

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-testing activities are considered to be part of the inspection program. The guide presents recommended plans for the various types of inspection activities and means of implementing the program. Recommended minimum levels of inspection for various purposes and various types of projects are given.

Keywords: concretes; construction; quality assurance; quality control; test.

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Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

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CHAPTER 1—INTRODUCTION

1.1—General scope

This document is intended for guidance in the development of an inspection and testing program that is part of an overall plan to assure quality in the finished product. It is recommended that an overall quality plan be developed as outlined in ACI 121R and that this document be used to develop the inspection and testing program as referenced in that document.

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1.2—Philosophy

Individuals and organizations involved with inspection should recognize that inspection needs and requirements vary and should be tailored to each individual project. The actual level of inspection depends on the type and complexity of the project, special features involved, quality level desired, specific legal requirements, and the purpose of the inspection program. Any of these may make necessary the addition of more detailed inspection requirements or may warrant lessening the requirements.

1.3—General

Inspection is not an end in itself. It is simply a subsystem of the quality assurance system and of a contractor or producer's quality-control system. In addition, inspection may be part of the activities of a governmental body charged with enforcing legal codes and other regulations. Inspection and testing only confirm that inspection elements of the product or process meet the criteria established. They do not add quality to inspected items. The information derived from the inspection and testing process, however, when properly evaluated and with conclusions and decisions implemented, will result in improvement of the quality of the product or process. The intended quality is achieved only by implementation of an adequate quality-assurance program. Such a program affects the complete 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 the workers. 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, although 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 design drawings and specifications.

1.4.2 Quality control (QC)—A production tool for those actions related to the physical characteristics of the materials, processes, and services that provide a means to measure and control the characteristics within predetermined quantitative criteria.

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. For many purposes in this report, the term "owner" includes those organizations or individuals acting as agent for the owner.

1.4.4 Architect/engineer (A/E)—The architectural or engineering organization with responsibility to the owner to perform the structural design, produce design drawings, define construction requirements, implement inspection and testing programs, and prepare project specifications for the project.

1.4.5 Contractor—The organization responsible for constructing a project according to the project specifications and design drawings.

1.4.6 Construction manager or owner's representative—The person or management organization that becomes the owner-engineer team in a system that varies from the traditional design-bid-build system. Their role is to coordinate and communicate the entire project process to minimize project construction time and price.

1.4.7 Inspection organization—The organization/agency that may also be a testing laboratory, and is responsible for providing acceptance inspection and testing for the owner, or providing quality-control inspection and testing for the contractor or producer.

1.4.8 Inspection—The term "inspection," as used herein, includes not only visual observations and field measurements but also laboratory testing and the assembly and evaluation of test data.

1.4.9 Inspection/test report—A document signed by a certified inspector or individual assigned to do the task, and used to demonstrate and provide evidence of the verified attributes plus the results of the inspection/test activity performed.

1.4.10 Testing laboratory—An independent commercial organization that provides testing services and, when required, inspection personnel to owners, governmental agencies, architects, engineers, contractors, and material or product manufacturers.

1.4.11 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—Functional classification of inspection

Inspection activities and organizations are mainly concerned with the following four functions:

1.5.1 Acceptance inspection—A series of formalized activities and procedures that provide the owner of the structure being built, with an acceptable degree of assurance that the contractor has satisfied his or her obligations to construct in accordance with the contract documents. The evaluation of tests performed and of the observation of procedures and practices used in the construction should permit the determination of conformance to prescribed acceptance standards.

1.5.2 Quality-control inspection—contractor—Quality-control inspection by the contractor is a series of formalized activities and procedures that are part of the contractor's operation, providing in-process evaluation of the quality of construction. This helps to ensure the contractor that the finished construction will meet all requirements of the project plans, drawings, and specifications, and will be accepted by the owner's representative.

1.5.3 Quality-control inspection—producer—Quality-control inspection by the producer is a series of formalized activities and procedures. They are part of the fabricating or manufacturing operation of a producer of concrete materials, reinforcement producer/fabricators, or products, who furnishes to the construction industry rather than only to a specific

project. Examples are operations of cement and aggregate producers, ready-mixed 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 Regulatory inspection—A series of formalized activities and procedures used by governmental bodies (such as licensing boards and building permit boards), charged with responsibility for enforcing building codes and other regulations. In this case, the inspectors have responsibility for ensuring that the finished structure conforms to the requirements of the codes or regulations. The organization and activities of these inspectors are governed almost entirely by legal regulations.

