Guide for Submittal of Concrete Proportions

Reported by ACI Committee 211

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Chairman

Richard M. Wing
Subcommittee Chairman

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Information required for the preparation and review of a concrete mixture submittal is contained in reference documents such as codes and standards, project drawings and specifications, and other contract documents. These requirements depend on the intended use of the concrete, the available information, and the size of the project. This guide is intended to assist both the submitter and reviewer by providing a description of necessary information to ensure that the appropriate information is provided. Use of the guide may be limited when contract documents define the submittal format. The guide emphasizes that the concrete mixture is a unique combination of specific ingredients, from particular sources, and in quantities necessary to achieve the intended purpose.

Keywords: admixture; aggregate; compressive strength; fiber reinforcement; hydraulic cement; mixture proportion; required strength; water-cementitious materials ratio.

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ACI 211.5R-01 supersedes ACI 211.5R-96 and became effective September 7, 2001.

CHAPTER 1—INTRODUCTION

1.1—General

Project specifications, reference publications, drawings, and other contract documents contain the requirements for concrete materials, proportions, and characteristics. Concrete mixture proportions, intended to satisfy these requirements, are usually submitted based on field test results, laboratory trial batch test results, or both. The purchaser's acceptance of materials and proportions is based on conformance of the submitted details to the criteria contained in the contract documents.

1.2—Purpose

This guide provides information to assist in the submittal and review of materials and concrete mixture proportions. It is intended to benefit both the submitter and the reviewer. Beginning with the preparation of the concrete mixture proportions and supporting documentation by the concrete producer, followed by the actual submittal of the mixture proportions by the concrete contractor to the general contractor, and subsequently to the architect and engineer, each should find this information helpful.

1.3—Scope

This guide is limited to the preparation and review of the submittal of proposed materials and concrete mixture proportions for conformance with the requirements of the contract documents. It is not intended to impose additional requirements, but rather to help the user recognize and implement current ACI practices and procedures that may be required for the project.

1.4—Definitions

Admixture—A material other than water, aggregate, hydraulic cement, and fiber reinforcement, used as an ingredient of concrete or mortar and added to the batch immediately before or during its mixing (ACI 116R).

Aggregate—Granular material, such as sand, gravel, crushed stone, crushed hydraulic-cement concrete, or iron blast-furnace slag, used with a hydraulic cementing medium to produce either concrete or mortar (ACI 116R).

Aggregate, lightweight—Aggregate of low density, such as: expanded or sintered clay, shale, slate, diatomaceous shale, perlite, vermiculite, or slag; natural pumice, scoria, volcanic cinders, tuff, and diatomite; and sintered fly ash or industrial cinders, used in lightweight concrete (ACI 116R).

Cement, hydraulic—A cement that sets and hardens by chemical interaction with water and is capable of doing so underwater (ACI 116R).

Concrete—A composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate, usually a combination of fine aggregate and coarse aggregate; in portland-cement concrete, the binder is a mixture of portland cement and water, with or without admixtures (ACI 116R).

f'_c—Specified compressive strength of concrete used in design (ACI 104R).

f'_{cr}—Required average compressive strength of concrete, used as the basis for selection of concrete proportions (ACI 104R).

Fiber reinforcement—Discontinuous discrete fibers produced from steel, synthetic (organic), glass, or natural materials, in various shapes and sizes that are added before or during mixing of the concrete.

Materials, cementitious—Cements and pozzolans used in concrete and masonry construction (ACI 116R).

Water-cementitious materials ratio—The ratio of the mass of water, exclusive only of that absorbed by the aggregate, to the mass of cementitious material (hydraulic) in concrete, mortar, or grout (ACI 116R).

CHAPTER 2—MATERIALS AND PRODUCTION

2.1—Quality of materials

Cementitious materials, aggregates, admixtures, fibers, and water should comply with the contract documents. Evidence of satisfactory performance of each material should be provided on request. If a deviation from the specified material is necessary, a full explanation to the architect and engineer should be included in the submittal.

