An ACI Manual

Manual of Concrete Inspection

ACI 311.1R-07 with Selected References

MNL-2(19)

American Concrete Institute
Always advancing

Manual of Concrete Inspection

ACI 311.1R-07 with Selected References

Reported by ACI Committee 311

PUBLICATION MNL-2(19)
American Concrete Institute
Farmington Hills, MI

American Concrete Institute
Always advancing

ELEVENTH EDITION

First Printing, February 2019

Printed in the United States of America.

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI
48331-3439 USA
+1.248.848.3700
www.concrete.org

ISBN: 978-1-64195-052-7

CONTENTS

ACKNOWLEDGMENTS

The committee wishes to thank Anne Balogh for her extensive work in redrafting and unifying the previous text in preparation for this edition.

Additionally, the committee wishes to express its thanks to Portland Cement Association (PCA) for generously providing many of the new photos contained in the manual and to committee member Michelle L. Wilson who organized and coordinated the selection of photos and graphics throughout the document.

Finally, the committee wishes to thank Chair George R. Wargo for his efforts in coordinating the work of all contributors.

ABOUT THIS BOOK

This manual is based on information from many sources, organizations, and individuals whose contributions are gratefully acknowledged. Published references are listed at the end of the text. References to standard specifications and methods of testing are listed separately.

The original manuscript was prepared by Joe W. Kelly, Chair of ACI Committee 311, and revised over a period of years to achieve a first edition in 1941. The second edition, also in 1941, included a number of corrections and minor revisions.

The third edition, in 1955, incorporated many constructive suggestions from users. The fourth edition, in 1957, brought several sections up to date and contained editorial corrections.

The fifth edition provided new information on settlement of concrete, shoring and forming, strength requirements, cold-weather concreting, and shotcrete. The sixth edition primarily provided updated information in all chapters and included editorial and substantive changes throughout.

The seventh edition presented a complete revision of the manual by eliminating sections of the previous edition covering concrete methods no longer in use. Chapters 2, 11, 12, 13, 14, 15 (partial), 16, 17, and 18 covered material that was included in the manual for the first time. The eighth and ninth editions were revised to reflect changes in technology and construction practices.

The tenth edition presented an extensive revision and update to the text along with new photos, charts, and forms. This eleventh edition substitutes *311.5-04 Guide for Concrete Plant Inspection and Testing of Ready-Mixed Concrete* with *311.6-18 Specification for Testing Ready Mixed Concrete* and *311.7-18 Specification for Inspection of Concrete Construction*.

ON THE COVER

2018 ACI Excellence in Concrete Construction Awards Overall Winner

Viaduct Over River Almonte: Cáceres, Extremadura, España

Nominator: Asociación Española de Ingeniería Estructural
Owner: Arenas & Asociados
Architectural & Engineering Firm: Arenas & Asociados - Idom
General & Concrete Contractor: FCC Construcción - Conduril
Concrete Supplier: CG Hormigones

The Viaduct Over the Almonte River is located in the Alcántara-Garrovillas reservoir section stretching 6265 meters. It forms part of the Madrid-Extremadura High-Speed Railway Line that runs through the municipalities of Garrovillas de Alconétar and Santiago del Campo, in Cáceres. The multi-criteria analyses highlighted the concrete arch solution as the most economical, the best in terms of durability and maintenance, and the one that would perform best in resisting dynamic load effects and wind. This focus on service life prevailed during design and construction with the aim of creating a bridge that would resist the passage of time with minimum maintenance.

Visit *www.ACIExcellence.org* for specific details on the winning projects.

