimen, the lower its alkali threshold is, further highlighting the importance of leaching when testing aggregate reactivity.


The major complaint about ASTM C 1293 is the duration of the test
(one year for aggregates,
two years for SCM's, lithium, etc.)



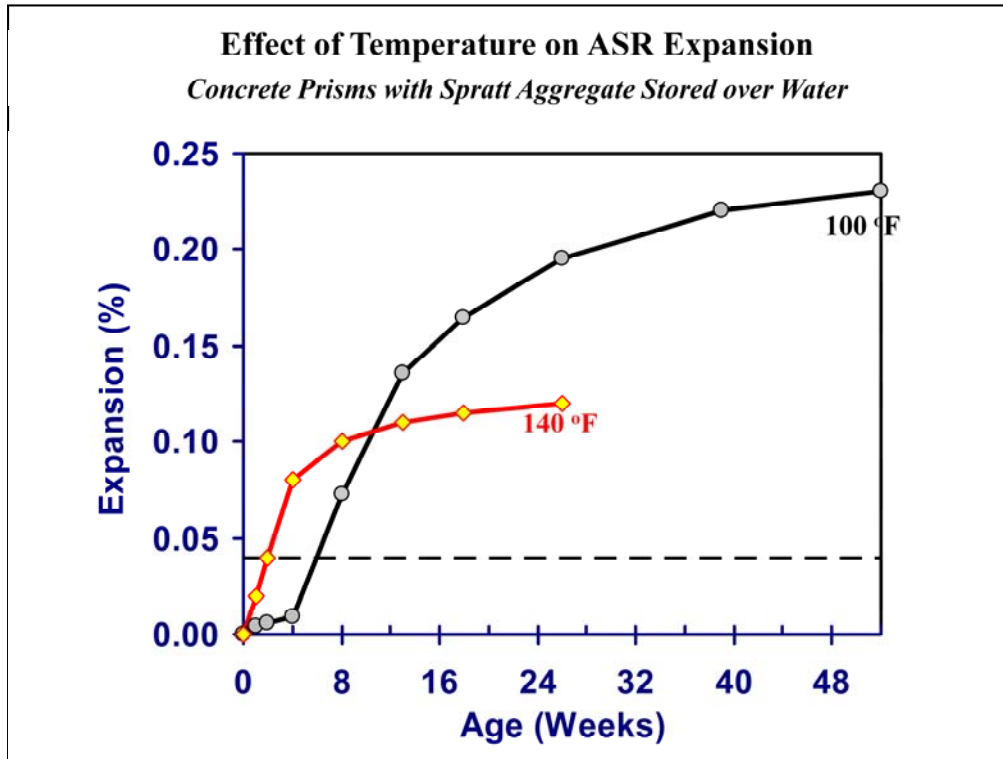
ASTM, CSA, and RILEM have all considered an accelerated version of ASTM C 1293, conducted at 140 °F (instead of 100 °F)



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There has been considerable interest over the years in trying to shorten the duration of ASTM C 1293 by increasing the temperature at which the prisms are stored above water. Efforts within ASTM, CSA, and RILEM have specifically focused on trying to accelerate the concrete prism test by raising the temperature from 38 to 60 °C.



Unfortunately, the results have not been promising. The graph shown above shows that expansion is reduced considerably when the temperature is increased to 60 °C.

The results are counterintuitive in that the rate of chemical reactions increases with temperature, and one might think that higher expansions might be generated when storing prisms at 60 °C, instead of 38 °C.

Accelerated Concrete Prism Test (140 F version)

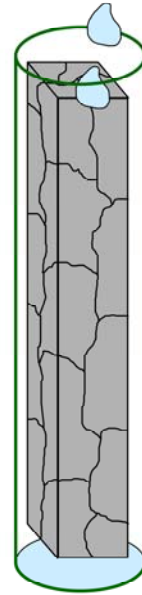
- Higher temperature of the test leads to
 - Increased leaching rate
 - Selection of the non-reactive aggregate also significant in this test
 - Reduction in pore solution pH as sulfates are drawn into solution and replace hydroxyl ions

After considerable investigation, it was found that several factors are responsible for the reduced expansion at elevated temperatures, including increased leaching, increased drying of specimens, and the effects on pore solution pH (highlighted in the following slides).

Modified C 227

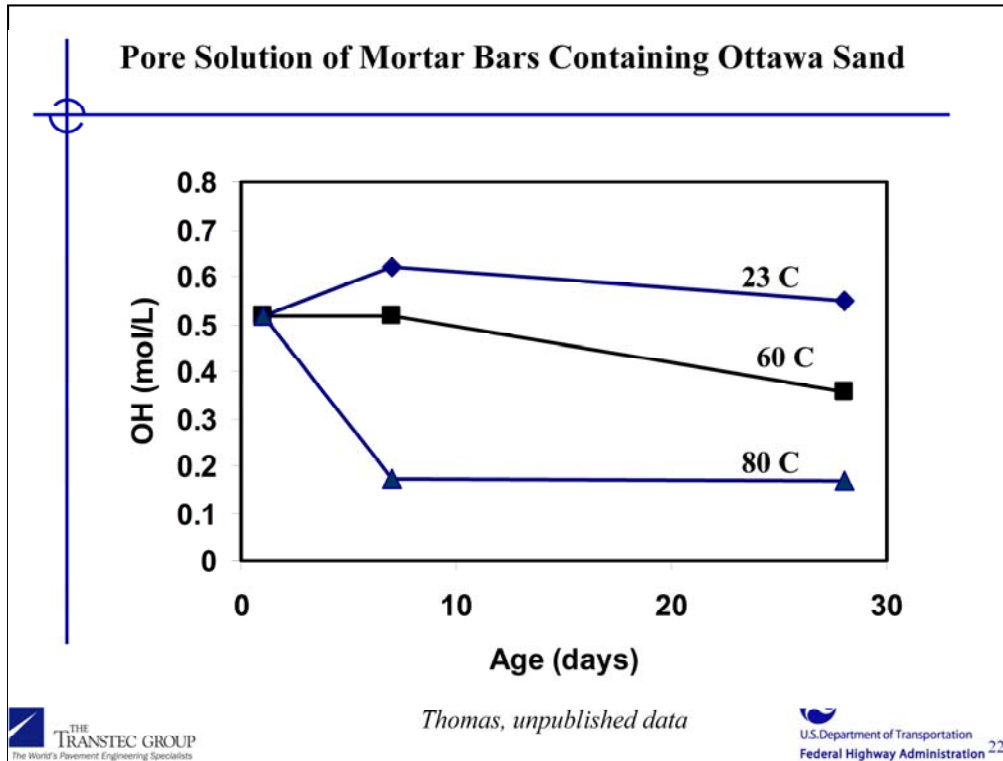
- Seal mortar bar to prevent evaporation
- Provide small quantity of moisture to maintain RH whilst minimizing leaching
- Store at elevated temperature (e.g. 60 to 80°C to accelerate reaction (& expansion) rate

e.g. place in tight-fitting, heat-resistant plastic bag with a few drops of water



