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HOW TO AVOID ASR GEL IN YOUR CONCRETE

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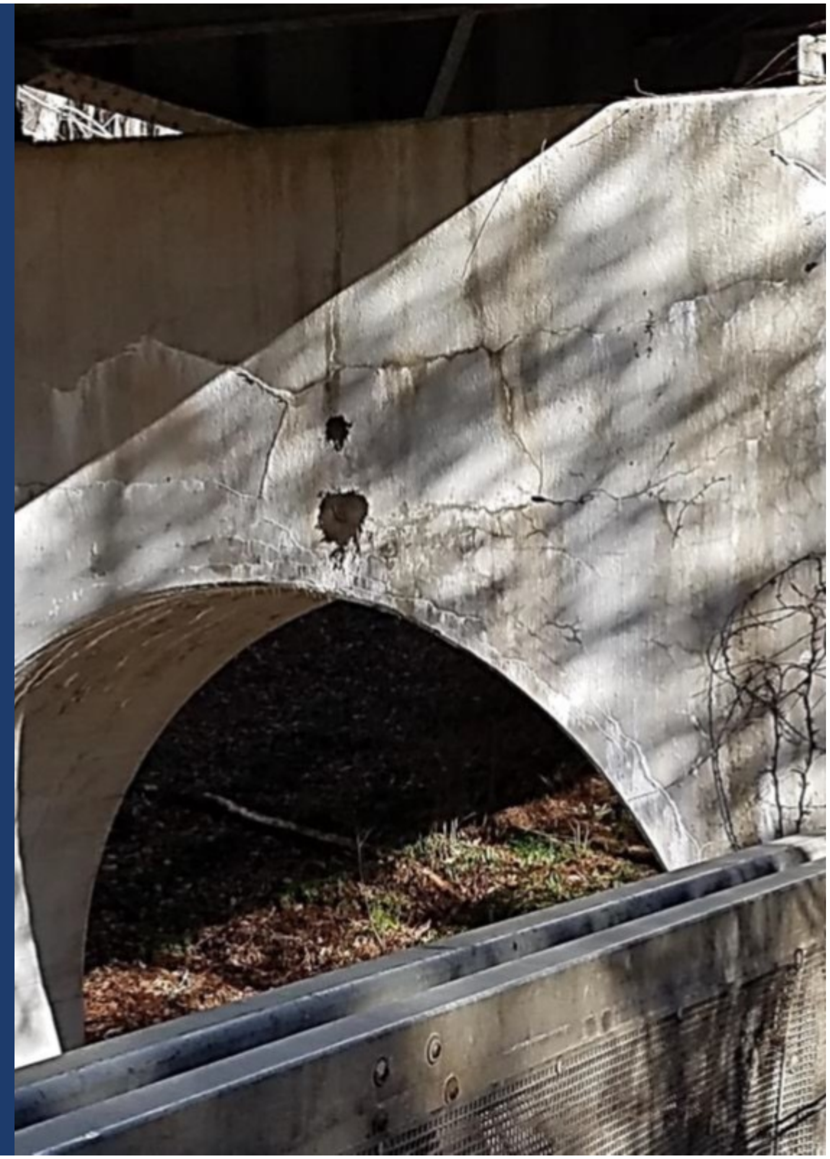
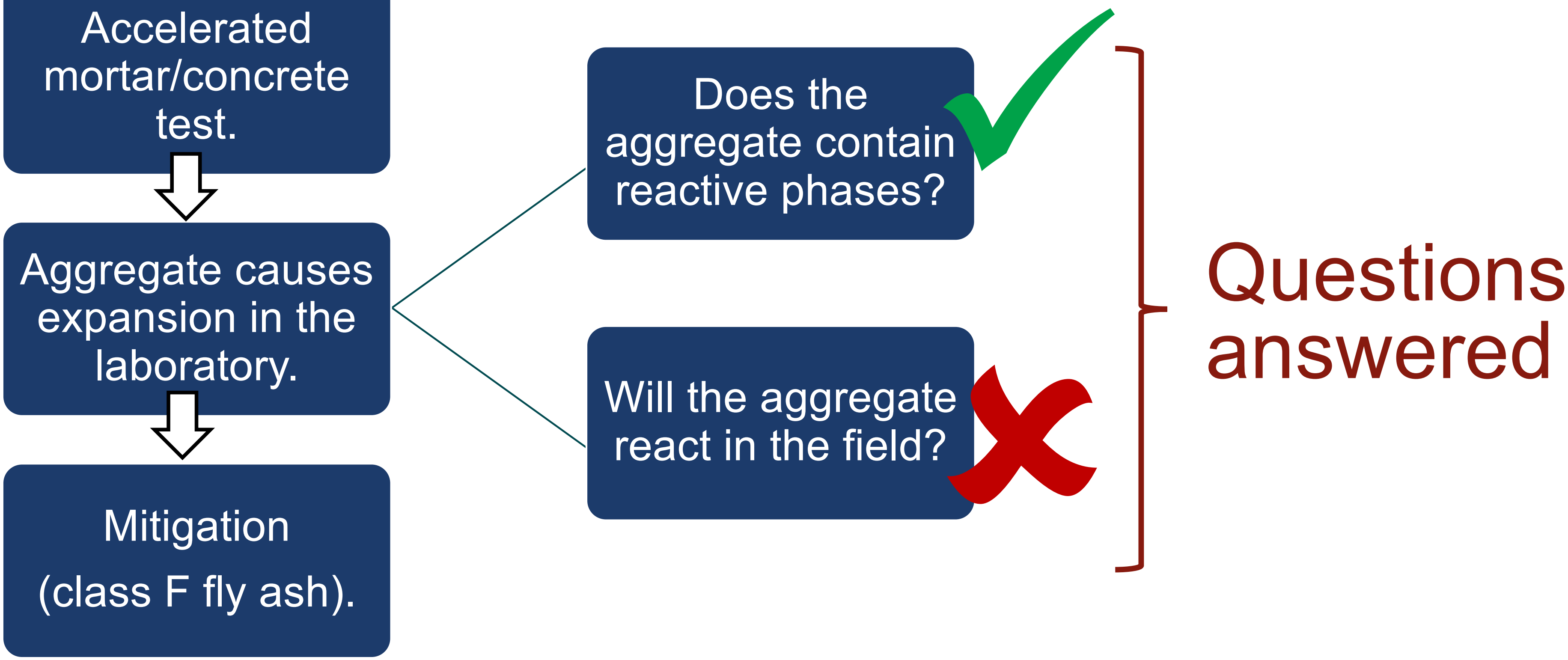
Source FHWA.



Outline

- Testing philosophy of accelerated tests and TFHRC ASR tools
- Brief recap of T-FAST
- T-FAST results:
  - General classification
  - Correlation with AMBT, CPT and MCPT
- Brief recap of ATT
- ATT results:
- Practical applications of T-FAST and ATT
  - Alkali loading and alkali threshold
  - Performance approach example
  - Prescriptive approach example
- Conclusions

Testing Philosophy of Accelerated ASR Tests



Testing Philosophy of TFHRC ASR Tests

Aggregate fails T-FAST → Does the aggregate contain reactive phases? ✓

Alkali threshold measurement (ATT) → Will the aggregate react in the field? ✓

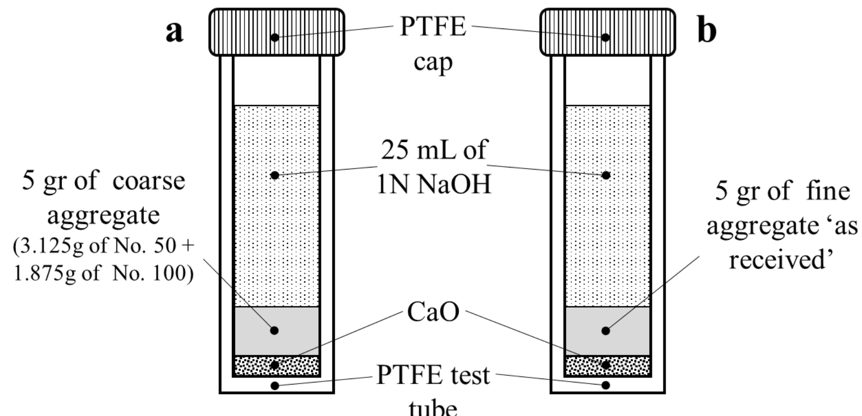
Mitigation Yes/No

Questions answered

T-FAST: Test Tube Preparation

Summary of T-FAST Conditions.

