The National Academies of
SCIENCES · ENGINEERING · MEDICINE

TRANSPORTATION RESEARCH BOARD

Practical Perspectives on Alkali Silica Reactivity

October 14, 2021

@NASEMTRB
#TRBwebinar

PDH Certification Information:

- 1.5 Professional Development Hour (PDH) – see follow-up email for instructions
- You must attend the entire webinar to be eligible to receive PDH credits
- Questions? Contact TRBWebinars@nas.edu

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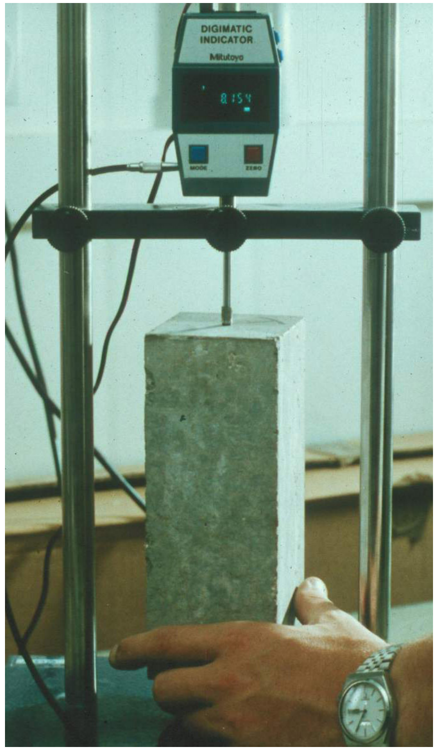
RCEP

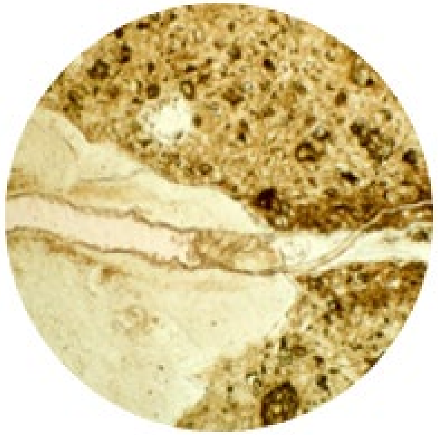
REGISTERED CONTINUING EDUCATION PROGRAM

#TRBwebinar

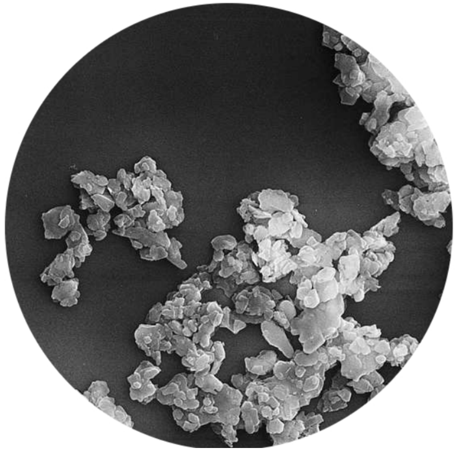
Learning Objectives

1. Compare and contrast different ASR practices and specifications
2. Identify ASR practices being used by various agencies



U.S. and International ASR Standards



Michael Thomas, PhD, PEng, FACI, FICT

Professor of Civil Engineering

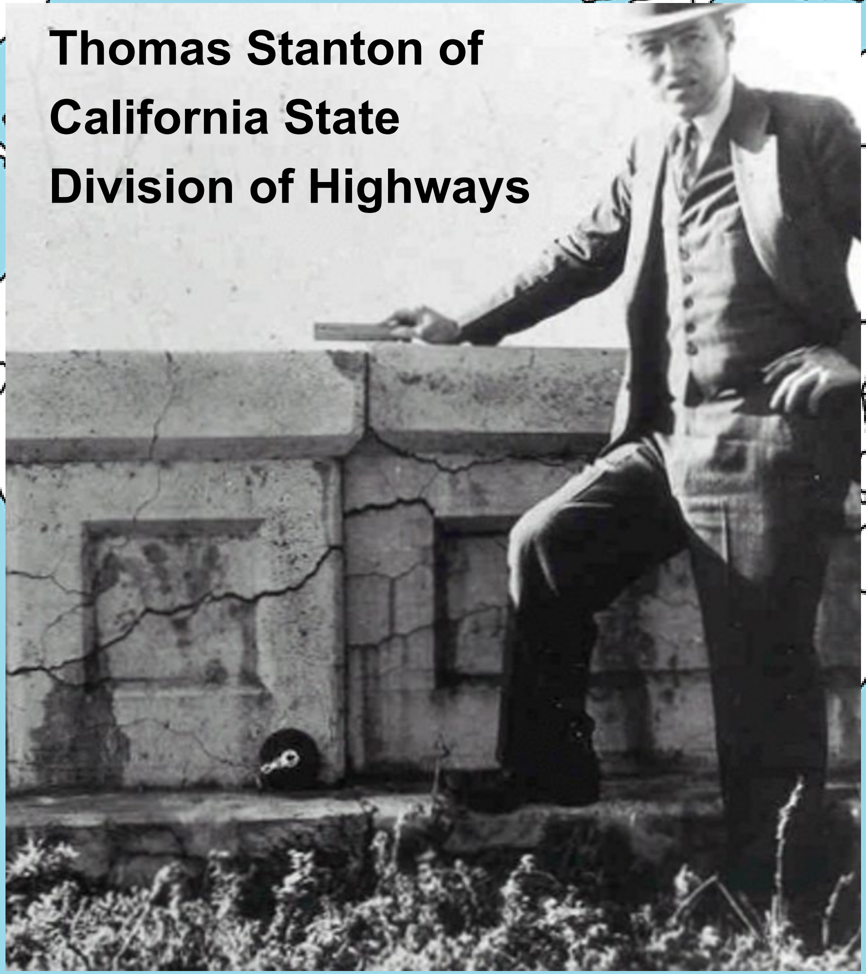
University of New Brunswick

TRB Webinar: Practical Perspectives on Alkali Silica Reactivity

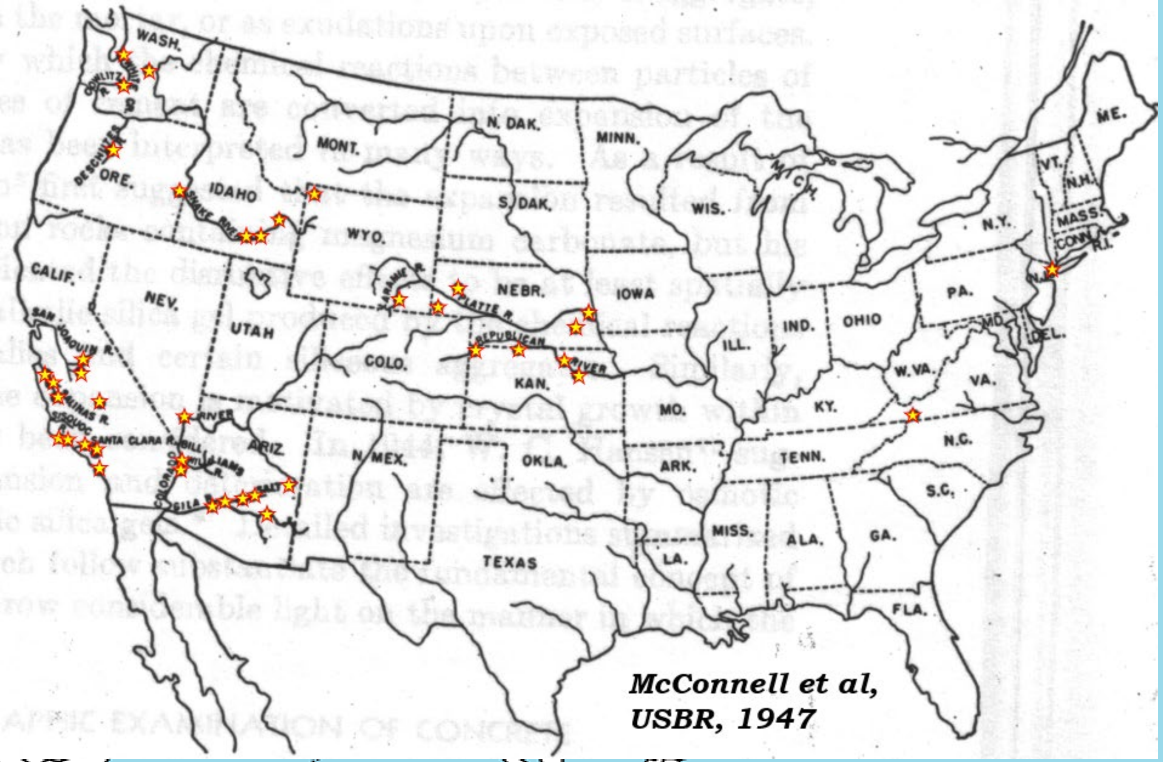
Sponsored by Technical Standing Committee on Durability of Concrete (AKM70) – October 14, 2021

Where it all began

Monterrey County & Los Angeles County in late 1930's



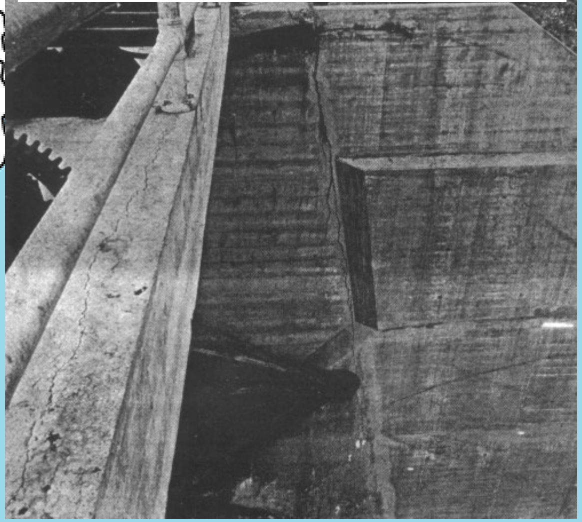
Thomas Stanton of California State Division of Highways

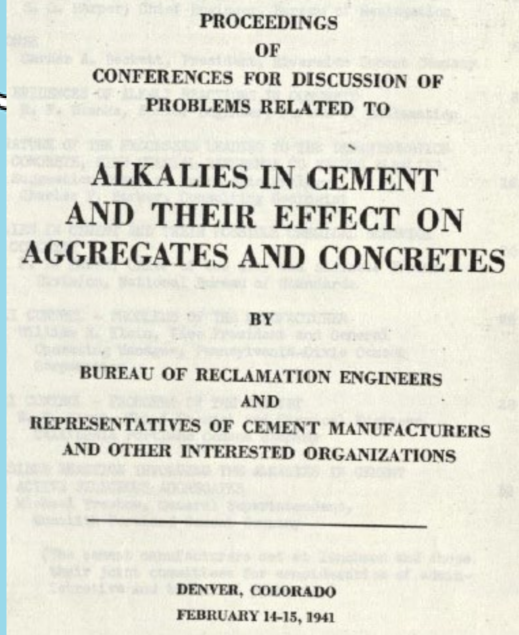


McConnell et al, USBR, 1947

Parker Dam, California – Arizona

Built 1934 -1938 (Meissner, 1941)





PROCEEDINGS

OF

CONFERENCES FOR DISCUSSION OF PROBLEMS RELATED TO

ALKALIES IN CEMENT AND THEIR EFFECT ON AGGREGATES AND CONCRETES

BY

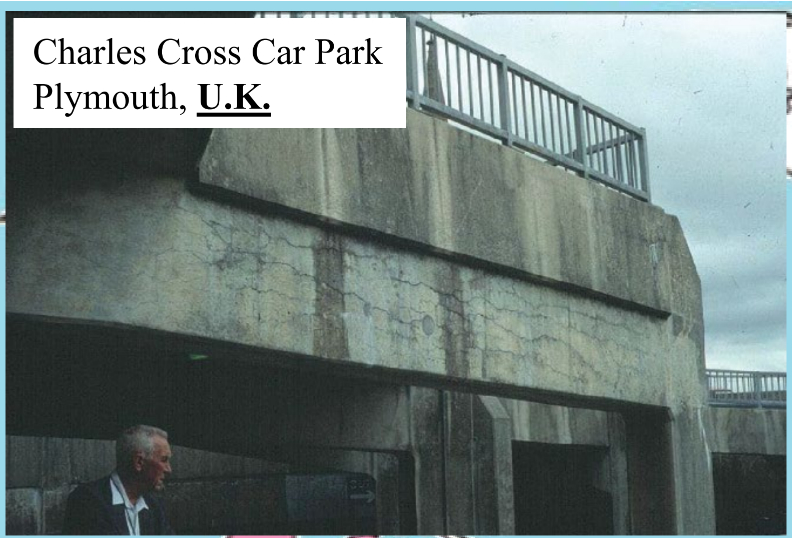
BUREAU OF RECLAMATION ENGINEERS

AND

REPRESENTATIVES OF CEMENT MANUFACTURERS AND OTHER INTERESTED ORGANIZATIONS

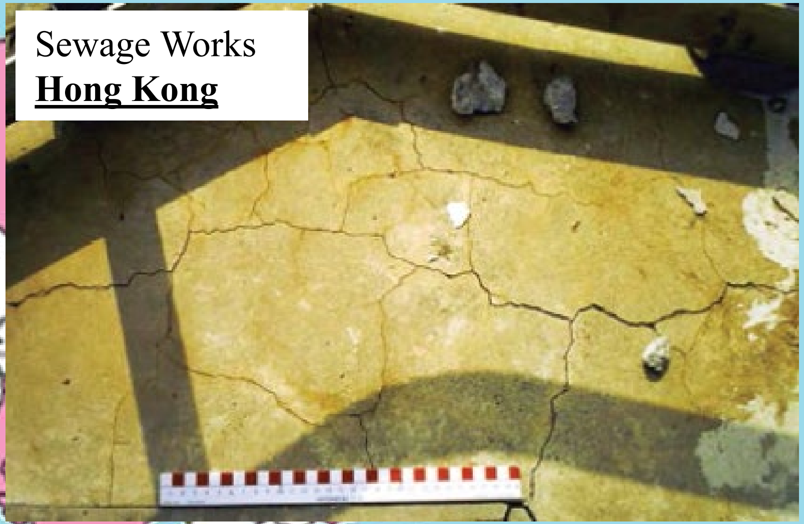
DENVER, COLORADO

FEBRUARY 14-15, 1941



Charles Cross Car Park
Plymouth, **U.K.**

Adnan Menderes Airport
Izmir, **Turkey**



Sewage Works
Hong Kong

Air Base Pavement
New Zealand

Mactaquac Dam
Canada

Railway Sleepers
U.S.S.R

Countries & Regions investigated for AAR in this Book

Reported/published cases of AAR

No reported cases of AAR

No information available

Alkali-Aggregate Reaction in Concrete: A World Review
Sims & Poole (Editors) 2017

Mechanisms of ASR

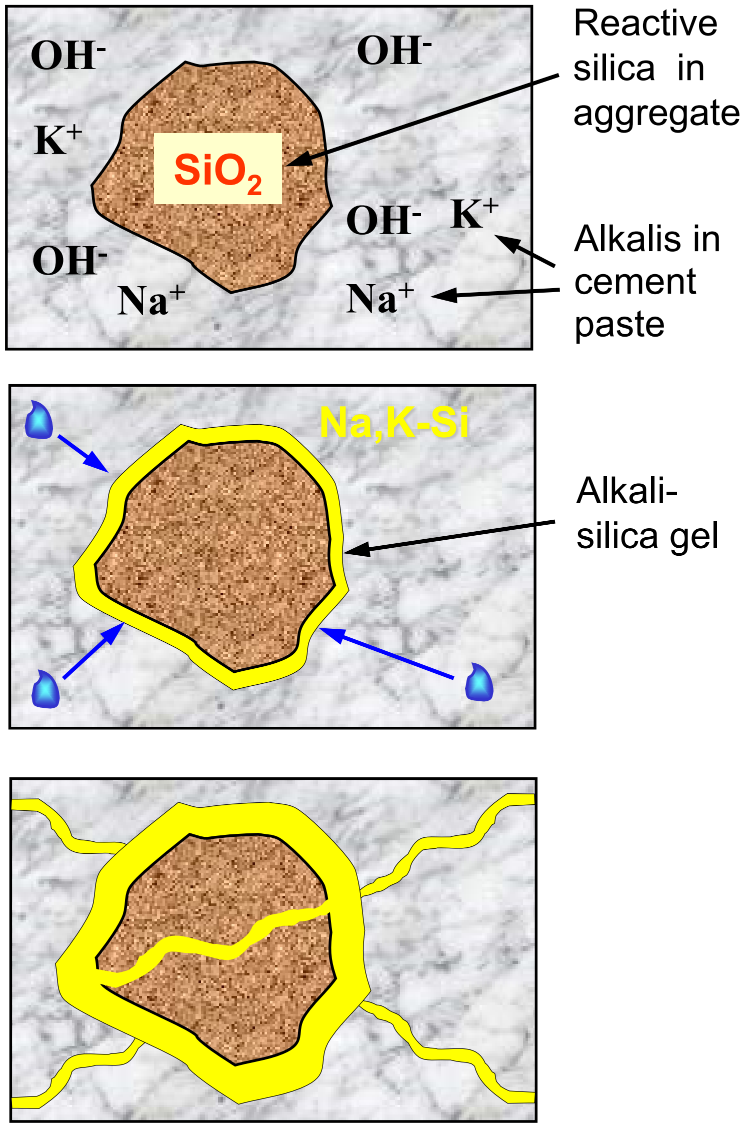
Reaction between the alkalis (Na, K & OH) from the cement and unstable silica, SiO_2, in some types of aggregate

The reaction produces an alkali-silica gel

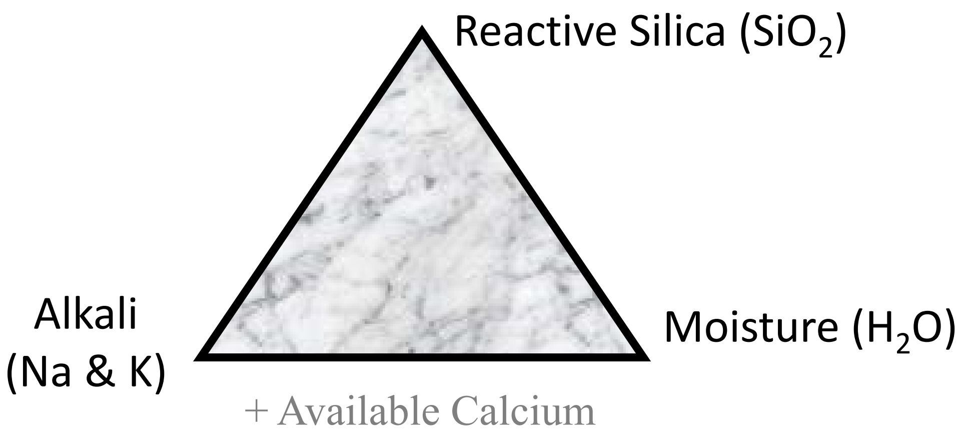
The gel absorbs water from the surrounding paste …

… and expands.

The internal expansion eventually leads to cracking of the surrounding concrete.