ACI Manual of Concrete Inspection

Reported by ACI Committee 311

George R. Wargo
Chair

Michael T. Russell
Secretary

Gordon A. Anderson
Joseph F. Artuso
Mario R. Diaz
Donald E. Dixon
John V. Gruber
Jimmie D. Hannaman, Jr.
Robert L. Henry
Charles J. Hookham
Venkatesh S. Iyer
Claude E. Jaycox
Robert S. Jenkins
Roger D. Tate
Woodward L. Vogt
Bertold E. Weinberg
Michelle L. Wilson
Roger E. Wilson

PREFACE

This manual is intended to guide, assist, and instruct concrete inspectors and others engaged in concrete construction and testing, including field engineers, construction superintendents, supervisors, laboratory and field technicians, and workers. Designers may also find the manual to be a valuable reference by using the information to better adapt their designs to the realities of field construction. Because of the diverse possible uses of the manual and the varied backgrounds of the readers, it includes the reasoning behind the technical instructions.

The field of concrete construction has expanded dramatically over the years to reflect the many advances that have taken place in the concrete industry. Although many of the fundamentals presented in previous editions of this manual remain relevant and technically correct, this tenth edition incorporates new material to address these advances in technology. A list of only a few of the recent developments in materials, equipment, and processes includes:

- *Shrinkage-compensating cement;*
- *Increased use of supplementary cementitious materials (SCMs);*
- *Polymer-modified mixtures;*
- *Self-consolidating concretes;*
- *New and refined admixtures;*
- *Fiber-reinforced concrete;*
- *Epoxy resins;*
- *High-capacity and automated concrete production equipment;*
- *High-performance and high-strength concrete; and*
- *Epoxy-coated and stainless steel-clad reinforcement.*

The need to cover new issues affecting inspection is the reason ACI Committee 311 continues to revise the ACI Manual of Concrete Inspection. *In preparing this edition of the manual, as with previous editions, the committee's task was to interpret the policies set forth by other authorized bodies rather than to make policy on construction practices. The main emphasis of the manual is on the technical aspects of inspection and construction. For further information about construction practices, readers are encouraged to refer to the* ACI Manual of Concrete Practice.

Because the content of this manual is general and broad in nature, no part of the manual should be included by reference in contract documents. Applicable inspection requirements for each project should be determined and included in the specifications.

ACI 311.1R-07 supersedes ACI 311.1R-99 and was adopted December 2007 and published March 2008.

CHAPTER 1—INSPECTION AND THE INSPECTOR

1.1—Inspection processes

1.1.1 *Why inspection is needed*—The purpose of inspection is to verify that the requirements and intent of the contract design documents are faithfully accomplished. In concrete construction, inspection includes not only visual observations and field measurements, but also field and laboratory testing and the collection and evaluation of test data. In many instances, inspectors also act as or are assisted by the field technicians assigned to perform the testing.

One important responsibility of the concrete inspector is to assess the quality of the materials used in the concrete. It is difficult, and usually impossible, to produce specified concrete from nonconforming materials. Thus, the final materials entering the concrete mixture should be of specified quality.

An important factor in quality construction is good workmanship in all operations and processes (Fig. 1.1). Observing this aspect becomes an important responsibility of the inspector. Even when concrete is made using high-quality materials, proportioned correctly, and batched correctly, the resulting concrete structure can be unsatisfactory if construction workmanship is of poor quality.

Manual skills, technical knowledge, motivation, and pride all contribute to good workmanship. Most individuals involved with concrete design and construction take pride in their efforts and strive to attain superior quality (Fig. 1.2). Not all personnel, however, will receive the necessary training to do their jobs properly. The need to meet fast-track construction schedules and stay within cost limits often places too much emphasis on production rates. If speed becomes a top priority, construction quality may not receive adequate attention if not properly executed. Ironically, cost may also suffer. Techniques that speed concrete placement can actually add to material costs or result in the need for expensive repairs.

Jacob Feld, a noted investigator of structural failures, listed examples in his book, *Lessons from Failures of Concrete Structures*, showing that a high percentage of failures of concrete structures that he had investigated were caused in significant part by poor construction—in other words, poor workmanship. He stated: "The one thing which these failures conclusively point to is that all good concrete construction should be subjected to rigid inspection... It is believed that only by this kind of inspection is it possible to guard against the failure of concrete structures" (Feld 1964).

For every monumental structural collapse, innumerable instances of small failures occur. This is particularly true when important concrete properties, such as durability and watertightness, do not conform to design requirements.