Condition	CaO (g)	Temperature (ºC)
1	0.13	55
2	0.25	55
3	0.34	55
4	0.25	80



Source: FHWA.

Configuration of the test tubes.

Oven for 21 d → Analysis* for Silicon Si, Ca, Al → Apply Si and Al criteria → Apply classification tables

*Ion coupled emission spectroscopy or wavelength dispersive x-ray fluorescence.

CaO = calcium oxide; PTFE = polytetrafluoroethylene.

T-FAST Si and Al Criteria

1. If [Si] measured in Condition 4 (80 ℃) is ≤ 1 mM → Nonreactive.

High-Al Aggregates

If [Si] measured in Condition 4 (80 ℃) is > 1 mM and [Al] measured in Condition 2 (55 ℃) is > 0.2 mM → Calculate RI for all the conditions and follow first classification table.

$$RI = \frac{[Si]}{[Ca] + [Al]}$$

Low-Al Aggregates

If [Si] measured in Condition 4 (80 ℃) is > 1 mM and [Al] measured in Condition 2 (55 ℃) is ≤ 0.2 mM → Use [Si] in Condition 4 and follow second classification table.

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T-FAST: First Classification Table (High-Al Aggregates)

Classification for Coarse Aggregates. **Classification for Fine Aggregates.**

Condition 1 Condition 2 Condition 3 (Coarse)	Condition 4 (Coarse)	Description of Aggregate Reactivity	Condition 1 Condition 2 Condition 3 (Fine)	Condition 4 (Fine)
RI ≤ 0.45 for three cases	RI ≤ 2	Nonreactive	RI ≤ 1 for three cases	RI ≤ 10
0.45 < RI ≤ 2 for one case	2 < RI ≤ 100	Slow reactive	1 < RI ≤ 10 for one case	10 < RI ≤ 150
0.45 < RI ≤ 2 for at least two cases	2 < RI ≤ 100	Moderately reactive	1 < RI ≤ 10 for at least two cases	10 < RI ≤ 150
RI > 2 for at least one case	100 < RI ≤ 1,000	Highly reactive	RI > 10 for at least one case	150 < RI ≤ 1,000
RI > 2 for at least one case	RI > 1000	Very highly reactive	RI > 10 for at least one case	RI > 1,000

Source: FHWA.

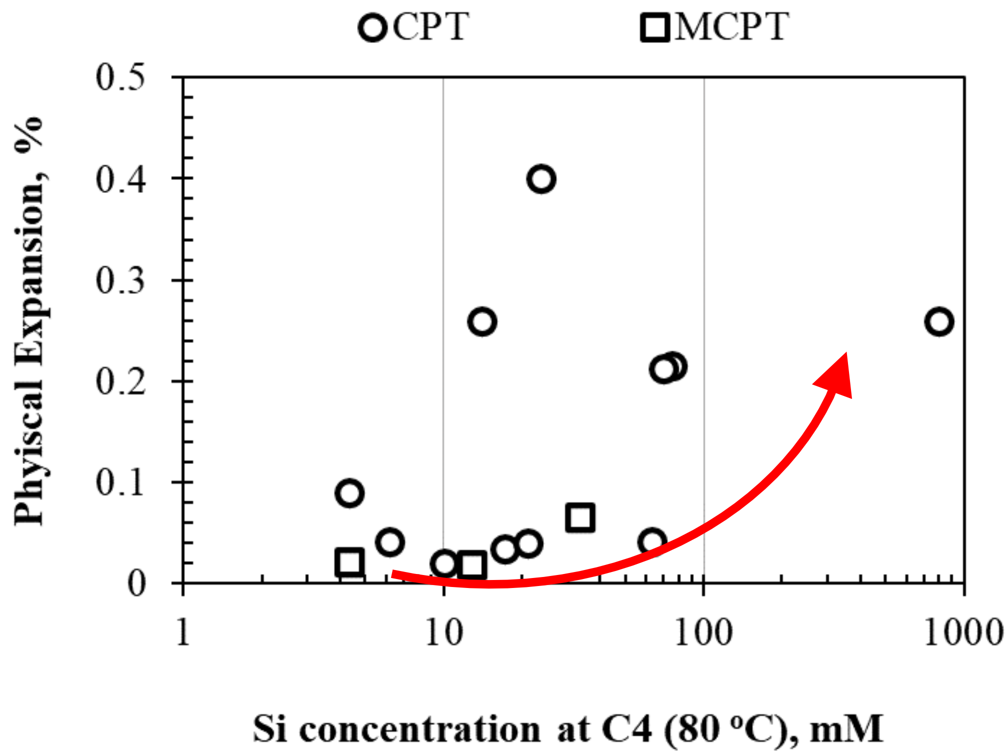
T-FAST: Second Classification Table (Low-Al Aggregates)

[Si] in Condition 4	Description of Aggregate Reactivity
1 < RI ≤ 50	Slow reactive
50 < RI ≤ 100	Moderately reactive
100 < RI ≤ 1,000	Highly reactive
RI > 1000	Very highly reactive

Source: FHWA.

T-FAST: Classification Criteria (Low-Al Aggregates)

- ▷ Mainly dolomites, dolomitic limestones, dolostones and certain limestones.
- ▷ The physical expansion correlates with the amount of SiO_2 in the aggregate.*

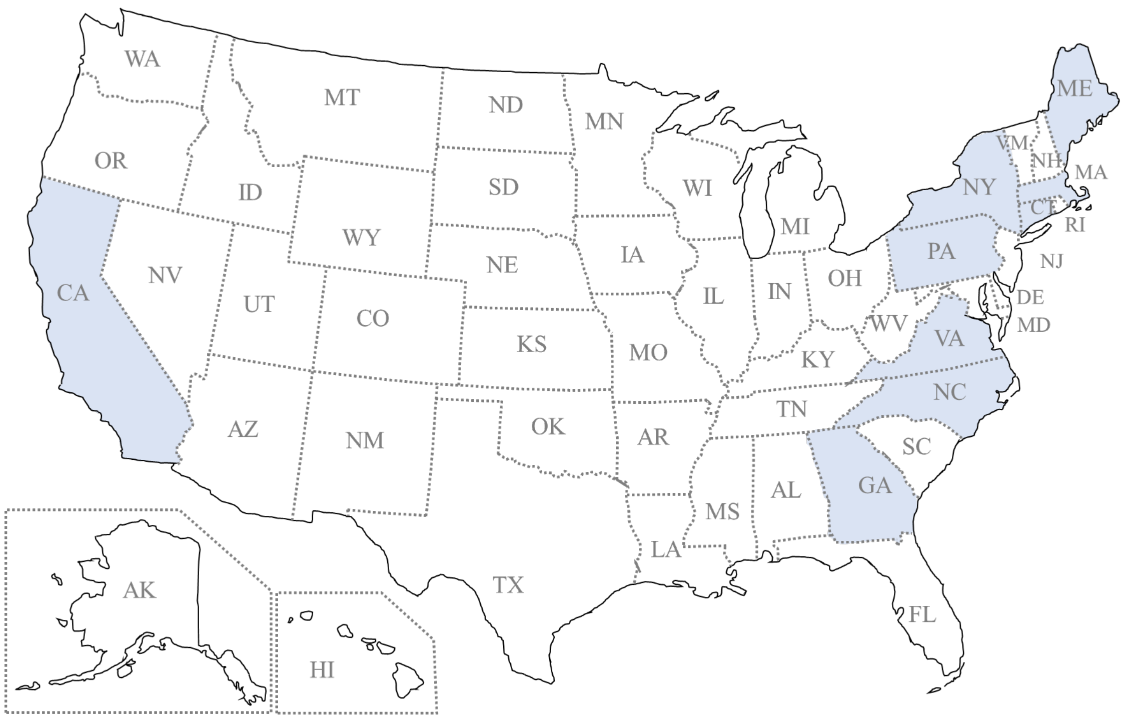


Source: FHWA.

