Chapter 5
Preconstruction Testing and Evaluation

5-1. General

Regardless of the size of the project, some form of preconstruction testing and evaluation must be done to assure that competent personnel, equipment, and materials are provided. Prior to application of shotcrete, the quality assurance team must assess the suitability of the shotcrete nozzleman, the materials and mixture proportions, the equipment, crew, and application process. These are confirmed by submittal or performance of:

a. Nozzleman Certification.

b. Mixture Proportioning Testing and/or Data.

c. Preconstruction Demonstration and Testing.

5-2. Nozzleman Certification

a. The success of any shotcrete application is dependent, in large part, on the skills and abilities of the nozzleman. It is imperative that only qualified individuals perform this work. Unlike some other work processes, the application of shotcrete cannot tolerate inexperience or marginal workmanship.

b. The ACI has an ongoing Nozzleman Certification Program. Specifications should require that all nozzlemen hold such certification. Certification requires the successful completion of a two-part written examination on general shotcrete knowledge and specific application knowledge. A shotcrete demonstration, the construction of test panels which are subsequently evaluated for strength, uniformity, and other applicable properties, is also required.

c. Final approval of ACI certified nozzlemen must be contingent on successful demonstration of abilities by applying shotcrete to preconstruction test panels.

5-3. Mixture Proportioning Evaluation

Unlike the evaluation of conventional concrete mixtures, shotcrete testing is difficult to perform in a laboratory environment. The equipment and technique are integral factors in the performance of the mixture. The mixture proportioning study should therefore be conducted under field conditions insofar as practicable. Mixture proportions are submitted in one of two ways, trial batching or historical data submission.

a. Trial batching. Mixture proportions or materials, which have had no previous use, are accompanied by data verifying material properties, mixture proportions, field conditions, test data, and performance. This work is performed specifically for the project on which it will be used. This process requires significant lead time, often in excess of 45 days, to attain the required 28-day strength results. More extensive testing will add more time to this process. This is not a laboratory exercise but a full-scale production of test panels with actual equipment, personnel, and materials. Test panels should be fabricated as described in paragraph 5-4: Preconstruction Demonstration and Testing.

b. Historical data. Often, materials and mixture proportions that will meet the requirements for the current project are available from use on previous projects. If past documentation and performance is acceptable, no further testing is necessary. Submission of the historical mixture proportions will suffice. This process greatly reduces the lead time required of the contractor. A historical data submittal includes all material data, mixture proportions, field conditions, and test reports or data summaries.

5-4. Preconstruction Demonstration and Testing

a. Acceptable equipment and personnel. Prior to placement of any shotcrete for payment, the contractor should demonstrate the acceptable performance of equipment and personnel. This is done by the fabrication of a series of test panels for each nozzleman. These test panels may also serve for approval of the materials and mixture proportions.

b. Test panels. Fabrication of test panels mounted in a framework is the typical way to evaluate the shotcrete process (Figures 5-1 and 5-2). A separate panel should be fabricated for each nozzleman, for each shooting position to be encountered in the structure; e.g., slab, vertical, or overhead. Where the field shotcrete will contain reinforcement, this should be duplicated in at least part of the panels to show whether sound shotcrete is obtained behind reinforcing bars or wire fabric. Each panel should be large enough to obtain all the test specimens needed and also large enough to indicate what quality and uniformity may be expected in the structure: not less than 30 inches square for mortar mixtures and

not less than 36 inches square for concrete mixtures. The thickness should equal that of the structure but should measure no less than 3 inches.

c. Specimen testing.

(1) At least five cubes or cores (Figure 5-3) should be extracted from the interior (at least 4 inches from the edge) of each panel for testing. Cores should have a minimum diameter of 3 inches and a length-to-diameter ratio (L/D) of at least one, if possible. Core strengths should be corrected for L/D as described in CRD-C 27 (ASTM C 42). Cube strengths may be reported as determined, or converted to cylinder (L/D = 2) strengths by multiplying by the factor 0.85.

(2) Panels should be cored or sawn no sooner than after 7 days of standard curing. The specimens should be tested in compression at 28 days to evaluate the mixture performance. It is not necessary to test at such a late age to evaluate the process. Depending on the expected strengths, testing at 7 or 14 days is adequate to determine the suitability of the nozzlemen and process.