2.2—Submittal information

Cement/cementitious materials—The source and type of each material proposed for use on the project should be identified and included. Mill test reports, manufacturer's certification of compliance, or both, should be submitted, if required, or be available upon request by the purchaser.

Aggregates—The sources, types, and individual gradings for each aggregate should be identified. In conformance with ASTM C 33 and C 330, the combined gradings of the total blended aggregate when combined aggregate concepts are used and should be included for each mixture as described in ACI 301. The fineness modulus of fine aggregate should be reported. The saturated-surface-dry (SSD) specific gravity and absorption of all aggregates as per ASTM C 127 and C 128, and dry-rodded unit weight for coarse aggregate as per ASTM C 29, should be provided. Similarly, loose unit weight of lightweight aggregate (oven dry) should be provided when lightweight aggregate is used.

For coarse aggregates, the size designation (as described in ASTM C 29, C 33, C 330, or D 448) or the nominal maximum size is needed. Because all of these aggregate properties influence the proportioning of the concrete mixture, they should be submitted to support the proposed mixture proportions.

Admixtures—The vendor and type of all admixtures proposed for use should be identified in accordance with ASTM C 260, C 494, or another governing standard. These admixtures should be of the same type as those used in the trial mixtures from which strength data were obtained. If admixtures are to be added at a point other than the concrete batching facilities, the location should be identified.

Water—The source of mixing water should be identified. Nonpotable water requires evidence of satisfactory use in mortar or concrete in accordance with ASTM C 94, Table 2. Some specifications may restrict the chloride-ion content of the concrete.

Chloride-ion content—Evidence of soluble chloride-ion content for each ingredient or for the hardened concrete may be required.

Fibers, color pigments, and other additions—Where the source and type of specific additions are required by the contract, they should be contained in mixtures from which strength data were obtained. Materials identified in the submittal as alternates to products specified by name should include evidence of satisfactory performance and compliance to appropriate material standards.

Production—Information supporting compliance with the contract documents or ASTM C 94 should be available upon request by the purchaser. If more than one production facility is proposed for use, the above information should be available for each facility.

CHAPTER 3—CONCRETE MIXTURE PROPORTIONS

3.1—Proportioning

The concrete mixture proportions expressed in terms of quantity of each component per unit volume of concrete, combined with the freshly mixed concrete properties and the hardened concrete characteristics, constitute the submittal. The mass and the absolute volume contributed by each material in the mixture should be included in the submittal of the mixture proportions. Omission of components, quantities, or properties by the submitter may result in rejection of the submittal.

3.2—Quantities by mass

The quantity of cementitious material added in the powder state should be expressed as pound-mass per cubic yard (lb/yd^3) or kilograms per cubic meter (kg/m^3). Pozzolans that are added in a slurry should have their respective solid and water contents expressed as pound-mass per cubic yard or kilograms per cubic meter. The quantity of each separately batched size of coarse aggregate and fine aggregate should be expressed as pound-mass per cubic yard or kilograms per cubic meter in an SSD condition. If lightweight aggregate is used, the oven-dry and estimated wet weight should be stated.

Admixtures dispensed as liquids should be expressed as fluid ounces per cubic yard (fl oz/yd^3) or liters per cubic meter (L/m^3) and where applicable, the expected dosage range should be stated. The quantity of any premeasured, prepackaged additives, such as fibers or color pigments, should be expressed in incremental units (sacks, bags, boxes, or tins) and pound-mass per cubic yard or kilograms per cubic meter.

3.3—Quantities by volume

The absolute volume of each material, air content, and the total sum of the absolute volumes of all materials should be provided in cubic feet (ft^3) or cubic meters (m^3). If lightweight aggregate is used, the bulk volume in the saturated condition should be stated. It is customary and acceptable in most localities to proportion mixtures to yield slightly in excess of 27.00 ft^3/yd^3 or (1.00 m^3/m^3). The practice provides producers with a systematic means of handling charges of short yield due to air content fluctuation provided that the actual expected yield is identified in the submittal.