Correlation between physical expansion and [Si] at C4 (80 °C).

* Grattan-Bellew, P. E., Mitchell, L. D., Margeson, J., & Min, D. (2010). Is alkali–carbonate reaction just a variant of alkali–silica reaction ACR= ASR?. *Cement and Concrete Research*, *40*(4), 556-562.

T-FAST: Sample Population



Source: FHWA.

Distribution of the aggregates analyzed under T-FAST

- ▷ 245 aggregates analyzed with T-FAST.
- ▷ From 9 different States.
- ▷ Wide range of mineralogies.

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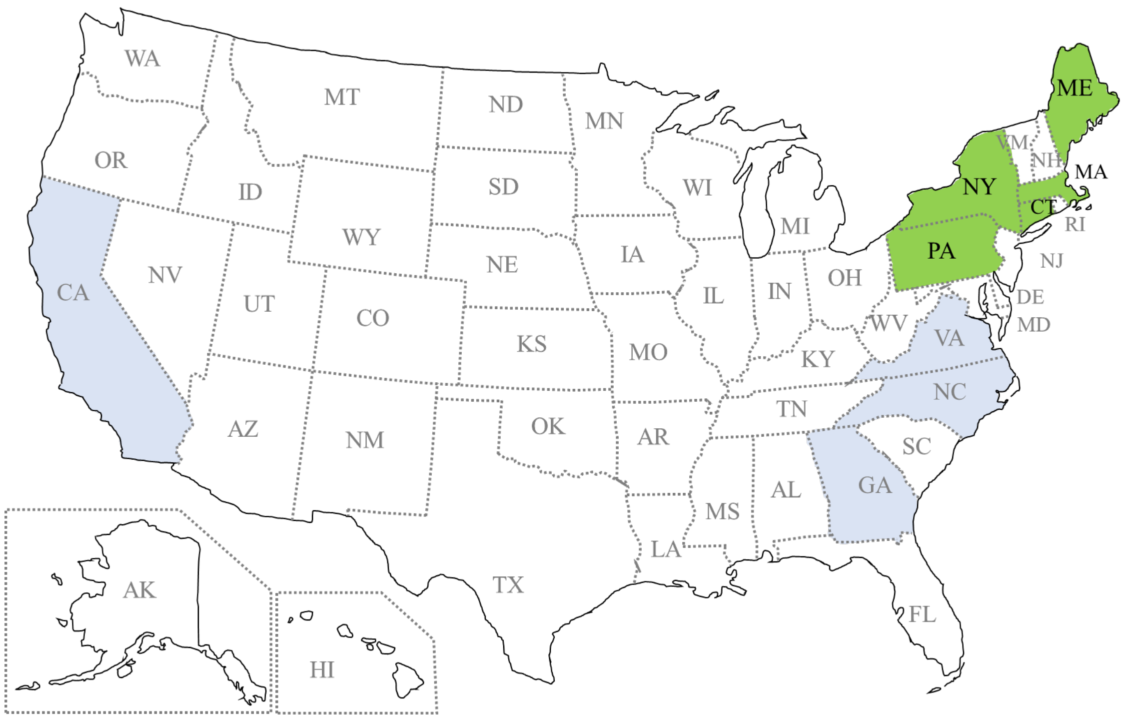
T-FAST: Sample Population (Northeast Region)

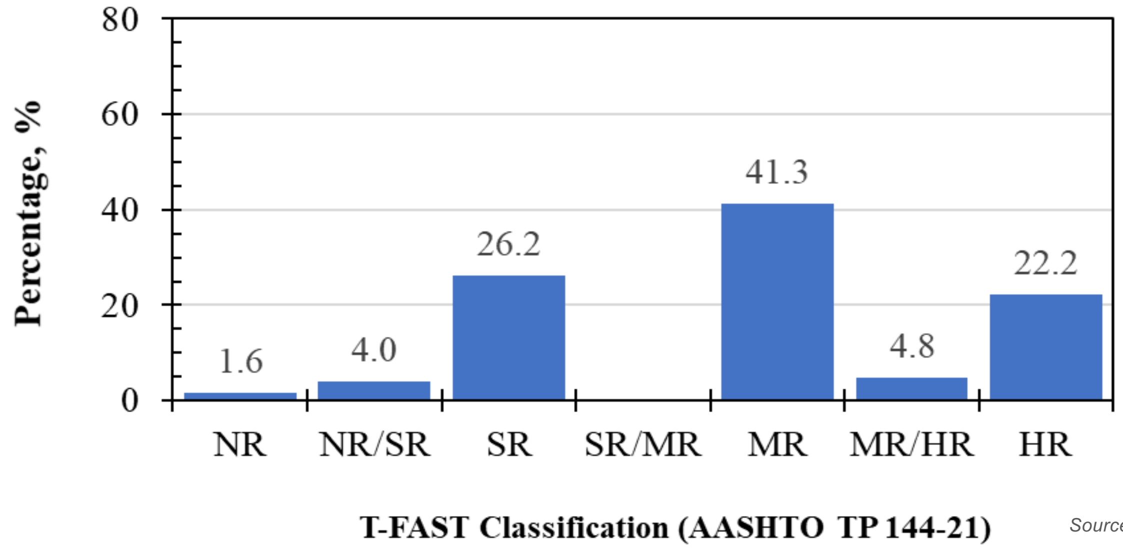


Source: FHWA.

Distribution of the aggregates analyzed under T-FAST

- ▷ 185 aggregates analyzed with T-FAST.
- ▷ From 5 different States (MA, NY, PA, CT, ME).
- ▷ Significant proportion of carbonate aggregates (NY and PA).

T-FAST Results under Current Mitigation Specifications

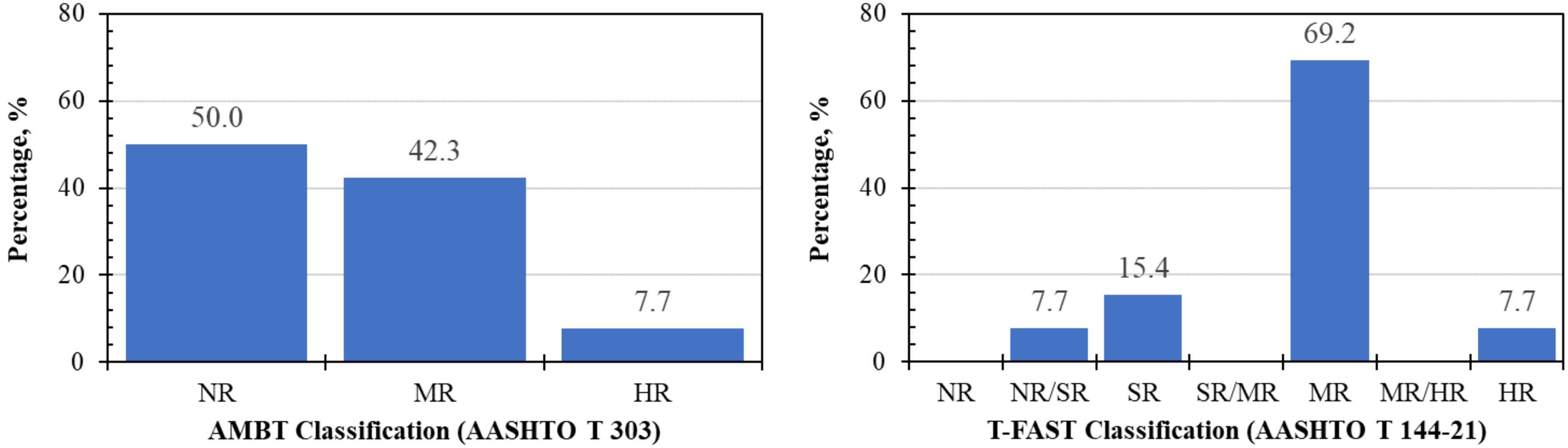


Source: FHWA.