Superior concrete structures can be built at a reasonable cost if concrete producers and contractors are vigilant. As the late F. R. McMillan said in the foreword to his famous *Concrete Primer* (McMillan and Tuthill 1987): "Many who have been interested in the cause of better concrete have noted the difficulty of making any real progress until someone in authority has been convinced that good concrete can be had, that it should be had, and, having been so convinced, has sent out the word that it must be had."

1.1.2 *Purposes of inspection*—The desire for quality has led to the use of inspection personnel to monitor and document quality of concrete construction. The responsibilities and duties of inspectors have broadened over the years. Today, several inspection teams may be used on one project to represent the interests of the various parties involved. Inspectors may be employed:

- By project owners to provide quality assurance for the work;
- By government agencies and large industries to assure the quality;
- By architects and engineers to verify and document compliance with project specifications and drawings;
- By contractors to provide quality-control inspection for projects under construction. This helps provide assurance to the contractor that the finished construction will meet all requirements of the contract documents and thus will be accepted by the owner;
- By producers of concrete materials and products who need assurance that finished products will meet the requirements of the contract documents. Examples include producers of cement, aggregate, ready mixed concrete, and precast products;
- By licensing and building-permit jurisdictions charged with enforcing building codes and other regulations. In this case, the inspector will be responsible only for assuring that the finished structure conforms to requirements of the codes or regulations; or

Fig. 1.1—Increasingly sophisticated building designs call for higher standards of materials and workmanship.

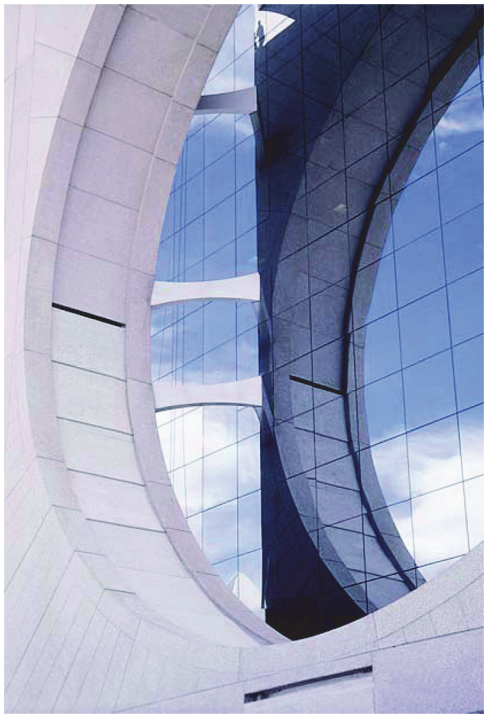

Fig. 1.2—Concrete's ability to be formed into any shape lets artistry and function go hand in hand.

- By commercial laboratories designated to provide testing and inspection services.

Regardless of the function, inspection, including laboratory and field testing, may be performed by a team or, for very small projects, by just one person (Fig. 1.3).

1.1.3 *Owner and contractor inspections*

1.1.3.1 *Owner inspection*—Owner inspection provides assurance to owners that the requirements of the contract documents (drawings and specifications) are fulfilled. ACI 311.4R, Section 2.3, was prepared to guide architects, engineers, and owners in the development of effective inspection programs. It states:

> 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.
>
> 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.
>
> The fee for owner inspection and testing 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.

Fig. 1.3—ACI-certified field technician performing a slump test.

Under a typical construction contract, inspectors representing the owner have no responsibility or authority to manage the contractor's workforce. The owner's inspection team is responsible for determining that materials, procedures, and end products conform to the requirements of the contract documents. Because inspectors are only responsible for evaluating the contractor's work for conformance, they may

Fig. 1.4—Building design accented with horizontal joints; quality construction provides a highly functional and aesthetic workplace.

not burden the contractor by adding requirements not given in the contract documents.