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, including testing, may be performed by a variety of groups such as:

1.6.1 Owner's inspection personnel—Qualified inspection personnel maintained by the owner. Examples would be permanent or semipermanent personnel of governmental agencies, or large industries with continuing building programs.

1.6.2 Architect/engineer's inspection personnel—Inspectors trained, certified, and maintained by a firm for work on projects designed by the firm.

1.6.3 Laboratory's inspection force—Inspection and testing personnel trained, certified, and maintained by a testing laboratory to provide contractual testing and inspection services.

1.6.4 Contractor's inspection force—Inspection personnel trained, certified, and maintained by a contractor to provide quality-control (in-process) inspection on projects it constructs.

1.6.5 Material manufacturers and suppliers inspection force—Inspection (and testing) force trained, certified, and maintained by a concrete material and product manufacturing and fabricating firm for its own in-house use in quality-control (in-process) inspection and testing.

CHAPTER 2—RESPONSIBILITIES

2.1—Chapter scope

This section defines the general responsibilities placed upon the owner, A/E, contractor, and manufacturer or fabricator in conforming to the recommendations of this guide.

2.2—Owner's responsibilities

2.2.1 The owner is responsible for acceptance inspection and testing. A/E's should provide owners with alternatives and information enabling the owner to recognize and evaluate the quality/price/maintenance relationships involved in the construction. Owners should understand that field inspection and testing need to be provided to ensure conformance to

codes and quality requirements. The owner should review the inspection plan with the A/E and, where appropriate, select the level of acceptance inspection required, consistent with the size, quality, complexity, and needs of the project.

2.2.2 The acceptance inspection personnel are responsible for, and can only be involved with, determining that inspected materials, procedures, and end products conform to the requirements of the design drawings and project specifications. The contractor is obligated to meet all requirements of the project specifications. For the inspector to accept less than required deprives the owner of full value, whereas requiring more than called for in the design drawings and project specifications places an unacceptable burden on the contractor. Either action is a contract violation.

2.2.3 The inspectors personnel representing the owner have no responsibility or authority to manage the contractor's personnel. Inspection requirements on projects supervised by a construction manager should be detailed by the A/E and should be carried out by the owner.

2.2.4 The owner should be responsible, in conjunction with the A/E, for arranging a preconstruction conference including all parties involved in the construction project. The conference should establish lines of communication and identify responsibilities to achieve quality. To be effective, the inspection personnel should have the acknowledged support of the owner.

2.2.5 The fee for acceptance inspection should be a separate and distinct item and should be paid by the owner directly to the inspection organization or to the A/E (unless the A/E is also the contractor) who will in turn pay the inspection organization. The owner or A/E should avoid the undesirable practice of arranging payment for acceptance inspection and testing services through the contractor. Such a practice is not in the owner's interest. Impartial service is difficult under such circumstances, and the price is eventually paid by the owner in any case.

2.3—Architect/engineer's responsibilities

2.3.1 For the protection of the owner and the public, the responsibility for planning and detailing acceptance inspection should be vested in the A/E as a continuing function of the design responsibility. The responsibility of the engineer for this inspection may be discharged directly or may be delegated to an independent inspection organization responsible to the A/E.

2.3.2 If the A/E is also responsible for construction, an independent inspection organization should be retained by the owner. In those cases in which the owner provides the A/E service, the owner should also provide acceptance inspection, or retain an independent inspection organization.

2.4—Inspection organization/laboratory responsibilities

2.4.1 The inspection organization/laboratory selected by the owner should perform acceptance testing and inspection in accordance with the requirements of ACI 301.

2.4.2 They should perform the acceptance inspection as given in [Section 3.6.2](#), including tests and inspections of the

concrete and reinforcing materials as the work progresses. Failure to detect any defective work or material does not relieve the contractor of their responsibility to meet quality requirements for the work. It does not in any way prevent later rejection when such defect is discovered and does not obligate the owner or A/E for final acceptance.