Requirements for ASR

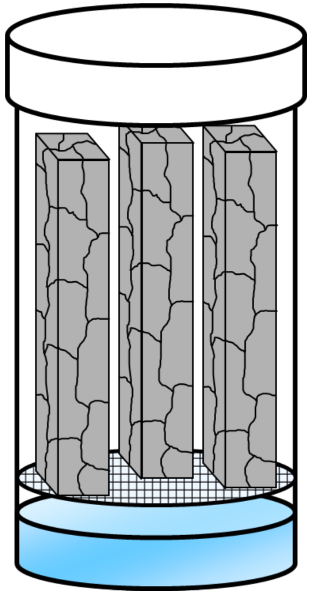


Minimizing the Risk of ASR Expansion

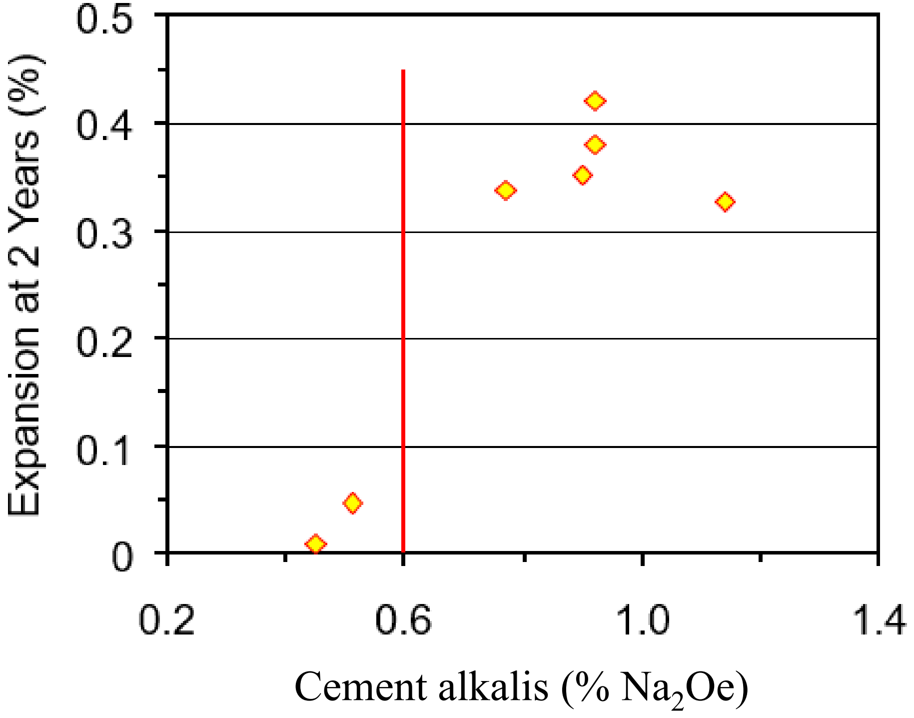
- Use of non-reactive aggregate (no reactive SiO_2)
- Limit alkali content of concrete
  - Use of low-alkali cement (reduce Na & K)
  - Use pozzolans and/or slag (reduce availability of Na & K)
- Eliminate moisture (??)
- Use lithium compounds (change swelling behaviour of the reaction product)

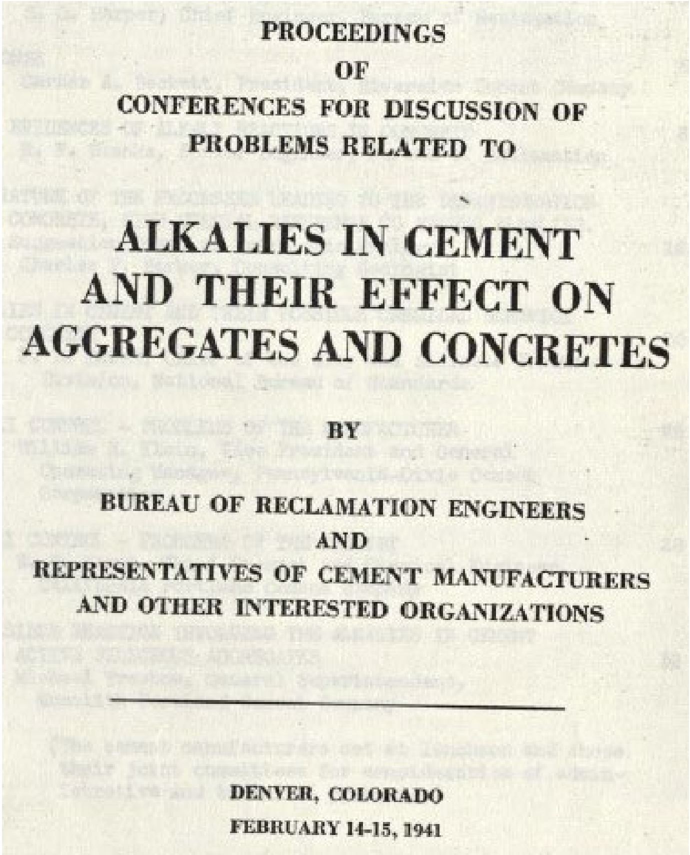
Use of Low-Alkali Cement to Control ASR

Stanton's Mortar Bar Test *(Stanton, 1940)*



1-inch mortar bars stored over water at 100°F (38°C)





PROCEEDINGS
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AND OTHER INTERESTED ORGANIZATIONS

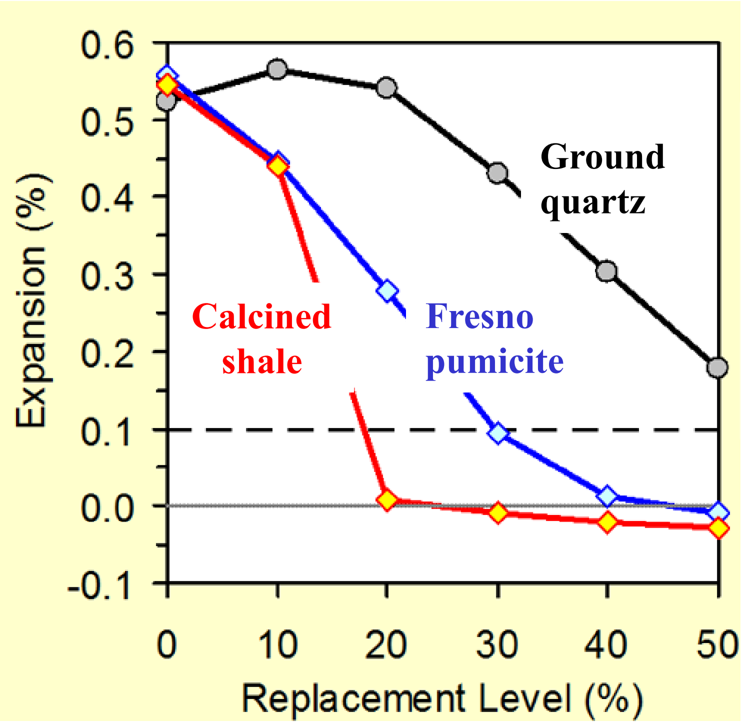
DENVER, COLORADO
FEBRUARY 14-15, 1941

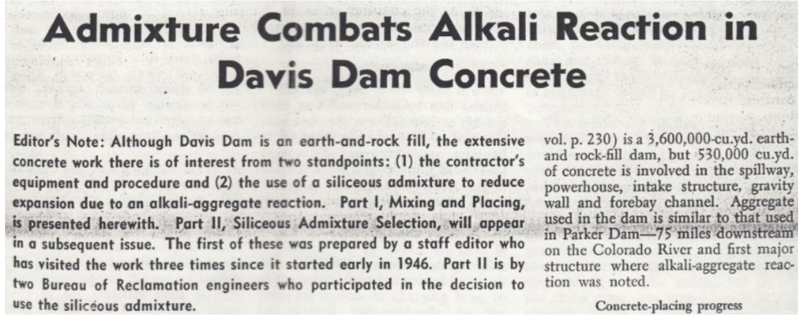
Garner Beckett, President, Riverside Cement Company, 1941 " … the imposition of some **proper limit on the alkali content of portland cement** is accepted in good grace as representing the **only practicable action which is possible at the moment** … it is wholly unnecessary to dwell on the inadequacy of the data supporting such limitation.

- Low-alkali cement (≤ 0.60% Na_2Oe) was prescribed for use with reactive aggregates for almost 80 years in the U.S.
- 2019 was the first year that ASTM C150 did **not** have an optional limit for low-alkali cement

Use of Pozzolans to Control ASR

In 1940 Stanton demonstrated the potential for pozzolans to control ASR



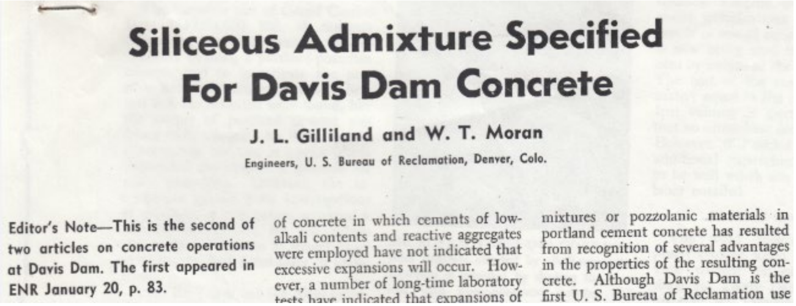


Admixture Combats Alkali Reaction in Davis Dam Concrete

Editor's Note: Although Davis Dam is an earth-and-rock fill, the extensive concrete work there is of interest from two standpoints: (1) the contractor's equipment and procedure and (2) the use of a siliceous admixture to reduce expansion due to an alkali-aggregate reaction. Part I, Mixing and Placing, is presented herewith. Part II, Siliceous Admixture Selection, will appear in a subsequent issue. The first of these was prepared by a staff editor who has visited the work three times since it started early in 1946. Part II is by two Bureau of Reclamation engineers who participated in the decision to use the siliceous admixture.

vol. p. 230) is a 3,600,000-cu.yd. earth- and rock-fill dam, but 530,000 cu.yd. of concrete is involved in the spillway, powerhouse, intake structure, gravity wall and forebay channel. Aggregate used in the dam is similar to that used in Parker Dam—75 miles downstream on the Colorado River and first major structure where alkali-aggregate reaction was noted.

Concrete-placing progress



Siliceous Admixture Specified For Davis Dam Concrete

J. L. Gilliland and W. T. Moran

Engineers, U. S. Bureau of Reclamation, Denver, Colo.

Editor's Note—This is the second of two articles on concrete operations at Davis Dam. The first appeared in ENR January 20, p. 83.

of concrete in which cements of low-alkali contents and reactive aggregates were employed have not indicated that excessive expansions will occur. However, a number of long-time laboratory tests have indicated that expansions of

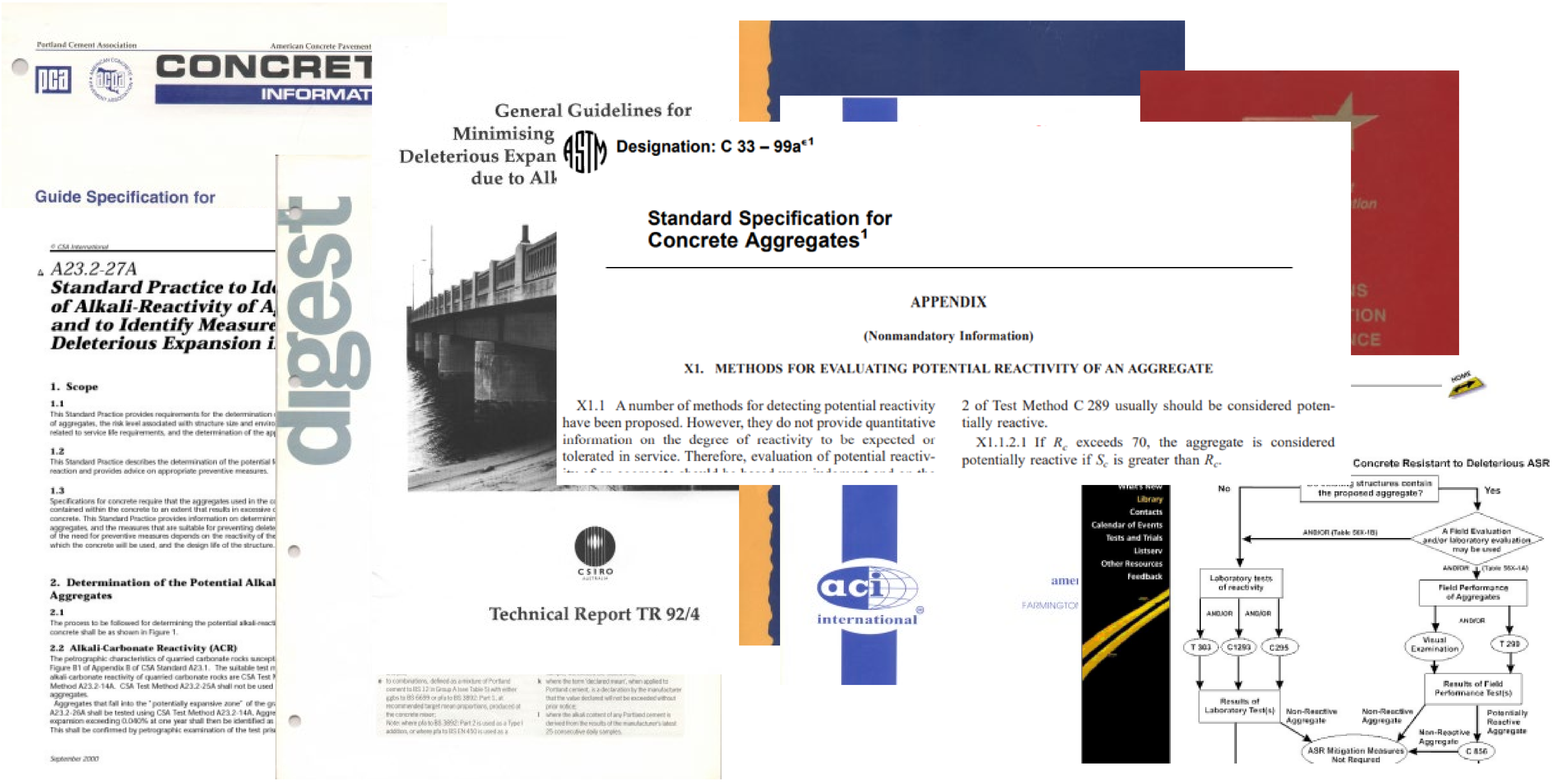
mixtures or pozzolanic materials in portland cement concrete has resulted from recognition of several advantages in the properties of the resulting concrete. Although Davis Dam is the first U. S. Bureau of Reclamation use

Davis Dam (completed in 1951)

- Lime-pozzolan strength ≥ 600 psi at 7 days (6d at 130°F)
- Reduction-in-alkalinity (pozz + NaOH at 80°C for 24h)
- Reduction in 14-d expansion of at least 75% for mortar bars produced with high-alkali cement + 20% pozz + <u>Pyrex glass</u> (at 100°F)
- Chemical requirements: $SiO_2 \geq 60\%$, $Al_2O_3 \geq 15\%$, $Fe_2O_3 \geq 2\%$, $CaO \leq 10\%$, $Na_2Oe \leq 4\%$, Soluble Alkalis $\leq 0.1\%$

Engineering News Record, 1949

Specifications for Minimizing the Risk of AAR



Specifications for Minimizing the Risk of AAR

Prescriptive Specification - Example

If potentially reactive aggregates are used then one of the following options shall be adopted:

- Limit concrete alkali content ≤ 3.0 kg/m^3 Na_2Oe
- Use a minimum of 25% Class F fly ash
- Use a minimum of 50% slag
- Use a minimum of 8% silica fume
- Use a minimum of 12% metakaolin
- Use a 30% lithium nitrate solution at a dose rate of 4.6 litres of $LiNO_3$ solution per 1 kg or Na_2Oe

Performance Specification - Example

- Use an aggregate that passes either the accelerated mortar bar test or the concrete prism test
- If the aggregate to be used does not pass these tests, then it may still be used in combination with fly ash, slag, silica fume, natural pozzolan, or any blend of these SCM's provided that the combination of SCM's and aggregate passes a modified version of either the accelerated mortar bar test or the concrete prism test
- Alternatively the aggregate can be used with lithium nitrate and SCM's provided the combination of materials passes the concrete prism test.

Disclaimer - this information is **only** intended as an example.

The preventive measures & test procedures listed above may **not** be sufficient in all cases!

Chronology:

2000 **Canadian Standards Association: CSA A23.2** Latest version 2019

- A23.2-27A Standard Practice to identify degree of alkali-reactivity of aggregates and to identify measures to avoid deleterious expansion in concrete — **Prescriptive**
- A23.2-28A Standard Practice for laboratory testing to demonstrate the effectiveness of supplementary cementitious materials and lithium-based admixtures to prevent alkali-silica reaction in concrete — **Performance-based**

2010 **AASHTO Designation: PP 65-10 (Provisional)** Latest version 2017 (R 80)

- Standard Practice for Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction — **Prescriptive & performance-based**

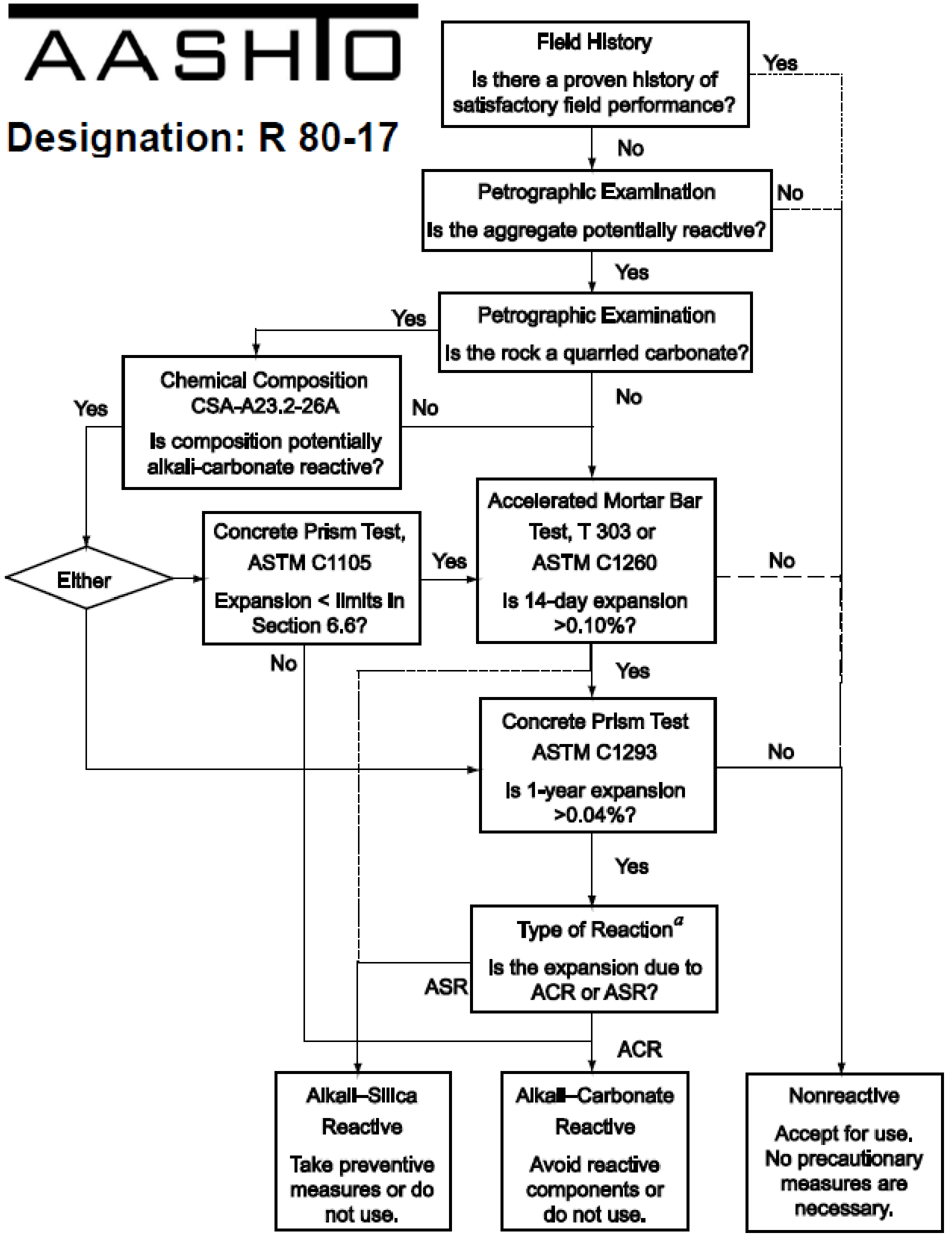
2014 **ASTM Designation: C1778-14** Latest version 2019