Distribution of the T-FAST classification of the Northeast aggregates

- ▷ Few non-reactive aggregates were detected by TFAST.
- ▷ 67.5% of the aggregates were classified as SR or MR.

T-FAST Results: Correlation with AMBT



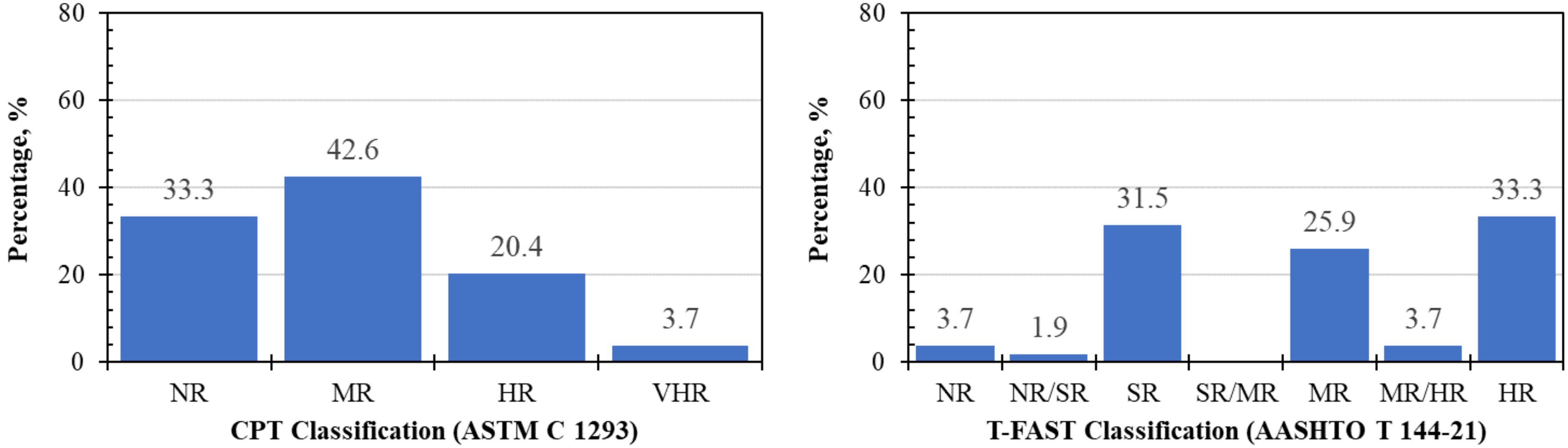
Source: FHWA.

Comparison of ASR classification reported by AMBT and TFAST.

- The AMBT classified 50% of the aggregates as NR, while the T-FAST reported none.

AMBT = accelerated mortar bar test; HR = highly reactive; MR = moderately reactive; NR = nonreactive; SR = slow reactive.

T-FAST Results: Correlation with CPT



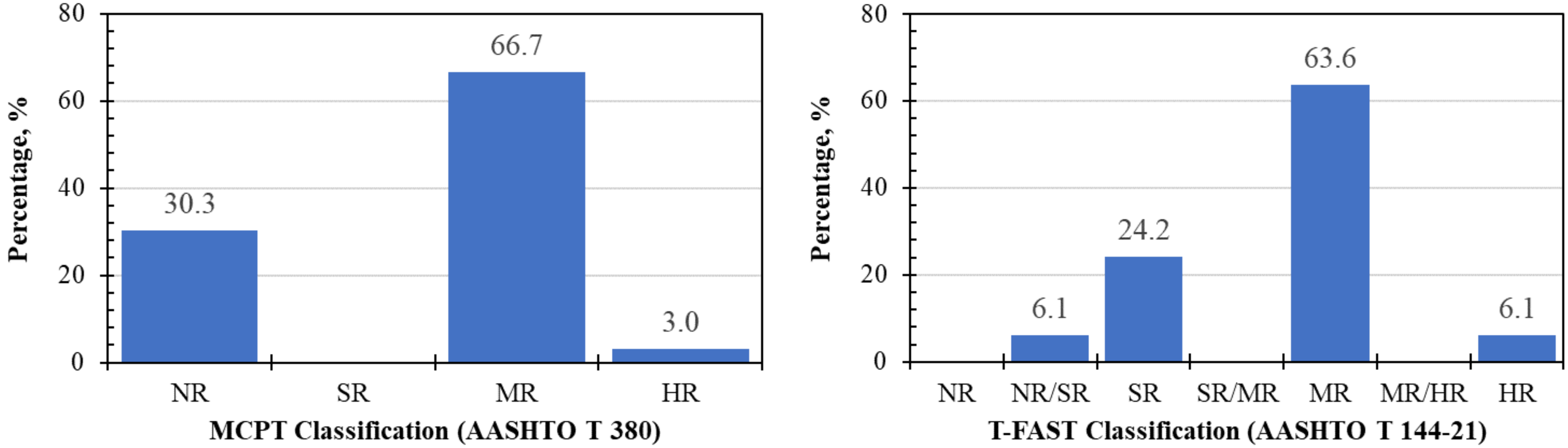
Source: FHWA.

Comparison of ASR classification reported by CPT and TFAST.

- The CPT classified 33.3% of the aggregates as NR, while the T-FAST only reported 3.7%.

CPT = concrete prism test; HR = highly reactive; MR = moderately reactive; NR = nonreactive; SR = slow reactive; VHR = very highly reactive.

T-FAST Results: Correlation with MCPT



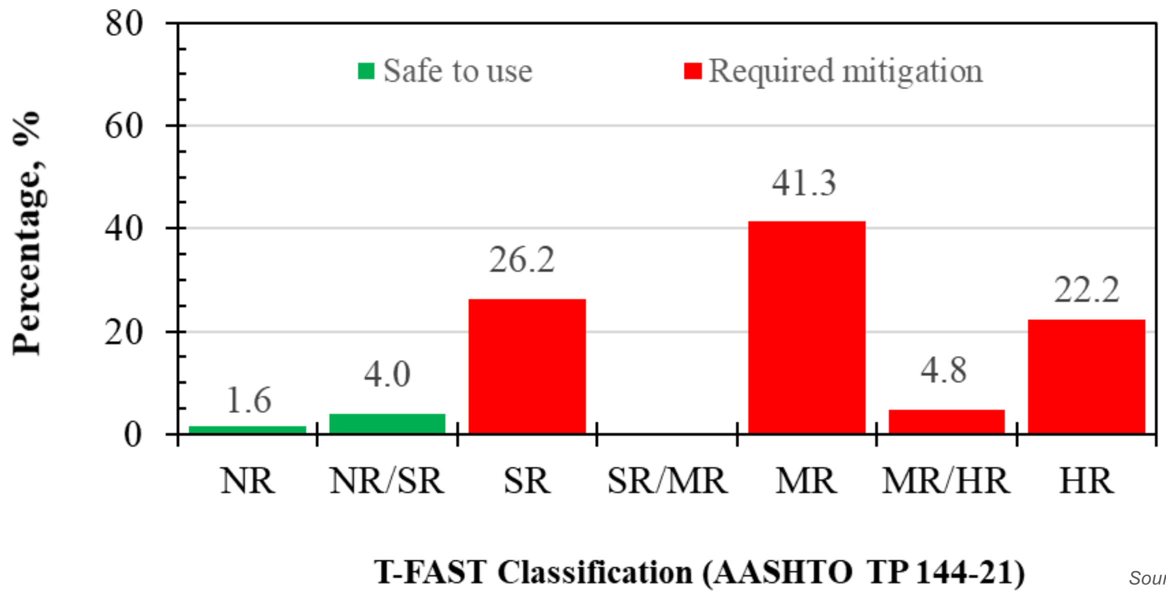
Source: FHWA.

Comparison of ASR classification reported by MCPT and TFAST.

- The MCPT classified 30.3% of the aggregates as NR, while the T-FAST reported none.

MCPT = miniature concrete prism test; HR = highly reactive; MR = moderately reactive; NR = nonreactive; SR = slow reactive.

T-FAST Results: Current mitigation approach



Source: FHWA.

Distribution of the T-FAST classification of the Northeast aggregates

- 94% aggregates would require mitigation.

