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Concrete Craftsman Series:
Slabs-on-Ground
Third Edition

American Concrete Institute®
Advancing concrete knowledge

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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

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Reported by ACI Committee E703

William D. Palmer
Chair

Scott Anderson
Daniel P. Dorfmueller
Reynold Franklin
Beverly A. Garnant
Michael G. Hernandez
Katherine Martin
Harry Moats
William R. Nash
Michael V. Pedraza
William R. Phillips
Thomas Roth

PREFACE

The concrete craftsman can greatly influence the quality, durability, and appearance of the finished product. This manual from the ACI Concrete Craftsman Series presents information on concrete that should be useful to concrete craftsmen and deals mainly with construction practices relating to slabs-on-ground. This information can be used to train concrete craftsmen and is especially useful for those interested in earning credentials as ACI certified finishers.

Information in this manual is a guide to good practice but does not supersede the provisions in the plans and specifications for any project. If provisions in the plans and specifications vary from the guidance given in this manual, discuss the variances with the design professional. For more detailed information, also read ACI 302.1R, "Guide for Concrete Floor and Slab Construction," and other documents listed in the reference section of this manual. Prior editions of this manual included a considerable amount of information on concrete materials and testing. For expanded coverage of materials and testing information, the reader is referred to The Contractor's Guide to Quality Concrete Construction *(ASCC-1), published jointly by the American Society of Concrete Contractors (ASCC) and ACI.*

This manual was first issued under the guidance of the ACI Educational Activities Committee in 1982 as the first book in the ACI Concrete Craftsman Series. A second edition was approved and issued in 1994. Since 1987, when ACI launched the Concrete Flatwork Finisher/Technician certification program, ACI has been using this document as the primary reference for that program. The certification program was designed to provide a basis for certifying concrete finishers and to improve the quality of concrete construction. As a result of program growth, more than 7500 people have become certified Concrete Flatwork Finishers/Technicians. Some major retailers now specify that contractors constructing concrete floors for their stores have certified ACI Flatwork Finishers on site performing the work.

ACI Committee 301, Specifications for Concrete, took a major step toward formally recognizing the value of using ACI-certified finishers and technicians when, in 2002, they approved language in ACI 301, "Specifications for Concrete," that states in part, "...Unless otherwise permitted, a minimum of one finisher or finishing supervisor shall be a certified ACI Flatwork Finisher/Technician or a certified Flatwork Technician as defined in ACI CP-10 or equivalent." This was the first time ACI Committee 301 had included language requiring the use of qualified flatwork finishers for concrete placement.

ARCOM, a partner of the American Institute of Architects, also includes optional language in their MASTERSPEC® Specification System requiring cast-in-place concrete installers to be certified ACI Flatwork Finishers and Technicians, and installer supervisors to also be certified ACI Flatwork Technicians.

CCS-1(10) (third edition) supersedes CCS-1(94) (second edition) and was adopted and published January 2010.

CONTENTS

CHAPTER 1—PLANNING FOR A SLAB-ON-GROUND PLACEMENT

Introduction

Specifications are written to help ensure that the contractor constructs a slab-on-ground that satisfies the owner. This manual supplements specifications by presenting basic information about slab-on-ground placing and finishing practices for commercial, industrial, and institutional projects. Most of the information can also be used to improve the quality of flatwork for residential projects. In the field, concrete placements are often referred to as concrete pours. In this manual, the preferred term *placement* will be used in place of the term *pour*.