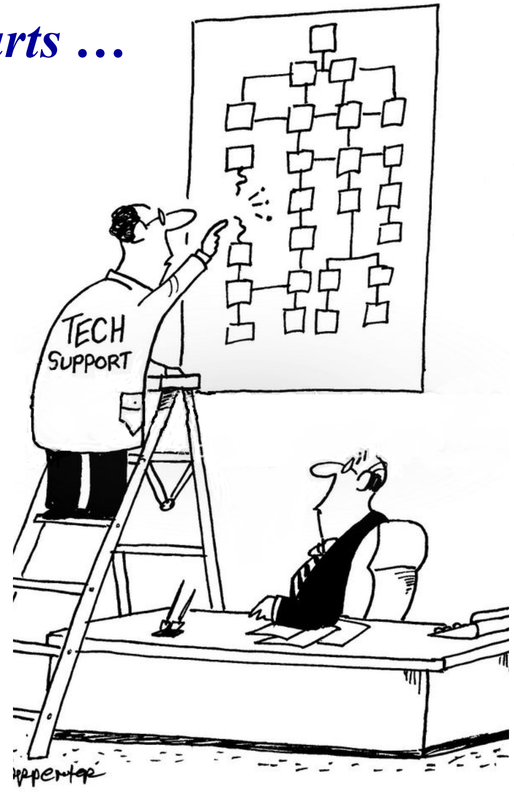
- Standard Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete — **Prescriptive & performance-based**

Engineers love flow charts …

AASHTO

Designation: R 80-17

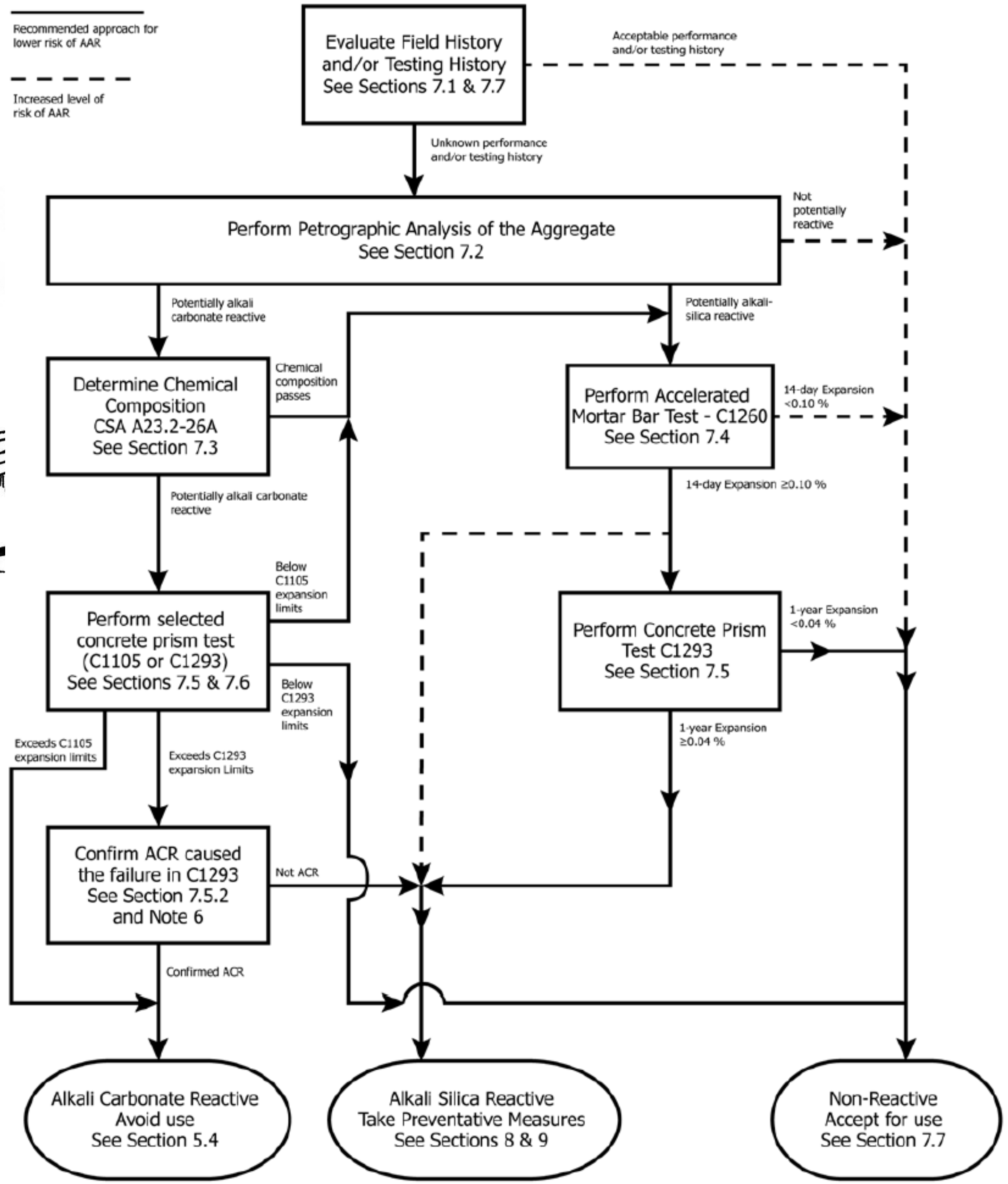


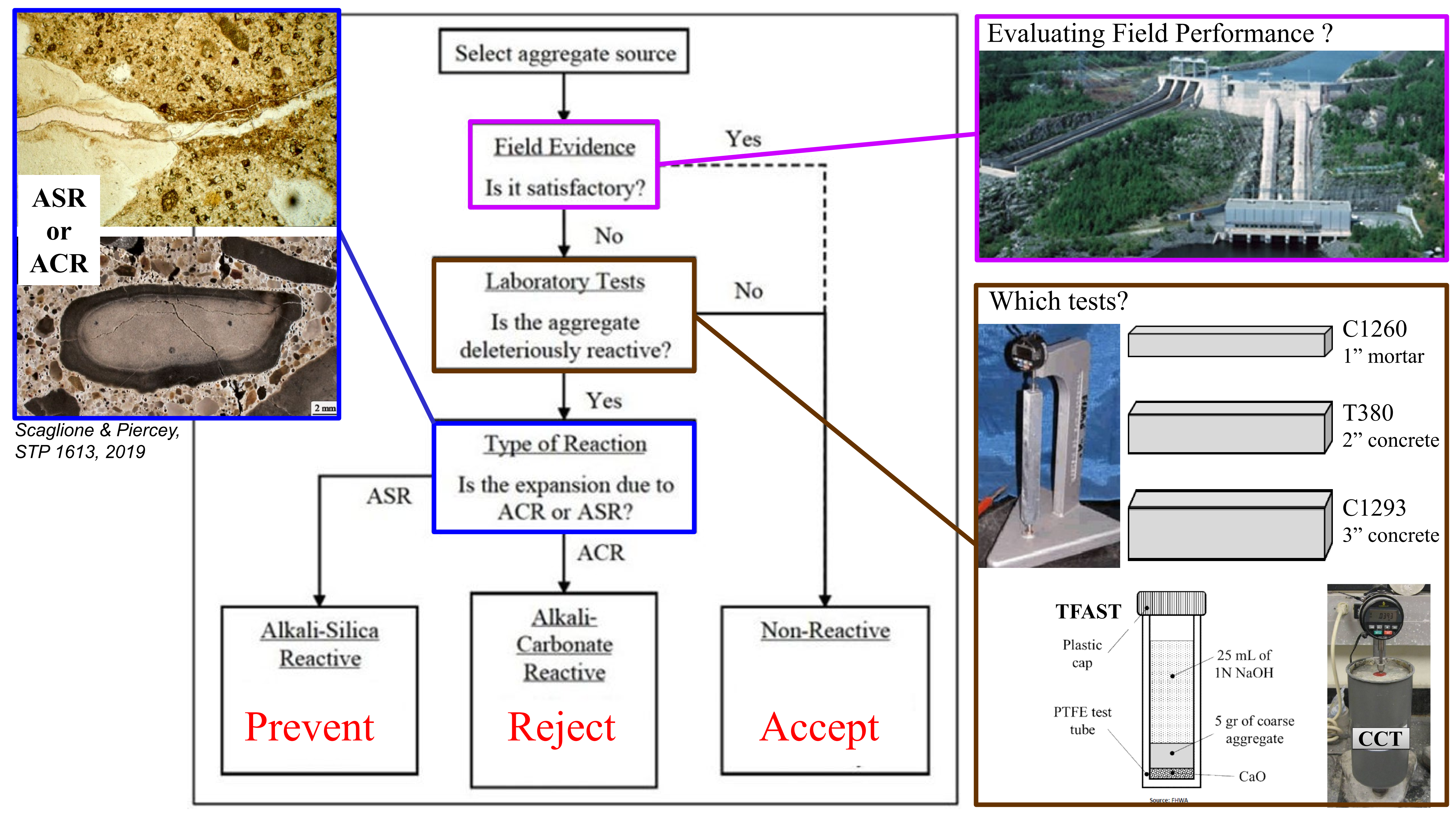


"Here's your problem."

ASTM INTERNATIONAL

Designation: C1778 – 20




ASR
or
ACR
2 mm
Scaglione & Piercey, STP 1613, 2019
Select aggregate source
Field Evidence
Is it satisfactory?
Yes
No
Laboratory Tests
Is the aggregate deleteriously reactive?
No
Yes
Type of Reaction
Is the expansion due to ACR or ASR?
ASR
ACR
Alkali-Silica Reactive
Prevent
Alkali-Carbonate Reactive
Reject
Non-Reactive
Accept
Evaluating Field Performance ?
Which tests?
C1260
1” mortar
T380
2” concrete
C1293
3” concrete
TFAST
Plastic cap
25 mL of 1N NaOH
PTFE test tube
5 gr of coarse aggregate
CaO
Source: FHWA
CCT

AASHTO R 80: Standard Practice for Determining the Reactivity of Concrete Aggregates **and** Selecting Appropriate Measures for Preventing Expansion in New Construction

As the title implies there are **two** steps to the practice:

Step 1: Determine aggregate reactivity (3 possible outcomes)

• Non-reactive	Accept
• Alkali-carbonate reactive	Reject
• Alkali-silica reactive	Reject or use Preventive Measures – Go to Step 2

Step 2: Select Preventing Measures (for ASR aggregates only)

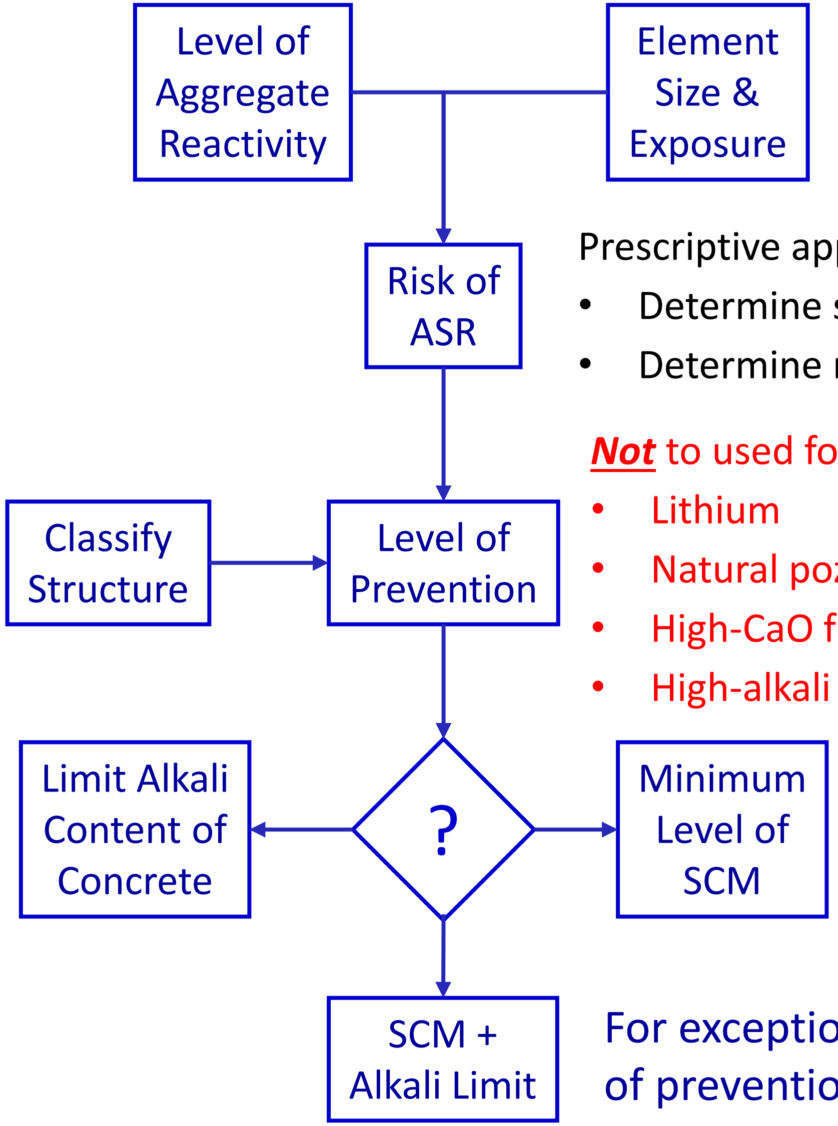
- Limit alkali content of concrete
- Use SCM
- Use lithium nitrate
- Combination – limit alkalis + SCM

Determine using either:

- Performance testing
- Prescription

Step 2: Selecting Preventive Measures for Alkali-Silica Reaction

Prescriptive Approach



Prescriptive approach used to:

- Determine safe level of alkali
- Determine minimum level of SCM

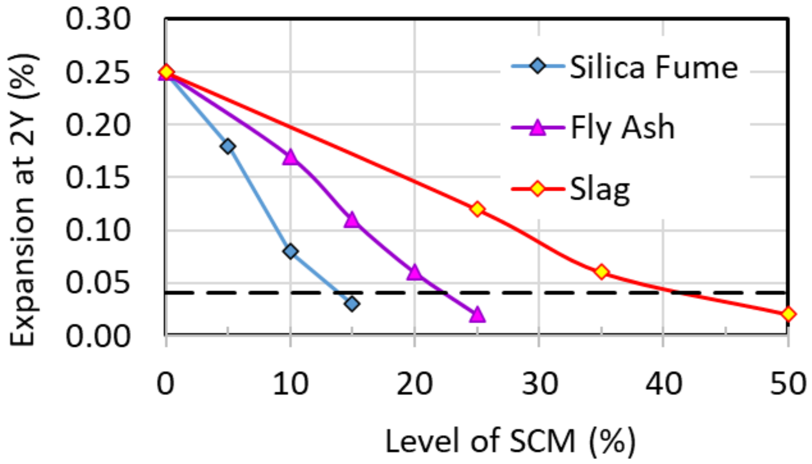
Not to used for evaluating:

- Lithium
- Natural pozzolans
- High-CaO fly ash
- High-alkali SCM

For exceptional level of prevention

Performance Approach

- Run expansion test (either AMBT or CPT) with varying level of SCM (including natural pozzolans) or lithium to determine the minimum level required to control expansion below limit



Neither expansion test to be used for evaluating:

- The safe level of alkali
- Combinations of low-alkali cement & SCM

AMBT **not** to be used for

- High-alkali SCM
- Testing lithium (personal opinion – AASHTO R 80 allows)

ACI 301-20 Specifications for Concrete Construction

4.2.2.6(a) *Resistance to alkali-silica reaction*

For concrete exposed to moisture in service use one of the three following options:

a) Expansion of concrete with each aggregate $\leq$ 0.04% at 1 year in ASTM C1293 (Concrete Prism Test)

b) Expansion of mortar with each aggregate & cementing materials combination $\leq$ 0.10% at 14 days in ASTM C1567 (Accelerated Mortar Bar Test)

Option not to be used for fly ash with alkali > 4.0% Na_2Oe

c) Alkali content in concrete (calculated from Portland cement component only):

$\leq$ 4 lb/yd^3 (2.4 kg/m^3) for moderately reactive aggregate (0.04% to 0.12% in CPT)

$\leq$ 3 lb/yd^3 (1.2 kg/m^3) for highly reactive aggregate (0.12% to 0.24% in CPT)

Option not to be used for very highly reactive aggregate (> 0.24% in CPT) or with natural pozzolan or fly ash with > 18% CaO or fly ash with alkali > 4.0% Na_2Oe

ACI 350 Code Requirements for Environmental Engineering Concrete Structures

Draft for Public Review (2021)

4.6.1.2 Determining preventative measure for alkali-silica reaction

When an aggregate is determined to be potentially reactive, or in lieu of test data, use of the following two approaches:

a) Performance based approach to evaluate preventive measures

Expansion ≤ 0.04% at 2 years in concrete prism test (for SCM or $LiNO_3$)

Expansion ≤ 0.10% at 14 days in accelerated mortar bar test (for SCM only)

b) Prescriptive based approach

Use minimum levels of SCM shown in Table 4.1.3.A

For concrete exposed to alkalis in service alkali content (from Portland cement) ≤ 1.8 lb/yd^3. (1.08 kg/m^3)

Table 4.3.1.A

SCM Type	**Alkali of SCM (% Na_2Oe)**	**Minimum SCM (%)**	
		PC alkali < 1.00 %Na_2Oe)	PC alkali > 1.00 %Na_2Oe)
Fly ash (< 15% CaO)	< 3.0	25	35
	3.0 – 4.0	30	40
Slag	< 1.0	50	60
Silica fume	< 1.0	1.8 x LBA	2.5 x LBA

Note: LBA = alkali content of concrete (lb/yd^3) calculated from the Portland cement

Texas Department of Transportation – ASR Specification

For concrete containing reactive aggregate:

1. Use 20% to 35% Class F fly ash
2. Use 35% to 50% slag cement or MFFA
3. Use 35% to 50% of a combination of Class F fly ash, slag cement, MFFA, UFFA, metakaolin or silica fume (fly ash ≤ 35% and silica fume ≤ 10%
4. Use Type IP, IS, or IT blended cement (as allowed in Table 5 for each class of concrete). Up to 10% of the blended cement may be replaced with Class F fly ash, slag cement or silica fume (total silica fume ≤ 10%)
5. Replace 35% to 50% of cement with a combination of Class C fly ash and at least 6% silica fume, UFFA or metakaolin (total silica fume ≤ 10%)
6. Use lithium nitrate at a minimum dosage determined by testing (Tex-41-A)
7. Ensure that the alkali contribution from the cement in the concrete ≤ 3.5 lb/yd^3 (2.1 kg/m^3) Na_2Oe (for concrete without SCM only)
8. Option 8 – next slide

Texas Department of Transportation – ASR Specification

- **Option 8 – Performance testing**

Table 10
Option 8 Testing and Mix Design Requirements

<table>
<tr><th rowspan="2">Scenario</th><th colspan="2">ASTM C1260 Result</th><th rowspan="2">Testing Requirements for Mix Design Materials or Prescriptive Mix Design Options[1]</th></tr>
<tr><th>Mix Design Fine Aggregate</th><th>Mix Design Coarse Aggregate</th></tr>
<tr><td>A</td><td>> 0.10%</td><td>> 0.10%</td><td>Determine the dosage of SCMs needed to limit the 14-day expansion of each aggregate[2] to 0.08% when tested individually in accordance with ASTM C1567; or
Use a minimum of 40% Class C fly ash with a maximum CaO[3] content of 25%.</td></tr>
<tr><td rowspan="2">B</td><td>≤ 0.10%</td><td>≤ 0.10%</td><td>Use a minimum of 40% Class C fly ash with a maximum CaO[3] content of 25%; or
Use any ternary combination which replaces 35% to 50% of cement.</td></tr>
<tr><td>≤ 0.10%</td><td>ASTM C1293 1 yr. Expansion ≤ 0.04%</td><td>Use a minimum of 20% of any Class C fly ash; or
Use any ternary combination which replaces 35% to 50% of cement.</td></tr>
<tr><td>C</td><td>≤ 0.10%</td><td>> 0.10%</td><td>Determine the dosage of SCMs needed to limit the 14-day expansion of coarse and intermediate[2] aggregate to 0.08% when tested individually in accordance with ASTM C1567; or
Use a minimum of 40% Class C fly ash with a maximum CaO[3] content of 25%.</td></tr>
<tr><td rowspan="2">D</td><td>> 0.10%</td><td>≤ 0.10%</td><td>Use a minimum of 40% Class C fly ash with a maximum CaO[3] content of 25%; or
Use any ternary combination which replaces 35% to 50% of cement.</td></tr>
<tr><td>> 0.10%</td><td>ASTM C1293 1 yr. Expansion ≤ 0.04%</td><td>Determine the dosage of SCMs needed to limit the 14-day expansion of fine aggregate to 0.08% when tested in accordance with ASTM C1567.</td></tr>
</table>

1. Do not use Class C fly ash if the ASTM C1260 value of the fine, intermediate, or coarse aggregate is 0.30% or greater, unless the fly ash is used as part of a ternary system.
2. Intermediate size aggregates will fall under the requirements of mix design coarse aggregate.
3. Average the CaO content from the previous ten values as listed on the mill certificate.

RILEM Technical Committees Related to Alkali-Aggregate Reaction

1988 TC 106-AAR: International Assessment of Aggregates for Alkali-aggregate Reactivity

2001 TC 191-ARP: Alkali-Reactivity & Prevention – Assessment, Specification and Diagnosis

2006 TC 219-ACS: Alkali Aggregate Reaction in Concrete Structures: Performance Testing and Appraisal

2014 TC 258-AAA: Avoiding Alkali Aggregate Reaction in Concrete - Performance Based Concept

2014 TC 259-ISR: Prognosis of Deterioration and Loss of Serviceability in Structures Affected by ASR

2020 TC ARM : Alkali-Aggregate Reaction Mitigation

2020 TC ASR : Risk Assessment of Concrete Mixture Designs with Alkali-Silica Reactive (ASR) Aggregates

RILEM: International Union of Laboratories and Experts in Construction Materials, Systems and Structures

Founded in1947, with the aim to promote scientific cooperation in the area of construction materials and structures

*<u>**R**</u>éunion <u>**I**</u>nternationale des <u>**L**</u>aboratoires et <u>**E**</u>xperts des <u>**M**</u>atériaux, systèmes de construction et ouvrages*

RILEM TC 191-ARP: Alkali-reactivity and prevention - Assessment, specification and diagnosis of alkali-reactivity

Table 1. Structures classified by risk category

Category -consequences of damage	Acceptability of ASR damage	Examples
S 1 Safety, economic or environmental consequences of deterioration small or negligible	Some deterioration from ASR is acceptable	• Non load-bearing elements inside buildings • Temporary or short service life structures (likely design life 10 to 20 years) • Small numbers of easily replaceable elements • Most low-rise domestic structures
S 2 Some safety, economic or environmental consequences if major deterioration	Minor ASR damage is acceptable/ manageable	• Most building and civil engineering structures • Precast elements where economic costs of replacement are severe; e.g. railway sleepers • Normally designed for service life up to 100years
S 3 Serious safety, economic or environmental consequences if any deterioration	No significant damage acceptable	• Long service life (+100years) or highly critical structures/elements where the risk of deterioration from AAR damage is judged unacceptable, such as: • Nuclear installations, dams, tunnels • Exceptionally important bridges or viaducts • Structures retaining hazardous materials • Exceptionally critical elements impossible/very difficult to inspect or replace/repair

RILEM Test Methods Related to Alkali-Aggregate Reaction

AAR-0: Outline guide to the use of RILEM methods in assessments of aggregates for potential alkali-reactivity

AAR-1: Detection of potential alkali-reactivity of aggregates – petrographic method

AAR-2: Detection of Potential Alkali-Reactivity—Accelerated Mortar-Bar Test Method for Aggregates

AAR-3: Detection of Potential Alkali-Reactivity—38 °C Test Method for Aggregate Combinations Using Concrete Prisms

AAR-4.1: Detection of Potential Alkali-Reactivity—60 °C Test Method for Aggregate Combinations Using Concrete Prisms

AAR-5: Rapid preliminary screening test for carbonate aggregates (microbar test)

AAR-8 Determination of Alkalis Releasable by Aggregates in Concrete

AAR-10.1 & 10.2 Determination of binder combinations for non-reactive mix design using concrete prisms – 38°C test method

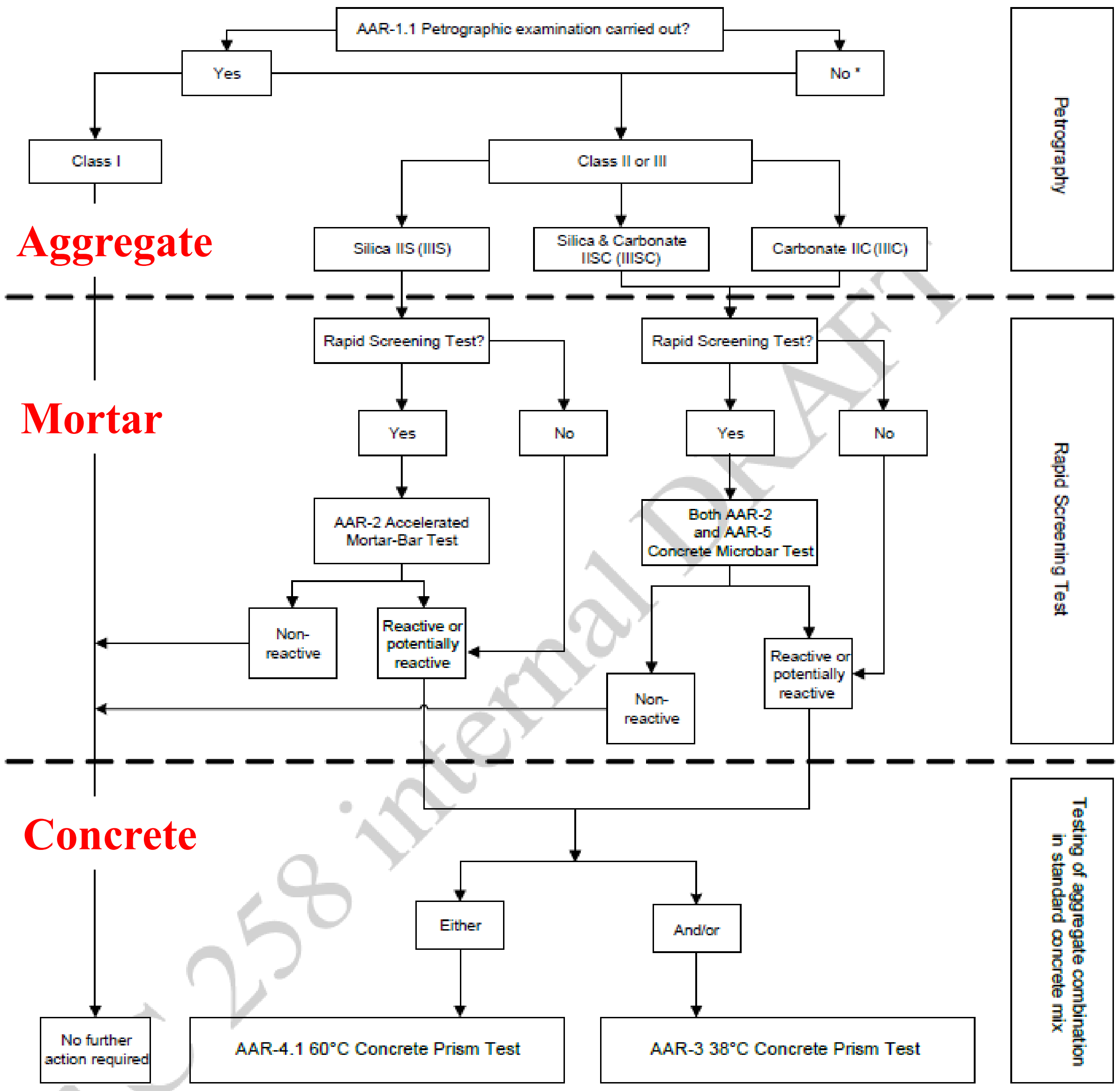
AAR-11.1, 11.2 & 11.3 Determination of binder combinations for non-reactive mix design or the resistance to alkali silica reaction of concrete mixes using concrete prisms – 60°C test method

AAR-12.1, 12.2 & 12.3 Determination of binder combinations for non-reactive mix design or the resistance to alkali silica reaction of concrete mixes using concrete prisms – 60°C test method with alkali supply

AAR-13 Application of alkali-wrapping for concrete prism testing assessing the expansion potential by alkali-silica reaction

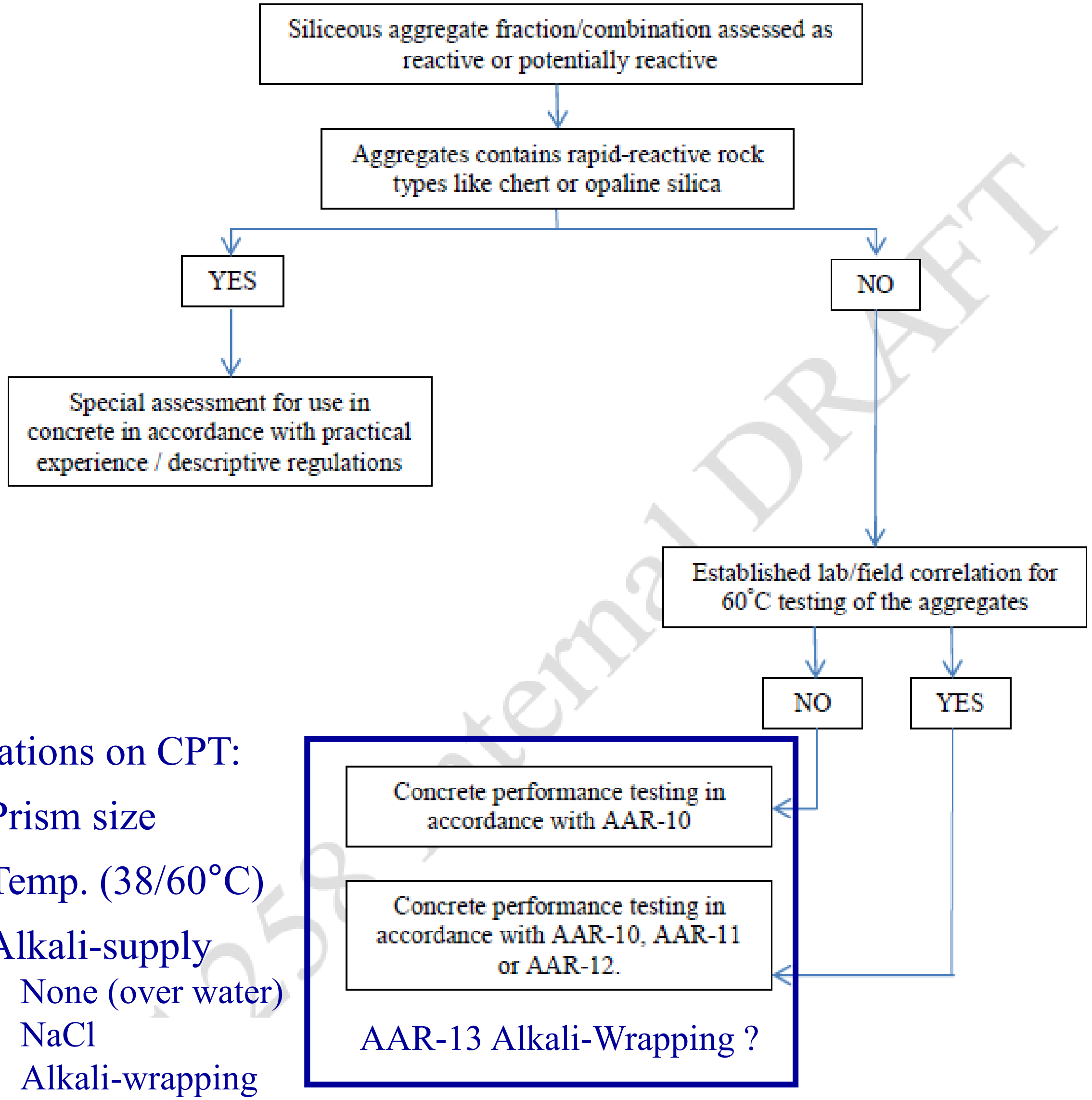
RILEM AAR-0 Outline Guide to the Use of RILEM Methods in the Assessment of the Alkali-Reactivity Potential of Concrete

Aggregate Reactivity Assessment



* If no petrographic examination has been carried out, assume Class II (or III)

Performance Testing of Job Mixture



Variations on CPT:

- Prism size
- Temp. (38/60°C)
- Alkali-supply
  - None (over water)
  - NaCl
  - Alkali-wrapping

BRE

digest

Alkali–silica reaction in concrete

Detailed guidance for new construction

Digest 330

Part 2

2004 Edition

BRE Centre for Concrete Construction

Concrete can deteriorate as a result of an interaction between alkaline pore fluids (principally originating from Portland cements) and reactive minerals in certain types of aggregates.
The mechanism of deterioration is known as alkali–aggregate reaction (AAR); it can occur in a number of forms, the most common being alkali–silica reaction (ASR).

This Digest is in four parts

Part 1 gives the background to the detailed and simplified guidance contained in Parts 2 and 4. **Part 2** gives detailed guidance for minimising the risk of damaging ASR in new construction. **Part 3** gives worked examples. **Part 4** gives simplified guidance for new construction using aggregates of normal reactivity.

Advice on the prevention of ASR caused by opal, glass, calcined flint and other forms of extremely reactive material is outside the scope of this Digest.

Concrete core surface showing divergent ASR induced expansive microcracking centred on quartzite coarse aggregate particles

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Alkali limits based on aggregate reactivity →

Table 1 Recommended limits for alkali contents of concrete			
Aggregate type or combination	Alkali content of the CEM I-type component of the cement (Table 6) or the CEM I component of a combination with ggbs or pfa		
	Low alkali (guaranteed ≤0.60%Na_2O eq on spot samples)	Moderate alkali (declared mean ≤0.75% Na_2O eq)	High alkali (declared mean >0.75% Na_2O eq)
Low reactivity	Self-limiting: no mix calculation needed †	Self-limiting: no mix calculation needed †	Limit: ≤5.0 kg Na_2O eq/m^3 ‡◊
Normal reactivity	Self-limiting: no mix calculation needed #	Limit: ≤3.5 kg Na_2O eq/m^3 ◊§	Limit: ≤3.0 kg Na_2O eq/m^3 ‡◊
High reactivity	Limit: ≤2.5 kg Na_2O eq/m^3 ♦	Limit: ≤2.5 kg Na_2O eq/m^3 ♦	Limit: ≤2.5 kg Na_2O eq/m^3 ♦

List of low-reactivity aggregates →

Table 2 Rocks and minerals considered to be of low reactivity

This table is based on current experience in the UK. In other countries, some of the rock types (eg younger basalts) have been found to be more reactive

andesite	gabbro	schist
basalt	gneiss	slate
chalk †	granite ◊	syenite
diorite	limestone #	trachyte
dolerite	marble	tuff
dolomite	microgranite	
feldspar ‡	quartz ‡§	
air cooled blastfurnace slag		
expanded clay/shale/slate		
sintered pfa		

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Aggregate reactivity based on concrete-prism test (BS 812-123) →

Table 3 Concrete prism test from BS 812-123

Suggested criteria for interpretation: applies to low and normal reactivity UK aggregates (BSI Working Group B/502/6/10)

Expansion for up to 12 months† (%)	Classification for the aggregate combination tested‡	Aggregate type from Table 1	Notes	Some examples from UK sources
>0.20	Expansive	Normal reactivity	Exhibited by combinations known to have been involved in cases of actual damage to concrete	Chert and flint-bearing sand with non-reactive, low porosity coarse aggregates
0.10 to ≤0.20	Possibly expansive	Normal reactivity	Includes combinations which have sometimes been involved in cases of actual damage to concrete structures, but also includes some widely used combinations with no record of causing damage to concrete	Quartzitic gravels and sands from the English Midlands and some crushed rock containing microcrystalline quartz
>0.05 to ≤0.10	Probably non-expansive	Low reactivity	Combinations in this range have rarely been associated with actual cases of damage to concrete structures. However, these might be considered unsuitable in extreme conditions	Some of the quartzitic gravel sands from the English Midlands
≤0.05	Non-expansive	Low reactivity	Combinations which have no record of causing damage to concrete	Crushed limestone and igneous rock aggregates‡; chert and flint bearing coarse/fine combinations with > 60% chert and flint contents

