



Guidelines for Shotcrete Construction

Purpose

To provide minimum inspection and testing requirements for the use of shotcrete as part of the Lateral Force Resisting System of a building code regulated structure.

Background

There has been concern related to the use of shotcrete in other than the non-critical systems of a structure. The most recent edition of the ACI318-19 clarifies that shotcrete is cast-in-place concrete. With quality controls in place, shotcrete can be used with confidence in many systems of a structure, both critical and non-critical.

References

- 2019 California Building Code (CBC) section 1908.
- American Concrete Institute (ACI) 506R-16, "Guide to Shotcrete"
- ACI 506.2-13 "Specifications for Shotcrete"
- ACI 506.4R-19 "Guide for the Evaluation of Shotcrete."

Findings

1. Approval of the shotcrete procedure by the Engineer of Record (EOR) and the City of San Jose (CSJ) is required prior to the application of structural shotcrete on any project. Approvals are required for the design mix, slump, lift height, nozzle, nozzle's assistant (blow pipe operator), equipment, method of taking compression test samples, and pre-construction testing. CSJ approval is for the entire procedure and may be revoked if changes are made without first obtaining CSJ approval. Permitted projects which do not specifically specify the shotcrete method of placement shall not use shotcrete without the approval of the EOR and CSJ. Areas of the structure to utilize shotcrete shall be specifically shown on the structural drawings and in the structural general notes.
2. A pre-construction meeting is required for all projects where the shotcrete method of placement is used. The meeting shall be held after the EOR has designated the areas to use shotcrete and the shotcrete subcontractor has been selected. The EOR, general contractor, shotcrete contractor, reinforcing steel placement company, inspection agency, and CSJ shall attend the pre-construction meeting and discuss the following: the number of nozzlers and helpers required for the project, the number of pre-construction test panels needed, the schedule of placing shotcrete, and the acceptability criteria required.
3. Pre-Construction testing is required for all projects.
 - a. Nozzler's Qualification Panel: Each nozzle must shoot at least one mock-up panel. A mock-up panel shall be shot, cured, cored or sawn, and visually examined prior to commencement of the project to demonstrate each nozzle's ability to do the work. Each shoot of a mock-up panel shall be witnessed by a special inspector registered in shotcrete from the authorized inspection agency for the project. The special inspector shall document the test panel in sufficient detail to allow the EOR and CSJ to compare it with the intended final installed product.

The mock-up panel shall represent the project and simulate the job environment as closely as possible. The mock-up panel thickness and reinforcing steel shall reproduce the thickest and most congested area

specified for the structure, as identified by the EOR. The EOR shall state which section of the design drawings shall be represented by the panel. Or, where the panel is to be a composite of sections, the EOR shall provide the contractor with a detailed sketch of the mock-up panel. The mock-up panel shall be a minimum of 3 feet x 3 feet by the actual shotcrete thickness of the area represented. Reinforcing steel, type of splices, dowels, and embedded items shall be represented in the mock-up panel.

The mock-up panel must be shot using the same nozzle, nozzle's assistant, and equipment that will be used on the actual project, and with the same concrete mix design (from the concrete producer who will supply the actual project), and at the same angle as will be used on the project. Where the nozzle will have to shotcrete a lift higher than shoulder height, the mock-up panel shall be set so the maximum height the nozzle will shoot on the job is duplicated in the panel. Concrete used for the actual project shall be within 1/2 inch +/- of the slump used on the test panel. Lift heights on the project shall not be greater than those in the test panel. The panel shall not be shot until the concrete mix is approved by the EOR and CSJ.

When the mock-up panel is to be sawn for visual examination, it shall be sawn diagonally and as nearly in half as practical. When the mock-up panel is to be cored for visual examination, a minimum of three cores shall be taken. Each core shall be 4" in diameter and cut through the entire thickness of the panel. Cores shall be cut at random locations marked by the special inspector, EOR or CSJ. In general, the center of any core should not be closer than 6" to any edge of the panel except where special members or procedures exist and these areas are critical to design performance. Cores shall be intentionally located to intersect the most congested reinforcement intersections.