3.4—Freshly mixed concrete properties

Slump, unit weight, and air content should be reported for each set of mixture proportions intended for use. Placement methods, such as pumping and slip forming, associated with each proposed mixture should be indicated where appropriate. Sometimes, different freshly mixed concrete properties will be needed for different placement procedures and conditions; these should be consistent with the limits set in the contract documents. When the concrete is to be delivered to the point of placement by concrete pump or other conveyance, the location at which the above properties are to be achieved should be clarified in advance. Sampling of the concrete should be in accordance with ASTM C 172.

CHAPTER 4—DOCUMENTATION OF COMPRESSIVE STRENGTH

4.1—Required average strength (f'_{cr})

A submittal of concrete mixture proportions should demonstrate a compressive strength equal to or exceeding the required average strength (f'_{cr}). Provisions for calculating f'_{cr} are contained in ACI 211.1, ACI 214, ACI 301, and ACI 318. The required average strength is based on the specified compressive strength (f'_c) for a class of concrete, which should include an overdesign amount as found in ACI 301, and ACI 318, when based on laboratory trial batches. When past performance records of uniformity of the concrete production are available, the statistical probability of a certain number of test results falling below the design strength is anticipated and controlled by selection of the appropriate f'_{cr}. Submittal of concrete mixture proportions should contain the method used to select f'_{cr} for each class of concrete.

4.2—Past performance record submittal

When compressive strength data are available from concrete production using the proposed materials and batching facilities, the statistical analysis of the data should be calculated in accordance with ACI 214, ACI 301, or ACI 318. A data summary identifying the mixture proportions and individual test results and batching facilities should be part of the submittal. These records become the basis for verifying the required average strength and validation of the proposed mixture. Concrete sampled and tested under conditions more stringent than those imposed by the contract documents may be excluded from use in calculation of the required average strength based on past performance.

4.3—Trial batch record submittal

If past performance records for the proposed mixture proportions are not available, trial batches may be required by specification. When trial batches are used to establish strength relationships or to verify strength characteristics of the mixture, the least favorable combination of mixing water and air content should be used (ACI 211.1, ACI 301, ACI 318). This will provide a conservative estimate of strength. Trial batch procedures and report records should comply with ASTM C 192.

4.4—Resubmittals

During the conduct of work, if any changes to the mixture proportions or materials are made, the revised proportions should demonstrate a compressive strength equal to or exceeding the current required average strength established by job records.

CHAPTER 5—ADDITIONAL SUGGESTED DOCUMENTATION

5.1—Transmittal letter

Each submittal should be introduced by an original transmittal letter identifying the proposed concrete mixture(s) to be furnished, the project for which it is submitted, and the method used to select proportions. The transmittal should be signed and dated by the person that prepared the submittal and the person selecting the mixture proportions. If more than one party contributed to the submittal, each contributor's role should be identified.

5.2—Certification of compliance

A statement certifying compliance of all materials proposed for the work, excepting those instances where a variance is requested, with the requirements of the contract documents is suggested. This can be conveniently handled by inclusion in the transmittal letter or by attaching separately.

5.3—Submittal forms

The quantity of each ingredient, as described in Chapter 3, and the mixture proportions format should be prepared as an independent document suitable for distribution. There are several commercial, computerized formats available that conveniently handle source information, mixture proportions, physical properties of materials used to establish the proportions, and strength documentation. For this reason, a specified format is discouraged because it can either preclude the use of commercial computerized submittals, be repetitive in nature, or both. All of the information identified herein should be included on the submittal form(s) or in the documentation submitted.

Additional data summarizing the past performance records or trial batch data should be integral parts of the submittal, as should special certification test data of materials. The form should be signed and dated by the person compiling or verifying the tabulation.

CHAPTER 6—REFERENCES

6.1—Referenced standards and reports

The standards and reports listed below were the latest editions at the time this document was prepared. Because these documents are revised frequently, the reader is advised to contact the proper sponsoring group if it is desired to refer to the latest version.

