
SHOTCRETE CONSTRUCTION: 2022 CBC

Disciplines: Structural

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PURPOSE

This Interpretation of Regulations (IR) clarifies requirements necessary to qualify concrete construction placed by the shotcrete method on projects under DSA jurisdiction. This includes requirements of the construction documents, preconstruction demonstration, and quality assurance during construction.

SCOPE

This IR is applicable to design and construction employing the shotcrete method to install all or a portion of the concrete on a project. The American Concrete Institute (ACI) in its Building Code Requirements for Structural Concrete (ACI 318) defines shotcrete as “concrete placed pneumatically by high velocity projection from a nozzle onto a surface.”

BACKGROUND

The California Building Code (CBC) has historically contained provisions for shotcrete, including amendments to the model code adopted by DSA, in Sections 1908 and 1908A. With its adoption of the 2019 edition of ACI 318, the 2021 edition of the International Building Code (IBC), which serves as the model code for the CBC, eliminated its shotcrete provisions in deference to those contained in ACI 318. Code amendments adopted by DSA pertaining to shotcrete construction remain in Sections 1705A, 1909, 1905A, and 1908A.

In addition to the requirements of ACI 318, the American Concrete Institute publishes various specification and practice documents related to shotcrete construction, including the following:

- ACI 506R: Guide to Shotcrete
- ACI 506.2: Specification for Shotcrete
- ACI 506.4R: Guide for the Evaluation of Shotcrete
- ACI 506.6T (TechNote): Visual Shotcrete Core Quality Evaluation
- ACI PRC-506.7: Shotcrete Preconstruction Mockup—TechNote

1. CONSTRUCTION DOCUMENTS

The shotcrete method of installing concrete is not simply a means of construction that can be left to the discretion of the contractor. Because the code dictates requirements specific to shotcrete construction, the construction documents must clearly define any concrete that will be placed by this method. The construction documents must specify the requirements of code-compliant shotcrete construction as established by the CBC, ACI 318, and ACI 506.2, including but not limited to the information defined in this section.

1.1 Specifications

The specifications component of the construction documents is commonly organized as a project manual in a book-type format; however, this presentation is not mandated. Whether contained on the drawings or compiled into a separate manual, the specifications shall include

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the requirements listed in the following subsections as applicable. These requirements are specific to shotcrete work and are in addition to those commonly specified for cast-in-place concrete construction.

1.1.1 Nozzle operator qualification requirements including demonstration by preconstruction mockup panel and associated evaluation per CBC Section 1705A.3.9.2. See also ACI 318 Section 26.5.2.1, Item (p).

1.1.1.1 Sufficient detail must be specified to communicate and make enforceable the requirements of Section 2.2 below.

1.1.1.2 In coordination with Section 1.2.2 below, reference should be given to the conditions identified on the construction drawings that must be reproduced in the mockup panels.

1.1.1.3 Any specific cutting, coring, and examination requirements the structural engineer or architect has for the mockup panel should be listed in consideration of the acceptance requirement described in Section 2.3.6 below. ACI 506.4R Sections 10.3.2 and 11.2.1 advise that the design professional should dictate evaluation of the mockup panel. Refer to ACI PRC-506.7 for an example.

1.1.2 Nozzle operator certification requirement per ACI 318 Section 26.5.2.1, Item (o).

1.1.3 Required compliance with ACI 506.2 in accordance with CBC Section 1908A.1.

1.1.4 Construction tolerances in accordance with CBC Section 1901A.7.1, Exception #2.

1.1.5 Material requirements as follows:

1.1.5.1 Aggregate gradation conforming with American Society of Testing and Materials (ASTM) C1436 per ACI 318 Section 26.4.1.2.1, Item (d).

1.1.5.2 Admixtures conforming with ASTM C1141 per ACI 318 Section 26.4.1.5.1, Item (d).

1.1.5.3 Packaged, preblended, dry, combined materials conforming with ASTM C1480 per ACI 318 Section 26.4.1.7.1, Item (a), if applicable.

1.1.6 Mix proportion documentation requirements in accordance with ACI 318 Section 26.4.4.1, Item (d).

1.1.7 Performance requirements in accordance with ACI 318 Section 26.4.3.1, Item (e).

1.1.8 Air-entrainment requirements in accordance with ACI 318 Section 19.3.3.3 through 19.3.3.6 when applicable.

1.1.9 Preparation requirements in accordance with ACI 318 Section 26.5.2.1, Items (j), (k), (l), (m), (n), and (q) as modified by CBC Section 1905A.1.16.

1.1.10 Curing requirements in accordance with ACI 318 Section 26.5.3.2, Item (f).

1.2 Construction Drawings

As the primary document for communicating the scope, dimensions, details, and requirements of the finished project, the construction drawings shall include the following information pertaining to shotcrete work as applicable:

1.2.1 Definition of the scope of concrete work to be installed by the shotcrete method in accordance with ACI 318 Section 26.3.1, Item (b). When shotcrete abuts concrete installed by traditional cast-in-place methods, the transitional construction joints shall be delineated and dimensioned on the drawings.