If joint configuration is of primary concern, such as in top-down constructed permanent wall systems, the configuration of the joint shall be part of the test, and acceptance or rejection of the panel shall depend upon successful joint achievement as well as on the results of the cores. The EOR and/or CSJ may require additional cores in the area of the joint.

The nozzle's qualification panel shall be completely stripped of its forms and the formed sides shall be examined for evidence of sags and delaminations as well as voids, rock pockets, etc. In addition to a visual examination, these formed surfaces shall be hit with a hammer to discover the extent of any defect visible on the surface. The mock-up panel should demonstrate that the nozzle can effectively encase the reinforcing steel without voids, rock pockets, or similar defects, and that shotcrete can be applied with an overall dense nonporous appearance.

The cores or sawn surface shall be reviewed by the special inspector, EOR and CSJ. They shall discuss acceptability of the quality of work including: number of voids, bar placement, bar cover, and porosity. When the test panels meet the agreed-upon quality, the work may proceed.

The EOR and CSJ may waive their review of the mock-up panel. The test panels and any cores shall remain on site for follow-up examination by the EOR and CSJ. When the visual examination of the formed and cut or cored surfaces of the shotcrete panel reveals voids, rock pockets, sand streaks or other defects, the special inspector shall notify the EOR and CSJ immediately, so they may examine the sample(s), and decide whether or not the nozzle's work is acceptable and the shotcreting may commence.

EXCEPTION: The requirement to pass a mock-up panel for a specific project may be waived by the building official provided:

- a. All reinforcing bars are #5 or smaller
- b. The minimum spacing for reinforcing bars specified in CBC 1908.4.2 is met
- c. Lap splices comply with CBC 1908.4.3
- d. There are no pilasters, columns, beams, or other complicated members included in the proposed shotcrete work

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- e. No overhead or other especially difficult shooting positions are required

After all reinforcing steel is in place for the areas to be shotcreted, the special inspector or EOR and CSJ shall verify that the criteria for approval of the test mock-up panel or the exception have been met. Where several members are to be placed at different times, approval may be given for one area at a time.

- b. Compressive Strength Test Panels: Provided the shotcrete mix has a minimum of 7 sacks of cement per cubic yard and provided the strength specified is 4000 psi or less, no compressive strength tests are required at the time of the nozzle's qualification panels. Where it is proposed to use a mix with less than 7 sacks of cement per cubic yard and/or where design strengths more than 4000 psi are specified, the strength test shall be required at the same time and from the same batch of concrete as the nozzle's qualification panels. Test panels to determine the strength of the shotcrete are also required during the shooting of the actual project.
4. When it will take more than one 8-hour work day to complete the shotcrete on a project, more than one nozzle may be required to pass a mock-up panel test before the shotcreting may start. No shotcrete shall be placed by any person other than a nozzle who is pre-qualified and has been approved for the project. If only one nozzle is approved for the project and that person is unable to complete the project for any reason, work shall stop until another qualified nozzle is approved.
 5. Cores for strength tests may be taken from the actual work or from strength test panels in accordance with Section 1908.10 of the CBC. Where strength test cores are taken from the actual work, they shall be discarded if reinforcing steel is accidentally included in the core. Where test panels are used, the qualified nozzle shall shoot the panels at the same angle and in the same manner as the in-place work. Every effort shall be made to assure the concrete in the test panel is representative of that in the actual structure. The strength test specimens shall be protected from moisture loss, temperature extremes, and damage while at the jobsite in accordance with ASTM C31-19.
 6. The inspection agency employing the special inspector shall provide field training and supervision of the special inspector to assure compliance with this Plan Review Note and good inspection practices. The special inspector shall follow CBC Chapter 17, and shall follow the recommendations of ACI 506R-16.
 7. In addition to general inspection procedures during the mock-up panel for nozzle's qualification, the special inspector shall:
 - a. Record the name of the nozzle and the assistant for each mock-up panel
 - b. Record how the mock-up panels are reinforced and note whether lapped splices, dowels, and embedded items are represented. Record the type of splices used (contact with one bar behind the other, non-contact, mechanical coupler, etc.)
 - c. Record which concrete mix, supplier, pump, compressor, and nozzle are used
 - d. Record the slump of the concrete used and the height of the lifts taken in the test panels;
 - e. Verify that principal steel is marked in such a manner on the outside of the forms so that its locations will be determinable after the panel is shotcreted. Do not allow nails to be pounded into any part of the shotcrete panel forms where there is fresh or green shotcrete. Do not allow nails to be put on the edges of the forms which are parallel to the finished surface where they will interfere with finishing the surface of the panel. Do not allow the use of ink or chalk markers, which will be eradicated by overspray. Photography could be utilized with a definitive method of matching the photograph to the panel.
 8. In addition to general inspection procedures and procedures required by the inspection/testing agency during the shotcreting of the actual project, the special inspector shall also be responsible to perform and document the following:
 - a. Verify that reinforcing steel conforms to project specifications and the CBC, with particular attention given to assure that the reinforcement is tied securely, is clean, and lapped splices are in accordance