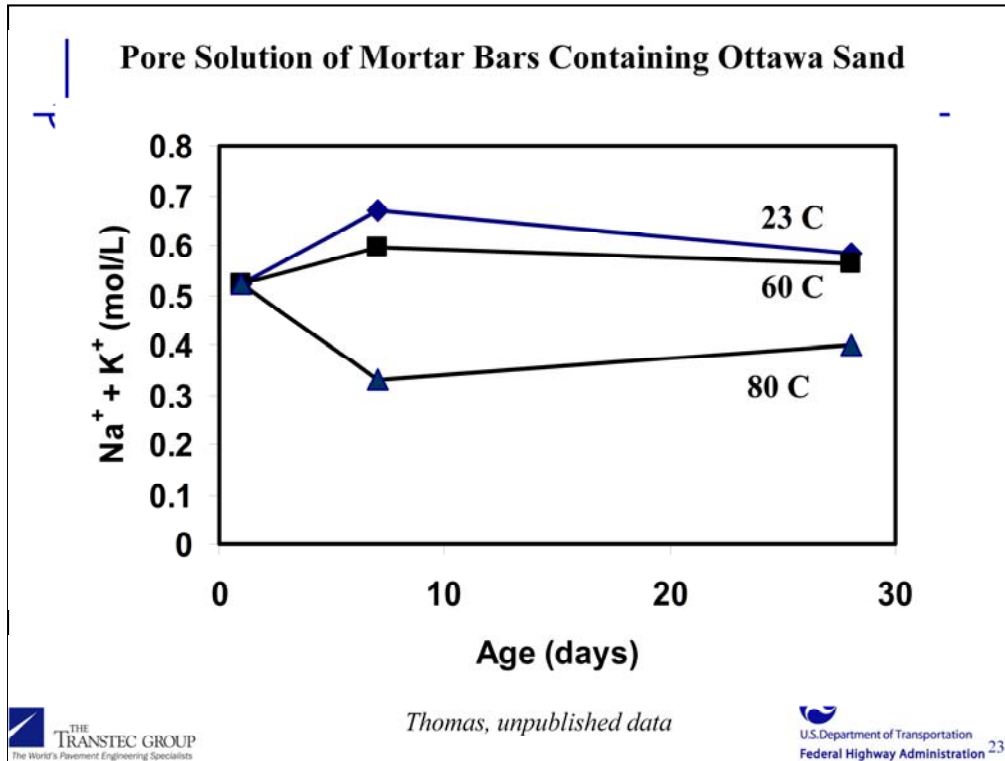
Thomas, unpublished data

Mortar bars were stored in sealed plastic bags, with a small quantity of water at the bottom of the bag. This set-up was intended to minimize any effects of evaporation and to minimize leaching of alkalis from the bars.

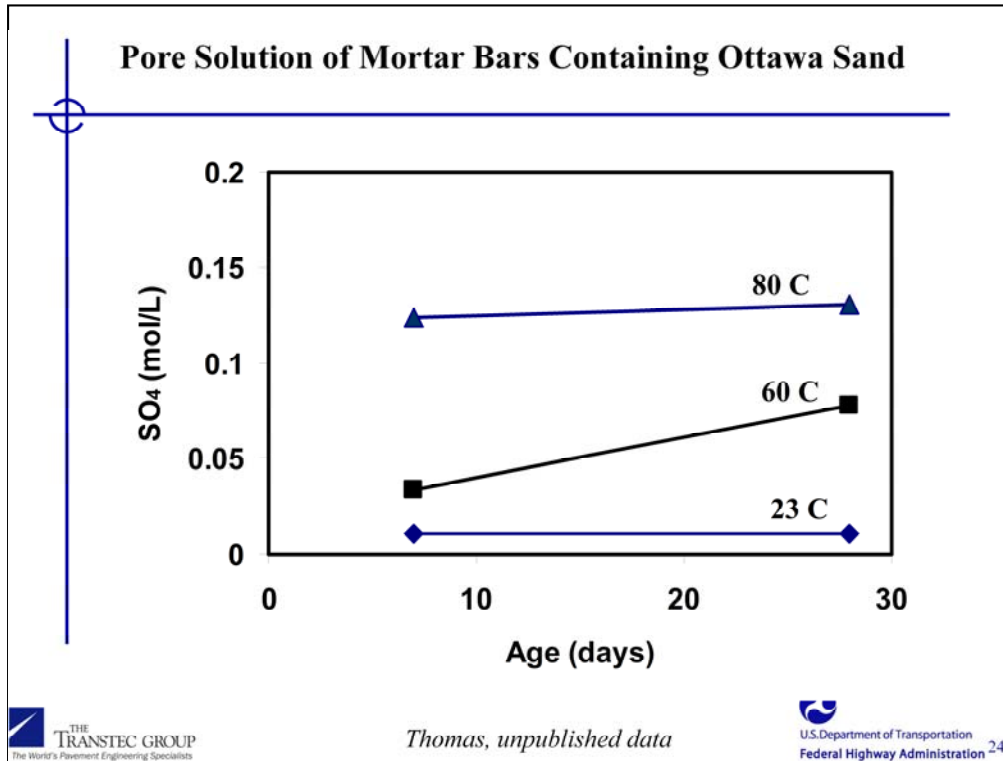


At various ages of storage, mortar bars were removed from testing and their pore solution was extracted (using a high-pressure pore press) and evaluated.

This graph shows that the OH⁻ content of the pore solution decreased with increasing temperature, with the most significant effects occurring at 80 °C.



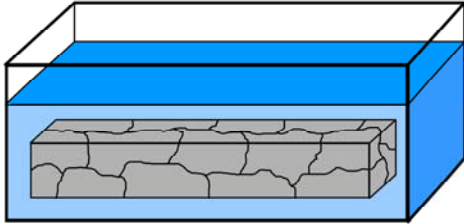
The alkali content of the pore solution was found to decrease with increasing temperature, but the effects were not as pronounced as they were for the OH^- content. This suggests that another anion may be entering the pore solution, in lieu of the OH^- ions. Evidence of this is shown in the next slide.



At higher temperatures, it is quite evident that sulfate ions are entering the pore solution as ettringite is becoming unstable at higher temperatures.

This helps to explain why higher temperatures are resulting in lower expansions – the higher temperature is causing sulfates to take the place of hydroxyl ions in the pore solution, lowering the pH and the potential for ASR-induced expansion and cracking.

