# Engineer’s Authority and Specification Conformance

ACPTP
Airport Concrete Pavement Technology Program

ACPA

# Learning Objectives:

- ✈ Learn the background of some problematic FAA P-501 specifications
- ✈ Understand the legacy components of the specifications that create issues
- ✈ Learn how to deal with these types of provisions in P-501 using Section 50 Control of Work
- ✈ Understand how to provide a technical evaluation to support acceptance of some legacy provision that do not apply to today’s paving materials and processes
- ✈ Understand the role of the Resident Project Representative

# Example of Legacy provisions in P-501

**501-2.3 Cementitious materials.**

**a. Fly ash.** Fly ash shall meet the requirements of ASTM C618, with the exception of loss of ignition, where the maximum shall be less than 6%. Fly ash shall have a Calcium Oxide (CaO) content of less than 15% and a total alkali content less than 3% per ASTM C311. The Contractor shall furnish the previous three most recent, consecutive ASTM C618 reports for each source of fly ash proposed in the concrete mix, and shall furnish each additional report as they become available during the project. The reports can be used for acceptance or the material may be tested independently by the Resident Project Representative (RPR).

# Example of Legacy provisions in P-501

**501-2.7 Dowel and tie bars.** Dowel bars shall be plain steel bars conforming to ASTM A615 and shall be free from burring or other deformation restricting slippage in the concrete.

**a. Dowel Bars**. Before delivery to the construction site each dowel bar shall be epoxy coated per ASTM A1078, Type 1, with a coating thickness after curing greater than 10 mils. Patched ends are not required for Type 1 coated dowels. The dowels shall be coated with a bond-breaker recommended by the manufacturer. Dowel sleeves or inserts are not permitted. Grout retention rings shall be fully circular metal or plastic devices capable of supporting the dowel until the grout hardens.

**b. Tie Bars.** Tie bars shall be deformed steel bars and conform to the requirements of ASTM A615. Tie bars designated as Grade 60 in ASTM A615 or ASTM A706 shall be used for construction requiring bent bars.

# Example of Legacy Provision in P-501

**a. Fly ash.** When fly ash is used as a partial replacement for cement, the replacement rate shall be determined from laboratory trial mixes, and shall be between 20 and 30% by weight of the total cementitious material. If fly ash is used in conjunction with slag cement the maximum replacement rate shall not exceed 10% by weight of total cementitious material.

# What do we do with these?

- Fly Ash CaO Content is 17 % ?
- Fly Ash Alkali content is 3.04?
- Epoxy coating on bar delivered to the project is 8 to 12 mil thick?
- Type 2 (purple epoxy coated) bars are delivered?
- NewCem+ (50/50 blend slag/fly ash) used at 35% replacement rate?
- Who has authority to decide?

# Where do these provision requirement come from? Problems with the Requirement…

- 17% CaO limit on fly ash?– based on limited 2005 research; some good mitigating ashes exceed 17%

- 3% limit on fly ash alkali?—based on limited 2005 research; some good ashes exceed 3%

- 10 mil min thickness on dowel bar epoxy limit?—no technical reason; ASTM 1078 standard is 8 mil min; special run increase cost

- Type 1 versus Type 2 coating?—rebar industry; difference is when the coating is applied; some states only use Type 2 dowels; special run increases cost

- 10% fly ash limit with slag cement?—good product with very good mitigating results; can fill the scarce mitigating ash issue

# Sustainable Benefits of Fly Ash and Natural Pozzolans (and Ground Granulated Blast Furnace Slag)

- Increased resistance to ASR and sulfate attack
- Lower heat of hydration, lower permeability, **enhanced durability**
- **Reduction in $CO_2$ generation**
- Higher waste recycling (conformity with Resource Conservation and Recovery Act and DOD affirmative procurement regulations)
- Increased resistance to high temperatures from jet blast
- Higher long term (fly ash) or 28-day strength (Grade 120 GGBFS)
- **Reduced concrete costs** (up to 4%) for
  - 25% replacement with fly ash
  - 50% replacement with GGBFS

**Class F Ash was all that was allowed Thought was—to restrictive**

# Dowel Bar Coatings

## What the ASTM A 1078 Type1 & Type 2 Specs Require

- ASTM A 1078 Type 1 (Coating **Greater** Than 8 mils)
  - Green Epoxy Powder = ASTM A 775
  - Coated Before Fabrication
  - Ends Must Be Patched (Cold or Wet)
- ASTM A 1078 Type 2 (Coating **Greater** Than 8 mils)
  - Purple Epoxy Powder = ASTM A 934
  - Coated After Fabrication
  - Ends Are Fusion Bonded just like the sides of the dowel bar
- There is No default value, the spec must indicate Type 1 or Type 2

# Dowel Bar Coatings

## These are some of the ways we see this Spec Listed in the Contract Documents Job Specifications:


- ASTM A 1078 Type 1, > 8 mils, ends must be patched
- ASTM A 1078 Type 1, 8 mils or >
- ASTM A 1078 Type 1, > 10 mils
- ASTM A 1078 Type 1, 10 mils or >
- ASTM A 1078 Type 1
- ASTM A 1078
- ASTM A 1078 Type 1, > 10 mils, patched ends are not required

# Section 50-01 Authority of the RPR

- *The RPR has **final authority** regarding the interpretation of project specification requirements.*
- *The RPR shall determine the **acceptability** of the quality of material furnished, method of performance of work performed, and the manner and rate of performance of the work.*
- *The RPR **does not** have the authority to accept work that does not conform to specification requirements.*

# Section 50-02 Conformity with plans and specifications

- *All work and all materials furnished shall be in* ***reasonably close conformity*** *with the lines, grades, grading sections, cross-sections, dimensions, material requirements, and testing requirements that are specified (including specified tolerances in the contract, plans, or specifications.*

- *The term "reasonably close conformity" shall not be construed as waiving the Contractor's responsibility to complete the work in accordance with the contract, plans, and specifications.*

- *The term shall not be construed as waiving the RPR's responsibility to insist on strict compliance with the requirements of the contract, plans and specifications during the Contractor's execution of the work, when, in the RPR's opinion, such compliance is essential to provide an acceptable finished portion of the work.*

# Section 50-02 Conformity with plans and specifications

- *The term "reasonably close conformity" is also intended to provide the RPR with the authority, **after consultation with the Sponsor and FAA**, to **use sound engineering judgement** in their determination to accept work that is not in strict conformity, but will provide a finished product **equal to or better than required** by the requirements of the contract, plans and specifications.*

Note: If the RPR's technical analysis is thorough and logical once the Sponsor and FAA are consulted the RPR can approve the "reasonably close conformity" work within their authority established in 50-01.