(3) Beams for toughness evaluation and flexural strength testing can be sawn from the test panels. Typical beam dimensions are 4 by 4 by 16 inches. Beams must be sawn from the interior of the panel and not closer than 4 inches from any edge. Beams must be tested in the same orientation as shotcrete on the structure. For example, shotcrete for thin linings results in a fiber orientation parallel to the finished surface. Beams sawn from test panels should be tested with the shot surface normal to the load application.

d. Visual examination. Visual examination of sawn surfaces is the best method of determining the uniformity of the shotcrete. Panels should be sawn into quadrants after 7 days of standard curing. The cut surfaces of the specimens should be carefully examined, and additional surfaces should be exposed by sawing the panel when this is considered necessary to check the soundness and uniformity of the material. Figure 5-4 shows some problem conditions that may be encountered. All cut and broken surfaces should be dense and substantially free from laminations and sand pockets.

e. Accelerated testing. Often it is advantageous to correlate accelerated strength development of the shotcrete mixtures with the standard laboratory strength development. This correlation will allow determination of mixture performance at ages of 3 to 5 days. Special equipment and extensive laboratory evaluations are necessary prior to construction for this testing procedure.

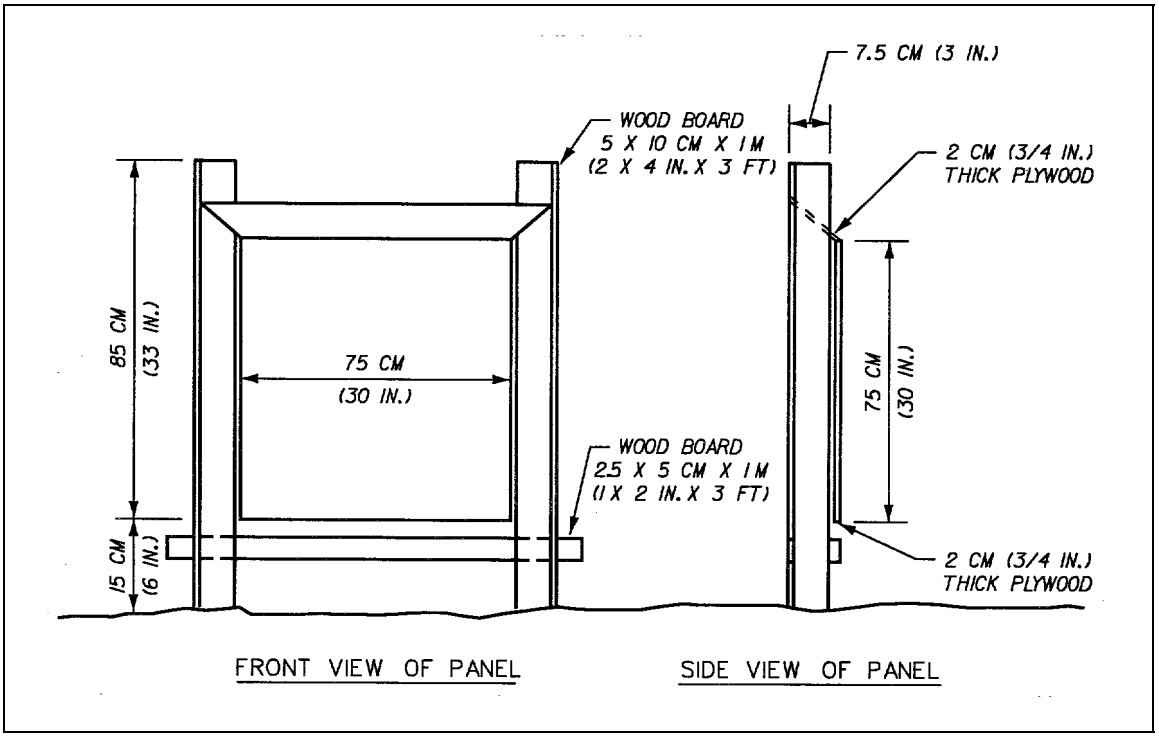


Figure 5-1. Test panel support system (Mahar, Parker, and Wuellner 1975)