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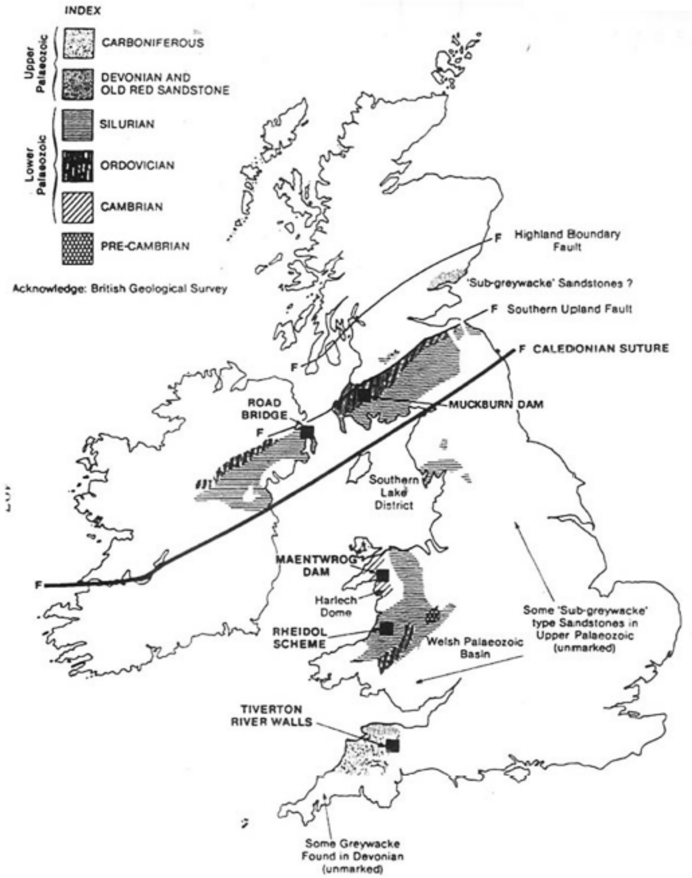
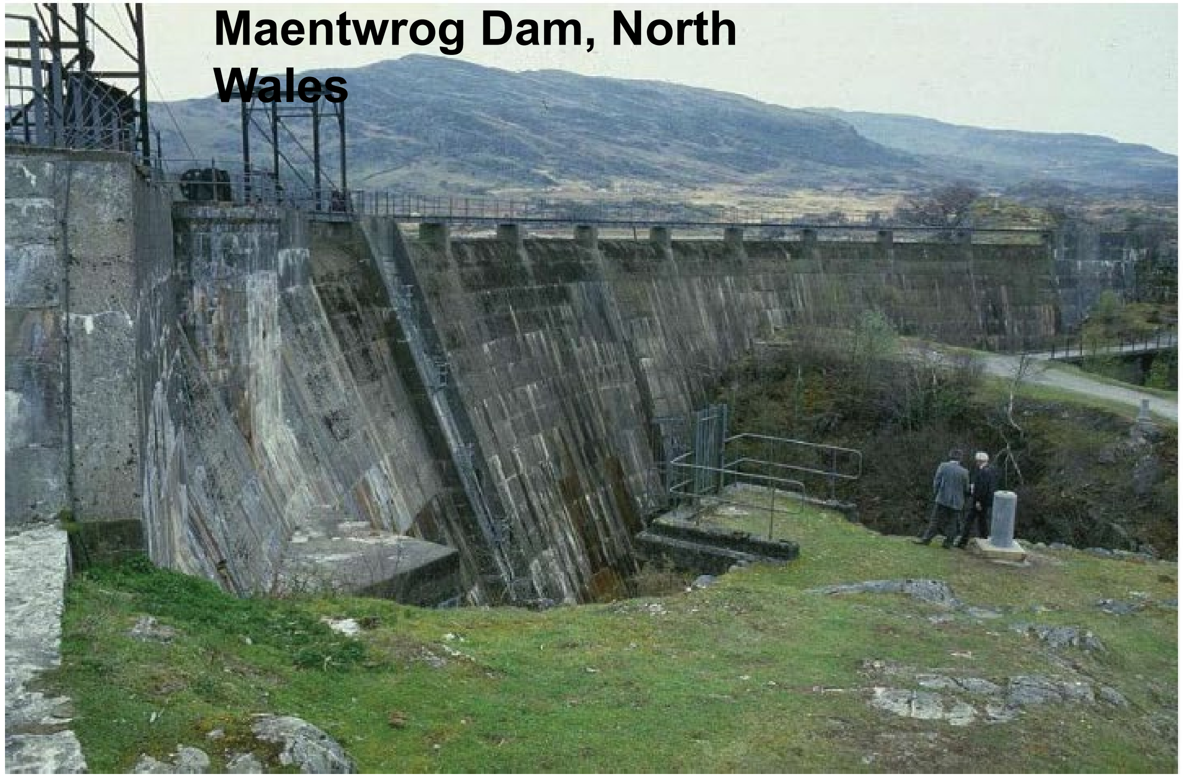
High-reactivity aggregates →

Table 4 Aggregates considered to be of high reactivity

Aggregate type	Comments
Crushed greywacke, greywacke-type sandstones, greywacke-type siltstone or mudstones, or mixtures containing more than 10% of these	Applied to aggregate from a primary source and excludes materials found as normal, uncrushed, constituent of some natural sand and gravel deposits; unless the sand and gravel deposit contains, or is subsequently blended with, 10% or more greywacke and/or greywacke-type sandstone and/or siltstone or mudstone material that has been crushed (regardless of whether this crushed material is from a primary or gravel source)





Maentwrog Dam, North Wales

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- Low reactivity aggregate together with a high alkali cement, or
- Normal reactivity aggregate together with a low, moderate or high alkali cement

Alkali Contribution from Slag & Fly Ash →

To be used in the calculation of concrete alkali content for Table 1

SCM	SCM Replacement Level	Fraction of SCM alkali to be used in calculation of concrete alkali content
Slag (Table 7)	> 40%	None
	25 - 40%	$^1/_2$
	< 25%	All
Fly Ash (Table 8)	> 25%	None
	20 - 24%	$^1/_5$
	< 20%	All

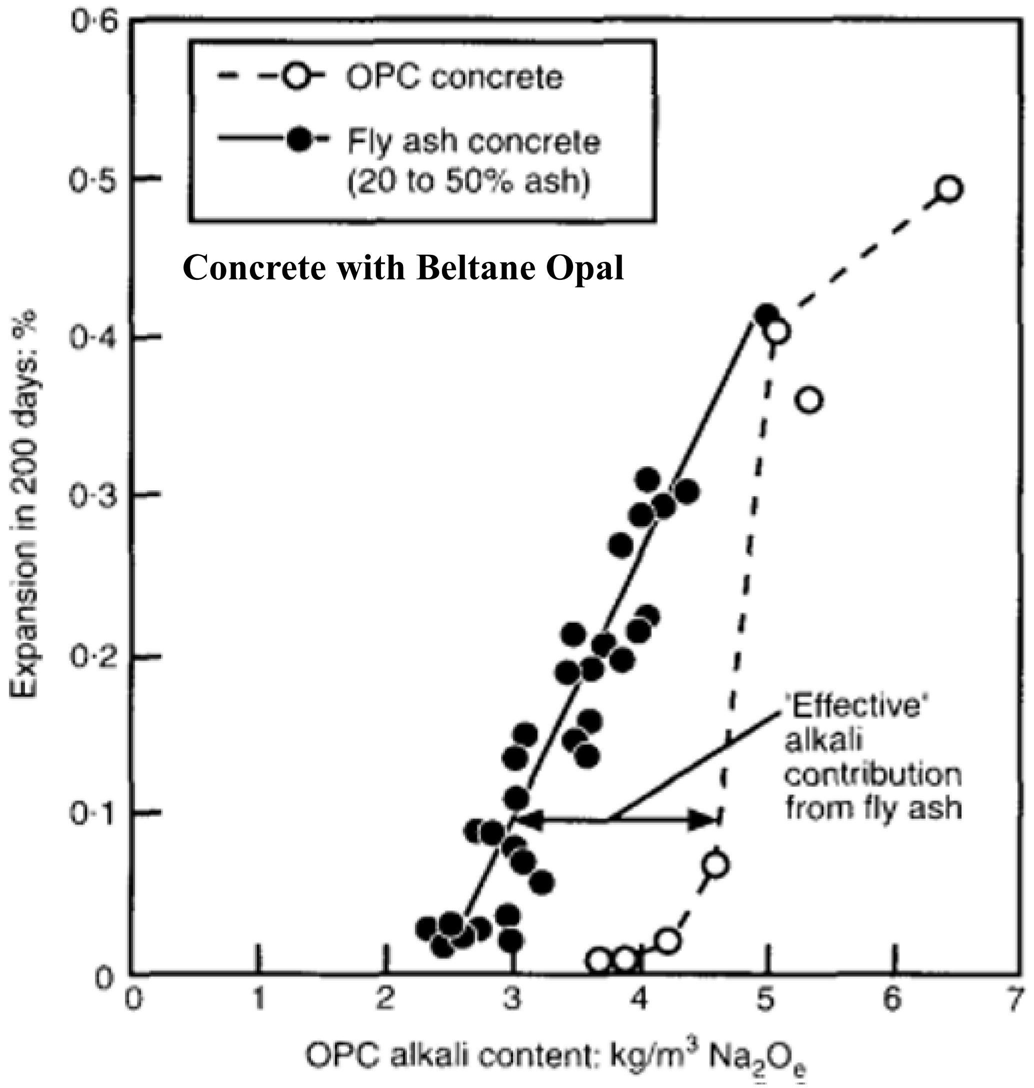
- Low reactivity aggregate together with a low or moderate alkali cement

  No contribution of alkali from fly ash or slag
  (no minimum proportions are recommended)

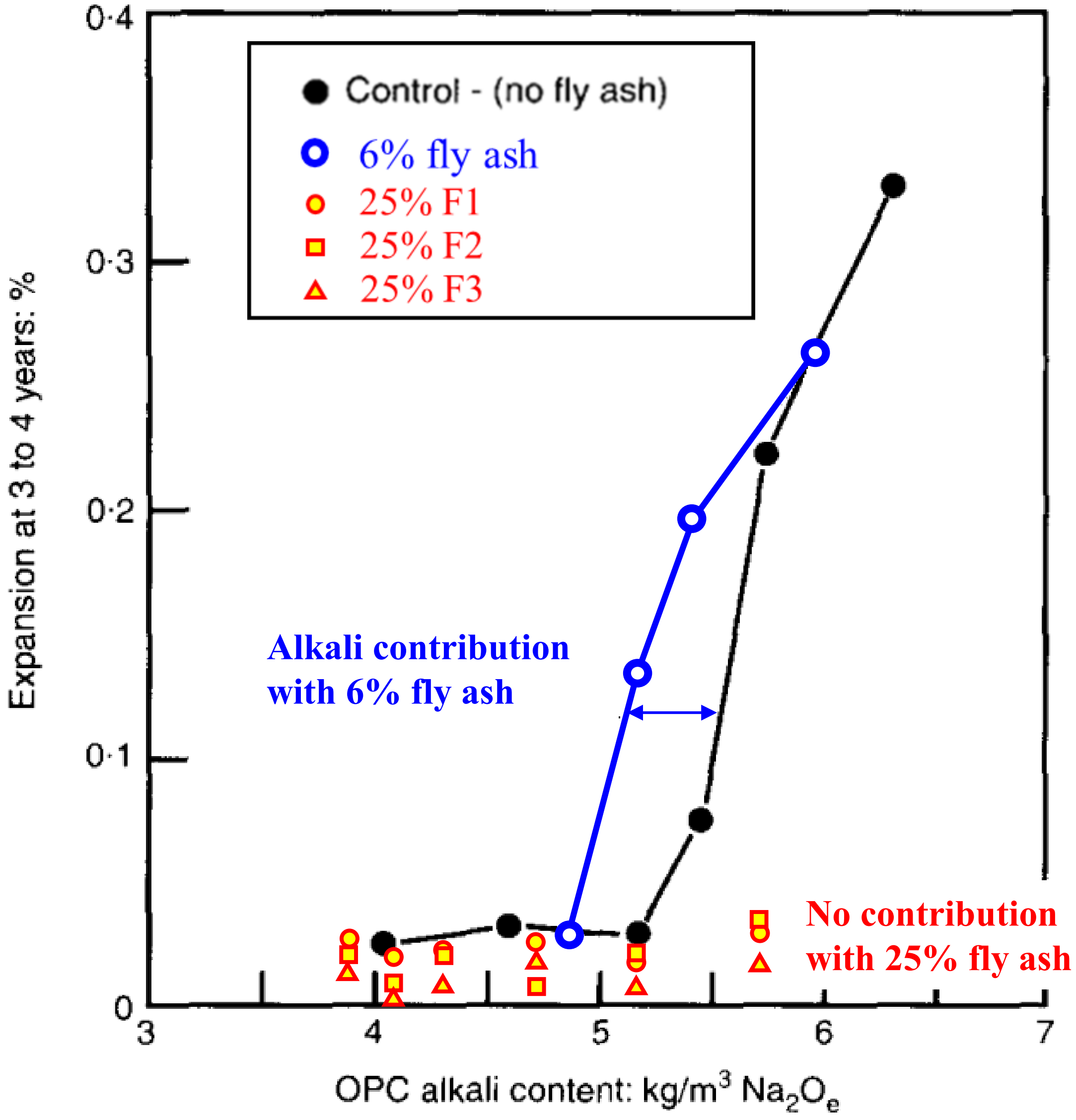
- High reactivity aggregate, irrespective of the classification of the cement.

  *Proportions less than 50% by mass for slag or 40% by mass for fly ash are **not** recommended*

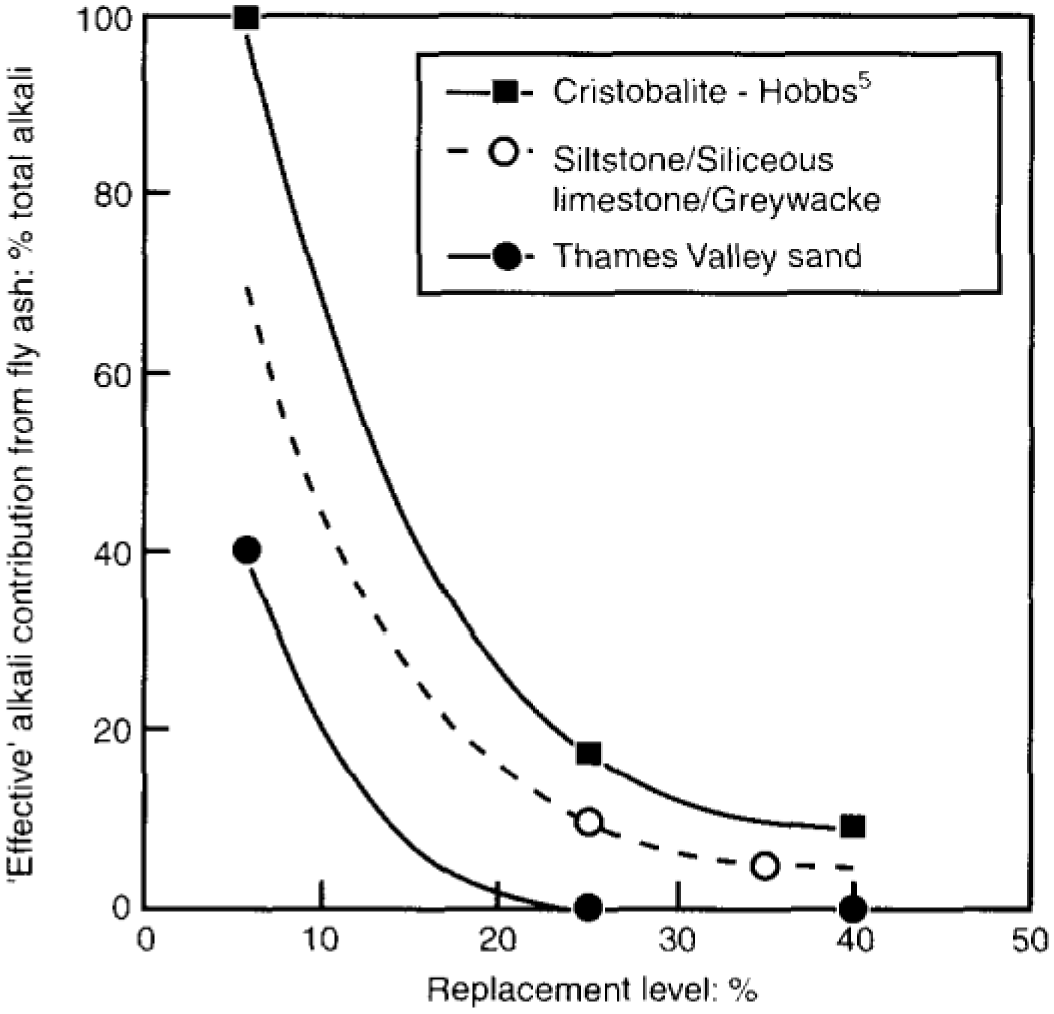
Hobbs' (1989) methodology for calculating alkali contribution



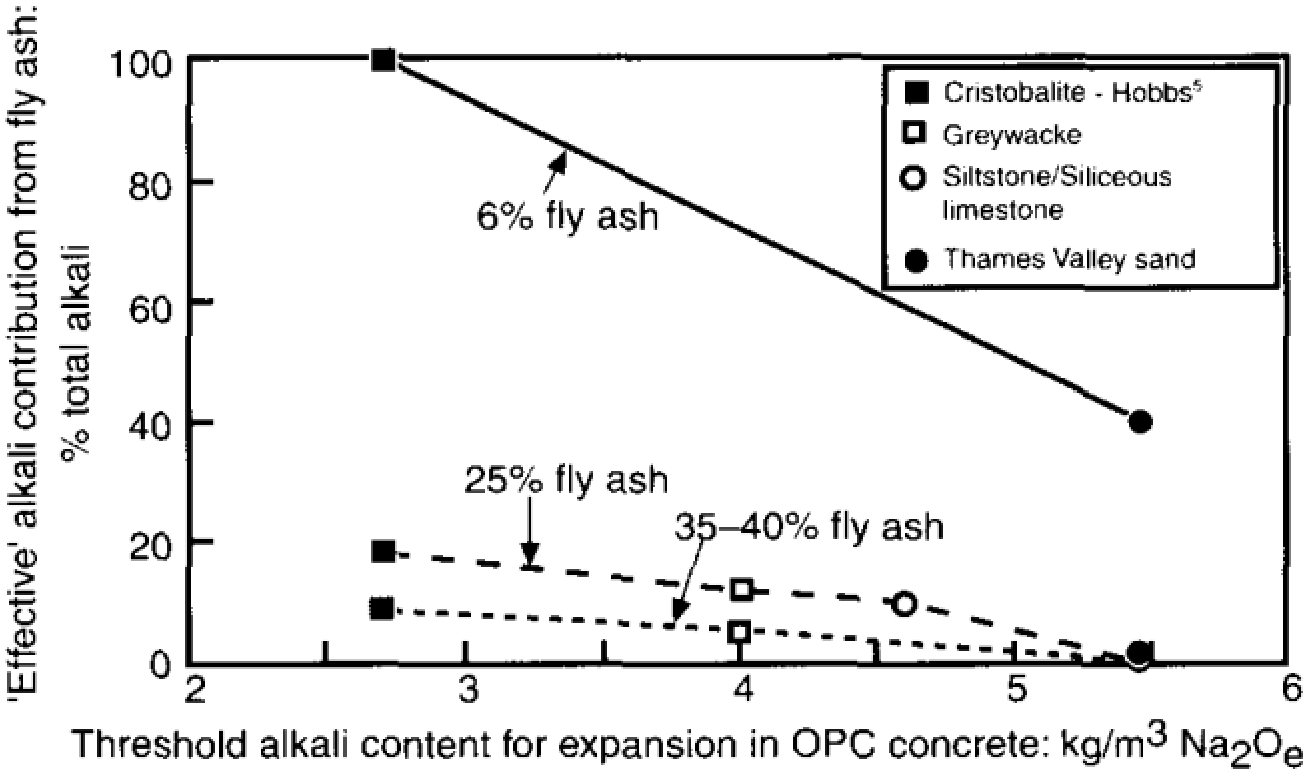
Thomas et al. (1996) results for TV flint sand