Specification requirements

Just as project specifications may require the contractor to use certified ACI Flatwork Finishers, they also may contain much more information on the specific requirements for the slab-on-ground placements. It's important that the finisher foreman read and understand the specifications (Fig. 1.1) because they convey the owner's requirements. Typical project specifications contain requirements related to:

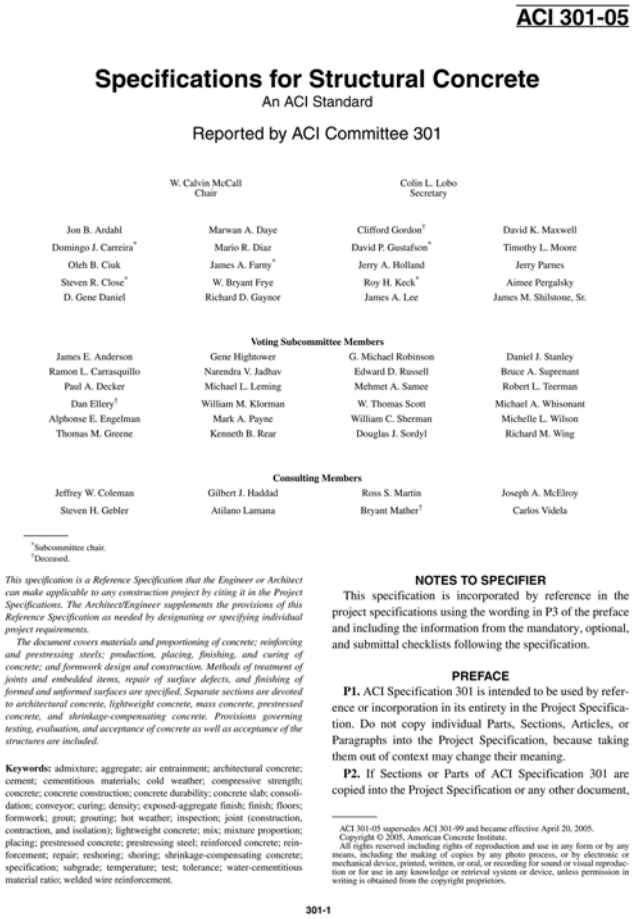
- Material properties;
- Concrete strength and durability;
- Mixture proportions;
- Vapor retarders or barriers;
- Reinforcement;
- Slab flatness and levelness;
- Joint spacing and depth, and timing of the joint forming (whether by grooving the fresh concrete or sawing with an early-entry or conventional saw); and
- Curing and protection.

If the specifications or drawings do not address these issues, it's best to address them at the preconstruction meeting before starting any slab-on-ground placement.

Determining the size of concrete placements

Slab-on-ground placements can range from very small to more than 50,000 ft^2 (4650 m^2) in a single placement (Fig. 1.2). Refer to the sidebar for the factors to consider when determining the appropriate size of the concrete placement. The concrete delivery rate should be matched with the placing equipment capability and production capabilities of the placing and finishing crews. If a concrete producer is told to deliver 300 yd^3/hour (230 m^3/hour) to a job on which a crane and bucket can place only 50 yd^3/hour (38 m^3/hour), placement delays can cause fresh concrete properties to vary from truck to truck. Inconsistent concrete properties make the finishers' job more difficult.

Many contractors make a small first placement on every project to ensure smooth coordination between the concrete producer, the placing equipment, and the placing and finishing crews. After confirming that all activities are coordinated, placement size can be increased. Construction schedules and contractor economics typically dictate daily concrete placements of 10,000 to 20,000 ft^2 (900 to 1800 m^2) unless a laser-guided, wheel-mounted screed is used, in which case daily placements from 30,000 to 50,000 ft^2 (2800 to 4600 m^2) are possible.



ACI 301-05

Specifications for Structural Concrete
An ACI Standard

Reported by ACI Committee 301

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*Subcommittee chair.
†Deceased.

This specification is a Reference Specification that the Engineer or Architect can make applicable to any construction project by citing it in the Project Specifications. The Architect/Engineer supplements the provisions of this Reference Specification as needed by designating or specifying individual project requirements.

The document covers materials and proportioning of concrete; reinforcing and prestressing steels; production, placing, finishing, and curing of concrete; and formwork design and construction. Methods of treatment of joints and embedded items, repair of surface defects, and finishing of formed and unformed surfaces are specified. Separate sections are devoted to architectural concrete, lightweight concrete, mass concrete, prestressed concrete, and shrinkage-compensating concrete. Provisions governing testing, evaluation, and acceptance of concrete as well as acceptance of the structures are included.

