Guide for Concrete Inspection

Reported by ACI Committee 311

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This guide discusses the need for inspection of concrete construction and other related activities, the types of inspection activities involved, and the responsibilities of various individuals and organizations involved in these activities. Field and laboratory testing activities are also considered part of inspection. This guide presents recommendations for inspection plan content and a detailed checklist of inspection attributes that can be adopted for use depending on the scope and needs of individual projects.

Keywords: concrete; construction; inspection; quality assurance; quality control; testing.

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CHAPTER 1—INTRODUCTION

1.1—Scope

This document is primarily intended for guidance in the development of inspection and testing plans that are part of the overall system designed to ensure quality in the finished concrete product. ACI Committee 311 recommends that the owner develop a quality plan, as outlined in ACI 121R, and

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that 311.4R be used to develop inspection and testing plans by those organizations assigned by the owner's quality plan to conduct inspections.

1.2—Philosophy

Inspection and testing requirements typically vary, based on the specific scope and needs of construction, and should therefore be tailored to each project individually. The content of an inspection plan is dependent on the type and complexity of the project, special features involved, quality level desired, building code requirements, and the responsibilities of the inspection organization performing the work. Any of these may necessitate the addition of more detailed inspection than conventional or may warrant a reduction from conventional requirements.

1.3—General

Inspection is simply a subsystem of the quality plan. It may be employed by the owner to evaluate future acceptance of the work or by contractors and material producers for quality-control purposes. In addition, inspection may be part of a program of activities performed by government agencies charged with enforcing building codes and other government regulations. The inspection process does not add quality to inspected items. Inspection simply establishes the status of inspected items relative to specified requirements. The information derived from inspections and tests, however, when properly evaluated, and with conclusions and decisions implemented, can result in the improvement of the quality of the product or process. The specified quality is achieved only by implementation of an adequate quality plan. Such a plan affects the entire project, from planning through design and construction to acceptance by the owner. Quality of work during the construction phase is achieved almost entirely by the contractor or producer's quality-control program. This quality-control program involves everyone from management to field supervisors to workers. Quality assurance and quality control should have strong, active support from top management and the active concern and participation of everyone involved in the construction process. Inspection and testing are only a part, though a very important part, of both quality-assurance and quality-control programs.

1.4—Definitions

1.4.1 *Quality assurance (QA)*—A management tool for all planned and systematic actions necessary to ensure that the final product meets the requirements of the contract documents and standards of good practice for the work.

1.4.2 *Quality control (QC)*—Actions taken by a contractor or material producer to provide and document control over what is being done and what is being provided so that the applicable standards of good practice and the contract documents for the work are followed.

1.4.3 *Owner*—The individual or organization having financial and legal responsibility for construction of a project, as well as bearing the ultimate responsibility for the public health, welfare, and safety related to the project. The term "owner" includes those organizations or individuals acting as agents for the owner.

1.4.4 *Architect/engineer (A/E)*—The architect, engineer, architectural firm, engineering firm, or architectural and engineering firm issuing project drawings and specifications, administering the work under contract specifications and drawings, or both.

1.4.5 *Contractor*—The organization responsible for constructing a project according to the project specifications and design drawings. The contractor may also possess the responsibilities of the A/E in designing and building the project and contract execution.

1.4.6 *Construction manager or owner's representative*—The person or management organization responsible to the owner for coordination and review of all contracted work. The person's or organization's role is to coordinate and communicate the entire scope of work to achieve a more efficient construction process.

1.4.7 *Inspection organization*—The organization, agency, or testing laboratory that is responsible for providing inspection and testing for the owner or for providing quality-control inspection and testing for the contractor or producer.

1.4.8 *Inspection*—Visual observations, measurements, and field and laboratory testing of activities, components, and materials to specified requirements along with the recording and evaluation of such data.

1.4.9 *Inspection/test report*—A document that records the results of observations, measurements, and tests as verified by the initials or signature of the individual responsible for the inspection/test activity.

1.4.10 *Material manufacturer or supplier*—The organization responsible for producing or manufacturing a product or material used in the process of construction, or for supplying products or materials to a project, with or without performing additional operations on the product or material.

1.5—Categories of inspection

Inspection activities generally fall into one of the categories described in 1.5.1 through 1.5.4.

1.5.1 *Owner's inspection*—Inspections and tests conducted by or for the owner either by the owner's in-house inspection group or by an independent inspection agency. Owner inspection is a part of the external quality assurance program conducted by the owner. Results of these inspections form the basis of the owner's decision to ultimately accept the work performed by the contractor. Owner-inspection programs should be structured so as to provide the owner with an acceptable degree of assurance that the work of the contractor is in conformance with the contract documents.

1.5.2 *Quality-control inspection: contractor*—A series of formalized activities and procedures that are part of the contractor's operation, providing in-process evaluation of the quality of construction. These activities help to assure the contractor that the finished construction will meet all requirements of the project plans, drawings, and specifications, and will be accepted by the owner.

1.5.3 *Quality-control inspection: producer*—A series of formalized activities and procedures that are part of the

fabricating or manufacturing operation of a producer or fabricator of concrete materials, reinforcement, or products who furnishes products to the construction industry or to a specific project. Examples are operations of cement and aggregate producers, concrete producers, precasters, prestressing concrete fabricators, and reinforcing steel mills and fabricators. Production-inspection personnel operate essentially the same way as those described for the contractor. They aid in ensuring that finished products will meet general specifications or those specifications relative to a specific project.

