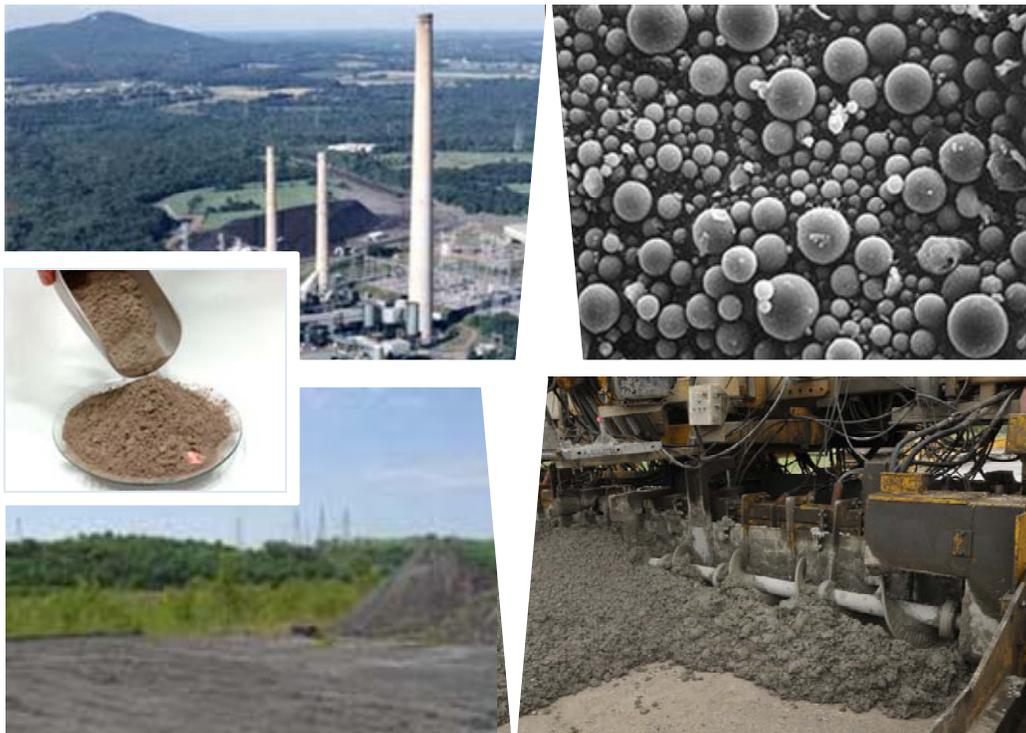


An **IPRF** Research Report
Innovative Pavement Research Foundation
Airport Concrete Pavement Technology Program

Report IPRF-01-G-002-06-2

Mix Optimization Catalog for
Proportioning Fly Ash as
Cementitious Material in
Airfield Pavement Concrete
Mixtures



Programs Management Office
5420 Old Orchard Road
Skokie, IL 60077

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Reynolds, Smith and Hill

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented within. The contents do not necessarily reflect the official views and policies of the Federal Aviation Administration. This report does not constitute a standard, specification, or regulation.

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Principal Investigators

- Dr. Chetana Rao, ARA
- Mr. Richard D. Stehly, AET

Contributing Authors

- Mr. Ahmad Ardani, formerly of ARA

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MIX OPTIMIZATION CATALOG

SCOPE

This catalog was developed to assist airfield pavement contractors and concrete materials engineers in proportioning fly ash as a cementitious material in concrete mix designs used for airfield pavement construction. The catalog provides systematic guidelines on fly ash properties, admixture selection, curing regimes, and relevant standard verification tests necessary to obtain the desired level of workability, finishing and placement quality, concrete strength, and durability for a given project. It provides a basis for the best use of local materials, as mix constituents, proportions, and construction practices can be adjusted accordingly.

Recommendations in the catalog are based largely on empirical mix design and performance data collected from various sources, including literature, laboratory tests, and real-world projects. These recommendations shall not be considered final unless verified through the laboratory tests that are listed herein.