Keywords: admixture; aggregate; air entrainment; architectural concrete; cement; cementitious materials; cold weather; compressive strength; concrete; concrete construction; concrete durability; concrete slab; consolidation; conveyor; curing; density; exposed-aggregate finish; finish; floors; formwork; grout; grouting; hot weather; inspection; joint (construction, contraction, and isolation); lightweight concrete; mix; mixture proportion; placing; prestressed concrete; prestressing steel; reinforced concrete; reinforcement; repair; reshoring; shoring; shrinkage-compensating concrete; specification; subgrade; temperature; test; tolerance; water-cementitious material ratio; welded wire reinforcement.

NOTES TO SPECIFIER

This specification is incorporated by reference in the project specifications using the wording in P3 of the preface and including the information from the mandatory, optional, and submittal checklists following the specification.

PREFACE

P1. ACI Specification 301 is intended to be used by reference or incorporation in its entirety in the Project Specification. Do not copy individual Parts, Sections, Articles, or Paragraphs into the Project Specification, because taking them out of context may change their meaning.

P2. If Sections or Parts of ACI Specification 301 are copied into the Project Specification or any other document,

ACI 301-05 supersedes ACI 301-99 and became effective April 20, 2005.

301-1

Fig. 1.1—ACI 301, "Specifications for Structural Concrete," requires at least one finisher or finishing supervisor to be a certified ACI Flatwork Concrete Finisher/Technician or a certified ACI Flatwork Technician.

Factors to consider when determining appropriate placement size

- Concrete delivery rate, yd^3/hour (m^3/hour);
- Placing equipment rate, yd^3/hour (m^3/hour);
- Placing crew production, yd^2/hour (m^2/hour);
- Finishing crew production, ft^2/hour (m^2/hour);
- Availability of equipment or manpower in case of a breakdown or shortage;
- Ability to install an emergency construction joint;
- Ability to handle problems that may arise due to cold or hot weather;
- Concrete setting time;
- Experience of equipment operators and placing and finishing crew;
- Floor flatness and levelness requirements;
- Specialty surface finishes, toppings, or dry-shake hardeners required;
- Construction schedule; and
- Economics

Ordering concrete

Concrete is sold by volume—in cubic yards or cubic meters—while in a freshly mixed unhardened state and as discharged from the truck mixer. The next sidebar contains

Fig. 1.2—Construction schedules and contractor economics typically require concrete placements of 10,000 to 20,000 ft^2 (900 to 1800 m^2) or from 30,000 to 50,000 ft^2 (2800 to 4600 m^2) when a laser-guided, wheel-mounted screed is used. This figure shows a 300,000 ft^2 (27,900 m^2) placement that was completed within 24 hours.

an example of how the volume of concrete needed for a slab placement is calculated.

In addition to the volume of concrete needed, the concrete producer needs to know who is ordering the concrete, what properties are required, where the concrete will be delivered, and when it is needed. Be prepared to provide an accurate delivery address, date and time of delivery, quantity, and mixture properties desired. The items in the following checklist should be given to the concrete producer when ordering concrete.

Checklist for ordering concrete

- Volume of concrete;
- Who is ordering;
- Where to deliver;
- When to deliver;
- Delivery rate; and
- Mixture properties:
  - Strength;
  - Water-cementitious material ratio;
  - Slump;
  - Air content; and
  - Maximum aggregate size.

Concrete delivery

Because fresh concrete properties start to change as soon as the concrete is mixed with water, finishers should be prepared for concrete delivery. First, make sure the truck has adequate space to enter the site and reach the placement area. This may require the use of a flagger to direct traffic and keep all other traffic out of the way when the concrete truck arrives. Other construction materials can sit for hours and

How is concrete quantity calculated?