Accelerated Mortar Bar Test
AASHTO T 303 (ASTM C 1260)




Aggregate/cementitious material = 2.25


W/CM = 0.5

Portland cement = 0.8 to 1.0% Na₂O_e

Mortar bars, 1" X 1" X 11.25", stored in 1M NaOH at 176°F for **14 days** (or 28 days)

ASTM C 1567 – same test procedure, but allows for testing SCMs


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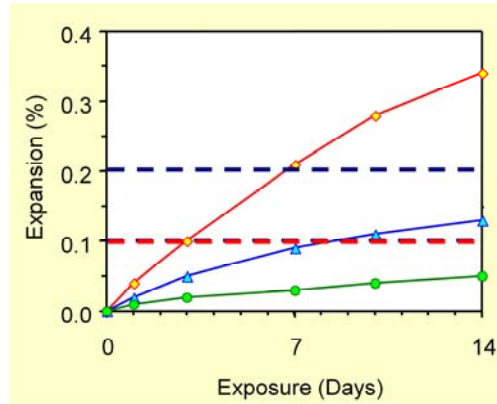

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The accelerated mortar bar test (AASHTO T 303/ASTM C 1260) was initially developed by Oberholster and Davies in South Africa. It is a highly-accelerated test that involves immersing small mortar bars in 1 N NaOH solution at 80 °C.

To test a coarse aggregate, it must be crushed down to a prescribed sand size. The test is typically run for 14 days, although some users and specifiers extend the test to 28 days.

ASTM C 1567 is a modified version of AASHTO T 303 that allows for testing SCMs. This is discussed later in the presentation.

ASTM C 1260 - Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)



ASTM C 1260 expansion criteria:

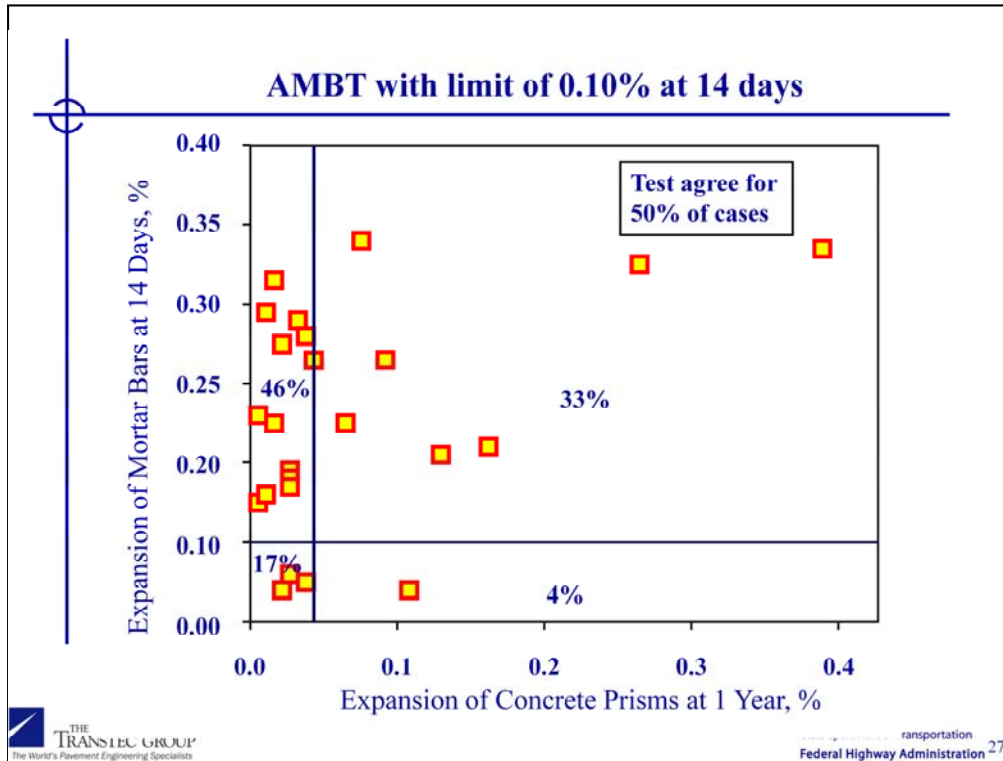
> 0.20 percent = reactive

0.10 to 0.20 percent = potentially reactive

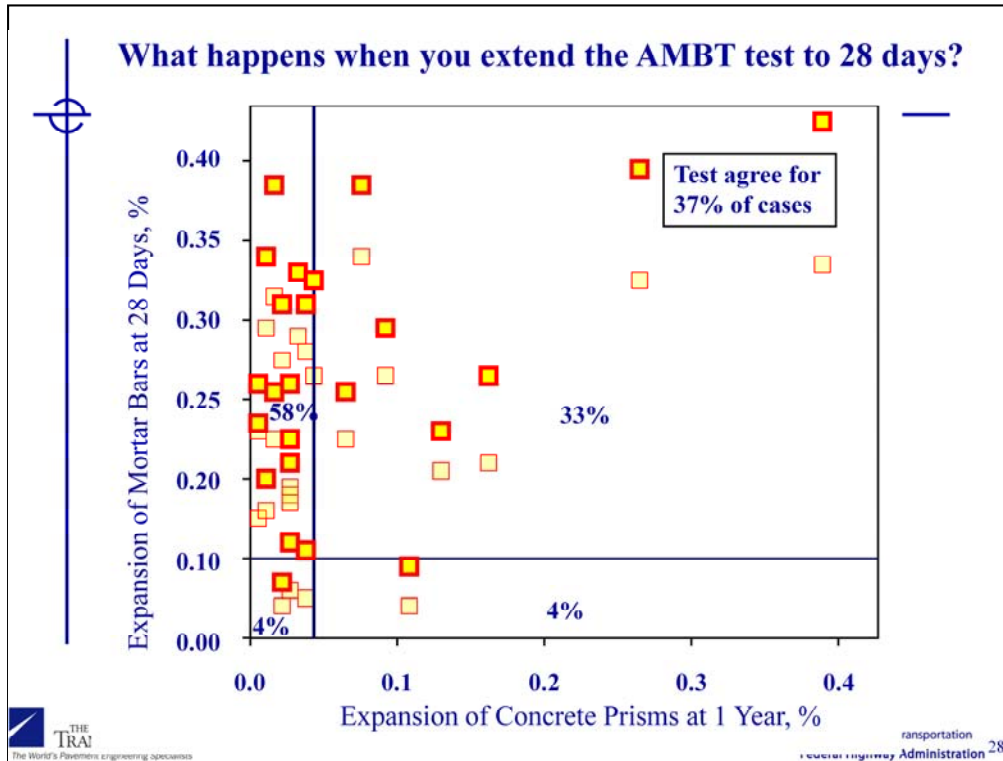
< 0.10 percent = innocuous

Note - other agencies/organizations specify different expansion limits and/or test durations...