1.5.4 *Compliance inspection*—A series of formalized activities and procedures performed by government agencies charged with the responsibility for enforcing building codes and other regulations. In these cases, compliance inspectors have the responsibility for ensuring that the finished structure conforms to specified codes or regulations. The organization and activities of these inspectors are governed almost entirely by the requirements of building codes or government regulations. An overlap of compliance inspection and owner inspection often occurs when the owner engages the services of a special inspector, as required by some building codes, to oversee and confirm the performance of inspections required by the code. In most cases, the technical requirements of the building code are similar, if not identical, to the requirements given in project specifications and drawings.

1.6—Inspection team

Regardless of classification, an inspection team or group may consist of a number of individuals or, for very small projects, a single individual. Inspection may be performed by a variety of groups, such as:

- Owner's inspection personnel;
- A/E's inspection personnel;
- Laboratory's inspection force;
- Contractor's inspection force; and
- Material manufacturer's and supplier's inspection force.

All inspection force personnel should be qualified and, as applicable, certified to conduct inspections and tests for which they are assigned.

CHAPTER 2—RESPONSIBILITIES

2.1—Scope

This chapter defines the general responsibilities for inspection placed on the owner, A/E, inspection organization contractor, and manufacturer or fabricator in conforming to the recommendations of this guide.

2.2—Owner's responsibilities

2.2.1 The owner should provide for a program of inspection separate and distinct from quality-control inspection conducted by the contractor or by material producers. The A/E should provide the owner with recommendations for the scope and content of inspections and tests to be included in the owner's inspection plan. The owner should review the inspection plan with the A/E and, where appropriate, select the level of inspection required that is consistent with project size, quality, complexity, and the requirements of the local building code.

2.2.2 In conjunction with the A/E, the owner should be responsible for arranging a preconstruction conference that includes all parties involved in the construction project. The conference should include review of the inspection and testing plan(s), and confirm lines of communication, responsibilities, and minimum quality levels for the project. To be effective, the inspection personnel should have the active support of the owner.

2.2.3 The fee for owner inspection should be a separate and distinct item and should be paid by the owner, or by the A/E acting on behalf of the owner, directly to the inspection organization. The owner or A/E should avoid the undesirable practice of arranging payment through the contractor for inspection services intended for use by the owner as a basis of acceptance. Such a practice is not in the owner's interest and may result in a conflict of interests. Impartial service is difficult under such circumstances, and the fees for inspection are eventually paid by the owner in any case.

2.2.4 As a professional service, the selection of the inspection organization/laboratory should be based primarily on qualifications, not on price. It should be done as carefully as the selection of the A/E. The owner should check the physical facilities of the organization/laboratory, review the supervisory program and the qualifications of the supervisory staff, and review accreditations, the latest evaluation, or both, made by the evaluation authority and ensure that any necessary corrective measures have been taken. It should review the organization's ongoing training program of its personnel. The personnel should be certified and meet the qualifications of Section 3.5. The owner should also review the qualifications of all testing and inspection personnel to be assigned to the owner's project. The owner's approval should be required for all personnel before such assignment.

2.2.5 When the project specifications require extensive quality-control inspection by the contractor, the owner should not reduce or eliminate owner inspection. If the contractor's quality-control inspection program becomes the owner's inspection program, the system is nullified. The objections are exactly as stated previously against the practice of having the contractor hire and pay an inspector to perform inspection for the owner. When the owner requires the contractor to have a quality-control inspection program, the owner should still accept responsibility for inspection to provide assurance that the contractor's quality-control program achieves its objectives.

2.3—Architect/engineer's inspection responsibilities

2.3.1 For the protection of the public and the owner, the responsibility for planning and detailing owner inspection should be vested in the A/E as a continuing function of the design responsibility. The A/E should ensure that the program for owner inspection meets all requirements of design specifications and the local building code. The inspection responsibility may be discharged directly, may be

conducted by owner personnel, or may be delegated to an independent inspection organization reporting to the A/E.

2.3.2 If the A/E is also responsible for construction, an independent inspection organization should be retained directly by the owner. When the owner provides the A/E service, the owner should also provide inspection or retain an independent inspection organization. Inspection requirements on projects supervised by a construction manager should also be detailed by the A/E and should be carried out by inspection personnel representing the owner.

2.3.3 Some local building codes require that the A/E or another registered professional be engaged by the owner to conduct periodic inspection visits during construction along with an overall review of inspection/testing activities to ensure that work is conducted in compliance with the code.

2.4—Owner's inspection organization responsibilities

2.4.1 The inspection organization/laboratory selected by the owner should perform required inspections in accordance with the contract documents. It is recommended that owner inspections be conducted for items listed in Table 3.1 or as otherwise directed by the owner or A/E. Failure of the owner's inspection to detect defective work or material does not relieve contractors of their responsibility to meet quality requirements for the work. It does not prevent later rejection when such defect is discovered, and does not obligate the owner or A/E for final acceptance.

2.4.2 The inspection organization should be accredited in accordance with ASTM E 329. Testing laboratories should be accredited by ASTM C 1077 and should have its facilities, personnel, and procedures inspected by a qualified evaluation authority at intervals of approximately 24 months.

2.4.3 Owner inspection personnel are responsible for, and can only be involved with, determining that inspected materials, procedures, and final products, as installed, conform to the requirements of the contract documents. The contractor is obligated to meet the requirements of the contract documents. For the inspector to accept less than that required deprives the owner of full value, whereas requiring more than is called for in the contract documents places an unacceptable burden on the contractor. Either action is a misuse of the inspector's authority. The inspection personnel representing the owner have no responsibility or authority to manage the contractor's personnel.