Alkali Threshold Test (ATT)

- The minimum amount of alkali needed to trigger the reaction.
- Alkali threshold helps predict whether an aggregate would react under specific field conditions.
- ATT is a fast and reliable method to measure the alkali threshold.

Source: FHWA.

ATT: Test Tube Preparation

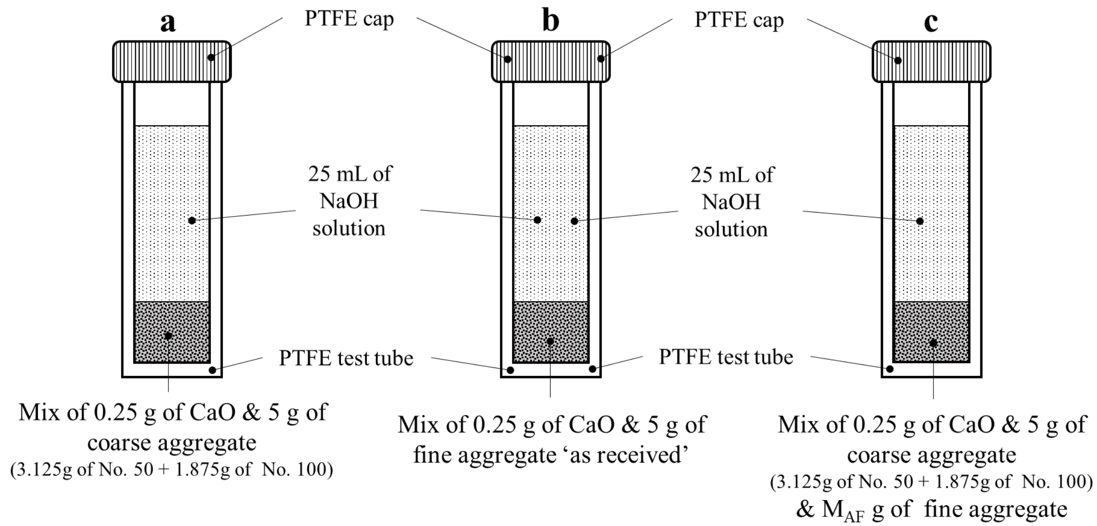
Summary of ATT Conditions.

Test Tube Configuration	
CaO (g)	0.25
Alkali Loading Na_2O_{eq} kg/m^3	1.1–6.51
Temperature (°C)	55

Oven for 21 d → Analysis* for Si, Ca, Al →

$$RI = \frac{[Si]}{[Ca] + [Al]}$$

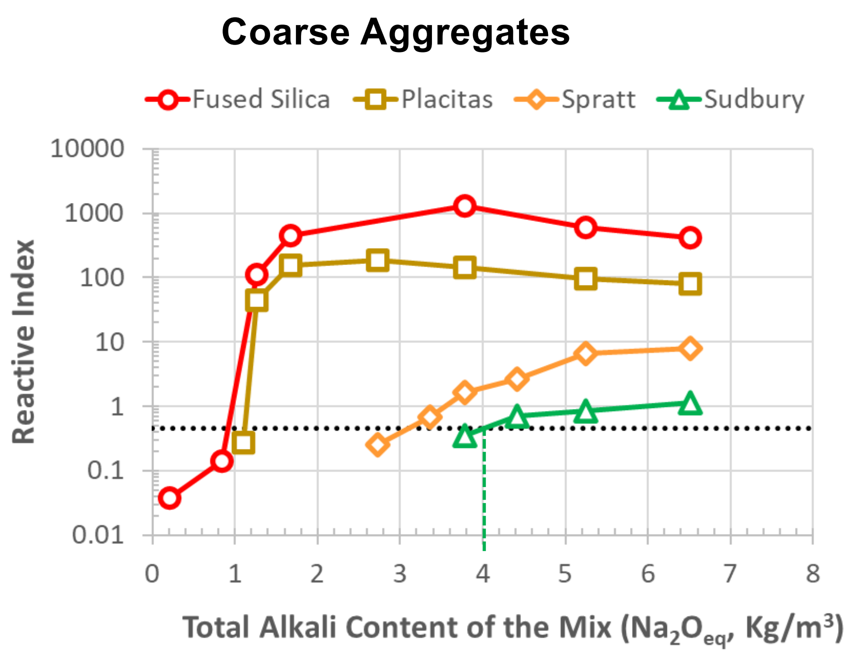
*Ion coupled emission spectroscopy or wavelength dispersive x-ray fluorescence.



Configuration of test tubes.

Source: FHWA.

ATT: Interpretation of the Results



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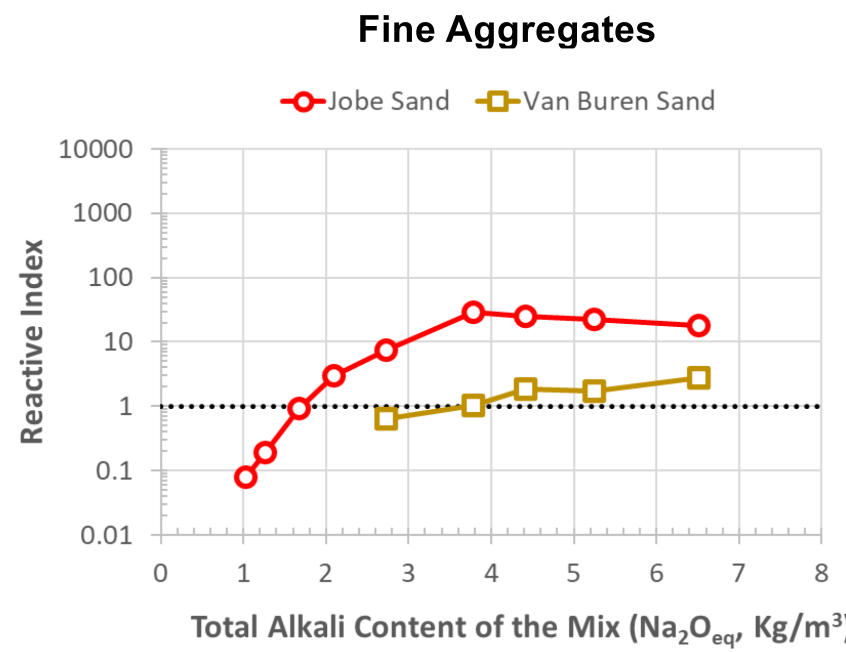
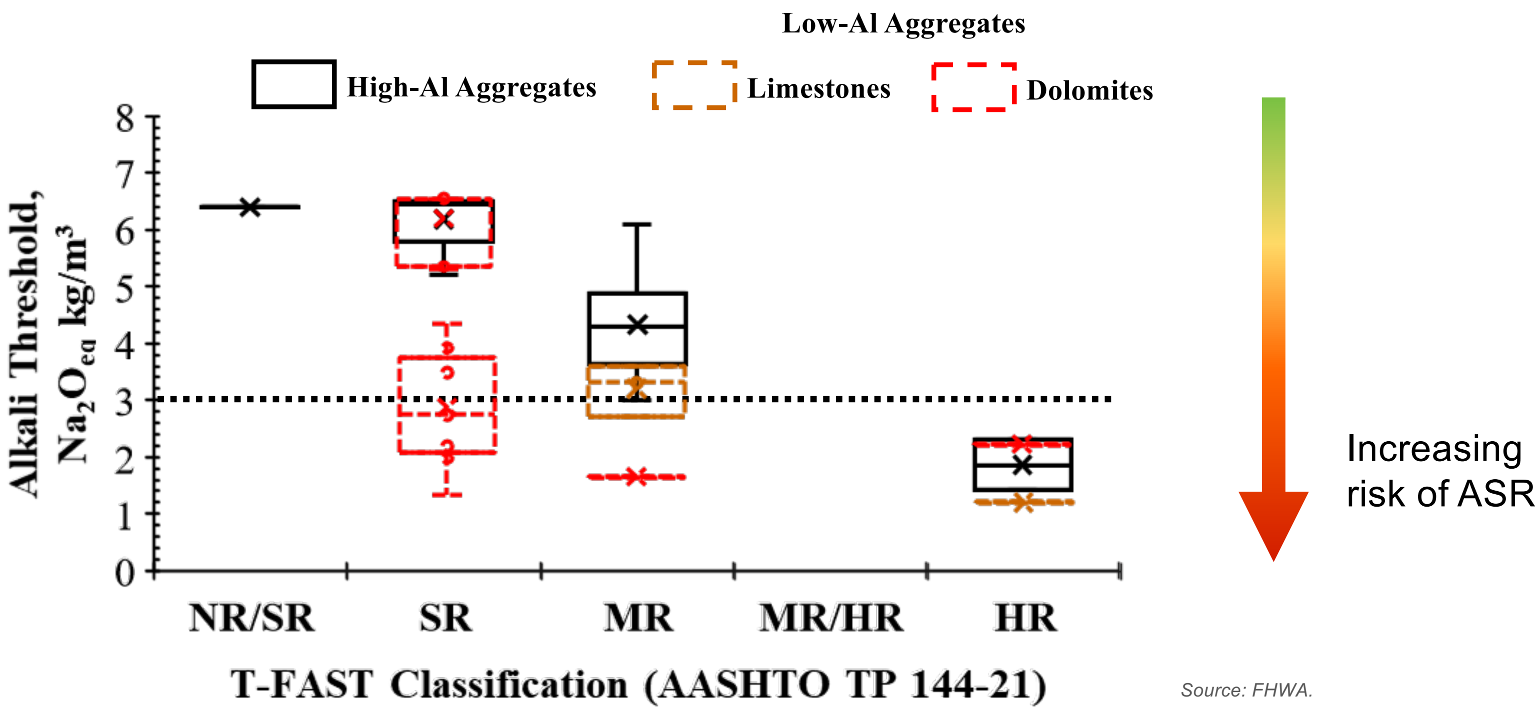