# Section 50-02 Conformity with plans and specifications

- *If the RPR finds the materials furnished, work performed, or the finished product **not within reasonably close conformity** with the plans and specifications, **but** that the portion of the work affected will, **in their opinion**, result in a finished product having a level of **safety, economy, durability, and workmanship** acceptable to the owner, the RPR will advise the Owner of their determination that the affected work be accepted and remain in place.*

- *The RPR will document the determination and **recommend** to the Owner a **basis of acceptance** that will provide for an **adjustment in contract price** for the affected portion of the work. Changes in the contract price must be covered by contract change order or supplemental agreement as applicable.*

# Section 50-02 Conformity with plans and specifications

- *For Airport Improvement Program (AIP) contracts, the Owner must keep the FAA* ***advised*** *of the Engineer's (should be RPR) determination as to acceptance of work that is* ***not in reasonably close conformity*** *to the contract, plans and specifications*

- *All change orders, supplemental agreements, and contract modifications must* ***eventually*** *be reviewed by the FAA. Unless* ***specifically requested*** *by the FAA, the Owner* ***does not have to obtain prior FAA approval*** *for contract changes except for the Buy American review if required.*

- *However, if an Owner proceeds with contract changes without FAA approval it is at the Owner's risk.*

# What do we do with these?

- Fly Ash CaO Content is 17 % ?
- Fly Ash Alkali content is 3.04?
- Epoxy coating on bar delivered to the project is 8 to 12 mil thick?
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- Who has authority to decide?

# Fly Ash Unanswered Questions

- Can we use a Class C ash to prevent ASR?
- Can we use an ash that is not Class F nor C?
- If we have 2 Ashes, which one is better?
- If we have a given cement, a given aggregate reactivity, and a given ash (F or C), how much replacement do we need to mitigate ASR?

# Where do the P-501 limits come from?

**USE OF FLY ASH IN**
**DOD AIRFIELD CONCRETE PAVEMENTS**

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**Presented at the**
**2007 FAA Worldwide Airport Technology Transfer Conference**
**Atlantic City, NJ**
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# How much alkali do we allow in fly ash?

**(ASTM C 1260/1567 cannot measure effect)**

- **Cement and Concrete Association of Australia (1996)**
- **The UK Concrete Society (1999) and BRE (1999)**
- **New Zealand Concrete and Cement Association (2003, TR3 ASR)**
- **Canadian Standard CSA A23.2-27A (2000)**
- **New Mexico DOT**

Suggest use limit in ash of 3% total alkalis

# Fly Ash Chemical Constituents and their Effect on ASTM C 1567 Expansion

**Deleterious Constituents (promote expansion)**

CaO (calcium oxide) **

$Na_2O$ and $K_2O$ (alkalis) ***

MgO (magnesium oxide)

$SO_3$ (sulfur trioxide)

**Beneficial Constituents * (reduce expansion)**

$SiO_2$ (silicon dioxide)

$Al_2O_3$ (aluminum trioxide)

$Fe_2O_3$ (iron oxide)

**(When this research was done)**

***ASTM requires > 70% of these total oxides for Type F Ash**

**** CSA requires < 8% ± 1% CaO for Type F Ash (used to be 8% ± 2%)**

***** < 0.6% for low-alkali cement**

# Fly Ash Chemical Constituents and their Effect on ASTM C 1567 Expansion

C618 – 23$^{\varepsilon 1}$

TABLE 1 Chemical Requirements

| | Class | | |
|---|---|---|---|
| | N | F | C |
| Silicon dioxide ($SiO_2$) plus aluminum oxide ($Al_2O_3$) plus iron oxide ($Fe_2O_3$), min, % | 70.0 | 50.0 | 50.0 |
| Calcium oxide (CaO), % | report only | 18.0 max. | >18.0 |
| Sulfur trioxide ($SO_3$), max, % | 4.0 | 5.0 | 5.0 |
| Moisture content, max, % | 3.0 | 3.0 | 3.0 |
| Loss on ignition, max, % | 10.0 | 6.0[A] | 6.0 |

[A]The use of Class F coal ash containing up to 12.0 % loss on ignition may be approved by the user if either acceptable performance records or laboratory test results are made available.

TABLE 2 Physical Requirements

| | Class | |
|---|---|---|
| | F | C |

‹ 2/5 ›

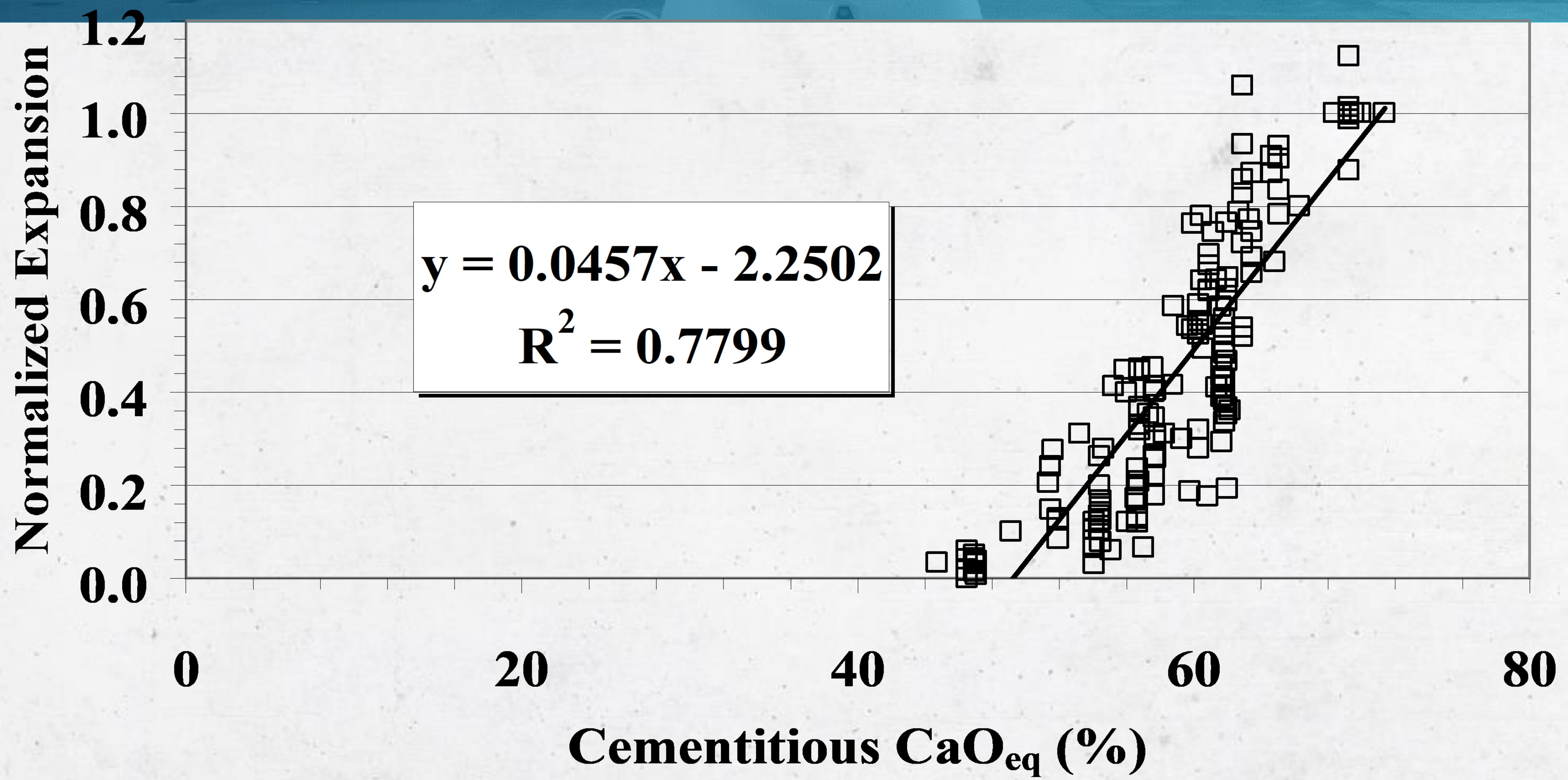
(When this research was done)

