



# GUIDE TO IMPROVING SPECIFICATIONS FOR READY MIXED CONCRETE

**NRMCA Publication 2PE004-26**



WITH NOTES ON REDUCING  
EMBODIED CARBON FOOTPRINT,  
RESPONSIBLE SOURCING, LEED v5  
AND ENVISION

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# **GUIDE TO IMPROVING SPECIFICATIONS FOR READY MIXED CONCRETE**

**With Notes on Reducing Embodied Carbon Footprint, Responsible Sourcing, LEED v5 and Envision Version 3**

**2026**

## **FOREWORD**

This publication has been developed by the National Ready Mixed Concrete Association (NRMCA) and its members through the Research Engineering and Standards (RES) Committee. This document evolved based on comments developed when reviewing project specifications used in the concrete construction industry. This publication is intended as a guide for design professionals who develop project specifications and for ready mixed concrete and contractor personnel who are responsible for compliance with project specifications. This document proposes specification clauses and includes accompanying commentary as guidance. The commentary essentially emphasizes the fundamental concepts of specifications for ready mixed concrete addressed in industry standards published by ACI or ASTM International. Provisions of ACI CODE-318-25, *Building Code for Structural Concrete*, as it relates to requirements for concrete ingredient materials and mixtures, production and delivery, and acceptance of concrete supplied to projects are incorporated in this document. Requirements in this document are consistent with those addressed in ACI SPEC-301-20, *Specification for Concrete Construction*.

This publication uses the most recent version of the AIA MasterSpec format, Section 033000 for Cast-in-place concrete to provide context to the typical sections seen in project specifications of private design firms or owners. The document only covers those sections pertinent to concrete materials and mixtures. It does not include or discuss sections pertinent to reinforcement, formwork or other products and construction means and methods. This publication is not written as a guide or reference specification. The intent of writing this publication in this format is to provide advisory information to designers, contractors, concrete producers, and other stakeholders on a project to discuss the intent or for the designers to incorporate these suggestions. It is anticipated that this publication will be updated as standards evolve or with feedback, which is encouraged.

**Notes on Reducing Embodied Carbon Footprint, Responsible Sourcing, LEED v5 and Envision Version 3:** Items specific to these topics are listed in blue.

**Reducing Embodied Carbon Footprint of Concrete:** Concrete is unique among building materials. The composition of each mixture is highly influenced by its application. Design professionals and contractors have a greater influence on concrete mixture composition than they do with other building products. Concrete's mixture proportions have the greatest impact on carbon footprint of concrete supplied to projects. The specification by the design professional and the constructability needs of the contract impact the mixture proportions proposed by the concrete supplier. This guide provides recommendations for specifying concrete to meet specific carbon footprint reduction goals while still maintaining all the performance characteristics required for concrete on the project. It

provides guidance on how to establish a carbon budget for a building, the submittals required to demonstrate compliance and the recommended qualifications of concrete producers participating on a project that has a carbon reduction goal.

**Responsible Sourcing of Concrete:** Responsible sourcing integrates ethical, sustainable, and socially conscious principles into procurement and supply chain management. It ensures that transactions between buyers and suppliers are conducted in ways that minimize negative impacts on the environment, protect workers and communities, and promote transparency, accountability, and long-term value. In the concrete sector, producers — along with their two most critical upstream suppliers, aggregate producers and cement manufacturers — face growing pressure to document and verify that their products are manufactured responsibly. To address this challenge, the global concrete industry is advancing a comprehensive certification system through the Concrete Sustainability Council (CSC). The CSC Responsible Sourcing Certification is recognized in LEED and Envision for meeting responsibly sourced material requirements. Details can be found at [www.csc.eco](http://www.csc.eco). NRMCA is a Regional System Operator of the CSC certification for the U.S.

**LEED v5 and Envision 3.0:** Both LEED v5 and Envision Version 3 have credits for embodied carbon reduction and responsible sourcing.

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## Disclaimer

This publication is intended for the use of professional personnel, competent to evaluate the significance and limitations of its content, and who will accept responsibility for the application of the material it contains. The National Ready Mixed Concrete Association and the other organizations cooperating in the preparation of this publication strive for accuracy but disclaim any and all responsibility for application of the stated principles or for the accuracy of the sources.

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# Guide to Improving Specifications for Ready Mixed Concrete

## With Notes on Reducing Embodied Carbon Footprint, Responsible Sourcing, LEED v5 and Envision Version 3

2026

This list of contents is based on AIA MasterSpec. This publication only covers discussion on all or some of the articles in the sections identified in **bold** font relevant to ready mixed concrete.

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## SECTION 033000 – CAST-IN-PLACE CONCRETE

### PART 1 – GENERAL

- Referenced documents that are incorporated as part of this specification and Contract Documents need to be written in mandatory language. Referenced standards, such as ASTM standards, should include the date of adoption because they are revised often. In some cases, it may be necessary to reference version of standards referenced in the locally adopted building code.
- Non-mandatory language documents, such as guides, guide specifications, state-of-the-art reports or recommended practices should not be referenced in a project specification. Guide documents are written in non-mandatory language; they often have several alternative recommendations; and they often do not require any specific action. Referring to a Guide results in ambiguity in the specification. If the intent of a specific reference is not clear, enforcement of this intent is subject to interpretation and opinion. Many ACI documents such as ACI PRC-302, PRC-304, PRC-305, PRC-306, PRC-311, and PRC-347 are guide documents and are not written in mandatory language. These should not be included in the list of referenced standards section or referenced for compliance in the body of the specification. If there are specific items in these guides that the specification writer intends to use, these should be written into the specification in mandatory language so that the requirements and responsibilities are clearly defined.
- In general, referencing the Code, either an ACI Code or the locally adopted one, in the specification should be avoided unless design is delegated to a specialty engineer, typically hired by the contractor for portions of the work. The Code is written to the designer. Requirements in the Code applicable to the Project should be directly written in the specification. ACI CODE-318-25 states: *General references requiring compliance with the Code in the project specifications should be avoided since the contractor is rarely in a position to accept responsibility for design details or construction requirements that depend on a detailed knowledge of the design.* It is recognized that specific portions of the design can be delegated to a specialty engineer employed by the contractor – typical for precast concrete members, formwork, tilt-up construction, etc. Design-build projects also typically have responsibility for design and construction by the same entity. ACI 318 indicates that specifications and contract documents should contain all the necessary requirements to ensure that construction is in compliance with the Code. Ensuring compliance with the construction requirements of the Building Code is the responsibility of the design professional who is in a position to know the design requirements, detailing, and applicable exposure conditions for all concrete members. The applicable requirements should be stated in the project specifications.
- In 318-25, Chapter 26 collects all construction requirements that must be incorporated in construction documents as applicable to the project. The requirements are split into “design information” and “compliance requirements”. Design information includes project-specific requirements based on the design of the structure; compliance requirements are construction-related requirements to provide an acceptable level of construction quality. Requirements applicable to the project should be included in project specifications or drawings. A comprehensive list of Code-related requirements for concrete mixtures that must be addressed in construction documents is included in 26.4.2 of ACI CODE-318-25. Section 26.13 of ACI CODE-318-25 includes inspection requirements to be used in the absence of general building code inspection provisions. Inspection requirements are intended to provide verification that the Work complies with the construction documents. Inspection requirements of the governing jurisdiction or the general building code take precedence over those included in Section 26.13 of ACI CODE-318.
- Reference specifications, such as ACI SPEC-301, can be incorporated by reference in project specifications. The date of the referenced specification needs to be included. ACI construction specifications, such as ACI 301, has a mandatory requirements checklist that includes items that the design professional has to state in contract documents to make the reference specification complete. Do not copy individual sections, parts, articles, or paragraphs into the project specifications because taking them out of context may change their meaning. Do not refer to section numbers in a reference specification because of the loss of context and flow. ACI reference specifications, such as ACI SPEC-301, establish default requirements and have optional requirements checklists that advise the designer on alternatives. ACI reference specifications, such as ACI 301, permit the contractor to submit a written alternative to any requirement in the specification.

## 1.1 SUMMARY

### A. Section Includes:

1. Form-facing materials.
2. Form liners.
3. Insulating concrete forms.
4. Waterstops.
5. Steel reinforcement.
6. Welded-wire reinforcement.
7. Concrete standards.
8. Concrete materials.
9. Admixtures.
10. Fiber reinforcement.
11. Vapor retarders.
12. Floor and slab treatments.
13. Liquid floor treatments.
14. Curing materials.
15. Accessories.
16. Repair materials.
17. Concrete mixture materials.
18. Concrete mixture class types.
19. Concrete mixing.

### B. Related Requirements

*<Retain subparagraphs below to cross-reference requirements Contractor might expect to find in this Section but are specified in other Sections>*

1. Section 031000 “Concrete Forming and Accessories” – for form-facing materials, form liners, insulating concrete forms, and waterstops
2. Section 032000 “Concrete Reinforcing” – for steel reinforcing bars and welded-wire reinforcement.
3. Section 033300 “Architectural Concrete” – for general building applications of specially finished formed concrete.
4. Section 033543 “Polishing Concrete Finishing” – for floors scheduled to receive a polished concrete finish
5. Section 035300 “Concrete Topping” – for emery- and iron-aggregate concrete floor toppings
6. Section 321000 “Earth Moving” – for drainage fill under slabs-on-ground.
7. Section 321313 “Concrete Paving” – for concrete pavement and walks.
8. Section 321316 “Decorative Concrete Paving” for decorative concrete pavement and walks.
9. Section 018113 “Sustainable Design Requirements” for project goals, product requirements, and documentation

*<Provide list of reference standards as used in the following specification from standards setting organizations such as ACI, ASTM International, AASHTO, etc. Include the date of the standard in the document designation.>*

## 1.2 DEFINITIONS

- A. **Cementitious Material:** an inorganic material or a mixture of inorganic materials that sets and develops strength by chemical reaction with water by formation of hydrates and is capable of doing so under water. Cementitious materials include portland or blended cement alone, or in combination with supplementary cementitious materials.
- B. **Supplementary Cementitious Material (SCM):** inorganic materials that contributes to the properties of a cementitious mixture through hydraulic or pozzolanic activity, or both. SCMs include coal ash, slag cement, blended SCM, raw or calcined pozzolans, ground glass pozzolans, and possibly other materials that have been demonstrated to be reactive in a cementitious system.
- C. **Water-to Cementitious Materials Ratio ( $w/cm$ ):** ratio of mass of water, excluding that absorbed by aggregate, to the mass of cementitious materials in a mixture, stated as a decimal.

- Supplementary cementitious materials (SCM) are reactive materials that contribute to concrete performance for strength or to improve durability. Fly ash has been broadened to include bottom ash from burning coal in power plants and material harvested from associated landfills or impoundments – hence the term “coal ash”. Ground glass pozzolans are finely ground powders typically from container glass. There are several natural pozzolans that are available in the market. SCMs should comply with one of the ASTM specifications. Inert fillers, such as finely ground limestone, calcium carbonate or other minerals, if not a component of a blended cement, are not considered to be SCMs or part of the cementitious materials.
- All cementitious materials, including portland and blended cements, and supplementary cementitious materials are included in the calculation of  $w/cm$
- The mixing water content in a mixture includes batch water (water weighed or metered at a plant), ice, free moisture on aggregates, wash water retained in the mixer before batching, water added at the jobsite or by an automated truck mixer system, and water introduced from admixtures if the quantity added increases the  $w/cm$  by more than 0.01 (ASTM C94/C94M)

- D. **Embodied Carbon:** is the carbon dioxide equivalent ( $CO_2e$ ) footprint of a building or infrastructure project before it becomes operational. Embodied carbon is distinct from operational carbon — the carbon that comes from energy, heat, lighting, etc. during the use phase. Embodied carbon is expressed as Global Warming Potential. Typically, the embodied carbon is the initial embodied carbon which only accounts for cradle-to-gate impacts.
- E. **Global Warming Potential (GWP):** is the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of carbon dioxide. GWP is 1 for  $CO_2$ . For other gases it depends on the gas and the time frame. GWP for concrete is expressed in kg of  $CO_2e$  per unit of concrete (cubic yard or cubic meter) and most commonly over a 100-year time horizon.
- F. **Environmental Product Declaration (EPD):** quantifies environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function. EPDs are developed in accordance with a Product Category Rule for the specific product being evaluated. (International Organization for Standardization) standards ISO 14025 and ISO 21930 provide requirements for EPDs.
- G. **Product Category Rules (PCR):** are a set of rules, requirements, and guidelines for developing Environmental Product Declarations (EPD) for one or more product categories. The PCR for Concrete is published by NSF International.

- H. Life Cycle Assessment (LCA): is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service.
- I. Responsible Sourcing: is a strategy for procuring products and services that are produced sustainably and responsibly. It encompasses environmental stewardship (reducing CO<sub>2</sub> emissions, resource efficiency, biodiversity, circular economy), social responsibility (health & safety, human rights), governance (business ethics, transparency, legal compliance), and economic resilience.

### 1.3 SUSTAINABLE DESIGN GOALS

*<Retain subparagraphs below if the project has a carbon reduction goal and indicate if the project is designed to meet the owners embodied carbon reduction requirements, and/or LEED requirements, and/or Envisions requirements.>*

#### A. Embodied Carbon Footprint Goals

1. This project is being designed to meet the owner's requirements for embodied carbon footprint reduction detailed here \_\_\_\_\_. *<provide link to a website or provide summary of requirements>*
2. This project is being designed to achieve LEED v5 requirements for embodied carbon reduction MRp2 Quantify and Assess Embodied Carbon, a pre-requisite and MRc2 Reduce Embodied Carbon, worth up to 6 points.
3. This project is being designed to achieve LEED v5 MRpc182 Procurement of Innovative Low-embodied Carbon Concrete, worth 1 point.
4. This project is being designed to achieve Envision Credit CR1.1 Reduce Net Embodied Carbon worth up to 20 points.

*<Retain the subparagraph below indicating there is an-embodied carbon footprint reduction goal on the project and for concrete. Define the target for GWP for concrete in Section 2.>*

5. This project has a goal of reducing the embodied carbon footprint relative to a benchmark or typical project. Specific targets for Global Warming Potential (GWP) for concrete are provided in Section 2. The benchmark for concrete is established based on the NRMCA Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete Version 3 (or later). It shall be permitted to propose innovative products and manufacturing processes for approval by the Engineer of Record. Proposed alternatives shall meet all performance criteria for strength, durability, and constructability, and achieve the required reduction in carbon footprint.

*<Retain subparagraph below if the project is being designed to meet Envision credit CR1.1 Reduce Net Embodied Carbon as a way to ensure the overall carbon footprint of the concrete plant(s) is also reduced in addition to the concrete on the project.>*

6. The concrete on the project shall be supplied by a concrete plant(s) certified by the Concrete Sustainability Council at the Silver, Gold or Platinum Level with CO<sub>2</sub>-Module Score 1, 2, 3 or 4 Stars.

- To aid the contractor in understanding the project goals for embodied carbon reduction, list the project owner's embodied carbon reduction goals or policies and/or if the building project is pursuing LEED certification and/or if the infrastructure project is pursuing Envision certification.
- By establishing upfront that the project has a carbon reduction goal, it provides the concrete contractor and producer indication that they should develop mix designs that not only meet the typical performance criteria for concrete, such as strength, durability and other physical properties, but they should also take into account

concrete mixtures with lower carbon footprint than typical concrete mixtures. It also encourages the use of innovative products and processes to meet these goals. Recognize that the compilation of data and information for submittals on carbon footprint reduction and test data complying with the specification may require substantial lead time. It may also impact the cost of the proposed products.

