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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.

This tenth edition presents an extensive revision and update to the text along with new photos, charts, and forms.

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.

ACI Manual of Concrete Inspection

Reported by ACI Committee 311

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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

ACI Committee Reports, Guides, Manuals, Standard Practices, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This document is intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. The American Concrete Institute disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom.

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.

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.

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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