2.4.4 At the conclusion of the project, the owner's inspection organization is often asked to submit a final statement covering the results and final status of inspection/testing activities. Because inspection is typically conducted on only a portion of the total work, the inspection organization is generally not capable of certifying that all work is in conformance with the contract documents (although this type of statement is frequently requested). Properly worded statements usually indicate only that "items documented in inspection and test reports were found to be in conformance…" Should there be items or work that are nonconforming, such as those not corrected by the contractor or accepted by the A/E, the items should be clearly identified in the final statement of inspection.

2.5—Contractor's inspection responsibilities

2.5.1 Coordination and providing scheduling notice to the owner's inspection organization should be included in the contractor's work plans and overall schedule. This will enable timely inspection by the owner's representatives and avoid possible construction delays.

2.5.2 Quality-control inspection, or in-process inspection, is usually performed by contractor personnel or by others, such as independent inspection laboratory personnel, hired by the contractor. To be effective, quality-control inspection results should be reported directly to and have the active support of contractor management. Inspection by or for the contractor, subcontractors, or material suppliers is separate and distinct from inspection conducted for the owner. Qualification and certification requirements for personnel conducting quality-control inspections should be the same as that described previously for owner inspection personnel.

In some construction contracts, the contractor is required to provide a specified amount of inspection as part of a formal quality-control program. When not contractually required, many contractors still maintain a quality-control program that includes inspection personnel separate from the line of supervision, reporting directly to management. The initial cost is often returned many times over through the reduction of mistakes and rejections, resulting in savings in both replacements and repairs. Frequently, this inspection work is an informal and automatic part of the contractor's operations performed by regular production supervisors, although a formal program is more effective.

2.5.3 Inspection performed by, or for, the contractor, particularly when contractually required, will often be much more detailed than is the usual practice for owner inspection. The contractor's personnel should make a more detailed inspection of form alignment, reinforcement positioning, cleanup of forms, and other concrete placement issues. Even if not required by the project specifications, the contractor should use quality-control inspection to reduce the possibility of later rejection by the owner.

2.5.4 Quality-control inspection other than or in addition to that required by the project specifications will be as directed by the contractor's management. These inspection details and criteria will be based on management's judgment as to items and criteria necessary to ensure that all aspects of workmanship and the finished product will meet the requirements of the contract documents and will thus be accepted by the owner.

2.6—Manufacturer's or fabricator's inspection responsibilities

Quality-control inspection by the manufacturer or fabricator should parallel the contractor's programs. Program content depends on contractual requirements, building code requirements, and on the manufacturer's quality-control process. Where facility certifications are available to the industry, they should be required by the owner.

CHAPTER 3—PLANNING FOR INSPECTION

3.1—Scope

This chapter gives specific recommendations to the A/E on inspection-related items that should be included in the contract documents. Recommendations for scheduling meetings or conferences are also discussed due to their direct effect on achieving improved quality in the final work.

3.2—Written inspection plan

All projects can benefit from a written inspection plan. A small project may require only a list of items to be inspected and tests to be conducted for acceptance purposes, but it becomes invaluable in developing adequate communication and understanding among the owner, A/E, contractor, and the inspection organization. All projects should use some form of written plan or checklist. On complex projects, the owner's quality-control plan, as referenced in ACI 121R, detailing the owner's policy statement, quality objectives, scope of work, organizational responsibilities including responsibilities for owner inspection, interface between owner and contractor inspection activities, procedures for documentation of inspections and tests, scheduling and frequency of inspection, reporting of results, handling of nonconformances and design changes, record retention, and auditing of the progress of the work is a necessity. Specifications developed by the A/E should include requirements for the development and submittal of written inspection plans as part of the quality manuals that should be developed by appropriate inspection groups involved with the project.

3.3—Building code requirements for special inspections

Many states and municipalities have adopted the International Building Code (IBC) along with the requirements for special inspections of concrete and other structural materials. Although the manner in which special inspections are carried out can vary, in most cases, a design or engineering professional must be engaged by the owner to oversee and verify that required inspections and tests are performed and that corrective action or engineering evaluation/acceptance is conducted for all items identified as nonconforming to the design specifications or building code requirements. The special inspector provides regular reports during construction to the owner, the A/E, and the local building official, and a final report summarizing and confirming that the work was conducted in accordance with the building code, the contract documents, and the instructions of the A/E. Reference to special inspections should be included in the contract documents where applicable. The recommended outline of concrete inspection activities presented in Table 3.1 of this document was developed to meet or exceed IBC special inspection requirements for activities and materials commonly encountered in concrete construction.

Table 3.1—Outline of recommended inspection program activities for concrete construction