2.4.3 The inspection organization/agency should be accredited in accordance with ASTM E 329. The testing laboratory is responsible for having its facilities, personnel, and procedures inspected by a qualified national authority, such as the Cement and Concrete Materials Reference Laboratory (CCRL) at the National Institute of Standards and Technology (NIST), at intervals of approximately 24 months, as required by ASTM C 1077.

2.4.4 As a professional service, the selection of the organization/laboratory for acceptance inspection should be based on qualifications. 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, review accreditations and the latest evaluation made by the evaluation authority, such as that made by CCRL, headquartered at NIST, 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.

2.5—Contractor's responsibilities

2.5.1 Coordination and scheduling of acceptance inspection should be made a responsibility of the contractor. This will provide timely inspections and avoid owner-caused construction delays.

2.5.2 Quality-control inspection, or in-process inspection, is performed by contractor personnel or others specially hired by the contractor. These inspectors are most effective when they report directly to the contractor's management. It is important that these activities be actively supported by management. Inspection and testing by or for the contractor, subcontractors, or concrete suppliers is separate and distinct from acceptance inspection for the owner.

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

2.5.4 Inspection performed by, or for, the contractor, particularly when contractually required, will often be much more detailed than is the usual practice for acceptance in-

spection. The contractor's personnel should make a much more detailed inspection of form alignment, reinforcing bar positioning, cleanup of forms, and other concrete placement. Even if not required by the project specifications, the contractor should use quality-control inspection to ensure against later rejection of a complex placement. If such items are not covered by a formal quality-control inspection team, they should be covered by the contractor's supervisory personnel.

2.5.5 When the project specifications require extensive quality-control inspection and testing by the contractor, the owner should not reduce or eliminate acceptance inspection. If the contractor's quality-control inspection program becomes the owner's acceptance 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 acceptance testing for the owner. When the owner requires the contractor to have a quality-control inspection program, the owner should still accept responsibility for acceptance inspection to provide assurance that the contractor's quality-control program achieves its objectives.

2.5.6 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 project plans and specifications and will thus be accepted by the owner.

2.6—Manufacturer's or fabricator's responsibilities

Quality-control inspection by the manufacturer or fabricator should parallel the contractor's programs. Program content depends on contractual requirements and on the manufacturer's quality-control process.

CHAPTER 3—GUIDANCE FOR ARCHITECTS/ENGINEERS

3.1—Scope

This section gives specific recommendations to the A/E in implementing inspection and testing programs.

3.2—Written inspection plan

Even the smallest project 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 between the owner, A/E, contractor, and inspection and testing organization. It is recommended that all projects use some form of written plan or checklist. On complex projects, a written plan detailing responsibilities for acceptance inspection and testing, procedures for documentation of inspections and tests, scheduling and frequency of testing, reporting of results, handling of non-conformances and changes, record retention, and auditing the progress of the work is a necessity.

3.3—Construction conferences

In accordance with **Section 2.2.4**, a preconstruction conference is recommended for all except the very smallest 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 and establish procedures that will allow construction to proceed in a manner that will ensure the best possible quality in line with the established prices.

3.4—Meetings

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

3.5—Qualifications of personnel for inspection and testing duties

3.5.1 The qualifications of personnel conducting inspections and tests are critical to attaining the desired level of quality, as erroneous results of tests and inspections can cause costly actions that are unwarranted.

3.5.2 The ACI certification program currently outlines training programs and certification of personnel in the following areas: CP 1—Concrete Field Testing Technician (Grade I); CP 16—Concrete Laboratory Testing Technician (Grades I and II); Concrete Construction Inspector has been replaced by the joint ACI/code committee's Reinforced Concrete Special Inspector; Concrete Transportation Construction Inspector, and Inspector In-Training; CP 8—Concrete Flatwork Finisher and Concrete Flatwork Technician; CP 19—Concrete Strength Testing Technician; and the newest program: Aggregate Testing Technician.

All personnel performing concrete inspection and testing work should be certified and demonstrate a knowledge and ability to perform the necessary test procedures equivalent to the minimum guidelines for certification in the appropriate category.