*ASTM requires > 70% of these total oxides for Type F Ash

** CSA requires < 8% ± 1% CaO for Type F Ash (used to be 8% ± 2%)

*** < 0.6% for low-alkali cement

# Combination of Deleterious Constituents

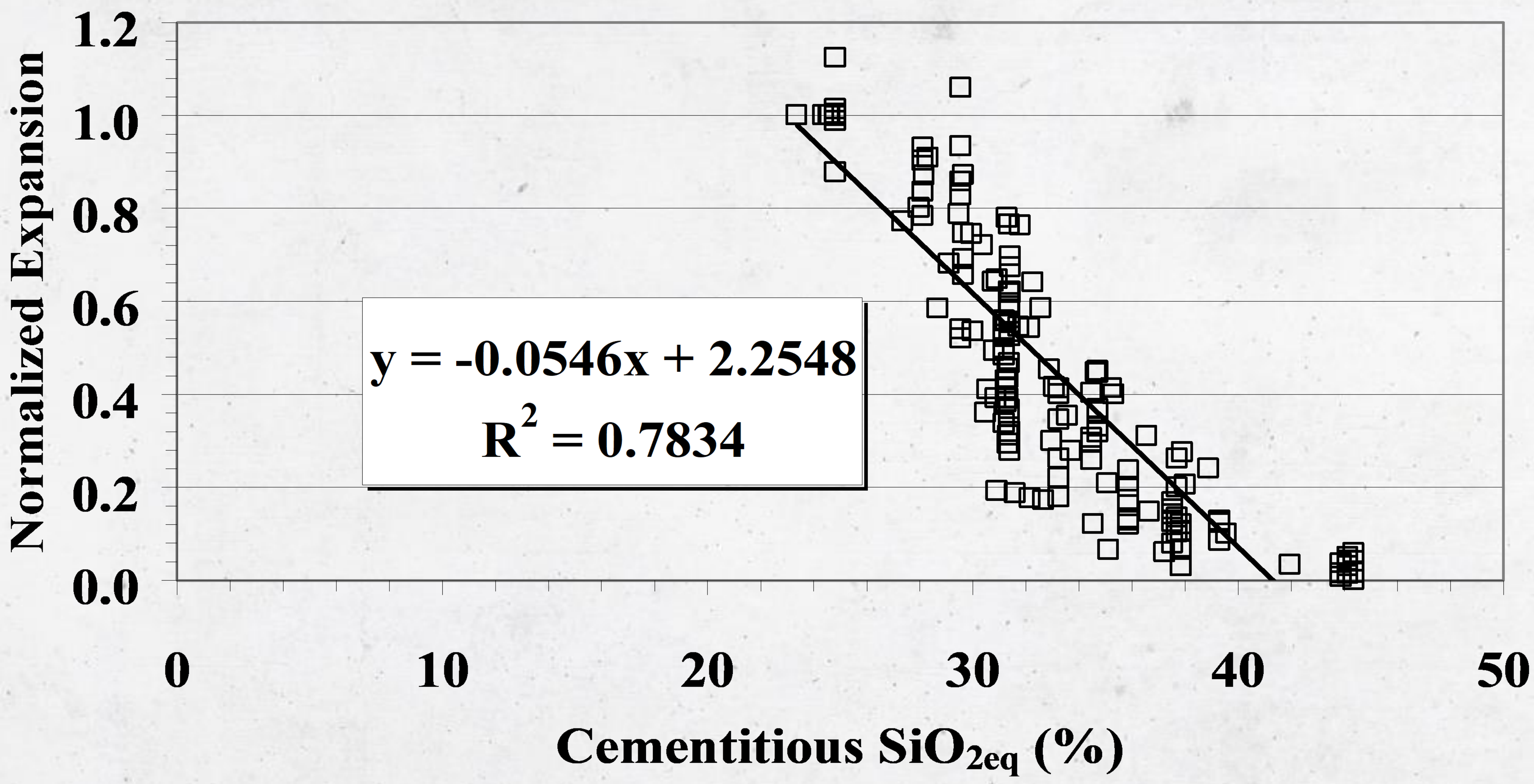



- Combine all constituents promoting expansion (molar equivalents)

$$CaO_{eq} = CaO + 0.905\ Na_2O_{eq} + 1.391\ MgO + 0.700\ SO_3$$

- Best correlation of any single/combination of deleterious constituent(s)