1.2.2 Identification of the location(s) within the shotcrete design that must be reproduced in a mockup panel as required by CBC Section 1705A.3.9.2. If the thickest, most congested, and most difficult shooting position occur at different locations, each shall be identified on the

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drawings. Unless the splice locations are specifically defined elsewhere, the drawings must require inclusion of the applicable splice type (e.g., lap or mechanical) in the mockup panel. See Section 2.2 below for additional information.

1.2.3 Identification of the locations from which the cores required by CBC Section 1705A.3.9.1 will be taken from the final as-built construction. Dimensions and any additional reinforcement required for the coring must be defined on the drawings.

1.2.4 Construction joint details in accordance with ACI 318 Section 26.5.6.1, Items (a) and (b). Construction joints shall comply with ACI 318 Section 26.5.6.1, Item (c) and Section 26.5.6.2, Item (g).

1.2.5 Details specifying reinforcement complying with the spacing requirements of ACI 318 Sections 25.2.7, 25.2.8, 25.2.9, and CBC Section 1905A.1.15 as applicable.

1.2.6 Details specifying reinforcement lap splices complying with the requirements of ACI 318 Sections 25.5.1.6 and 25.5.1.7 as applicable.

1.3 Construction Change Documents (CCD)

During the construction phase of a project, design changes are commonly accomplished through the creation, submission, and approval of construction change documents (CCD). Refer to *IR A-6: Construction Change Document Submittal and Approval Process* for additional information. In addition to changes typical of concrete work, the following changes specific to shotcrete construction require DSA approval as a CCD:

1.3.1 Proposed shotcreting of concrete not specified as shotcrete on the originally approved construction drawings in accordance with ACI 318 Section 26.3.2, Item (a).

1.3.2 Proposed changes to construction joint locations in accordance with ACI 318 Section 26.5.6.2, Item (h).

2. QUALIFICATION AND QUALITY ASSURANCE

In accordance with CBC Chapter 17A, shotcrete construction requires both preconstruction qualification of nozzle operators and typical quality assurance measures during construction in the form of material tests and inspections. These should be understood as separate and distinct requirements on different timelines.

2.1 Procedure for Nozzle Operator Qualification

Prior to the start of shotcrete construction, qualification is required of each nozzle operator who will perform the work. This qualification consists of construction, evaluation, and acceptance of shotcrete mockup panels. Refer to ACI PRC-506.7 for additional guidance. Mockup panel construction and evaluation typically follows the procedure described in ACI 506.4R Section 11.3 and includes the following steps:

2.1.1 Planning meeting is conducted as described in ACI 506.4R Section 11.3.2.3. The DSA field engineer must be invited to the preconstruction meeting with at least one week advance notification.

2.1.2 Mockup panel shop drawings are prepared by the contractor and approved by the architect in general responsible charge and structural engineer of record per ACI 506.4R Section 11.4.1. In addition to dimensions and rebar erection details, the shop drawings should define the shooting conditions as required by Section 2.2.4 below.

2.1.3 Mix design is prepared by the contractor, reviewed by the project's laboratory of record (LoR), and approved by the structural engineer of record per ACI 506.4R Sections 11.4.1 and 11.3.2.6.

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2.1.4 Mockup panel formwork and reinforcement are constructed by the contractor according to the shop drawings and in compliance with the construction documents.

2.1.5 Mockup panel formwork and reinforcement are inspected by the special inspector according to the construction documents and shop drawings.

2.1.6 Mockup panel is shot by the candidate nozzle operator to be qualified. See Section 2.2 below for additional information.

2.1.7 Mockup panel is evaluated. See Section 2.3 below for additional information. Nozzle operators are qualified for work on the project when confirmed by the LoR and the design professional in general responsible charge or the structural engineer of record.

2.2 Mockup Panel Construction

In accordance with CBC Section 1705A.3.9.2, preconstruction mockup panels are required to qualify each nozzle operator. Each mockup panel shall comply with ACI 506.2 Section 1.5 and be constructed, shot, evaluated, and accepted prior to the nozzle operator performing any work on the project.

2.2.1 The mockup panel shall reproduce the dimensions and reinforcement of the project-specific condition(s) identified on the construction drawings per Section 1.2.2 above. The mockup panel shall capture a section of the wall no less than 30-inches in height and width.

2.2.2 If the thickest, most congested, and/or most difficult shooting positions occur at different locations, nozzle operators may be qualified for these conditions with separate mockup panels. However, nozzle operators will not be permitted to perform work for which they have not been qualified.

2.2.3 Shooting of the mockup panel by each nozzle operator must match the project construction in all respects, including the mix design and equipment used. If variations in the mix or equipment are proposed for the project, separate mockup panels are required for each combination.

2.2.4 The requirements of CBC Section 1705A.3.9.2 that the mockup panel “*simulate job conditions as closely as possible*” and be “*shot at the same angle*” as the project is meant to capture all conditions contributing to the difficulty of the shotcreting application that could affect the quality of the final project construction. The mockup panel should be shot under the most severe conditions required of the project, including the following:

2.2.4.1 Position: Panels shall be shot in the horizontal, vertical, or overhead position as dictated by the project requirements. Refer to ACI 506 Section 3.4.1 for additional information.

