APPENDIX D: Recommended Changes to Guidelines

Appendix D of *NCHRP Research Report 1083: Alkali-Silica Reactivity Potential and Mitigation: Test Methods and State of Practice* (NCHRP Project 10-103).

The National Cooperative Highway Research Program (NCHRP) is sponsored by the individual state departments of transportation of the American Association of State Highway and Transportation Officials. NCHRP is administered by the Transportation Research Board (TRB), part of the National Academies of Sciences, Engineering, and Medicine, under a cooperative agreement with the Federal Highway Administration (FHWA). Any opinions and conclusions expressed or implied in resulting research products are those of the individuals and organizations who performed the research and are not necessarily those of TRB; the National Academies of Sciences, Engineering, and Medicine; the FHWA; or NCHRP sponsors.

AASHTO R 80

In Section 2.
Add:

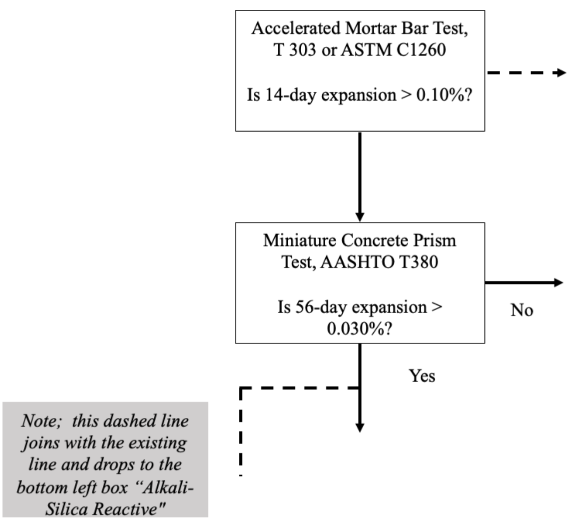
Section 2.1. AASHTO Standards

AASHTO T 380 Potential Alkali Reactivity of Aggregates and Effectiveness of ASR Mitigation Measures (Miniature Concrete Prism Test, MCPT)

In Section 3.
Add:

3.10. Miniature concrete prism test (MCPT) - test method is used to detect the potential for deleterious alkali–silica reaction of aggregate in miniature concrete prisms. The effectiveness of supplementary cementitious materials to prevent alkali-silica reaction can also be assessed in this test.

In Section 5.
In Figure 1 add a text box (and step) for AASTHO T 380 between the box for AASHTO T303 and ASTM C1293. The lines indicate connection to the existing box above (ASTM C1260) and the existing box below (ASTM C1293)



In Section 6.
Add a new section 6.6 and increase the existing section 6.6 to 6.7:

6.6. *Miniature Concrete Prism Test (AASHTO T 380)*

6.6.1. The aggregate may be tested in accordance with T 380 if it meets one of the following three criteria: (1) the aggregate is not a quarried carbonate, (2) the aggregate is a quarried carbonate with a composition that falls outside of the region of "aggregates considered potentially expansive" in Figure 2 when tested in accordance with CSA A23.2-26A, or (3) the aggregate is a quarried carbonate that does not cause excessive expansion when tested in ASTM C1105 in accordance with Section 6.7.

6.6.2. The miniature concrete prism test is considered to have a similar reliability to ASTM C1293 (the most reliable laboratory test for predicting the field performance of aggregates). The test should be conducted in accordance with AASHTO T 380.

6.6.3. This test is intended to evaluate coarse and fine aggregates separately and should not be used to evaluate job combinations of coarse and fine aggregates.

6.6.4. If the aggregate being tested is a coarse aggregate, it is blended with a nondeleteriously reactive fine aggregate for testing. Similarly, if the aggregate being tested is a fine aggregate, it is blended with a nondeleteriously reactive coarse aggregate for testing. The coarse-fine aggregate combination is used to produce concrete prisms that have a specified high alkali loading.

6.6.5. If the expansion of miniature concrete prisms is not greater than 0.030 percent after 56 days, the aggregate is considered nondeleteriously reactive and may be used in concrete with no further testing (for ASR or ACR).

6.6.6. If the expansion of miniature concrete prisms is greater than 0.030 percent at 56 days, the aggregate is considered potentially deleteriously reactive. It is recommended to verify its reactivity by testing in ASTM C1293 (Section 6.5). If there is insufficient time or resources to run ASTM C1293, the aggregate should be treated as potentially reactive and appropriate preventive measures must be selected.

