Arizona Rock Products Association

ARIZONA RECOMMENDED SPECIFICATIONS FOR NORMAL WEIGHT READY MIXED CONCRETE

WITH NOTES

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DISCLAIMER

It is the intent of the Arizona Rock Products Association that this recommended practice be used not only as a reference specification, but also as a guide specification, which could be edited in the preparation of the rough draft of actual project specifications by individuals who are competent and understand the significant and limitations of the contents.

Due to the many factors that can affect the compressive strength and the appearance of the in-place concrete, the Arizona Rock Products Association disclaims any and all responsibility for the in-place concrete when produced based upon the application of this recommended practice.

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READY MIXED CONCRETE

1.0 GENERAL

This recommended specification applies only to the materials, equipment, methods and procedures used in the production and delivery of normal weight ready mixed structural concrete for building construction; the desired properties of the plastic concrete as delivered; and the control testing necessary to determine the acceptability and compliance of the concrete as delivered with the technical provisions of the specifications. This specification does not cover special types of concrete, such as: structural light weight aggregate; insulating, refractory, architectural, mass, cellular, paving concrete; job-mixed concrete; plant-fabricated precast concrete elements; and other materials used in reinforced concrete; nor does it pertain to concrete construction practices and procedures.

ACI Standard 301, "Specifications for Structural Concrete for Building," provides the best available reference on specifications for concrete building construction.

The following recommended specification represents a modified version of the ACI 301 chapters pertaining to Materials for Concrete; Proportioning; Placing and Consolidation; Testing and Evaluation and Acceptance of Concrete and incorporates changes, as necessary, to reflect local experience, practice and materials.

The specification has been prepared in two-column format. The left column contains the outline specification provision. The right hand column contains notes and instructions to the specifier calling attention to the editing which must be done to fit local conditions, and explaining the philosophy and interpretation of the specification provisions. Some items contain blank spaces, which must be completed. Where words or sentences in the recommended outline provisions are not applicable, they should be deleted or revised to suit individual requirements.

It should be noted that published standards of the American Society for Testing Materials (ASTM), the American Concrete lnstitute (ACI), and other national organizations are incorporated into the outline provisions by reference at various points. In general, the designation of the referenced specification is shown without the title or the year of current issue. The intent is that the latest issue in effect at the time invitations for bids are issued would be applicable.

SUGGESTED USE

Although this recommended specification can be used as a reference specification, it is intended primarily for use as a guide specification which can be marked-up, cut-up, and edited in the preparation of the rough draft of actual project specifications. Additional copies are available from the Arizona Rock Products Association.

ARIZONA RECOMMENDED SPECIFICATIONS
FOR
NORMAL WEIGHT READY MIXED CONCRETE

OUTLINE SPECIFICATIONS	NOTES TO SPECIFIER
2.0 CONCRETE MATERIALS	
2.1 Cement	2.1 ASTM C 150 provides for five basic types of portland cement: Type I General Use Type II Moderate Sulfate Resistance Type III High Early Strength Type IV Low Heat of Hydration Type V High Sulfate Resistance The suggested provision allows use of many of these basic types. White portland cement is produced to meet C 150 requirements and use should be allowed. The general use portland cement produced in Arizona is a gray low-alkali type meeting the physical and chemical property requirements of ASTM C 150, Type II. Use of low alkali cement is recommended in concrete made with aggregates, which may be deleteriously reactive. ASTM C 595 provides for four types of portland pozzolan cement with two optional provisions. See ASTM C 595, latest revision. Type IP (MS) - portland pozzolan cement for use in general concrete construction. The general use portland pozzolan cement produced in Arizona meets the standard physical and chemical requirements of ASTM C 595, Type IP (MS).
1) Portland cement shall conform to ASTM C 150 Type _____, low-alkali or C 595, Type IP (MS).	
2.1.2 The same brand and type of cement shall be used throughout the work unless use of different brands or types is approved by the architect or engineer. NOTE: All ASTM and/or ACI designated specifications represented by a section number shall be considered as meaning the latest revision of that reference.	This provision is intended to provide some measure of control of color uniformity throughout the work. The color of hardened concrete is affected by various factors in addition to the color of the particular brand or type of cement used. Variations in water-cement ratio and color of sand can significantly affect the color of concrete. Use of only one brand and type of cement *will not ensure* color uniformity.