# Combination of Beneficial Constituents

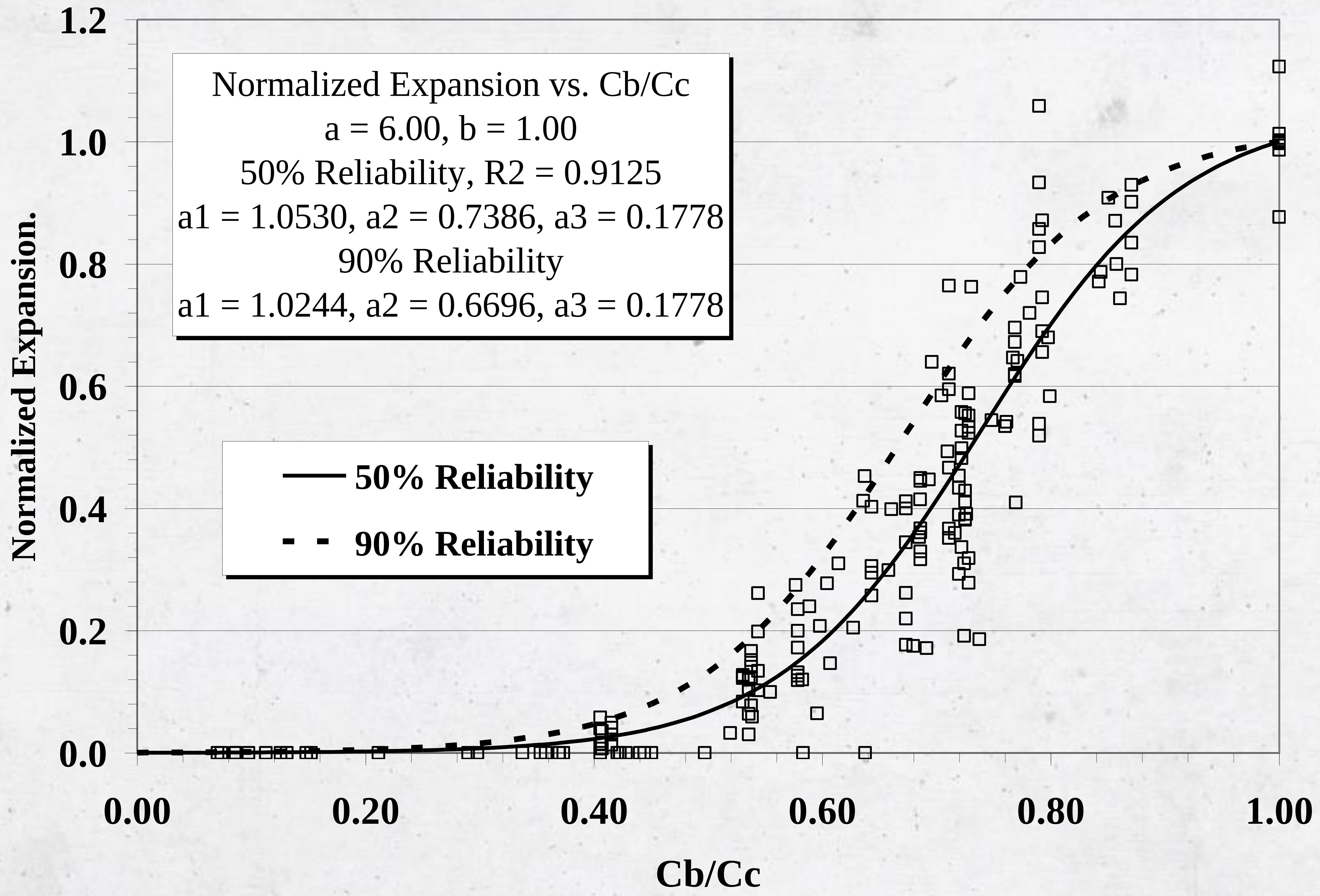



- Combine all constituents promoting expansion (molar equivalents)

  $SiO_{2eq} = SiO_2 + 0.589\ Al_2O_3 + 0.376\ Fe_2O_3$

- Best correlation of any single/combination of deleterious constituent(s)

# Combination of Deleterious & Beneficial Constituents, Hyperbolic Tangent Model

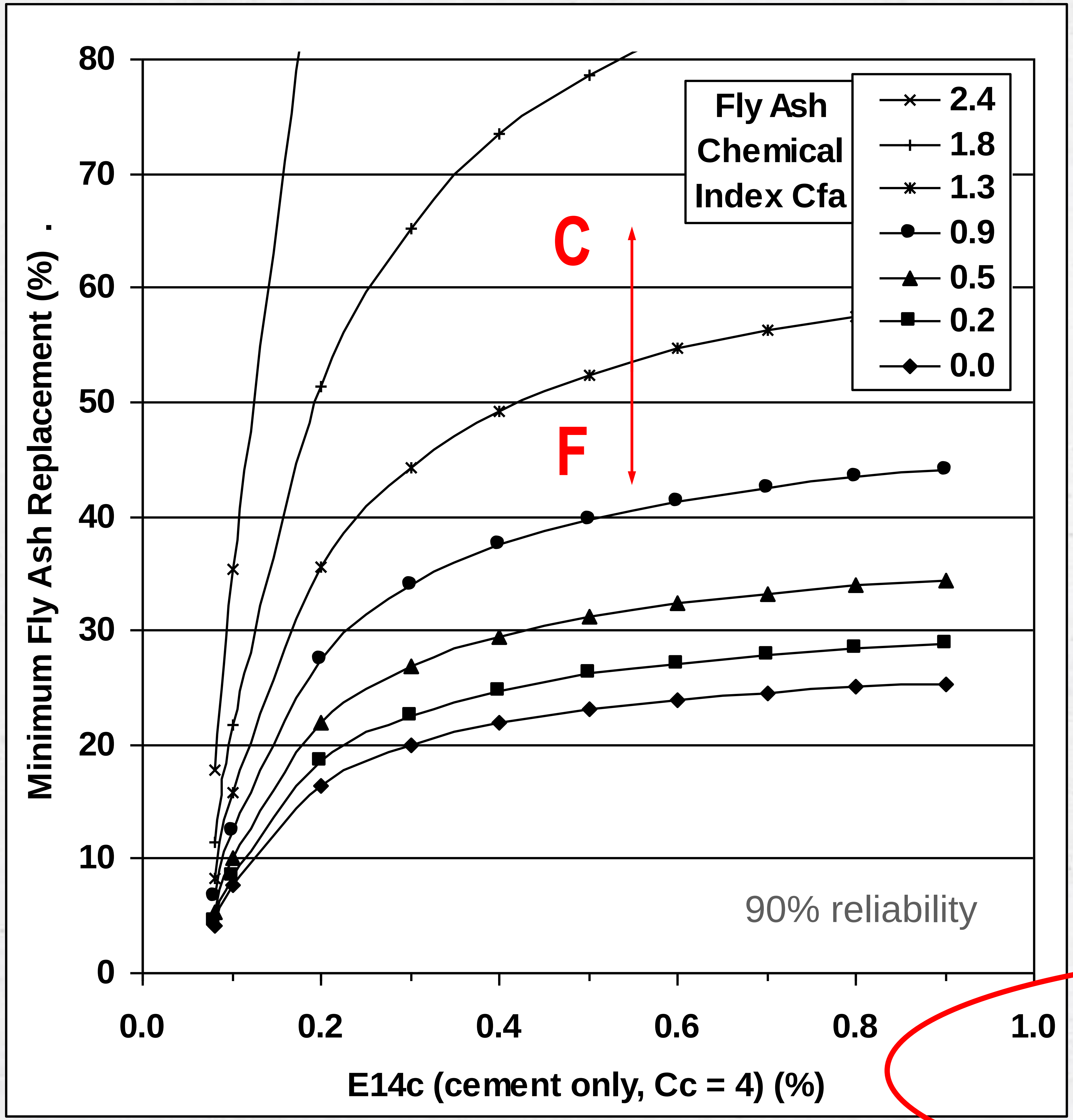



$$\frac{E_{14b}}{E_{14c}} = \frac{a_1}{2}\left[1 + \tanh\left(\frac{(C_b / C_c) - a_2}{a_3}\right)\right]$$

$$C_b = \frac{CaO_{eq\alpha b}}{SiO_{2eq\beta b}} = \frac{CaO + \alpha\left(0.905\, Na_2O_{eq} + 1.391 MgO + 0.700\, SO_3\right)}{SiO_2 + \beta\,(0.589\, Al_2O_3 + 0.376\, Fe_2O_3)}$$