I—Concrete production
a. Submittal review of mixture proportions and supporting test data
b. Submittal review of material certifications for concrete materials
c. Preconstruction sampling and testing of concrete materials
d. In-process sampling and testing of concrete materials
e. Inspection of concrete batching and mixing operations
f. Inspection/qualification of concrete mixer trucks
g. Mixer uniformity testing
h. Use of approved mixture proportions in production
II—Inspection and testing of concrete
a. Truck/ticket review and control
b. Field additions of water, admixtures, and other materials
c. Sampling and testing of concrete or grout
d. Initial curing/storage of lab specimens in the field
e. Storage of field-cured specimens
f. Transportation of test specimens to the testing facility
g. Laboratory curing/storage of test specimens
h. Strength testing of specimens
i. Other required tests
III —Preplacement inspection
a. Inspection/testing of subgrade and subbase
b. Inspection of forms and decking
c. Inspection of reinforcing bars
d. Inspection of anchor bolts and embedments
e. Inspection of prestressing strands/bars
f. Inspection of pretensioning
g. Inspection of welding of reinforcing steel
h. Inspection of shear stud installation
IV—Placement inspection
a. Inspection of concrete transportation and handling
b. Inspection of concrete placement and consolidation
c. Inspection of leveling and screeding operations
d. Inspection of finishing operations
e. Inspection of surface treatment applications
f. Inspection of initial curing and protection
V—Postplacement inspection
a. Inspection of concrete moist curing
b. Inspection of concrete protection and monitoring of curing temperatures
c. Verification of in-place strength before removal of shoring or loading of the structure
d. Inspection of post-tensioning
e. Inspection for damage following form removal or loading
f. Inspection of surface treatments and surface repairs
g. Inspection of repairs to A/E instructions
h. Examination of in-place concrete strength by testing of cores or nondestructive methods
VI—Precast erection
a. Inspection of transportation and lifting of elements
b. Inspection of bearing and alignment
c. Inspection of grouted connections
d. Inspection of welded connections

3.4—Preconstruction conferences

A preconstruction conference is recommended for all projects to establish lines of communication at the start of a project. This conference should include all parties involved with the construction. Its main purpose is to identify responsibilities, clarify flow of documents, and establish procedures that will allow construction to proceed in a manner that will ensure the best possible construction quality in the finished work, in accordance with specifications.

3.5—Meetings

Regular meetings of the contractor, A/E, concrete producer, inspection organization, and testing laboratory are recommended. The frequency of meetings is contingent on the size, schedule, complexity of the project, and on the existence of unidentified problems. These meetings allow for open dialogue and should be used to identify potential problem areas before they develop; meetings can also provide a platform to resolve noncompliant construction. The agenda should allow for review of the past period's activity and a schedule of activities for current and future periods.

3.6—Qualifications of inspection and testing personnel

The qualifications of personnel conducting inspections and tests are critical to attaining the desired level of quality. Nonstandard testing practices and ineffective inspection can miss critical items and result in an inaccurate assessment of the work examined and are of no benefit to the project. Erroneous results of tests and inspections can also cause costly actions that are unwarranted.

The ACI certification program currently outlines training programs and certification of inspection personnel in the following categories (ACI certification program [CP] study guides in parentheses):

- Concrete field testing technician—Grade I (CP 1);
- Concrete laboratory testing technician—Grades I and II (CP 16 and 17);
- Concrete strength testing technician (CP 19);
- Aggregate field testing technician (CP 40);
- Aggregate laboratory testing technician (CP 41);
- Concrete construction special inspector (CP 21);
- Concrete transportation construction inspector (CP 31); and
- Concrete flatwork technician (CP 10).

All personnel performing concrete inspection and testing work should be certified and demonstrate a knowledge and ability to perform the necessary inspection and testing procedures equivalent to the minimum guidelines set forth for certification by ACI for the appropriate category listed. Personnel may be certified by ACI or by organizations whose programs provide for written and performance examinations considered equivalent to the corresponding ACI program.

3.7—Recommendations for inspection and testing

3.7.1 *General*—Owner inspection need only be detailed enough to permit adequate evaluation of the product or process. The contractor and concrete producer should be encouraged to provide their own formalized quality-control programs.

In many instances, there is a tendency for contractors and concrete producers to rely on the activities of the owner's inspection to control quality instead of conducting their own quality-control inspection. Specifications that provide for a program of inspection on behalf of the owner should include a statement indicating that the activities of the owner's inspection group do not relieve the contractor of his ultimate responsibility for quality of the work. Additionally, failure of the owner's inspection activities to identify nonconforming conditions does not prevent rejection at a later date and does not obligate the owner or A/E for final acceptance.

If there is concern by the owner or A/E about the adequacy of the quality control planned by the contractor, project specifications can direct the contractor to provide specific testing and inspection activities as part of the quality-control program, with results transmitted to the owner and A/E. When this is done, owner inspection should not be eliminated, but its scope may be adjusted, as deemed appropriate, to satisfy quality-assurance concerns.

Should a concern about the adequacy of quality control develop during the course of the project, the scope and frequency of owner inspection should necessarily be increased until the contractor's quality-control performance removes reason for concern.

3.7.2 *Owner's inspection*—The A/E should evaluate the necessity of conducting prequalification tests of the materials to be used in the project. If materials with past service records are to be used, earlier qualification tests may be relied on, or satisfactory performance in a similar environment may be used as the basis for acceptance. If prequalification tests are to be conducted, the A/E should specify the tests and the acceptance criteria.

The approval of concrete mixture proportions to be used should be based on reliable historical performance data or trial mixture results that should accompany the submittals. Methods of proportioning and other criteria established by ACI 318 and ACI 301 should be followed.

Based on the project's size and complexity, evaluate the need for certification of batch plants before concrete production and consider a qualification program for truck mixers, including mixer uniformity tests. National Ready Mixed Concrete Association certification procedures are recommended.

Sampling and testing concrete materials at established intervals during construction is usually required, and some properties will need to be monitored on a daily, weekly, or monthly basis as established by the A/E. Generally, qualification tests will not need to be repeated during construction, but new qualification tests should be performed whenever there is a change in material or material source. Material test reports for cement, admixtures, and reinforcing steel can usually be relied on for acceptance of these materials as delivered from the material manufacturer. To ensure more reliability, manufacturers' quality-assurance and quality-control programs should be formulated in accordance with ACI 121R.