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2.2 Admixtures	2.2 It is recommended that specifiers be well acquainted with the advantages, which can result from the use of admixtures before specifying or allowing their use in concrete. An excellent general discussion and recommendations on this subject are included in "Guide for the Use of Admixture in Concrete", a report prepared by ACI Committee 212.
2.2.1 The following types of admixtures may be used when approved by the architect or engineer. They shall conform to the appropriate specifications as indicated:	
2.2.1.1 Air-Entraining-Admixtures - ASTM C 260	2.2.1.1 Air entrainment may be produced in concrete through use of regular non-air-entraining cement in combination with an air-entraining admixture. Air entrainment is not commonly used in Arizona where the elevation is below 3000 feet. (See note 3.4.1)
2.2.1.2 Chemical Admixtures - ASTM C 494	2.2.1.2 Chemical admixtures are commonly used in Arizona. ASTM C 494 Type A Water Reducers, which include normal range and mid-range water reducers are used in nearly every mix of concrete. Additionally, ASTM C 494 Type F High Range Water Reducers are commonly used throughout Arizona. Maricopa Association of Government and Arizona Department Of Transportation have approved and consistently use the above admixtures.
2.2.1.3 Fly Ash (Pozzolanic) Materials - ASTM C 618	2.2.1.3 Fly ash is commonly and successfully used in Arizona. ADOT, International Building Code and M.A.G. allow fly ash replacement in all mixes. Class F fly ash is primarily used in Arizona.
2.3 Water	
1) Mixing water for concrete shall conform to ASTM C1602 requirements.	
2.4 Aggregates	
2.4.1 Aggregates shall conform to ASTM C 33 requirements.	
2.4.2 Coarse aggregates shall meet the gradation limits as specified in Table II of ASTM C 33, for the following sizes:	2.4.2 ASTM C 33 Size #67 is typically not available in Arizona. The aggregate sizes listed are those produced and stocked as standard sizes by Arizona aggregate and ready mix concrete

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#467 1-1/2 in. to #4 #57 1 in. to #4 #5 1 in. to 1/2 in. #7 1/2 in. to #4 #8 3/8 in. to #4	producers. Where use of other or special graduations will be required, appropriate changes should be made, or the list of sizes deleted. See 3.6 - Maximum Size of Coarse Aggregates and 5.2.1.1 (2) Concrete Materials.
3.0 PROPORTIONING	
3.1 General	
1) Concrete for all parts of the work shall be homogeneous and when hardened shall have the required strength, durability, abrasion resistance, water tightness, appearance, and other specified properties.	
3.2 Type	3.2 ACI 318-Ch.5, Section5.1.1 - Concrete shall be proportioned and produced to provide an average compressive strength sufficiently high to minimize frequency of strength tests results below the value of the specified compressive strength of concrete, f'c, (See Sec.5.3,5.4 and5.5).
1) Concrete shall be of the ultimate strength type, and shall conform to "Building Code Requirements for Reinforced Concrete" -- ACI 318, Ch. 5.	ACI 318, Sec.5.3 and5.4 provide for proportioning the concrete mix on the basis of any of three methods: 1) Proportioning on the basis of field experience. This allows a producer to utilize his records of strength tests of similar materials. This method is the most commonly used for commercial and private projects in Arizona. 2) Proportioning by laboratory trial batches. This will be used when sufficient data is not available as required by (1) above. 3) Proportioning by water-cement ratio. This may be used if methods (1) or (2) are not applicable. (for 5000 psi maximum f'_c) ACI 318 (Chapter 4) provides for special exposure requirements.
3.3 Strength	3.3 The specifier must complete this provision by listing the specified compressive strengths (f' c), which will be required in the various parts of the structure, and the age at which this strength is to
1) The strength of the concrete for each	

portion of the structure shall be designated on the project drawings or in the following:

LOCATION	SPECIFIED COMPRESSIVE STRENGTH (f'c)	AGE
_____	_____	_____
_____	_____	_____
_____	_____	_____

be attained. Usual practice is to specify 28-day strengths. High performance concrete strengths are often specified at later ages than 28 days (56 to 90 days).

3.4 Durability

3.4.1 Concrete used at the locations or in elements as listed in the following shall contain entrained air.

_____

_____

_____

_____

3.4.1 Air-entrainment normally is not required for durability in work located in valley areas at elevations below about 3,000 ft. except where it is desired to improve the impermeability, sulfate resistance or workability; or in work which will not be exposed to freeze-thaw exposures at high elevations. Air-entrainment should be required in all exposed work at elevations above 3,000 ft.

3.4.2 When air entrainment is required the total air content shall be within the range indicated in the following:

Total Air Content, +/- 1.5%				
Exposure	Max. Size Coarse Aggregate, in.			
Condition	1/2	3/4	1	1 1/2
Mild	4.0	3.5	3.0	2.5
Moderate	5.5	5.0	4.5	4.5
Severe	7.0	6.0	6.0	5.5

3.4.2 Air-entrainment often is used in percentages below the amounts required by this provision to improve workability, impermeability and sulfate resistance in concrete which will not be exposed to freeze-thaw action. The intent of this provision is not to exclude or prohibit use of air contents below those required for freeze-thaw durability in such work. It is important to note that air content *below those* required by this provision are not considered adequate for freeze-thaw durability.

The air contents specified are intended to apply to concrete as discharged from the ready mix truck. In-place air contents can be adversely affected by mean of placements (vibrating apparatus, pump, conveyor, etc.).

In slabs and floors, which are to be smooth, hand troweled, entrained air in excess of 3% may increase finishing problems such as plastic shrinkage, blistering, and peeling.