1.1.3.2 *Quality-control inspection*—Personnel maintained or hired by the contractor perform inspection and testing services used to control quality during construction. In some construction contracts, particularly those with certain government agencies, the contractor is required to provide a specified amount of inspection and testing as part of a formal quality-control program. Even when not contractually required, many contractors maintain inspection and testing personnel, separate from the line of supervision, to monitor quality control. These inspectors report directly to the contractor's management. Sometimes inspection work is performed by the contractor's construction supervisors as an automatic part of construction operations.

By performing their own quality-control inspection, contractors can avoid later rejection of work that would be very costly to replace or correct. Inspection performed by or for the contractor, particularly when contractually required, should be more detailed than that performed for owner inspection, with greater attention being given to form alignment, positioning of embedments and reinforcing bars, and general placement practices. Even when contract documents require extensive quality-control inspection and testing by the contractor, however, owners should not reduce or eliminate their own inspection efforts. The owner should maintain formal oversight of the contractor to ensure that the quality-control program achieves its objectives (Fig. 1.4).

Manufacturers of concrete materials and products also use inspection and testing to maintain quality control and to ensure that contract requirements are met. These programs should parallel the contractor's quality-control efforts. Owners should independently audit and assess the effectiveness of these quality-control programs.

1.2—Inspector

1.2.1 *Duties*—Although the duties and emphasis of the different inspection teams involved on a project may vary and sometimes overlap, the basic approach is the same. The owner's inspectors generally emphasize inspection of subgrade and contact surfaces, inspection of reinforcing steel, inspection of concrete materials as they are delivered, testing of the unhardened and hardened concrete, and inspection of the finished structure. The contractor's quality-control inspectors usually emphasize inspection of materials production, setting of formwork, and placement and curing of concrete. The duties that inspectors are most frequently asked to perform include:

- Identifying and examining materials before acceptance. This includes verifying quality based on certifications and test results provided by producers and suppliers as well as sampling and testing materials delivered to the job site;
- Monitoring batching and mixture proportioning (including adjustments) and testing concrete for consistency, air content, temperature, and density;
- Examining foundations, subgrade, forms, reinforcing steel, embedded items, and other work in preparation for concreting;
- Inspecting the mixing, conveying, placing, consolidating, finishing, curing, and protection of concrete;
- Preparing required concrete specimens for laboratory tests, including monitoring for adequate field curing and proper protection of the specimens;
- Observing the equipment, working conditions, weather, and other items affecting the concrete or other related parts of the structures;
- Observing methods used for curing and protection of concrete, especially during periods of hot or cold weather;
- Evaluating test results for conformance to the specifications;
- Reporting nonconforming conditions and materials in a prompt manner;
- Verifying that unacceptable items and procedures are corrected; and
- Preparing records and reports.

To be effective, inspectors need support from management. They need to also be observant and able to evaluate the relative importance of various work items to give priority to more important matters. Above all, inspectors should be completely familiar with all acceptance criteria in the contract documents, and they should promptly document and report any nonconformance to these criteria to contractors and to their own supervisors.

1.2.2 *Education and certification*—Inspectors and technicians can receive related technical training at colleges, trade schools, and similar educational institutions. ACI Certification Program Sponsoring Groups may also provide specific training before certification exam sessions. Certification of inspectors and technicians is becoming the standard and, in many cases, is mandatory. It provides third-party assurance that the inspector or technician has at least the basic skills and knowledge to perform the job. Some states and local jurisdictions require certification, but in most cases, the requirement is placed in industry standards and then referenced in the building codes. Industry standards containing a certification requirement or recommendation for certification include ACI 301, 311.4R, 311.5, 318, and 349 and ASTM C31/C31M, C39/C39M, C42/C42M, C78, C94/C94M, C192/C192M, C685/C685M, C1077, and E329.