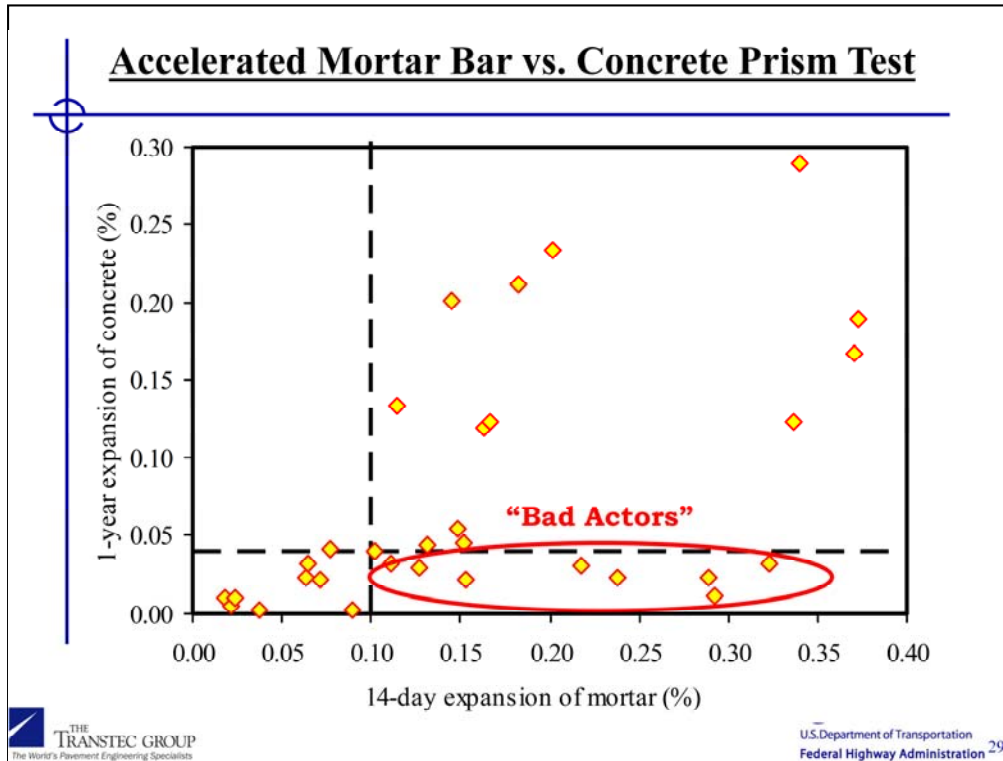
According to ASTM C 1260, aggregates that expand less than 0.10 percent are considered innocuous, aggregates that expand between 0.10 and 0.20 percent are considered potentially reactive, and aggregates that expand by more than 0.20 percent are considered reactive. AASHTO PP 65-11 specifies an expansion limit of 0.10 percent at 14 days.



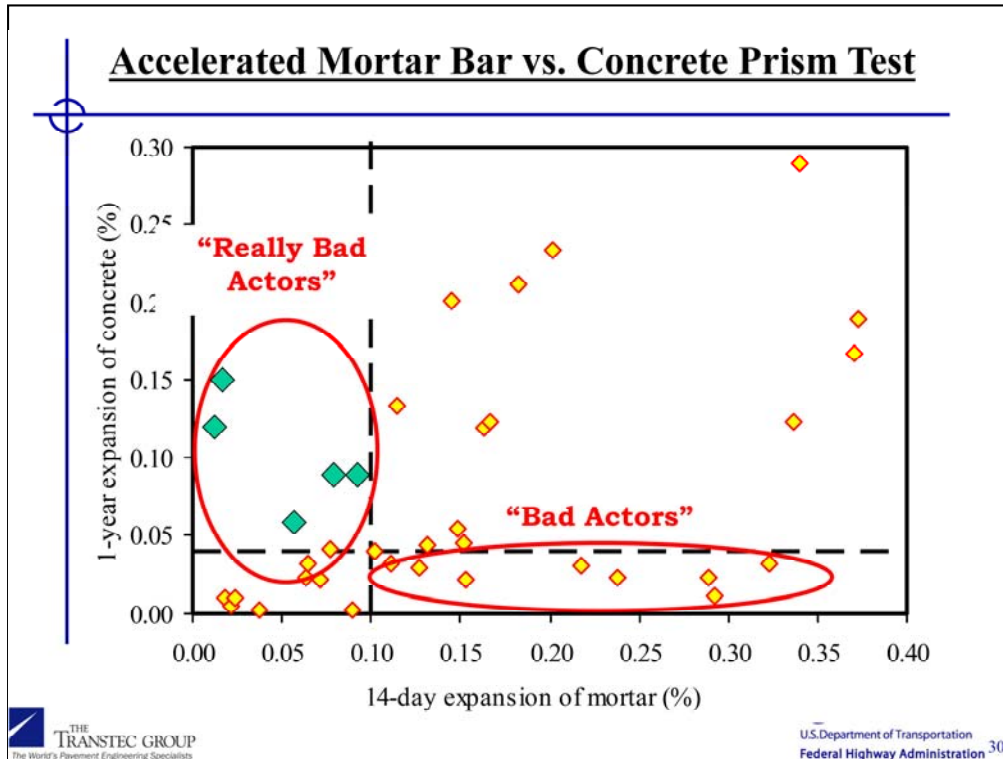
As previously mentioned, ASTM C 1293, although it is far from a perfect test, is recognized as the test that best correlates with field performance of aggregates. Unfortunately, AASHTO T 303 is known to generate results that are not in agreement with ASTM C 1293 for a number of aggregates. This graph shows that the results of the accelerated mortar bar test agree about half the time with the results from the concrete prism test, when using a 14-day test duration.



Some users and agencies have proposed using a 28-day expansion limit for testing aggregates (and preventive measures) using AASHTO T 303. Unfortunately, this tends to increase the number of discrepancies between the mortar bar test and concrete prism test. This graph shows that only 37 percent of the times will the two tests yield similar results when the test duration is increased to 28 days.



The dataset shown in this graph highlights the potential discrepancies between AASHTO T 303 and ASTM C 1293. The data points highlighted in red are sometimes referred to as “bad actors” – these are aggregates that fail AASHTO T 303 but pass ASTM C 1293. The potential for this disagreement has been known for quite a few years and is mainly owed to the very aggressive nature of AASHTO T 303 – high temperature and essentially an infinite supply of alkalis can cause some aggregates to expand that will not otherwise expand in ASTM C 1293 or in field structures.