It should be noted that air contents within the limits specified in 3.4.2 will result in reduced compressive strength in rich mixes. However, the effect will be less important in lean mixes. Air contents in excess of the recommended

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	percentages will reduce the compressive strength approximately 5 percent per 1 percent increase in air and as a result further reduce abrasion resistance. See ACI 302 Section 5.2.7. Where concretes with high strength and air contents will be required, specifiers should consult with the concrete producer to determine practical limitations before establishing compressive strength requirements in the specifications.
3.5 Slump	
3.5.1 Where mechanical vibration will be used in the placement, the slump of concrete as determined by ASTM C 143, shall be within the range indicated below:	3.5.1 The limitations on slump are intended to apply to the concrete when discharged from the ready mix truck. The use of the slump cone test (ASTM C 143) is recommended as an acceptance test procedure.
Type Construction — **Slump (in.)** Reinforced & plain footings, Caissons & substructure walls — 3 ± 1 **Type Construction** — **Slump (in.)** Slabs, beams, reinforced walls & buildings columns — 4 ± 1	During cool or cold weather, when air and concrete temperatures are low, it often will be advantageous to use concrete with a stiffer consistency and lower slumps than required by 3.5.1 Slump may be increased one (1) inch for methods of consolidation other than vibration.
3.5.2 In no case shall the slump exceed the maximum unless a new mix design, showing a compliance with all other provisions of the specifications is submitted to and accepted by the engineer.	3.5.2 This provision is intended to apply to general condition concrete where water is used for attaining slump in excess of the specified range. When it is necessary to exceed the maximum slump, the use of a high range or mid-range water-reducing admixture is recommended~~,~~ and commonly used in Arizona. See 3.7.2
3.6 Maximum Size of Coarse Aggregate	3.6 The maximum size limitations for coarse aggregate are based on ACI 318, Sec. 3 requirements. Where special conditions will require use of smaller sizes of coarse aggregate, these provisions should be modified to suit project conditions.

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3.6.1 The normal maximum size of the coarse aggregate shall not exceed: 1/5 the narrowest dimension between sizes of forms 1/3 the depth of slabs 3/4 the minimum clear distance between reinforcing bars and forms.	
3.6.2 In columns, the nominal maximum size shall be limited as above, and in addition, shall not exceed 2/3 the minimum clear distance between bars.	
3.6.3 Coarse aggregate in concrete may be one maximum size for all concrete placed in one day when the quantities to be placed are too small to permit economical use of more than one mix design. When a single mix design is so used, the maximum nominal size shall be as required for the most critical condition as established in the preceding.	
3.7 Admixtures	
3.7.1 Accelerating An approved accelerating type chemical admixture may be used in the proportion recommended by the manufacturer when the ambient temperature is less than 40ºF except where use is specifically prohibited. Calcium chloride shall not be used in quantities exceeding 2 percent of the weight of the cement. Admixtures containing chlorides shall not be used in concrete to be pre-stressed or in concrete where aluminum conduit, couplings, or accessories are to be embedded without adequate corrosion protection for the embedded items.	3.7.1 Accelerating admixtures in concrete serve to increase the rate of strength gain at early ages. It is not an antifreeze agent and the addition of an accelerating admixture will not significantly lower or otherwise change the freezing point of a concrete mix – unless it is specifically designed for that purpose. Use of accelerating agents can be helpful in reducing the length of time concrete placed in cold weather must be protected against freezing. It will not eliminate the need for such protection. Refer to 2.2.1.2 and 4.2 for additional provisions and comments concerning admixtures and their use in concrete. Non-chloride admixtures should be used where it is desired to use an accelerating admixture but where chloride content must be held to a minimum. It is recommended that specifiers consult with local ready mix producers to determine local experience with specific admixtures before specifying or approving.

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3.7.2 Water Reducing Approved water reducing chemical admixtures may be used in the proportion recommended by the manufacturer.	3.7.2 Normal range and mid-range water reducers are commonly used in Arizona. Mid-range water reducers can be used to increase slumps (over 5 inches) and improve the concrete's finishing characteristics. High range water reducers can be used to improve the flow of mix (increase slump to 8 to 10 inches). High range water reducers are dosed at the batching facility or jobsite, depending on manufacturer's recommendation.
3.8 Proportioning of Ingredients	
3.8.1 The proportioning of ingredients shall be such as to produce the necessary placeability, durability, strength and other required properties; and a mixture which will work readily into corners and angles of the forms and around reinforcements when placed by the methods to be employed in the work without permitting materials to segregate or the accumulation of an excess of free water on the surface.	
3.8.2 The contractor shall submit his proposed mix design for each class of concrete to be supplied for the project for review and approval by the architect or engineer. When the contractor or concrete supplier submits a written statement certifying that the proposed mix designs will meet the specified strength and other properties and is of the type required by these specifications, a laboratory mix design or verification will not be required. Approval of such mix designs by the architect or engineer will in no way relieve the concrete supplier of his responsibility for the performance of the	