Furthermore, the recommendations in this catalog are limited to concrete mixes with cement and fly ash as the cementitious material. They are not applicable to ternary mixes or mixes containing slag and/or other supplementary cementitious materials.

The research report prepared under this study may be referenced for further details on the development of the mix optimization protocol.

USING THE CATALOG

Each page of the mix optimization catalog consists of five sections:

1. Project Conditions: This section lists the project conditions that are known to affect the selection of fly ash type and quantities.
2. Recommendations for Fly ash Properties: This section lists the fly ash properties that are recommended for the project conditions selected by the user.
3. Recommendations for Admixtures and Curing: This section lists the factors that need to be considered in the mix design and during construction.
4. Recommended Tests: This section lists the standard tests that need to be performed while evaluating the mix.
5. Sulfate Check: Based on the final recommendations, this section provides a check on the fly ash properties to resist sulfate attack for different levels of sulfate exposure.

The first section is the only place where the user's selection is displayed. Sections 2, 3, and 4 form the recommendations for optimizing the mix. Section 5 is applicable only to projects subject to sulfate exposure.

The catalog provides two levels of recommendations—primary and secondary. The primary recommendation for a given parameter is the optimum value or consideration, but the secondary recommendation also has significant potential to meet performance requirements. Throughout the catalog, the primary recommendations are highlighted in green, and the secondary recommendations are highlighted in yellow.

The recommendations are developed for five broad categories of project conditions:

- Deicer exposure – deicer or non-deicer.
- Aggregate reactivity – reactive or non-reactive aggregates.
- Cement type – high alkali or low alkali cement.
- Opening time requirements – quick opening time or non-critical opening time.
- Paving weather – cool, moderate, or hot.

There are 48 possible combinations of project-specific variables, each of which is provided with a unique set of recommendations for fly ash properties, mix design methods, and construction practices for good performance. For each combination of variables, the catalog recommends tests that are necessary to evaluate the mix design and verify its strength and durability characteristics. These tests also are appropriate for the project environment and for preventing potential problems that may arise with the recommended materials and mix design.

The recommendations for each combination of project-specific variables are summarized on a separate sheet. The catalog therefore contains 48 sheets of recommendations for mix optimization, as shown in figure 1. The catalog sheets are grouped under four different tabs:

- Non-deicer exposure with reactive aggregates
- Non-deicer exposure with non-reactive aggregates
- Deicer exposure with reactive aggregates
- Deicer exposure with non-reactive aggregates

Finally, for projects with sulfate exposure, a sulfate check is recommended. The guidelines for the sulfate check are provided on the last sheet of the catalog.

Based on the recommendation, the user is expected to select at least three fly ash replacement rates within the range and perform the recommended tests to verify performance. Next, the user should review and plot data for analysis so that an optimum may be determined. The catalog provides some guidelines for iteratively selecting the mix design. Finally, the user needs to re-batch and test at optimum fly ash replacement level for approval.