Uses 2 weighting factors $(\alpha,\beta) = (4.42,0.75)_{\text{best fit}} = (6,1)_{\text{approximate}}$

# Minimum Fly Ash Cement Replacement
# To Insure ASR Mitigation (0.08% @ 14 days)



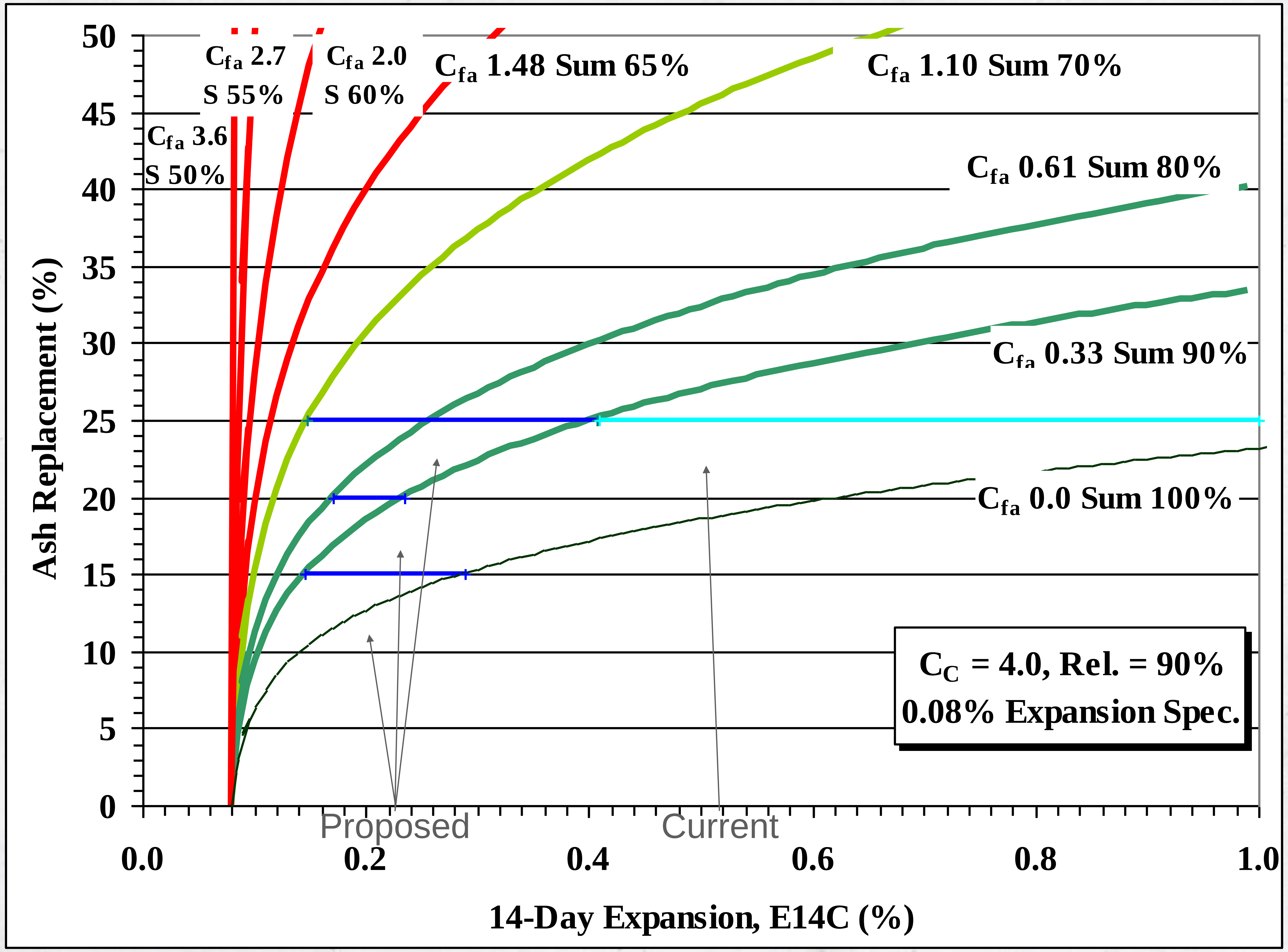

**For a given cement, fly ash, and aggregate reactivity, this graph tells us how much replacement is needed to insure less than 0.08% expansion @ 14 days**

$$W = \frac{1 - g(0.08/E_{14c})}{\left(1 - \frac{CaO_{eq\alpha\,fa}}{CaO_{eq\alpha\,c}}\right) - \left(1 - \frac{SiO_{2eq\beta\,fa}}{SiO_{2eq\beta\,c}}\right) g(0.08/E_{14c})}$$

Notes:

- C ashes are less efficient.
- $C_{fa}$ = 0 is theoretical limit
- 25% replacement can mitigate from low to high reactivity
- Graph valid for typical cement with $C_c$ = 4
- Limitations of ASTM C 1260 and C 1567 apply
- ASTM C 1567 must be run to verify expansion

# Current Navy versus Proposed Tri-Service Specification for Minimum Requirements




$$C_{fa} = \frac{CaO_{eq\alpha\, fa}}{SiO_{2eq\beta\, fa}} = \frac{CaO + 6.0(0.905Na_2O + 0.595K_2O + 1.391MgO + 0.700SO_3)}{SiO_2 + 1.0(0.589Al_2O_3 + 0.376Fe_2O_3)}$$

# Where did the current Specification Come from?

**9 CONCLUSIONS**

Data from previous research studies were used to assess the effectiveness of fly ashes in preventing ASR, based on their chemical composition, the composition of the cement, and the reactivity of the aggregates. A chemical index was derived based on the fly ash (or cement) constituents, which was optimized to maximize the correlations with test data. For the fly ashes, this index, Cfa, correlated well with ASTM C 618 and CSA A3001 fly ash classifications, and in particular with the sum of ASTM specified oxides ($SiO_2+Al_2O_3+Fe_2O_3$), the latter being recommended for criteria development. This index was also used to assess the efficiency of other ashes that did not meet either specification. For a given aggregate reactivity, a given cement, and a given ash, it was possible to derive the minimum cement replacement that is needed to insure with 90% reliability that the 14-day AMBT expansion would remain below 0.08%.