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concrete.	
3.8.3 A mix design used successfully on a previous project, under conditions as anticipated and with the same ingredients proposed for use in this project, may be used when approved by the architect or engineer.	3.8.3 It is assumed the architect or engineer will require the contractor or concrete supplier to furnish test data or reports, as evidence that the proposed mix design will produce concrete meeting the specification requirements. See ACI 318 Sec. 4.
3.8.4 When the proposed mix designs are not established by other allowed methods, they shall be based on the results obtained from tests of trial mixes made with the same materials as will be used in the concrete supplied for the project by a testing laboratory or agency approved by the architect or engineer, and in accordance with the procedures given in ACI 211.1, "Recommended Practice for Selecting Proportions for Concrete."	3.8.4 This provision requires use of mix designs based on results obtained from actual trial mixes, and does not allow use of mix designs arrived at solely from theoretical calculations. If use of calculated mix designs will be permitted, this provision should be modified to so indicate. It should be recognized that mix designs based on theoretical calculations or trial mixes conducted prior to start of construction often will have to be adjusted in the field to allow for the effect of differences in materials and actual climatic conditions as compared to those assumed or experienced in the design or determination of the proposed design mixes.
4.0 BATCHING AND MIXING	
4.1 General	
4.1.1 Ready mix concrete shall be batched, mixed, and transported in accordance with the applicable provisions of ASTM C 94.	4.1.1 The applicable provisions of ASTM C 94 include Sections 7, 8, 9, 10, and 11. These constitute the general provisions and those relating to batching, mixing and delivery.
4.1.2 Batch plants used in the production of ready mixed concrete shall comply with the "Concrete Plant Standard" set forth by the Concrete Plant Manufacturers Bureau.	
4.1.3 Truck mixers, agitators, and non-agitating units used to mix and transport ready mixed concrete shall comply with the "Truck Mixer & Agitator Standards" of the Truck Mixers Manufacturers Bureau.	
4.1.4 Certification of the concrete supplier's batch plant and truck mixers under the Plant Certification Program of the Arizona Rock Products Association will be accepted as evidence that the equipment complies with the requirements of these specifications.	4.1.4 The intent of this section is to ensure that batching equipment and mixer trucks used in the production of concrete will be capable of producing uniform concrete of the specified quality in the volumes required. The Plant Certification Program established by the Arizona Rock Products Association (ARPA)

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	provides the specifier a convenient means of obtaining such assurance. Both of the NRMCA Standards referred to in 4.1.2 & 4.1.3 are incorporated in the Arizona Rock Products Association certification program. Copies of these standards and information concerning the Plant Certification program are available upon request from the Arizona Rock Products Association. Arizona Department of Transportation (ADOT) and MAG accepts the ARPA certification program.
4.2 Admixtures	
4.2.1 Air entraining and chemical admixtures, when used, shall be incorporated into the mix in the amounts and manner recommended by the manufacturer. That accuracy of measurement of any admixture shall be within ±3 percent.	
4.2.2 Two or more admixtures may be used in the same concrete, provided such admixtures are added separately and that the combination has no deleterious effect on the concrete.	
4.3 Retempering	
4.3.1 Concrete shall be delivered to the site and discharged within 90 minutes or before 300 revolutions of the mixer drum, after introduction of mixing water to the cement and aggregates or of the cement to the aggregates.	4.3.1 The requirement that concrete be discharged within 90 minutes after batching of the ingredients into the mixer generally will ensure that the concrete is discharged before initial set has begun. The specifier may allow discharge times greater than 90 minutes for mixes with past experience or successful trial batches. The specifier should require mixes with proposed discharge times greater than 90 minutes to include specific discharge times and specific ambient and mix temperatures and/or chemical admixtures. Prolonged mixing may result in excess heat generation, aggregate breakdown, slump loss, and an increased water demand and should be avoided where possible. It also should be recognized that the setting time of concrete is influenced by temperature, air temperature, type of cement used, and a number of other variables.

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	When concrete and air temperatures are low, the 90 minutes or 300 revolutions limitation may be waived with no adverse effect on the concrete if the concrete is of such slump that it can be placed without the addition of water to the load. In hot weather or under conditions contributing to quick stiffening of concrete, unless provisions have been taken to properly retard the concrete, a time less than 90 minutes may be desirable. However, discharge times of 90 minutes or greater can be successfully obtained using temperature control techniques, (cold water, ice, spray bars, etc.) and/or chemical admixtures.
4.3.2 Indiscriminate addition of water to increase slump is prohibited.	
4.3.3 When concrete arrives at the project with a slump below that suitable for placing, water may be added providing the maximum permissible slump is not exceeded. If water is added, it must be incorporated by additional mixing equal to at least 30 revolutions of the drum at 8-12 rpm. The architect or engineer, their authorized representative, or an authorized representative of the concrete supplier must approve any addition of water.	4.3.3 This provision is intended to allow for the occasional load which may be delivered to the job at a consistency or slump below that suitable for placing due to unexpected changes in moisture content of aggregate, delays in delivery within the maximum time of discharge permitted by the specifications or other of the many variables which may affect the slump of concrete without significantly affecting strength or other properties. It is not intended to allow for continual addition of water to mixes when the slump of the concrete as delivered is consistently below that specified and unsuitable for placing. The requirement that any addition of water be approved by the architect or the concrete supplier ensures that such addition of water be allowed only on the approval of persons having some knowledge of the effects of addition of water on the quality of the concrete mix. Inadequate mixing of water added on the jobs is a common tendency, and it is recommended the minimum additional mixing required by this recommended provision be strictly enforced.
	4.3.4 The specifier would do well to reach some

