Guide for Concrete Plant Inspection and Testing of Ready-Mixed Concrete

Reported by ACI Committee 311

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This guide is intended for use in establishing basic duties and reports required of inspection personnel. It can be used for all types and sizes of projects but should be supplemented with additional inspection requirements when the complexity of the project so dictates. Refer to ACI 311.4R for guidance on additional requirements and to SP-2 for more detailed information on concrete production practices and inspection and testing of concrete.

This guide recommends minimum requirements for inspection at the concrete plant when such inspections are required by specifications or the owner. It also recommends minimum requirements for field and laboratory testing of concrete. It is intended for use by specifiers, architects, engineers, owners, contractors, or other groups needing to monitor the ready-mixed concrete producers' activities at the concrete plant and concreting activities at the project site through the use of an independent inspection agency or in-house inspection organization.

This guide also recommends minimum testing laboratory qualifications, minimum inspector qualifications, duties, and reports.

Keywords: batch plants; contract documents; curing; high-strength concrete; quality control; ready-mixed concrete; test.

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CHAPTER 1—PLANT INSPECTION OF READY-MIXED CONCRETE

1.1—Introduction and scope

This chapter recommends minimum requirements for inspection of the concrete plant when required by specifications or the owner. It is intended for use by specifiers, architects, engineers, owners, contractors, or other groups interested in monitoring the ready-mixed-concrete producers' activities at

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the plant through the use of an independent inspection agency or in-house inspection organization. This chapter recommends:

1. Minimum qualifications of an inspector;
2. The minimum duties of an inspector; and
3. The type of reports that should be made.

The scope and responsibility involved in plant inspection should be established in the contract documents, which should also define the relationships between the owner, concrete contractor, concrete supplier, and the inspector.

1.2—Inspector qualifications

The plant inspector should be qualified by education, training, and experience to perform the minimum duties set forth in this guide. The inspector should have a technical understanding of the materials used to produce concrete along with the principles involved in concrete batching and should know the basic operating sequence of the concrete plant. The inspector should provide evidence of his or her training and experience. ACI inspector or technician certifications, Reinforced Concrete Special Inspector Certification (co-sponsored by ACI and various building code organizations) or appropriate state agency certifications are acceptable evidence that the person has completed minimum training and examination requirements for specific areas of inspection and testing covered in this document. The inspector should also have and become familiar with the published standards referenced in this guide and with project specification requirements.

The authority of the plant inspectors and to whom they report should be established before the start of the project.

1.3—Inspector duties

1.3.1 To determine required inspections, the inspector should review and fully understand the project specifications, plans, and other project documents. The inspector should observe that the facilities, scales, and truck mixers meet the specified project requirements. The provisions of the following documents should normally be incorporated in the project specification:

- ACI 301;
- ASTM C 94/C 94M;
- Plant qualification in accordance with the National Ready Mixed Concrete Association (NRMCA) checklist for certification of ready-mixed concrete production facilities; and
- Local, state, or federal agency specifications.

1.3.2 Inspectors should conduct activities in accordance with all safety policies, health standards, and safe work practices in effect at the job site.

1.3.3 The inspector should verify proper storage of all materials on a daily basis. All storage areas should be clean and free of contamination. Cementitious materials should be stored in weatherproof silos or similar structures. Aggregate storage areas should provide for separation and free draining of stockpiled materials. Storage areas should be equipped with water spray systems for maintaining aggregates in a saturated condition. Means for protecting and preventing freezing of aggregates during winter production should also be provided. Admixture storage areas should be suitably insulated or heated to prevent freezing.

1.3.4 All tests and inspections should be conducted at the frequencies required by the project specifications in a manner that does not interfere unnecessarily with the manufacture and delivery of the concrete. During the first batch being shipped to the project under the inspector's jurisdiction, the inspector should be present at the batching console to verify that the specified type and amount of materials, conforming to the approved design mixture proportions, are batched and delivered to the mixer.

If the operation is automated and recorded, the inspector should make observations as often as possible, preferably on a continuous basis, but at least once per hour.

If the batching operation is manual, the inspector should be present at the batching console during all batching. The inspector should verify that quantities of materials for each batch fall within the tolerances set forth by the project specifications.

1.3.5 The inspector should verify that coarse- and fine-aggregate gradation tests are being performed in accordance with ASTM C 136 and that the results meet the project requirements. If deviation occurs, batch plant personnel and the client should be notified immediately, or previously authorized action should be taken.

1.3.6 The inspector should verify that aggregate moisture contents are properly determined in accordance with ASTM C 566, and that the batch quantities of materials are adjusted to compensate for free moisture in the aggregates. If aggregate moisture contents are being measured by rapid methods, daily correlation tests following ASTM C 566 should be conducted.