Thomas et al. (1996) Alkali Contribution of Fly Ash
Role of FA Replacement Level and Aggregate Type



Thomas et al (1996) Alkali Contribution of Fly Ash
Role of Aggregate Alkali Threshold



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Use of Silica Fume & Metakaolin →

Table 10 Recommendations for use of metakaolin and silica fume to minimise ASR damage: recommended limits for the alkali contents of concrete

The alkali contents are calculated in accordance with Table 1 and its notes

Aggregate type	Alkali content of cement		
	Low	Moderate	High
Low reactivity	Self-limiting	Self-limiting	≤5.0 kg Na_2O eq/m^3 with 10% metakaolin and ≥8% silica fume
Normal reactivity	Self-limiting	≤5.0 kg Na_2O eq/m^3 with 10% metakaolin	≤5.0 kg Na_2O eq/m^3 with 10% metakaolin
		≤4.0 kg Na_2O eq/m^3 with ≥8% silica fume	≤3.5 kg Na_2O eq/m^3 with ≥8% silica fume
High reactivity	≤5.0 kg Na_2O eq/m^3 with 10% metakaolin	≤5.0 kg Na_2O eq/m^3 with 10% metakaolin	≤5.0 kg Na_2O eq/m^3 with 10% metakaolin
	≤3.0 kg Na_2O eq/m^3 with ≥8% silica fume	≤3.0 kg Na_2O eq/m^3 with ≥8% silica fume	≤3.0 kg Na_2O eq/m^3 with ≥8% silica fume

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Use of Lithium Salts →

Table 11 Minimum recommended additions of lithium salts to minimise ASR damage

The recommendations in this table are applicable only if the total alkali content of the mix (in accordance with Table 1 and its notes) does not exceed 5.0 kg/m³

Aggregate type	Lithium salts	Pfa by mass of total binder (%)	Lithium salts or solution per kg of Na_2O eq (Kg)	Salt admixture per kg of Na_2O eq (litres)	Volume reduction in mixing water per litre addition of admixture (litres)
Low reactivity	No addition needed				
Normal reactivity	$LiOH.H_2O$	0–25	0.75	–	–
	$LiNO_3$, 30% solution	0–25	3.75	3.15	2.6
High reactivity	$LiOH.H_2O$	0–14	1.3	–	–
		15–25	1.0	–	–
	$LiNO_3$, 30% solution	0–14	5.95	5.0	4.15
		15–25	5.2	4.4	3.6

Mactaquac G.S. – Fredericton, N.B. (Completed 1968)

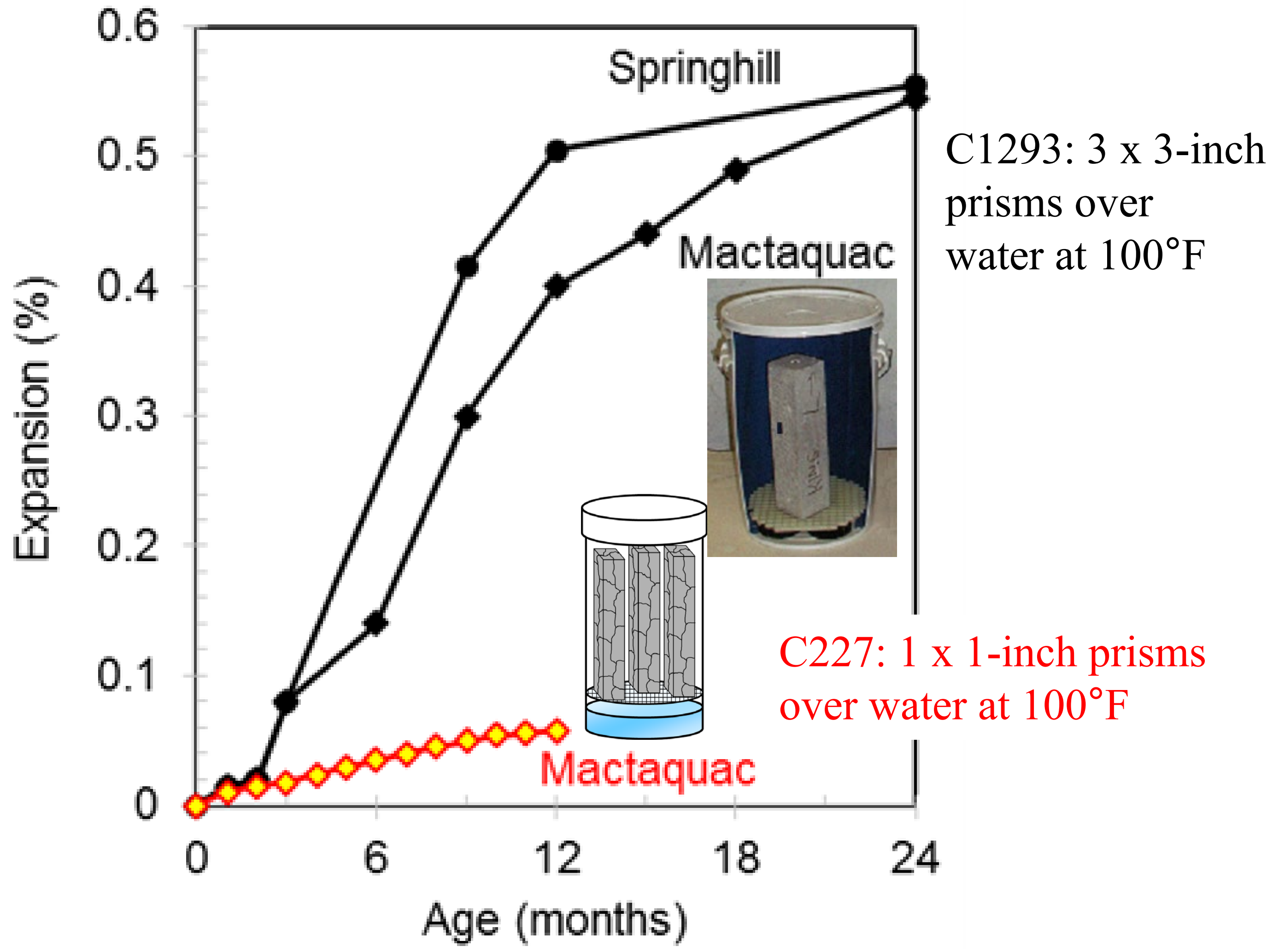
- Aggregate non-reactive by ASTM C 227
- ~ 60 cm (24 in.) concrete removed from the intake structure by slot cutting
- Intake structure grown in height ~ 23 cm (9 in.)
- Growth rate approx. 120 to 150 μs/y
- Remediation due to ASR ~ $6M per year
- Projection until 2016 was that concrete structures will be replaced by 2030

Question: Can the same aggregate be used again?

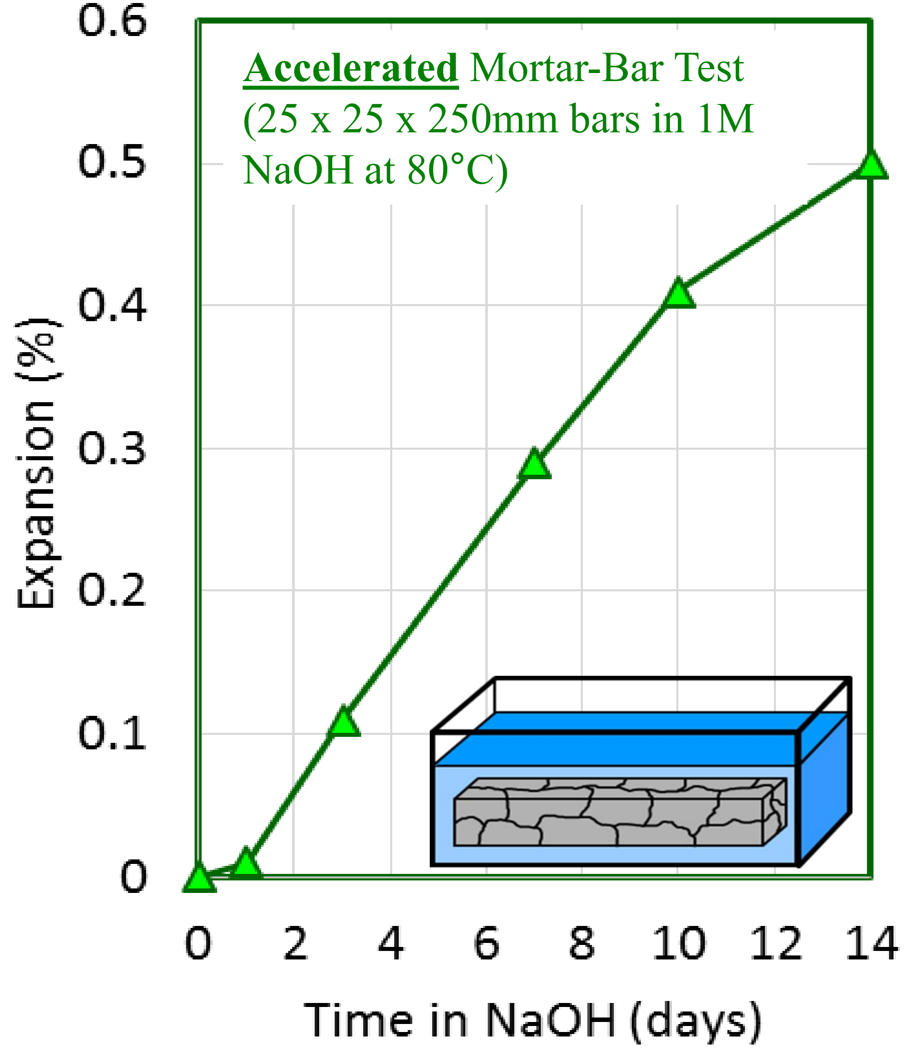
Preventive Measures for the Reconstruction of Mactaquac: Using Fly Ash

Aggregate Reactivity

ASTM C227 vs ASTM C1293



ASTM C1260



Preventive Measures for the Reconstruction of Mactaquac: Using Fly Ash

AASHTO R-80 / ASTM C 1778

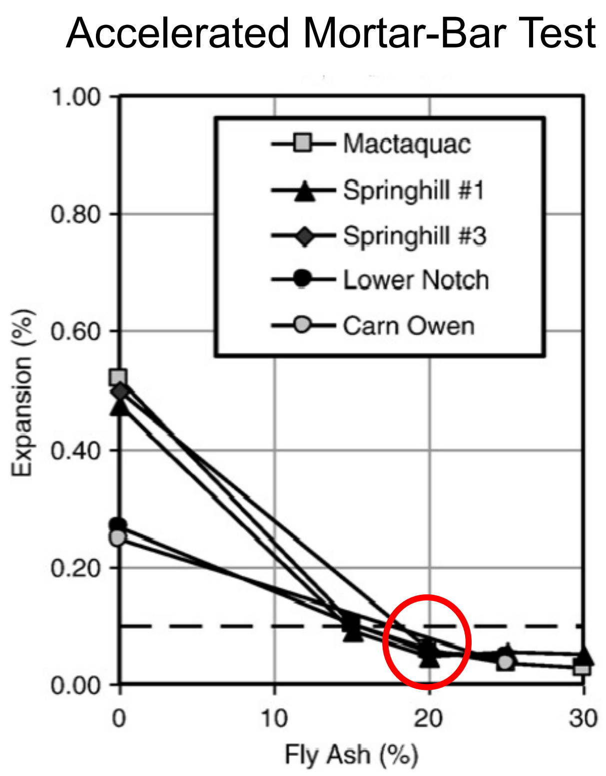
- Aggregate reactivity = R3 (highest)
- ASR risk = Level 5 (2nd highest)
- Class of structure = S4 (most critical)
- Level of prevention = ZZ (highest)

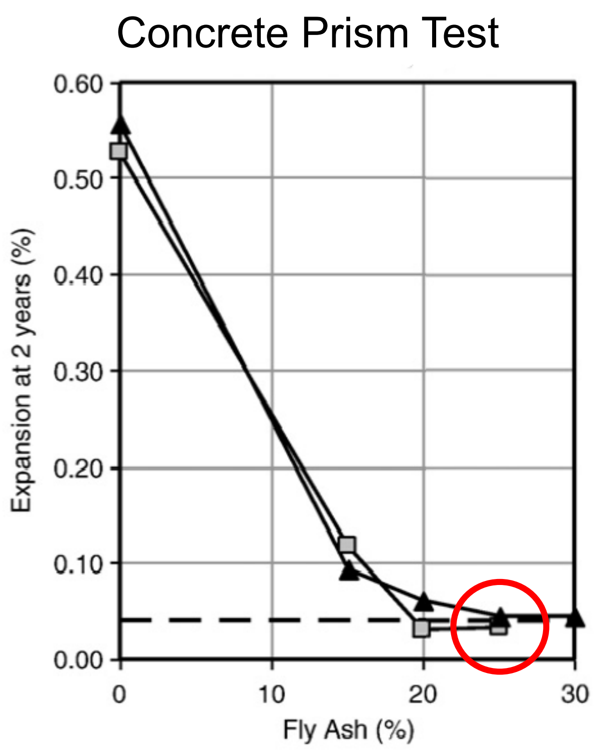
TABLE 8 Using SCM and Limiting Alkali Loading of Concrete to Provide Highest Levels of Prevention

Prevention Level	SCM as Sole Prevention	Limiting concrete alkali loading plus SCM	
	Minimum SCM level	Maximum alkali loading, kg/m³ [lb/yd³]	Minimum SCM level
Z	SCM level shown for Level Z in Table 6	1.8 [3.0]	SCM level shown for Level Y in Table 6
ZZ	Not permitted	1.8 [3.0]	SCM level shown for Level Z in Table 6

- **use 35% Class F fly ash and**
- **limit alkali content from PC ≤ 3.0 lb/yd³ Na_2Oe**

Performance Approach





- **ASTM C1567 – use 20% Class F fly ash**
- **ASTM C1293 – use 25% Class F fly ash**

Preventive Measures for the Reconstruction of Mactaquac: Using Fly Ash

AASHTO R-80 / ASTM C 1778

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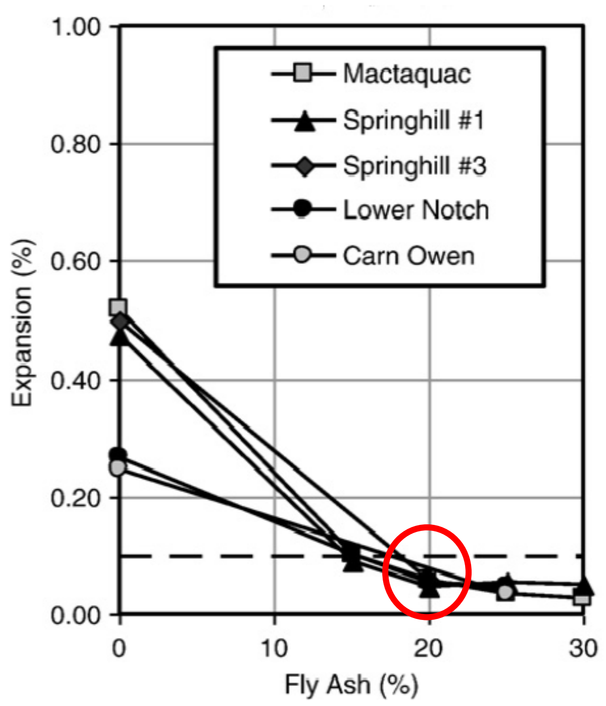
Z	SCM level shown for Level Z in Table 6	1.8 [3.0]	SCM level shown for Level Y in Table 6
ZZ	Not permitted	1.8 [3.0]	SCM level shown for Level Z in Table 6

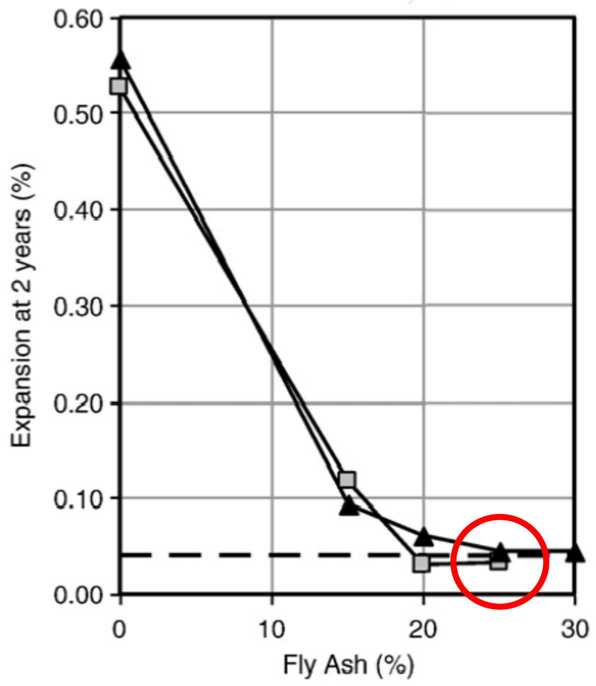
- **use 35% Class F fly ash and**
- **limit alkali content from PC ≤ 3.0 lb/yd^3 Na_2Oe**

Performance Approach

Accelerated Mortar-Bar Test



Concrete Prism Test



- **ASTM C1567 – use 20% Class F fly ash**
- **ASTM C1293 – use 25% Class F fly ash**

