

Information for ACI 318A in Preparation for Shotcrete Provisions

Current Code Requirements for Shotcrete

There are no current provisions within ACI 318-14, or previous editions, for shotcrete. However, shotcrete design and construction has been accepted for many years through the International Building Code (IBC) since its inception in 2000 and in previous Codes (Uniform Building Code, etc.) before that time. Since the shotcrete industry has been successfully utilizing the IBC provisions for 15 years it was considered beneficial to understand the current state-of-the-art in these Code provisions.

In addition, if ACI 318 were to add provisions for shotcrete it would eliminate the need for IBC to have duplicate shotcrete provisions. IBC would likely eliminate their shotcrete provisions if ACI 318 adequately covered that topic. If IBC eliminated their provisions, that would also allow ACI 318 to consider using current IBC shotcrete provisions, if appropriate.

Thus a review of IBC shotcrete provisions was undertaken with respect to ACI documents on shotcrete.

Historical View of IBC Shotcrete Provisions

IBC has included shotcrete provisions in all their Codes; 2000, 2003, 2006, 2009, 2012 and 2015. The Code¹ and Commentary² provisions have not changed in content from 2000 to 2015 except for renumbering of the provision due to other changes. Shotcrete was in Section 1914 in IBC 2000 and 2003, Section 1913 in IBC 2006 and 2009, Section 1910 in IBC 2012 and recently changed to Section 1908 in IBC 2015.

The titles and numbering of the IBC 2015 shotcrete provisions are shown below:

Section Number	Title	Section Number	Title
1908.1	General	1908.7	Joints
1908.2	Proportions and materials	1908.8	Damage
1908.3	Aggregate	1908.9	Curing
1908.4	Reinforcement	1908.9.1	Initial curing
1908.4.1	Size	1908.9.2	Final curing
1908.4.2	Clearance	1908.9.3	Natural curing
1908.4.3	Splices	1908.10	Strength tests
1908.4.4	Spirally tied columns	1908.10.1	Sampling
1908.5	Preconstruction tests	1908.10.2	Panel criteria
1908.6	Rebound	1908.10.3	Acceptance criteria

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1. There was a one sentence procedural change in IBC 2015 on preconstruction testing.
 2. The IBC 2015 Commentary is not available until late April and thus can't be verified. However, since only one sentence was changed in IBC 2015 with respect to shotcrete, it is unlikely that the Commentary has changed.

ACI Documents Reviewed for Shotcrete Information

The information in ACI documents were reviewed with respect to the shotcrete provisions in Section 1908 in IBC 2015. Since the IBC shotcrete provisions had not changed since 2000, it was considered that the IBC provisions might be taken or referenced from ACI documents in the 1990's. As a result, old and new versions of ACI documents were reviewed to evaluate where the IBC provisions might have originated.

The ACI documents¹ that were considered in this process are shown below:

- ACI 506R-90 "Guide to Shotcrete"
- ACI 506R-05 "Guide to Shotcrete"
- ACI 506.1-98 "Report on Fiber-Reinforced Shotcrete"
- ACI 506.1-08 "Guide to Fiber-Reinforced Shotcrete"
- ACI 506.2-95 "Specification for Shotcrete"
- ACI 506.2-13 "Specification for Shotcrete"
- ACI 506.4R-94 "Guide to the Evaluation of Shotcrete"
- ACI 506.5R-09 "Guide to Specifying Underground Shotcrete"
- ACI 350-06 "Code Requirements for Environmental Engineering Concrete Structures: Appendix G Circular Wire and Strand Wrapped Prestressed Concrete Environmental Structures"²
- ACI 350.5-12 "Specifications for Environmental Concrete Structures"³

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1. ACI 506.3R-91 "Guide to Certification of Shotcrete Nozzlemen" has been discontinued. ACI has shotcrete nozzleman programs for both wet-mix and dry-mix processes that are covered in ACI CCS-4(08) "Shotcrete for the Craftsman".
 2. Appendix G of ACI 350-06 provides Code requirements for the use of shotcrete in these applications.
 3. ACI 350.5-12 in the preface states "*The document covers materials and proportioning of concrete; reinforcement and prestressing reinforcement; production, placing, finishing, and curing of concrete; formwork design and construction; and shotcrete.*" However, the coverage of shotcrete in this document is to refer to ACI 506.2-95 "Specifications for Shotcrete."

References to ACI and ASTM within IBC Shotcrete Provisions

The 2015 IBC, Section 1908 Shotcrete, does not reference any ACI or ASTM standard within the Code. The Commentary does reference some ACI documents and ASTM standards. The ACI and ASTM documents that are referenced in Section 1908 are shown in the Table below. This Table also shows in which shotcrete provision that the documents are referenced. The ACI and ASTM documents shown in blue are meant to highlight that they are *only* included in the IBC Section 1908 Commentary.