- The NRMCA document listed in Item 5 above is published by NRMCA to establish benchmark mixtures with industry average impacts for various common concrete mixtures. This document was developed by NRMCA using a third party verified Cradle-to-Gate Life Cycle Assessment. Armed with this information, one can conduct a Whole Building LCA to determine and compare the embodied impacts of the concrete of a benchmark building using typical concrete mixtures with typical amounts of SCMs, and a proposed building using concrete mixtures with strategies to meet the carbon reduction goal.
- There may be other documents that use the same rigorous statistical methodologies and LCA principles to establish benchmarks for GWP and other impacts. These could be developed by other organizations such as state and local ready mixed concrete associations, or federal, state and local government entities that could be used as substitutes for the NRMCA benchmarks. Substitute those documents in this section, when applicable, and elsewhere in this specification to be used as the basis for embodied carbon budget determination. NRMCA provides a Concrete Carbon Calculator tool that can be useful to establish project goals by designers and for producers to evaluate if their mix designs achieve project goals. This is available at [www.nrmca.org/sustainability](http://www.nrmca.org/sustainability).
- The Envision rating system permits concrete that meets the Concrete Sustainability Council certification Silver or above with CO<sub>2</sub>-Module as a way to ensure the concrete plant's overall carbon footprint is reduced in addition to the concrete supplied on the project.

*<Retain subparagraphs below if the project has a responsible sourcing goal and indicate if the project is designed to meet the owners responsible sourcing requirements, and/or LEED requirements, and/or Envisions requirements.>*

## B. Responsible Sourcing Goals

1. This project is being designed to meet the owner's requirements for responsible sourcing detailed here \_\_\_\_\_. *<provide link to a website or provide summary of responsible sourcing requirements>*. The concrete on the project shall be supplied by concrete plants certified by Concrete Sustainability Council at the *<select which level>* [**Bronze or Silver Level or above**] [**Gold or Platinum Level**].
2. This project is being designed to achieve LEED v5 requirements for responsible sourcing Multi-Attribute Structure, Enclosure, Hardscape, and Other Building Materials Project Priority Credit, MRpc181, worth up to 2 points. The concrete on the project shall be supplied by concrete plants certified by Concrete Sustainability Council at the *<select which level>* [**Bronze or Silver Level**] [**Gold or Platinum Level**] *<select module>* [**CO<sub>2</sub>-Module Score 1 Star**] [**CO<sub>2</sub>-Module Score 2, 3 or 4 Star**]
3. This project is being designed to achieve Envision Credit RA1.1 Support Sustainable Procurement Practices worth up to 12 points. The concrete on the project shall be supplied by concrete plant(s) certified by Concrete Sustainability Council at the Gold or Platinum Level.
4. This project is being designed to achieve Envision Credit RA1.2 Use Recycled Materials worth up to 16 points. The concrete on the project shall be supplied by concrete plant(s) certified by Concrete Sustainability Council at the Silver, Gold or Platinum Level with R-Module Score 1, 2, 3 or 4.

- To help the contractor in understanding the project goals for responsible sourcing, list the project owner's responsible sourcing or sustainable procurement policies and/or if the building project is pursuing LEED certification and/or if the infrastructure project is pursuing Envision certification.

- Responsible sourcing encompasses environmental stewardship (reducing CO<sub>2</sub> emissions, resource efficiency, biodiversity, circular economy), social responsibility (health & safety, human rights), governance (business ethics, transparency, legal compliance), and economic resilience. Concrete companies can demonstrate excellence by being certified through the Concrete Sustainability Council.
- Responsible sourcing of concrete is demonstrated by meeting the requirements of the Concrete Sustainability Council Responsible Sourcing certification detailed in *Concrete Sustainability Council Technical Manual – Version 3.0* (or later) found at <https://www.csc.eco>. There are 4 levels of CSC certification depending on the percentage of criteria achieved in the certification program and the level of supply chain (cement, aggregate, etc.) certification. Bronze and Silver certification can be achieved by a concrete plant alone, without supply chain (cement and aggregate) certification. Requiring Gold or Platinum certification will require cement and aggregates suppliers are also CSC certified. Select which level of certification the producer must meet. The owner’s responsible sourcing policies, LEED, and Envision have different requirements. There are two additional modules available in the CSC certification, CO<sub>2</sub>-Module and R-Module, each with Score of 1, 2, 3 or 4 Stars depending on the level of achievement.

## 1.4 PREINSTALLATION MEETINGS

- A. Conduct a pre-installation meeting **[at Project site] [by web conference]** at least **[period]** before first placement **<Insert location>**.
1. Attendees: Installers, fabricators, representatives of manufacturers, ready mixed concrete producers, inspectors, testing agency for field tests. Notify attendees and Construction Manager, Structural Engineer, Contractor’s superintendent, independent testing agency, ready mixed concrete producer, concrete subcontractor of scheduled meeting dates.
  2. Review the following:
    - a. Concrete mixtures – specification and constructability requirements
    - b. Scheduling and details for placement
    - c. Contact information of responsible persons during placement
    - d. Placement procedures and rate of placement
    - e. Jobsite adjustments permitted and decision process
    - f. Cold and hot weather requirements
    - g. Concrete protection
    - h. Concrete inspection and field quality assurance
    - i. Testing frequency, and sampling location, define sampling procedures if not covered in referenced standards
    - j. Initial curing of standard-cured and field curing of field-cured test cylinders (ASTM C31/C31M.)
    - k. Initial curing facilities and site access for strength test and other specimens
    - l. Protection of field-cured cylinders and intent of results
    - m. Distribution of test reports

- There are several other topics that should be addressed at these meetings. The list only includes important topics relative to ready mixed concrete.
- NRMCA and American Society of Concrete Contractors have published the *Checklist for the Concrete Pre-Construction Conference*. A preinstallation meeting is essential for major and/or complex concrete installations. Decisions made should be documented and distributed to stakeholders. These meetings help minimize misunderstandings, allow for a review of specification requirements or project conditions and facilitate resolution of problems during construction. Contact information of all stakeholders should be exchanged to facilitate seamless communication and address contingencies during construction.
- Acceptance testing, if not performed in accordance with the standards, is often a problem that can cause delays to project schedules to address low strength test results. Details regarding facilities for initial curing and

the responsibilities (and associated cost) to comply with standard curing requirements (maintaining specimens in the required temperature range without loss of moisture) should be clarified at the preconstruction meeting.

- It is recommended that these meetings be scheduled at least 30 days prior to each major class of concrete placed. Multiple meetings may be required.

## 1.5 ACTION SUBMITTALS

*<Action submittals are submittals requiring responsive action and return of reviewed documents to Contractor.>*

### A. Product Data for each product used for concrete mixtures:

- “Action submittals” are those representing products or materials that require review and approval by the A/E. “Informational submittals” (Sec 1.6) are used to represent compliance with contract requirements that are not within the scope of work for the project. This type of submittal includes items like warranties, quality control certifications, and information to support the work, but is not part of it. Informational submittals are usually kept as record documents and typically do not require a response from the designer.
- Product data for materials used in concrete typically represent mill test reports and can include additional information or test results required by the specification.
- New products are being developed that may not fit in one of the traditional concrete material categories. If the project is incorporating sustainable design, then innovative products should be encouraged to meet low-embodied carbon goals.

### B. Concrete Mixtures: For each concrete mixture, submit the following:

1. Mixture Identification relative on member to be constructed
2. Type and source information on concrete materials proposed for use including:
  - a. Cementitious Materials
  - b. Aggregates
  - c. Mineral Fillers
  - d. Admixtures
  - e. Water
  - f. Fibers – steel, synthetic microfiber, synthetic macrofiber, if applicable
  - g. Color pigments, and
  - h. Other additions
3. Specified compressive strength,  $f'_c$ , at 28 days or other age as specified for each class of concrete
4. Compressive strength required at stages of construction
5. Required average compressive strength,  $f'_{cr}$ , for each class of concrete
6. Documentation of strength test records of similar class of concrete used to establish standard deviation in accordance with ACI 301, when test records exist
7. Documentation of compliance with  $f'_{cr}$  of proposed mixture(s) and test age
8. Durability exposure classes for Exposure Categories F, S, W, and C.
9. Maximum  $w/cm$  – the lowest value as required by the assigned exposure classes.
10. Nominal maximum aggregate size or Size number (ASTM C33) of coarse aggregate
11. Target slump or slump flow
12. Air content of concrete assigned to Exposure Classes F1 and F2
13. Equilibrium density of lightweight concrete and associated density of fresh concrete
14. Cementitious materials and documentation of tests or service for concrete assigned to Exposure Class S1, S2, and S3

15. Documentation on chloride content of concrete mixtures for conformance to limits in Exposure Class C – calculated total chloride or measured water-soluble chlorides by ASTM C1218/C1218M, expressed as a percentage of cementitious materials.
16. Documentation on alkali aggregate reactivity for concrete assigned to Exposure Class W1 or W2, as specified
17. Intended placement method
18. Equilibrium density of lightweight concrete and correlated density of fresh concrete, if specified
19. Documentation supporting other specified requirements of concrete mixtures
20. Intended placement method
21. Adjustments to proposed mixtures when characteristics of materials, Project conditions, weather, test results, or other circumstances warrant changes.

- These submittal items are drawn from a list that the designer must include in construction documents related to concrete mixtures from Section 26.4 in ACI 318-25. These are related to Code requirements for concrete mixtures for strength and durability. Some additional items are included. Some of these items may not be applicable to a specific project and should be modified based on project requirements. In a performance-based specification some of these prescriptive items would be replaced by performance-based requirements. Details regarding acceptance criteria of performance-based requirements should be stated in this specification.

- Mixture proportioning process of establishing required average strength based on the specified strength and the documentation for proposed concrete mixtures is covered in Article 4.2.3 of ACI 301.
- ACI 301 establishes the required average strength,  $f_{cr}$ , for a concrete mixture proposed for the project to be established based on:

1. *Strength test record exists:* In this case, the standard deviation from a strength test record of a similar class of concrete produced under similar conditions is used to calculate the required average strength. The specified strength,  $f_c$ , of the similar class should be within 1000 psi of that for the proposed Work. The strength test record cannot be more than 24 months old and has to have been collected over a period not less than 45 days.

2. *Strength test record does not exist:* If there is no strength test record of a similar class of concrete, the required average strength,  $f_{cr}$ , is established by adding a fixed value to the specified strength,  $f_c$ . The increment varies from 1000 psi to  $(1.1 f_c + 700)$  psi depending on the level of  $f_c$ .

Case 2 results in a larger value for the required average strength than Case 1. A fixed over-design value should not be specified as a default requirement for establishing  $f_{cr}$ . Establishing the required average strength based on the standard deviation is preferred if a strength test record for that class of concrete exists. The use of an unnecessary higher level of required strength should be avoided as it can cause unintended consequences related to higher heat of hydration (due to a higher quantity of cementitious materials) and increased shrinkage that increase the potential for cracking and curling of concrete slabs.

If Case 2 is used to establish  $f_{cr}$  to start a project, the designer should permit a reduction of the level of strength after at least 15 strength tests are collected and the standard deviation of that test record is used to indicate that a lower required average strength can be used. This requires a submittal of the revised mixture proportions to achieve the reduced level of average strength.

- The concrete supplier submits information on the proposed concrete mixture documenting that it will achieve the established required average strength and other specification requirements. This can include:
  1. *Field data:* Field test records of at least 10 consecutive strength tests of the proposed class of concrete documenting the strength equals or exceeds the established  $f_{cr}$ , including documentation that it meets other specification requirements. This test record can be different from that used to determine the standard deviation. It should be permitted to interpolate information from two sets of field test records of similar classes of concrete to establish the water-cementitious materials ratio or cementitious material content for the classes of mixtures for proposed Work.

2. *Laboratory trial mixture data:* ACI 301 permits the concrete supplier to interpolate using three or more trial mixtures varying w/cm or cementitious materials content to arrive at the proportions of the proposed mixture. Laboratory trial mixtures can be used even if the  $f'_{cr}$ , was established using the standard deviation method to document that the proposed mixture will satisfy the specified requirements. It is also acceptable to document the characteristics of a proposed mixture by producing a batch of at least 3 cu. yd. in the concrete production facility. Laboratory trial batch evaluation should not be required when a satisfactory field test record exists.

ACI 318-25 requires that trial mixture data should have been developed within 24 months of submittal. The time restriction for test records applies only to strength tests. Some durability tests require a longer lead time and older data should be considered acceptable if similar materials are used.

- The specification should not require laboratory trial batches to be prepared by an independent laboratory. The concrete supplier should have the option to use an independent lab if they do not have in-house facilities. If the concrete supplier has laboratory facilities, documentation of concrete mixtures for submittals is best accomplished in those facilities. The concrete supplier is most familiar with the ingredient materials used and the ability to optimize their use to develop mixture proportions for a mixture submittal. Ultimately the acceptance criteria on a project govern. An inappropriate submittal represents a significant risk to the concrete supplier and the project.
- A guide to submittal of concrete mixture proportions is provided in ACI 211.5R. A recommended format is in Appendix B of this document.
- If the specification includes performance-based requirements, the submittal information should be pertinent to compliance with the performance requirements of the specification. Documentation of concrete material quantities and other details of mixture proportions may not necessarily indicate such compliance. A certification of concrete mixtures signed by a professional engineer and test record and other prequalification performance data linked to the mixture designation should suffice as the submittal to the design professional. It is appropriate to require information about the concrete materials to demonstrate compliance with applicable material specifications. Development of optimized performance-based mixtures involves significant cost and effort by concrete producers, and the resultant mixtures represent their proprietary intellectual property. Public disclosure of such information can impact their competitiveness. If mixture proportions of performance-based concrete are required to be submitted because of contractual requirements, this information should be retained by the owner's representative under a confidentiality agreement with the producer.
- The designer's review of the submittal of concrete mixtures for compliance with the project requirements should be the responsibility of the engineer of record or a qualified delegate.
- Review of the submittal could include verification that the concrete mixture certification is signed and sealed by a licensed engineer; include documentation that demonstrates compliance with certified requirements; and includes specific properties that can be verified during construction. These can include slump or slump flow, air content, density, temperature or other properties. Some of these can be used as indicators that the mixture delivered is similar to that in the submittal. The density of fresh concrete is a good measure of batch-to-batch uniformity and is useful for detecting batching errors.
- The submittal can include anticipated changes to mixtures for seasonal changes – this can include minor changes in material quantities (stated as a range), or changes in admixture types and dosage.
- Some of the fresh concrete properties should be selected by the contractor and producer unless it is specifically required by the design professional for approving the construction means and methods. These characteristics can include slump and its adjustment, setting characteristics, finishability characteristics, characteristics for pumping mixtures, air content adjustments to accommodate placement methods, etc. The designer should avoid specifying a slump requirement as it might impact the ability to place the concrete. ACI 301 indicates slump selection by the contractor and the established value be documented in the submittal. Characteristics of fresh concrete recommended by the contractor, such as slump, may be used as a measure of consistency of concrete furnished to the project.
- (Item 12) The required air content of concrete depends on anticipated exposure of the concrete member and the nominal maximum size of the coarse aggregate. Air content should be as required for the applicable

Exposure Class for Exposure Category F. It is permitted to reduce the air content by 1 percentage point from the table values for specified strength equal to or exceeding 5000 psi. This recognizes that air content results in a greater reduction of strength for higher strength and can increase the content of cementitious materials to achieve the required strength. Additionally, higher strength concrete has reduced porosity, which reduces its potential for becoming saturated with water that affects freeze thaw resistance. Exterior vertical members can be assigned to Exposure Class F1 that requires a lower air content because these are unlikely to become saturated in service. The commentary of ACI 318-25 provides guidance on assignment of exposure classes F1 and F2 to different types of members.