Source: FHWA.

Effect of alkali content on the RI.

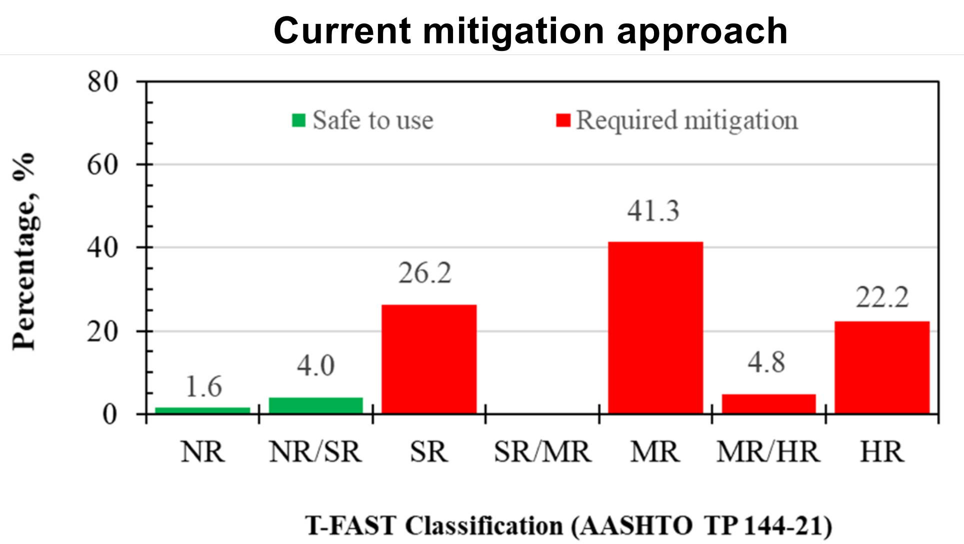
ATT: Interpretation of the Results



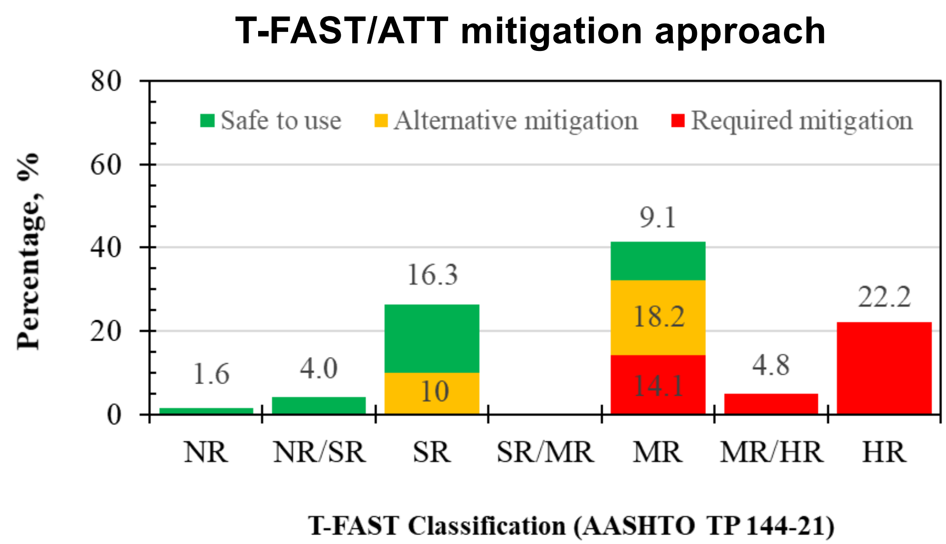
Source: FHWA.

Correlation between T-FAST classification and alkali threshold of the high and low-Al aggregates.

T-FAST Results: Mitigation Approach



Source: FHWA.



Source: FHWA.

- Current mitigation approach: 94% aggregates would require mitigation.
- T-FAST/ATT mitigation approach: 41.1% aggregates would require mitigation.

Alkali Loading (AL) and Alkali Threshold (AT)

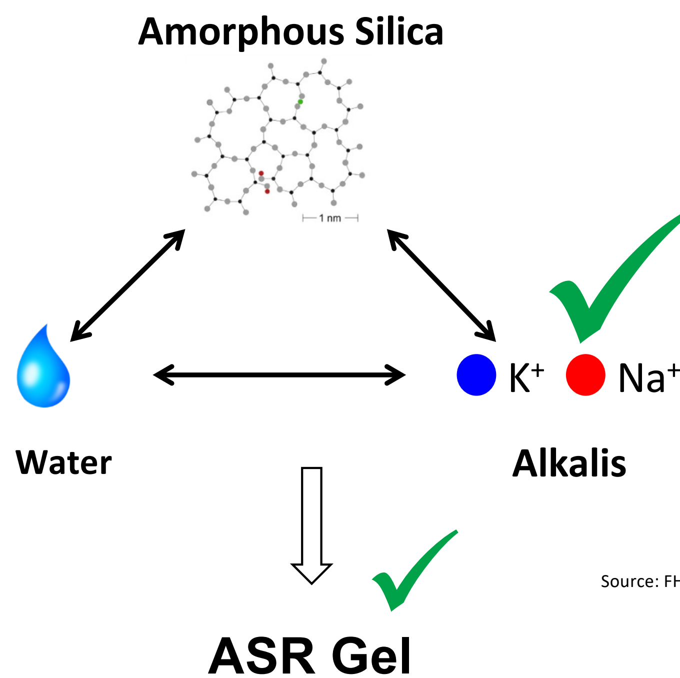
Alkali Loading of Concrete: Total alkali content in the concrete. Depends on:

- amount of cement
- alkali content of cement
- amount and alkali content of other constituents (e.g., aggregates and supplementary cementitious materials). The alkali contribution of these constituents is more difficult to quantify.

$$\textbf{Concrete alkali loading kg/m}^{3}\ \mathbf{Na_2O_{eq}} = \frac{\text{Cement content kg/m}^3 \times \text{Cement alkalis wt. \% } Na_2O_{eq}}{100}$$

Alkali Loading (AL) and Alkali Threshold (AT)