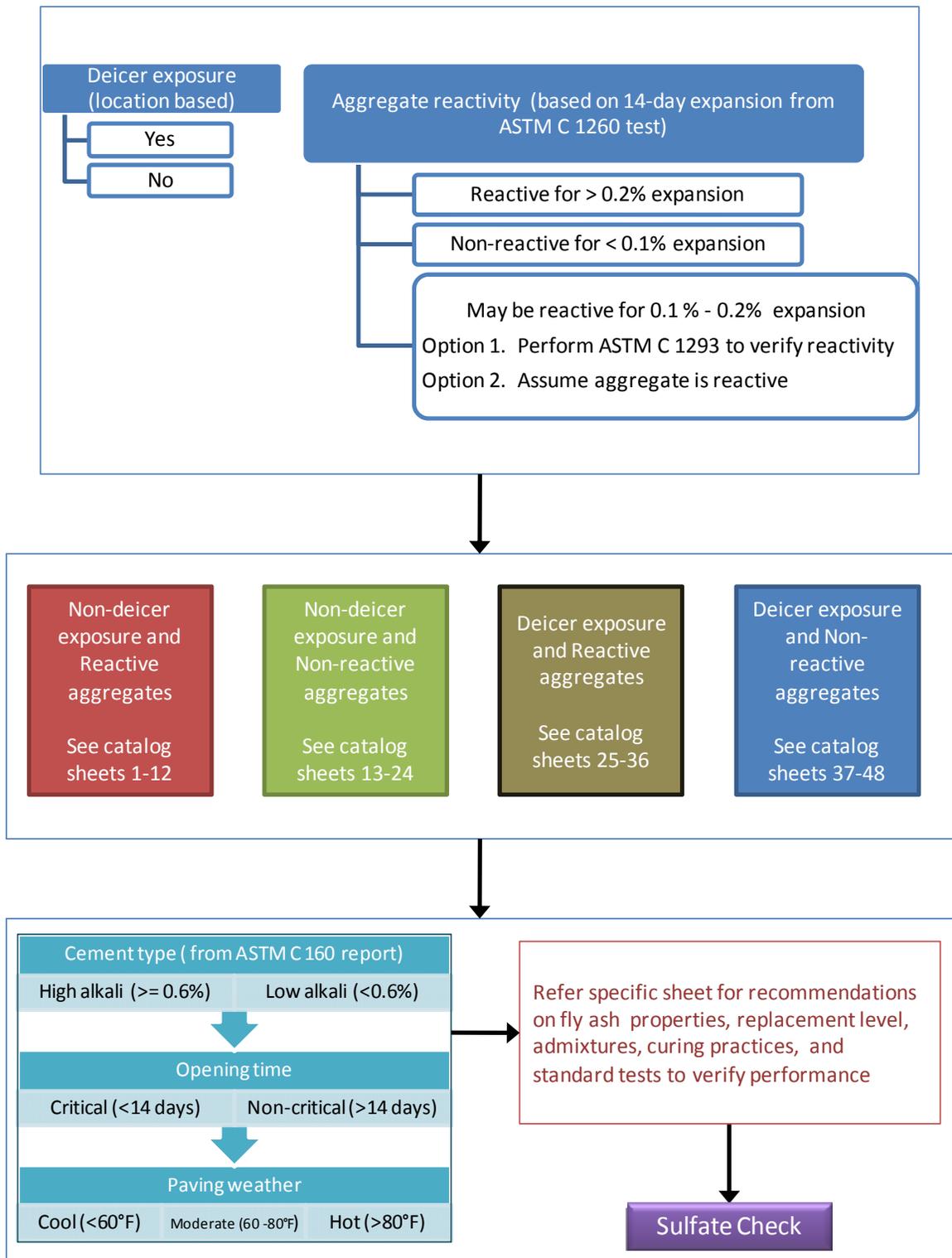


Figure 1. Project-specific selections for using the catalog

NON-DEICER EXPOSURE AND REACTIVE AGGREGATES

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78,	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The key is to maintain a replacement level high enough to mitigate ASR but low enough to meet opening strength requirements. Therefore, lower values in the high replacement range or higher values in the moderate range can be optimal. If early strength gain is a concern, increasing the total cementitious content may also be considered.
2. Wet extended curing is recommended for the high replacement level.

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2. Curing blankets may be necessary for opening strength requirements.
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PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, (Modified ASTM C 1567)	ASR and deicer reactivity	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. Strength requirements will need to be evaluated for replacements in the very high range.
2. Wet normal curing may be adequate for the moderate replacement level. However, wet extended curing is recommended for the high and very high replacement levels.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The high replacement level may be optimal, but moderate and very high levels might be optimal depending on the project conditions.
2. Wet extended curing is recommended for high and very high replacement levels. Wet normal curing might be adequate for the moderate replacement level.