- (Item 14) For Exposure Category S, besides using cementitious materials listed in ACI 318-25 Table 19.3.2.1, mixtures with SCMs that improve sulfate resistance as documented by previous service record or ASTM C1012 results are permitted.
- (Item 15) Water-soluble chloride limits are stated on the basis of total cementitious material content. Compliance with the chloride limits can be done by either the calculated chloride content based on the chloride content of constituent materials (if known) and mixture proportions; or a water-soluble chloride content measured in accordance with ASTM C1218/C1218 at an age of 28 to 42 days.
- (Item 16) Documentation for alkali-silica reactivity can include test results indicating that the aggregates proposed for use are non-reactive. If aggregates are reactive, mitigation may include using a minimum quantity of coal ash, natural pozzolans, or slag cement as determined by testing in accordance with ASTM C1567 or the calculated alkali content in the concrete in lb./yd<sup>3</sup> can be documented to be less than specified limits provided in ACI 301. Only the alkali from portland cement (including limestone components in portland and portland limestone cements) of the concrete mixture is used in this calculation. More detail on alkali aggregate reactivity is covered in guide ASTM C1778.
- Consider defining the period of time for retention of batch records of individual concrete deliveries for forensic purposes (3-5 years from delivery date). Ready mixed concrete companies have internal policies for retention of records.
- The contractor might have requirements for uniform setting characteristics of deliveries of concrete batches. These requirements can be established by the producer and concrete contractor along with a means to verify this requirement. This can impact the changing types and dosage of admixtures depending on environmental conditions.
- The concrete producer may need to make adjustments to concrete mixtures during the course of a project. This may be due to changes in material characteristics, ambient or other project conditions, when strength tests fail the acceptance criteria or when trends indicate a potential for failure. The designer may require that these adjustments have to be submitted for acceptance. Alternatively, if the concrete producer anticipates changes in conditions throughout the project, they could submit mix design(s) with ranges of material quantities that meet all the project requirements to avoid resubmittals. However, in many cases, it is difficult to anticipate all potential changes in conditions and if changes to mixtures are made, documentation will have to be resubmitted.

## 1.6 INFORMATIONAL SUBMITTALS

*<Informational submittals are submittals that require review by Architect, but they do not require Architect's responsive action and return of reviewed documents to Contractor, provided submittals comply with requirements. If rejected, submittals with responsive action must be returned to Contractor.>*

### A. Research Reports

1. Products with ICC evaluation
2. Performance data for ASTM C494 Type S admixtures

*<Coordinate "Qualification Data" Paragraph below with qualification requirements in Section 014000 "Quality Requirements" and as supplemented in "Quality Assurance" Article. If inserting additional entities or specialists, add qualifications in "Quality Assurance" Article.>*

B. Qualification Information

1. Installer: Include copies of applicable ACI Certificates

*<Retain subparagraph below if Contractor retains testing agency for field quality control.>*

2. Testing agency retained by the contractor for field quality control: Include conformance to ASTM C1077 or ASTM E329 and copies of ACI certificates of testing technicians

C. Qualification Statements: for **[delegated design engineer] [testing and inspection agency]**

D. Concrete Mixture Certification:

1. Documentation of test results indicating compliance with specified requirements for each concrete mixture
2. Identity characteristics of each mixture that will be used for quality assurance during construction

- Research Reports could include ICC evaluation reports or other reports of concrete materials that may not comply with available specifications or special properties needed of concrete mixtures for projects.
- For performance-based specifications where mixture submittals do not include proportions of mixtures, certification of concrete mixtures by an independent licensed engineer indicating compliance with specification requirements may be appropriate. This review can cover documentation of test data for different requirements for all classes of concrete. It can reduce some of the documentation in action and informational submittals traditionally required by the project design professional. Review of these details would be accomplished by the independent engineer.
- Several performance requirements for durability, volume change, and some mechanical properties of proposed concrete mixtures would be accomplished using pre-qualification testing. The process should indicate some identity characteristic of the different concrete mixtures that can be reliably measured when concrete is delivered for the purpose of quality assurance. This would not replace longer term testing of samples obtained at the jobsite, such as for strength at different ages.

*<Retain "Material Certificates" Paragraph below to require submittal of material certificates from manufacturers. Revise list to suit Project.>*

E. Material Certificates: For each material provided by the material supplier

1. Cementitious materials
2. Aggregates
3. Ground calcium carbonate or mineral filler
4. Admixtures
5. Fiber Reinforcement

*<Retain "Material Test Reports" Paragraph below for material test reports that are the Contractor's responsibility. Include the list of required evaluations needed for Project.>*

F. Material Test Reports: For the following, from a qualified testing agency

G. Floor surface flatness and levelness measurements report, indicating compliance with specified tolerances.

H. Preconstruction Test Reports: For each concrete mixture as specified

I. Field quality-control reports

J. Minutes of preinstallation meetings

*<Retain subparagraph below if the project has an embodied carbon reduction requirement, and/or LEED v5 MRp2 Quantify and Assess Embodied Carbon and/or MRc2 Reduce Embodied Carbon and/or Envision Credit CR1.1 Reduce Net Embodied Carbon.>*

K. Embodied Carbon Footprint Submittals

1. Product specific Environmental Product Declaration (EPD) for each concrete mixture proposed for the project accompanying each concrete mixture submittal

*<Retain subparagraph below if Industry Average EPDs are permitted.>*

- a. It shall be permitted to substitute plant-specific EPDs with those listed in NRMCA Member Industry Average EPD for Ready Mixed Concrete if the proposed mixtures are similar to those listed and the concrete producer participated in providing data for the NRMCA Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete.
2. A calculation showing that the total Global Warming Potential (GWP) of all the concrete supplied for the project is lower than the GWP target set in Section 2.

*<Retain Subparagraph below for LEED v5 MRpc182 Procurement of Innovative Low-embodied Carbon Concrete for each unique class of concrete which applies.>*

- L. Evidence that a novel binder or aggregate – cementitious, pozzolanic, or aggregate materials (i.e. LC3 cement, glass, volcanic, etc.) was used for at least 15 cy on structural concrete and least 30 cy for non-structural concrete and calculations that shows an overall Global Warming Potential value of 20% better than NRMCA Member Regional LCA Benchmark Industry Average or international equivalent.

*<Retain Subparagraph below for Envision Credit CR1.1 Reduce Net Embodied Carbon if this a requirement on the project listed in Section 1.1.>*

- M. Evidence that the concrete on the project is supplied by concrete plant(s) certified by the Concrete Sustainability Council at the Silver, Gold or Platinum Level with CO<sub>2</sub>-Module Score 1, 2, 3 or 4 Stars.

- For each concrete mixture, supply a product specific EPD from a specific plant. An EPD includes several environmental impacts including GWP. GWP reported in the EPD should be used as the basis for calculating the embodied carbon footprint for the building.
- In some cases, the concrete mixtures proposed for use on the project are similar to those listed in the NRMCA Member Industry Average EPD for Ready Mixed Concrete. In those case, concrete producer may identify those mixtures from the Industry Average EPD in lieu of product-specific EPDs. Consider permitting Industry Average EPDs on small projects in remote areas where the cost of product-specific EPDs is not justified.
- The calculation showing that the GWP of the concrete supplied for the building is lower than the target carbon budget shown in Section 2 can be achieved using sophisticated LCA software or quantified by the following equations:

$$GWP_{\text{actual}} = \sum_{i=1}^n [GWP_{\text{actual } i} \times VOL_i]$$

$$GWP_{\text{benchmark}} = \sum_{i=1}^n [GWP_{\text{benchmark } i} \times VOL_i]$$

$$R_{\text{gwp}, \%} = (GWP_{\text{benchmark}} - GWP_{\text{actual}}) / GWP_{\text{benchmark}} \times 100$$

Where:

$GWP_{\text{actual}}$  = Total global warming potential of all concrete mixtures proposed for use on project

$GWP_{\text{benchmark}}$  = Total global warming potential for industry average benchmark measurement index

$GWP_{\text{actual } i}$  = global warming potential for individual (i) concrete mixtures proposed for use on project for mixture

$GWP_{\text{benchmark } i}$  = global warming potential for industry average benchmark measurement index for individual concrete mixture class representative of proposed individual mixture (i)

n = number of classes of concrete mixtures for benchmark and mixtures proposed for use on project

$R_{\text{gwp}, \%}$  = Reduction in GWP

$VOL_i$  = Volume of concrete for concrete mixture class (i).

- NRMCA has a Concrete Carbon Calculator tool that can accomplish these calculations and provide a report that can be used as the submittal. NRMCA also has examples of how the tool is used to accomplish the calculations. Both the tool and examples can be found at [www.nrmca.org/sustainability](http://www.nrmca.org/sustainability).

*<Retain subparagraph below if the project has a responsible sourcing requirement.>*

#### N. Responsible Sourcing Submittals

1. Copy of the certificate from the Concrete Sustainability Council that the plant(s) supplying concrete on the project are certified at the *<select which level depending on the level of certification required in Section 1.1>* **[Bronze or Silver Level or above] [Gold or Platinum Level]** with **[CO2-Module Score 1, 2, 3 or 4 Stars] [R-Module Score 1, 2, 3 or 4 Stars]**.

## 1.7 QUALITY ASSURANCE

A. **Installer Qualifications:** A qualified installer who employs Project personnel qualified as an ACI-certified Concrete Flatwork Associate and Concrete Flatwork Finisher and a supervisor who is a certified ACI Advanced Concrete Flatwork Finisher/Technician or an ACI Concrete Flatwork Finisher with experience installing and finishing concrete.

1. **Post-Installed Concrete Anchors Installers:** ACI-certified Adhesive Anchor Installer

- Flatwork finisher certification is important for constructing slabs on grade, however, general standard of care of concrete construction is addressed in this certification program. ACI Flatwork Finisher certification is a requirement in ACI 301. Review the levels and criteria for ACI Flatwork certification at [www.concrete.org](http://www.concrete.org).
- The concrete contractor can be required to submit a quality control plan that outlines activities and procedures to minimize problems on the project.

B. **Ready Mixed Concrete Manufacturer Qualifications:** A company experienced in manufacturing ready mixed concrete products and that complies with ASTM C94/C94M requirements for production facilities and equipment.

1. Concrete shall be supplied from concrete plants with current certification under the NRMCA Certification of Ready Mixed Concrete Production Facilities, certification or approval by a state or highway agency or equivalent. Criteria of equivalent certification shall be included in the submittal.
2. Quality Control personnel with responsibility for concrete mixtures shall document qualifications demonstrating knowledge and experience with concrete technology and development of performance-based concrete mixtures. certified as an NRMCA Concrete Technologist Level 2, or equivalent. Details covered in equivalent certification program shall be documented in the submittal.
3. When requested, the manufacturer shall furnish a Quality Plan.

- NRMCA certified concrete production facilities demonstrate compliance with requirements of ASTM C94 relative to production and delivery of ready mixed concrete. The certification includes an annual inspection and certification of delivery vehicles by inspectors approved by NRMCA. The certification of the production facility is valid for 2 years from the date of the inspection. Proper procedures for handling and storage of concrete ingredient materials that are important for product quality are also verified through the NRMCA Certification program. An equivalent state transportation department's plant approval or a company possessing ISO 9001 certification are acceptable alternatives.
- Industry programs can be considered for qualifications of ready mixed concrete personnel responsible for review of specifications and development of mixtures for performance-based and other specifications. ACI has the Concrete Quality Technical Manager certification. NRMCA has the Concrete Technologist Certification Program Levels 2, 3, and 4 that validates a person's knowledge of fundamentals of concrete technology, including mixture proportioning and concrete durability. Other NRMCA certifications pertinent to concrete quality include the Concrete Plant Operator certification for batch plant operators and the Concrete Delivery Professional certification for mixer truck drivers. For more information visit [www.nrmca.org/certifications](http://www.nrmca.org/certifications).
- NRMCA has developed a guideline for development of a quality plan. The document, along with a sample quality plan is available at [www.nrmca.org/quality](http://www.nrmca.org/quality). Quality plans are encouraged on larger projects as a means to improve production consistency, potentially yielding improvements to overdesign which can impact sustainability measures. Improved production quality often directly results in improved sustainability as less overdesign of concrete mixtures is needed.

*<Retain subparagraph below if the project has an embodied carbon reduction requirement.>*

4. Documentation that the concrete supplier participated in supplying data to the NRMCA Cradle-to-Gate Life Cycle Assessment of Ready-Mixed Concrete.

- If industry-wide NRMCA benchmarks are used, producers should have participated in the LCA report to be able to compare their product specific EPD results to the industry benchmarks. A list of companies that participated in the industry average benchmark report is provided at [www.nrmca.org/sustainability](http://www.nrmca.org/sustainability). NRMCA has a program in place where producers can retroactively participate in the Industry-Wide EPD and benchmark report.
- There may be other documents that use the same rigorous statistical methodologies and LCA principles to calculate benchmark and average GWP and other impacts. These could be developed by other organizations such as state and local ready mixed concrete associations, designer groups, or federal, state and local government entities that could be used as substitutes for these documents. Substitute those documents in this Section and elsewhere in this specification to be used as the basis for embodied carbon budget determination.

*<Retain subparagraph below if the project has a responsible sourcing requirement.>*

5. Documentation that the concrete plant(s) supplying concrete on the project are certified by Concrete Sustainability Council at the *<select which level as specified in Section 1.1>* [Bronze or Silver Level or above] [Gold or Platinum Level] with [CO<sub>2</sub>-Module Score 1, 2, 3 or 4 Stars] [R-Module Score 1, 2, 3 or 4 Stars].

- To demonstrate compliance, a concrete producer can submit a copy of the CSC certificate for the plant(s) supplying concrete on the project.
- There are 4 levels of CSC certification depending on the percentage of criteria achieved in the certification program and the level of supply chain (cement, aggregate, etc.) certification. Bronze and Silver certification can be achieved by a concrete plant alone, without supply chain (cement and aggregate) certification. Requiring Gold or Platinum certification ensures that cement and aggregates suppliers are also certified. Select which level of certification the producer must meet. The owner's responsible sourcing policies, LEED and Envision have different requirements. There are two additional modules available in the CSC certification, CO<sub>2</sub>-Module and R-Module, each with Score of 1, 2, 3 or 4 Stars depending on the level of achievement.

C. Testing Agency Qualifications: An independent testing agency [**acceptable to authorities having jurisdiction**] qualified in accordance with ASTM C1077 and ASTM E329 for testing indicated.

1. Personnel performing laboratory tests to be an ACI Concrete Strength Testing Technician or ACI Concrete Laboratory Testing Technician – Level I, or equivalent. Testing agency laboratory supervisor tests to be an ACI-certified Concrete Laboratory Testing Technician, Level 2.
2. Test results for the purpose of acceptance shall be certified by a registered design professional employed with the Testing Agency.

D. Field Quality-Control Testing Agency Qualifications: An independent testing agency [**acceptable to authorities having jurisdiction**] qualified in accordance with ASTM C1077 and ASTM E329 for testing indicated.

1. Personnel performing field tests on fresh concrete properties are to be qualified as an ACI Concrete Field Testing Technician Grade I in accordance with policies from ACI CPP 610.1, or an equivalent certification program.

- ACI 318, ACI 301, and ASTM C94 require that testing agencies contracted to perform acceptance testing should comply with ASTM C1077. Compliance with ASTM C1077 can be a documented laboratory inspection

by organizations such as the Cement and Concrete Reference Laboratory (CCRL) or accreditation by the AASHTO Accreditation Program (AAP). These programs involve a thorough evaluation of laboratory equipment, procedures, personnel qualifications, and certifications and require participation in reference sample testing program to assure proficiency of testing. Other national, local, or regional evaluation authorities also perform inspection and accreditation functions to verify conformance to ASTM C1077. This standard establishes the requirements and criteria for evaluating the proficiency of testing laboratories involved in testing concrete and aggregates. The standard defines certification requirements for field and laboratory personnel of the testing agency.