In Section 7.
Replace 7.1.1. with:

7.1.1. The 2-year concrete prism test has been found to underestimate percentage replacement or dosage rates for SCMs or lithium nitrate, respectively, for high alkali loading mixtures [e.g. $\geq$ 3.78 kg/m^3 (6.37 lb/yd^3)]. Further, this test in its current form, is unable to assess the impact of different alkali loadings on aggregate reactivity. As a result, this test method should not be used for evaluating the efficacy of preventive measures and/or alkali loading.
Delete 7.1.2. to 7.1.5.

Add a new section 7.2 and increase 7.2 to 7.3.

7.2. *Using the Miniature Concrete Prism Test (AASHTO T 380) to Evaluate Preventive Measures*

7.2.1. The miniature concrete prism test may be used to evaluate the efficacy of supplementary cementitious materials (SCM), such as pozzolans and slag and blended cements (containing SCM) for preventing damaging alkali–silica reaction. It is prudent to conduct a number of tests using varying levels of SCM to determine the amount required to prevent deleterious expansion.

Note 7 – Research on modifications to this test method to evaluate chemical admixtures such as lithium salts have not been done and are thus not yet included in this test method.

7.2.2. If the expansion of concrete prisms is not greater than 0.025 percent after 84 days, the combination of SCM and reactive aggregate is considered acceptable for use in concrete construction.

7.2.3. If the expansion of concrete prisms is greater than 0.025 percent after 84 days, the preventive measure is not deemed to be effective with the reactive aggregate. A new test should be done using that reactive aggregate with an increased level of SCM.

7.3. (New number) *Using the Accelerated Mortar-Bart Test (T303) to Evaluate Preventive Measures*

7.3.1 (Remove existing section and replace with new section below)
~~Before the accelerated mortar-bar test (AMBT) is used to determine the performance of a specific blended cement-aggregate, SCM-aggregate, or lithium nitrate-aggregate combination, it is recommended that it first be demonstrated that the aggregate being evaluated responds well to the accelerated test. This requires a comparison of the results from the accelerated mortar-bar test and the concrete prism test for the aggregate being used (without preventive measures). After subjecting the aggregate to both tests, the results are plotted on Figure 3. If data do not fall within Zone 3 indicated in Figure 3, accelerated mortar-bar test (ASTM C1567) can then be used to determine efficacy of blended cements, SCMs, and lithium nitrate. Neglecting to perform this type of comparison may result in either: (1) an overly conservative estimate of aggregate reactivity using AMBT, resulting in overestimation of required SCM or lithium nitrate amounts or (2) a less conservative estimate of aggregate reactivity using AMBT, resulting in underestimation of required SCM or lithium nitrate amounts. This represents an inherent risk in relying solely on the results of accelerated mortar-bar test or concrete prism test. The results from the accelerated mortar-bar test and the concrete prism test should be compared every 2 years unless the results of petrography or other tests indicate a significant change in the composition of the material in the quarry, in which case new tests should be commenced immediately. If there is insufficient time to conduct a comparison between the two tests, then the accelerated mortar-bar test can be used; however, there is an increased level of risk associated with making decisions based on this test alone.~~

Delete Figure 3.

Add:
7.3.1. To use the accelerated mortar-bar test (ASTM C1567) to evaluate preventive measures, the results of aggregate reactivity testing using AASHTO T303 and AASHTO T 380 should be compared. If there is agreement, (e.g. an aggregate exceeds the expansion limit in both tests), then ASTM C1567 can be used to evaluate preventive approaches. If they do not agree (e.g. pass/fail or fail/pass), then AASHTO T 380 should be used to evaluate preventive measures for that aggregate.

Change 7.2.3 to:
7.2.3.
If the expansion of mortar bars containing blended cement or supplementary cementitious materials is not greater than 0.10 percent after ~~14~~ 28 days in sodium hydroxide solution, the combination of blended cement or SCM and reactive aggregate shall be considered acceptable for use in concrete construction provided the alkali content of the portland cement used in the job does not exceed 1.00 percent Na_2O_e.

Change 7.2.4 to
7.2.4
If the expansion of mortar bars containing blended cement or supplementary cementitious materials is greater than 0.10 percent after ~~14~~ 28 days in sodium hydroxide solution, the blended cement or level of SCM tested is not deemed to be effective with the reactive aggregate. Consideration should be given to retesting the aggregate with an increased level of SCM, a different blended cement, or a combination thereof.

