Guide for Concrete Floor and Slab Construction

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FOREWORD

The quality of a concrete floor or slab is highly dependent on achieving a hard and durable surface that is flat, relatively free of cracks, and at the proper grade and elevation. Properties of the surface are determined by the mixture proportions and the quality of the concreting and jointing operations. The timing of concreting operations—especially finishing, jointing, and curing—is critical. Failure to address this issue can contribute to undesirable characteristics in the wearing surface such as cracking, low resistance to wear, dusting, scaling, high or low spots, poor drainage, and increasing the potential for curling.

Concrete floor slabs employing portland cement, regardless of slump, will start to experience a reduction in volume as soon as they are placed. This phenomenon will continue as long as any water, heat, or both, is being released to the surroundings. Moreover, because the drying and cooling rates at the top and bottom of the slab will never be the same, the shrinkage will vary throughout the depth, causing the as-cast shape to be distorted and reduced in volume.

This guide contains recommendations for controlling random cracking and edge curling caused by the concrete's normal volume change. Application of present technology permits only a reduction in cracking and curling, not elimination. Even with the best floor designs and proper construction, it is unrealistic to expect crack-free and curl-free floors. Consequently, every owner should be advised by both the designer and contractor that it is normal to expect some amount of cracking and curling on every project, and that such occurrence does not necessarily reflect adversely on either the adequacy of the floor's design or the quality of its construction (Ytterberg 1987; Campbell et al. 1976).

Refer to the latest edition of ACI 360R for a detailed discussion of shrinkage and curling in slabs-on-ground. Refer to the latest edition of ACI 224R for a detailed discussion of cracking in reinforced and nonreinforced concrete slabs.

This guide describes how to produce high-quality concrete slabs-on-ground and suspended floors for various classes of service. It emphasizes aspects of construction such as site preparation, concreting materials, concrete mixture proportions, concreting workmanship, joint construction, load transfer across joints, form stripping procedures, finishing methods, and curing. Flatness/levelness requirements and measurements are outlined. A thorough preconstruction meeting is critical to facilitate communication among key participants and to clearly establish expectations and procedures that will be employed during construction to achieve the floor qualities required by the project specifications. Adequate supervision and inspection are required for job operations, particularly those of finishing.

Keywords: admixture; aggregate; concrete; consolidation; contract documents; curing; curling; deflection; durability; form; fracture; joint; mixture proportioning; mortar, paste, placing; quality control; slab-on-ground; slabs; slump test; specification.

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ACI 302.1R-04 supersedes ACI 302.1R-96 and became effective March 23, 2004.

CHAPTER 1—INTRODUCTION

1.1—Purpose and scope

This guide presents state-of-the-art information relative to the construction of slab-on-ground and suspended-slab floors for industrial, commercial, and institutional buildings. It is applicable to the construction of normalweight and structural lightweight concrete floors and slabs made with conventional portland and blended cements. Slabs specifically intended for the containment of liquids are beyond the scope of this document.

The design of slabs-on-ground should conform to the recommendations of ACI 360R. Refer to ACI 223 for procedures for the design and construction of shrinkage-compensating concrete slabs-on-ground. The design of suspended floors should conform to requirements of ACI 318 and ACI 421.1R. See Section 1.2 for relevant work by these and other committees.

This guide identifies the various classes of floors as to

- Use;
- Design details as they apply to construction;
- Necessary site preparation; and
- Type of concrete and related materials.

In general, the characteristics of the concrete slab surface and the performance of joints have a powerful impact on the serviceability of floors and other slabs. Because the eventual success of a concrete floor installation depends on the mixture proportions and floor finishing techniques used, considerable attention is given to critical aspects of achieving the desired finishes and the required floor surface tolerances. This guide emphasizes choosing and proportioning of materials, design details, proper construction methods, and workmanship.

1.1.1 *Prebid meeting*—While this guide does provide a reasonable overview of concrete floor construction, it should be emphasized that every project is unique; circumstances can dictate departures from the recommendations contained herein. Accordingly, contractors and suppliers are urged to make a thorough review of contract documents before bid preparation.