3.6—Planning for inspection and testing

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

Even if acceptance inspection becomes very detailed, contractors and concrete producers often rely on acceptance inspection and tests in lieu of their own quality control.

If there is concern by the owner or A/E about the adequacy of the quality-control function, project specifications can direct that the contractor provide specific testing and inspections as part of the quality-control program, with results disseminated to the owner and A/E. When this is done, acceptance inspection should not be eliminated, but it

usually does not require the detail or emphasis that might otherwise be required to satisfy quality-assurance concerns.

During the course of the project, when a concern about the adequacy of quality control exists, acceptance inspection should necessarily be more rigorous until the contractor's quality-control activities remove reason for concern.

3.6.2 Acceptance inspection

3.6.2.1 The A/E should evaluate whether or not it is necessary to conduct prequalification tests of the materials to be used in the project. In the event materials with past service records are to be used, earlier qualification tests may be relied upon, 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.

3.6.2.2 Approval of mixture proportions to be used in the project should be based on reliable criteria. It is recommended that the procedures and criteria established by ACI 301 be followed.

3.6.2.3 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.

3.6.2.4 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. 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 upon for acceptance of these materials as delivered from the material manufacturer. To ensure more reliability, manufacturers' QA/QC programs should be formulated in accordance with ACI 121R.

3.6.2.5 Daily inspection of batching may be needed, depending on the level of plant automation, concrete strength, and quality level required. Regular checks for yield and aggregate moisture content are desirable.

3.6.2.6 Inspection of forming, preplacement, placement, and postplacement 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.

3.6.2.7 When form removal times are of importance to structural strength and stability, they may require monitoring by field curing of strength specimens or by using some form of nondestructive testing. Procedures and criteria established by ACI 305R and 306R are recommended.

3.6.2.8 Strength tests of concrete to correlate concrete production quality and design assumptions are almost always required.

3.6.3 Quality control

3.6.3.1 Quality control is a function of the construction contractor. The contractor, however, may or may not be directly involved in the production of the concrete. Contractual relationships will determine these responsibilities and whether or

Table 3.1—Inspection activities recommended for complex projects

	Inspection and testing Level A
Project examples	High-rise construction; Parking garage construction; Dam construction; Major bridge construction; Power plant construction; Interstate or primary highway construction; and Marine structures and harbor construction.
Scope of activities recommended for acceptance inspection programs	Sampling and testing of concrete materials for complete prequalification of materials for required properties.
	Sampling and testing of concrete materials at established intervals during construction with close monitoring of some properties on a daily, weekly, or monthly basis. Some qualification tests will not be repeated during the construction phase or may be replaced by acceptance of material test reports submitted by the manufacturer.
	Approval of concrete mixtures based on ACI 301 and ACI 318.
	Inspection and certification of batch plant to National Ready-Mixed Concrete Association requirements prior to construction.
	Qualification program for concrete mixer trucks with regular program of inspection during construction, including tests for mixer uniformity, calibration of water meters, and inspection of blade wear.
	Inspection as needed of batching operation during construction with checks for yield.
	Full-time inspection of preplacement, placement, and postplacement activities (including curing). Special attention to mass concrete, hot weather concreting, cold weather concreting, and high-strength concrete. Also, verification of tolerances on placement of reinforcement and dimensions of completed structures.
	Sampling and testing of concrete in the field at established intervals by independent testing laboratory or other qualified personnel acting as agents for the owner.
	Monitoring maturity of concrete before form removal or monitoring of other activities, such as post-tensioning, by means of a field-cured cylinder test program, or a nondestructive testing program.
	Laboratory tests of concrete cylinders for acceptance of concrete strength.