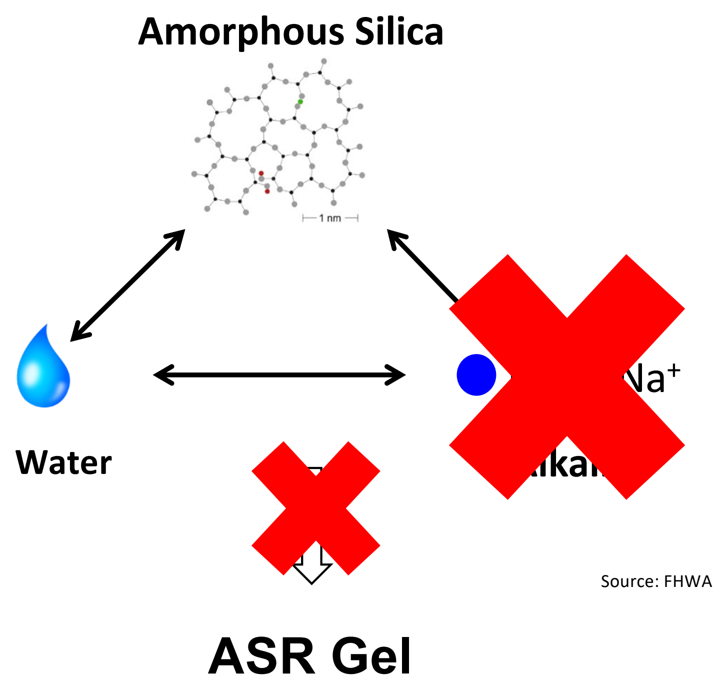
AL > AT of the aggregates



Source: FHWA

Alkali Loading (AL) and Alkali Threshold (AT)

AL < AT of the aggregates



Source: FHWA

Practical Applications of T-FAST and AT

- Performance Approach Example

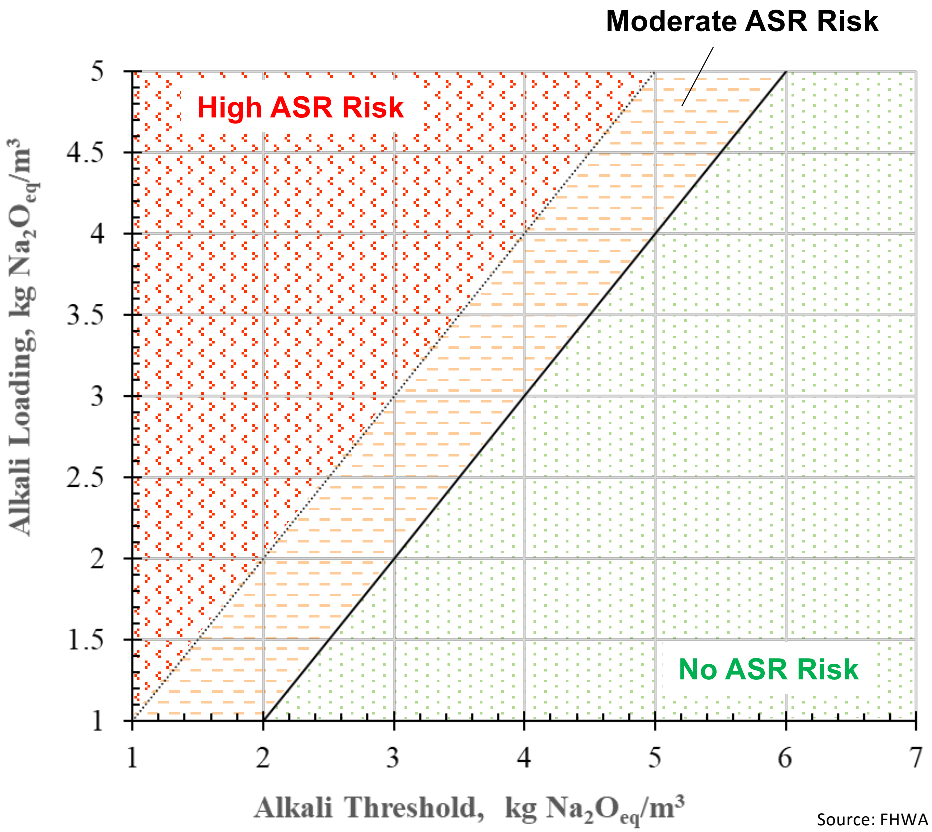
Requirement: Evaluate the AT of the combination of coarse and fine aggregate as in the mix design.

Pros: Provides flexibility to safely allow the use of high alkali cements and/or off-spec SCMs.
Possibility to control quality of concrete mixes in iconic construction projects (e.g., Bridges, Tunnels, etc.).

Cons: Labor intense depending on the number of concrete mixes authorized per year.

Practical Applications of T-FAST and ATT

Performance Approach Example



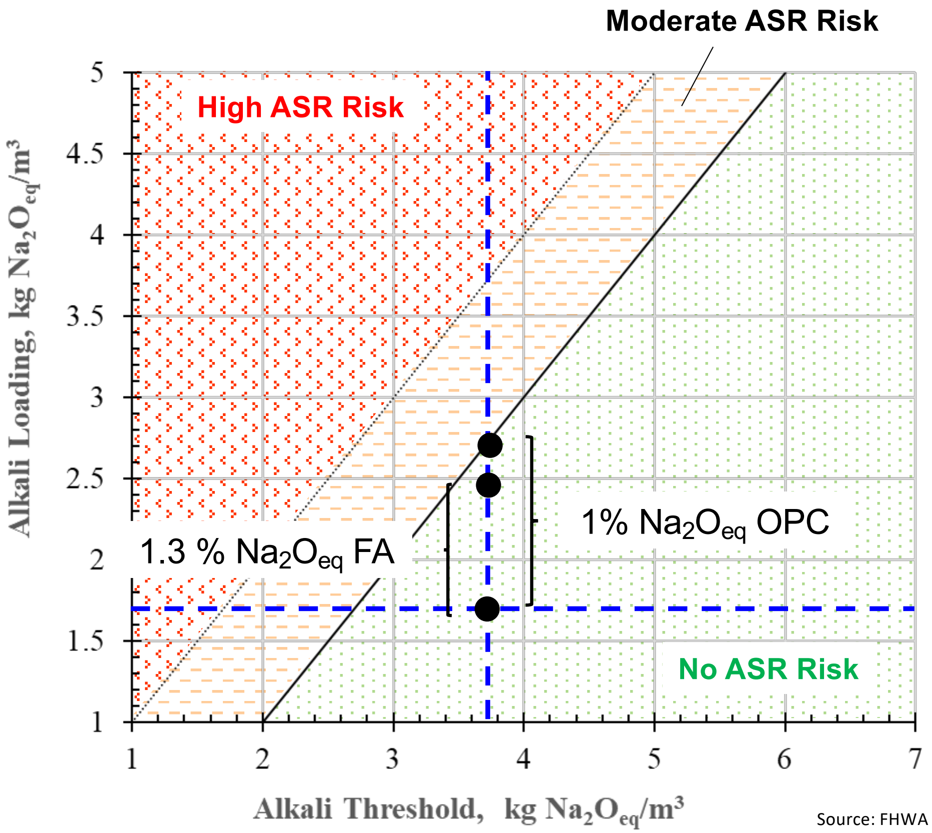
ASR risk assessment chart for concrete mixes.

No ASR Risk region:
High alkali cements and/or off-spec SCMs permissible.

Moderate and High ASR Risk regions:
Follow mitigation methods recommended as per specifications.

Practical Applications of T-FAST and ATT

Performance Approach Example



ASR risk assessment chart for concrete mixes.

Type of Concrete	Pavement
Binder content	525 lb/yd³ (311 kg/m³)
SCM Replacement level, %	25
Aggregates AT	3.7 kg/m³

Content, kg/m³		**% Na_2O_{eq}**	**AL, kg/m³**
OPC	234	0.6	1.4
Fly Ash	78	1.3	1

Concrete AL	2.4 kg/m³

Practical Applications of T-FAST and ATT

- Prescriptive Approach Example

Requirement: Classify coarse and fine aggregate separately with T-FAST and ATT (Example. List of approved aggregates).

Pros: Provides flexibility to safely allow the use of high alkali cements and off-spec SCMs.
Improve efficiency of periodic aggregate evaluation campaign.
Detect intrinsic mineralogical variation within quarries.

Cons: More restrictive than the performance approach.