The best forum for such a review is the prebid meeting. This meeting offers bidders an opportunity to ask questions and clarify their understanding of contract documents before submitting their bids. A prebid meeting also provides the owner and the owner's designer an opportunity to clarify intent where documents are unclear and to respond to last-minute questions in a manner that provides bidders an opportunity to be equally responsive to the contract documents.

1.1.2 *Preconstruction meeting*—Construction of any slab-on-ground or suspended floor or slab involves the coordinated efforts of many subcontractors and material suppliers. It is strongly recommended that the designer require a preconstruction meeting to be held to establish and to coordinate procedures that will enable key participants to produce the best possible product under the anticipated field conditions. This meeting should be attended by responsible representatives of organizations and material suppliers directly involved with either the design or construction of floors.

The preconstruction meeting should confirm and document the responsibilities and anticipated interaction of key participants involved in floor slab construction. Following is a list of agenda items appropriate for such a meeting; many of the items are those for which responsibility should be clearly established in the contract documents. The following list is not necessarily all-inclusive:

1. Site preparation;
2. Grades for drainage, if any;
3. Work associated with installation of auxiliary materials, such as vapor barriers, vapor retarders, edge insulation, electrical conduit, mechanical sleeves, drains, and embedded plates;
4. Class of floor;
5. Floor thickness;
6. Reinforcement, when required;
7. Construction tolerances: base (rough and fine grading), forms, slab thickness, surface configuration, and floor flatness and levelness requirements (including how and when measured);
8. Joints and load-transfer mechanism;
9. Materials: cements, fine aggregate, coarse aggregate, water, and admixtures (usually by reference to applicable ASTM standards);
10. Special aggregates, admixtures, or monolithic surface treatments, where applicable;
11. Concrete specifications, to include the following:
    a. Compressive strength, flexural strength, or both, and finishability (Section 6.2);
    b. Minimum cementitious material content, if applicable (Table 6.2);
    c. Maximum size, grading, and type of coarse aggregate;
    d. Grading and type of fine aggregate;
    e. Combined aggregate grading;
    f. Air content of concrete, if applicable (Section 6.2.7);
    g. Slump of concrete (Section 6.2.5);
    h. Water-cement ratio (w/c) or water-cementitious material ratio (w/cm); and
    i. Preplacement soaking requirement for lightweight aggregates.
12. Measuring, mixing, and placing procedures (usually by reference to specifications or recommended practices);
13. Strikeoff method;
14. Recommended finishing methods and tools, where required;
15. Coordination of floor finish requirements with those required for floor coverings such as vinyl, ceramic tile, or wood that are to be applied directly to the floor;
16. Curing procedures, length of curing, necessary protection, and time before opening slabs for traffic (ACI 308R);
17. Testing and inspection requirements; and
18. Acceptance criteria and remedial measures to be used, if required.

Additional issues specific to suspended slab construction are as follows:

1. Form tolerances and preplacement quality assurance survey procedures for cast-in-place construction;
2. Erection tolerances and preplacement quality assurance survey procedures for composite slab construction (see ANSI/ASCE 3 and ANSI/ASCE 9 [Section 12.1]);
3. Form stripping procedures, if applicable; and
4. Items listed in Section 3.3 that are appropriate to the structural system(s) used for the project.

1.1.3 *Quality assurance*—Adequate provisions should be made to ensure that the constructed product meets or exceeds the requirements of the project documents. Toward this end, quality control procedures should be established and maintained throughout the entire construction process.

The quality of a completed concrete slab depends on the skill of individuals who place, finish, and test the material. As an aid to ensuring a high-quality finished product, the

specifier or owner should consider requiring the use of prequalified concrete contractors, concrete suppliers, accredited testing laboratories, and concrete finishers who have had their proficiency and experience evaluated through an independent third-party certification program. ACI has developed programs to train and certify concrete flatwork finishers and concrete inspectors and testing technicians throughout the United States, Mexico, and Canada.