1.3.7 The inspector should determine that the trucks are in good operating condition and not loaded beyond their rated capacities for mixing and agitation. Trucks should also be inspected (safety regulations regarding confined spaces should be followed, if applicable) for blade wear, build-up of concrete on the blades, and for proper mixing speed as described in Section 3 of the NRMCA Quality Control Manual. Truck mixers should be equipped with counters or similar means to enable verification of the number of revolutions applied to the drum.

1.3.8 The inspector should verify that the scales and other measurement systems have been properly calibrated within the time period specified by the project specifications or referenced documents

1.3.9 The capability of the production facility to produce concrete within the temperature limits of the project specification should also be evaluated and verified. In cold weather this generally requires a water and aggregate heating capacity of 15 boiler horsepower per 100 yd^3 (76 m^3) production. In hot weather, this generally requires a system for spraying and cooling aggregates and a system for efficiently weighing and delivering crushed ice to the mixer in the range of 40 to 100 lb per yd^3 (18 to 45 kg per m^3).

1.3.10 For each batch of concrete the inspector should verify that the concrete plant is furnishing to the purchaser a delivery ticket conforming to ASTM C 94/C 94M. A place should be provided on the ticket to reflect the following information:

- Name of the concrete plant;
- Serial number of the ticket;
- Date;
- Truck number;
- Name of the purchaser;
- Project designation (name and location);
- Class or designation of concrete;

- Amount of concrete batched;
- Time batched;
- The amount of water added by receiver of concrete and receiver's initials;
- The amount of water withheld during batching, if any, and the admixtures that may be added at the jobsite; and
- Any additional information required by the purchaser or the project specification.

1.4—Reports

1.4.1 The inspector should sign the delivery ticket, issue an inspection report, or supply other evidence that the concrete batching has been inspected.

1.4.2 The inspector should issue a daily inspection report showing all test results and documenting observations made during the day. Deficiencies and to whom they were reported should be clearly identified. *The ACI Manual of Concrete Inspection* (SP-2) contains guidance on reporting and samples of reports.

CHAPTER 2—TESTING OF READY-MIXED CONCRETE

2.1—Introduction and scope

This chapter recommends minimum requirements for the testing of ready-mixed concrete at the project site when required by specifications. It includes requirements for curing of specimens, testing of specimens for strength, and qualification requirements for testing technicians and laboratories. It is intended for use by specifiers, architects, engineers, owners, contractors, or other groups interested in monitoring the concreting activities at the project site through the use of an independent inspection agency or in-house inspection organization.

2.2—Qualifications

Technicians conducting field tests of concrete are required by ASTM C 94/C 94M to be certified as an ACI Concrete Field Testing Technician—Grade I, or equivalent. For laboratory testing, ACI certification as a Laboratory Testing Technician or Concrete Strength Testing Technician, or equivalent, is required. Technicians should also be furnished with and become familiar with published standards as referenced in this guide and with project specification requirements.

Before the start of the project, the owner should establish the technician's scope of authority and the requirements for submittal of reports and notification of deficiencies.

2.3—Testing laboratory

All required laboratory acceptance tests (that is, laboratory curing and testing of concrete strength specimens) should be performed by an independent testing laboratory or by the owners' in-house testing personnel. The laboratory conducting acceptance testing shall meet the requirements of ASTM C 1077. To comply with ASTM C 1077 the laboratory must be inspected by an independent agency such as the Cement and Concrete Reference Laboratory (CCRL) or the AASHTO Material Reference Laboratory (AMRL) within the last 3 years and should show that any deficiencies mentioned in the report of that inspection have been corrected.

The laboratory should be accredited by the AASHTO Accreditation Program (AAP), the National Voluntary Laboratory Accreditation Program (NVLAP), the American Association for Laboratory Accreditation (A2LA), or similar programs as approved by the owner.

2.4—Duties

2.4.1 The field technician should check each delivery ticket to verify that the mixture with the correct designation is being delivered and, if possible, determine whether adjustments to proportions, such as admixtures, have been made.

Immediate action should be taken, as authorized, in the case of a discrepancy. Immediate verbal notification should be given to the placing contractor and the concrete supplier.

2.4.2 The field technician should determine that:

- Truck mixers are not loaded in excess of mixer plate capacity;
- Concrete appears to be uniform and adequately mixed before discharge at the project site;
- Field additions of water, admixtures, or fiber reinforcement are properly conducted and documented;
- Concrete delivery and placement falls within the time constraints of the project specifications; and
- All data required by ASTM C 94/C 94M, the purchaser, or the job specification are included on the delivery ticket.