- Results of concrete testing are sensitive to how specimens are fabricated, cured, handled, and tested. Procedural requirements for acceptance testing are addressed in ASTM C94/C94M and the referenced standard practices and test methods. Field and laboratory procedures that conform to established standards are essential to achieving reliable results. Deviations from standardized procedures will most often result in unacceptable results that increase project costs and delay schedules. Hence, technician certification is essential. Equivalent certifications to ACI should include a component whereby the technician physically demonstrates the performance of the test method and practices, and written examination on the content of the applicable standards.
- Improved testing accuracy prevents excessive overdesign of concrete mixtures which would impact performance, sustainability, and cost.

## 1.8 PRECONSTRUCTION TESTING

A. Preconstruction Testing Service: Engage a qualified testing agency or accept testing reports from the concrete supplier to perform preconstruction testing on each concrete mixture.

1. Include the following information in each test report

- a. Admixture dosage rates
- b. Density
- c. Slump
- d. Air content
- e. 7-day and 28-day compressive strength

*<Retain subparagraph below if the project requires a test placement of mockup.>*

- f. Results of test placement or mockup
- g. Other information as needed for the Project

- Many ready mixed concrete companies have well equipped laboratory facilities and can perform most of the common tests on concrete and concrete materials. A separate testing agency should not be required if the laboratory can perform mixture development and most of the standard test methods. The company may choose to contract any testing or specific special tests to an independent testing agency to perform.

## 1.9 DELIVERY, STORAGE, AND HANDLING

A. Comply with ASTM C94/C94M and ACI SPEC-301.

- ACI SPEC-301 includes several defaults preceded with “unless otherwise specified” that the specifier can modify by reviewing the Optional Requirements Checklist. There are several project-specific requirements that have to be addressed. The specifier should review the Mandatory Requirements Checklist and address these items to ensure that the reference to the ACI reference specification is complete.

## 1.10 FIELD CONDITIONS

A. Cold-Weather Placement: Comply with ACI SPEC-301:

B. Hot-Weather Placement: Comply with ACI SPEC-301 and ACI SPEC-305.1

- There could be some conflicts between cold weather and hot weather requirements in ACI 301 and ACI specifications for hot weather concreting (ACI SPEC-305.1). Review these ACI specifications for differences if they are invoked. Guidance for hot and cold weather concrete construction are addressed in the respective guides developed by these committees (ACI PRC-305 for hot weather, and ACI PRC-306 for cold weather). The guides should not be referenced in a specification.
- For placement in cold weather, ACI 301 includes minimum concrete temperature as delivered based on minimum section dimension: 55°F if less than 12 in.; 50°F between 12 to 36 in.; 45°F between 36 to 72 in.; and 40°F if greater than 72 in. Temperature of embedded items, including bars with cumulative cross-sectional area less than 4 in<sup>2</sup>, and formwork should be greater than 10°F. Temperature of ground, base, or mud mats should be at 32°F or greater before concrete is placed.
- For placement in hot weather, ACI 301 requires that temperature of reinforcement, embedments, or formwork should be less than 120°F.

## PART 2 – PRODUCTS

### 2.10 CONCRETE STANDARDS

A. Comply with ACI 301 unless modified by requirements in the Contract Documents

### 2.11 SOURCE LIMITATIONS

- A. Obtain all concrete mixtures from the same ready mixed concrete manufacturer for entire Project.
- B. Use cementitious materials, aggregates, and admixtures of the same type or class and from the same sources as materials used in concrete represented by submitted concrete mixtures.

- Many specifications include a clause requiring a single source of materials for the duration of the project. It is sometimes not practical to use single sources of materials for the duration of the project. Even single supply sources of materials vary over time and in periods of high demand there may be some changes in point sources of manufacture of cement or the collection of supplementary cementitious materials (SCMs) such as coal ash, slag cement, silica fume and other materials.
- Cement companies and suppliers of supplementary cementitious materials attempt to control the uniformity of products shipped to the concrete producer. It is also the responsibility of the concrete supplier to make minor changes to concrete mixture proportions to address these material source variations. These minor adjustments should not typically require re-submittals. The designer should permit minor adjustments as needed and could define the level of adjustments that would need a re-submittal.
- Single source is appropriate for architectural concrete and concrete producers will generally isolate a sufficient supply of such materials for the duration of a project.

### 2.12 SUSTAINABILITY REQUIREMENTS

*<Retain subparagraph below if the project has an embodied carbon reduction requirement.>*

- A. Develop concrete mixtures to meet all performance criteria for strength, durability, workability, finishability and other physical properties such that the total GWP of all proposed concrete on the project is less than or equal to \_\_\_\_\_ kg of CO<sub>2</sub>e or a weighted average of \_\_\_\_\_ kg of CO<sub>2</sub>e/yd<sup>3</sup>.

- The design professional should establish a target for GWP, or a carbon budget for all the concrete on the project. Examples of how to establish a carbon budget can be found at [www.nrmca.org/sustainability](http://www.nrmca.org/sustainability). The concrete supplier and contractor then can work together to provide concrete mixtures that have GWP such that the total GWP for all the concrete supplied for the project will be lower the target established here. See Section 1.5 for details on how the contractor demonstrates that the concrete supplied has lower GWP than the target. An example of this calculation of determining target GWP or Target weighted average GWP/yd<sup>3</sup> is illustrated in Table below

Member	Est. Volume, yd <sup>3</sup>	Benchmark GWP, per yd <sup>3</sup>	Benchmark Total GWP	Target GWP, per yd <sup>3</sup>	Target Total GWP	Reduction, %
Foundation	4,000	289	1,156,000	210	840,000	27%
Slabs	5,000	306	1,530,000	260	1,300,000	15%
Columns and Walls	1,000	349	349,000	275	275,000	21%
<b>Total</b>	<b>10,000</b>	<b>304</b>	<b>3,035,000</b>	<b>242</b>	<b>2,415,000</b>	<b>20%</b>

## 2.13 CONCRETE MATERIALS

### A. Regional Materials:

### B. Indigenous Materials:

### C. Cementitious Materials: Materials conforming to the following are permitted:

1. Portland Cement: ASTM C150/C150M,
2. Blended hydraulic cement: ASTM C595/C595M, excluding Type IS (>70) and Type IT (S>70)
3. Hydraulic cement (performance): ASTM C1157/C1157M
4. Coal Ash: ASTM C618/C618M
5. Natural Pozzolans: ASTM C1945
6. Slag cement: ASTM C989/C989M
7. Silica Fume: ASTM C1240/C1240M
8. Blended Supplementary Cementitious Materials: ASTM C1697
9. Ground Glass Pozzolan: ASTM C1866/C1866M
10. Supplementary Cementitious Materials: ASTM C1912

- ASTM C150 is the specification for portland cement that defines 4 types. Type I is for general use; Type II is for moderate sulfate resistance – this cement type is more common; Type III is a high early strength cement, typically used by the precast industry; Type V is a high sulfate resistance cement that is typically limited in its availability to regions that need higher level of sulfate resistance.
- ASTM C595 is a specification for blended cements that include SCM and/or limestone, and defines 4 essential types: Portland-pozzolan cement - Type IP(X) with pozzolan such as coal ash or calcined clay, Portland blast-furnace slag cement - Type IS(X) with granulated blast furnace slag, Portland-limestone cement - Type IL(X) with limestone; and Ternary blended cement – Type IT (AX) (BY) that contains 2 of pozzolan, slag, or limestone. The quantity of the blended material is indicated by the value X in the type designation (In Type IT, X is the content of first product A, and Y is the content of the second blended product B). There are maximum limits to the quantity of the blended components in the blended cement – pozzolan max 40%; limestone between 5 and 15%. Slag can be blended up to 95%. The specification establishes different requirements for blended cement containing more than 70% (S>70). These blended cements are not permitted by ACI 318 for structural concrete.  
Revisions to C595 will continue to evolve: Blended Types IP and IS can contain up to 15% limestone; Type IT is permitted to contain 2 SCMs in addition to 15% limestone; A new Type IC (composite) cement is approved to accommodate limestone calcined clay (LC3) cements or other products with no specific limits on the blended components but including a minimum portland cement clinker content of 30%.  
Blended cements can be qualified for special properties at the option of the user – MS (moderate) and HS (high) sulfate resistance; (HE) for high early strength.  
Because of attempts to reduce the carbon footprint of cement, and eventually of concrete, blended cement, primarily portland-limestone cement, has increased in availability to replace traditionally used portland cement. In many markets, portland cement is not available to concrete producers. A specification should not require the use of a default or specific cement type.  
Concrete producers can use additional SCMs with blended cement to meet strength and durability requirements. For projects that have a sustainability goal for reduced embodied carbon, blended cements and separately added SCMs can reduce the carbon footprint of concrete. Requiring a specific cement type or setting limits on cement or SCM content in concrete mixtures for sustainability goals should be avoided in a specification as these could impact achieving performance and constructability requirements.
- ASTM C1157 is a performance specification for cement that does not restrict its composition but establishes requirements in terms of performance tests. There are 6 different types – GU for general use; MS and HS for sulfate resistance; HE for high early strength; and MH and LH for lower heat of hydration. ASTM C1157

cements are not commonly available, but could be used to qualify innovative cementitious products. Some cements that comply with C150 or C595 are listed as complying with C1157.

- If there is no pertinent durability concern such as sulfate resistance or concerns with excessive heat build-up, do not restrict the specific type of hydraulic cement. In most cases the predominant cement used by a concrete supplier will be ASTM C150 Type II, ASTM C595 Types IL, IP, or IS, or ASTM C1157 Type GU. Other cement types or optional provisions of cement standards are generally invoked for durability concerns, high early strength, or reduced heat of hydration.
- Several specifications for SCMs are listed ASTM C618 is evolving to only include coal ash, Class F and Class C (where CaO exceeds 18%), depending on the burned coal source. Natural pozzolans are covered in ASTM C1945 – raw or calcined varieties are available in different markets (Natural pozzolans are currently identified as Class N in C618; but the intent is to eventually remove this class from C618).  
ASTM C989 is a specification for slag cement, derived from granulation of slag, a byproduct from iron blast furnace. Grades of slag 80, 100, and 120) are established based on relative strength compared to control cement mortar, reported as the strength activity index. Slag cements available in the US are generally classified as Grade 100 or 120.  
ASTM C1240 is a specification for silica fume, a very fine pozzolanic material derived as a byproduct from the manufacture of silicon or ferro-silicon metal.  
ASTM C1697 permits the blending of SCMs that conform to the applicable specification.  
ASTM C1912 was developed as a performance-oriented specification to primarily cover pozzolanic and cementitious materials that do not fall in the scope of the other SCM specifications.  
ASTM C1866 covers ground glass pozzolans with two types – GS derived from soda-lime-silica glass used for containers and GE derived from remnants of glass fiber manufacturer. Type GS glass pozzolan typically has a higher alkali content.
- Avoid limiting the type or minimum and maximum quantities of SCMs like coal ash, slag cement, silica fume or other SCMs, as this may limit the performance of concrete. SCMs provide many benefits to the mechanical and durability properties of concrete. Further, the use of SCMs supports sustainable construction and can be used to reduce the embodied carbon content of concrete. The concrete supplier may need to work with the contractor to establish limits on the type and quantity of SCM for constructability reasons. Such limitations will be indicated in a submittal. ACI 318-25 has eliminated Exposure Class F3 from previous version of the Code that set maximum limits on the quantity of SCMs. These limits on SCMs have been eliminated from the Code and should not be specified.
- Consideration should be given to not restrict coal ash only to Class F. In many parts of the country good quality Class C coal ash is also available. In some regions good quality natural pozzolans, such as calcined clay or other naturally extracted and sometimes processed materials are available. Avoid invoking limits on the loss on ignition (LOI) of coal ash to less than that in reference specifications. ASTM C618 has a LOI limit of 6%. Most coal ashes that are commercially available will not comply with a lower specified LOI limit, so in effect this will restrict its use. Avoid including limits on the available alkali of coal ash. ASTM has recognized that the available alkali does not have a good correlation to the performance of coal ash or its ability to mitigate alkali aggregate reactions and has deleted this limit from the specification.
- Note that concrete producers will not generally stock more than one or two types of SCMs. The project specification will need to address local availability and experience. Requiring the use of material that is not locally available will increase cost and could cause problems due to unfamiliarity with its use. There may be increased environmental impacts from transporting materials that aren't locally available.
- Silica fume is mostly available in a densified powder form and batched in bags or bulk. Avoid specifying minimum (such as 10%) or maximum quantities of silica fume. Using higher quantities of silica fume can lead to stickiness and increased tendency for early age cracking unless additional precautions are taken during construction (see ACI 234R). There are synergies on concrete strength, permeability and ASR mitigation when coal ash and/or slag cement are used in combination with lower quantities of silica fume.
- Separately batched SCMs can be used with blended cements. Mixtures containing 3 or more cementitious materials are also used. The specification should not restrict these uses or place limits on separately added SCMs to mixtures using blended cement.

D. Normal-weight Aggregate: Coarse and fine aggregate that conform to ASTM C33

1. Coarse Aggregate: ASTM C33/C33M *<indicate ASTM C33 Class A through E if applicable>*
2. Nominal maximum size of coarse aggregate: *<indicate the size as per design requirements for each class of concrete>*
3. Fine Aggregate: ASTM C33/C33M

- ASTM C33 is the specification for aggregates that can be used in concrete. It addresses requirements for coarse and fine aggregates and sets limits on grading, deleterious materials, and other requirements. Coarse aggregate grading is defined by Size number with grading limits for each size fraction and defines the maximum size and nominal maximum size of the aggregate. Size restrictions on coarse aggregate should be based on clear cover and spacing of reinforcing steel and minimum dimension of members. ASTM C33 permits the use of aggregates that do not comply with its requirements when there is adequate documentation of the aggregate's use and performance in concrete. Local aggregates sources in some regions of the country will not comply with some requirements in ASTM C33 but will likely have a long history of successful use in those regions.
- ASTM C33 establishes Classes A through E for coarse aggregate depending on the type of concrete construction and the anticipated exposure in the region of use. These Classes establish maximum limits on the quantity of deleterious substances permitted in the coarse aggregate source.
- Combined aggregate grading requirements such as Coarseness Factor - Workability Factor charts or other criteria are good concrete mixture optimization tools that can be used by the concrete producer when appropriate for the application and if the aggregate sources available make this possible. Including these as specified requirements should be avoided as they are generally not verifiable or enforceable. The goal of optimizing the combined aggregate grading is to reduce the void content between aggregates to allow for a reduction of the volume of cementitious paste. If the volume of cementitious paste is not reduced (possibly due to other requirements) with optimized aggregate grading, it defeats the purpose. With some aggregate sources this will improve workability and reduce shrinkage and cracking. However, studies have shown that there is no assurance that a requirement for combined aggregate grading criteria will result in reduced mixing water content or reduce shrinkage as is typically intended. If the intent is to control shrinkage – a shrinkage limit using ASTM C157 can be specified. This information can be included in the submittal.
- Use of aggregate that does not meet a coarse aggregate gradation size number within ASTM C33 but would otherwise meet all the other coarse aggregate requirements of C33 can be considered. This is often necessary when the concrete producer needs to optimize the grading of available local aggregates. This has the potential to improve concrete performance and such supporting documentation of concrete performance can be included in the submittal. The scope section of ASTM C33 has language that allows for this.

*<Retain subparagraph 4 below if the project permits the use of recycled aggregate>*

4. Recycled Aggregate: Provide documentation of characteristics of recycled aggregate and mechanical properties and durability of proposed concrete, which incorporates recycled aggregate to conform to applicable requirements for the class of concrete.

- The concrete producer can typically use recycled crushed concrete aggregate derived from concrete returned to the plant. There are various options to develop recycled concrete aggregate by using admixtures, or crushing the discharged concrete after it has hardened. Recycled aggregate can be used as the coarse fraction, as a percentage of the total aggregate, or other. ACI 318 informs the designer that they should specifically approve the use of recycled aggregate based on documentation indicating that the required mechanical properties and durability are achieved for the members where this concrete is used and that there is a quality control activity to verify the consistency of the aggregates used. See 26.4.1.2.1(c). ACI PRC-555 and ACI PRC-221 provides guidance on use of recycled aggregates. Recycled aggregate may help achieve sustainability goals.