Practical Applications of T-FAST and ATT

Prescriptive Approach

Step 1: select the Zone # based on AT values of the coarse and fine aggregates.

AT (Na_2O_{eq}, kg/m^3)		Zone #
CA	**FA**	
≥5	≥5	ZI
4.0-5.0	4.0-5.0	ZII
3.5-4.0	3.5-4.0	ZIII
≤ 3.5	≤ 3.5	ZIV
All other combinations		Select Zone for lowest AT value

Practical Applications of T-FAST and ATT

Prescriptive Approach

<u>Step 2</u>: select the recommendation based on the Zone # and the T-FAST classification of the coarse and fine aggregates.

<table>
<tr><th rowspan="2">Zone #</th><th colspan="2">T-FAST Reactivity</th><th rowspan="2">Recommendation</th><th rowspan="2">Description</th></tr>
<tr><th>CA</th><th>FA</th></tr>
<tr><td rowspan="2">I</td><td colspan="2">NR</td><td>RI</td><td>High alkali cements and/or off-spec SCMs permissible; AL< 4 kg/m^3.</td></tr>
<tr><td colspan="2">All other combinations</td><td rowspan="2">RII</td><td rowspan="2">High alkali cements and/or off-spec SCMs permissible; AL < 3 kg/m^3.</td></tr>
<tr><td rowspan="2">II</td><td colspan="2">Between NR to SR</td></tr>
<tr><td colspan="2">All other combinations</td><td rowspan="2">RIII</td><td rowspan="2">High alkali cements and/or off-spec SCMs permissible; AL < 2 kg/m^3.</td></tr>
<tr><td rowspan="2">III</td><td colspan="2">Between SR to MR</td></tr>
<tr><td colspan="2">All other combinations</td><td rowspan="2">RIV</td><td rowspan="2">Follow mitigation methods recommended as per specifications.</td></tr>
<tr><td>IV</td><td colspan="2">Any combination</td></tr>
</table>

Practical Applications of T-FAST and ATT

Step 1. Select Zone # based on AT values of the coarse and fine aggregates

AT (Na_2O_{eq}, kg/m³)		Zone #
CA	**FA**	
≥5	≥5	ZI
4.0-5.0	4.0-5.0	ZII
3.5-4.0	3.5-4.0	ZIII
≤ 3.5	≤ 3.5	ZIV
All other combinations		Select Zone for lowest AT value

Step 2. Select Recommendation based on T-FAST classification and zone of the coarse and fine aggregates

Zone #	T-FAST Reactivity		Recommendation
	CA	**FA**	
I	NR		RI
I	All other combinations		RII
II	Between NR to SR		RII
II	All other combinations		RIII
III	Between SR to MR		RIII
III	All other combinations		RIV
IV	Any combination		RIV

AT (Na_2Oeq, kg/m³)	
CA	FA
5.8	4.3

TFAST	
CA	FA
SR	MR

Conclusions: T-FAST

- T-FAST is a highly sensitive test in comparison to AMBT, CPT and MCPT.
- High sensitivity toward carbonate aggregates, mainly dolomites, dolomitic limestones, dolostones and limestones.
- Minimize the risk of mislabeling aggregates (e.g. Slow or moderate classified as non-reactive) thus lowering the risk of inadequate mitigation strategies in the field.

Conclusions: T-FAST & ATT Combination

- ATT is a cost-efficient test that allows to understand field performance of the aggregates.
- T-FAST/ATT combination brings higher accuracy in aggregate classifications (T-FAST and ATT should show agreement).
- Possibility to design performance or prescriptive specification based on T-FAST and ATT.
- Widen your portfolio of mitigation strategies (e.g. use of SCMs other than Class F and Class N).
- Selective usage of effective SCMs (e.g. Class F fly ash) for the more reactive aggregates.

Thank you!

Any questions?

Contact

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Alkali Loading (AL) and Alkali Threshold (AT)

Alkali Content: amount of alkalis (Na^+ and K^+) of any concrete component (cement, aggregates, etc) expressed as weight % of equivalent alkalies (wt. % Na_2O_{eq})

$$\textbf{wt. \% } \mathbf{Na_2O_{eq}} = (\text{wt. \% } Na_2O) + (0.658 \times \text{wt.\% } K_2O)$$

Example: Alkali content of Cement

Typical Cement Oxide XRF Analysis

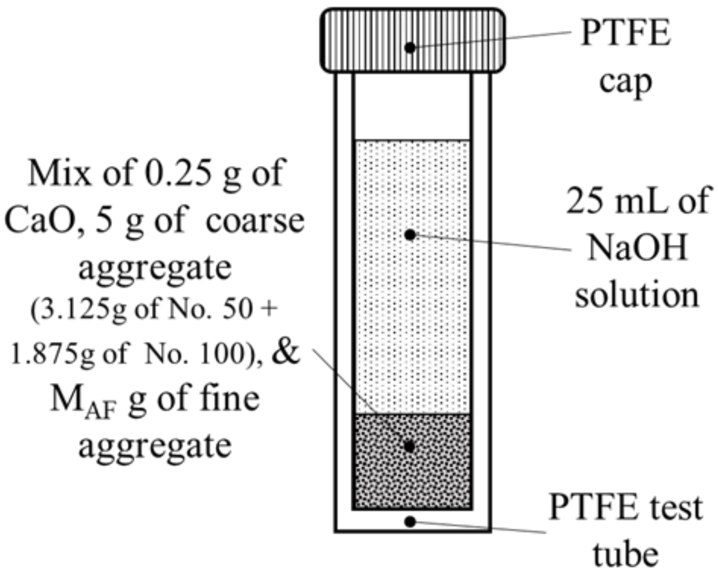
Oxide	%
SiO_2	20.55
Al_2O_3	5.07
Fe_2O_3	3.10
CaO	64.51
MgO	1.53
K_2O	0.73
Na_2O	0.15
SO_3	2.53
LOI	1.58

Source: FHWA.

$$\textbf{wt. \% } \mathbf{Na_2O_{eq}} = (0.15) + (0.658 \times 0.73) = 0.63 \text{ \% } Na_2O_{eq}$$

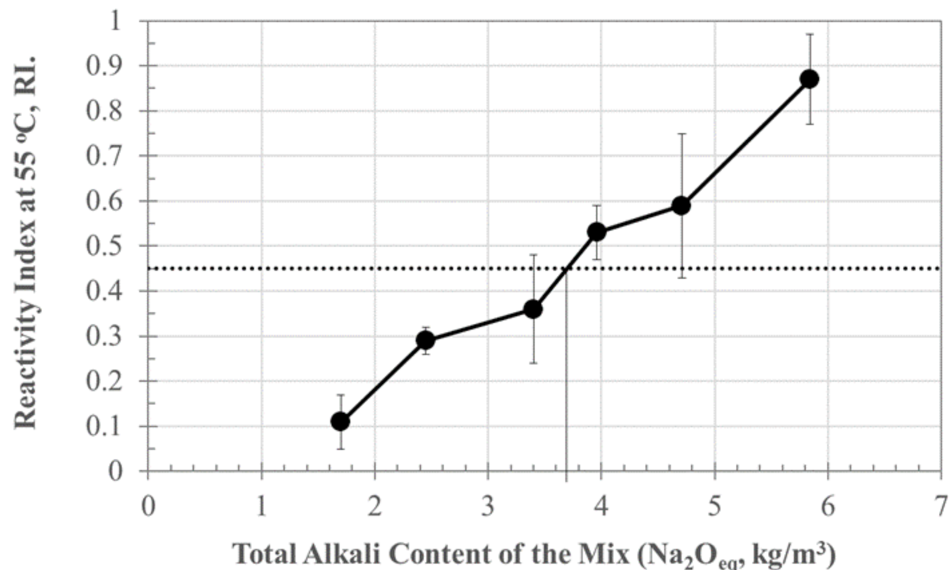
Practical Applications of T-FAST and ATT

- ▶ Performance Approach Example



Source: FHWA

T-FAST configuration to evaluate the AT of a combination of coarse and fine aggregate.



Source: FHWA

Example of AT of a combination of coarse and fine aggregate.