Reference in IBC Code and Commentary to ACI and ASTM Documents			
Section 1908	Title	ACI Documents ¹	ASTM Documents ²
1908.1	General	506R, 318	None
1908.2	Proportions and materials	None	None
1908.3	Aggregate	506.2	C33, C330

1908.4	Reinforcement	None	None
1908.4.1	Size	None	None
1908.4.2	Clearance	None	None
1908.4.3	Splices	None	None
1908.4.4	Spirally tied columns	318	None
1908.5	Preconstruction tests	None	C42
1908.6	Rebound	None	None
1908.7	Joints	None	None
1908.8	Damage	506.4R	None
1908.9	Curing	306R, 318	None
1908.9.1	Initial curing	None	C309
1908.9.2	Final curing	None	C171
1908.9.3	Natural curing	None	None
1908.10	Strength tests	None	C42
1908.10.1	Sampling	None	None
1908.10.2	Panel criteria	None	None
1908.10.3	Acceptance criteria	506R	C42

1. ACI documents referenced: ACI 506R "Guide to Shotcrete", ACI 318 "Building Code Requirements for Structural Concrete", ACI 506.2 "Specifications for Shotcrete", ACI 506.4R "Guide to the Evaluation of Shotcrete", ACI 306R "Guide to Cold Weather Concreting".
2. ASTM documents referenced: ASTM C33 "Standard Specification for Concrete Aggregates", ASTM C 330 "Standard Specification for Lightweight Aggregates for Structural Concrete", ASTM C 42 "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete", ASTM C 309 "Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete", ASTM C 171 "Standard Specification for Sheet Materials for Curing Concrete".

ASTM Standards on Shotcrete

Although not utilized by IBC, there are a number of ASTM standards that pertain directly to shotcrete. The titles for these standards^{1, 2} are shown below:

- C 1140-11 "Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels"
- C 1141-08 "Standard Specification for Admixtures for Shotcrete"
- C 1385-10 "Standard Practice for Sampling Materials for Shotcrete"
- C 1436-13 "Standard Specification for Materials for Shotcrete"
- C 1480-07 (2012) "Standard Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet and Dry Shotcrete Application"
- C1604-05 (2012) "Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete"

1. ASTM C1398-07, "Standard Test Method for the Laboratory Determination of the Time of Setting of Hydraulic Cement Mortars Containing Additives for Shotcrete by the Use of Gillmore Needles" (Withdrawn 2010).
2. Other ASTM standards are used to evaluate the individual materials within shotcrete such as the cement and aggregates. In addition, the use of fibers in shotcrete is often evaluated using ASTM C1550-12a, "Test Method for Flexural Toughness of Fiber-Reinforced Concrete (Using Centrally Loaded Round Panel)" and ASTM C1609/C1609M-12, "Standard Test Method for Flexural Performance of Fiber- Reinforced Concrete (Using Beam with Third-Point Loading.)"

Comparing IBC Shotcrete Provisions to ACI Documents

There are individual tabulated comparisons of the appropriate sections of ACI documents that pertain to IBC shotcrete provisions (Code and Commentary) in separate WORD documents. In general each shotcrete provision in 2015 IBC has been provided as a separate WORD document. The only combination was for curing as the ACI

documents did not lead to a distinction in separating curing as initial curing and final curing. Thus section 1908.9 curing, 1908.9.1 initial curing, 1908.9.2 final curing and 1908.9.3 natural curing are all included in one WORD document.

In reviewing the ACI documents with respect to the IBC shotcrete provisions the following observations were made:

1. The IBC shotcrete provisions have remained the same over the last six editions from 2000 to 2105. Thus the shotcrete provisions have not evolved or benefited from industry improvements or acknowledged changes in industry practices.
2. The IBC provisions being the same since 2000, utilized information in ACI documents published in the 1990's. While the information in the ACI documents has changed, the IBC shotcrete provisions have not. As a result the IBC shotcrete provisions are dated and need to be updated to reflect current technology, information and practices.
3. Unlike ACI Codes and Standards, the IBC shotcrete provisions do not utilize ASTM standards in setting requirements. Thus the six different ASTM standards that pertain directly to shotcrete are not in IBC. ACI 318 could utilize the ASTM standards to effectively and efficiently communicate material, testing and construction requirements to shotcrete designers and contractors.
4. Since the IBC shotcrete provisions are outdated, it appears that existing shotcrete design and construction are utilizing preconstruction testing as the main means to verify shotcrete acceptance. As an example, the shotcrete provision (1908.4.1) limiting the maximum size of reinforcement to a No. 5 bar, is often exceed on current shotcrete projects. As IBC allows, preconstruction testing on larger bars is being utilized for this acceptance.