Immediately report any discrepancies to the placing contractor and the concrete supplier.

2.4.3 The technician should cast at least one set of strength test specimens in accordance with ASTM C 31/C 31M for each 100 yd^3 (76 m^3), or fraction thereof, of each class of concrete placed in any one day. Tests of concrete that should be conducted whenever strength specimens are cast include the following: slump, air content, temperature, and density (whenever yield is to be calculated or as required by project specifications).

When sampling concrete, a composite sample representing concrete conditions as delivered to the forms should be obtained in accordance with ASTM C 172, and the date, time, placement location, truck number, and ticket number should be reported.

2.4.4 The first truckload of concrete should be tested for slump, concrete temperature, air content, and, if specified, density, so that any necessary adjustments can be made at the plant to bring concrete within specifications immediately.

2.4.5 The technician should measure slump in accordance with ASTM C 143/C 143M for composite samples used to cast strength test specimens and whenever the consistency of the concrete appears to vary.

2.4.6 The technician should determine the air content of composite concrete samples for each strength test in accordance with ASTM C 173, ASTM C 231, or ASTM C 138, and density (when required) in accordance with ASTM C 138.

2.4.7 Specimens for determining equilibrium density of low-density concrete should be cast and tested in accordance with ASTM C 567.

2.4.8 The technician should determine the ambient air temperature and the composite concrete sample temperature at the time of sampling for each strength test in accordance with ASTM C 1064.

2.4.9 For each test age specified for acceptance, the technician should cast a minimum of two strength specimens according to ASTM C 31/C 31M from each composite concrete sample. Casting of additional specimens for informational testing at other ages may also be required.

2.4.10 The contractor should provide a suitable area or container at the project site for initial storage and curing (up to the first 48 h after molding) of specimens cast for acceptance testing purposes. Specimens should be stored under conditions that maintain the temperature immediately adjacent to the specimens in the range of 60 to 80 ºF (16 to 27 ºC) and which prevent damage and loss of moisture from the specimens. Initial curing should meet the requirements of ASTM C 31/C 31M.

2.4.11 Where verification of in-place concrete strength is required before removal of forms, shoring, or placement of the structure in service, additional specimens should be cast for field curing in accordance with ASTM C 31/C 31M. Specimens should be stored as near as possible to the structure and protected in a manner similar to the structure until they are transported for testing.

2.4.12 In accordance with ASTM C 31/C 31M, the testing laboratory should pick up and transport specimens cast for acceptance testing within 16 to 48 h after molding. If the specimens are not transported to the laboratory within 48 h, the molds should be removed within 16 to 32 h, and the specimens should be moist cured at 73 ± 3 ºF (23 ± 2 ºC) until they are transported. The transportation time should not exceed 4 h. Specimens should be protected from damage, moisture loss, and freezing during transport. Within 30 min after removal from the molds, the specimens should be stored at a temperature of 73 ± 3 ºF (23 ± 2 ºC) in moist rooms or saturated lime-water tanks conforming to the requirements of ASTM C 511. Moist rooms should be maintained at a minimum relative humidity of 95%, and free water should be maintained on the specimens' surfaces at all times. Beam specimens that are cured in moist rooms should be moved to saturated lime-water storage for 24 ± 4 h before testing.

2.4.13 The testing laboratory should test compressive strength specimens in accordance with ASTM C 39/C 39M and test flexural strength specimens in accordance with ASTM C 78 or ASTM C 293. Before testing, ends of compressive strength specimens and contact surfaces of beams may need to be sawed, capped, or ground to meet bearing surface requirements of the applicable test procedure. A minimum of two specimens should be tested at the designated age for determining conformance with the specified strength. Additional specimens may be tested at other ages for information. A test result is obtained by averaging the strengths of the specimens tested at the age designated for determining conformance with the specified strength.

2.4.14 In accordance with ACI 318/318R, the strength level of an individual class of concrete is considered satisfactory if both of the following requirements are met:

(a) Every arithmetic average of any three consecutive strength test results equals or exceeds the specified strength of concrete f'_c; and

(b) No individual strength test (average strength of test specimens) falls below the specified strength of concrete by more than 500 psi (3.4 MPa).

2.5—Testing high-strength concrete

2.5.1 High-strength concrete is usually defined as concrete having a specified compressive strength of 6000 psi (40 MPa) or greater. ACI 363.2R provides extensive commentary and recommendations on adjustments to standard field and laboratory testing practices that may need to be implemented to maintain accuracy and consistency of test results.