Daily inspection of batching may be needed, depending on the level of plant automation, concrete strength, and quality level required as established by the A/E. Regular checks for yield and aggregate moisture content are desirable. ACI 311.5 provides recommendations for this type of inspection.

Inspection of forming, preplacement, placement, and post-placement of concrete activities should be part of the acceptance process for most projects, and special precautions should be considered during hot- and cold-weather concreting.

When the time frame for form removal or loading of the structure is dependent on the structural strength and stability

of the concrete, monitoring of in-place concrete strength by testing of field-cured cylinders or by using some form of nondestructive testing is required. Procedures and criteria established by ACI 305R, 306R, and 347 should be followed.

Daily strength tests of concrete to confirm concrete production quality and design assumptions are almost always required.

3.7.3 *Quality-control inspection*—Quality-control inspection is a functional responsibility of the contractor. As a minimum, the contractor has direct quality-control responsibility for all preplacement, placement, and postplacement activities. Contractual relationships will determine whether the contractor or the concrete producer will be directly responsible for concrete quality control.

Contractors purchasing concrete from an independent concrete producer usually rely on the producer's quality control and seldom get directly involved in the production process. The contractor, however, should monitor the quality-control reports of the concrete producer and the properties of plastic concrete delivered to the project.

Contractors operating their own concrete production facilities should assume direct responsibility for all quality-control activities.

3.7.4 *Recommended inspection activities*—Table 3.1 presents an outline of inspection activities that should be implemented for owner inspection of concrete structures where the safety of the public must be considered. When not otherwise restricted by building code requirements, the A/E may reduce the scope of inspection activities presented in Table 3.1 as deemed appropriate for the size and nature of the concrete work. Some or all of the activities noted in the table may be adopted by contractors or material suppliers as part of their quality-control programs for inspection.

Appendix I presents an expanded checklist of inspection attributes that are intended for use in the development of detailed inspection checklists for each inspection activity listed in Table 3.1. Examples of inspection checklists and reports can be found in the *ACI Manual of Concrete Inspection* (SP-2).

3.7.4.1 *Specialty work*—Some construction projects may require items of inspection not listed in Table 3.1 or Appendix I. Such items can be added by the A/E to ensure adequate conformance to quality requirements. For this reason, the inspection items listed are intended to cover only those construction activities and materials most commonly encountered in concrete construction. Inspection items for specialty work, such as pressure grouting, shotcrete, high-performance concrete, self-consolidating concrete, two-course floors, super-flat floors, terrazzo, stucco, masonry, cast stone, tile, architectural concrete, painting, preplaced-aggregate concrete, tilt-up construction, underwater construction, vacuum concrete, and slipform construction are intentionally omitted from Table 3.1 and Appendix I. It is intended that the A/E will develop inspection criteria for specialty work that is appropriate to the specific needs of these activities.

3.7.4.2 Appendix II is a synopsis of ACI 311.5, which has been developed as a separate document. ACI 311.5 is intended to be used on projects where the A/E needs specific guidance on items to include in a batch-plant inspection program or in a program of testing for fresh and hardened properties of ready mixed concrete. Instructions should be modified as necessary to meet the individual needs and requirements of each project.

3.7.4.3 *High-strength concrete*—The use of high-strength concrete (8000 psi [55 MPa] or greater) requires more testing and inspection because a high degree of confidence of quality is required. Recommendations from ACI 363R and 363.2R should be followed, as this report does not address any special requirements for high-strength concrete.

3.8—Reporting and evaluating inspection and test results

Results of all inspections and tests conducted by the owner's inspection personnel should be documented in inspection (test) reports and promptly transmitted or communicated to the A/E. Distribution of these reports to the owner, the contractor, and, in some instances, to the local building official, is also frequently required. Contract documents typically require that results of contractor quality-control inspections and tests also be transmitted to the A/E and others for review.

Results of inspections and tests, specifically those results that fail to meet requirements, need to be evaluated and dispositioned by the A/E. The A/E's disposition of a nonconforming condition generally falls into one of the following categories:

- Accept as is;
- Rework/repair and reinspect; or
- Reject (remove or replace).

Follow-up inspection and reporting of repair/rework activities shall be conducted by the responsible inspection group in accordance with the disposition instructions provided by the A/E.

CHAPTER 4—REFERENCES

4.1—Referenced standards and reports

The standards and reports listed below were the latest editions at the time this document was prepared. Because these documents are revised frequently, the reader is advised to contact the proper sponsoring group if it is desired to refer to the latest version.

American Concrete Institute

116R	Cement and Concrete Terminology
121R	Quality Management System for Concrete Construction
301	Specifications for Structural Concrete
305R	Hot Weather Concreting
306R	Cold Weather Concreting
311.5	Guide for Concrete Plant Inspection and Field Testing of Ready-Mixed Concrete
318	Building Code Requirements for Structural Concrete
347	Guide to Formwork for Concrete
363R	State-of-the-Art Report on High-Strength Concrete

363.2R Guide to Quality Control and Testing of High-Strength Concrete

CP 1 Concrete Field Testing Technician—Grade I
CP 10 Concrete Flatwork Technician Finisher
CP 16 Concrete Laboratory Testing Technician—Grade I
CP 17 Concrete Laboratory Testing Technician—Grade II
CP 19 Concrete Strength Testing Technician
CP 40 Aggregate Field Testing Technician
CP 41 Aggregate Laboratory Testing Technician
CP 21 Concrete Construction Special Inspector
CP 31 Concrete Transportation Construction Inspector

ASTM International

C 1077 Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
E 329 Standard Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction

The preceding publications may be obtained from the following organizations:

American Concrete Institute
P.O. Box 9094
Farmington Hills, Mich. 48333-9094
www.concrete.org

ASTM International
100 Barr Harbor Dr.
West Conshohocken, Pa. 19428-2959
www.astm.org

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Annual Book of ASTM Standards, V. 04.01, Cement, Lime, and Gypsum, and V. 04.02, Concrete and Mineral Aggregates, ASTM International, West Conshohocken, Pa.