Table 3.2—Inspection activities recommended for moderate projects

	Inspection and testing Level B
Project examples	Industrial and commercial building construction; Low-rise construction; Small bridge construction; and Arterial streets or feeder route construction.
Scope of activities recommended for acceptance inspection programs	Sampling and testing of concrete materials before construction and at established intervals during construction.
	Use of proven materials and material test reports accepted for some required tests.
	Approval of concrete mixtures based on ACI 301 and ACI 318.
	Inspection of batch plant storage, production facilities, and delivery trucks before construction.
	Random inspection of batching operation during construction with checks for yields
	Preplacement, placement, and postplacement inspection of concreting activities (including curing). Special attention to mass concrete, hot weather concreting, and cold weather concreting.
	Sampling and testing of concrete in the field at established intervals by independent test laboratory or other qualified personnel acting as agents for the owner.
	Monitoring maturity of concrete before form removal or monitoring of other activities, such as post-tensioning, by means of a field-cured cylinder test program, or a nondestructive testing program.
	Laboratory tests of concrete cylinders for acceptance of concrete strength.

not the contractor or the ready-mixed concrete producer will be directly responsible for concrete quality control.

3.6.3.2 Contractors purchasing ready-mixed concrete from an independent ready-mixed concrete producer usually rely on the producer's quality control and do not get directly involved in the production process. The contractor, however, should monitor the quality-control reports of the ready-mixed concrete producer.

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

3.6.4 Implementation

3.6.4.1 Three levels of inspection and testing, with appropriate project examples and criteria, have been developed to aid in the selection of items to be included in an owner's acceptance inspection program. They are:

Inspection and Testing Level A—Inspection activities recommended for complex projects (Table 3.1);

Inspection and Testing Level B—Inspection activities recommended for moderate projects (Table 3.2); and

Inspection and Testing Level C—Inspection activities recommended for minor projects (Table 3.3);

The activities specified for each level are typical activities. In practice, due to the specific needs of a particular project, it may be desirable to add additional items, or in a special case, to lower the requirements. The items addressed in Levels A, B, and C are intended for acceptance inspection activities when adequate quality control is presumed on the part of the contractor. If some of these items are to be included in project specifications, and are to be performed by the con-

Table 3.3—Inspection activities recommended for minor projects

	Inspection and testing Level C
Project examples	Residential construction; Single-family homes construction; Catch basins and small drainage structures construction; and Residential streets, curbs, and gutters construction.
Scope of activities recommended for acceptance inspection programs	Use of proven materials and concrete mixture proportions recommended.
	Random testing of concrete and materials during construction.
	Random inspection of concreting activities.
	Submittal of test samples by the contractor in some instances.
	Laboratory tests of concrete cylinders for acceptance of concrete strength.

tractor, modification should be made in the acceptance inspection requirements.

3.6.4.2 Appendix I has been developed as an inspection and testing checklist that details the scope of activities given in each of the inspection levels (Tables 3.1, 3.2, and 3.3). Appendix I can be used both for selecting specific owner acceptance inspection items and determining appropriate contractor quality-control items.

3.6.4.3 *Specialty work*—The special nature of some construction projects may require items of inspection not listed in Appendix I. Such items can be added by the A/E to ensure adequate conformance to quality items deemed important. For this reason, the inspection items given in Appendix I 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, two-course floors, terrazzo, stucco, masonry, cast stone, architectural concrete, painting, preplaced-aggregate concrete, tilt-up construction, underwater construction, vacuum concrete, and slipform construction are intentionally omitted from 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.

3.6.4.4 Appendix II is the synopsis of ACI 311.5R, which has been developed as a separate document. ACI 311.5R is intended to be used on projects of a limited nature when the A/E needs specific guidance on items to include in a batch-plant inspection program or field testing of a ready-mixed concrete program. It should be supplemented for more complex projects.

3.6.4.5 *High-strength concrete*—The use of high-strength concrete, 6000 psi (41 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.

3.7—Reporting and evaluation of inspection and test results

3.7.1 Results of all inspections and tests conducted by the owner's quality-assurance inspection personnel should be documented on inspection (test results) and promptly transmitted or communicated to the A/E. Distribution of these reports to the owner and contractor is also frequently required. Additionally, specifications may require that results of con-

tractor quality inspections and tests also be transmitted to the A/E and others for review.

3.7.2 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; and
- Reject (remove or replace).