New section 7.2.5

7.2.5. *Reducing Risk of ASR as the Criticality of the Structure Increases*

If the mixture will be used in a structure that meets an SC3 or SC4 category in Table 4 (Section 8), choose the appropriate ASR Risk Level from Table 3. Then the alkali loadings corresponding to that Risk Level in Table 7 should be used in conjunction with preventive measures identified in the performance-based approach.

Note X – Extreme care should be taken in building an SC4 structure with an R2 or R3 aggregate. The licensed design professional should consult with a concrete durability expert, with specific expertise in alkali-aggregate reaction, to determine the appropriate preventive approach.

In Section 8.

Update Table 1

Table 1 - Classification of Aggregate Reactivity

Aggregate-Reactivity Class	Description of Aggregate Reactivity	1-Year Expansion in CPT, %	56-day Expansion in MCPT, %	14-day Expansion in AMBT, %
R0	Nonreactive	x ≤ 0.04	x ≤ 0.030	x ≤ 0.10
R1	Moderately reactive	0.04 < x ≤ 0.12	0.030 < x ≤ 0.120	0.10 < x ≤ 0.30
R2	Highly reactive	0.12 < x ≤ 0.24	0.121 < x ≤ 0.240	0.30 < x ≤ 0.45
R3	Very highly reactive	x > 0.24	x > 0.240	x > 0.45

Update Table 6

Table 6 – Minimum Levels of SCM to Provide Various Levels of Prevention

Type of SCM	Alkali Level of SCM (%Na_2O_e)	Minimum Replacement Level ** (% by mass of Cementitious Material)				
		Level W	Level X	Level Y	Level Z	Level ZZ
Fly Ash (CaO ≤ 18%)	x ≤ 3.0	20	25	25	35	Table 7
	3.0 < x ≤ 4.5	25	30	Not Permitted	Not Permitted	
Slag Cement	< 1.0	30	40	50	65	
Natural Pozzolan *(Meeting ASTM C618 Class N)*	x ≤ 8.0	25	Assess in C1567/ T 380	Assess in C1567/ T 380	Assess in C1567/ T 380	

Silica Fume ($SiO_2 \geq 0.85$)	≤ 1.0%	2.0 x KGA 1.2 x LBA	2.5 x KGA or 1.5 LBA	Not permitted as a sole preventive option	Not permitted as a sole preventive option

[a] The SCM may be added directly to the concrete mixer or it may be a component of a blended cement. SCMs should meet the requirements of M 295, M 302, or M 307. Blended cements should meet the requirements of M 240M/M 240 or ASTM C1157.

[b] The use of high levels of SCM in concrete may increase the risk of problems due to deicer salt scaling if the concrete is not properly proportioned, finished, and cured.

[c] The minimum level of silica fume (as a percentage of cementitious material) is calculated on the basis of the alkali (Na_2Oe) content of the concrete contributed by the portland cement and expressed in either units of kg/m^3 (KGA in Table 6) or lb/yd^3 (LBA in Table 6). KGA is calculated by multiplying the cement content of the concrete in kg/m^3 by the alkali content of the cement divided by 100. For example, for a concrete containing 300 kg/m^3 of cement with an alkali content of 0.91 percent Na_2Oe, the value of KGA = 300 × 0.91/100 = 2.73 kg/m^3. For this concrete, the minimum replacement level of silica fume for Level X is 2.5 × 2.73 = 6.8 percent. LBA is calculated by multiplying the cement content of the concrete in lb/yd^3 by the alkali content of the cement divided by 100. For example, for a concrete containing 500 lb/yd^3 of cement with an alkali content of 0.81 percent Na_2Oe the value of LBA = 500 × 0.81/100 = 4.05 lb/yd^3. For this concrete, the minimum replacement level of silica fume for Level Y is 1.8 × 4.05 = 8.1 percent. Regardless of the calculated value, the minimum level of silica fume shall not be less than 7 percent when it is the only method of prevention.

Delete 8.6.1.2.4

Delete 8.6.1.2.5. and replace with:
8.6.1.2.4 (new) Table 7 provides recommendations for adjusting the alkali content of the portland cement portion of the concrete for prevention levels X, Y and Z.