NON-DEICER EXPOSURE AND NON-REACTIVE AGGREGATES

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The high replacement level might be an option if strength gain rate can meet opening strength requirements. It might be necessary to use the low replacement level if strength gains with moderate level replacements do not meet project specifications. If early strength gain is a concern, increasing the total cementitious content may also be considered.
2. Wet extended curing is recommended for the high replacement level.
3. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The high replacement level might be an option if strength gain rate can meet opening strength requirements. If early strength gain is a concern, increasing the total cementitious content may also be considered.
2. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.
3. Wet extended curing is recommended for the high replacement level. Wet normal curing may be adequate for the moderate replacement level.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The high replacement level might be an option if strength gain rate can meet opening strength requirements. If early strength gain is a concern, increasing the total cementitious content may also be considered.
2. Curing blankets may be necessary for opening strength requirements.
2. Wet extended curing is recommended for the high replacement level.
4. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. A very wide range of replacement levels is feasible for these project conditions.
2. Wet extended curing is recommended for high and very high replacement levels. Wet normal curing may be adequate for the moderate replacement level.
3. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. A very wide range of replacement levels is feasible for these project conditions. If high or very high replacement levels pose limitations with strength gain, the moderate replacement level might be evaluated.
2. Wet extended curing is recommended for high and very high replacement levels.
3. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. Lower values in the high replacement level range might be feasible if strength gain requirements can be met. If strength gain is a concern with the modern replacement level, then replacement in the low category might be optimal.
2. Wet extended curing is recommended for the high replacement level.
3. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. Lower values in the high replacement level range might be feasible if strength gain requirements can be met.
2. Wet extended curing is recommended for the high replacement level.
3. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. Lower values in the high replacement level range might be feasible if strength gain requirements can be met.
2. If early strength gain is a concern, increasing the total cementitious content may also be considered.
3. Curing blankets may be necessary for opening strength requirements.
4. Wet extended curing is recommended for the high replacement level.
5. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. A wide range of replacement levels is feasible for these project conditions.
2. Wet extended curing is recommended for high and very high replacement levels.
3. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. A wide range of replacement levels is feasible for these project conditions. While high and very high replacement levels are recommended, other project-specific considerations can make the moderate replacement level an option.
2. Wet extended curing is recommended for high and very high replacement levels.
3. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

DEICER EXPOSURE AND REACTIVE AGGREGATES

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The key is to maintain a replacement level high enough to mitigate ASR but low enough to meet opening strength requirements. Therefore, lower values in the high replacement range or higher values in the moderate range can be optimal. If early strength gain is a concern, increasing the total cementitious content may also be considered.
2. Wet extended curing is recommended for the high replacement level.
3. The high replacement level might increase scaling potential. ASTM C 672 and C 666 are recommended this level.
4. The low LOI level is recommended, but the moderate level may be adequate to meet air void requirements.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The key is to maintain a replacement level high enough to mitigate ASR but low enough to meet opening strength requirements. Therefore, lower values in the high replacement range or higher values in the moderate range can be optimal. If early strength gain is a concern, increasing the total cementitious content may also be considered.
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Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
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RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The key is to maintain a replacement level high enough to mitigate ASR but low enough to meet opening strength requirements. Therefore, lower values in the high replacement range or higher values in the moderate range can be optimal. If early strength gain is a concern, increasing the total cementitious content may also be considered.
2. The high replacement level might increase scaling potential. ASTM C 672 and C 666 are recommended for this level.
3. The low LOI level is recommended, but the moderate level may be adequate to meet air void requirements.
4. Curing blankets may be needed to meet opening strength requirements.
5. Wet extended curing is recommended for the high replacement level.

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
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			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The key is to maintain a replacement level high enough to mitigate ASR, but if necessary, it might be possible to optimize the mix to lower replacement levels if scaling potential increases. Therefore, lower values in the moderate range can be an option.
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RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
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Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

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RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
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RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
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Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

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RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
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RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
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Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The high replacement level might increase scaling potential. ASTM C 672 and C 666 are recommended for this level of replacement, but strength gain may be a concern to meet opening strength requirements at this level.
2. The low LOI level is recommended, but the moderate level may be adequate to meet air void requirements.
3. If early strength gain is a concern, increasing the total cementitious content may also be considered.
4. Wet extended curing is recommended for the high replacement level. Wet normal curing may be adequate for the moderate replacement level.