American Concrete Institute (ACI)

104R	Preparation of Notation for Concrete
116R	Cement and Concrete Terminology
211.1	Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete
214	Recommended Practice for Evaluation of Strength Test Results of Concrete
301	Specifications for Structural Concrete
318	Building Code Requirements for Structural Concrete
544.3R	Guide for Specifying, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete

American Society for Testing and Materials (ASTM)

C 29	Standard Test Method for Unit Weight and Voids in Aggregates
C 33	Standard Specification for Concrete Aggregates
C 127	Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate
C 128	Standard Test Method for Specific Gravity and Absorption of Fine Aggregate
C 172	Standard Practice for Sampling Freshly Mixed Concrete
C 192	Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
C 260	Standard Specification for Air-Entraining Admixtures for Concrete
C 330	Standard Specification for Lightweight Aggregate for Structural Concrete
C 494	Standard Specification for Chemical Admixtures for Concrete
D 448	Classification for Sizes of Aggregate for Road and Bridge Construction

The publications listed above may be obtained from the following organizations:

American Association of State Highway and Transportation Officials (AASHTO)
444 North Capitol Street NW, Suite 225
Washington, DC 20001

American Concrete Institute (ACI International)
P.O. Box 9094
Farmington Hills, MI 48333-9094

American Society for Testing and Materials
100 Barr Harbor Drive
West Conshohocken, PA 19428

6.2—Other references

ACI Committee 201, 1992, "Guide to Durable Concrete, (ACI 201.2R-92)," American Concrete Institute, Farmington Hills, Mich., 41 pp.

ACI Committee 211, 1993, "Guide for Selecting Proportions for High-Strength Concrete with Portland Cement and Fly Ash (ACI 211.4R-93)," American Concrete Institute, Farmington Hills, Mich., 13 pp.

ACI Committee 211, 1998, "Standard Practice for Selecting Proportions for Structural Lightweight Concrete, (ACI 211.2-98)," American Concrete Institute, Farmington Hills, Mich., 18 pp.

ACI Committee 212, 1991, "Chemical Admixtures for Concrete (ACI 212.3R-91)," American Concrete Institute, Farmington Hills, Mich., 31 pp.

ACI Committee 223, 1998, "Standard Practice for the Use of Shrinkage-Compensating Concrete, (ACI 223-98)," American Concrete Institute, Farmington Hills, Mich., 28 pp.

ACI Committee 232, 1996, "Use of Fly Ash in Concrete (ACI 232.2R-96)," American Concrete Institute, Farmington Hills, Mich., 34 pp.

ACI Committee 233, 1995, "Ground Granulated Blast-Furnace Slag as a Cementitious Constituent in Concrete (ACI 233R-95)," American Concrete Institute, Farmington Hills, Mich., 18 pp.

ACI Committee 303, 1997, "Standard Specification for Cast-in-Place Architectural Concrete (ACI 303.1-97)," American Concrete Institute, Farmington Hills, Mich., 10 pp.

ACI Committee 304, 1997, "Guide for Measuring, Mixing, Transporting, and Placing Concrete (ACI 304R-97)," American Concrete Institute, Farmington Hills, Mich., 41 pp.

ACI Committee 363, 1992, "State-of-the-Art Report on Fiber Reinforced Concrete (ACI 363R-92)," American Concrete Institute, Farmington Hills, Mich., 55 pp.

ACI Committee 544, 1993, "Guide for Specifying, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete (ACI 544.3R-93)," American Concrete Institute, Farmington Hills, Mich., 10 pp.

ACI Committee 544, 1996, "State-of-the-Art Report on Fiber Reinforced Concrete (ACI 544.1R-96)," American Concrete Institute, Farmington Hills, Mich., 66 pp.

ASTM C 31, 2000, "Standard Practice for Making and Curing Test Specimens in the Field, ASTM C 31/ C 31M-00e1," American Society for Testing and Materials, West Conshohocken, Pa., 5 pp.