Replace Table 7 and 8 with:

Table 7 - Using SCM and Limiting the Alkali Content of the Concrete to Provide Highest Levels of Prevention

Prevention Level	SCM as sole prevention	Limiting concrete alkali content plus SCM	
	Minimum SCM level	Maximum alkali content, kg/m^3 (lb/yd^3)	Minimum SCM level
X	Use SCM level in Table 6	N/A	N/A
Y	Not permitted	4.0 (6.7)	SCM Level Shown for Level Y in Table 6
Z	Not permitted	3.0 (5.1)	SCM level shown for Level Z in Table 6
ZZ	Not permitted	1.8 (3.0)	SCM level shown for Level Z in Table 6

In Section 11.

Add:

Drimalas, T., Folliard, K.J., Ideker, J.H., Parashar, A., Fournier, B., Ghanizadeh, A. and Thomas, M.D.A., “Improving Guidance of AASHTO R 80/ASTM C1778 for Alkali-Silica Reactivity (ASR) Potential and Mitigation,” NCHRP Project Report 10-103, submitted for review March 31, 2023, 74 pp.

Commentary

Add the following commentary:

Section X1.6.

X1.x.x.x. Recent research has shown that AASHTO T 380, using a test duration of 84 days and an expansion limit of 0.025% is a more reliable test method for assessing the efficacy of preventive measures in mixtures with alkali loadings $\geq$ 3.78 kg/m^3 (6.37 lb/yd^3). (reference Drimalas et al., 2023)

X1.x.x.x. Recent research has shown a good correlation between ASTM C1567, using a 28-day expansion limit of 0.10 percent, and outdoor concrete exposure blocks with alkali loadings $\geq$ 3.78 kg/m^3 (6.37 lb/yd^3). (reference Drimalas et al., 2023)

X1.x.x.x. Based on recent research ternary blends should not have reduction factors as these values were found to be unconservative in high alkali loading concrete blocks. Research is underway to determine if these reductions would be appropriate for low or moderate alkali loading blocks. For preventive levels Y and Z silica fume should not be used as a sole preventive measure. (Drimalas et al., 2023)

Drimalas, T., Folliard, K.J., Ideker, J.H., Parashar, A., Fournier, B., Ghanizadeh, A. and Thomas, M.D.A., “Improving Guidance of AASHTO R 80/ASTM C1778 for Alkali-Silica Reactivity (ASR) Potential and Mitigation,” NCHRP Project Report 10-103, submitted for review March 31, 2023, 74 pp.

ASTM C1778

In Section 2. Referenced Documents

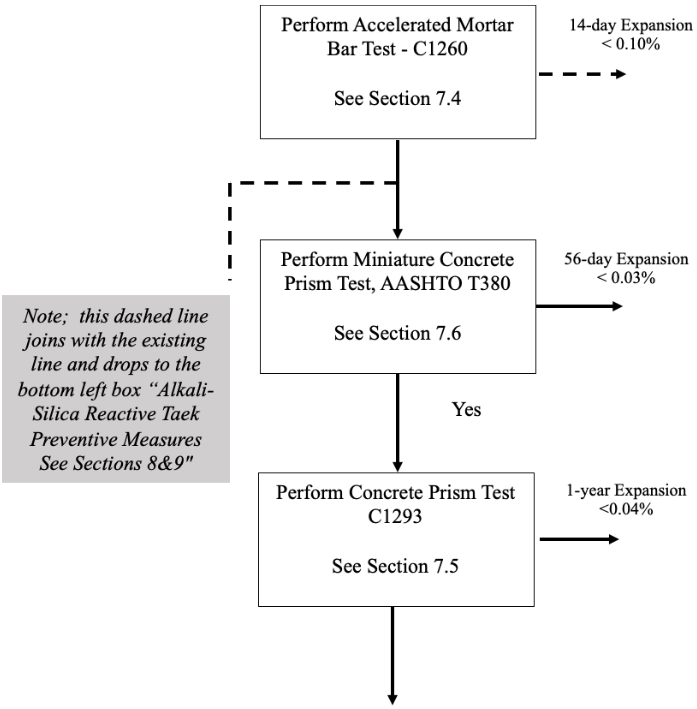
Add:

AASHTO T 380 Potential Alkali Reactivity of Aggregates and Effectiveness of ASR Mitigation Measures (Miniature Concrete Prism Test, MCPT)

In Section 6.

