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Example Specification for Concrete using Current Building Code Requirements

DISCLAIMER: This specification is an example that accompanies a seminar titled *The P2P Initiative: Performance-based Specs for Concrete* and is used for demonstration purposes only. The example has not been developed using a consensus process by NRMCA or any other specification writing body. This example addresses portions of a specification relative to the strength and durability provisions of the ACI 318-05 *Building Code for Structural Concrete*. Other potential mechanical and chemical performance parameters such as ASR, abrasion, shrinkage, cracking, curling, finishes and creep that are not addressed in the Code are not addressed in this example. It is anticipated that guidance on these and other aspects pertinent to various concrete applications will be developed as the P2P Initiative progresses. NRMCA nor its members make no express or implied warranty with respect to this publication or any information contained herein.

EXAMPLE: The objective of this example is to minimize prescriptive requirements. Comply with ACI 318-05 Chapters 3, 4 and 5. Assume a 3 story concrete building with first level parking. Concrete elements include: structural slabs, beams, and columns; slab-on-grade (parking); foundation walls; footings. Exposure conditions include: freezing and thawing (with deicing chemicals); soils containing sulfates (severe). The example will cover the sections relating to concrete mixing and placing (highlighted below).

SECTION 03300 – CAST-IN-PLACE CONCRETE

PART 1 – GENERAL

1.1 RELATED DOCUMENTS
1.2 SUMMARY
1.3 DEFINITIONS
1.4 SUBMITTALS
1.5 QUALITY ASSURANCE
1.6 DELIVERY, STORAGE, AND HANDLING

PART 2 – PRODUCTS

2.1 MANUFACTURERS
2.2 FORMING MATERIALS
2.3 STEEL REINFORCEMENT
2.4 REINFORCEMENT ACCESSORIES
2.5 CONCRETE MATERIALS
2.6 WATERSTOPS
2.7 VAPOR RETARDERS
2.8 FLOOR AND SLAB TREATEMENTS
2.9 CURING MATERIALS
2.10 RELATED MATERIALS
2.11 REPAIR MATERIALS
2.12 CONCRETE MIXTURES

PART 3 – EXECUTION

3.1 FORMWORK
3.2 EMBEDDED ITEMS
3.3 REMOVING AND REUSING FORMS
3.4 SHORES AND RESHORES
3.5 VAPOR RETARDERS
3.6 STEEL REINFORCEMENT
3.7 JOINTS
3.8 WATERSTOPS
3.9 CONCRETE PLACEMENT

3.10 FINISHING FORMED SURFACES
3.11 FINISHING FLOORS AND SLABS
3.12 MISCELLANEOUS CONCRETE ITEMS
3.13 CONCRETE PROTECTING AND CURING
3.14 LIQUID FLOOR TREATEMENTS
3.15 JOINT FILLING
3.16 CONCRETE SURFACE REPAIRS
3.17 FIELD QUALITY ASSURANCE

SECTION 03300 – CAST-IN-PLACE CONCRETE

PART 1 – GENERAL

1.2 SUMMARY

A. This Section specifies cast-in place concrete, including formwork, reinforcement, concrete materials, mixture design, placement procedures, and finishes.

1.3 SUBMITTALS

A. Submit field or laboratory test records used to document that proposed mixture will achieve the required average compressive strength and other specified requirements in section 2.12 for each class of concrete. Field test records must be from concrete supplied from the same production facilities proposed for the work. Test data shall be from concrete mixtures containing similar materials proposed for the work.

B. Submit properties of mix design for each class of concrete including:

1. Specified compressive strength, f'_c
2. Documentation of strength test results of similar concrete mixtures indicating the standard deviation in accordance with ACI 318
3. Required average compressive strength, f'_{cr}
4. Average compressive strength of proposed mixture(s)
5. Placement method
6. Slump or slump flow
7. Air content
8. Density
9. w/cm ratio
10. Maximum aggregate size
11. Sources and designations of ingredient materials proposed for use including:
    a. Cementitious Materials
    b. Aggregates
    c. Admixtures
    d. Water
    e. Fibers, color pigments, and other additions

C. Submit documentation indicating installer, manufacturer, and testing agency meet the qualifications specified in Section 1.5 Quality Control.