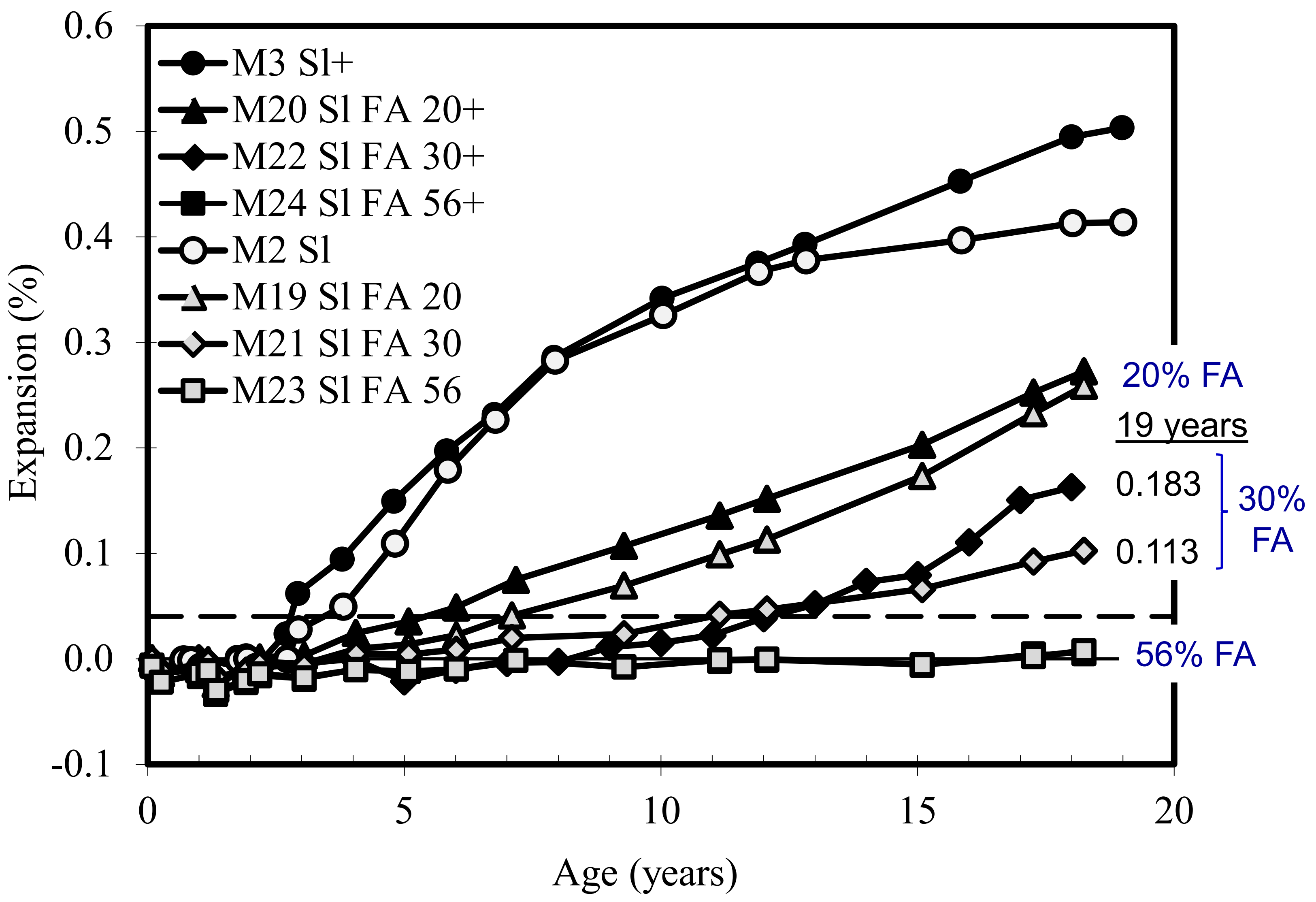
Preventive Measures for the Reconstruction of Mactaquac: Using Fly Ash

Other specifications discussed in this presentation

AASHTO R80 & ASTM C 1778	20 to 25% Class F fly ash	Expansion testing in mortar or concrete
	35% Class F fly ash **and** alkali ≤ 1.8 lb/yd^3 Na_2Oe	Prescriptive requirements
CSA A23.2-27A/28A	25% Class F fly ash*	Expansion testing in mortar or concrete * SCM not less than Level Y for extremely reactive aggregate
	35% Class F fly ash **and** alkali ≤ 1.2 lb/yd^3 Na_2Oe	Prescriptive requirements
ACI 301 & 350	20 to 25% Class F fly ash	Expansion testing in mortar or concrete
	25% Class F fly ash (ACI 350)	Prescriptive requirements in Table 4.1.3A
TxDOT	20 to 35% Class fly ash	Prescriptive requirement
	20% Class F fly ash	Expansion testing in mortar (Scenario A in Table 10)
BRE Digest 330	40% Class fly ash **and** alkali ≤ 4.2 lb/yd^3 Na_2Oe	Prescriptive requirement for high reactivity aggregate (greywacke)

Expansion of Exposure Blocks on CANMET Site (Ottawa)

Springhill Aggregate & Class F Fly Ash



- Springhill aggregate (similar to aggregate used in Mactaquac)
- 420 kg/m^3 (708 pcy) cementing material
- PC alkali = 0.9% Na_2Oe

[At 30% fly ash, concrete alkali = 2.65 kg/m^3 (4.4 pcy) Na_2Oe]

Field Performance of Fly Ash & Reactive Greywacke Aggregate

No fly ash | With fly ash

Dams in Ontario

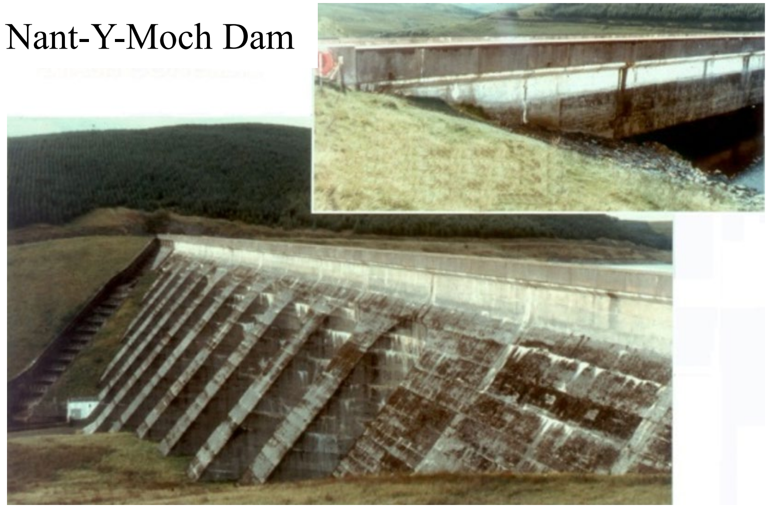
Many structures with same highly reactive (greywacke) aggregate have moderate to severe ASR

Lower Notch Dam: high-alkali cement, 20 – 30% fly ash; no ASR after 50 years

Dams in Wales (UK)

Dinas Dam: no fly ash; severe ASR after 50 years

Nant-y-Moch Dam: 25% fly ash, same aggregate as Dinas; no ASR after 60 years



Conclusions

- There are numerous specifications for minimizing the risk of damage due to ASR both within the USA & internationally
- Although there are a many different test methods available, most performance specifications today rely one or both of two test procedures; these are:
    - The concrete-prism test (ASTM C1293 or similar)
    - The accelerated-mortar-bar test (ASTM C1260/C1567 or similar)
- Many specifications provide the option to select prescriptive remedies including:
    - Control of concrete alkali
    - Use of SCM
    - Use of lithium compounds
- There is an ongoing need to validate existing specifications by benchmarking the options against field-performance data

Questions?

PennDOT: ASR Prevention Program

PATRICIA BAER

PENNDOT

BUREAU OF PROJECT DELIVERY

CONSTRUCTION AND MATERIALS DIVISION

History:

- 1992- Start of ASR testing program
  - AASTHO T 303
  - Tested once – unless issues

    464 aggregates – 75% had expansion test results over 0.10% linear expansion

- 2013 – Pro-team formed to investigate improving our ASR mitigation program
  - Pro-team decided to use AASHTO R 80
    - Tested aggregates according to ASTM C 1293

- 2015 – Started testing fine and coarse aggregates for all aggregates sources wanting to participate.
  - Two years to finish with four independent labs
    - First year- testing initially on aggregate sources with T-303 expansions less than or equal to 0.15%
    - Second year – the rest of the sources
    - Five-year testing cycles was established

Aggregate Evaluation:

- 2020 - Started second round of testing
  - Department testing
  - Purchased a second warm room
  - Approximately 75 samples per year
  - Quality Assurance Section gathered samples
    - Consistency

Aggregate Evaluation(continued):

- Problems-
  - First year testing- collected AASTHO #57’s
    - For some sources had to ask for additional material.
    - Coarse aggregate- 3/8” screen (issue)
      - Solution :
        - Three 50 lb. bags of AASTHO # 57’s
        - Two 50 lb. bags of AASHTO # 8’s

Aggregate Evaluation(continued):

- Testing according to ASTM C 1293
  - Also testing AASHTO C 380
  - Gathering materials to test according to AASHTO TP 144 (TFHRC T-FAST)
  - Continue to research and evaluate other test methods
- If reactivity level change, concrete suppliers have 90 days to complete
  - Some of our sources have changed reactivity level
    - Borderline results

ASTM C 1293

Results as of August 2017:

- Currently, 36% of our aggregates are reactive compared to 75% prior to starting the ASTM C 1293 testing

Reactivity Level	Number of Aggregates
R0	240
R1	99
R2	33
R3	2

Example #1- Using current specification

Step #1:

Using a coarse aggregate with a reactivity of 0.18% and a fine aggregate with a reactivity of 0.03%

- According to Table C:

Aggregate Reactivity Class	Description of Aggregate Reactivity	1-Year Expansion in ASTM C1293 (percent)	14-d Expansion in AASHTO T 303 (percent)
R0	Non-reactive	≤ 0.04	≤ 0.10
R1	Moderately reactive	>0.04 to ≤ 0.12	>0.10 to ≤ 0.30
R2	Highly Reactive	>0.12 to ≤0.24	>0.30 to ≤0.45
R3	Very Highly Reactive	>0.24	>0.45

- The coarse aggregate is a R2 reactivity class.
- The fine aggregate is non reactive or R0.
- For mix designs use the highest reactivity level of any aggregates used.

Example #1 continued

Step #2:

The next step is to figure out the level of ASR risk

- According to Table D: Aggregate Reactivity Class

Aggregate Reactivity Class	R0	R1	R2	R3
Level of ASR Risk	Risk Level 1	Risk Level 2	Risk Level 3	Risk Level 4

- This aggregate would be at a Risk Level 3

Example #1 continued

Step #3:

Determine Level of prevention. The structure classification needs to be know in order to determine the level of prevention.

- See Table F:

If this mix design was for concrete paving under section 506, then the structure class would be S2.

If this mix design was for LLCP- long life concrete pavement under section 530, then the structure class would be S3.

Structure Class	Consequences	Acceptability of ASR	Structure/Asset Type	Sections
S1	Safety and future maintenance consequences small or negligible	Some deterioration from ASR may be tolerated	Temporary structures. Inside buildings. Structures or assets that will never be exposed to water	620, 621, 624, 627, 628 643, 644, 859, 874, 930, 932, 934, 952, 953, and 1005
S2	Some minor safety, future maintenance consequences if major deterioration were to occur	Moderate risk of ASR acceptable	Sidewalks, curbs and gutters, inlet tops, concrete barrier and parapet. Typically structures with service lives of less than 40 years	303, 501, 505, 506, 516, 518, 523, 524, 525, 528, 540, 545, 605,607, 615, 618, 622, 623, 630, 633, 640, 641, 658, 667, 673, 674, 675, 676, 678, 714, 852, 875, 910, 948, 951, 1001, 1025, 1040, 1042, 1043, 1086, 1201, 1210, 1230, and Miscellaneous Precast Concrete
S3	Significant safety and future maintenance or replacement consequences if major deterioration were to occur	Minimal risk of ASR acceptable	All other structures. Service lives of 40 to 75 years anticipated.	530, 1001, 1006, 1031, 1032, 1040, 1080, 1085, 1107, MSE walls, Concrete Bridge components, and Arch Structures

Example #1 continued

Step #4: Let's say the design is for concrete pavement (RPS– section 506)

- The Structure Classification would be S2

- From Table E – Determining the level of prevention

Level of ASR Risk	S1	S2	S3
Risk Level 1	V	V	V
Risk Level 2	V	W	X
Risk Level 3	W	X	Y
Risk Level 4	X	Y	Z

- With a Risk Level of 3 and a S2 classification, this mix needs a prevention level X

Example #1 continued

Step #5:

- Let's say we are going to pozzolan to mitigate for ASR.
- See Table G for the minimum replacement levels

Type of SCM [1]	Alkali Level of SCM (% Na2Oe) [2] [3]	Level V [4]	Level W	Level X	Level Y	Level Z [5] [11]
Class F or C flyash [6]	≤ 3.0	-	15	20	25	35
Class F or C flyash [6]	>3.0, ≤ 4.5	-	20	25	30	40
GGBFS	≤ 1.0	-	25	35	50	65
Silica Fume [7] [8] [9] [10]	≤ 1.0	-	1.2 LBA	1.5 x LBA	1.8 x LBA	2.4 x LBA

- The mix needs a Level X replacement so the pozzolan replacement levels would be:
  - 20% for a Class F or C flyash with an alkali level of 3.0% or less
  - 25% for a Class F or C flyash with an alkali level greater than 3.0% or less than or equal to 4.5%
  - 35% for GGBFS
  - 1.5 x LBA for Silica Fume but not less than 7%

Next Steps:

- Finish this round of testing (3 more years)
- Start T-Fast testing
- Evaluate test results between ASTM C 1293 and AASHTO C 380
- Department and Industry are still evaluating and looking at new test methods that are being developed.
- Continue Review of on-going research (mini-concrete prism test, alternate SCM's etc.).
- Identify additional ASR affected assets and document using AASHTO ASR inventory tool.

Contact Information:

Patricia Baer

- PennDOT Materials and Testing Lab
- Email: patrbaer@pa.gov

U.S. ARMY CORPS ASR MITIGATION PROGRAM

Stephanie G. Wood, Ph.D.
Research Civil Engineer
Concrete and Materials Branch (CMB)
Geotechnical and Structures Laboratory (GSL)

TRB Webinar – Practical Perspectives on Alkali-Silica Reactivity

14 October 2021

US Army Corps of Engineers

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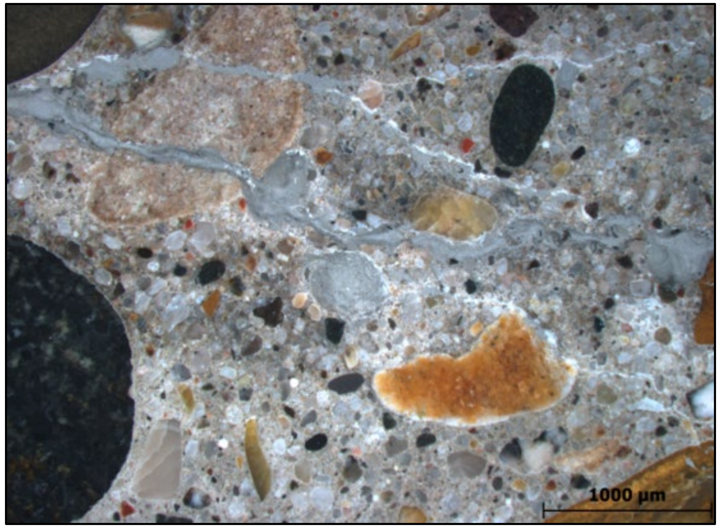
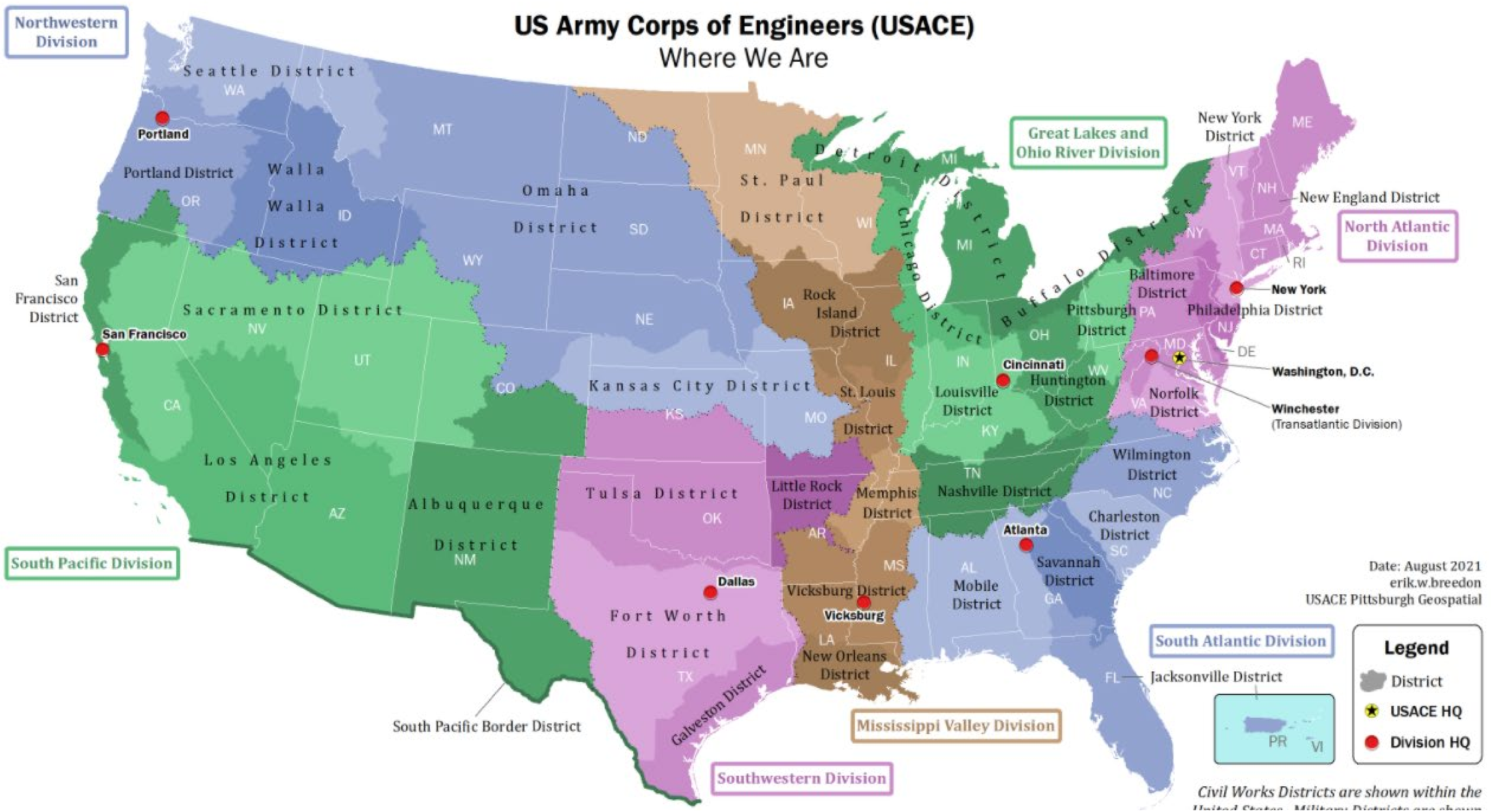
ASR in USACE Infrastructure

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Kansas City District
KS
MO
Tulsa District
OK
Little Rock District
AR
Memphis District
TN
Nashville District
Wilmington District
NC
Charleston District
SC
Atlanta
Savannah District
GA
AL
Mobile District
MS
Vicksburg District
Vicksburg
LA
New Orleans District
Dallas
Fort Worth District
TX
Galveston District
South Pacific Border District
Southwestern Division
Mississippi Valley Division
South Atlantic Division
FL
Jacksonville District
PR
VI
Date: August 2021
erik.w.breedon
USACE Pittsburgh Geospatial
Legend
District
USACE HQ
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Civil Works Districts are shown within the

United States
Environmental Protection
Agency

Solid Waste and
Emergency Response
(OS-305)

EPA/530-SW-91-086
January 1992

Office of Solid Waste

EPA

Environmental Fact Sheet

EPA Guideline for Purchasing Cement And Concrete Containing Fly Ash

Coal fly ash, like portland cement and volcanic ash, is composed of mineral matter mainly in the form of oxide compounds derived from limestone, iron ore, silica sand, and clay. Fly ash has been used for decades in the production of durable and economical concrete, and can be purchased either in blended cement or as a mineral admixture for concrete.