Make Change to Figure 1:

In Figure 1 add a text box (and step) for AASHTO T 380 between the box for AASHTO ASTM C1260 and ASTM C1293. The lines indicate connection to the existing box above (ASTM C1260) and the existing box below (ASTM C1293)



In Section 7.

Add a new section 7.6 and move old 7.6 to 7.7 and 7.7 to 7.8

7.6 *Miniature Concrete Prism Test (AASHTO T 380)*- The aggregate may be tested in accordance with AASHTO T 380 if it meets one of the following three criteria: (1) the aggregate is not a quarried carbonate, (2) the aggregate is a quarried carbonate with a composition that falls outside of the region of "aggregates considered potentially expansive" in Figure 2 when tested in accordance with CSA A23.2-26A, or (3) the aggregate is a quarried carbonate that does not cause excessive expansion when tested in ASTM C1105 in accordance with Section 6.7.

7.6.1 If the expansion of miniature concrete prisms is not greater than 0.030 percent after 56 days, the aggregate is considered nondeleteriously reactive and may be used in concrete with no further testing (for ASR or ACR).

7.6.2 If the expansion of miniature concrete prisms is greater than 0.030 percent at 56 days, the aggregate is considered to be potentially deleteriously reactive. It is recommended to verify its reactivity by testing in ASTM C1293 (Section 6.5). If there is insufficient time or resources to run ASTM C1293, the aggregate should be treated as potentially reactive and appropriate preventive measures must be selected.

Add new language to 7.8 Interpretation of Results from Laboratory Tests and use of Existing Tests

7.8.3 The miniature concrete prism test is considered to have a similar reliability to ASTM C1293 (the most reliable laboratory test for predicting the field performance of aggregates). The test should be conducted in accordance with AASHTO T 380.

This test is intended to evaluate coarse and fine aggregates separately and should not be used to evaluate job combinations of coarse and fine aggregates.

If the aggregate being tested is a coarse aggregate, it is blended with a nondeleteriously reactive fine aggregate for testing. Similarly, if the aggregate being tested is a fine aggregate, it is blended with a nondeleteriously reactive coarse aggregate for testing. The coarse-fine aggregate combination is used to produce concrete prisms that have a specified high alkali loading.

Changes to: 8.0 Performance-based approach for Selecting Appropriate Preventive Measures

8.1 In the performance-based approach, the efficacy of the preventive measure in combination with the reactive aggregate is tested using either AASHTO T 380 or Test Method C1293 or C1567 (Note 9). This approach is suitable for selecting the appropriate level of supplementary cementitious materials (SCMs). The effect of different alkali loadings on the performance of concrete mixtures made with reactive aggregates cannot be determined using AASHTO T 380 (in its current form) Test Methods C1293 and C1567, nor can these tests be used to determine a maximum safe alkali loading (see Note 10). Mitigation measures using limits on alkali loading should be determined using Section 9.

Replace 8.2 with
8.2 Performance Testing Using Test Method C1293 - The 2-year concrete prism test has been found to underestimate percentage replacement or dosage rates for SCMs or lithium nitrate, respectively, for high alkali loading mixtures [e.g. ≥ 3.78 kg/m3 (6.37 lb/yd3)]. Further, this test in its current form, is unable to assess the impact of different alkali loadings on aggregate reactivity. As a result, this test method should not be used for evaluating the efficacy of preventive measures and/or alkali loading. Research is underway to determine if the 2-year concrete prism test, where prisms are cast with 5.25 kg/m3 (8.85 lb/yd3 Na2Oeq) alkali, correlate concrete mixtures with alkali loading < 3.78 kg/m3 (6.37 lb/yd3).

Replace 8.3 with
8.3 Performance Testing Using Test Method C1567 – To use the accelerated mortar-bar test (ASTM C1567) to evaluate preventive measures, the results of aggregate reactivity testing using ASTM C1260 and AASHTO T 380 should be compared. If there is agreement, (e.g. an aggregate exceeds the expansion limit in both tests), then ASTM C1567 can be used to evaluate preventive approaches. If they do not agree (e.g. pass/fail or fail/pass), then AASHTO T 380 should be used.