- A guide to submittal of concrete mixture proportions is provided in ACI 211.5R.
- In a performance-based specification, the submittal information should be pertinent to compliance with the performance requirements of the specification and should not necessarily include actual ingredient material quantities and other details of mix design. It is appropriate to request source and classifications of ingredient materials. When mixture proportions 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 manufacturer. Performance-based mixtures developed by a manufacturer are his intellectual property, involve a cost for development and govern the manufacturer's ability to compete.
- A test record and other performance data linked to a mix code of a proposed mixture should suffice as the submittal for the design professional.
- Consider defining the period of time for retention of individual recorded batch records for forensic purposes (3-7 years from delivery date).
- Most of the fresh concrete properties will be selected by the contractor and producer unless it is specifically required by the design professional for approving the construction means and methods. For example slump, which is a measure of flowability or consistency, is a property of plastic concrete and should not be restricted by the engineer. The contractor and producer should select the slump based on the placement and finishing requirements of the concrete. Air content for air entrained concrete is generally governed by the nominal maximum size of coarse aggregate.

1.5 QUALITY ASSURANCE

A. Installer Qualifications: Installer who employs an on-site supervisor of the finishing crew who qualified as ACI Certified Concrete Flatwork Technician for flatwork placing and finishing.

- Flatwork finisher certification is important for constructing slabs on grade, however, general standard of care of concrete construction is addressed in this certification program.

- Manufacturer Qualifications: Concrete supplied from concrete plants with current certification under the NRMCA Certification of Ready Mixed Concrete Production Facilities. Individual with responsibility for concrete mixtures certified as an NRMCA Concrete Technologist Level 2. When requested the manufacturer shall furnish a Quality Plan.

- NRMCA certified concrete production facilities demonstrate compliance with requirements of ASTM C 94. The certification includes an annual certification of delivery vehicles.
- The NRMCA Concrete Technologist Level 2 Certification validates personnel's knowledge of fundamentals of concrete technology including mixture proportioning. Certification is obtained by passing a 90 minute exam administered by NRMCA with ACI Grade 1 Field Testing Technician Certification as the prerequisite.
- NRMCA is in the process of developing a guideline for a Quality Plan for ready mixed concrete producers.

B. Testing Agency Qualifications: Independent testing agency shall meet the requirements of ASTM C 1077.

1. Personnel conducting field tests for acceptance shall be certified as ACI Concrete Field Testing Technician Grade I.

2. Personnel conducting laboratory tests for acceptance shall be certified as ACI Concrete Strength Testing Technician or ACI Concrete Laboratory Testing Technician – Grade I.

3. Test results for the purpose of acceptance shall be certified by a registered design professional employed with the Testing Agency.

- Compliance with ASTM C 1077 can be demonstrated by a laboratory inspection by organizations such as the Cement and Concrete Reference Laboratory
- Concrete testing is very sensitive to the way specimens are collected, cured, and tested. Proper field and lab procedures are essential to achieving meaningful results.

C. Pre Installation Conference: Conduct conference at Project site to comply with requirements in Division 1 Section "Project Management and Coordination."

1. Require representatives of each entity directly concerned with cast-in-place concrete to attend, including:
   a. Architect
   b. Structural Engineer
   c. Contractor
   d. Installer (Concrete Contractor)
   e. Pumping Contractor
   f. Manufacturer (Ready-mixed concrete producer)
   g. Independent testing agency

- NRMCA and American Society of Concrete Contractors have a document titled Checklist for the Concrete Pre-Construction Conference

PART 2 – PRODUCTS

2.5 CONCRETE MATERIALS

A. Cementitious Materials: use materials meeting the following requirements with limitations specified in Section 2.12.

1. Hydraulic Cement: ASTM C 150 or ASTM C 1157 or ASTM C 595
2. Fly Ash: ASTM C 618
3. Slag: ASTM C 989
4. Silica Fume: ASTM C 1240

B. Normalweight Aggregate: ASTM C 33

C. Water: ASTM C 1602

D. Chemical Admixtures:

1. Air Entraining: ASTM C 260
2. Water reducers, accelerating and retarding: ASTM C 494
3. Admixtures for flowing concrete: ASTM C 1017
4. Admixtures with no standard designation shall be used only with the permission of the design professional when its use for specific properties is required.