1.2—Terminology

adjusted mix optimization indicator (MOI-Adj)—intersection of the coarseness factor value and the adjusted workability factor on the coarseness factor chart.

adjusted workability factor (W-Adj)—the workability factor adjusted for cementitious content. For each 94 lb (43 kg) of total cementitious material above 564 lb/yd^3 (335 kg/m^3), increase the workability factor by 2.5%. For each 94 lb (43 kg) of total cementitious material below 564 lb/yd^3 (335 kg/m^3), decrease the workability factor by 2.5%. (Example for a workability factor of 33% and 600 lb/yd^3 [356 kg/m^3] of cementitious material: 600 lb/yd^3 [356 kg/m^3] – 564 lb/yd^3 [335 kg/m^3] = 36 lb/yd^3 [21 kg/m^3]; 36 lb [16 kg]/94 lb [43 kg] = 0.38; 0.38 × 2.5% = 0.95%; W-Adj = 33% workability factor + 0.95% = 33.95%).

coarseness factor—the percentage of combined aggregate that is larger than the 3/8 in. (9.5 mm) sieve, divided by the percentage of combined aggregate that is larger than the No. 8 (2.36 mm) sieve, expressed as a percent. (Example: 33% retained on the 3/8 in. [9.5 mm] sieve/45% retained on the No. 8 [2.36 mm] sieve = 73.3%).

differential set time—the difference in timing of initial power floating of sequential truck loads of concrete as they are delivered to the jobsite.

dry shake—metallic or mineral hardener mixed with cement and applied dry to the surface of concrete during finishing operations.

floating—a term used to describe smoothing and subsequent compaction and consolidation of the unformed concrete surface.

mix optimization indicator (MOI)—intersection of the coarseness factor value and the workability factor on the coarseness factor chart.

pumping—the vertical displacement and rebound of the soil support system in response to applied wheel loads.

rutting—the creation of troughs in the soil support system in response to applied wheel loads.

score—the creation of lines or notches in the surface of a concrete slab.

water slump—the magnitude of slump, measured in accordance with ASTM C 143, which is directly attributed to the amount of water in the concrete mixture.

window of finishability—the time period available for finishing operations after the concrete has been placed, consolidated, and struck-off, and before final troweling.

workability factor—the percentage of combined aggregate that passes the No. 8 (2.36 mm) sieve.

1.3—Related work of other committees

1.3.1 *ACI committees*

117—Prepares and updates tolerance requirements for concrete construction.

201—Reviews research and recommendations on durability of concrete and reports recommendations for appropriate materials and methods.

211—Develops recommendations for proportioning concrete mixtures.

223—Develops and reports on the use of shrinkage-compensating concrete.

224—Studies and formulates recommendations for the prevention or control of cracking in concrete construction.

301—Develops and maintains reference specifications for structural concrete for buildings.

308—Prepares guidelines for type and amount of curing required to develop the desired properties in concrete.

309—Studies and reports on research and development in consolidation of concrete.

311—Develops guides and procedures for inspection and testing.

318—Develops and updates building code requirements for reinforced concrete and structural plain concrete, including suspended slabs.

325—Reports on the structural design, construction, maintenance, and rehabilitation of concrete pavements.

330—Reports on the design, construction, and maintenance of concrete parking lots.

332—Gathers and reports on the use of concrete in residential construction.

347—Gathers, correlates, and reports information, and prepares recommendations for formwork for concrete.

350—Develops and updates code requirements for concrete in environmental structures.

360—Develops and reports on criteria for design of slabs-on-ground, except highway and airport pavements.

421—Develops and reports on criteria for suspended slab design.

423—Develops and reports on technical status, research, innovations, and recommendations for prestressed concrete.

435—Provides recommendations for deflection control in concrete slabs.

503—Studies and reports information and recommendations on the use of adhesives for structurally joining concrete, providing a wearing surface, and other uses.

504—Studies and reports on materials, methods, and systems used for sealing joints and cracks in concrete structures.

515—Prepares recommendations for selection and application of protective systems for concrete surfaces.

544—Studies and reports information and recommendations on the use of fiber-reinforced concrete.

640—Develops, maintains, and updates programs for use in certification of concrete construction workers.

1.3.2 *The American Society of Civil Engineers*—ASCE publishes documents that can be helpful for floor and slab construction. Two publications that deal with suspended slab construction are ASCE Standard for the Structural Design of Composite Slabs (ANSI/ASCE 3) and ASCE Standard Prac-