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Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

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RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
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RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
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Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The high replacement level might increase scaling potential. ASTM C 672 and C 666 are recommended for this level of replacement, but strength gain may be a concern to meet opening strength requirements at this level.
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Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
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RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
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RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
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Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The high replacement level might increase scaling potential. ASTM C 672 and C 666 are recommended for this level of replacement, but strength gain may be a concern to meet opening strength requirements at this level.
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4. Curing blankets may be necessary for opening strength requirements.
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PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
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RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
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Set accelerating	Curing blanket /autogeneous-curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
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COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The high replacement level might increase scaling potential. ASTM C 672 and C 666 are recommended.
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RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
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RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
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Admixtures	Curing
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RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

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DEICER EXPOSURE AND NON-REACTIVE AGGREGATES

PROJECT CONDITIONS SELECTED

Deicer exposure	Aggregate reactivity	Cement type	Opening time	Paving weather
No	Reactive (> 0.2%)	High alkali (>= 0.6%)	Quick (< 14 days)	Cool (< 60°F)
Yes	Non-reactive (<0.1%)	Low alkali (< 0.6%)	Non-critical (> 14 days)	Moderate (60 to 80°F)
	May be reactive (0.1 to 0.2%)			Hot (> 80°F)

RECOMMENDATIONS FOR FLY ASH PROPERTIES

Calcium oxide	Fineness	LOI	Replacement level
Low (<10%)	Coarse	Low (<2%)	Low (< 15%)
Moderate (10 to 20%)	Fine	Moderate (2 to 6%)	Moderate (15-30%)
High (>20%)	Fine ground	High (>6%)	High (30%-50%)
			Very high (>50%)

RECOMMENDEDATIONS FOR ADMIXTURES AND CURING

Admixtures	Curing
Air entraining agent	Wet - normal
Water reducer	Wet - extended
Set accelerating	Curing blanket /autogeneous curing

RECOMMENDATIONS FOR STANDARD TESTS (ASTM)

Fresh concrete	Hardened concrete	Mortar bar	Materials review
Slump (C 143)	Strength (C 39, C 78, C 469)*	ASR potential (C 1567)	Fly ash (C 618, C 311)
Air (C 138 or C 173)	Strength gain rate (C 39, C 78, C 469)*	ASR and deicer reactivity (Modified ASTM C 1567)	Aggregates (C 1260, C 1293, C 227, C 295, C 289)
Unit weight (C 138)	Hardened air voids (C 457)		Cement (C 150)
Set time (C 403)	Rapid freeze thaw (C 666)		
Bleed test (C 232)	Scaling resistance (C 672)		

COMMENTS AND OTHER CONSIDERATIONS

* Strength tests include ASTM C 39 for compressive strength, C 78 for flexural strength, and C 469 for elastic modulus.

1. The high replacement level might increase scaling potential. ASTM C 672 and C 666 are recommended for this level of replacement. If strength gain is a concern to meet opening strength requirements at this level, increasing the total cementitious content may also be considered.
2. The low LOI level is recommended, but the moderate level may be adequate to meet air void requirements.
3. Wet extended curing is recommended for the high replacement level.
4. Preferably use the low or moderate calcium oxide levels. For the high level examine tendency for rapid set, which may be retarded with the addition of gypsum to the mix. Mix optimization may be more involved in this case.

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SULFATE CHECK

SULFATE EXPOSURE	RECOMMENDATIONS			
	Cement type and Fly ash	Fly ash Oxide	Fineness	Additional Test Required
No	Follow recommendations from catalog for project conditions			None
Moderate	Type I with Class F ash or Type II	Low oxide only	Fine or fine ground	ASTM C 1012
Severe	Type II with Class F fly ash	Low oxide only	Fine or fine ground	ASTM C 1012