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4.3.4 When water is added at the project, the amount added shall be noted on the delivery ticket and the delivery ticket signed by the person authorizing the addition of water.	agreement with the concrete supplier and the contractor as to the person or persons who will have authority to approve additions of water on the job prior to start of concreting. In any event, there should be a clear understanding between the architect, the contractor, and the concrete supplier as to who will have the responsibility for quality of the concrete as delivered when water is added to the concrete mix on the job.
4.3.5 Concrete shall be available within the permissible range of slump for a period of 30 minutes starting either on arrival of job site or after the initial slump adjustment permitted in Sec. 4.3.3 whichever is later. The first and last 1/4 cu. yd. discharged are exempt from this requirement. If the contractor is not prepared for discharge of the concrete from the delivery vehicle, the concrete supplier shall not be responsible for the limitation of the minimum slump after 30 minutes have lapsed starting either on arrival of the vehicle at the jobsite or at the required delivery time, whichever is the later.	
4.4 Special Conditions	
4.4.1 Cold Weather	4.4.1 For detailed information and recommendations on cold weather concreting practices, specifiers should refer to: ACI Standard 306, “Recommended Practice for Cold Weather Concreting”.
4.4.2 Hot Weather The temperature of the concrete when discharged shall not exceed 95°F.	4.4.2 For more detailed information and recommendations on hot weather concrete, refer to ACI Standard 305-, “Recommended Practice for Hot Weather Concreting”. The use of cold water or crushed ice as a substitute for part or all of the mixing water is a recognized method of controlling temperature under hot weather conditions.

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5.0 QUALITY ASSURANCE TESTING	
5.1 General	
5.1.1 Routine testing of concrete materials, mix designs, and of resulting concrete to determine compliance with the technical requirements of the specifications shall be performed by a testing agency designated by the owner under the supervision and direction of the architect and/or engineer at the _____ expense.	5.1.1 Specifier should designate whether cost of control testing will be at owner's or contractor's expense. This provision reserves to the owner the right to select and control the work of the testing agency. Most testing authorities highly recommend that control testing be performed at the owner's expense whenever possible. An alternate sometimes used requires bidders to include a fixed allowance in their bids for control testing. When total testing charges exceed this amount, the owner pays the excess; if total charges are less the contractor credits or refunds the difference to the owner.
5.1.2 The contractor may engage a separate testing agency to perform additional tests for his information and guidance at his expense. Testing of field cured test specimen testing required because of changes in concrete materials or mix proportions required by the contractor, and extra testing of concrete or materials occasioned by their failure to meet specification requirements shall be at the contractor's expense. ???	5.1.2 Field-cured specimens should not be used to determine compliance of the concrete as delivered with the specifications. Testing of field-cured specimens is helpful in determining the effect of job climatic conditions and curing procedures on the quality of the in-place hardened concrete; and to determine when the in-place concrete has developed sufficient strength to permit form removal or when the structure may be placed in service. When testing of field-cured specimens will be required by the owner, a suitable provision specifying the frequency and procedures to be used should be added in this or other appropriate sections of the specifications. Also, if the owner will pay for testing of field-cured specimens, this provision should be modified to so indicate.
5.2 Testing Services	
5.2.1 The testing agency shall secure production samples of concrete materials and of concrete during the course of the work and test for compliance with the specifications in accordance with the following procedures:	5.2.1 Specifier should here designate an approved inspection agency showing evidence that the agency conforms with ASTM C 1077, "Inspection and Testing Agencies for Concrete, Steel and Bituminous Materials as Used in Construction", and be accredited under the AASHTO Accreditation Program or equivalent. Additionally, the technician performing the work should be ACI certified.

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5.2.1.1 Concrete Materials Submittal of a written certification, test data, and/or mill certificates by the contractors or concrete supplier stating or demonstrating that concrete materials have been tested and comply with the specifications, may be accepted in lieu of actual testing of the concrete materials by the designated testing agency. 1) Portland Cement - Sample and test by methods specified in ASTM C 150. 2) Blended Cement - Sample and test by methods specified in ASTM C 595. 3) Aggregates - Sample and test by methods specified in ASTM C 33. 4) Chemical Admixtures - Sample and test by methods specified in ASTM C 494. 5) Air Entraining - Sample and test by methods specified in ASTM C 260. 6) Pozzolans - Sample and test by methods specified in ASTM C 618.	5.2.1.1 If certification as evidence of compliance of concrete materials with specifications will not be accepted, eliminate the appropriate portion of this section. If non-potable water, or water from unknown or unproven sources, will be used for mixing water in concrete, add a provision requiring submittal of evidence or testing to show that the water is suitable for use in concrete.
5.2.1.2 Concrete 1) Sampling - ASTM C 172. Each sample to be tested shall be obtained from the middle portion of the batch on a representative random basis. Refer to Appendix B 2) Strength Tests a) Fabrication of cylinders: all compressive strength specimens shall be cured in accordance with the provisions of ASTM C 31 and initial curing shall be in accordance	5.2.1.2 1) Use of standard method of sampling, and in the handling and protection of samples, is essential to achieve reliable and representative results in control testing. Here it must be emphasized that the testing agency is responsible for the handling of strength testing specimens in strict accordance with ASTM C 31. a) Plastic reusable molds are generally used in Arizona to cast compressive test specimen and provide good results when used with care. The referred paragraphs of ASTM C 31 call