3.7.3 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 the 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 Systems for Concrete Construction
301	Standard 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
363R	State-of-the-Art Report on High-Strength Concrete
363.2R	Guide to Quality Control and Testing of High-Strength Concrete

ASTM

C 1077	Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation
E 329	Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction
CP 1	Concrete Field Testing Technician

CP 8	Concrete Flatwork Finisher and Concrete Flatwork Technician
CP 16	Concrete Laboratory Testing Technician
CP 19	Concrete Strength Testing Technician

The preceding publications may be obtained from the following organizations:

American Concrete Institute
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Farmington Hills, Mich. 48333-9094

ASTM
100 Barr Harbor Dr.
West Conshohocken, Pa. 19428-2959

4.2—Cited references

1. *Quality Control Manual*, National Ready-Mixed Concrete Association, Silver Spring: Section 1, Ready-Mixed Concrete Quality Control Guide; Section 2, Ready-Mixed Concrete Quality Control Checklist; and Section 3, Certification of Ready-Mixed Concrete Production Facilities.

4.3—Recommended additional reading

Abdun-Nur, E. A., 1981, "Contractual Relationships, An Essential Ingredient of the Quality Assurance System," *Transportation Research Record* No. 792, Transportation Research Board, pp. 1-2.

Abdun-Nur, E. A., 1982, "Inspection and Quality Assurance," *Concrete International*, V. 4, No. 9, Sept., pp. 58-62.

Abdun-Nur, E. A., 1982, "Incentive Specifications for Concrete," *Concrete International*, V. 4, No. 9, Sept., pp. 20-24.

ACI Manual of Concrete Practice, Part 2, Construction Practices and Inspection; Pavements, American Concrete Institute, Farmington Hills, Mich.

ACI Manual of Concrete Inspection, 1999, 9th Edition, American Concrete Institute, Farmington Hills, Mich., 220 pp.

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

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APPENDIX I—CHECKLIST FOR USE WITH INSPECTION AND TESTING LEVELS A, B, AND C Prequalification 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 D 1411;
 - g. Reactivity of aggregate, ASTM C 227, C 289, C 342, and C 586;
 - 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, Corps of Engineers CRD C 119; and
 - c. Friable particles, ASTM C 142.
4. *Cement*
 - a. Physical properties as required by ASTM C 150, C 595, or C 845; and
 - b. Chemical properties as required by ASTM C 150 or C 595.
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. Admixture for flowing concrete, ASTM C 1017 as required;
 - d. Mineral admixtures, ASTM C 618 as required;
 - e. Ground granulated blast-furnace slag, ASTM C 989 as required; and
 - f. Review of test documentation and warnings.
7. *Reinforcing steel*—ASTM A 615, A 706, A 616, A 617, A 767, A 775, A 934, or A 955M
 - 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 882, or A 866
 - 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 682 and C 666.

Mixture proportions approval

As defined by ACI 301.

Certification of batch plants and truck mixers

Certification to National Ready-Mixed Concrete Association requirements prior to construction.

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

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 from manufacturer or vendor storage).
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 three months local storage).
4. *Admixture storage and usage*
 - a. Temperature control;
 - b. Contamination control;
 - c. Agitation;
 - d. Retesting (if longer than 6 months manufacturer or vendor storage); 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 $\pm 0.20\%$ of scale capacity;
 - c. Digital scales accurate within $\pm 0.25\%$ 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 $\pm 1\%$;
 - k. Separate dispensers for each admixture;
 - l. Admixture dispensing system leak free and accurate to $\pm 3\%$; and
 - m. Indicating devices in full view of operator.
6. *Batching operation*—ASTM C 94—C 685
 - a. Cement and cementitious materials measured within $\pm 1\%$ of desired weight;
 - b. Aggregates measured within $\pm 2\%$ of desired weight ($\pm 1\%$ when a cumulative weight is taken);
 - c. Allowable water adjusted for free moisture in aggregates;
 - d. Admixtures discharged separately using a method that does not allow concentrated admixtures to contact each other; and
 - e. Verification of batch ticket information to the 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. Mixer uniformity tests for stationary or truck mixtures;
 - 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 $\pm 1\%$.
8. *Sampling and testing aggregates during construction*
 - a. Sampling, ASTM D 75;
 - b. Grading and fineness modulus, ASTM C 136;
 - c. Friable particles, ASTM C 142; Coal and lignite, ASTM C 123;
 - d. Coal and lignite, ASTM C 123;
 - e. Specific gravity and absorption, ASTM C 127 or C 128; and
 - f. 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*
 - 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; and
 - m. Accessories (such as ties, cones, and clamps).
11. *Reinforcing steel*
 - a. Size (diameter, length, bends, and anchorage);
 - b. Grade;
 - c. Location (number of bars, spacing, cover);
 - d. Splicing (weld joint, overlap, 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); and
 - g. Protective coating.
 12. *Prestressing steel (pre- and post-tensioned)*
 - a. Strand, wire, or bar placement (wire tying, bar supports, and side-form spacers);
 - b. Size;
 - c. Location;
 - d. Type;
 - e. Anchorage;
 - f. Tensioning sequence;
 - g. Loading and elongation measurements;
 - h. Concrete stressing strength verification;
 - i. Cleanliness;
 - j. Condition of sheathing and protective coating;
 - k. Grouting of post-tensioned tendons; and
 - l. Sealing of end anchors.
 13. *Embedments*
 - a. Location;
 - b. Size; and
 - c. Condition.
 14. *Blockouts*
 - a. Location;
 - b. Size; and
 - c. Condition.