What is more concerning are the “really bad actors,” as shown in the graph. These aggregates pass AASHTO T 303 but fail the concrete prism test and result in expansion and cracking of field structures. Quite a few coarse aggregates fit in this category. This is of more concern because many agencies would deem any of these aggregates to be non-reactive and no preventive measures would be prescribed. Recent work has shown that aggregates that tend to pass AASHTO T 303 but fail in ASTM C 1293 are often aggregates containing chert, and the main reason for the erroneous result in the mortar bar test is related to the classic “pessimum effect,” where chert is most reactive when it is present in aggregates at about 8-10 percent by mass. The proportion of chert in AASHTO T 303 is well above this as a given coarse aggregate is tested by itself (100 percent aggregate content); thus expansion is not observed for these aggregates in AASHTO T 303.

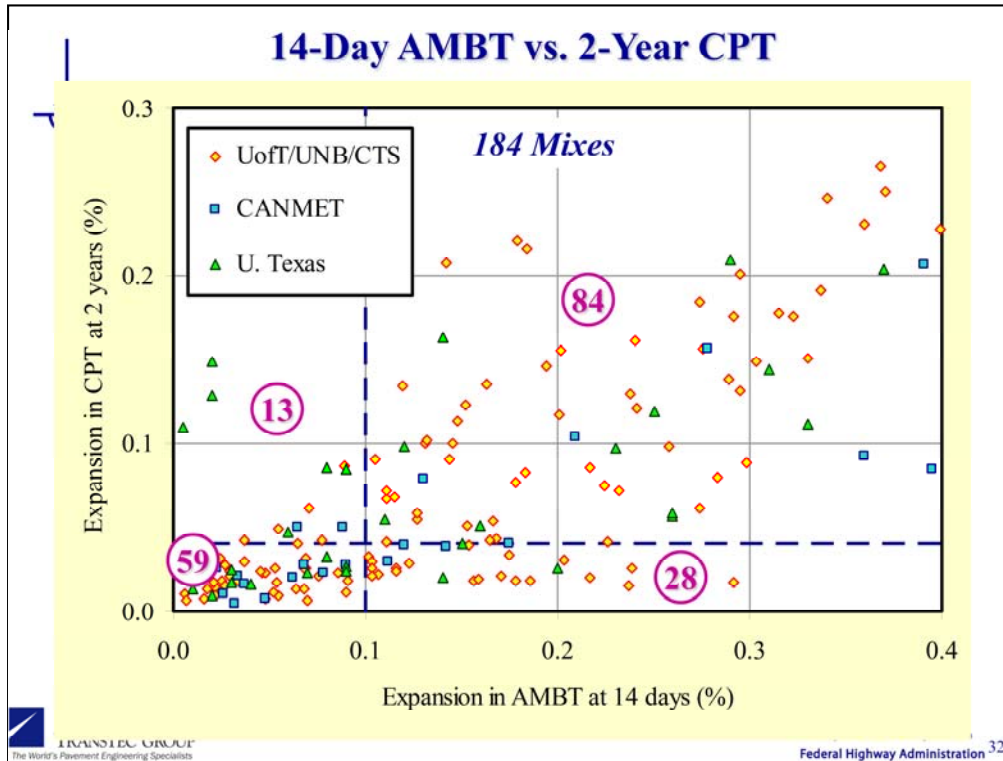
ASTM C 1567- Testing SCMs in Accelerated Mortar Bar Test

Testing SCM's using ASTM C 1567

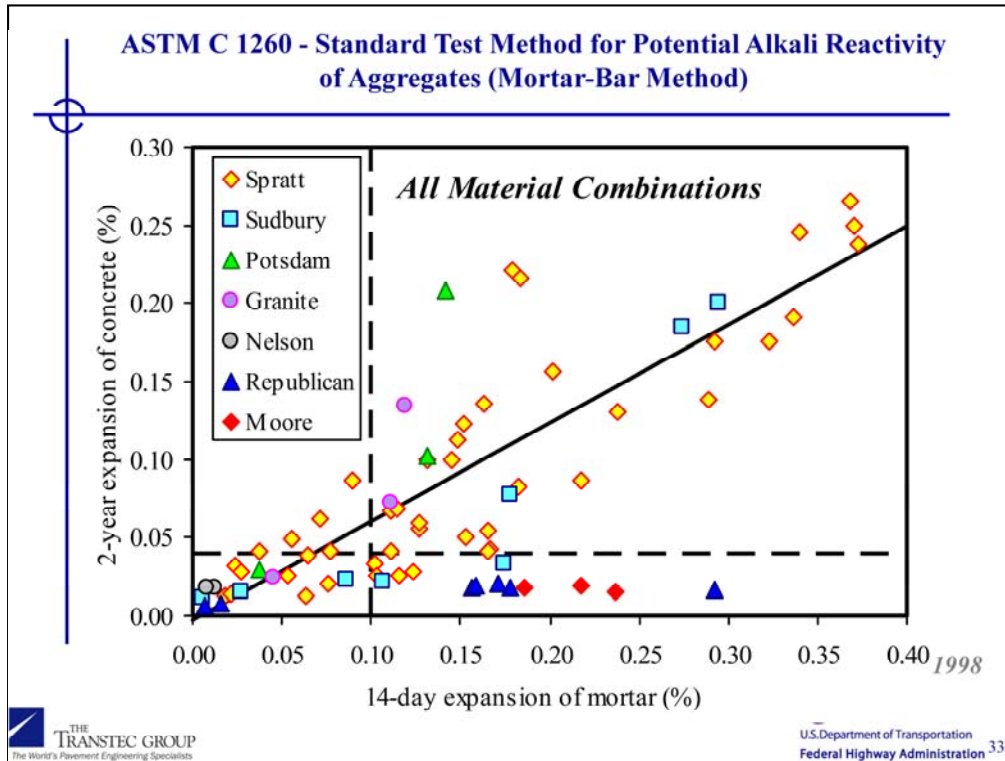
- To test SCM's, the same basic procedures are used as described in ASTM C 1260.
- Only difference is substitution of portland cement by SCM or SCM's.
 - w/cm = 0.47
 - CSA specifies Na_2O_e of portland cement to be $0.9 \pm 0.1\%$
 - Proposed ASTM version does not specify cement alkalinity
- Expansion limit = 0.10 percent at 14 days (CSA and proposed ASTM)
- Test not able to assess alkalis present in SCM's (due to leaching effect)
- Good correlation with ASTM C 1293 (2-year data), as illustrated next... (for aggregates that show good correlation between results in CPT and AMBT)

ASTM C 1567 is identical to AASHTO T 303 in terms of specimen size and storage conditions; the only difference is that ASTM C 1567 allows for testing SCMs to determine the amount needed to suppress expansion of a given reactive aggregate.