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APPENDIX I—EXPANDED CHECKLIST OF INSPECTION ATTRIBUTES

Preconstruction testing of materials

1. *Coarse and fine aggregate properties*
   a. Grading and fineness modulus, ASTM C 136;
   b. Amount of material finer than 75 μm (No. 200), ASTM C 117;
   c. Soundness, ASTM C 88;
   d. Lightweight particles, ASTM C 123;
   e. Specific gravity and absorption, ASTM C 127 or C 128;
   f. Water-soluble chlorides, ASTM C 1218;
   g. Reactivity of aggregate, ASTM C 227, C 289, C 342, C 586, C 1260, and C 1293;
   h. Bulk unit weight, ASTM C 29; and
   i. Petrographic examination, ASTM C 295.

2. *Fine aggregate properties*
   a. Organic impurities, ASTM C 40; and
   b. Effect of organic impurities on strength, ASTM C 87.

3. *Coarse aggregate properties*
   a. Abrasion, ASTM C 131 or C 535;
   b. Flat or elongated particles, ASTM D 4791; and
   c. Friable particles, ASTM C 142.

4. *Cementitious materials*
   a. Physical properties, ASTM C 150, C 595, C 845, or C 1157;
   b. Chemical properties, ASTM C 150 or C 595;
   c. Physical/chemical properties of silica fume, ASTM C 1240;
   d. Physical/chemical properties of fly ash and natural pozzolans, ASTM C 618; and

e. Physical/chemical properties of ground-granulated blast-furnace slag, ASTM C 989.

5. *Water*
   a. Strength versus control, ASTM C 109;
   b. Time of set versus control, ASTM C 191;
   c. Total solids content, ASTM D 1888;
   d. Total chlorides, ASTM D 512; and
   e. Potable water (local health standards).

6. Admixtures
   a. Air-entraining admixtures, ASTM C 260 as required;
   b. Water-reducing admixtures, ASTM C 494 as required;
   c. Admixtures for flowing concrete, ASTM C 1017 as required; and
   d. Review of test documentation and warnings.

7. *Reinforcing steel—ASTM A 615, A 617, A 706, A 767, A 775, A 934, A 955M, or A 996*
   a. Deformations: spacing, height, and gap;
   b. Weight per linear ft;
   c. Bending properties;
   d. Tensile properties: yield, strength, tensile strength, and percentage of elongation; and
   e. Chemical properties.

8. *Prestressing steel—ASTM A 416, A 421, A 722, A 779, A 866, or A 882*
   a. Quantity (ft/lb);
   b. Diameter of strand;
   c. Grade of strand;
   d. Packaging;
   e. Special requirements; and
   f. Item 7 requirements for bars.

9. *Concrete*
   Freezing-and-thawing resistance, ASTM C 666

Mixture proportion qualification and approval

- As defined by ACI 318 and ACI 301.

Certification of batch plants and truck mixers

- Certification to National Ready-Mixed Concrete Association requirements before construction.
- Certification of ready-mix operations to ASTM C 94 requirements.

Inspection of batch plants and truck mixers before or during construction—ACI 304R

1. *Aggregate storage areas*
   a. Cleanliness;
   b. Separation of materials;
   c. Handling of materials;
   d. Aggregate spray system and drainage;
   e. Approved sources;
   f. Cold-weather provisions (heat, cover); and
   g. Hot-weather provisions (cool, cover).

2. *Cement silo storage*
   a. Weathertight;
   b. Temperature of shipment;
   c. Mill certification with bulk shipment; and
   d. Retesting (if longer than 6 months of storage by manufacturer or vendor).

3. *Cement bag storage*
   a. Storage on pallets;
   b. Identification of type, brand, and manufacturer;
   c. Protection from moisture;
   d. Mill certification with bag shipment; and
   e. Retesting (if longer than 3 months of local storage).

4. *Admixture storage and usage*
   a. Temperature control;
   b. Contamination control;
   c. Agitation;
   d. Retesting (if longer than 6 months of storage by manufacturer or vender); and
   e. Identification of type, brand, and manufacturer.

5. *Batching equipment*
   a. Check of scales and measuring devices every 90 days;
   b. Dial and balance scales accurate within ±0.20% of scale capacity;
   c. Digital scales accurate within ±0.25% of scale capacity;
   d. Return to zero indication;
   e. Adequate separation of bins;
   f. Free discharge of materials with tight closing gates;
   g. Weighing hoppers freely suspended;
   h. Conditions of fulcrum and pivot points;
   i. Water delivery system leak-free;
   j. Measurement of water accurate to ±1%;
   k. Separate dispensers for each admixture;
   l. Admixture dispensing system leak free and accurate to ±3%; and
   m. Indicating devices in full view of operator.

6. *Batching operations—ASTM C 94, C 685*
   a. Cement and supplementary cementitious materials measured within ±1% of desired weight;
   b. Aggregates measured within ±2% of desired weight (±1% when a cumulative weight is taken);
   c. Allowable water adjusted for free moisture in aggregates;
   d. Admixtures discharged separately within a volumetric tolerance of ±3% using a method that does not allow concentrated admixtures to contact each other; and
   e. Verification of batch ticket information to requirements of ASTM C 94.