E. Fibers: ASTM C 1116

- Avoid limiting the type or quantities of cementitious materials that can be used unless required for certain performance attributes.
- Avoid limiting the type of admixtures that can be used unless there is a specific reason (eg. Chloride based admixtures for corrosion).
- Consider specifying or allowing the use of admixtures which do not have a specific ASTM designation with appropriate documentation indicating beneficial use to concrete properties. These

may include colors, viscosity modifying 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.

2.12 CONCRETE MIXTURES

A. Prepare design mixtures for each class of concrete on the basis of laboratory trial mixtures or field test data, or both according to ACI 318, Chapter 5. Design mixtures shall meet the requirements listed in Table 2.12.

Table 2.12 Concrete Mixtures									
Class	Application	Exposure	f'_c	Nominal Maximum Aggregate Size[1]	Air Content	Maximum water-cementitious materials ratio by weight	Cementitious Materials	Admixtures	Maximum water soluble chloride ion (Cl^-) in concrete, by weight of cement
1	Slabs and beams	None	4,000 psi	3/4”	N/A[2]	N/A	See section 2.5 A	See section 2.5 D	1.00
2	Columns	None	5,000 psi	3/4”	N/A[2]	N/A	See section 2.5 A	See section 2.5 D	1.00
3	Slabs on grade Foundation walls	Freeze/Thaw, Deicing Chemicals, Sulfate (severe)	4,500 psi	1-1/2”	5-1/2 %[3]	0.45	Limits on hydraulic cement[4] Limits on fly ash, slag, and silica fume[5]	No calcium chloride admixtures	0.15
4	Footings	Sulfate (severe)	4,500 psi	1-1/2”	N/A[2]	0.45	Limits on hydraulic cement[4]	No calcium chloride admixtures	0.30

1. A smaller nominal maximum aggregate size may be used at the discretion of the contractor, installer, and manufacturer.
2. No air entrainment is required. Contractor, installer, and manufacturer may choose to include air entrainment to improve placement and finishing characteristics. Air content of concrete for slabs with hard trowel finish shall not exceed 3%.
3. Air content indicated in the table is for concrete with matching nominal maximum aggregate size indicated. If smaller maximum aggregate size is selected air content shall be adjusted upwards in accordance with ACI 318 Table 4.2.1.
4. Hydraulic Cement: ASTM C 150 type V
5. Limits on the amount of fly ash, slag, and silica fume by mass of total cementitious materials:
    a. Fly Ash: Maximum 25%
    b. Slag: Maximum 50%
    c. Silica Fume: Maximum 10%
    d. Total of fly ash, slag, and silica fume: Maximum 50%
    e. Total of fly ash and silica fume: Maximum 35%

B. The installer and manufacturer shall coordinate to establish properties of the fresh concrete to facilitate placement and finishing with minimal segregation and bleeding. Factors shall include but are not limited to slump or slump flow, set time, method of placement, rate of placement, hot and cold weather placement, curing, and concrete temperature.