Consider as an example a 10,000 ft^2 (900 m^2) strip concrete placement measuring 200 ft (60 m) long x 50 ft (15 m) wide and 5 in. (125 mm) thick. First, convert all measurements (length, width, and thickness) to feet (meters) and then multiply them together. This gives the volume of concrete in ft^3 (m^3). For the example, convert the 5 in. to feet by dividing by 12 to obtain 5/12 ft = 0.42 ft (convert 125 mm to meters by dividing by 1000 to obtain 125/1000 m = 0.125 m). Because all the other measurements are in feet (meters), multiply the length times the width times the thickness, or 200 ft × 50 ft × 0.42 ft to get 4200 ft^3 (60 m × 15 m × 0.125 m to get 112.5 m^3). Because there are 27 ft^3 in 1 yd^3, divide the volume in ft^3 by 27 to obtain the volume in yd^3. For this example, 4200/27 = 155.6 yd^3.

It's common to add 10% or 15% to small loads and 5% to 10% to larger orders to compensate for subgrade settlement, uneven subgrade, spillage, and waste. In this example, add 5% of the total: 155.6 yd^3 × 0.05 = 7.8 yd^3 (112.5 m^3 × 0.05 = 5.6 m^3). The volume of concrete to be ordered for this placement would be 155.6 yd^3 + 7.8 yd^3 = 163.4 yd^3 (112.5 m^3 +5.6 m^3 = 118.1 m^3). Usually, the order is rounded up to the nearest yd^3 (m^3), or 164 yd^3 (119 m^3). That would require 16 trucks carrying 10 yd^3 loads and one partial load of 4 yd^3 (15 trucks carrying 7.5 m^3 loads and one partial load of 6.5 m^3).

Some finishers mark locations on the forms where they should have placed a given volume of concrete. For this example, when the placement is halfway done, the amount of concrete used should be about 164 yd^3/2 = 82 yd^3 (119 m^3/2 = 59.5 m^3). For 10 yd^3 (7.5 m^3) trucks, about eight truckloads should have been placed at the halfway point of the placement. If more than eight trucks have discharged when the halfway point is reached, more concrete than originally anticipated may be needed to finish the placement. The concrete supply needs should be re-evaluated during placement, and any changes should be communicated to the concrete producer.

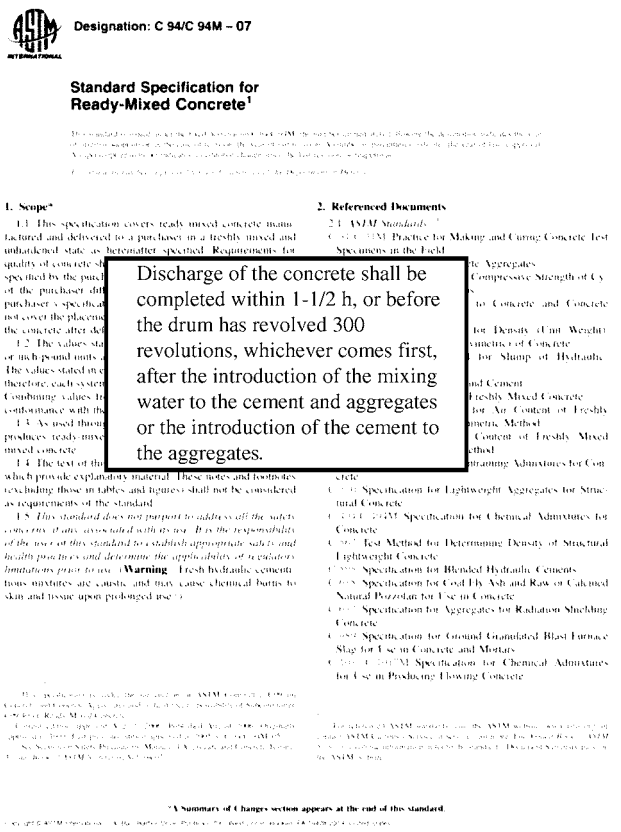
still be useable, but delays in concrete placement can result in concrete that is hard to transport, place, and finish.