It is proposed that current fly ash guidelines for use in DOD airfield concrete pavements be modified as follows:

- For non-reactive aggregates, use Class F fly ash with total alkalis ≤ 3%, and require the following minimum fly ash contents (also reflected in Table 3):
  - 25% if $SiO_2+Al_2O_3+Fe_2O_3 \geq 70\%$
  - 20% if $SiO_2+Al_2O_3+Fe_2O_3 \geq 80\%$
  - 15% if $SiO_2+Al_2O_3+Fe_2O_3 \geq 90\%$
- For reactive aggregates, use Class F fly ash with the additional requirements of CaO ≤ 13% and total alkalis ≤ 3% (together with a maximum allowable expansion of 0.08% per ASTM C 1567 for the final mix). Required replacements to mitigate reactivity with 90% reliability can be estimated with Figure 6 and Table 3, and should exceed the minimum requirements for non-reactive aggregates.

**Current FAA Specification Requirements:**
**FA CaO < 15%**
**FA alkali <3%**
**Cement Alkali < 3 pounds/cubic yard**

- CaO is the biggest Contribution to ASR expansion
- FAA focused on CaO content (simple method)
- Changed to 15% for Cold Creek Ash
- Oxides can override the CaO in some cases
- Evaluate > 15% CaO on case-by-case basis
- ASTM Must be run for acceptance

# What do we do with these?

- Loss on Ignition (LOI) is 6%? (Limit < 6%, ASTM C618—6% max)
- CaO Content is 17%? (Limit < 15%)
- Alkali content is 3.04? (Limit < 3%)

# A case Study

**Mix design**:

- 480 Pounds St Mary's Charlevoix Type 1L (0.69% alkalis)
- 120 pounds Elm Road Type C ash (25%)
- Coarse 1 – 41% or 1313 pounds
- Coarse 2 – 22% or 702 pounds
- Fine – 37% or 1182 pounds

**ASTM C1260**

- Coarse 1 – 0.05% PASSING
- Coarse 2 – 0.04% PASSING
- Fine – 0.19% FAIL (0.142% at 14 days)

**ASTM C1567**

- C1567 Result – 0.07% PASSING

**CaO=18.3**

**LOI=0.47**

**No other FA available**

**(Is the Agg reactive?)**

**Fly Ash Chemistry**

| | |
|---|---|
| CaO | 18.30 |
| $Na_2O$ | 1.49 |
| $K_2O$ | 1.00 |
| MgO | 4.38 |
| $SO_3$ | 1.82 |

$CaO_{eq\alpha\ fa}$ **= 74.16**

and

| | |
|---|---|
| $SiO_2$ | 36.82 |
| $Al_2O_3$ | 19.34 |
| $Fe_2O_3$ | 10.30 |

$SiO_{2eq\beta\ fa}$ **= 52.08**

$$C_{fa} = \frac{CaO_{eq\alpha\ fa}}{SiO_{2eq\beta\ fa}} = \frac{CaO + 6.0(0.905Na_2O + 0.595K_2O + 1.391MgO + 0.700SO_3)}{SiO_2 + 1.0(0.589Al_2O_3 + 0.376Fe_2O_3)}$$

$C_{fa}$ **= 1.42**

in the section on Zero Readings except that the specimens are returned to their own container after measurement.

## 10. Calculation

10.1 Calculate the difference between the zero comparatory reading of the specimen and the reading at each period to the nearest 0.001 % of the effective gage length and record as the expansion of the specimen for that period. Report the average expansion of the three specimens of a given cement-aggregate combination to the nearest 0.01 % as the expansion for the combination for a given period.

## 11. Report

11.1 Report the following information:

11.1.1 Type and source of aggregate,

11.1.2 Type and source of portland cement,

11.1.3 Autoclave expansion and alkali content of cement as percent potassium oxide ($K_2O$), sodium oxide ($Na_2O$), and calculated sodium oxide ($Na_2O$) equivalent ($Na_2O_{eq}$= %$Na_2O$ + 0.658 × %$K_2O$),

11.1.4 Average length change in percent at each reading of the specimens,

11.1.5 Any relevant information concerning the preparation of aggregates, including the grading of the aggregate when it differs from that given in 8.2,

11.1.6 Any significant features revealed by examination of the specimens during and after test,

11.1.7 Amount of mixing water expressed as mass percent of cement,

11.1.8 A graph of the length change data from the time of the zero reading to the end of the 16 day period.

## 12. Precision and Bias

12.1 *Within-Laboratory Precision*—It has been found that the average within-laboratory coefficient of variation for materials with an average expansion greater than 0.1 % at 14 days is 2.94 % (**5**) (Note 7). Therefore, the results of two properly conducted tests within the same laboratory on specimens of a sample of aggregate should not differ by more than 8.3 % (Note 7) of the mean expansion.

12.2 *Multi-Laboratory Precision*—It has been found that the average multilaboratory coefficient of variation for materials with an average expansion greater than 0.1 % at 14 days is 15.2 % (**5**) (Note 7). Therefore, the results of two properly conducted tests in different laboratories on specimens of a sample of aggregate should not differ by more than 43 % (Note 7) of the mean expansion.

NOTE 7—These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.

12.3 *Bias*—Since there is no accepted reference material for determining the bias of this test method, no statement on bias is being developed.

## 13. Keywords

13.1 aggregate; alkali-silica reactivity; length change; mortar; sodium hydroxide

# APPENDIX

## (Nonmandatory Information)

## X1. INTERPRETATION OF TEST RESULTS

X1.1 There is good agreement in the published literature (**1,2,7-10**) for the following expansion limits:

X1.1.1 Expansions of less than 0.10 % at 16 days after casting are indicative of innocuous behavior in most cases (see Note X1.1).

X1.1.2 Expansions of more than 0.20 % at 16 days after casting are indicative of potentially deleterious expansion (see 4.3).

X1.1.3 Expansions between 0.10 and 0.20 % at 16 days after casting include both aggregates that are known to be innocuous and deleterious in field performance. For these aggregates, it is particularly important to develop supplemental information as described in 4.3. In such a situation, it may also be useful to take comparator readings until 28 days (**8,10**).

NOTE X1.1—Some granitic gneisses and metabasalts have been found to be deleteriously expansive in field performance even though their expansion in this test was less than 0.10 % at 16 days after casting (**10**). With such aggregate, it is recommended that prior field performance be investigated. In the absence of field performance data, mitigative measures should be taken as discussed in 4.4.