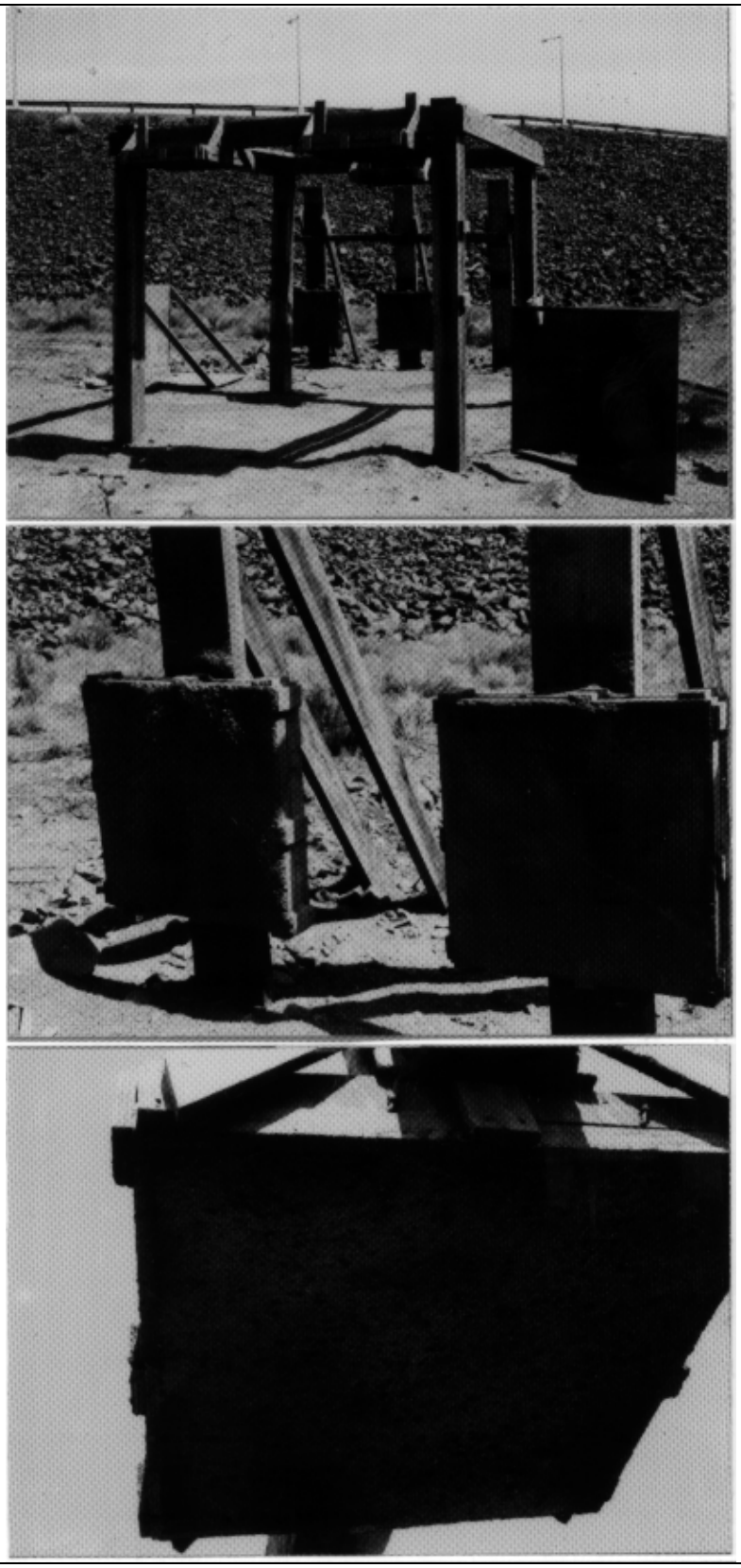


Figure 5-2. Test panel frame system

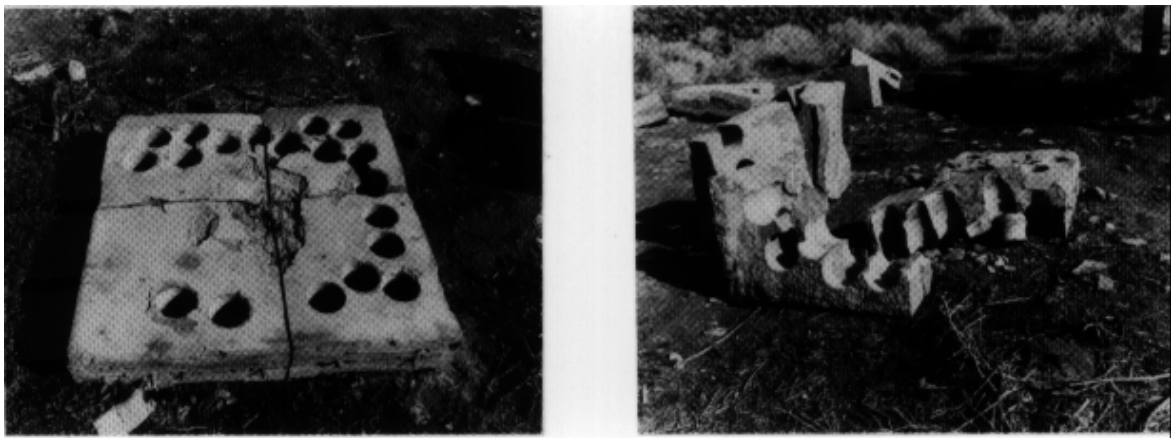
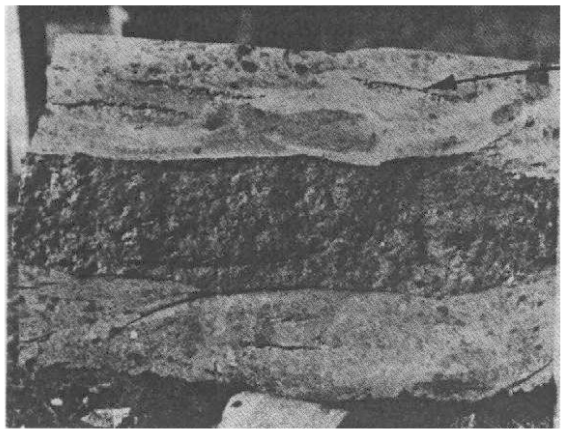
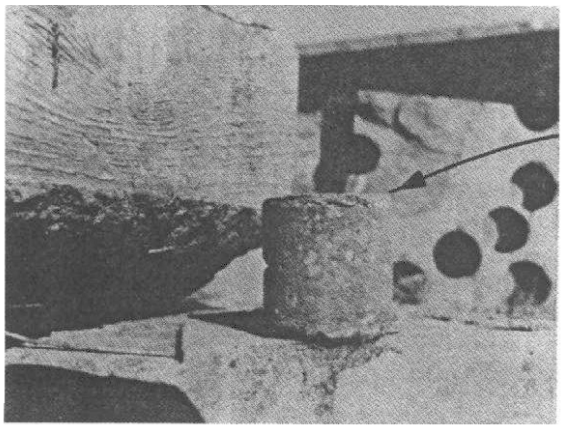


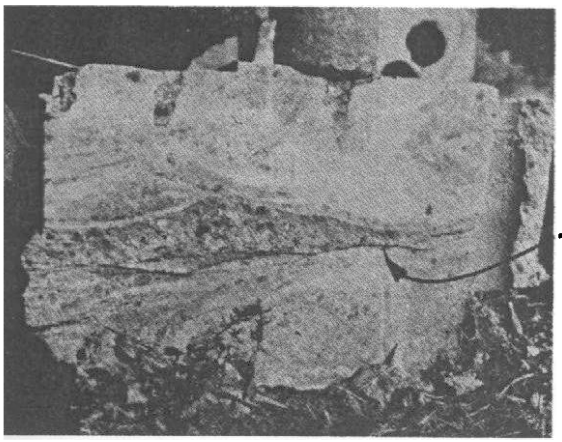
Figure 5-3. Cored and quartered test panels



VOIDS OR "SAND LENSES" CREATED DURING LAYERING PROCESS



DELAMINATED FLASH COAT ON FINISHED SURFACE OF SHOTCRETE



VOIDS BEHIND REINFORCING STEEL

Figure 5-4. Shotcrete problems obvious from a visual inspection

f. Load deflection testing. Fiber shotcrete performance should be specified by use of toughness index values as determined by CRD-C 65 (ASTM C 1018). The test procedure should be done using the specified equipment, preferably a deflection control testing machine of sufficient stiffness to not bias the results. Toughness index values, termed I5, I10, and I20, should be selected to be compatible with project service conditions. Designers should avoid specifying minimum limits for the I5 index and instead specify limits for the I10 or I20 indexes.

g. Other tests. Tests for absorption, drying shrinkage, resistance to freezing and thawing, and other properties may also be made if desired, using appropriate specimens cored or sawed from the panels.

5-5. Alternate Considerations

a. Typically, preconstruction testing and evaluation must precede the actual work by more than 30 days to allow time for nozzleman certification at the start and ending with strength testing at 28 days. This protracted start-up period may add significant costs to a small repair contract and may delay the start of actual construction.

b. In the case where previous acceptable mixture proportions information is available for the proposed materials and proportions, it may be advantageous to eliminate the later-age testing of the shotcrete mixture. Some contracting organizations have found it cost effective to evaluate the nozzleman and equipment at a site convenient to the contractor, often in conjunction with the contractor's ongoing work, to eliminate the early mobilization and extended standby time of equipment and personnel.

c. The designer must always consider the criticality of the shotcrete placement and the qualifications of the nozzleman when considering whether or not to waive some of the preconstruction requirements.