with Section 1908.4.3 of the CBC. Verify that the splice used in-place is the same type of splice used in the nozzle's qualifying panel (non-contact lapped splices, mechanical couplers, etc.)

- b. Verify that no portion of the work to be shotcreted has reinforcing steel more congested (more bars, larger bars, or closer spacing) or is otherwise significantly more difficult to shoot than the "worst case" represented by the nozzle's qualifying panel.
- c. Verify that the concrete truck delivery tickets show that the mix delivered is the same as the approved mix. If the batch weights do not appear on the first trip ticket, the inspector shall ask the concrete truck driver to call his/her dispatcher for the weights and write them on the ticket. Subsequent tickets shall show the mix number, cement content, maximum size aggregate and admixtures (if any) and amount of water that may be added at the site.
- d. Verify that the slump of the shotcrete is within ½ inch of that used in the nozzle's qualifying panel.
- e. No admixtures shall be added at the nozzle unless approved by the EOR and CSJ. (Approval to use admixtures may be given only if accurate measurements of the amount of the admixture being added can be verified for any specific area placed.)
- f. Check each load of concrete visually for obvious problems such as wrong size aggregate, high slump, etc.
- g. Check forms, previously placed shotcrete, masonry, or other material to which shotcrete is to be placed and assure it is free of dirt, standing water, oil, grease, debris, rebound, or any other material that could interfere with the bonding of the shotcrete. Pay particular attention to drainage fabric placed over vertical earth cuts. Make sure the drainage fabric is "nailed" to the earth and does not move during application of shotcrete. (Note: the weight of overspray on drainage fabric can cause it to sag during shotcreting. This is unacceptable and must be corrected.) Notify the soils EOR and CSJ immediately if significant cave-ins occur resulting in voids behind the wall where shotcrete is applied directly onto vertical earth cuts. Voids in excess of a few cubic feet and frequent small cave-ins should be reported. All concrete contaminated with earth shall be removed.
- h. Before the application of shotcrete verify that the surface to be shotcreted is thoroughly wet, and that free water does not remain on the surface.
- i. Verify that the nozzle, nozzle's assistant, pump, air compressor, and nozzle are the approved personnel and equipment for the project.
- j. Verify that guide wires are set at specified thicknesses, are located at intervals sufficient to ensure proper thickness and that they remain tightly strung throughout the placement.
- k. Verify that joints are properly cleaned and sloped. If the reinforcing steel protruding from the lift is blown clean immediately after shotcreting stops, additional cleaning of the reinforcing may not be necessary. However, if overspray is allowed to dry on protruding steel it shall be removed prior to placing additional concrete. Where joints are placed on earth (for example, in top-down constructed permanent wall systems) special care must be executed to keep dirt from being incorporated into the shotcrete. A thin layer of sand shall be used to interface with the shotcrete for all but the cleanest of sandy soils. Also, such joints must be carefully contoured by hand to slope down in the back to accommodate cleaning the joint and placing the next lift down. In top-down construction after excavating the earth for the next lift down, the joints shall be cleaned, with air or water under pressure, to the satisfaction of the special inspector.
- l. Verify that the concrete deposited in the last pass of a lift has been roughened by scraping or other means approved by the EOR to improve the bond of the succeeding layer and to prevent a weak, porous joint.
- m. Verify that no rebound is used to patch holes or otherwise reintroduced into the work.
- n. Verify that reinforcement does not move during application of shotcrete.
- o. Verify that the nozzlers are using good ACI 506R-16 placement technique, paying particular attention to angle of placement, distance of nozzle to work, even distribution of concrete on the work surface, depth of pea gravel impact craters, etc. Monitor the consolidating of the shotcrete by making sure the nozzle keeps the nozzle moving sufficiently to prevent shotcrete from swelling out around the impact area (such material is not pneumatically consolidated and is not acceptable).
- p. Continuously maintain an observation position a few feet from the nozzle during actual shooting while remaining aware of the laborers moving pump lines, scaffolding, cleaning up rebound, etc., and stay out of their way.