ASTM C 39, 2001, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM C 39/C 39M-01," American Society for Testing and Materials, West Conshohocken, Pa., 5 pp.

ASTM C 94, 2000, "Standard Specification for Ready-Mixed Concrete, ASTM C 94/C 94M-00e1," American Society for Testing and Materials, West Conshohocken, Pa., 10 pp.

ASTM C 143, 2000, "Standard Test Method for Slump of Hydraulic Cement Concrete, ASTM C 143/C 143M-00," American Society for Testing and Materials, West Conshohocken, Pa., 3 pp.

ASTM C 150, 2000, "Standard Specification for Portland Cement, ASTM C 150-00," American Society for Testing and Materials, West Conshohocken, Pa., 7 pp.

ASTM C 173, 2001, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method, ASTM C 173/C 173M-01," American Society for Testing and Materials, West Conshohocken, Pa., 9 pp.

ASTM C 231, 1997, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method, ASTM C 231-97e1," American Society for Testing and Materials, West Conshohocken, Pa., 8 pp.

ASTM C 595, 2000, "Standard Specification for Blended Hydraulic Cements, ASTM C 595-00ae1," American Society for Testing and Materials, West Conshohocken, Pa., 7 pp.

ASTM C 618, 2000, "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete, ASTM C 618-00," American Society for Testing and Materials, West Conshohocken, Pa., 4 pp.

ASTM C 845, 1996, "Standard Specification for Expansive Hydraulic Cements, ASTM C 845-96," American Society for Testing and Materials, West Conshohocken, Pa., 3 pp.

ASTM C 989, 1999, "Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars, ASTM C 989-99," American Society for Testing and Materials, West Conshohocken, Pa., 5 pp.

ASTM C 1017, 1998, "Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete, ASTM C 1017/C 1017M-98," American Society for Testing and Materials, West Conshohocken, Pa., 8 pp.

ASTM C 1116, 2000, "Standard Specification for Fiber-Reinforced Concrete and Shotcrete, ASTM C 1116-00," American Society for Testing and Materials, West Conshohocken, Pa., 8 pp.

6.3—Suggested checklist

Section/Part/Article	Submittal items and notes to Submitter/Contractor/Engineer
2.2—Submittal information	Cementitious materials—Mill test reports may be needed if there is a special concern for alkali-aggregate reaction or sulfate attack. Aggregates—Source, geological type, size, shape, grading, specific gravity, and absorption are necessary to evaluate proper proportioning and performance characteristics. Admixtures—Vendor and type are essential in evaluating performance for an intended usage. Water—Source of water should be identified. Nonpotable water, such as gray water, requires evidence of satisfactory use in mortar or concrete in accordance with ASTM C 94, Table 1. Chloride-ion content—If corrosion is a design concern, such as in the case of reinforced concrete, that will be more than superficially wet, evidence of soluble chloride-ion content for each ingredient indicated in the hardened concrete may be required. Caution should be used when evaluating chloride-ion content in a mixture by individual ingredients because this method usually results in a greater chloride content than that obtained from samples of hardened concrete. Chloride requirements should comply with ACI 318 and ACI 301. Fibers, color pigments, and other additions—Should be included in the mixture from which the strength data were obtained unless evidence is provided indicating no influence on strength.
3.2—Quantities by mass	Individual ingredients will be proportioned by mass. Liquid slurry-type pozzolans should have their respective solid and water contents expressed as a mass unit. Liquid admixtures may be expressed in liquid volumetric units. Aggregates should be expressed in SSD mass units. To verify these, it will be necessary to list the absorption values for the fine and coarse aggregates.
3.3—Quantities by volume	Absolute volumes of each respective material and the entrapped and entrained air. To verify absolute volumes of the proposed materials and their respected total, it is necessary to list their respective Bulk Specific Gravities (in the case of the aggregate, Bulk Specific Gravity—SSD).
4.0—Documentation of average strength	In accordance with contract documents, ACI 301, or ACI 318 requirements.
4.2—Past performance record submittal, or 4.3—Trial batches	Method used should be identified in the submittal.