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with Section 9 thereof. Test cylinders shall be cured in molds conforming to the requirements of ASTM C 470. Four-inch diameter molds, eight inches long, are acceptable.	for specimen to be protected against loss of moisture and to be stored at temperatures between 60-80°F during the 24-hour period immediately after they are molded, and removal of the molds and subsequent storage in a moist atmosphere at 73° (+3°F) until tested. This is universally recognized as the standard method of curing to be employed for specimen used in tests, which will serve as a *basis for acceptance* of concrete as delivered. During winter weather area practice has the specimens cured for the first 24 ± 8 hours by submerging the specimens in water in a box or container, which has insulating materials around the specimens to act as an insulator. Summer weather area practice has the initial curing of the specimen being accomplished by submerging the specimens in water in a barrel and the barrel being shaded to protect it from direct sun exposure. In all cases, the cylinders should be protected from moisture loss and kept in a range of 60 to 80 degrees Fahrenheit. When testing of field-cured specimens will be required, Specifier should designate how specimens are to be cured and handled. This can be handled by referring to Section 9 of ASTM C 31, which covers recommended methods of curing field-cured specimens.
b) Compressive Strength Test Method: ASTM C 39 Cylinder capping shall be accomplished in accordance with ASTM C 617 or ASTM C 1231. A test shall consist of the average of the strengths obtained from the results of not less than 2 specimens from the same sample of concrete and tested at the specified age. If a specimen shows evidence of improper sampling, molding, or testing, it shall be discarded and the results not included in computing the average strength for the test. When more than one specimen in a test group is defective, the entire test shall be discarded.	b) The reliability and accuracy of a test increases as the number of specimens constituting a test is increased. ACI recommends a minimum of two specimens to be tested on the established verification date (usually age 28 days). Additional specimens are made to provide early and later indications of performance. In Arizona, sets of 4 specimens are usually specified to be tested 1 at age 7 days, 2 on the date of verification, and 1 held for additional information if needed. (See ACI 214.) Special handling and/or capping procedures may be required for HPC (high strength concrete - 6,000 psi and higher) or low strength concretes. These special handling instructions should be included within a mix design submittal. Particular emphasis

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Frequency: Make one strength test for each 100 cu. yd. or fraction thereof for each mix design placed in any one day. When less than _____ cu. yd. of a class of concrete is placed in a day, the requirement for a strength test of this class on that day may be waived by the architect and/or engineer.	should be made on handling and capping of HPC concretes with psi of 10,000 or more. Often only a small volume of a given class of concrete may be placed in a day. This provision requires at least one strength test per day regardless of the volume. When the specifier will consider waiving the strength test requirement for a small volume, he should designate the maximum volume, which can be placed without a strength test.
3) Slump Test Method: ASTM C 143 Frequency: Whenever a strength test sample is taken and *at other times as necessary.*	.
4) Air Content Test Method: ASTM C 231 or ASTM C 173 Samples of concrete used in air content tests shall not be used for slump, strength, or other physical property tests. Frequency: At least once each day for each class of air-entrained concrete used when the volume placed during the day will exceed _____ cu. yd., and at other times as necessary.	4) The amount of entrained air generated in concrete will depend on the type and amount of air-entraining agent used, mix proportions and consistency, aggregate gradation, mix temperature and other factors. Air contents should be checked whenever a significant change in any of these factors is experienced. A minimum of one test per day per class of air-entrained concrete placed is required by this provision unless the specifier stipulates some maximum volume below which an air content test will not be required.
5) Unit Weight Test Method: ASTM C 138 Frequency: At least once each day for each class of concrete when the total volume to be placed during the day will exceed _____ cu. yd., and at other times as necessary.	5) Indicate the maximum volume, which can be placed in a day without a unit weight test being required if desired. The unit weight test is relatively simple and easy to perform and provides data essential to proper evaluation of other control tests.
6) Temperature Test Method: ASTM C1064. The temperature of the concrete mix shall be determined with a thermometer accurate to ±2°F. The thermometer shall be inserted	6) The concrete mix temperature can significantly affect virtually all physical properties of the plastic and hardened concrete. A temperature check is relatively simple and easy to perform and provides data essential to a proper evaluation of the results obtained in other control tests.