5. Alkali Silica Reactivity: Comply with one of the following for each aggregate used:

- a. Expansion Result of Aggregate: Not more than 0.04 percent at one year when tested in accordance with ASTM C1293; Alternatively, not more than 0.10 percent at 14 days in solution when tested in accordance with ASTM C1260.
- b. Expansion Results of Aggregate and Cementitious Materials in Combination: Not more than 0.10 percent at 14 days in solution when tested in accordance with ASTM C1567. Do not use this option with coal ash, ground glass pozzolan, or natural pozzolan with an alkali content greater than 4.0 percent. Submit supporting data for each aggregate showing expansion in excess of 0.10 percent when tested in accordance with ASTM C1260.
- c. Alkali content in concrete: Not to exceed 4 lb./yd<sup>3</sup> for aggregate with expansion greater than or equal to 0.04 percent and less than 0.12 percent; or 3 lb./yd<sup>3</sup> for aggregate with expansion greater than or equal to 0.12 percent and less than 0.24 percent. Aggregate expansion results are as tested in accordance with ASTM C1293. Calculate alkali content of concrete in accordance with ACI SPEC-301. Do not use this option with natural pozzolan or coal ash that has a calcium oxide content greater than 18 percent or an alkali content greater than 4.0 percent; or for an aggregate with expansion at one year greater than or equal to 0.24 percent when tested by ASTM C1293.

- For alkali aggregate reactivity and associated deterioration, service records of aggregate in a region should be used with caution. Changes in aggregate sources and other ingredients in concrete can change the performance characteristics of concrete relative to alkali aggregate reaction. However, if there are no visible signs of ASR distress in exterior structures in a region, it could be considered when establishing specification requirements for ASR.
- Mitigation measures for alkali aggregate reactions are pertinent to structural members that will be wet in service (Exposure Class W1 and W2) and when there is a history of deleterious ASR cracking in the region. There is considerable guidance on ASR. ASTM C1778, *Guide for Reducing Risk of Deleterious Alkali-Aggregate Reaction in Concrete*, is a comprehensive process of assessment of ASR and establishing prescriptive and performance-based requirements for mitigation. The options for ASR addressed in 5 are consistent with that in ACI 301 and are based on the guidance in ASTM C1778.
- ASTM C1260 is a severe test that has a high frequency of classifying non-reactive aggregates as being potentially reactive. If an aggregate source passes this test, there is a good likelihood that it will be non-reactive in service. However, there are few aggregate sources that will test to be non-reactive by this test and have shown ASR distress in structures. ASTM C1260 is commonly used because of its shorter testing duration.
- The more reliable test relative to field service performance is the concrete prism test, ASTM C1293, which requires 1-year for results to be obtained and does not suit most project schedules, unless such data already exists. ASTM C1293 evaluates the potential reactivity of aggregates (1-year test).
- ASTM C1567 is a standard test method for determining effectiveness of the cementitious materials with a source of potentially reactive aggregates in minimizing the potential deleterious expansive cracking due to alkali-silica reactivity (ASR) in the field. The test can be completed in 2 weeks. Generally, coal ash, slag cement, or other pozzolans are used in concrete mixtures as measures to reduce the risk of ASR in concrete. Higher quantities of SCMs typically results in improved mitigation but can impact early age strength. If the service records or tests indicate that the aggregate is potentially reactive, the concrete supplier can perform ASTM C1567 tests with different types and proportions of SCMs and choose that combination that results in a 14-day expansion less than or equal to 0.10%. For example, if the test result with 25% coal ash has an expansion equal to or less than 0.10% the concrete supplier should use at least 25% of that coal ash in the concrete mixture.
- An alternative option for ASR is to limit the total alkali content of the concrete mixtures, from the portland cement. ACI 301 includes limits of to 3 or 5 lb./yd<sup>3</sup> depending on the degree of reactivity of the aggregate based on expansions in either ASTM C1260 or ASTM C1293. Using a low-alkali cement is not considered a

reliable means of mitigating deleterious expansion due to ASR. ASTM C150 has removed the optional criteria that defines a “low-alkali” cement. See ACI PCR-221.2 for more information. Concrete alkali limits are stated (in this section above) based on expansions when tested by ASTM C1293. For aggregate expansions determined in accordance with C1260, refer to ASTM C1778 for limits on concrete alkali content.

- Other prescriptive alternatives to mitigate ASR, requiring minimum quantities of coal ash or slag cement based on the risk level of the structure are addressed in ASTM C1778.
- In regions where sources of coal ash, natural pozzolans, slag cement, or blended cement are of characteristics that cannot mitigate ASR or are not available, the use of lithium-based admixtures is an option. Refer to ASTM C1778 for guidance on use of lithium admixtures or consult with the admixture supplier on dosage requirements.
- A minimum cementitious materials content is not needed for mitigating deleterious expansions due to ASR and could be impact the producer’s ability to achieve a reduction in alkali loading in the mixture.

E. Ground Calcium Carbonate or Aggregate Mineral Filler: ASTM C1797. Unless otherwise permitted, do not use mineral filler derived from carbonate sources in concrete for members assigned to Exposure Class S1, S2, or S3.

- Finely ground mineral filler composed from calcium carbonate or other quarried aggregate sources can be used to improve workability and reduce segregation of concrete mixtures. Mineral fillers are often used in self-consolidating concrete mixtures. These materials can provide beneficial improvements to hardened concrete properties. ASTM C1797 includes requirements for three types of mineral filler – A, B, and C. Types A and B are derived from carbonate rock with differences primarily in fineness. Type C can be derived from any aggregate material. At this time, ACI 318 restricts the use of carbonate-based mineral fillers from use in concrete that will be exposed to sulfates (Exposure Category S), until more evaluation and research is available. Mineral fillers are not cementitious materials and are not included when determining the  $w/cm$  of concrete.

F. Lightweight Aggregate: ASTM C330/C330M <specify nominal maximum aggregate size>

1. Lightweight aggregate for internal curing shall be prewetted lightweight fine aggregate in accordance with ASTM C1761/C1761M

G. Heavyweight Aggregate: ASTM C637/C637M <specify nominal maximum aggregate size>

H. Water: ASTM C1602/C1602M

- ASTM C1602 includes provisions for using potable water and water from non-potable sources. This standard allows for alternative sources of water with appropriate testing and qualification. Documentation of such qualification can be requested in a submittal. The project specification should avoid restricting mixing water to only potable sources. Use of non-potable water and water from concrete production operations facilitates innovative concrete producers who have progressed to advanced environmental management systems to reuse recycled water from concrete production operations or from other sources. This supports sustainable construction initiatives.
- ASTM C1602 includes optional limits on concentration of sulfates, chlorides and alkalis and additional optional limit on total solids. These limits should be individually invoked when applicable.

## 2.14 CONCRETE ADMIXTURES:

A. Air-Entraining Admixture: ASTM C260/C260M

B. Chemical Admixtures; ASTM C494. Do not use calcium chloride or admixture containing chlorides in steel-reinforced concrete

1. Water-Reducing Admixture ASTM C494/C494M Type A
2. High-Range Water-Reducing Admixture: ASTM C494/C494M Type F or G
3. Accelerating Admixture: ASTM C494/C494M Type C or E

4. Retarding Admixture: ASTM C494/C494M Type B or D
5. Extended Set-Retarding Admixture: ASTM C494/C494M Type B or D
6. Workability-Retaining Admixture: ASTM C494/C494M Type S
7. Shrinkage-Reducing Admixture: ASTM C494/C494M Type S
8. Viscosity Modifying Admixtures: ASTM C494/C494M Type S
9. Alkali-Silica Reaction Inhibiting Admixture: ASTM C494/C494M Type S
10. Other admixtures with special properties with documentation of claimed performance enhancement, ASTM C494/C494M Type S
11. Corrosion-Inhibiting Admixture: ASTM C1582/C1582M
12. Color Pigment: ASTM C979/C979M

Admixtures that do not conform to an existing specification shall be used with the permission of the engineer of record when its use for specific properties is required.

- Avoid limiting the types of admixtures that can be used unless there is a specific reason.
- Set control admixtures should be permitted in cold weather concreting. Chloride based admixtures should be avoided only for prestressed or reinforced concrete. Chloride based admixtures are very effective for controlling set time and allowing rapid construction schedules in plain concrete such as ground supported building slabs or lightly reinforced walls.
- Listing brand name products should be avoided. It is preferable to make a reference to a generic classification, such as “Water reducers conforming to ASTM C494 Type A”.  
A list of acceptable brand name products cannot be all inclusive; often brand names listed are dated and not available; the ready mixed producer may not have the specific product available due to regional differences or business relationships with an admixture supplier; using a product unfamiliar to the producer may result in a cement-admixture incompatibility; and controlling brands stifles innovation. There are situations where invoking a brand name may be appropriate when there is experience with its use or documented performance significantly exceeds specification requirements for admixtures.
- Limits on chloride ions for admixtures should not be specified. Instead specify appropriate chloride limits for concrete mixtures consistent with ACI 318 and ACI 301. Defining the Exposure Class in Section 2.21 accomplishes this. Limiting chloride concentration for admixtures does not protect against chlorides from other sources and the potential for corrosion or reinforcing steel in concrete. It is not necessary and may not be justified for economic reasons to restrict chloride ions in admixtures for concrete without structural reinforcement (plain concrete) or for concrete structural members that will be dry in service.
- Consider specifying or permitting the use of admixtures which do not have a specific ASTM designation with appropriate documentation indicating beneficial use to concrete properties. These may include color pigments, viscosity modifying admixtures, shrinkage reducing admixtures, hydration stabilizing admixtures, pumping aids, anti-freeze admixtures, alkali silica reactivity, etc. Documentation should satisfy the professional engineer on the product performance and service history. ASTM C494 Type S is a general classification intended to cover admixture products that provide a specific performance enhancement to concrete. The performance enhancement should be documented by appropriate testing.

## 2.15 FIBER REINFORCEMENT

- A. Carbon-Steel Wire Fiber: ASTM A820/A820M, Type 1 <specify length and aspect ratio if needed>
- B. Carbon-Steel Cut Sheet Fiber: ASTM A820/A820M, Type 2 <specify length and aspect ratio if needed>
- C. Synthetic Monofilament Micro-Fiber: ASTM C1116/C1116M, Type III <specify length if needed>

- D. Synthetic Fibrillated Micro-Fiber: ASTM C1116/C1116M, Type III <specify length if needed>
- E. Synthetic Macro-Fiber: ASTM C1116/C1116M, Type III <specify length and quantity if needed>

- ASTM D7508/D7508M addresses requirements for polyolefin-based synthetic fibers and includes requirements for chopped strands for micro, macro, and hybrid fibers including denier, finish content, tensile strength, and cut length.

2.20 CONCRETE MIXTURE MATERIALS

- A. Provide concrete mix designs for all required classes, types, and strengths, proportioned to comply with ACI SPEC-301 requirements and assigned exposure classes from ACI CODE-318.
- B. Admixtures: Use specific admixtures in concrete mixtures as indicated for different classes. Use admixtures in accordance with manufacturer’s instructions
- C. Color Pigment: Use color pigment in accordance with manufacturer’s instructions. If specified, color of hardened concrete should match approved mockup.

2.21 CONCRETE MIXTURE CLASS TYPES

- A. Requirements for different classes of concrete mixtures for different locations or structural members shall be as follows:

<provide a schedule for different classes of concrete required for the structure. Include detailed requirements pertinent to exposure classes in accordance with ACI 318. Include performance-based requirements as an alternative to prescriptive requirements as needed for the Project.>

Class	Location	Nominal Max. Aggregate Size	Exposure Classes	$f'_{c}$ , psi @ age	Max w/cm	Slump or Slump Flow	Air Content	Water-soluble Chlorides

- Provide a schedule of concrete types (classes) for all components of the structure including the pertinent exposure class from ACI 318 based on anticipated exposure conditions for each location in the structure. When the exposure does not apply indicate the “\*0” class for that exposure category. The definition of exposure classes and the pertinent requirements for concrete as per ACI 318-25 are provided in Appendix A. The exposure categories include:
  - Category F – Exposure to cycles of freezing and thawing
  - Category S – Exposure to water soluble sulfates in soil or water
  - Category W – Concrete in contact with water
  - Category C – Conditions requiring corrosion protection of reinforcement.
- For clarity it is recommended to state the requirements pertinent to the governing exposure classes in the project specification as the contractor and concrete supplier may not be familiar with code-defined exposure classes and requirements. Ensure that the specified strength,  $f'_{c}$ , is consistent with the most restrictive requirement governed by structural design and the applicable exposure class for each class of concrete.

- The engineer should minimize prescriptive requirements on concrete mixtures and construction means and methods and increase the focus on measurable performance attributes when appropriate. The inclusion of both prescriptive and performance requirements in the specification can lead to inherent conflicts. It is unreasonable for a concrete producer to be held responsible for performance attributes implied (but not clearly stated) from prescriptive requirements.
- Nominal maximum aggregate size and specified compressive strength must always be indicated. Nominal maximum size of coarse aggregate should be in accordance with ACI 318 – 26.4.2.1 Aggregates. The nominal maximum size of aggregate pertains to restrictions of minimum section thickness, spacing of reinforcing steel and clear cover. Permitting the largest nominal maximum size is recommended for economy and reduced volume change characteristics. It should be ensured that the aggregate size is available locally. Using a large aggregate size can be difficult to handle during concrete production relative to control of segregation.
- Indicate strength as “specified strength” using notation  $f_c$  consistent with industry terminology. The strength acceptance criteria are based on this specified strength. This is the strength that the engineer uses in structural design. The higher of the specified strength required for durability criteria and design loads will apply. If the specified strength required by durability criteria governs, the design engineer should take advantage of that strength level when designing structural members.
- In general, specified strength for concrete applies at an age of 28 days. In some cases, it is necessary or appropriate to specify a strength requirement at an earlier or later age. For post-tensioned construction an early age strength requirement may be necessary. For high strength concrete when service loads are not anticipated to be applied until much later, it may be appropriate to use a later age, such as 56 or 90 days, for the specified strength. This allows for more optimized concrete mixtures without using excessively high cementitious materials content. Higher cement content can increase potential for cracking from shrinkage and thermal effects. It also increases cost and negatively impacts sustainability goals. Specifying later age strengths such as 56-days, 90-days for members that won’t be loaded until a later age can reduce carbon footprint of the mixture.
- The specified compressive strength requirement for the durability exposure classes is an attempt at matching the strength to the required water to cementitious materials ratio. This is because, in most cases, strength can be more easily verified by strength tests. The engineer should avoid indicating a specified strength that is significantly lower than what might be expected for a specified w/cm, for example 3000 psi and a 0.40 w/cm. A concrete mixture at a 0.40 w/cm will result in a strength level in excess of 6000 psi. The strength acceptance criteria do not work for this type of specification. There is no reliable method to verify the w/cm of samples of concrete obtained at the jobsite.
- Maximum w/cm, air content, cement type are controlled by exposure classes. Avoid specifying these requirements if they are not applicable to the anticipated service conditions of the structural members. Including a maximum w/cm for concrete where it is not essential can adversely affect the ability to place and finish concrete and the concrete performance because of possibly increased paste content, elevated concrete temperature, and increased propensity for cracking. Only specify w/cm where required by ACI 318 exposure criteria.
- Refer to water to cementitious materials ratio (w/cm) instead of water to cement ratio (w/c). SCMs are cementitious materials and should be included in the calculation of w/cm. Referring to a water-cement ratio based on the mass of only portland cement is misleading and contrary to industry practice as defined in ACI, ASTM, FHWA and all state departments of transportation.
- Unless there are specific design-related implications, the design professional should allow leeway to the contractor and manufacturer on the characteristics of fresh concrete to accommodate construction means and methods and ambient conditions.
- The engineer should avoid specifying a maximum or target slump as it may impact constructability. It is recommended that the slump should be selected by the contractor and concrete supplier based on the placement and finishing requirements of the concrete. This is the way slump is addressed in ACI 301. The target slump can be provided to the engineer of record in the submittal and can be used as a basis for quality assurance. Realize that with today’s concrete technology, slump is not a measure of quality or water content,

but it can be used as a determining factor of the batch-to-batch uniformity. If the engineer chooses to specify slump it should be specified as a target limit, where the appropriate  $\pm$  tolerances in ASTM C94/C94M will apply. A maximum slump limit is appropriate for slip form applications. Specifications for slump should not be set at a certain level before addition of water reducing admixtures with a subsequent limit after the addition. It is not possible to verify this type of requirement. Admixtures have evolved so that they are generally added at the concrete plant with better control rather than delegating this responsibility to mixer drivers at the jobsite. With the use of water reducing admixtures, slump cannot be taken as a representation of the quantity of water in the mixture.