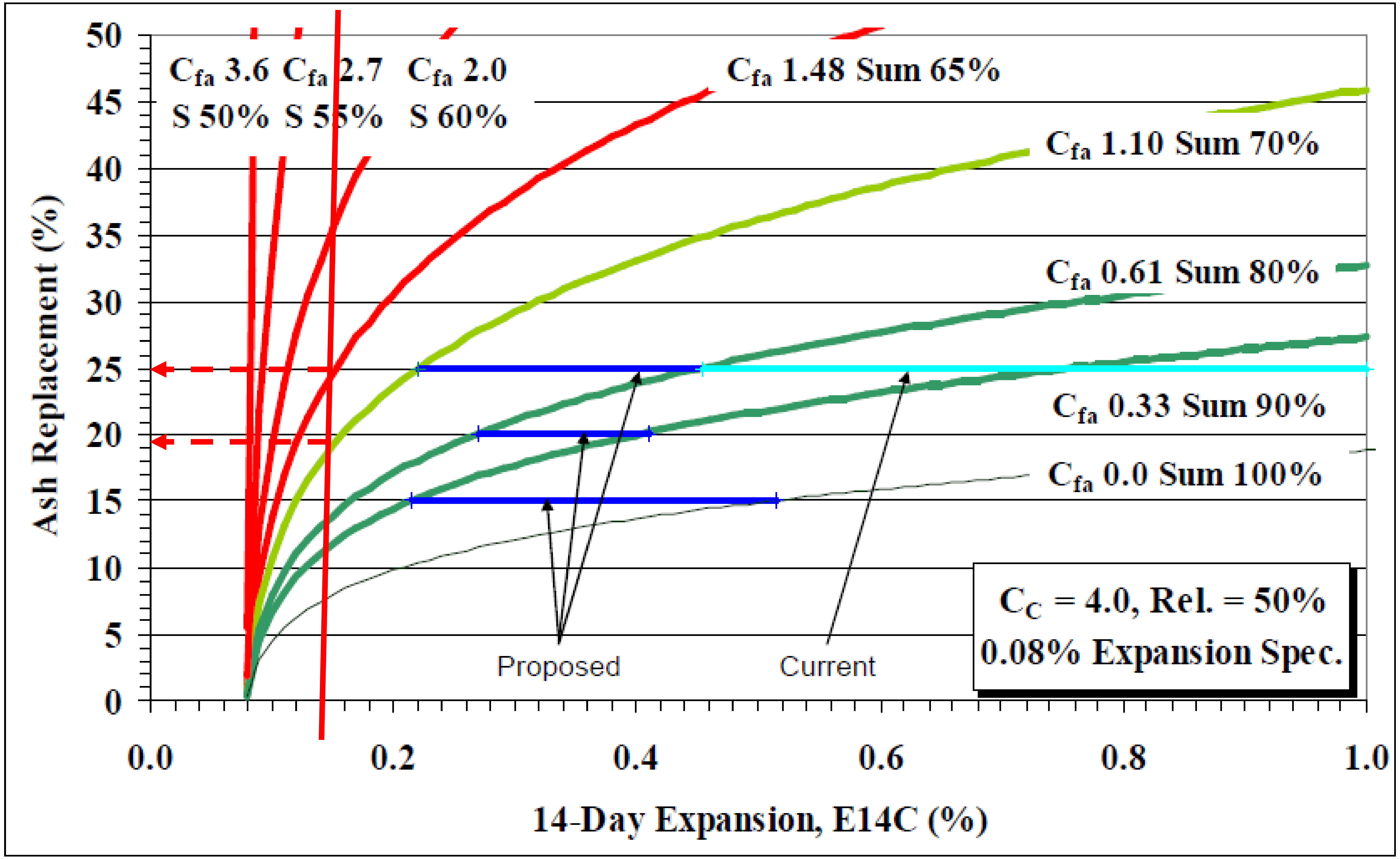



Figure 9. Determination of minimum fly ash replacement requirements.

# Other Considerations

Optimized Mixture
- Minimum fine aggregate quantities
- Minimum cement requirement

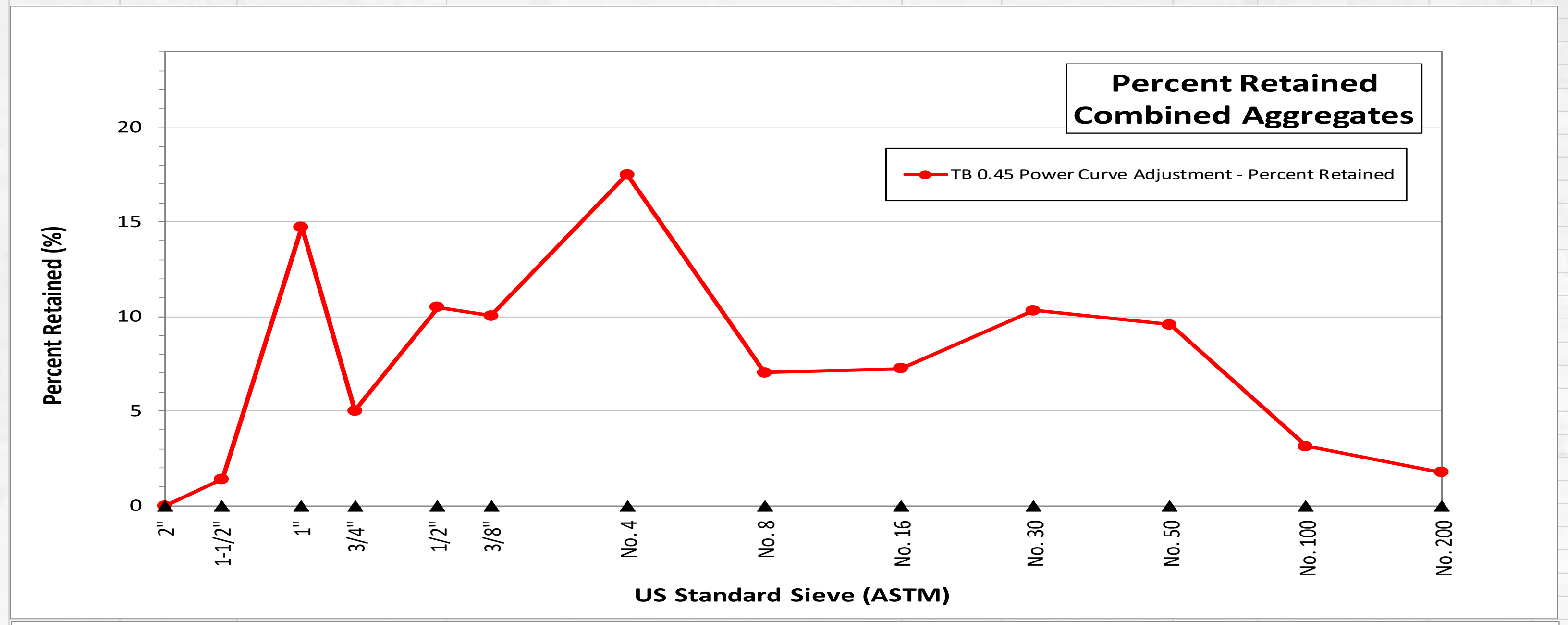
Cement Alkali Loading is low
- EB 106 calculation:

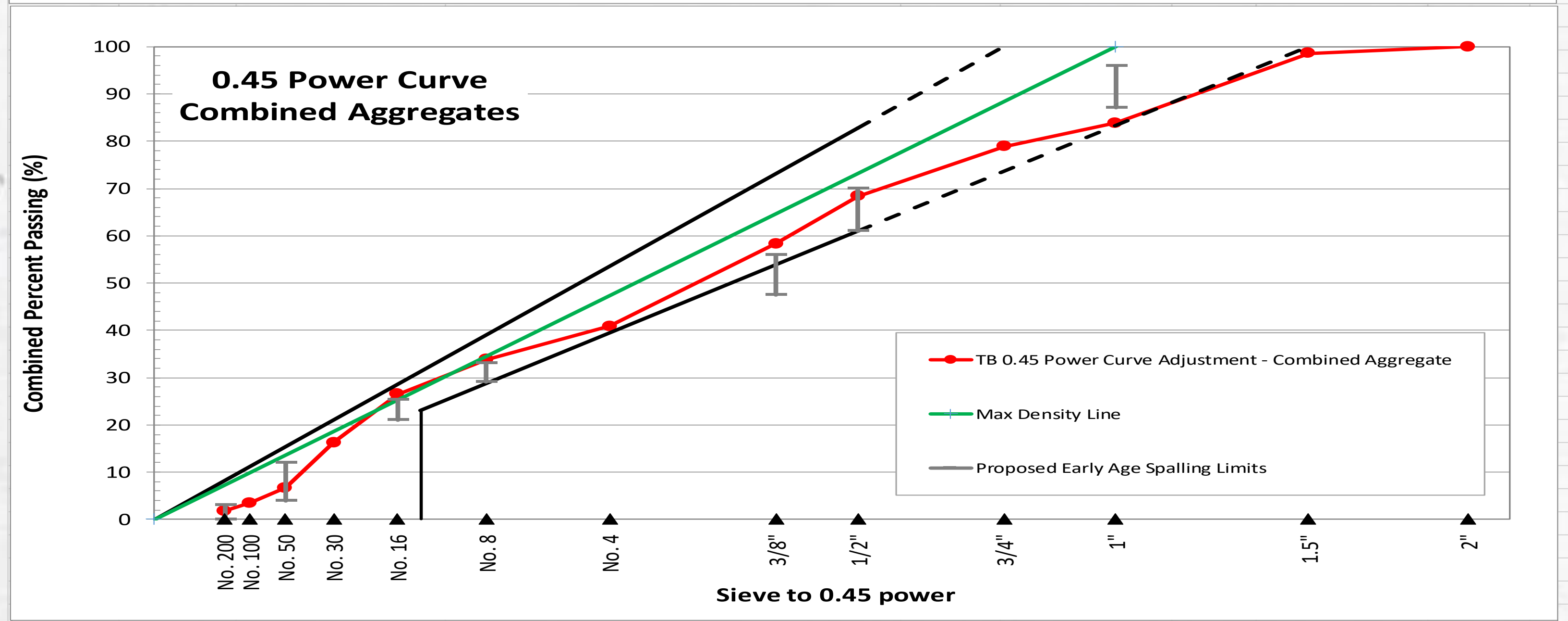
480 lbs./CY x 0.875 x (0.69/100) = 2.90 lbs./yd$^3$

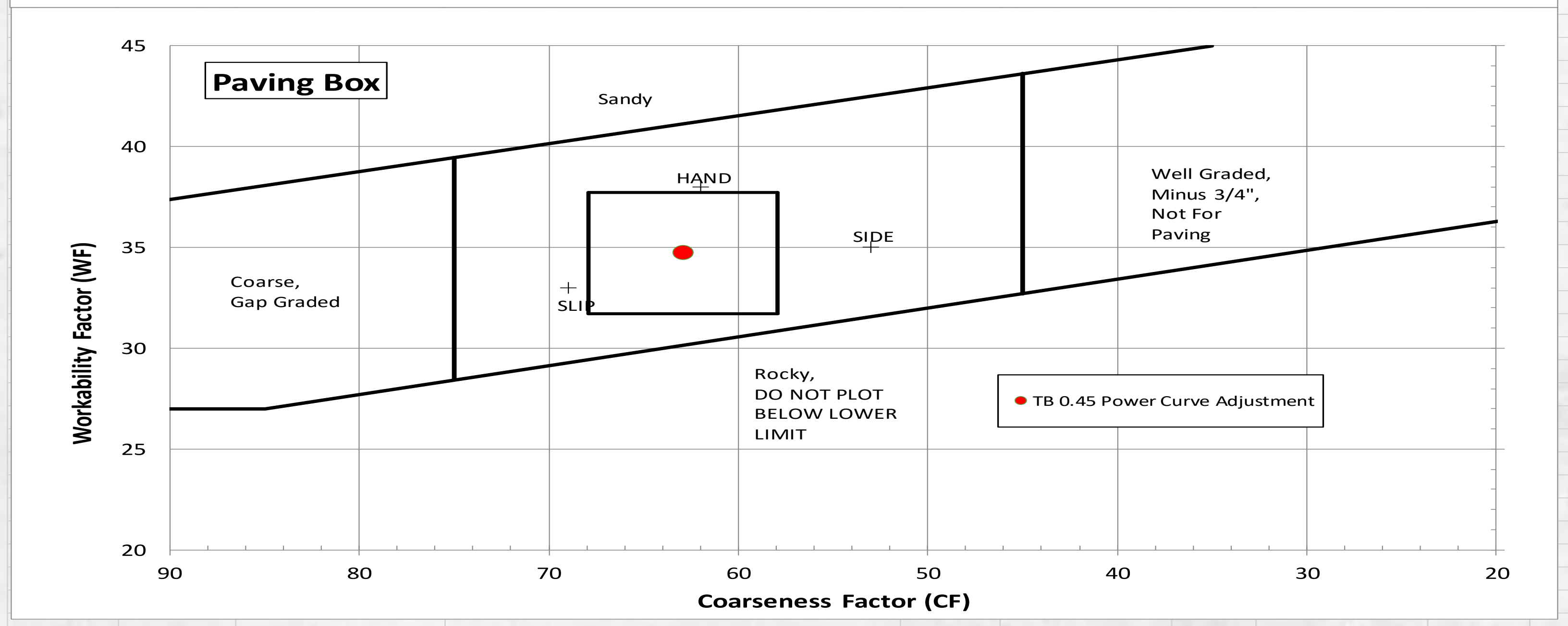
**(in this case should you approve fly ash with 3.04% alkalis)?**

Other options—slag, which adds $$$ and time

bring in FA from WKW @ $$$ and time…




**…What would you recommend?**

# Questions/Discussion

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