2.5.2 Field sampling and testing of high-strength concrete is conducted using the same standard testing procedures noted previously in this guide. The effects of any deviation from established testing procedures becomes magnified as the compressive strength of concrete increases.

2.5.3 Obtaining accurate and consistent compressive strength results for high-strength concrete is, to a large extent, dependant upon the end preparation of specimens before testing. Capping systems described in ASTM C 617 and ASTM C 1231/C 1231M are subject to restrictions and limitations when used for testing high-strength concrete.

ASTM C 617 presently requires qualification test data to be supplied by capping material manufacturers for sulfur mortar, high-strength gypsum plaster, and other materials, except neat cement paste, that are used to test concrete having strengths greater than 7000 psi (50 MPa). Compressive strengths of capped cylinders are compared to strengths of companion cylinders whose ends have been capped with a suitable neat cement paste or to cylinders whose ends have been ground plane to within 0.002 in. (0.05 mm). Table 1 of ASTM C 617 additionally requires that caps used in testing concrete greater than 7000 psi (50 MPa) have a maximum average thickness of 1/8 in. (3 mm).

ASTM C 1231/C 1231M presently requires qualification testing of elastomeric unbonded capping systems by the supplier or by the user before testing concrete in the range of 7000 to 12,000 psi (50 to 80 MPa). The compressive strengths of cylinders tested using unbonded caps are compared to strengths of companion specimens whose ends have been capped to meet ASTM C 617 or ground plane to within 0.002 in. (0.05 mm). Use of unbonded caps is not permitted for testing concrete strength in excess of 12,000 psi (80 MPa).

ACI 362.2R states that "The problems associated with capping can be eliminated by grinding the ends of test cylinders using equipment made for that purpose." Studies evaluating the effectiveness of various end preparation techniques are ongoing, and it is likely that additional changes to the referenced ASTM standards will need to be made as new information on testing high-strength concrete becomes available.

2.6—Reports

2.6.1 The technician should issue a daily inspection report of all field test results and document observations made during the day. Items not conforming to specifications should be reported immediately to the technician's supervisor and to the client.

2.6.2 The technician should complete a concrete data report for each set of concrete strength specimens to be tested by the testing laboratory.

2.6.3 The testing laboratory should issue timely reports containing:

- Project name;
- Client;
- Concrete supplier;
- Date sampled;
- Sampled by, with certification number, if applicable;
- Truck number, ticket number, or both;
- Time batched and time sampled;
- Air temperature and concrete temperature at time of sampling;
- Results of slump, air content, and other specified tests;

- Specified strength of the concrete;
- Concrete mixture designation, with identification of any optional admixtures batched;
- Location of placement and location of sample batch;
- Type and amount of admixture or water added after leaving the plant; and
- Elapsed time between the start of mixing to the completion of placement, and a description of any conditions encountered before, during, or after the placement that, in the opinion of the inspector, may affect the concrete quality.

2.6.4 The testing laboratory should issue timely lab testing reports containing the following information:

- All information for cylinders required by ASTM C 39/C 39M, including the date tested, specimen identification number, diameter, cross-sectional area, maximum load, compressive strength, type of fracture, defects, and the age of the specimens; and
- All information for beams required by ASTM C 78 or ASTM C 293, including the date tested, the specimen identification number, average width, average depth, span length, maximum load, modulus of rupture, and curing history. Information should also be included on the use of capping, grinding, or leather shims; whether the specimens were sawed or molded; whether defects are present; and the age of the specimens.

CHAPTER 3—REFERENCES

3.1—Referenced standards and reports

The documents of the various standard-producing organizations referred to in this document and other recommended references are listed below with their serial designation. The latest version should always be used unless specified otherwise.

American Concrete Institute (ACI)

301	Specification for Structural Concrete
318/318R	Building Code Requirements for Structural Concrete and Commentary
363.2R	Guide to Quality Control and Testing of High-Strength Concrete
SP-2	ACI Manual of Concrete Inspection

American Society for Testing and Materials (ASTM)

C 31/C 31M	Practice for Making and Curing Concrete Test Specimens in the Field
C 39/C 39M	Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 78	Test Method for Flexural Strength of Concrete (Using Simple Beam With Third-Point Loading)
C 94/C 94M	Specification for Ready-Mixed Concrete
C 138	Test Method for Density (Unit Weight), Yield and Air Content Gravimetric) of Concrete
C143/C143M	Test Method for Slump of Hydraulic Cement Concrete
C 172	Practice for Sampling Freshly Mixed Concrete
C 231	Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 293	Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading)
C 511	Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C 566	Test Method for Total Moisture Content of Aggregate by Drying
C 567	Test Method for Density of Structural Lightweight Concrete
C 617	Practice for Capping Cylindrical Concrete Specimens
C 1064	Test Method for Temperature of Freshly Mixed Portland-Cement Concrete
C 1077	Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
C 1231/ C 1231 M	Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders

National Ready Mixed Concrete Association

Quality Control Manual, Section 1—Ready-Mixed Concrete Quality Control Guide

Quality Control Manual, Section 2—Ready-Mixed Concrete Quality Control Checklist

Quality Control Manual, Section 3—Certification of Ready Mixed Concrete Production Facilities

The above publications may be obtained from the following organizations:

American Concrete Institute
P.O. Box 9094
Farmington Hills, MI 48333-9094

ASTM
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

AASHTO Material Reference Laboratory (AMRL) or Cement and Concrete Reference Laboratory (CCRL) at the National Institute of Standards and Technology
Gaithersburg, MD 20899
(301) 975-6704

3.2—Other references

ACI Committee 116, 2000, "Cement and Concrete Terminology (ACI 116R-00)," American Concrete Institute, Farmington Hills, Mich., 73 pp.

ACI Committee 304, 2000, "Guide for Measuring, Mixing, Transporting, and Placing Concrete (ACI 304R-00)," American Concrete Institute, Farmington Hills, Mich., 41 pp.

ACI Committee 304, 1997, "Batching, Mixing, and Job Control of Lightweight Concrete (ACI 304.5R-91) (Reapproved 1997)," American Concrete Institute, Farmington Hills, Mich., 9 pp.

ACI Committee 305, 1999, "Hot Weather Concreting (ACI 305R-99)," American Concrete Institute, Farmington Hills, Mich., 20 pp.

ACI Committee 306, 1988, "Cold Weather Concreting (ACI 306R-88) (Reapproved 1997)," American Concrete Institute, Farmington Hills, Mich., 23 pp.

ACI Committee 311, 2000, "Guide for Concrete Inspection (ACI 311.4R-00)," American Concrete Institute, Farmington Hills, Mich., 12 pp.

American Society for Testing and Materials, 2002, ASTM C 33, "Specification for Concrete Aggregates," ASTM, West Conshohocken, Pa., 11 pp.

American Society for Testing and Materials, 2001, ASTM C 70, "Test Method for Surface Moisture in Fine Aggregate," ASTM, West Conshohocken, Pa., 3 pp.

American Society for Testing and Materials, 2000, ASTM C 125, "Terminology Relating to Concrete and Concrete Aggregates," ASTM, West Conshohocken, Pa., 4 pp.

American Society for Testing and Materials, 2001, ASTM C 127, "Test Method for Specific Gravity and Absorption of Coarse Aggregate," ASTM, West Conshohocken, Pa., 6 pp.

American Society for Testing and Materials, 2001, ASTM C 128, "Test Method for Specific Gravity and Absorption of Fine Aggregate," ASTM, West Conshohocken, Pa., 6 pp.

American Society for Testing and Materials, 2001, ASTM C 136, "Test Method for Sieve Analysis of Fine and Coarse Aggregates," ASTM, West Conshohocken, Pa., 5 pp.

American Society for Testing and Materials, 2002, ASTM C 150, "Specification for Portland Cement," ASTM, West Conshohocken, Pa., 7 pp.

American Society for Testing and Materials, 2001, ASTM C 173/C 173M, "Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method," ASTM, West Conshohocken, Pa., 9 pp.

American Society for Testing and Materials, 2000, ASTM C 192/C 192M, "Practice for Making and Curing Concrete Test Specimens in the Laboratory," ASTM, West Conshohocken, Pa., 8 pp.

American Society for Testing and Materials, 1999, ASTM C 494/C 494M, "Specification for Chemical Admixtures of Concrete," ASTM, West Conshohocken, Pa., 9 pp.

American Society for Testing and Materials, 1997, ASTM D 75, "Practice for Sampling Aggregates," ASTM, West Conshohocken, Pa., 4 pp.

3.3—Laboratory evaluation and accreditation agencies

The following organizations may be contacted for information on laboratory evaluation inspections and accreditation programs:

AASHTO Accreditation Program
American Association of State Highway and Transportation Officials
444 N. Capital Street, N.W. Suite 249
Washington, D.C. 20001
(202) 624-5800

American Association for Laboratory Accreditation
656 Quince Orchard Road
Gaithersburg, MD 20878
(301) 670-1377

National Voluntary Laboratory Accreditation Program
U. S. Department of Commerce
National Institute of Standards and Technology
Gaithersburg, MD 20899

National Ready-Mixed Concrete Association
900 Spring Street
Silver Springs, MD 20910