- The contractor might have requirements for uniform setting characteristics of deliveries of concrete batches. These requirements can be established by the producer and concrete contractor along with a means to verify this requirement.
- The specification should avoid specifying minimum contents for cementitious materials. ACI 318-25 or ACI 301-20 do not include any requirement for minimum cementitious materials content. There is no technical reason to include minimum cementitious materials content for other structural elements provided the performance requirements are achieved. In some cases, these are specified for slabs requiring a hard-trowelled finish. However, minimum cement contents may not assure adequate finishability of floor slabs. These issues can be resolved between the concrete supplier and the contractor, more reliably than an expectation by imposing a limit on cementitious materials.
- For projects with a sustainability goal, a maximum cement content should not be specified for concrete mixtures. Cement content requirements vary considerably for constructability, early strength and other properties and should not be limited based on design strength of structural members. For sustainability goals, one option is to establish a carbon budget for all concrete on a project. This permits tradeoffs between mixtures used to satisfy different types of member design requirements – where concrete for a foundation that can achieve strength at later ages can be at a lower carbon footprint than a post-tensioned member that needs to achieve strength at an early age. Alternatively, reduction in carbon footprint relative to typical mixtures or industry benchmarks could be used.
- Do not restrict the minimum or maximum percentage of SCM unless there is a particular requirement in local building codes. ACI CODE-318-25 does not impose limits on SCMs. The concrete producer should be permitted to optimize SCM content based on strength, durability enhancement, and required characteristics for plastic concrete during placement and curing.
- It is recommended that the specification should not include restrictions on the quantity of SCMs, such as “1.2 pounds of coal ash replacement per pound of cement”. This is not a technically sound approach as the coal ash or SCM content as a percent of the cementitious materials will vary for strength targets at different ages, climatic conditions, use of admixtures, cement and SCM sources. This also increases the volume of paste in concrete and can increase the shrinkage. The concept of “replacement” of portland cement with SCMs is deprecated. SCM content is always stated as a percentage of total cementitious material.
- It is recommended that the specification should not include a requirement to simulate field temperature and humidity for lab trial batches. It is impossible to anticipate or cover all potential situations. Lab trial batches are tested in accordance with standard procedures by ASTM C192 where laboratory temperatures of  $73 \pm 3^{\circ}\text{F}$  apply. If hot weather job concreting must be simulated in the laboratory the approach suggested in ACI 305 for lab trial batches could be adopted. The established acceptance criteria for the project will still apply.

#### **Exposure Category F – Freezing and Thawing**

- In accordance with ACI CODE-318-25, for concrete members that will be exposed to cycles of freezing and thawing, specify minimum specified compressive strength  $f'_c$  and maximum w/cm:  
Class F1 - 3500 psi and 0.55;  
Class F2 - 4500 psi and 0.45;  
The commentary of ACI 318 provides examples of concrete members (include in Appendix A) for assignment of appropriate exposure classes in Exposure Category F. Exposure Class F3 that was in ACI CODE-318-19 has been removed in the current version.

- Air content requirements for exterior concrete should be in accordance with the appropriate exposure class in ACI CODE-318-25. For exposure classes F2 where concrete is considered to be saturated in service, a higher air content is required. The air content requirements depend on the nominal maximum size of coarse aggregate. For specified compressive strengths equal to or greater than 5000 psi, the air content is permitted to be reduced by 1.0%. Entrained air content reduces strength and will need a higher cementitious materials content to achieve specified strength requirements.
- Many regions of the country do not need air-entrained concrete for exterior applications. In these regions there is often little experience with producing and finishing air-entrained concretes. For concrete not exposed to freezing conditions an air content requirement should not be specified.
- Building slabs or floors that receive a hard trowelled finish should not be air entrained. This causes a high likelihood of delaminations of the concrete surface. ACI SPEC-301 specifies that air content of concrete for slabs to receive a hard trowel finish should not exceed 3%.
- A minimum cementitious materials content is not needed for freeze thaw durability.
- If this exposure category does not apply, assign the exposure class F0 for this category.

**Exposure Category S** – Concrete in contact with water soluble sulfates in soil and water.

- The following methods are used to determine the concentration of water-soluble in soil and water from which the assignment of Exposure Class applies: ASTM C1580, *Standard Test Method for Water-Soluble Sulfate in Soil*, ASTM D4130, *Standard Test Method for Sulfate Ion in Brackish Water, Seawater, and Brine*, and ASTM D516, *Standard Test Method for Sulfate Ion in Water*.
- For concrete members in contact with water-soluble sulfate in soil or water, specify minimum specified compressive strength  $f'_c$  and maximum w/cm:  
Class S1 – 4000 psi and 0.50;  
Classes S2 and S3 (Option 1) – 4500 psi and 0.45.  
Class S3 (Option 2) – 5000 psi and 0.40 that permits the use of Type V and blended cement with HS designation (high sulfate resistance) with no additional SCMs.
- Permitted types of cementitious materials are addressed in ACI 318 and the design professional may choose to select one of the options or provide the choice to the contractor to document the sulfate resistant cementitious materials proposed for use in the submittal.
- ACI 318 also provides an alternative to the cementitious types when the proposed cementitious materials have been qualified by testing in accordance with ASTM C1012. ASTM C1012 is a standard test method for length change of hydraulic-cement mortars exposed to a sulfate solution. Since the duration of this test is quite long, this qualification will generally be available for cements complying with ASTM C595 – options MS and HS or ASTM C1157 Types MS and HS. Evaluation of SCMs for sulfate resistance is covered as optional requirements in the respective specifications. For Exposure Class S3, Option 2 permits a shorter time test (1 year) with a max w/cm of 0.40 and specified strength of 5000 psi. Suppliers of fly ash or slag cement might have these data documented when these materials are used in regions with higher sulfate content in the soil. Calcium chloride admixtures are not permitted for Classes S2 and S3. ASTM C1012 information is documented in a submittal and not used as a jobsite acceptance test.
- Sulfate resistance of Portland-limestone cement is evaluated by ASTM C452 – this is a shorter duration test of 14 days (compared to the months for C1012). ASTM C595 establishes levels of sulfate resistance MS and HS with expansion criteria using ASTM C452. Combinations of portland-limestone cement and SCMs must still be evaluated by ASTM C1012 and meet the applicable expansion criteria for different exposure classes.
- Note that exposure to seawater is considered to be a milder exposure at Exposure Class S1 even though the sulfate ion concentration is high. The more aggressive chemical species in seawater is considered to be chloride ions and some protection is afforded with higher aluminate ( $C_3A$ ) content in cements for this condition. Members exposed to seawater will need to be assigned to Exposure Class C2 because of the external source of chlorides. The w/cm and specified strength for C2 will govern.
- A minimum cementitious material content is not needed for exposure to water-soluble sulfates.

- If there is no exposure to sulfates, assign the exposure class S0 for this category.

**Exposure Category W** – Concrete requiring low permeability in direct contact with water but not exposed to freezing and thawing, sulfates, or chlorides

- This exposure category has limited application in building structures when the other categories do not apply. Some applications might be for water tanks or substructure elements constructed underwater.
- However, for members assigned to Exposure Classes W1 and W2 – in contact with moisture – the specification should include considerations for alkali-aggregate reactivity. See earlier discussion on this.
- When Exposure Class W2 applies the minimum specified strength  $f'_c$  is 4000 psi and maximum w/cm is 0.50.
- A minimum cementitious material content is not needed for exposure class W1 or W2.
- If exposure class W1 or W2 do not apply, assign the exposure class W0 for this category.

**Exposure Category C** – Conditions requiring corrosion protection of reinforcing steel

- The primary intent of exposure classes C0 and C1 are to control an internal source of chlorides in concrete. Additionally, in exposure category C2 the intent is to minimize the penetration of chloride ions from external sources to cause corrosion of reinforcement.
- Chloride ion limits for concrete mixtures are based on ACI 318. The chloride ion content, expressed as a percent by weight of cementitious materials, can be documented by a calculation of the total chlorides contributed by all materials in the mixture such that the calculated value is less than the water-soluble chloride limit. Alternatively, the water-soluble chloride content is measured on hardened concrete specimens in accordance with ASTM C1218 at an age between 28 and 42 days.
- In accordance with ACI 318, the minimum specified strength of 5000 psi and maximum w/cm of 0.40 are only applicable for reinforced concrete structural members that will be exposed to an external source of chlorides in service – exposure class C2.
- For concrete exposed to chlorides (bridge decks, marine structures, parking garages) it is well known that coal ash, slag cement, silica fume, and possibly other pozzolans can delay the initiation of corrosion by reducing permeability, with increasing levels typically leading to improved performance. However, it is not advisable to require prescriptive proportions of coal ash and slag cement to achieve the improved performance. Corrosion inhibiting admixtures provide additional protection by delaying the time to initiation of corrosion.
- A minimum cementitious material content is not needed for corrosion protection.
- If this exposure category does not apply, assign the exposure class C0 for this category.

- For exposure categories F, S, W, and C, ACI 318 includes prescriptive max limits on w/cm for concrete. A limit on w/cm is intended to reduce the permeability of concrete and improve its durability for these exposure conditions. In general, the permeability of concrete is impacted by both the w/cm and the composition of the cementitious materials. The singular limit on w/cm does not recognize benefits to improved durability provided by SCMs. An alternative performance-based approach may be considered by the designer.
- ASTM C1202 is a standard test method for rapid indication of concrete's ability to resist chloride ion penetration. This is an electrical method whereby the electrical charge passed, in coulombs, has been correlated to the "permeability" property of concrete. A lower charge passed represents reduced permeability. Prescriptive limits on quantities of coal ash, slag or silica fume dosage should be avoided. It is suggested that the engineer require at the time of submittal documentation qualifying the proposed concrete mixture by ASTM C1202 with a test value lower than a specific coulomb value at 28 or 56 days depending on curing method used. An accelerated curing procedure in the standard recognizes the benefits provided by coal ash and other SCMs. This conditions (cures) test specimens for 7 days in water at 73°F followed by 21 days of curing in 100°F water. If a standard curing procedure is used, the test should be conducted after a curing period of 56 days. This allows for the SCMs to demonstrate effectiveness in reducing permeability of concrete. Requiring this test should be as an **alternative** to specifying a maximum w/cm.

- Consider the use of ASTM C1202 to replace both the w/cm and  $f'_c$  with the following alternative criteria:
  - w/cm = 0.50 → 2500 coulombs (max)
  - w/cm = 0.45 → 2000 coulombs (max)
  - w/cm = 0.40 → 1500 coulombs (max)
- Note that ASTM C1202 test has a high testing variability and often technicians and laboratories are not proficient in sample care and testing required for reliable results. It is not advised to use this test for acceptance purposes unless a statistical approach is adopted. One such statistical approach is discussed in the article *Acceptance Tests for Concrete Durability* in the May 2007 issue of Concrete International. Strength acceptance criteria can be used for quality assurance, as is done for specified w/cm.
- A more recent test method to measure transport properties of concrete is to measure its resistivity in accordance with ASTM C1876. Concrete with a higher measured resistivity is more resistant to penetration of dissolved chemicals. Resistivity in the range of 80 to 120  $\Omega \cdot m$  is typically used (higher value represents reduced permeability). Resistivity is impacted by degree of saturation and the composition of the mixture and its pore solution. If this method is selected indicate that the specimens should be cured/conditioned in saturated limewater until tested – this is the preferred option (B) of the two described in ASTM C1876 and is consistent with the curing method used for specimens used to measure compressive strength.
- Consider the use of ASTM C1876 to replace both the w/cm and  $f'_c$  with the following alternative criteria:
  - w/cm = 0.50 → 75  $\Omega \cdot m$  (min)
  - w/cm = 0.45 → 90  $\Omega \cdot m$  (min)
  - w/cm = 0.40 → 120  $\Omega \cdot m$  (min)

B. For members where control of curling or reduction in the potential for cracking is required and as designated in Contract documents, submit data on the length change characteristics of the concrete mixture tested in accordance with ASTM C157. Perform ASTM C157 tests and submit data showing length change not exceeding [0.050%] [0.045%] [0.040%] after 7 days of moist curing followed by 21 days of air drying.

- ASTM C157 is the standard test method for length change of hardened hydraulic-cement mortar and concrete. The precision in terms of repeatability or reproducibility is not very good. It is a laboratory test and therefore must be used only for mixture qualification documented in the submittal. The test and required specimen care is not conducive for use with samples obtained at the jobsite for concrete acceptance. These factors include preparation of samples, curing at the jobsite, specimen handling, strict adherence to the test procedures and other details that can impact the results and pose a high risk of rejecting acceptable concrete. Knowledge of local materials shrinkage characteristics, optimizing concrete mixtures for lowest paste volume, and the use shrinkage reducing admixtures, as needed, are ways to achieve reduced shrinkage.
- Establishing specification requirements on grading limits of aggregates does not always ensure reduced void content between aggregates, reduced paste volume, and thereby lower shrinkage.
- Shrinkage is impacted by quantity of water in concrete, paste volume, aggregate characteristics, and other factors. A low w/cm does not assure reduced shrinkage.

C. The installer and manufacturer shall coordinate to establish properties of the fresh concrete to facilitate placement and finishing with reduced potential for segregation and bleeding. Factors shall include but are not limited to slump or slump flow, setting time, method of placement, rate of placement, hot and cold weather placement, curing, and concrete temperature. Selection of fresh concrete properties shall be submitted.

- A smaller nominal maximum aggregate size may be needed for improved constructability.
- Air content for concrete is based on the nominal maximum aggregate size indicated. If smaller nominal maximum size aggregate is selected the air content (and acceptance range) should be adjusted accordingly.

- Even if no air entrainment is specified the contractor, installer, and manufacturer may choose to include air entrainment to reduce segregation and to improve placement and finishing characteristics.

D. Contractor shall indicate reportable changes in sources of materials and quantities when such changes are necessary to ensure constructability, performance of concrete and compliance with the specification requirements. The contractor is permitted to make minor adjustments less than the reportable deviations noted in the original submittal to concrete mixtures to ensure uniformity of concrete without a re-submittal for review or approval.

- Real time adjustments to concrete mixtures are necessary to accommodate changes in material characteristics, seasonal ambient conditions, and jobsite conditions. Examples include changing fineness modulus of sand or coarse aggregate grading, cement chemistry, moving from summer to winter construction, placement methods or jobsite constraints, to mention a few. Concrete mixtures will need adjustments to quantities of cementitious materials, admixture dosage, and aggregates to achieve consistent concrete. Requiring a re-submittal with 28-day strength data on relatively minor adjustments is not practical and will delay construction schedules. The design professional may consider obtaining an original submittal stated in acceptable ranges of ingredient quantities or one that documents anticipated changes. Some of these changes in material quantities cannot be ascertained at the beginning of the project. Significant changes in types of ingredients that have been pre-qualified for certain durability requirements may not be appropriate. It is recommended that this issue be discussed in pre-construction meetings.
- The engineer and contractor / concrete supplier should agree at the time of submittal on what is a reportable change that would require a re-submittal. Examples might be different source or classification of materials and defined deviations of quantities of mixture ingredients from that of the original submittal.