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 tests of concrete*
 - a. Use of specified mixture;
 - b. Field water additions (minimum 30 drum revs);
 - c. Sampling freshly mixed concrete, ASTM C 172;
 - d. Slump, ASTM C 143;
 - e. Temperature of freshly mixed concrete; and C 1064 (maximum and minimum as specified);
 - f. Air content (pressure or volumetric), ASTM C 231, C 173;
 - g. Unit weight, ASTM C 138;
 - h. Yield, ASTM C 138;
 - i. Cylinder specimens, ASTM C 31 (identification, mixture, location, 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 free-fall.
 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 the 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 water reinforcing bars.);
 - i. Even layering around openings and embedments;
 - j. Removal of bleed water; and
 - k. Removal of temporary ties and spacers.

Postplacement 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. *Reshoring and reshore removal*
 - a. Location;
 - b. Number;
 - c. Time of removal; and
 - d. Sequence of removal.
3. *Tests 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. Air dry unit weight of lightweight concrete, ASTM C 567;
 - g. Flexural strength, ASTM C 293, ASTM C 78;
 - h. Specific gravity, absorption, and voids, ASTM C 642
 - i. First crack strength and toughness (fiber-reinforced), ASTM C 1018;

- j. Nondestructive tests, ASTM C 597, ASTM C 803, ASTM C 805, ASTM C 900, ASTM C 1074;
- k. Petrographic analysis, ASTM C 856; and
- l. Restrained expansion of shrinkage-compensating concrete, ASTM C 878.

Appendix I Referenced standards and reports

The standards and reports listed as follows were the latest editions at the time the 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 Standard Specifications for Structural Concrete
- 304R Guide for Measuring, Mixing, Transporting, and Placing Concrete
- 311.4R Guide for Concrete Inspection
- 318 Building Code Requirements for Structural Concrete

ASTM

- A 416 Specification for Steel Strand, Uncoated Seven-Wire Stress-Relieved for Prestressed Concrete
- A 421 Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete
- A 615 Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
- A 616 Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement
- A 617 Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement
- A 706 Specification for Low-Alloy Steel Deformed Bars for Concrete Reinforcement
- A 72 Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete
- A 767 Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
- A 775 Specification for Epoxy-Coated Reinforcing Steel Bars
- A 779 Specification for Steel Strand, Seven-Wire, Uncoated, Compacted, Stress-Relieved for Prestressed Concrete
- A 866 Specification for Medium Carbon Anti-Friction Bearing Steel
- A 882 Specification for Epoxy-Coated Seven-Wire Prestressing Steel Strand
- A 934 Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
- A 955M Specification for Deformed and Plain Stainless Steel Bars for Concrete Reinforcement [Metric]
- A 970 Specification for Welded Headed Bars for Concrete Reinforcement
- C 29 Test Method for Unit Weight and Voids in Aggregate
- C 31 Practice for Making and Curing Concrete Test Specimens in the Field