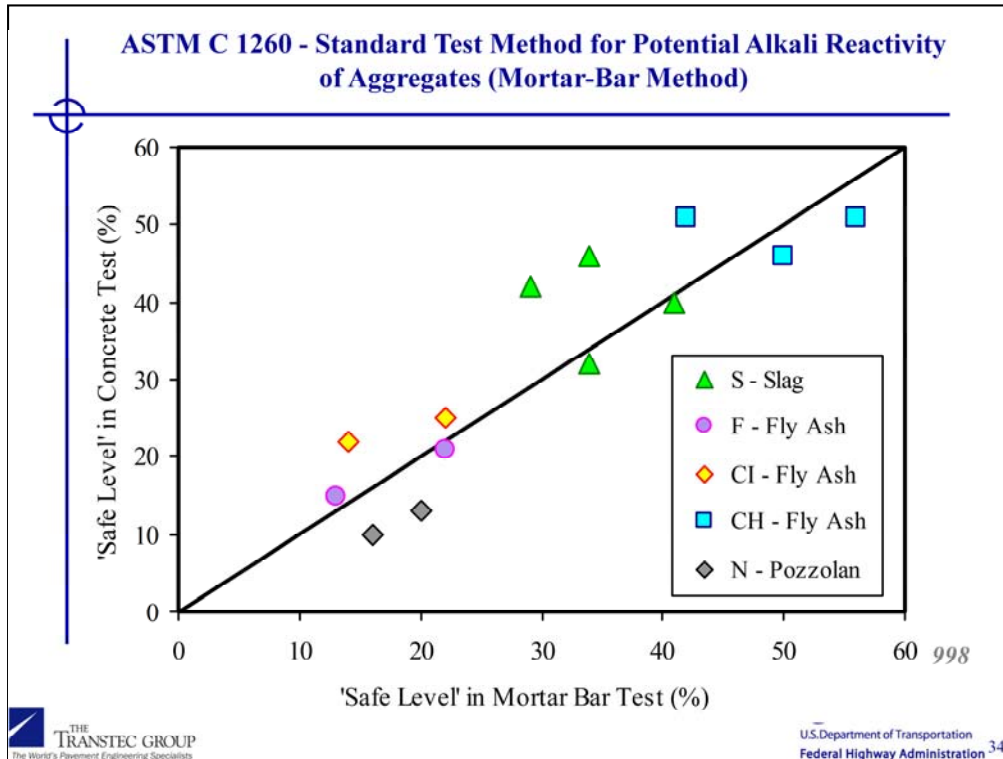
This test has the same inherent limitations as AASHTO T 303. However, for aggregates that yield similar results when tested using AASHTO T 303 and ASTM C 1293 (that is a pass/pass or fail/fail outcome), there is a reasonable correlation between testing a given SCM in ASTM C 1567 and ASTM C 1293, when using a 0.10 percent expansion limit at 14 days and a 0.04 percent expansion limit at two years, respectively.



As mentioned in the last slide, there is a reasonable correlation between testing a given SCM in ASTM C 1567 and ASTM C 1293, when using a 0.10 percent expansion limit at 14 days and a 0.04 percent expansion limit at two years, respectively. The correlation is not perfect, and there will still be some cases where the tests are not in agreement in terms of their pass/fail outcome, but there is a reasonable correlation for many aggregate types and sources.



This graph shows the same trend as the previous graph, for a different data set. Again, one can see a reasonable correlation between the two tests when testing SCMs in combination with a range of reactive types.



This graph shows the same trend as the last two slides, but it shows the data in a different manner – the x-axis shows the amount of SCM needed to control expansion in ASTM C 1567, and the y-axis shows the amount of SCM needed to control expansion in ASTM C 1293 (using the same expansion limits and test durations as detailed in the last couple slides). In this graph, it is shown that the two tests would estimate that one would need similar SCM contents to suppress expansions in the two tests. It should be noted that this data set is for aggregates for which a reasonable correlation has been established when testing the subject aggregate using AASHTO T 303 and ASTM C 1293 (so in other words, there are no “false positives” or “false negatives” included in this study).

AASHTO PP 65-11: Performance Approach

Performance Testing using the CPT

The concrete prism test cannot be used to determine the influence of portland cement alkalis on ASR expansion, in other words:

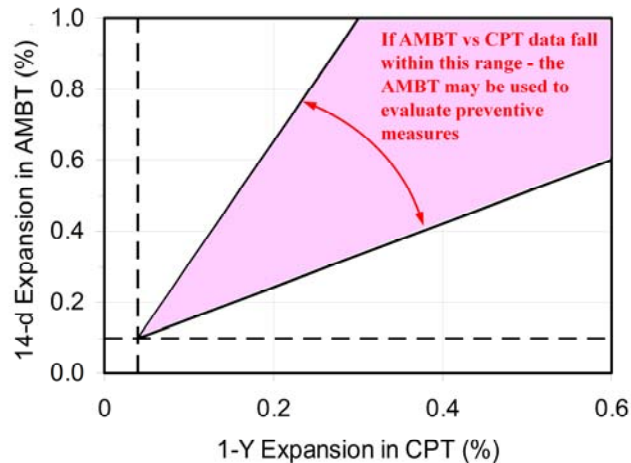
- CPT cannot be used to determine the safe alkali level for a particular aggregate
- CPT cannot be used to evaluate a combination of low-alkali cement and SCM
- Portland cement alkalis must be raised to 1.25% Na₂O_e in the CPT to compensate for leaching during test

In the next few slides, the testing regime recommended under AASHTO PP 65-11 will be described. This recommended practice recommends ASTM C 1293 (or CPT) for evaluating aggregates and SCMs, using an expansion limit of 0.04 percent at one year when testing aggregates and 0.04 percent at two years when testing SCMs. The same limitations are noted in AASHTO PP 65-11 as were previously discussed – that is leaching is still an issue and one cannot test for alkali thresholds or one cannot test the efficacy of low-alkali cements, due to the leaching of alkalies from the prisms during the course of a given test.

AASHTO PP 65-11: Performance Approach

Performance Testing using the AMBT

First establish correlation between AMBT & CPT for aggregate



In order to use ASTM C 1567 to determine how much SCM is needed to control the expansion of a reactive aggregate, it must first be proven that the aggregate yields comparable results when tested using AASHTO T 303 (or AMBT) and ASTM C 1293 (or CPT). The data should fall within the shaded area, as shown above. Once such a correlation has been found, one is then able to use ASTM C 1567 to determine the dosage of SCM(s) needed to control expansion for that aggregate.