## 2.22 CONCRETE MIXING

- A. Ready-Mixed Concrete: Measure, batch, mix, and deliver concrete in accordance with ASTM C94/C94M and furnish delivery ticket.
- B. Project-Site Mixing: Measure, batch, and mix concrete in accordance with ASTM C94/C94M. Mix concrete in acceptable stationary mixer.

## PART 3 – EXECUTION

### 3.15 INSTALLATION OF CAST-IN-PLACE CONCRETE

- A. Before placing concrete, verify that installation of formwork, reinforcement, and embedded items is complete and that required inspections have been performed.
- C. Water addition in transit or at Project site must be in accordance with ASTM C94/C94M and must not exceed the permitted amount indicated on the delivery ticket.

- Water addition at the job site is often necessary to facilitate placement and finishing and should be permitted if it is within the limits of the approved mixture. Ready mixed producers often hold back water to facilitate this job-site addition to accommodate traffic/jobsite delays in placement and to satisfy the needs of the concrete contractor. The concrete mixture can be designed and approved at the maximum stated mixing water content. On request, producers can indicate on the delivery ticket the amount of water that can be added at the jobsite. ASTM C94 permits the addition of water if measured slump is below target levels. It is also common to increase the slump of concrete using water reducing admixtures at the jobsite followed by appropriate mixing. However, admixture addition requires a certain degree of technical capability to ensure it is not overdosed and this may not be available on the job site. Improper tempering concrete with water reducing admixtures at the jobsite can result in excessive slump, setting time retardation or cement-admixture compatibility problems.
- Automated water measurement and slump monitoring devices inject water when a reduction in slump is detected. The quantity of water is recorded and the system can be set to prevent water addition in excess of a maximum limit.
- It is recommended that the specification should not include delivery time limits or change delivery time limits based on ambient conditions. The 90-minute limit has been removed from ASTM C94 to defer to time limit set by purchaser and producer. Judicious use of water reducing, workability retaining, and retarding admixtures and methods for reducing concrete temperature can generally ensure that the concrete will meet the project requirements for placing and finishing when discharged. ASTM C94/C94M permits limits on discharge for truck mixer revolutions or time from batching to be set between the contractor and the concrete producer. This is because project conditions vary considerably, and a default time or revolution limit is not considered to be appropriate or protective to the quality of concrete. If the intent of delivery time restriction is uniform setting time for slab pours the contractor and the concrete supplier can work to define an acceptable setting time window that will facilitate proper finishability. In places like Houston, Phoenix, or Florida, temperatures exceed 95°F for an extensive duration of the year and discharge of concrete after an extended duration from the time of batching is successfully accomplished with the use of admixtures.

### 3.24 FIELD QUALITY CONTROL OF CAST-IN-PLACE CONCRETE

- A. Special Inspections: Owner will engage a special inspector to perform field tests and inspections and prepare testing and inspection reports.
- B. Testing Agency: Owner will engage a qualified testing and inspecting agency to perform tests and inspections and to submit reports.
  - 1. Testing agency to provide curing facility for initial curing of strength test specimens onsite and verify that test specimens are cured in accordance with standard curing requirements in ASTM C31/C31M.
  - 2. Testing agency to report results of tests and inspections, in writing, to Owner, Architect, Contractor, and concrete manufacturer within 48 hours of inspections and tests.
  - 3. Test reports to include reporting requirements of ASTM C31/C31M, ASTM C39/C39M, and ACI SPEC-301, including the following as applicable to each test and inspection:

- (1) Project Name
  - (2) Name of testing agency
  - (3) Names and certification numbers of field and laboratory technicians performing tests
  - (4) Name of concrete manufacturer
  - (5) Date and time of inspection, sampling, and field testing
  - (6) Date and time of concrete placement
  - (7) Location in Work of concrete represented by samples
  - (8) Date and time sample was obtained
  - (9) Truck and batch ticket numbers
  - (10) Specified compressive strength and test age
  - (11) Concrete mixture designation
  - (12) Results of tests of fresh concrete performed
  - (13) Information on storage and curing of test specimens at Project site, including curing method and maximum and minimum temperatures during initial curing period
  - (14) Compressive strength test results at required test ages and type of fracture of specimens tested
4. The contractor shall provide space and source of power and other resources for curing and access to test specimens by the testing agency. Storage of test specimens shall be in a secure location.

- The initial curing period of test specimens at the jobsite is critical to obtain reliable test results for acceptance of concrete – typically for strength. One of the most frequent reasons for low strength test results is the lack of proper initial curing (temperature and humidity) of the cylinders as defined for “standard curing” in ASTM C31. The testing agency and contractor responsibilities for initial curing of acceptance specimens have been stated in Sections B and C here. It is generally the contractor’s responsibility to provide facilities and space for testing and storage of specimens during the initial curing period at the jobsite, ensure security, and provide access to testing agency personnel to transport test specimens to the lab as required. It is emphasized that the testing agency should be responsible for ensuring that the initial curing temperatures are within the stated range according to ASTM C31 for standard curing conditions. In some areas, the contractor is delegated this responsibility in the contract. The owner’s representative should ensure the responsibility for acceptance testing details are covered in contract documents. If the contractor or testing agency do not provide the necessary resources to perform proper testing or initial curing, such deficiencies should be communicated to the owner or his representative before any acceptance testing is performed.

C. Concrete Delivery Tickets: Comply with ASTM C94/C94M

D. Inspections:

1. Headed bolts and studs
2. Verification of concrete mixtures delivered consistent with submittal
3. Concrete placement, including conveying and depositing
4. Curing procedures and maintenance of curing temperature
5. Verification of concrete strength before removal of shores and forms from beams and slabs
6. Batch Plant Inspections – as required by Architect

- E. Concrete Tests: Testing of composite samples of concrete obtained in accordance with ASTM C172/C172M to be performed in accordance with the following requirements:
1. Testing Frequency: Obtain one composite sample for each class of concrete at least once per day, once for each 150 yd<sup>3</sup> of concrete, or once for each 5000 ft<sup>2</sup> surface area for slabs or walls.
    - a. If the total volume of concrete for a class is such that frequency of testing required is less than five tests, then samples shall be obtained from at least five randomly selected batches or from each batch if fewer than five batches are used.
  2. Slump: ASTM C143/C143M
    - a. One test at the point of delivery on each composite sample obtained to prepare strength test specimens
    - b. Perform additional tests as needed
  3. Slump Flow: When applicable for self-consolidating concrete ASTM C1611/C1611M
    - a. One test at the point of delivery on each composite sample obtained to prepare strength test specimens
    - b. Perform additional tests as needed
  4. Air Content: ASTM C231/C231M, or C173/C173M for lightweight concrete
    - a. One test on each sample obtained to prepare strength test specimens
    - b. Perform additional tests as needed
  5. Temperature: ASTM C1064/C1064M
    - a. One test on each sample obtained to prepare strength test specimens
    - b. One test hourly when ambient temperature is 40°F or lower or 90°F or higher
  6. Density: ASTM C138/C138M
    - a. One test on each sample obtained to prepare strength test specimens
    - b. For lightweight concrete, one test as needed and at least once daily to verify conformance to equilibrium density determined in accordance with ASTM C567/C567M
  7. Compressive Strength Specimens: ASTM C31/C31M
    - a. For strength specimens to be standard cured for acceptance of concrete, cast a set of cylinders and cure specimens at the jobsite in accordance with ASTM C31/C31M. Cast at least two specimens for each age that strength will be tested for information and additional reserve specimens as needed. Strength test results at the designated age shall be the average of two 4 × 8-in. or 6 × 12-in. specimens.
    - b. If required, cast additional sets of cylinders for field-curing in accordance with ASTM C31/C31M
    - c. Transport specimens to the lab within 48 hours after casting and cure them in accordance with final curing requirements of ASTM C31/C31M until tested.
  8. Compressive Strength Tests: ASTM C39/C39M
    - a. Test specimens for compressive strength at 7 days or at an alternative early age as required and one set at 28 days or at an alternate test age as designated for specified strength.
    - b. Acceptance of concrete shall be based on strength test results of standard cured cylinders in accordance with ASTM C31 and tested at 28 days in accordance with

- ASTM C39. Strength test results at the designated age shall be the average of two  $4 \times 8$ -in. or  $6 \times 12$ -in. specimens.
- c. When strength cylinders are made, tests of slump, air content, temperature and density shall be made and recorded with the strength test results.
  - d. Strength of each concrete class shall be deemed satisfactory when both of the following criteria are met:
    - (1) The average of three consecutive compressive-strength tests equals or exceeds specified compressive strength
    - (2) Any individual compressive-strength test result does not fall below specified compressive strength,  $f'_c$ 
      - (a) by more than 500 psi when  $f'_c \leq 5000$  psi
      - (b) by more than  $0.1f'_c$  when  $f'_c > 5000$  psi
  - e. Alternative procedures to estimate in-place compressive strength include:
    - (1) Tests of cast-in-place cylinders in accordance with ASTM C873. This method is limited to use for slabs where the depth of concrete is between 5 to 12 in.
    - (2) Penetration resistance in accordance with ASTM C803
    - (3) Pullout strength in accordance with ASTM C900
    - (4) Maturity index measurements and correlation in accordance with ASTM C1074
    - (5) Temperature-match curing of cylinders in accordance with AASHTO R72
  - f. When compressive strength tests fail to meet the provisions of (d), follow procedure in ACI 301 for evaluation of concrete strength tests.
  - g. When it is deemed necessary to evaluate the adequacy of concrete strength, at least 3 cores shall be obtained from the portion of the structure represented by the low strength tests. Cores shall be removed and conditioned in accordance with ASTM C42. The strength of cores shall comply with the following:
    - (a) Average strength of 3 cores  $\geq 0.85f'_c$
    - (b) Individual core strength  $\geq 0.75f'_c$

- Clearly indicate the sampling location for acceptance samples: “point of placement or discharge”. ASTM C172 does not describe procedures for sampling at the point of placement if another means of conveyance such as a pump, conveyor belt, or crane and bucket is employed. For determination that the concrete is supplied in accordance with the specified requirements, samples obtained from the point of discharge from the transportation unit is the stated requirement in ACI CODE-318, ACI SPEC-301, and ASTM C94.
- When the placement method can cause differences in fresh concrete characteristics as discharged from the transportation unit to the point of placement, the requirements for concrete at the point of discharge from the transportation unit should be established between the material supplier and the contractor/sub-contractor. The designer should be notified of a change in requirements for the concrete as discharged from the transportation unit.
- Placement methods, such as the use of pumps, can change the characteristics of slump and air content of the concrete for a variety of reasons. The point of discharge represents a change of “custody” and responsibility of concrete. The concrete producer has no control of placement operations employed by the operator of the placement device or the contractor. Obtaining samples at the point of discharge from the truck mixer has been standard industry practice and is implicitly “calibrated” to some anticipated change in characteristics for normal placement methods. If the design professional needs to ensure “point of discharge” air content levels at the point of placement then the concrete at the point of discharge will likely need to have a modified slump or air content. For this to occur there needs to be proper coordination between the concrete as delivered and the placement method. A typical option is to measure slump and air as the concrete is

discharged from the truck as well as at the point of placement to quantify the effects of the placement method. Concrete can be delivered at the job site to meet a **modified** slump and air content to compensate for an anticipated change. If the anticipated change through the placement procedure does not occur, a consequence will be reduced strength of concrete in the structure. Modifying slump and air content requirements to account for placement methods must be agreed upon at the pre-placement conference and if necessary, by conducting some trial pours. Density measurements at the two locations are a quick means of estimating changes in air content of concrete.

- Caution should be exercised when sampling at the discharge end of a pump to ensure that the slump and air content of subsequent loads are NOT adjusted to compensate for poor sampling or testing practices. Manipulation of the pumping process to facilitate sampling, such as shutting off, jogging etc., will cause temporary vacuum in the pump line resulting in lower air content in the concrete sample. This loss of air is minimized in productive conveyance of concrete in full pump lines in a constant discharge stream. Samples obtained from “sputtering” discharge will not be representative of the concrete delivered. The operative procedure when “point of placement” is specified, the concrete sample should be obtained at the “the point of placement” and not an alternate location. If sampling at the point of placement is not possible for safety reasons, sample location should then be at the point of discharge to eliminate the introduction of temporary, “non representative” conditions noted. A technician obtaining a sample of concrete from a pump line right beside the pump represents the worst sampling condition. A suggested method to obtain samples when “point of placement” is specified is to allow normal operation of pumps into the placement and obtain test samples from that location rather than to control the pumping operations to obtain samples in the sampling receptacle.
- Another problem with air content measurement, regardless of point of sampling, is insufficient effort when measuring air content by the volumetric method, ASTM C173 (roll-a-meter). This method is generally used for lightweight concrete. Insufficient agitation of the test sample will result in a lower measured air content that will then be called in for an adjustment at the plant. This often results in higher air content in the placed concrete and resulting lower strength.
- ACI CODE-318 states minimum frequency for strength tests. Random sampling from different delivery vehicles should be followed. For smaller volumes of concrete on a project, the Code permits the engineer to not require strength tests. It is typically not common to test every load of concrete as this can cause considerable delays in placement with associated problems.
- Consider strength testing at later ages such as 56 or 90 days when high volumes of SCMs are used particularly when the specified strength is not required at 28 days.
- An average of two 4 x 8-in or 6 x 12-in cylinders tested at 28 days represents a strength test result for acceptance. Consider allowing the use of 4 x 8-inch specimens. ASTM C39 recognizes 4 x 8-inch specimens as a standard size. The smaller specimens facilitate better care and curing, especially during the critical early age phase at the jobsite. The commentary of ACI 318 clarifies that the strength acceptance criteria apply as stated regardless of specimen size used.
- If additional cylinders are specified be sure to include exact requirements and use of those results. For example, if a cylinder is to be tested at 7 days for informational purposes, clearly indicate that purpose and that there are no acceptance criteria associated with this result. If 7-day tests indicate a potential for lower strengths, it provides the concrete supplier with an opportunity to make modest changes to the mixture to increase the level of strength and these adjustments should be permitted with appropriate notification to the design professional. If additional cylinders are specified to be tested at 56 days for the purposes of acceptance if the 28-day tests don’t meet the acceptance criteria, then that should be indicated in the specification. Strength tests, even for informational purposes, should be the average of at least two test specimens. The rate of strength gain of concrete depends on the type of mixture. There are no established percentage of 28-day strength at other test ages. These assumptions should not be used to “red-flag” results of tests performed at ages other than that required by the acceptance criteria.
- The installer and manufacturer may choose to make additional cylinders, identified as field-cured specimens, to monitor early age in-place strength to accommodate form removal, prestress release, opening to traffic

and reshoring. In cold weather, standard-cured cylinders (lab) may provide a false indication on whether the structure has achieved the necessary strength necessary for these construction stages. Field-cured cylinders should be stored in or on the structure as near to the concrete being evaluated for in-place strength as possible. Protect all surfaces of the cylinders from the elements in the same way as formed members. Provide the cylinders with the same temperature and moisture environment as the structural work. ASTM C31 has specific recommendations on storage of field cured cylinders that should be reviewed and followed by the technicians.