7. *Mixing operation and qualification of mixers*
   a. Mixer blades free of buildup;
   b. Inspection of blades for holes or cracks;
   c. Height of mixer blades measured for wear;
   d. Mixture uniformity tests for stationary or truck mixtures, ASTM C 94;
   e. Truck mixing 70 to 100 revs;

f. Central mixing—a minimum of 1 min for first m^3 (yd^3) + 15 s for each additional m^3 (yd^3); and
g. Truck water dispensers accurate to within ±1%.

8. *Sampling and testing aggregates during construction*
a. Sampling, ASTM D 75;
b. Grading and fineness modulus, ASTM C 136;
c. Amount of material finer than 75 μm (No. 200), ASTM C 117;
d. Friable particles, ASTM C 142;
e. Coal and lignite, ASTM C 123;
f. Specific gravity and absorption, ASTM C 127 or C 128; and
g. Organic impurities, ASTM C 40.

9. *Preplacement inspection*
a. Lines and grades;
b. Location;
c. Elevation;
d. Dimensions;
e. Shape;
f. Drainage;
g. Preparation of surface; and
h. Bearing.

10. *Forms and decking*
a. Specified type;
b. Location;
c. Dimensions;
d. Tolerances;
e. Alignment;
f. Stability (bearing, shores, tees, and spacers);
g. Surface preparation;
h. Tightness;
i. Chamfer strips;
j. Inspection openings;
k. Cleanliness;
l. Temperature;
m. Accessories (such as ties, cones, and clamps); and
n. Metal deck installation (puddle welds, tek screws, crimping, and overlaps).

11. *Reinforcing steel*
a. Size (diameter, length, bends, and anchorage);
b. Grade;
c. Location (number of bars, spacing, and cover);
d. Splicing (lap length, mechanical joint, weld joint, welder qualifications, and welding procedures);
e. Placement (wire tying, bar supports, and side-form spacers);
f. Cleanliness (no loose rust, oil, paint, or dried mortar);
g. Protective coating; and
h. Shear stud installation (size, location, and spacing).

12. *Prestressing steel (pretensioned and post-tensioned)*
a. Strand, wire, or bar placement (wire tying, bar supports, and side-form spacers);
b. Size;
c. Location;
d. Type;
e. Draping;
f. Anchorage;
g. Tensioning sequence;
h. Loading and elongation measurements;
i. Concrete stressing strength verification;
j. Cleanliness;
k. Condition of sheathing and protective coating;
l. Grouting of post-tensioned tendons; and
m. Sealing of end anchors.

13. *Embedments*
a. Location;
b. Size; and
c. Condition.

14. *Blockouts*
a. Location;
b. Size; and
c. Condition.

15. *Joints*
a. Type;
b. Location; and
c. Filler material.

Placement inspection

1. *Conditions*
a. Coordination of concrete delivery;
b. Protection against sun, rain, hot or cold weather conditions; and
c. Lighting and power.

2. *Field inspection and testing of concrete*
a. Use of specified mixture;
b. Field water additions (minimum 30 drum revs), verify *w/cm*;
c. Sampling freshly mixed concrete, ASTM C 172;
d. Slump, ASTM C 143;
e. Temperature of freshly mixed concrete and ASTM C 1064 (maximum and minimum as specified);
f. Air content (pressure or volumetric), ASTM C 231 and C 173;
g. Density (unit weight), ASTM C 138;
h. Yield, ASTM C 138;
i. Cylinder specimens, ASTM C 31 (identification, mixture, location, and date);
j. Discharge of ready-mixed concrete truckload before 300 revs or 90 min, ASTM C 94; and
k. Initial curing of cylinder specimens, ASTM C 31.

3. *Conveyance of concrete*
a. Nonreactive materials;
b. Prevention of segregation and loss of materials;
c. Prevention of contamination;
d. Condition of conveying equipment (smooth surfaces, no holes, and cleanliness); and

e. Use of drop-chutes or funnel hoses to contain freefall.

4. *Placement and consolidation of concrete*
   a. Precautions taken for hot or cold weather conditions;
   b. Preparation of contact surfaces;
   c. Ability of conveying method to place concrete in all areas of placement;
   d. Mortar bedding (use of starter mixture);
   e. Prevention of segregation (no chuting or dropping against forms or reinforcement);
   f. Depth of layer (maximum limit);
   g. External vibration (spacing to prevent dead spots);
   h. Internal vibration (depth of insertion, spacing, time, vertical insertion, no movement of concrete by vibration). Vibrators to be equipped with rubber heads when consolidating concrete around epoxy-coated reinforcing bars;
   i. Even layering around openings and embedments;
   j. Removal of bleed water; and
   k. Removal of temporary ties and spacers.

Post-placement inspection and tests

1. *Finishing, curing, and formwork and shore removal*
   a. Specified finish;
   b. Protection of surfaces from cracking due to rapid drying (avoid direct heat);
   c. Proper curing temperature;
   d. Form removal (field-cured cylinder tests or other approved tests);
   e. Curing compound (conformance to ASTM C 309, application); and
   f. Finish of formed surfaces (patching and repairs where necessary).

2. *Shoring and reshore removal*
   a. Verification of in-place strength;
   b. Location;
   c. Number;
   d. Time of removal; and
   e. Sequence of removal.