ACI provides certification programs for:

- Concrete Field Testing Technician—Grade I
- CSA-Based Concrete Field Testing Technician—Grade I
- Concrete Flatwork Finisher & Technician
- Specialty Commercial/Industrial Flatwork Finisher & Technician
- Concrete Strength Testing Technician
- Concrete Laboratory Testing Technician—Level 1 & 2
- Aggregate Base Testing Technician
- Aggregate Testing Technician—Level 1 & 2
- Concrete Construction Special Inspector & Associate
- CSA-Based Concrete Construction Special Inspector
- Concrete Transportation Construction Inspector
- Associate Concrete Transportation Construction Inspector
- Tilt-Up Supervisor & Technician
- Shotcrete Nozzleman (Dry Mix Process)
- Shotcrete Nozzleman (Wet Mix Process)

ACI continues to develop new certification programs in response to expanding industry needs.

In addition to having a technical understanding of the principles involved in the assigned construction, inspectors must have practical experience. They should know how and why the work is to be done in a particular way. Inexperienced but technically trained inspectors should undergo on-the-job training under the supervision of more experienced individuals before working alone. Employers also should encourage inspectors to keep their skills up to date by continuing their technical training. Employers can assist in this effort by providing periodic training courses.

1.2.3 *Authority*—The quality-assurance/quality-control duties and responsibilities of the owner, engineer, contractor, and supplier should be clearly detailed in the contract documents and thoroughly understood by all parties. These duties and responsibilities should be reviewed at a preconstruction or concrete preplacement meeting. Clearly defining each party's authority, responsibilities, and lines of communication before concrete is placed will have a positive impact on the concrete placement.

At the start of each job, the inspector's supervisor should clearly explain the authority that the inspector has and the actions to be taken in various situations that may be encountered. These duties and responsibilities should be provided to the inspector in writing. The inspector and his firm should contractually be a legal agent of the owner or contractor to have the authority to stop work. An inspector may be authorized to:

- Stop work until preliminary conditions (such as preparation of forms, contact surfaces, subgrades, construction joints, and the placing of reinforcement) are satisfactory and accepted and until inspection personnel are available to observe concreting operations; and
- Stop work if the materials, equipment, or workmanship do not conform to the contract documents.

In both cases, the inspector is usually authorized to take direct action in concert with the contractor's supervisors. Inspectors should stop work only as a last resort, when it is evident that nonconforming concrete will result from continuing operations, and only if authority to do so has been established. In cases where only construction personnel may stop work, inspectors should promptly advise responsible construction supervisors and owners or owner representatives of all nonconforming conditions as soon as they are identified. Actions taken by the contractor in response to this notification should be documented. Matters of general policy or major points not covered or clearly conveyed in the specifications should be discussed with the inspector's supervisor and then with the engineer, usually via request for information (RFI) communication (Fig. 1.5).

Fig. 1.5—A preconstruction meeting between certified inspector and contractor will help prevent problems during concreting operations.

1.2.4 *Relations with contractors, supervisors, and workers*—Inspectors representing the owner should cooperate with the contractor consistent with the owner's interests to help reduce construction costs and improve schedules. Inspections should be made promptly when requested, and conditions that will lead to unsatisfactory work should be pointed out to the contractor immediately to avoid the waste of materials, time, and labor. Inspectors should be on the job during reinforcement placement before concreting and whenever concrete is being placed, finished, cured, or repaired.

The inspector should not delay the contractor unnecessarily nor interfere with the contractor's methods unless it is evident that the work will be unacceptable. Demands should never be made of the contractor that are not in accordance with the contract documents. If the contract documents permit a choice of methods, the inspector may suggest, but not demand, which of the methods should be used. At no time is the inspector permitted to direct the work of the contractor.

Inspectors should maintain an impersonal, agreeable, and helpful attitude toward contractors and their employees. They should never accept personal favors nor criticize the contractor's organization or workers. By dealing fairly and recognizing and commending good work, inspectors usually can gain the respect and cooperation of the contractor's supervisors and workers.

Establishing a clear line of communication also is important. Formal communications should be conducted only with the authorized representatives of the contractor, preferably in the form of advisements relating to the quality of the work in progress. Matters involving a potential change in project costs, completion time, or other important factors should be referred to the owner or owner's authorized representative.