- An even better option for estimating in-place strength would be to take advantage of maturity-based techniques. ACI 318 permits the use of alternative in-place strength methods. These methods are not recognized for determining the acceptability of the quality of concrete furnished for the work. Alternative procedures such as penetration tests or maturity require sufficient data for the materials used in the Work to demonstrate correlation of measurements on the structure with the compressive strength of molded cylinders or drilled cores. ACI 228.1R discusses the use of these methods to evaluate the in-place strength of concrete. Temperature-match curing of cylinders in accordance with AASHTO R72, may be used to more closely represent the temperature within the concrete member during curing.
- Note that there are specific criteria in ACI CODE-318-25 for field cured cylinders to determine application of prestressing forces (PT) or for removal of shoring and formwork – strength of all cylinders should exceed the strength required for that stage of construction. See 26.12.4.1.
- ACI 318, in section 26.5.3, does recognize the use of field cured cylinders to determine whether curing and protection of the structure was adequate. The requirement indicating adequate curing and protection is when the field cured cylinders achieve a strength of at least 85% of standard cured cylinders but does not apply if the strength of the field cured cylinders exceed the specified strength by more than 500 psi. Note that this evaluation is not attributed to being the responsibility of the concrete supplier.
- It is important that the procedure for evaluating non-compliance with specification requirements, such as low strength and the ultimate referee testing and resolution procedures are clearly defined in the project specifications. All parties need to know their financial exposure and risk prior to bidding a job.
- ACI 318 requires tests of cores from the structure only when strength tests do not comply with acceptance criteria in d.(2) above. Core tests are required if the likelihood of low-strength is confirmed and calculations indicate that structural adequacy is significantly reduced. Cores should be obtained and conditioned in accordance with ASTM C42. The conditioning procedure is important to attain a uniform moisture distribution in the core as this has a significant effect on measured strength of cores.
- The acceptance criteria for cores (ACI CODE-318 and ACI SPEC-301) are: three cores are required for each placement represented by a low strength test result
  - Average of 3 cores  $\geq 0.85 f_c$ , and
  - Each individual core  $\geq 0.75 f_c$
- When it can be demonstrated that low strength test results are caused by non-adherence to standard practices for specimen preparation and it is documented that curing facilities used at the jobsite or at the laboratory did not conform to the standards, the expense associated with additional testing and evaluation should be appropriately covered at no cost to the contractor or concrete supplier.
- Only use air content testing as an acceptance criterion for concrete that has an air content requirement in the specification. It is also appropriate to test the air content of concrete that needs a hard-trowelled finish to ensure that there is no inadvertent generation of excessive air content. Density tests can also be used as an indicator for this purpose.
- For air content tests, C94 establishes a tolerance of  $\pm 1.5\%$ ; it permits a jobsite adjustment if the air content is less than the lower limit of the allowed tolerance; and sets forth procedures for retesting prior to a decision to reject the concrete. ASTM C94 requires that when air content needs to be verified, a preliminary sample be obtained from the initial portion of discharge. This sample is not in accordance with ASTM C172 and should not be used to make strength specimens. It permits an adjustment to the mixture if the air content is

not within required tolerance. ASTM C94 also requires a retest on a separate sample before a load of concrete is rejected for slump or air content that do not meet the specified requirements.

- Concrete contractor and concrete supplier may have a slump requirement and may choose to accept, reject or make jobsite adjustment to the concrete based on slump. Historically slump limits were specified due to concern of excessive water. With the use of admixtures, the relationship of slump to water content is weak. Compliance with target slump established by the producer and contractor as a means of verifying uniformity between loads of concrete.
- If the specifier chooses to specify slump, it should be specified as a target limit, where the appropriate  $\pm$  tolerances in C94 will apply. A maximum 8-in. slump limit will preclude the use of self-consolidating concrete that has the benefit of reduced consolidation requirements and reduced mix segregation. It is not advisable to require a target slump prior to addition of HRWR admixtures followed by a target after the addition. The general preference is for plant-added HRWR for better control. Allow a variance on slump limits with HRWR and include a statement regarding lack of segregation, if necessary. Also, C94 permits a jobsite adjustment if the slump is less than the lower limit of the allowed tolerance; and sets forth procedures for retesting prior to a decision to reject the concrete. The primary condition is that water addition should not exceed that required by the designed mixture.
- Slump flow of self-consolidating concrete is stated as the spread of the concrete after it is released from the slump cone. Other useful observation with the slump flow test is a visual stability index that is a qualitative measure of the degree of segregation of the mixture. The rate at which the concrete spreads is called the T50 value which is the time it takes to achieve a spread of 50 cm or 20 inches. This is a measure of the viscosity of the mixture that is important to the type of application being placed. A larger T50 value indicates a more viscous mixture.
- A commonly specified maximum temperature limit is 95°F, primarily to prevent the addition of excessive water for proper consistency for placement. With today's concrete technology it is possible to provide concrete within the designed water content at the appropriate slump. Thermal cracking in massive concrete members is another concern. If it is not critical for the Work, it is recommended that the specification should not include a maximum temperature limit. Such temperature limits may be unrealistic in southern states in summer. Controlling concrete temperature adds to the cost of concrete, especially with extreme steps like the use of liquid nitrogen are necessary.
- A thermal control plan is a good performance-based alternative for mass concrete structural elements. The thermal control plan should indicate how concrete construction will be managed even with higher concrete temperature. Guidance on mass concrete and thermal control plans is available in ACI PRC-207 and in ACI 301 in the section on mass concrete. CIP 42 from NRMCA discusses thermal cracking and prevention.
- Density is specified and used as an acceptance criterion only for lightweight or heavyweight concrete. While engineers use the equilibrium density of lightweight concrete in design, an equivalent value for the density of fresh lightweight concrete should be established for acceptance of lightweight concrete. The density of fresh concrete is typically 3 to 5 lb/ft<sup>3</sup> greater than the equilibrium density.
- Even for normal weight concrete it is strongly recommended that the density test (ASTM C138) be performed whenever cylinders are made. This is a requirement in ASTM C94. This set of tests support each other in case there are problems with the strength test results. ASTM C138 can be used as a check test for results of the ASTM C173, and ASTM C231. It is not unusual that improper testing procedures for measurement of air are followed; or for air meters to not function properly; and result in inaccurate air content measurements.
- Distribution of all test results is very important for quality control. The distribution of test reports is required by ACI 318 (26.12.1.1). The ready mixed concrete supplier must be provided with copies of test reports in a timely manner – 48 hours is reasonable and the use of electronic communication could narrow this time further. This facilitates rapid corrective action in the case of low strength results. Strength test reports should follow all the reporting requirements of ASTM C39 that includes important information on jobsite conditions and specimen care.
- Strength test results should also be made available to the other impacted parties.

## Appendix A

### Definition of Exposure Classes and Requirements for Concrete in accordance with ACI 318-25

**Table 19.3.1.1 – Exposure categories and Classes (ACI 318-25)**

Category	Class	Condition	
Freezing and thawing (F)	F0	Concrete not exposed to freezing and thawing cycles	
	F1	Concrete exposed to freezing and thawing cycles with limited exposure to water	
	F2	Concrete exposed to freezing and thawing cycles with frequent exposure to water	
Sulfate (S)		<b>Water-soluble sulfate (SO<sub>4</sub><sup>2-</sup>) in soil, percent by mass <sup>(1)</sup></b>	<b>Dissolved sulfate (SO<sub>4</sub><sup>2-</sup>) in water, ppm <sup>(2)</sup></b>
	S0	SO <sub>4</sub> <sup>2-</sup> < 0.10	SO <sub>4</sub> <sup>2-</sup> < 150
	S1	0.10 ≤ SO <sub>4</sub> <sup>2-</sup> < 0.20	150 ≤ SO <sub>4</sub> <sup>2-</sup> < 1500 or seawater
	S2	0.20 ≤ SO <sub>4</sub> <sup>2-</sup> < 2.00	1500 ≤ SO <sub>4</sub> <sup>2-</sup> ≤ 10,000
	S3	SO <sub>4</sub> <sup>2-</sup> > 2.00	SO <sub>4</sub> <sup>2-</sup> > 10,000
In contact with water (W)	W0	Concrete dry in service	
	W1	Concrete in contact with water and low permeability is not required	
	W2	Concrete in contact with water and low permeability is required	
Corrosion protection of reinforcement (C)	C0	Concrete dry or protected from moisture	
	C1	Concrete exposed to moisture but not to an external source of chlorides	
	C2	Concrete exposed to moisture and an external source of chlorides from deicing or other chemicals, salt, brackish water, seawater, spray, or airborne chlorides from these sources.	

<sup>(1)</sup> Percent sulfate by mass in soil shall be determined by ASTM C1580

<sup>(2)</sup> Concentration of dissolved sulfates in water, in ppm, shall be determined by ASTM D516

**Excerpted from ACI 318R – Commentary to the Building Code**

**Table R19.3.1—Examples of structural members in Exposure Category F**

Exposure Class	Examples
F0	<ul style="list-style-type: none"> <li>• Members in climates where freezing temperatures will not be encountered</li> <li>• Members that are inside structures and will not be exposed to freezing</li> <li>• Foundations not exposed to freezing</li> <li>• Members that are buried in soil below the design frost depth</li> </ul>
F1	<ul style="list-style-type: none"> <li>• Members not subject to ponding of water or snow and ice accumulation, such as exterior walls, beams, girders, and slabs not in direct contact with soil</li> <li>• Foundation walls likely to be saturated</li> </ul>
F2	<ul style="list-style-type: none"> <li>• Members subject to ponding of water or snow and ice accumulation, such as exterior elevated slabs</li> <li>• Foundation or basement walls extending above grade that have snow and ice buildup against them</li> <li>• Horizontal and vertical members in contact with soil above the design frost depth</li> </ul>

**Table 19.3.2.1—Requirements for concrete by exposure class (ACI 318-25)**

Exposure Class	Max w/cm <sup>(1,2)</sup>	Min f' <sub>c</sub> , psi	Additional Requirements			Calcium chloride admixture
			Air content			
F0	N/A	2500	N/A			
F1	0.55	3500	Table 19.3.1.1 for concrete or Table 19.3.3.3 for shotcrete			
F2	0.45	4500	Table 19.3.1.1 for concrete or Table 19.3.3.3 for shotcrete			
			Cementitious materials <sup>(3)</sup> - Types			
			ASTM C150	ASTM C595	ASTM C1157	
S0	N/A	2500	No type restriction	No type restriction	No type restriction	No restriction
S1	0.50	4000	II <sup>(4)(5)</sup>	Types with (MS) designation	MS	No restriction
S2	0.45	4500	V <sup>(5)</sup>	Types with (HS) designation	HS	Not permitted
S3	Opt. 1	0.45	V plus pozzolan or slag cement <sup>(6)</sup>	Types with (HS) designation plus pozzolan or slag cement <sup>(6)</sup>	HS plus pozzolan or slag cement <sup>(6)</sup>	Not permitted
	Opt. 2	0.45	V <sup>(7)</sup>	Types with (HS) designation	HS	Not permitted
			<b>Maximum water-soluble chloride ion (Cl<sup>-</sup>) content in concrete, percent by weight of cementitious materials</b>			
			Nonprestressed concrete	Prestressed concrete		
W0	N/A	2500	None			
W1	N/A	2500	26.4.2.2(d)			
W2	0.50	4000	26.4.2.2(d)			
C0	N/A	2500	1.00	0.06		
C1	N/A	2500	0.30	0.06		
C2 <sup>(8)</sup>	0.40	5000	0.15	0.06		

<sup>(1)</sup>The w/cm is calculated on all cementitious and supplementary cementitious materials in the concrete mixture.  
<sup>(2)</sup>The maximum w/cm limits do not apply to lightweight concrete.  
<sup>(3)</sup>Alternative combinations of cementitious materials to those listed are permitted for all sulfate exposure classes when tested for sulfate resistance and meeting the criteria in 26.4.2.2(b).  
<sup>(4)</sup>For seawater exposure, other types of portland cements with tricalcium aluminate (C3A) contents up to 10 percent are permitted if the w/cm does not exceed 0.40.  
<sup>(5)</sup>Other available types of cement such as Type I or Type III are permitted in Exposure Classes S1 or S2 if the C3A contents are less than 8 percent for Exposure Class S1 or less than 5 percent for Exposure Class S2.  
<sup>(6)</sup>The amount of the specific source of the pozzolan or slag cement to be used shall be at least the amount that has been determined by service record to improve sulfate resistance when used in concrete containing Type V cement. Alternatively, the amount of the specific source of the pozzolan or slag cement to be used shall be at least the amount tested in accordance with ASTM C1012 and meeting the criteria in 26.4.2.2(b).  
<sup>(7)</sup>If Type V cement is used as the sole cementitious material, the optional sulfate resistance requirement of 0.040 percent maximum expansion in ASTM C150 shall be specified.  
<sup>(8)</sup>Concrete cover shall be in accordance with 20.5.1.4.

**Table 19.3.3.1—Total air content for concrete exposed to cycles of freezing and thawing (ACI 318-25)**

Nominal maximum aggregate size, in	Target air content, %	
	F1	F2
3/8	6.0	7.5
1/2	5.5	7.0
3/4	5.0	6.0
1	4.5	6.0
1-1/2	4.5	5.5
2	4.0	5.0
3	3.5	4.5

**Table 26.4.2.2(c)—Requirements for establishing suitability of combinations of cementitious materials For Exposure Category S (ACI 318-25)**

Exposure class	Maximum length change for tests in accordance with ASTM C1012, percent		
	At 6 months	At 12 months	At 18 months
S1	0.10	No requirement	No requirement
S2	0.05	0.10 percent <sup>(1)</sup>	No requirement
S3	Option 1	No requirement	0.10 percent
	Option 2	0.05 percent	0.10 percent <sup>(1)</sup>

<sup>(1)</sup> The 12-month expansion limit applies only if the measured expansion exceeds the 6-month maximum expansion limit.

## Appendix B Suggested Mixture Submittal Format

<b>Concrete Supplier</b>					
<b>Address</b>					
<b>City, State, Zip</b>					
<b>Submitted by</b>					
<b>Phone</b>		<b>Fax</b>		<b>E-Mail</b>	

<b>Project</b>		<b>Date</b>	
<b>Location</b>		<b>Contractor</b>	

		CONCRETE MIX CODE				
<b>SPECIFICATION</b>	Mixture Identification by Class					
	Structural Requirements					
	• Specified Exposure Class in Section 2.12					
	• Minimum Specified Strength - age					
	• Air Content and range (%)					
	• Nominal Maximum Aggregate Size					
	Durability Requirements					
	• Alkali Aggregate Reactivity					
	• Other					
	Architectural Requirements					
• Color/Texture						
• Other						
<b>CONTRACTOR REQUIREMENTS</b>	Quantity, cubic yards					
	Rate (yd <sup>3</sup> /h)					
	Slump or Slump flow - Range (in)					
	Method of Placement					
	Strength/Age (psi/hr/days)					
	Other					
	Specialty Information					
	• Concrete Set (Delay, Normal, Accelerated)					
	Floor or Slab Type – (Exposed / Covered)					
Other (e.g. Fibers)						
<b>MATERIALS SECTION</b>	Type & Information					
	• Cement					
	• SCM – Slag, Coal Ash, Silica Fume, or other					
	• Fine Aggregate					
	• Coarse Aggregate					
	• Air Entraining Admixture					
	• Water Reducing Admixture					
• Other (e.g. Fibers)						

**NOTES:**

- 1) All Concrete and materials shall be supplied in conformance to ASTM C94.
- 2) Concrete test reports shall be provided to the owner, contractor and concrete supplier within 48 hours.
- 3) Concrete tests not done according to ASTM Standards shall not be accepted for any basis of measurement.
- 4) Additional supporting documentation as required by the project specification are attached to this submittal



**NRMCA Publication 2PE004-26 - Guide to Improving Specifications for Ready Mixed Concrete  
with Notes on Reducing Embodied Carbon Footprint, Responsible Sourcing, LEED v5 and  
Envision Version 3.**

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