3. T*ests of hardened concrete*
   a. Curing of specimens, ASTM C 31;
   b. Preparation of concrete cores, ASTM C 42;
   c. Capping, ASTM C 617;
   d. Tests for compressive strength, ASTM C 39;
   e. Tests for split tensile strength, ASTM C 496;
   f. Equilibrium unit weight of lightweight concrete, ASTM C 567;
   g. Flexural strength, ASTM C 293 and ASTM C 78;
   h. Density, absorption, and voids, ASTM C 642
   i. First crack strength and toughness (fiber-reinforced), ASTM C 1018;
   j. Nondestructive tests, ASTM C 597, C 803, C 805, C 900, and C 1074;
   k. Petrographic analysis, ASTM C 856; and
   l. Restrained expansion of shrinkage-compensating concrete, ASTM C 878.

Precast erection

   a. Number and location of lifting lugs;
   b. Blocking during storage and transportation;
   c. Placement and condition of bearing pads;
   d. Alignment of connection pockets;
   e. Sampling and testing of grout, ASTM C 109;
   f. Alignment of embedment plates and weld clips;
   g. Welding procedures and qualification of welders; and
   h. Inspection for damage and visual appearance.

REFERENCED STANDARDS AND REPORTS FOR APPENDIX I

The standards and reports listed below were the latest editions at the time this document was prepared. Because these documents are revised frequently, the reader is advised to contact the proper sponsoring group if it is desired to refer to the latest version.

American Concrete Institute

121R Quality Management System for Concrete Construction
301 Specifications for Structural Concrete
304R Guide for Measuring, Mixing, Transporting, and Placing Concrete
318 Building Code Requirements for Structural Concrete

ASTM International

A 416 Standard Specification for Steel Strand, Uncoated Seven-Wire Stress-Relieved for Prestressed Concrete
A 421 Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete
A 615 Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
A 617 Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement
A 706 Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
A 722 Standard Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete
A 767 Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
A 775 Standard Specification for Epoxy-Coated Steel Reinforcing Steel Bars
A 779 Standard Specification for Steel Strand, Seven-Wire, Uncoated, Compacted, Stress-Relieved for Prestressed Concrete
A 866 Standard Specification for Medium Carbon Anti-Friction Bearing Steel
A 882 Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand
A 934 Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
A 955M Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement [Metric]
A 996 Standard Specification for Rail Steel and Axle Steel Deformed Bars for Concrete Reinforcement
C 29 Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate

C 31 Standard Practice for Making and Curing Concrete Test Specimens in the Field
C 39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
C 40 Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
C 42 Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C 78 Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C 87 Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
C 88 Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
C 94 Standard Specification for Ready-Mixed Concrete
C 109 Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2 in. or [50 mm] Cube Specimens)
C 117 Standard Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
C 123 Standard Test Method for Lightweight Particles in Aggregate
C 127 Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
C 128 Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
C 131 Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
C 136 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
C 138 Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
C 142 Standard Test Method for Clay Lumps and Friable Particles in Aggregates
C 143 Standard Test Method for Slump of Hydraulic Cement Concrete
C 150 Standard Specification for Portland Cement
C 172 Standard Practice for Sampling Freshly Mixed Concrete
C 173 Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 227 Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
C 231 Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 260 Standard Specification for Air-Entraining Admixtures for Concrete
C 289 Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)
C 293 Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)
C 295 Standard Guide for Petrographic Examination of Aggregates for Concrete
C 309 Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
C 494 Standard Specification for Chemical Admixtures for Concrete
C 496 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
C 535 Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
C 567 Standard Test Method for Unit Weight of Structural Lightweight Concrete
C 586 Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregate (Rock-Cylinder Method)
C 595 Standard Specification for Blended Hydraulic Cements
C 597 Standard Test Method for Pulse Velocity Through Concrete
C 617 Standard Practice for Capping Cylindrical Concrete Specimens
C 618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C 642 Standard Test Method for Density, Absorption, and Voids in Hardened Concrete
C 666 Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C 685 Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing
C 803 Standard Test Method for Penetration Resistance of Hardened Concrete
C 805 Standard Test Method for Rebound Number of Hardened Concrete
C 845 Standard Specification for Expansive Hydraulic Cement
C 856 Standard Practice for Petrographic Examination of Hardened Concrete
C 878 Standard Test Method for Restrained Expansion of Shrinkage-Compensating Concrete
C 900 Standard Test Method for Pullout Strength of Hardened Concrete
C 989 Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
C 1017 Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
C 1018 Standard Test Method for Flexural Toughness and First-Crack Strength of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)
C 1064 Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
C 1074 Standard Practice for Estimating Concrete Strength by the Maturity Method

C 1077 Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

C 1157 Standard Performance Specification for Hydraulic Cement

C 1202 Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

C 1218 Standard Test Method for Water-Soluble Chloride in Mortar and Concrete

C 1240 Standard Specification for Silica Fume Used in Cementitious Mixtures

C 1260 Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

D 75 Standard Practice for Sampling Aggregates

D 512 Standard Test Methods for Chloride Ion in Water

D 1411 Standard Test Methods for Water-Soluble Chlorides Present as Admixtures in Graded Aggregate Road Mixes

D 4791 Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate

The preceding publications may be obtained from the following organizations:

American Concrete Institute
P.O. Box 9094
Farmington Hills, Mich. 48333-9094
www.concrete.org

ASTM International
100 Barr Harbor Dr.
West Conshohocken, Pa. 19428-2959
www.astm.org

APPENDIX II—SYNOPSIS OF ACI 311.5

Guide for Concrete Plant Inspection and Testing of Ready Mixed Concrete

Reported by ACI Committee 311

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.