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into the sample immediately after it is obtained and allowed to remain until the reading becomes stable. Frequency**:** Whenever strength tests and/or air content tests are made and at other times as necessary.	
5.3 Test Reports - The testing agency shall report the results obtained in all tests of concrete materials and concrete to the architect and/or engineer, the contractor, and the concrete supplier on the same day the tests are made Documentation of test results, either by electronic means or hard copy, shall be provided as soon as reasonably possible.	5.3 This provision requires the testing agency to automatically supply the results obtained in quality assurance testing to the concrete supplier as well as the contractor and the architect or engineer. Project control test data can be very helpful to the concrete supplier in his quality control operations and should be provided to him whenever possible. Since concrete designs are based upon statistical evaluation, it is extremely important that the supplier be furnished this data within 24 hours of test.
5.4 Authority and Duties of Testing Agency	5.4 These or similar provisions often are included under the General or other sections of project specifications. When included elsewhere, delete from this section.
5.4.1 The individual who samples and tests concrete for acceptance in strict accordance with these specifications shall have demonstrated a knowledge and ability to perform test procedures equivalent to the minimum guidelines for ACI Certification of Concrete Field Testing Technicians, Grade 1.	
5.4.2 Personnel of the testing agency shall not act as foreman or perform other duties for the contractor. The testing agency shall be responsible for checking the work as it progresses but failure to detect defective work or materials shall not in any way prevent later rejection should defects be discovered, nor shall it obligate the architect and/or engineer for final acceptance. The testing agency shall not have authority to revoke, alter, relax, enlarge, or release any requirement of the specification nor to approve or accept any portion of the work.	
	5.5 These or similar provisions often are included

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5.5 Responsibilities and Duties of Contractor	under the General or other section of project specifications. When included elsewhere, delete from this section. See Appendix A "Statement of Responsibilities" by National Ready Mixed Concrete Association and The Associated General Contractors of America.
5.5.1 The use of testing services shall in no way relieve the contractor of his responsibility to furnish materials and construction in full compliance with the plans and specifications.	
5.5.2 To facilitate testing services the contractor shall:	
5.5.2.1 Submit directly, through the testing agency or ready mix supplier, the concrete mix designs he proposes to use in the construction and make written request for approval.	
5.5.2.2 Furnish such casual labor as necessary to obtain and handle samples at the project or at other sources of material.	
5.5.2.3 Advise the testing agency sufficiently in advance of operations to allow for completion of quality tests and assignments of personnel.	
5.5.2.4 Provide and maintain for the sole use of the testing agency adequate facilities for safe storage and proper curing of concrete test cylinders on the project site.	
5.6 Evaluation of Control Test Results	
5.6.1 General	
5.6.1.1 Strength test results shall be evaluated in accordance with the procedures recommended in ACI 214.	5.6.1.1 ACI 214 presents methods of evaluating concrete test results by standard statistical methods and procedures. In this approach, it is recognized that some degree of variation in the strength and other properties of concrete must be accepted. The probability of a certain number of tests falling below the minimum design strength specified is recognized and a limited number of such tests allowed. An absolute minimum strength specification, one that requires all tests to be equal to or above the strength specified, is impractical and virtually impossible to meet.

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	If the statistical methods outlined in ACI 214 will not be acceptable as a method of determining compliance, this provision should be changed and an alternate defining the acceptable procedures substituted.
5.6.1.2 Test data obtained through use of an impact hammer or sonoscope, or other non-destructive testing methods shall not be considered conclusive in evaluating concrete strength or other properties unless properly calibrated and correlated with other test data., per ACI 228.1R.	5.6.1.2 Test results obtained with a properly calibrated impact hammer are most useful for rapidly surveying large areas of similar concrete under consideration. They may be used to assess the uniformity of concrete intensity, to delineate areas of poor quality or deteriorated concrete in structures, and to indicate changes in time in characteristics of concrete such as those caused by the hydration of cement so that it provides useful information in determining when forms and shoring may be removed. This method of test is not intended as an alternative for strength determination of concrete.
5.7 Acceptance Criteria	5.7 The acceptance criteria specified in these provisions conform to the requirements of ACI 318, Section.5.6.3.3 Due to the many factors that can affect the compression strength of concrete and the results of control tests, an occasional low test is not unusual and should not by itself be a cause for undue concern or rejection of the concrete.
5.7.1 Compressive strengths shall be considered satisfactory if the average of all sets of three consecutive tests of laboratory cured specimens representing the specified strength of concrete is equal to or greater than the specified strength, and no individual strength test falls below the specified strength by more than 500 psi (10 % of f'_c when f'_c>5000 psi).	
5.8 Testing of Hardened Concrete	5.8 The taking of core tests is expensive and not recommended as a general practice. Core tests to determine acceptance of concrete should be required only as a last resort. Cores should not be removed until the concrete has reached at