2.2.4.2 Platform: Panels should be shot by a nozzle operator supported from a working surface with comparable stability to that used in the final work. If the design professional in general responsible charge determines the platform (e.g., scaffolding, lift, etc.) from which the work will be shot will impact its quality, they may require the mockup panel to be shot from the same surface as the final work. Alternatively, the design professional may require (per Section 1.2.3 above) the in-situ cores be taken from locations that will be shot from the alternative surface and compare those results with the mockup panel shot from the ground.

2.2.4.3 Obstructions: ACI 506.2 Section 3.4.1.4 requires the nozzle operator have “unobstructed access to the receiving surface”; however, if existing structure or other components create obstructions that must be worked around in the final construction, these should be represented in the mockup panel construction.

2.3 Mockup Panel Evaluation and Core Sample Grading

In accordance with CBC Section 1705A.3.9.2, preconstruction mockup panels are required to

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qualify each nozzle operator. Each mockup panel shall be evaluated and accepted in accordance with ACI 506.2 Section 1.5, ACI 506.4R, and ACI 506.6T prior to the nozzle operator performing any work on the project.

2.3.1 In accordance with CBC Section 1705A.3.9.2 the mockup panels shall be cut, cored, examined, and tested. This evaluation shall be performed by the LoR, as listed on the form *DSA 102-IC: Construction Start Notice / Inspection Card Request*, or a qualified laboratory contracted by the LoR.

Note: This testing responsibility requirement differs from that given in ACI 506.2 Section 1.5.1.5.

2.3.2 The scope of cutting, coring, examination, and testing of the panel shall be in accordance with ACI 506.4R (refer to Chapters 10 and 11), standard industry practice, and any project-specific requirements as described in Section 1.1.1.3 above.

2.3.3 Cores and saw-cuts shall be evaluated for voids and encapsulation of reinforcement per ACI 506.6T and achieve the categorization of "Very Good" as defined therein. Refer to ACI 506 Figure 3.4.3f and ACI PRC-506.7 Figures 13 and 14 for examples of cores evaluated for reinforcement encasement.

2.3.4 Where project conditions require shooting to the underside of an existing slab, the top of the mockup panel shall be evaluated to confirm the nozzle operator is able to achieve a tight, clean joint without sagging or separation.

2.3.5 In accordance with CBC Section 1705A.3.9, the LoR shall prepare a report summarizing the results of the mockup panel evaluation and stating the LoR engineering manager's recommendation concerning the nozzle operator's qualification to perform the work. The report shall be distributed to the school district, design professional in general responsible charge, project inspector, and DSA.

2.3.6 In accordance with ACI 506.2 Section 1.5.1.10, the results of the mockup panel evaluation and testing must be found satisfactory by the design professional in general responsible charge or the structural engineer of record for the project. The architect or engineer shall provide a letter to the school district, project inspector, LoR, and DSA documenting their findings relative to the mockup panel results and their corresponding acceptance or rejection of nozzle operators for the project.

2.3.7 Refer to ACI 506.2 Section 1.5.1.10 for the rejection of preconstruction mockup panels.

2.4 Test Panels

As defined in ACI 318 Section 2.3, shotcrete test panels are separate and distinct from shotcrete mockup panels as described in Section 2.2 and 2.3 above. Test panels are used to demonstrate the strength of hardened shotcrete in lieu of sampling cylinders as in traditional cast-in-place concrete.

2.4.1 Throughout shotcrete construction operations, test panels shall be shot, cored, and tested in accordance with ACI 318 Section 26.12.1.1(b), ACI 318 Section 26.12.2.1(d), and ACI 506.2 Section 1.6.

2.4.2 Test panels shall comply with ASTM C1140.

2.4.3 Test panels shall be cored and tested by the LoR.

2.5 Special Inspection

Continuous special inspection is required of shotcrete construction per CBC Section 1705A.3.9 and shall be performed by a special inspector certified by DSA for the inspection of shotcrete construction. DSA-certified shotcrete special inspectors are listed on the eTracker portal, which is accessible from the DSA website.

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2.5.1 Prior to the nozzle operator shooting the mockup panel, the special inspector shall inspect the formwork and reinforcement as described in ACI 506.4R Section 11.4.3. The special inspector shall confirm any required corrective work is completed before the mockup panels are shot.

2.5.2 The special inspector shall observe the shooting of mockup panels and document the information listed in ACI 506.4R Section 11.4.3.

2.5.3 In addition to the duties listed in CBC Section 1705A.3.9 and the verification of all aspects of the construction dictated by their training and experience, the special inspector shall oversee the cores required by CBC Section 1705A.3.9.1 including the following actions:

2.5.3.1 Verify the cores are taken from the locations defined on the construction drawings per Section 1.2.3 above and transported to the LoR for evaluation.

2.5.3.2 Verify repair of the walls from which they are taken.

REFERENCES:

2022 California Code of Regulations (CCR) Title 24

Part 2: California Building Code (CBC), Sections 1705A.3.9, 1909, 1901A.7.1, 1905A.1.15, 1905A.1.16, 1908A.1

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