AASHTO PP 65-11: Performance Approach

Performance Testing using the AMBT

Evaluating SCM's using the AMBT

1. Use ASTM C 1567 except that the portland cement alkalis should be $0.90 \pm 0.10\% \text{ Na}_2\text{Oe}$
2. Do not use this test if fly ash alkalis $> 4.5\% \text{ Na}_2\text{Oe}$ or alkali content of other SCM's $> 1.0\% \text{ Na}_2\text{Oe}$
3. Expansion $< 0.10\%$ at 14 days

The details are shown in this slide on how to test SCMs under the AASHTO recommended practice. The alkali content of the portland cement is specified to be between 0.8 and 1.0 percent as it has been shown that the alkali content of the portland cement can affect the results when evaluating SCMs. High-alkali SCMs are not allowed for testing in the AMBT because the effects of SCM alkali content are not discernible in the test, due to the infinite supply of alkalies coming from the host solution.

AASHTO PP 65-11: Performance Approach

Performance Testing using the AMBT

The accelerated mortar bar test **cannot** be used to determine the influence of portland cement alkalis on ASR expansion, in other words:

- AMBT **cannot** be used to determine the safe alkali level for a particular aggregate
- AMBT **cannot** be used to evaluate a combination of low-alkali cement and SCM

This slide reiterates some of the inherent limitations of using the AMBT – specifically, the inability to capture the alkali threshold for a given aggregate and the inability to evaluate low-alkali cements in combinations with SCMs.

How to test determine the requisite lithium nitrate dosage to control ASR-induced expansion?

- ASTM C 1293 for two years (0.04 percent expansion limit)
- Modified version of ASTM C 1260 (as per AASHTO PP 65-11)
- Prescriptive specification is not possible because there is no clear link between aggregate reactivity and lithium dosage needed to control expansion.

Within AASHTO PP 65-11, recommendations are provided for testing lithium admixtures. ASTM C 1293, using an expansion limit of 0.04 percent at 14 days, is the preferred approach, but a modified version of AASHTO T 303 is also allowed. Unfortunately, testing lithium admixtures in the laboratory is the only means of estimating the requisite dosage needed to control expansion. Prescriptive specifications are not given in AASHTO PP 65-11 because there is no clear link between aggregate reactivity and lithium dosage needed to control expansion.

AASHTO PP 65-11: Performance Approach

Performance Testing using the CPT

Evaluating Lithium Admixtures using the CPT

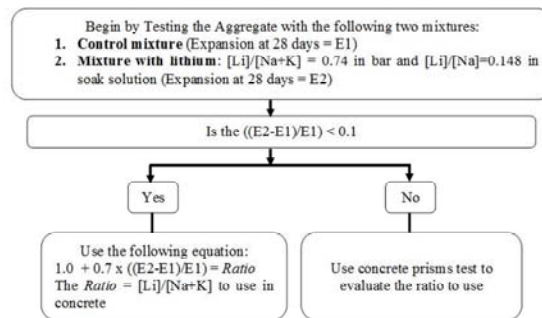
1. Total cementitious content = 708 lb/yd³ (420 kg/m³) – with or without SCM's
2. Alkali content of portland cement component raised to 1.25% Na₂O_e
3. LiNO₃ solution added to mix water at various levels
4. W/CM = 0.42 to 0.45 (include water in LiNO₃ solution)
Use high-range WRA if slump too low
Use VMA if high slump causes segregation
5. Expansion ≤ 0.04% at 2 years.

Under AASHTO PP65-11, guidance is given for testing lithium admixtures. ASTM C 1293 is recommended as the preferred method of testing lithium admixtures, and an expansion limit of 0.04 percent at two years is specified. The mixture proportions are the same when testing lithium admixtures as they are in ASTM C 1293, with the exception of the fact that lithium is used in the test, at a dosage selected by the user.

AASHTO PP 65-11: Performance Approach

Performance Testing using the AMBT

Evaluating Lithium Admixtures using the AMBT*



* See PP 65-11 for more specific details

This slide gives a snapshot of the modified version of ASTM C 1260 that is recommended for testing lithium admixtures. It is beyond the scope of this presentation to show all the details of this testing regime, see AASHTO PP 65-11 for more details. In a nutshell, this approach requires casting and testing two mortar mixtures, one with lithium and one without. Based on the outcome of this test, the amount of lithium needed to control expansion for that aggregate will be determined or the user will be instructed that the modified version of the AMBT is not suitable for the specific aggregate and the CPT must be run instead. This approach recognizes that certain aggregate types are not suitable for testing lithium admixtures in the modified AASHTO T 303 version – it has been shown that these aggregates will yield erroneous results (suggesting that lithium is controlling expansion when in fact concrete containing the same dosage will expand in crack in the CPT and outdoor exposure blocks.

Towards the ideal test...

- **Capable of evaluating efficacy of SCMs & chemical admixtures – i.e. determining quantity required to suppress expansion in a given system**
- **Measures effect of aggregate reactivity**
- **Measures impact of cement alkalies**
- **Short duration (i.e. rapid test)**
- **Reliable – correlates with field performance**