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- q. Verify that the nozzle's assistant is in continuous attendance and keeps rebound blown out so it is not incorporated into the work. (Additional workers may be required to remove rebound if it cannot be removed by the air blow pipe.)
 - r. Verify that any area which sloughs off is removed and reshot. The shotcrete above and behind any sloughed off area may have moved when the slough off occurred. Any movement by adjacent shotcrete will result in voids around the reinforcement in these areas and is unacceptable. Cuts to remove shotcrete shall be vertical and perpendicular to the surface of the member. Where, in the opinion of the special inspector, movement may have occurred adjacent to a slough off, the shotcrete in question shall be removed.
 - s. Verify that samples for compressive strength tests are shot and stored in accordance with CBC 1908.10.
 - t. Verify that cores are drilled in accordance with the approved shotcrete procedure and schedule, and in the locations specified by the EOR. (Unless otherwise specified by the EOR, cores are drilled 2 days after the shotcrete is placed. If this does not happen the inspector shall notify CSJ immediately.)
 - u. Verify that specified curing procedures are followed. Verify that no material which may interfere with bonding is used in areas where finishing plaster coats, additional shotcrete lifts or other cement products will be applied. (Note: Where applicable, only water soluble curing compounds which will not interfere with the bond of additional concrete shall be used. Where shotcrete is cured with a chemical curing compound, good construction practice is to use two applications on vertical shotcrete members, the first being placed immediately after finishing the shotcrete surface, the second 8 to 16 hours later. Each application should be at twice the manufacturer's recommended rate for horizontal surface.)
 - v. Notify the shotcrete contractor immediately if shotcreting should be discontinued because of heavy rain, high wind, or low ambient temperatures (40 degrees F or less).
 - w. Promptly report to CSJ and the EOR any deviation from ACI 506R-16, CBC Section 1908, or this Plan Review Note, and immediately report any observed defect which was not corrected.
 - x. In addition to the general information required for all inspection reports, the shotcrete inspector shall report the names of the nozzle and nozzle's assistant, the brand names and types of pump, compressor, and nozzle; heights of lifts, slumps, total yardage used, and the type(s) of test samples taken.
9. The special inspection documentation requirements of item 8 may be exempted if the shotcrete contractor is certified by the American Shotcrete Association (ASA) as an ASA Advanced Qualified Contractor.