Determine whether there is enough space for two or more concrete trucks to be on site and discharging concrete without truck-to-truck delays. For concrete placements using a pump, it's best to have access so that two concrete trucks can both be in position to discharge into the pump hopper. That way, as one truck is finishing, the other truck can already be backed in and ready to unload concrete so there is a continuous flow of concrete to the pump.

Most project specifications refer to ASTM C94, "Standard Specification for Ready-Mixed Concrete" (Fig. 1.3). This specification limits how long the truck can wait before the concrete is used. The concrete must usually be completely discharged within 1-1/2 hours after water has been added to the cement and aggregates or before the drum has reached 300 revolutions, whichever comes first. The truck driver's batch ticket lists the time that the concrete was loaded, so the end of the 1-1/2-hour time period can be determined. Trucks are equipped with a revolution counter that records the number of times the drum revolves. An inspector looks at the batch ticket and the revolution counter to determine if the concrete can still be used. Workers should be prepared before concrete is delivered so they can discharge the trucks before the time limit or drum revolutions is reached.

The number of trucks arriving for each placement will vary. Plan to get the trucks onto the site for discharge, then to a washout area and away from the site as quickly as possible.

A 10 yd^3 (7.5 m^3) load of concrete can be completely discharged from a concrete truck in about 4 to 5 minutes, but trucks are unlikely to discharge that quickly on most jobs. Typically, it takes about 15 to 20 minutes to empty a truck, depending on whether it can discharge completely in one spot or must be moved to different areas before the mixing drum is empty. Because of the time limit on discharging concrete, limited space at most construction sites, and congestion at the point of truck discharge, most finishers prefer concrete truck arrivals to be spaced about 15 minutes apart, especially when concrete will be discharged from the chute and onto the slab base course. This usually allows enough time for the first truck to be about empty when the next truck has arrived on site. The new load of concrete can be checked or tested, and the new truck can be positioned when the preceding truck pulls away.



Designation: C 94/C 94M – 07

Standard Specification for Ready-Mixed Concrete[1]

1. Scope*

2. Referenced Documents

Discharge of the concrete shall be completed within 1-1/2 h, or before the drum has revolved 300 revolutions, whichever comes first, after the introduction of the mixing water to the cement and aggregates or the introduction of the cement to the aggregates.

*A Summary of Changes section appears at the end of this standard.

Fig. 1.3—Most project specifications refer to ASTM C94, "Standard Specification for Ready-Mixed Concrete."

Equipment

Required equipment for each placement varies, but some general equipment is required on each job. Spare equipment, such as vibrating screeds, power trowels, or curing compound sprayers, may be needed in case of breakdowns. Materials for installing emergency bulkheads (forms for closing a section of the slab and creating a construction joint) should also be available. Emergency bulkheads may be needed if concrete delivery is interrupted or if placing equipment breaks down and can't be replaced.

The productivity of each piece of equipment varies greatly depending on the experience of the placing and finishing crews and the concrete properties. Some average production rates to assist finishers in selecting the needed equipment (Fig. 1.4) for a placement include:

- Walk-behind power trowel: 1000 to 3000 ft^2 (90 to 280 m^2) daily;
- Ride-on trowel: 3000 to 6000 ft^2 (280 to 560 m^2) daily; and
- Laser-guided, wheel-mounted screed: 30,000 to 50,000 ft^2 (2800 to 4600 m^2) daily.

For comparison purposes, an experienced hand-finishing crew can finish about 1000 to 2000 ft^2 (90 to 190 m^2) of slab in a day.

Size of placing and finishing crews

The size of each crew affects the labor cost for the placement. Although keeping placing and finishing crew size to a minimum reduces labor costs, it might not provide enough labor to handle some possible job-site contingencies, such as:

- Workers who call in sick or are injured during the placement;
- Concrete that sets faster than expected due to weather changes;
- Inconsistent fresh concrete properties that delay finishing;
- Equipment breakdowns; and
- The need for early sawing to prevent cracking on windy days.

Overlapping placing and finishing crews provides some flexibility. If the finishing crew needs more help, some