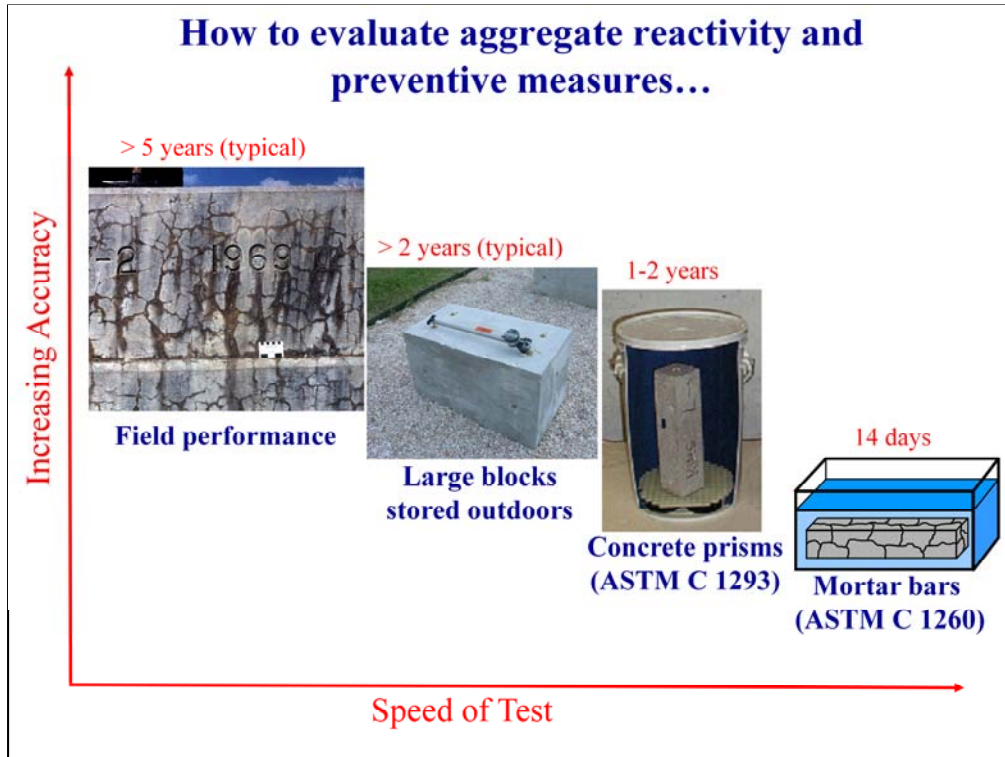
So far, I have described the various tests that have been used over the years, including those recommended under the AASHTO PP 65-11. As mentioned throughout this presentation, the tests recommended under this recommended practice (AASHTO T 303, ASTM C 1567, and ASTM C 1293) are not ideal in that they all have inherent limitations. None of the tests meet the description of the “ideal test” – a test that can test aggregates, SCMs and chemical admixtures, as well as alkali thresholds and the impact of low-alkali cements. Ideally, a test in the future will be able to accomplish all of these goals, while also being short-term in nature (e.g., not 1-2 years) and correlating well with field performance. Research is in progress that will someday help us to develop such an “ideal test,” but we are not there yet.

Requirements of test method for measuring preventive measures

Where do we stand?

	SCMs	Chemical Admix.	Aggregate Type	Cement Alkalis	Rapid	Reliable
C 441	✓	✓		?	✓	X
C 227	✓	✓	✓	X	?	X
Exposure Site	✓	✓	✓	✓	X	✓
Prism	✓	✓	✓	?	X	✓
Acceler. Prism	✓	✓	✓	?	✓	?

Using the criteria from the previous slide, one can grade the various test methods discussed in this presentation in terms of how well they meet the “ideal test” checklist. None of the tests meet all the criteria. Those that are most reliable are those that take the longest, and there are inherent technical flaws with the various tests that limit their potential, such as leaching in ASTM C 1293 or the severe nature of AASHTO T 303.



This slide shows conceptually what I just mentioned – that is, the tests that take the longest tend to be those that are the most accurate and vice-versa. Such is the nature of durability testing sometimes – we also see similar trends when testing for freeze-thaw resistance, corrosion resistance, and sulfate resistance. The more realistic the test conditions, the more accurate the results will be. But it is usually not possible to wait so long for the “right” answer, and accelerated testing is necessary to obtain results in a reasonable amount of time. It is hoped that the ongoing testing and research on ASR will allow for developing a rapid, reliable test that correlates with field performance.

Test Methods for Identifying Reactive Aggregates



- **ASTM C 295** - Standard Guide for Petrographic Examination of Aggregates for Concrete
- ASTM C 289 - Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)
- **ASTM C 227** - Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Concrete (Mortar-Bar Method)
- ASTM C 441 - Standard Test Method for Effectiveness of Mineral Admixtures or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
- **ASTM C 1260** - Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
- **ASTM C 1293** - Standard Test Method for Concrete Aggregates by Determination of Length Change of Concrete Due to Alkali-Silica Reaction

Aggregate Tests

Mortar Tests

Concrete Test

Currently Recommended Tests

In summary, the test methods that we can recommend today are highlighted in this slide – petrographic evaluation, the AMBT, and the CPT. By judiciously using these three tests, and their modifications, it is possible to achieve a reasonable degree of confidence in assessing aggregate reactivity and in selecting preventive measures. Although none of the tests, individually or in combination, are “ideal,” they are the best we have today and there is enough underpinning for the AASHTO PP 65-11 approach to justify its use today.



One of the most important aspects of ASR test methods is correlating laboratory results to field performance. Fortunately, our research groups have been very active in constructing and monitoring outdoor exposure sites, and the results from these exposure sites will serve as the basis for future test method development. Because outdoor exposure sites take quite a long time to yield results, it is highly likely that the current recommendations, as provided in AASHTO PP 65-11, will evolve with time, as we learn more. It is important to be flexible and to modify test methods, test durations, and expansion criteria as new data and information become available.

Field Performance Histories of Aggregates

The main objectives of laboratory (or exposure site) testing are to predict field performance of aggregates and assess methods of preventing ASR-induced damage.



For a given aggregate, can we use information on past field performance to predict future field performance?

One question that is often asked is, can one use the past field performance of a given aggregate to predict the future performance of new concrete cast using the aggregate of interest?

Field Performance Histories of Aggregates

Field performance history is useful in evaluating the potential reactivity of an aggregate, provided the following are considered (CSA 2000; ACI 1998):

- The cement content, and the alkali content of the cement, should be the same, or higher, in the field concrete as is proposed in the new structure.
- The concrete examined should be at least 10 years old.
- The exposure conditions of the field concrete should be at least as severe as those in the proposed structure.
- A petrographic examination should be conducted to demonstrate that the aggregate in the structure is sufficiently similar to the one being considered.
- The possibility of pozzolans or slag having been used should be considered.
- The w/cm of the concrete may affect performance.

The answer to the previous question is shown here. Yes, one can use past field performance to assess aggregate reactivity, but only if all the criteria shown on this slide is met. The materials, mixture proportions, and exposure conditions must all be identical, and at least 10 years of field performance is recommended, as per CSA and ACI. Unfortunately, it is very rare when all of these conditions can be met. So it is usually not possible to use past field performance, solely, to assess aggregate reactivity or to select preventive measures. However, one always learns from past field performance, and such experience can be combined with laboratory testing results to effectively evaluate aggregate reactivity and assess preventive measures, such as the use of SCMs and lithium admixtures.

Summary

- **Various ASR test methods exist, but only a few are recommended to test aggregate reactivity or to evaluate preventive measures.**
- **The tests that are the most reliable tend to take the longest to conduct, and vice-versa.**
- **We are making progress towards the “ideal test,” but we are a long way away...**

In summary, this presentation discussed a range of ASR test methods and focused primarily on tests that are most highly recommended and those that are included in AASHTO PP 65-11.

We still have a way to go in terms of developing and implementing the “ideal” ASR test. But what was presented today reflects the current state of the art and state of the practice. Hopefully, in the future, as more laboratory and field data become available, and more advances are made in test method development, we will have a better handle on how to more rapidly evaluate aggregate reactivity and preventive measures, while still maintaining a good correlation with field performance.