ACI 304R-00
(Reapproved 2009)

Guide for Measuring, Mixing, Transporting, and Placing Concrete

Reported by ACI Committee 304

American Concrete Institute®

American Concrete Institute®
Advancing concrete knowledge

Guide for Measuring, Mixing, Transporting, and Placing Concrete

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI. Proper use of this document includes periodically checking for errata at **www.concrete.org/committees/errata.asp** for the most up-to-date revisions.

ACI committee documents are 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. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided "as is" without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Order information: ACI documents are available in print, by download, on CD-ROM, through electronic subscription, or reprint and may be obtained by contacting ACI.

Most ACI standards and committee reports are gathered together in the annually revised *ACI Manual of Concrete Practice* (MCP).

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org

ACI 304R-00
(Reapproved 2009)

Guide for Measuring, Mixing, Transporting, and Placing Concrete

Reported by ACI Committee 304

Neil R. Guptill
Chairman

David J. Akers	John C. King	Kenneth L. Saucier
Casimir Bognacki	Gary R. Mass	James M. Shilstone, Jr.
James L. Cope	Patrick L. McDowell	Ronald J. Stickel
Michael R. Gardner	Dipak T. Parekh	William X. Sypher
Daniel J. Green	Roger J. Phares	J.A. Tony Tinker
Brian Hanlin	James S. Pierce	Robert E. Tobin
Terence C. Holland	Paul E. Reinhart	Joel B. Tucker
Thomas A. Johnson	Royce J. Rhoads	Kevin Wolf

This guide presents information on the handling, measuring, and batching of all the materials used in making normalweight, lightweight structural, and heavyweight concrete. It covers both weight and volumetric measuring; mixing in central mixture plants and truck mixers; and concrete placement using buckets, buggies, pumps, and conveyors. Underwater concrete placement and preplaced aggregate concrete are also covered in this guide, as well as procedures for achieving good quality concrete in completed structures.

Keywords: batching; continuous mixing; conveying; heavyweight concretes; lightweight concretes; materials handling; mixing; placing; preplaced aggregate concrete; pumped concrete; tremie concrete; volumetric measuring.

CONTENTS

ACI 304R-00 supersedes ACI 304R-89 and became effective January 10, 2000.

CHAPTER 1—INTRODUCTION

1.1—Scope

This guide outlines procedures for achieving good results in measuring and mixing ingredients for concrete, transporting it to the site, and placing it. The first six chapters are general and apply to all types of projects and concrete. The following four chapters deal with preplaced-aggregate concrete, underwater placing, pumping, and conveying on belts. The concluding three chapters deal with heavyweight, radiation-shielding concrete, lightweight concrete, and volumetric-measuring and continuous-mixing concrete equipment.

1.2—Objective

When preparing this guide, ACI Committee 304 followed this philosophy:

- Progress in improvement of concrete construction is better served by the presentation of high standards rather than common practices;
- In many, if not most, cases, practices resulting in the production and placement of high-quality concrete can be performed as economically as those resulting in poor concrete. Many of the practices recommended in this document improve concrete uniformity as well as quality, yielding a smoother operation and higher production rates, both of which offset potential additional cost; and
- Anyone planning to use this guide should have a basic knowledge of the general practices involved in concrete work. If more specific information on measuring, mixing, transporting, and placing concrete is desired, the reader should refer to the list of references given at the end of this document, and particularly to the work of the U.S. Bureau of Reclamation (1981), the U.S. Department of Commerce (1966), the Corps of Engineers (1994a), ASTM C 94, ACI 311.1R, and ACI 318. To portray more clearly certain principles involved in achieving maximum uniformity, homogeneity, and quality of concrete in place, figures that illustrate good and poor practices are also included in this guide.

1.3—Other considerations

All who are involved with concrete work should know the importance of maintaining the unit water content as low as possible and still consistent with placing requirements (Mielenz 1994; Lovern 1966). If the water-cementitious materials ratio (*w/cm*) is kept constant, an increase in unit water content increases the potential for drying-shrinkage cracking, and with this cracking, the concrete can lose a portion of its durability and other favorable characteristics, such as monolithic properties and low permeability. Indiscriminate addition of water that increases the *w/cm* adversely affects both strength and durability.

The more a form is filled with the right combination of solids and the less it is filled with water, the better the resulting concrete will be. Use only as much cement as is required to achieve adequate strength, durability, placeability, workability, and other specified properties. Minimizing the cement content is particularly important in massive sections subject to restraint, as the temperature rise associated with the hydration of cement can result in cracking because of the change in volume (ACI 207.1R and 207.2R). Use only as much water and fine aggregate as is required to achieve suitable workability for proper placement and consolidation by means of vibration.