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	least 14 days age unless…see first paragraph of Chapter 4 of ACI 214.4R.
5.8.1 Core tests, when required shall be conducted in accordance with ASTM C 42.	5.8.1 The condition of the cores at the time of testing is critical to obtaining comparative results. ASTM C42 has specific guidelines for extracting, conditioning and testing core samples and should be strictly followed.
5.8.2 At least three representative cores shall be taken from each concrete member or area of concrete to be tested at locations which will least impair the strength of the structure as designated by the architect and/or engineer. Cores damaged subsequent to or during removal shall be rejected and additional samples taken. Refer to ACI 214.4R	5.8.2 Specify the number and diameter of cores that will be required for a test. It is recommended that at least three cores be taken from each concrete member or area of concrete to be tested and the test reported as the average obtained through tests of the three specimens. The diameter of core specimens should preferably be a minimum of three times the nominal maximum size coarse aggregate used in the concrete, and *must* be at least two times the maximum nominal size of the coarse aggregate in the core sample. After capping, the length of the specimen should be as nearly as possible to twice its diameter. A core having a maximum height of less than 95% of its diameter before or after capping should not be tested. (See ASTM C 42.) Core specimens should be taken in the same direction as the concrete was cast. Since bleeding is always upward, a weak cement-aggregate bond is created under aggregate particles. These planes of weakness are always horizontal in the cast concrete due to the influence of gravity. Core specimens taken horizontally can be expected to show reduced strengths. It has been determined that the strength of concrete cast with the axis of loading vertical is about 8% higher in compression than the strength of concrete cast with the axis of loading horizontal. This value seems to be independent of the design strength of the concrete. When evaluating strength results from drilled cores, this effect should be considered when cores are drilled horizontally from structures such as columns ~~or~~ walls. (See Mindess & Young, *Concrete*).

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5.8.3 Strength tests of cores from concrete shall be considered satisfactory if their average is equal to or greater than 85 percent of the specified strength and no single core is less than 75 percent of the specified strength.	5.8.3 This section complies with ACI 318-Section 4.6.5.4. Failure of cores from the in-place concrete to produce strengths when tested equal to or above the specified design strength does not necessarily mean that the concrete as delivered did not comply with the specifications. Climatic conditions, the methods employed in transporting, placing and curing the in-place concrete and other factors must be considered when comparing the strength and quality of in-place concrete to that of the concrete as-delivered. When core tests are used, as the basis for acceptance as provided by this provision, the age of the concrete in the cores usually is not considered significant. If the core test results indicate concrete strengths are equal or greater than the levels indicate, it is assumed the concrete in the structure has achieved the required strength level and is acceptable. This concept is based on the known fact that concrete continues to gain in strength as it increases in age beyond the 28-day age at which as-delivered control specimens are normally tested.
5.8.4 All core holes shall be repaired as specified in the provisions relating to the repair of defective areas.	

APPENDIX A
LIST OF REFERENCED STANDARD SPECIFICATIONS AND OTHER STANDARDS

A. *American Society for Testing and Materials Standards*
1916 Race Street, Philadelphia, PA 19103

1. C 31- Standard Method for Making and Curing Concrete Compression and Flexure Test Specimens in the Field
2. C 33- Standard Specifications for Concrete Aggregates
3. C 39- Standard Method of Test for Compressive Strength of Molded Concrete Cylinders
4. C 40- Standard Method of Test for Organic Impurities in Sand for Concrete
5. C 42- Standard Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
6. C 94- Standard Specifications for Ready Mixed Concrete
7. C 136- Standard Method of Test for Sieve or Screen Analysis of Fine and Coarse Aggregates
8. C 138- Standard Method of Test for Weight per Cubic Foot, Yield, and Air Content (Gravirnetric) of Concrete
9. C 143- Standard Method of Test for Slump of Portland Cement Concrete
10. C 150- Standard Specification for Portland Cement
11. C 172- Standard Method of Sampling Fresh Concrete
12. C 173- Standard Method of Test for Air Content of Freshly Mixed Concrete by the Volumetric Method
13. C 231- Standard Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method
14. C 260- Standard Specification for Air-Entraining Admixtures for Concrete
15. C 494- Standard Specification for Chemical Admixtures for Concrete
16. C 618- Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
17. C 1064-Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
18. C 1077-Standard Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation1
19. D 75- Standard Methods of Sampling Stone, Slag. Gravel, Sand, and Stone Block for Use as Highway Materials

B. *American Concrete Institute Standards*
P.O. Box 9094, Farmington Hills, MI 48333
(248) 848-3700

1. ACI 214- Recommended Practice for Evaluation of Compression Test Results of Field Concrete

2. ACI 214.4 R- Guide for Obtaining Cores and Interpreting Compressive Strength Results

3. ACI 228.1R- In-Place Methods to Estimate Concrete Strength

2. ACI 318- Building Code Requirements for Reinforced Concrete

3. ACI 211- Recommended Practice for Selecting Proportions for Concrete

4. ACI 301- Specification for structural concrete for building

C. *Arizona Rock Products Association*
916 W. Adams St., Phoenix, AZ 85007

1. Certification of Ready Mixed Concrete Production Facilities

D. *National Ready Mixed Concrete Association Standards*
900 Spring Street, Silver Springs, #5, MD 20910

1. Concrete Plant Standards, 12th Revision, 2000, Concrete Plant Manufacturers Bureau

2. Truck Mixer and Agitator Standards, 15th Revision, 2001, Truck Mixer Manufacturers Bureau

Notes