- Provide a schedule of concrete types (classes) for all components of the structure including a description of exposure.
- There are few limits on materials for class 1 and 2 concrete since durability is not a concern. Compressive strength is based on structural design requirements. Maximum aggregate size controlled by ACI 318 – 3.3 Aggregates.
- Class 3 concrete is exposed to freeze-thaw, deicing chemicals, and sulfates.
    - Compressive strength, air content, maximum w/cm are based on ACI 318 4.2 Freezing and thawing exposure. If concrete is not exposed to freeze-thaw, do not include these limitations.
    - Limits on SCMs are based on ACI 318 4.2.3 for concrete exposed to deicing chemicals. If concrete is not exposed to deicing chemicals do not include these limitations.
    - Limits on cement type and restriction on using calcium chloride admixtures are based on ACI 318 4.3 Sulfate exposure. The strength and w/cm ratio criteria apply for this exposure too. If soil does not contain sulfates, do not include these limitations.
- Class 4 concrete is exposed to sulfates.
    - Compressive strength, cement type, maximum w/cm, and restriction on using calcium chloride admixtures are based on ACI 318 4.3 – Sulfate exposure. If soil does not contain sulfates, do not include these limitations.
- For concrete exposed to freeze-thaw, deicing chemicals, and/or sulfates the compressive strength requirement for durability will often be higher than that required for structural design. The compressive strength requirements in ACI 318 chapter 4 is the codes attempt at matching the strength to the required water-cementitious materials ratio.
- 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.

PART 3 – EXECUTION

3.9 CONCRETE PLACEMENT

A. Measure, batch, mix, deliver, and provide delivery ticket for each batch of concrete in accordance with ASTM C94.

1. Do not add water to concrete during delivery or during placement.
    a. Water is permitted to be added to a batch of concrete at the project site before placement of the batch begins provided that the amount of water added does not exceed the allowed amount indicated on the delivery ticket.

3.17 FIELD QUALITY ASSURANCE

A. Testing: Owner shall engage a qualified testing agency to perform concrete field tests and prepare test reports.

B. Concrete Field Tests:

1. Concrete Test Samples: Samples for concrete tests shall be taken in accordance with ASTM C 172.
2. Compressive Strength Tests on concrete:
   a. Samples for concrete compressive strength tests of each class of concrete placed each day shall be taken not less than once per day, nor less than once for each 150 yd^3 of concrete, nor less than once for each 5000 ft^2 surface area for slabs or walls. 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 made from at least five randomly selected batches or from each batch if fewer than five batches are used.
   b. Acceptance of concrete shall be based on strength test results of standard cured cylinders in accordance with ASTM C 31 and tested at 28 days in accordance with ASTM C 39. Strength test results are the average of two 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 by more than 500 psi.
   e. When compressive strength tests indicate low strength, follow procedure in ACI 318 chapter 5.6.4 Investigation of low-strength test results.

- Consider longer periods before testing when high volumes of supplementary cementitious materials are used.
- Average of two cylinders tested at 28 days represent a strength test result by ACI 318 for acceptance. 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 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. The installer and manufacturer may choose to make additional cylinders, identified as field cured specimens, to monitor early age strength to accommodate form removal and reshoring. The strength results of field cured specimens are not recognized for determining the acceptability of the quality of concrete furnished for the work.

3. Air Content: ASTM C 231. Test when concrete is sampled for strength tests.
   a. Air content tests shall be performed on concrete at least at the same frequency as compressive strength testing.
   b. The provisions of ASTM C 94 shall apply for acceptance of air content of concrete.

- Only use air content as an acceptance criterion for concrete that has an air content requirement in the specification.
- For air content tests, C 94 establishes a tolerance of ±1.5%; 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.
- When the placement method can cause differences in fresh concrete characteristics from the discharge of 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 engineer should be notified of a change in requirements for the concrete as discharged from the transportation unit.

4. Slump: ASTM C 143; one test when concrete is sampled for strength tests.

- Do not require slump tests as an acceptance criterion. Concrete contractor and producer might have a slump requirement and may choose to accept, reject or make jobsite adjustment to the concrete based on slump.

5. Temperature: ASTM C 1064; one test when concrete is sampled for strength tests.

6. Density: ASTM C 138; one test when concrete is sampled for strength tests.

7. Test results shall be reported to architect, engineer, concrete producer, and concrete contractor within 48 hours of testing.