CHAPTER 2—CONTROL, HANDLING, AND STORAGE OF MATERIALS

2.1—General considerations

Coarse and fine aggregates, cement, pozzolans, and chemical admixtures should be properly stored, batched, and handled to maintain the quality of the resulting concrete.

2.2—Aggregates

Fine and coarse aggregates should be of good quality, uncontaminated, and uniform in grading and moisture content. Unless this is accomplished through appropriate specifications (ASTM C 33) and effective selection, preparation, and handling of aggregates (Fig. 2.1), the production of uniform concrete will be difficult (Mielenz 1994; ACI 221R).

2.2.1 *Coarse aggregate*—The coarse aggregate should be controlled to minimize segregation and undersized material. The following sections deal with prevention of segregation and control of undersized material.

2.2.1.1 *Sizes*—A practical method of minimizing coarse aggregate segregation is to separate the material into several size fractions and batch these fractions separately. As the range of sizes in each fraction is decreased and the number of size separations is increased, segregation is further reduced. Effective control of segregation and undersized materials is most easily accomplished when the ratio of maximum-to-minimum size in each fraction is held to not more than four for aggregates smaller than 1 in. (25 mm) and to two for larger sizes. Examples of some appropriate aggregate fraction groupings follow:

Example 1

Sieve designations

No. 8 to 3/8 in. (2.36 to 9.5 mm)

No. 4 to 1 in. (4.75 to 25.0 mm)

3/4 to 1-1/2 in. (19.0 to 37.5 mm)

Example 2

Sieve designations

No. 4 to 3/4 in. (4.75 to 19.0 mm)

3/4 to 1-1/2 in. (19.0 to 37.5 mm)

1-1/2 to 3 in. (37.5 to 75 mm)

3 to 6 in. (75 to 150 mm)

2.2.1.2 *Control of undersized material*—Undersized material for a given aggregate fraction is defined as material that will pass a sieve having an opening 5/6 of the nominal minimum size of each aggregate fraction (U.S. Bureau of Reclamation 1981). In Example 2 in Section 2.2.1.1, it would be material passing the following sieves: No. 5 (4.0 mm), 5/8 in. (16.0 mm), 1-1/4 in. (31.5 mm), and 2-1/2 in. (63 mm). For effective control of gradation, handling operations that do not increase the undersized materials in aggregates significantly before their use in concrete are essential (Fig. 2.1 and 2.2). The gradation of aggregate as it enters the concrete mixer should be uniform and within specification limits. Sieve analyses of coarse aggregate should be made with sufficient frequency to ensure that grading requirements are met. When two or more aggregate sizes are used, changes may be necessary in the proportions of the sizes to maintain the overall grading of the combined aggregate. When specification limits for grading cannot be met consistently, special handling methods should be instituted. Materials tend to segregate during transportation, so reblending may be necessary. Rescreening the coarse aggregate as it is charged to the bins at the batch plant to remove undersized materials will effectively eliminate undesirable fines when usual storage and handling methods are not satisfactory. Undersized materials in the smaller coarse aggregate fractions can be consistently reduced to as low as 2% by rescreening (Fig. 2.2). Although rescreening is effective in removing undersized particles, it will not regrade segregated aggregates.

2.2.2 *Fine aggregate (sand)*—Fine aggregate should be controlled to minimize variations in gradation, giving special attention to keeping finer fractions uniform and exercising care to avoid excessive removal of fines during processing.

If the ratio of fine-to-coarse aggregate is adjusted in accordance with ACI 211.1 recommendations for mixture proportioning, a wide range of fine aggregate gradings can be used (Tynes 1962). Variations in grading during production of concrete should be minimized, however, and the ASTM C 33 requirement that the fineness modulus of the fine aggregate be maintained within 0.20 of the design value should be met.

Give special attention to the amount and nature of material finer than the No. 200 screen (75 μm sieve). As stated in ASTM C 33, if this material is dust of fracture, essentially free of clay or shale, greater percentages of materials finer than the No. 200 screen (75 μm sieve) are permissible. If the reverse is true, however, permissible quantities should be significantly reduced. The California sand equivalent test is sometimes used to determine quantitatively the type, amount, and activity of this fine material (Mielenz 1994; ASTM D 2419). Excessive quantities of material finer than the No. 200 screen (75 μm sieve) increase the mixing-water