Coal Fly Ash Uses

In the 1960s, the American Society for Testing and Materials (ASTM) developed standards for the use of fly ash in concrete that are updated annually (see box on Standards and Availability).

The application and performance of concrete containing fly ash has been documented by both the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers since the 1940s. Over the last 40 years, fly ash has been used in virtually every concrete market, including highways, airports, commercial and residential buildings, bridges, pipelines, and tunnels. Widely available in the United States, more than six million tons of coal fly ash are used annually in cement and concrete (see box on Standards and Availability).

Equal or reduced cost of total materials can be realized with the use of fly ash while maintaining or improving concrete properties. In cases where no cost savings are realized by using fly ash, it may be advantageous since fly ash can improve both the strength and durability of concrete.

Coal fly ash is also used in mixtures designated by ACI as controlled low-strength material (CLSM). CLSM mixtures are typically used to fill trenches or other excavations like mine shafts and in abandoned underground storage tanks. CLSM mixtures are proportioned with fly ash, sand, water, and small amounts of portland cement. A CLSM mixture is fluid and self-compacting, and can be proportioned to produce strengths equivalent to compacted soil.

Procurement Guideline

To increase the use of cement and concrete containing fly ash from coal combustion within both government and private sectors, on January 28, 1983, EPA issued a guideline for purchasing cement containing fly ash. It requires all federal agencies and all state and local government agencies and contractors that use federal funds to purchase cement and concrete to implement a preference program favoring the purchase of cement and concrete containing coal fly ash.

Coal Fly Ash Specifications

Coal fly ash reacts chemically with portland cement and water to form compounds possessing cementitious properties. The amount of fly ash in typical concrete applications is from 15 to 35 percent, by weight of total cementitious material, with amounts up to 70 percent and more in massive walls, girders, road bases, and dams.

Two general methods are used to incorporate coal fly ash in concrete mixtures: (1) a prescriptive method in which fly ash replaces a fixed portion of the portland cement and (2) a design method in which fly ash use is based on laboratory or field records to produce an optimum effect on concrete properties and performance. Each method has a valid place in engineering practice. With either method, the main requirement for assuring satisfactory workability, strength, and durability is not to exceed a maximum ratio of water to cementitious material [w/(c+f)], where w, c, and f represent the weights of water, portland cement, and fly ash, respectively. More information about fly ash use in concrete is available from the American Concrete Institute (ACI) (see Standards and Availability below).

Further Information

For further information, including copies of the cement and concrete procurement guideline, please contact EPA's procurement guidelines hotline at (703) 941-4452.

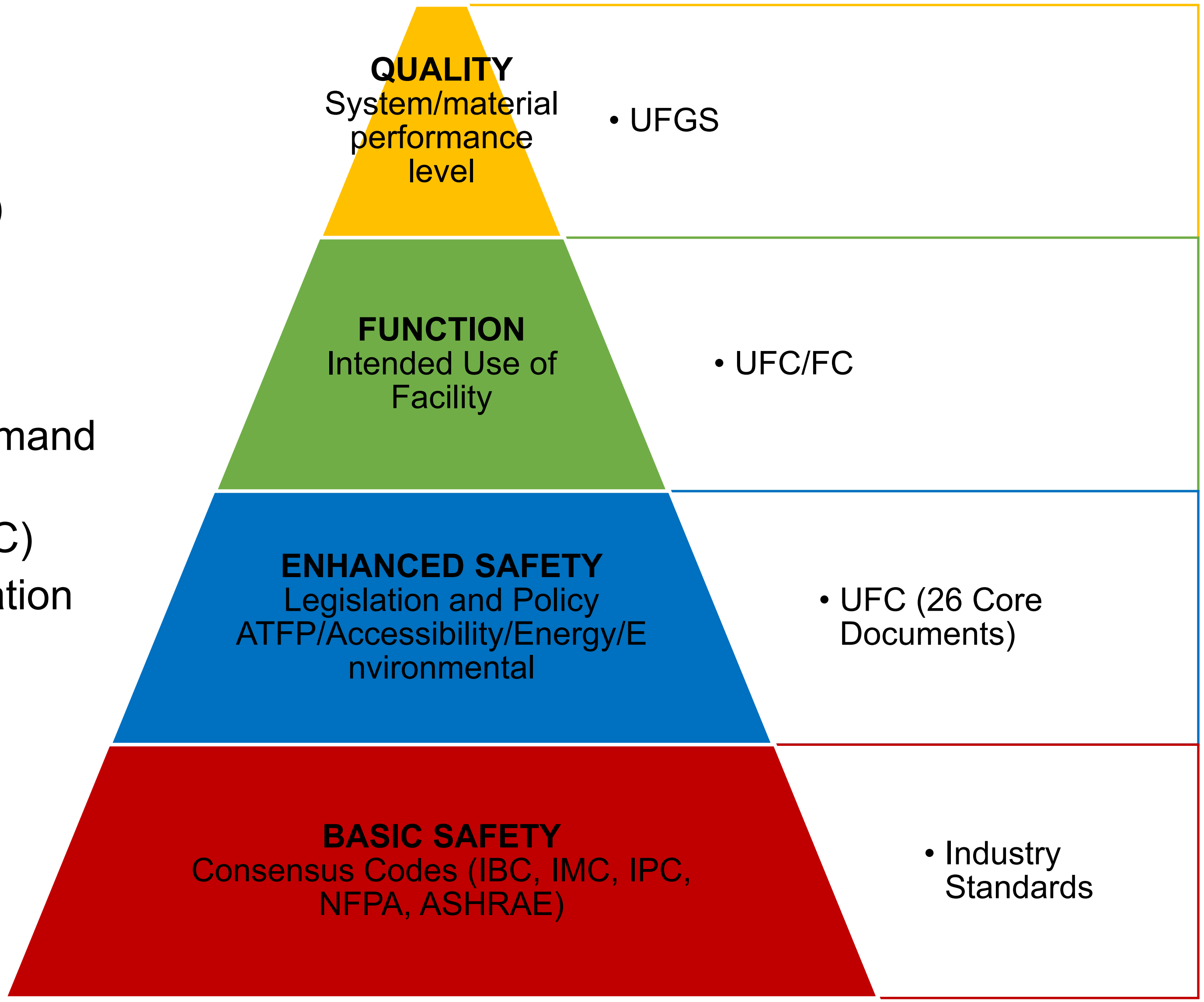
ASTM C1260 Expansion Limit

- DoD began using 0.08% at 28 days in 2001
- Driven by engineers at the Naval Facilities Engineering Service Center (NAVFAC)
- Based primarily on
  - Stark, David, Bruce Morgan, and Paul Okamoto. *Eliminating or minimizing alkali-silica reactivity*. No. SHRP-C-343. 1993.
  - De Grosbois, Marie, and Eric Fontaine. "Evaluation of the potential alkali-reactivity of concrete aggregates: Performance of testing methods and a producer's point of view." *Proceedings 11th International Conference on AAR*. 2000.
  - ACI 221.R-98 *Report on Alkali-Aggregate Reactivity.* American Concrete Institute. 1998.
  - AASHTO T 303 *Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction.* 2000.

NAS Point Mugu - $14M
Photo: L. Javier Malvar

Unified Facilities Guide Specifications (UFGS)

- Used by the U.S. Department of Defense (DoD)
- Joint effort in specifying construction for military services
  - U.S. Army Corps of Engineers (USACE)
  - Naval Facilities Engineering Systems Command (NAVFAC)
  - Air Force Civil Engineer Center (HQ AFCEC)
  - National Aeronautics and Space Administration (NASA)
- Based on industry reference standards



Adapted from Zenovia D. Wilcox (USACE-HQ)

UFGS 03 30 00 Cast-in-Place Concrete

(February 2019)

- Cementitious Materials
  - ASTM C150 Type I, II, II (MH), III, IV, V
  - ASTM C 595 Type IP, IS, IP (MS), IS (MS), IP (MH), IS (MH), IP (LH), IS (LH)
  - ASTM C1157 Type GU, MS, MH, HE
  - Suggests 35% replacement with fly ash with a minimum content of 15%. Class C not recommended. Class F preferred.
  - Note “Low-alkali cement could be specified; specifying it however, is not sufficient to mitigate ASR.”
- Aggregates
  - “Do not use any aggregate susceptible to alkali-carbonate reaction (ACR). Use one of the three options below for qualifying concrete mixtures to reduce the potential of alkali-silica reaction (ASR):

    a. For each aggregate used in concrete, the expansion result determined in accordance with ASTM C1293 must not exceed 0.04 percent at one year.

    b. For each aggregate used in concrete, the expansion result of the aggregate and cementitious materials combination determined in accordance with ASTM C1567 must not exceed 0.10 percent at an age of 16 days.

    c. Alkali content in concrete (LBA) must not exceed [2.4 kg per cubic meter] [4 pounds per cubic yard] [______] for moderately reactive aggregate or [1.8 kg per cubic meter] [3 pounds per cubic yard] [______] for highly reactive aggregate. Reactivity must be determined by testing in accordance with ASTM C1293 and categorized in accordance with **ASTM C1778**.”

UFGS 03 31 30 Marine Concrete

(February 2019)

- Cementitious Materials
  - Note: “Guidance for use of cementitious materials should be sought from the agency's Subject Matter Expert in Concrete Materials. Consideration should be given to the use of fly ash or GGBF slag for partial replacement of portland cement up to 50 percent. Type III cement should not be specified.”
  - ASTM C150 Type I, II, V with max Na_2O_e = 0.80%
  - ASTM C595 Type IP, IS
  - Class C fly ash not permitted
  - Must contain an SCM regardless of aggregate reactivity
- Aggregates
  - “Provide ASTM C1260 or ASTM C1567 test results conducted with 6 months of the submittal date .... Maximum allowable expansion is 0.08 percent at 14 days per ASTM C1260. If this is not met, then maximum allowable expansion for the proposed concrete mixture/s shall be 0.08 percent at 14 days per ASTM C1567. All aggregate sources shall be tested. Also, provide documentation that the aggregate has no history of chemical deterioration in concrete.”
  - “Should the test data indicate a potential risk of alkali-aggregate reaction, the aggregate(s) shall be rejected or procedures from **AASHTO R 80** shall be followed.”

UFGS 03 70 00 Mass Concrete

(February 2010, Change – August 2020)

- Cementitious Materials
  - ASTM C150, no types specified
  - Low-alkali OR portland cement + pozzolan / slag if expansion of the combination ≤ expansion of a low-alkali cement in ASTM C441
- Aggregates
  - Note refers the user to EM 1110-2-2000 Standard Practice for Concrete for Civil Works Structures for evaluating and mitigating ASR
  - The designer may use the specification method in UFGS 32 13 14.13 OR
  - Expansion less than 0.10 (0.08) percent at 16 days in ASTM C1260
    - Fine and coarse evaluated separately and in combination to match Contractor’s proposed mix design proportions
    - If aggregates fail, reject or conduct additional testing in ASTM C1260 and ASTM C1567 using low-alkali cement with slag or Class F fly ash

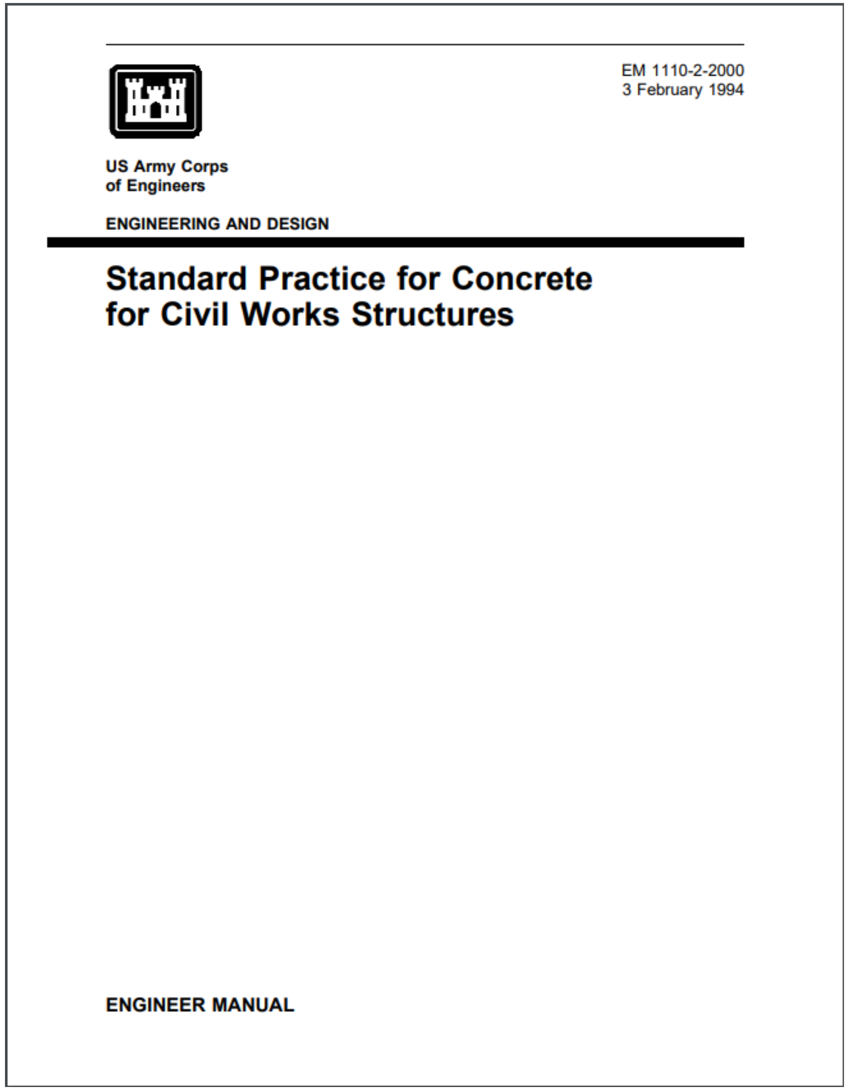
UFGS 32 13 14.13 Concrete Paving for Airfields and Other Heavy Duty Pavements

(August 2019)

- Cementitious Material
  - Note: “Guidance for use of cementitious materials must be sought from the Pavement Materials engineer or from the TSMCX, AFCEC pavement SME, or NAVFAC, especially for areas subject to alkali-aggregate reactivity, or sulfate attack.”
  - Low-alkali ASTM C150 Type I, II, or V
  - Low-alkali ASTM C595 Type IP or IS
  - SCMs
    - Note: “Class C fly ash not permitted for paving concrete.”
    - Navy must use one SCM regardless of results of ASR tests
    - Army and Air Force – Use of one of the SCMs is optional unless required to mitigate ASR
- Aggregates
  - Evaluate reactivity of all aggregates separately
  - Expansion less than 0.08 percent after 28 days in ASTM C1260.
  - If aggregates fail, reject OR test cement with SCMs in ASTM C1567 (0.08% at 28 days) OR test cement with lithium nitrate (no SCMs) in accordance with COE CRD-C 662
    - If aggregates fail, reject the aggregate(s) and submit new aggregate sources for retesting.

EM 1110-2-2000
Concrete for Civil Works Structures

- Created in 1994, updated sections of Ch. 2 in 2001
- Needs updating!
- Appendix D: Alkali-Silica Aggregate Reactions
  - ASTM C227, C289, and C586, CSA A23.2-14A (1986), ASTM C441, and a non-standardized accelerated mortar bar test with 0.11% expansion limit
  - Use low-alkali cement, a pozzolan, or both
- Appendix E: Alkali-Carbonate Aggregate Reactions
  - ASTM C295 and ASTM C586
  - Avoid use
  - Use low-alkali cement and pozzolan, use minimum aggregate size, or dilution so that reactive aggregate ≤ 20% of either fraction and 15% of the total if both are reactive


EM 1110-2-2000
3 February 1994

US Army Corps
of Engineers

ENGINEERING AND DESIGN

Standard Practice for Concrete for Civil Works Structures

ENGINEER MANUAL

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Melanie Leslie, Nashville District
Mike Wielputz, Savannah District
Bill Halczak, Sacramento District

Stephanie G. Wood
US Army ERDC-GSL-ESMD-GMC
Office: 601.634.5155
Mobile: 601.618.7786
Stephanie.G.Wood@erdc.dren.mil

Today’s Panelists

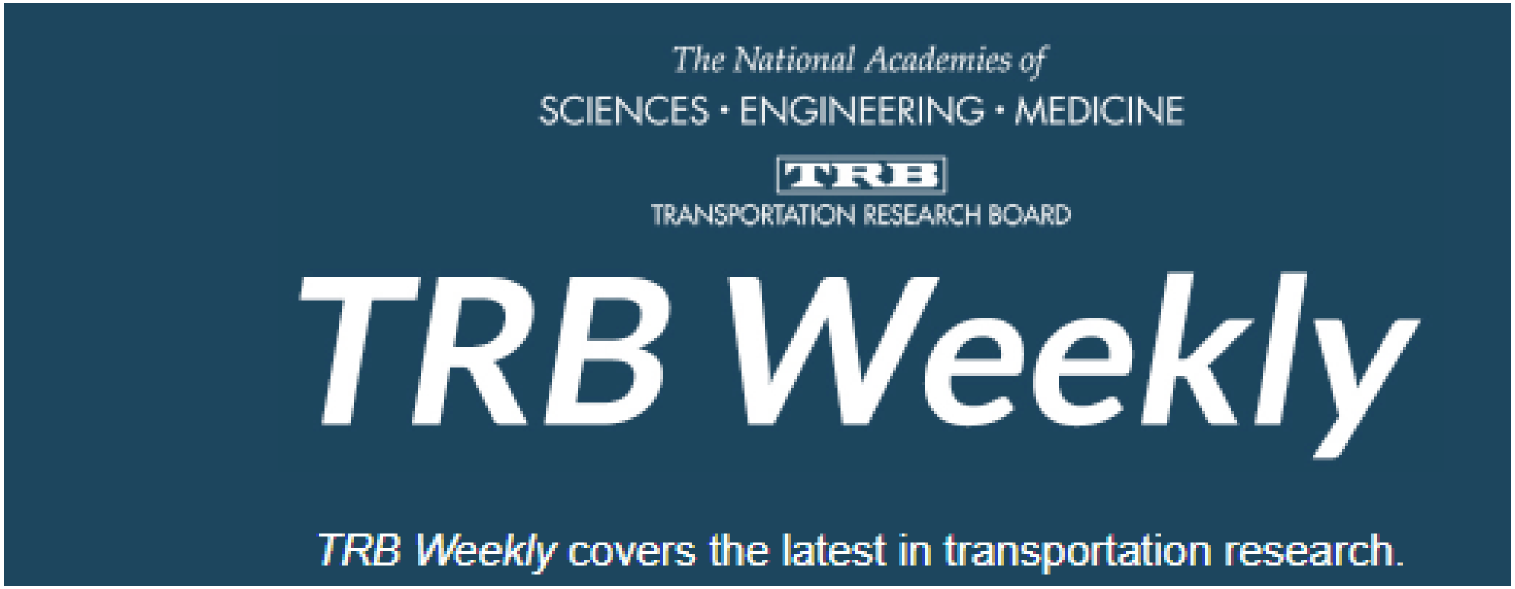
Moderator: Michael Praul,
FHWA

Patricia Baer,
Pennsylvania DOT

Michael Thomas,
The University of New Brunswick

Stephanie Wood,
USACE

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER



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