- C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens
- C 40 Test Method for Organic Impurities in Fine Aggregates for Concrete
- C 42 Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
- C 87 Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
- C 88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
- C 94 Specification for Ready-Mixed Concrete
- C 109 Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2 in. or 50 mm Cube Specimens)
- C 117 Test Method for Materials Finer than 75 mm (No. 200) Sieve in Mineral Aggregates by Washing
- C 123 Test Method for Lightweight Pieces in Aggregate
- C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate
- C 128 Test Method for Specific Gravity and Absorption of Fine Aggregate
- C 131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- C 136 Method for Sieve Analysis of Fine and Coarse Aggregates
- C 138 Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
- C 142 Test Method for Clay Lumps and Friable Particles in Aggregates
- C 143 Test Method for Slump of Portland Cement Concrete
- C 150 Specification for Portland Cement
- C 173 Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
- C 191 Test Method for Time of Setting of Hydraulic Cement by Vicat Needle
- C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
- C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
- C 260 Specification for Air-Entraining Admixtures for Concrete
- C 289 Test Method for Potential Reactivity of Aggregates (Chemical Method)
- C 293 Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)
- C 295 Guide for Petrographic Examination of Aggregates for Concrete
- C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete
- C 342 Test Method for Potential Volume Change of Cement-Aggregate Combinations
- C 494 Specification for Chemical Admixtures for Concrete
- C 496 Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

- C 535 Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
- C 567 Test Method for Unit Weight of Structural Lightweight Concrete
- C 586 Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregate (Rock Cylinder Method)
- C 595 Specification for Blended Hydraulic Cements
- C 597 Test Method for Pulse Velocity Through Concrete
- C 617 Practice for Capping Cylindrical Concrete Specimens
- C 618 Specification for Fly Ash and Raw or Calcined Natural Pozzolan, for Use as a Mineral Admixture in Portland Cement Concrete
- C 642 Test Method for Specific Gravity, Absorption, and Voids in Hardened Concrete
- C 666 Test Method for Resistance of Concrete to Rapid Freezing and Thawing
- C 682 Practice for Evaluation of Frost Resistance of Coarse Aggregates in Air-Entrained Concrete by Critical Dilation Procedures
- C 685 Specification for Concrete Made by Volumetric Batching and Continuous Mixing
- C 803 Test Method for Penetration Resistance of Hardened Concrete
- C 805 Test Method for Rebound Number of Hardened Concrete
- C 845 Specification for Expansive Hydraulic Cement
- C 856 Practice for Petrographic Examination of Hardened Concrete
- C 878 Test Method for Restrained Expansion of Shrinkage-Compensating Concrete
- C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
- C 900 Test Method for Pullout Strength of Hardened Concrete
- C 1017 Specification for Chemical Admixtures for Use in Producing Flowing Concrete
- C 1018 Test Method for Flexural Toughness and First-Crack Strength of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)
- C 1064 Test Method for Temperature of Freshly Mixed Portland Cement Concrete
- C 1074 Practice for Estimating Concrete Strength by the Maturity Method
- C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation

- D 75 Practice for Sampling Aggregates
- D 512 Test Methods for Chloride Ion in Water
- D 1411 Test Methods for Water-Soluble Chlorides Present as Admixtures in Graded Aggregate Road Mixes
- D 1888 Test Methods for Particulate and Dissolved Matter in Water

U.S. Army Corps of Engineers

- CRD C 119 Method of Test for 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

ASTM
100 Barr Harbor Dr.
West Conshohocken, Pa. 19428-2959

U.S. Army Corps of Engineers
Waterways Experiment Station
P.O. Box 631
Vicksburg, Miss. 39180

**APPENDIX II—SYNOPSIS OF ACI 311.5R
Batch plant inspection and field testing of
ready-mixed concrete**

Reported by ACI Committee 311

Synopsis—This report provides recommended minimum requirements when specifications require batch-plant inspection of ready-mixed concrete production and field testing of ready-mixed concrete at the project site. It is intended to be used by specifiers, architects, engineers, owners, or other groups who are interested in monitoring the ready-mixed concrete producer's or contractor's activities through the use of an independent inspection agency.

The user is cautioned that this report is intended for use in establishing the basic duties and the 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.