Delete Figure 3

Delete Note 13

8.3.1 Test Method C1567 was developed specifically for "determining the potential alkali-silica reactivity of combinations of cementitious materials and aggregates." Combinations of cementitious materials and aggregates will be deemed acceptable for use if the resulting expansion is <0.10 % after 28 days immersion in 1M NaOH (Note 11).
Add Section 8.4

8.4 Performance Testing using the *Miniature Concrete Prism Test AASHTO T 380 to Evaluate Preventive Measures*

8.4.1 AASHTO T 380 may be used to evaluate the efficacy of supplementary cementitious materials (SCM), such as pozzolans and slag and blended cements (containing SCM) for preventing damaging alkali–silica reaction. It is prudent to conduct a number of tests using varying levels of SCM to determine the amount required to prevent deleterious expansion. (Note 7)

Note 7 – Research on modifications to this test method to evaluate chemical admixtures such as lithium salts have not been done and are thus not yet included in this test method.

8.4.2. If the expansion of concrete prisms is not greater than 0.025 percent after 84 days, the combination of SCM and reactive aggregate is considered acceptable for use in concrete construction.

8.4.3. If the expansion of concrete prisms is greater than 0.025 percent after 84 days, the preventive measure is not deemed to be effective with the reactive aggregate. A new test should be done using that reactive aggregate with an increased level of SCM.

Add New Section 8.5
8.5 Reducing Risk of ASR as the Criticality of the Structure Increases
If the mixture will be used in a structure that meets an SC3 or SC4 category in Table 4 (Section 8) chose the appropriate ASR Risk Level from Table 3. Then the alkali loadings corresponding to that Risk Level in Table 7 should be used in conjunction with preventive measures identified in the performance-based approach. (NOTE 8)

Note 8 – Extreme care should be taken in building an SC4 structure with an R2 or R3 aggregate. The licensed design professional should consult with a concrete durability expert, with specific expertise in alkali-aggregate reactions, to determine the appropriate preventive approach.

Update Table 1 to:

TABLE 1 Classification of Aggregate Reactivity

Aggregate-Reactivity Class	Description of Aggregate Reactivity	56-Day Expansion in AASHTO T 380%	1-Year Expansion in Test Method C1293, %	14-Day Expansion in Test Method C1260, %
R0	Non-reactive	x ≤ 0.030	<0.04	<0.10
R1	Moderately reactive	0.030 < x ≤ 0.120	≥0.04, <0.12	≥0.10, <0.30
R2	Highly reactive	0.121 < x ≤ 0.240	≥0.12, <0.24	≥0.30, <0.45

R3	Very highly reactive	x > 0.240	≥0.24	≥0.45

Remove Table 5

Update Table 6:

TABLE 6 Minimum Levels of SCM to Provide Appropriate Level of Prevention

Type of SCM[A]	Alkali Content of SCM (% Na_2Oeq)	Minimum Replacement Level[D] (% by mass)				
		Level W	Level X	Level Y	Level Z	Level ZZ
Fly ash[B] (CaO ≤ 18 %)	<3.0	20	25	25	35	Table 8
	3.0 – 4.0	20	25	Not Permitted	Not Permitted	
Slag Cement	<1.0	25	35	50	65	
Natural Pozzolan	X < 8.0	25	Assess in C1567/ T 380	Assess in C1567/ T 380	Assess in C1567/ T 380	
Silica Fume[C] (SiO_2 > 85 %)	<1.0	2.0 × KGA or 1.2 × LBA	2.5 × KGA or 1.5 × LBA	Not permitted as the sole preventive option	Not permitted as the sole preventive option	

Replace Table 7 with:

TABLE 7 Using SCM and Limiting the Alkali Content of the Concrete to Provide Highest Levels of Prevention

Prevention Level	SCM as sole prevention	Limiting concrete alkali content plus SCM	
	Minimum SCM level	Maximum alkali content, kg/m^3 (lb/yd^3)	Minimum SCM level
X	Use SCM level in Table 6	N/A	N/A
Y	Not permitted	4.0 (6.7)	SCM Level Shown for Level Y in Table 6
Z	Not permitted	3.0 (5.1)	SCM level shown for Level Z in Table 6
ZZ	Not permitted	1.8 (3.0)	SCM level shown for Level Z in Table 6

Add to References:

Drimalas, T., Folliard, K.J., Ideker, J.H., Parashar, A., Fournier, B., Ghanizadeh, A. and Thomas, M.D.A., "Improving Guidance of AASHTO R 80/ASTM C1778 for Alkali-Silica Reactivity (ASR) Potential and Mitigation," NCHRP Project Report 10-103, submitted for review March 31, 2023, 74 pp.