Performance-Based Specifications for Shotcrete Contracts

By Phil T. Seabrook

Performance-based specifications (P-BS) for shotcrete contracts have recently been introduced to the North American construction industry. They have been in use in Europe and elsewhere for some time. To the best of the author’s knowledge, they have not seen significant use for shotcrete work. Because shotcrete is simply an alternate method of placing concrete, it would not be surprising if they were not adopted. However, there is no reason to believe that shotcrete P-BS should not evolve. This article discusses the potential for the use of P-BS in shotcrete contracts and notes some realities in that process.

The original North American impetus for P-BS came from the ready mixed concrete industry to reduce the prescriptive specifications as a method of protecting proprietary processes. Recently, the American Concrete Institute (ACI) has been active in developing the base for such specifications. An ACI Innovation Task Group (ITG) has recently published ITG-8R-10, “Report on Performance-Based Requirements for Shotcrete,” and at ACI also devoted three major sessions at the ACI Spring 2011 Convention to this development. Some information presented herein is from those sessions.

Nature of P-BS

There are a number of definitions for P-BS, but ITG-8R-1010 states: “A performance specification defines required results, the criteria to judge performance, and verification methods without requirements for how the results are to be obtained.” In addition, ACI notes that P-BS are “alternate” forms of a specification.1

It should be recognized that the use of P-BS is an evolving process. Much of this evolution is likely to be driven by various government authorities. Most prescriptive specifications now contain some performance elements. An example is the requirements for fireproofing systems. Some authorities have presented hybrid specifications containing a mixture of prescriptive and performance requirements.

With regard to bonus/penalty, there is obviously a challenge involved in the question, “Is P-BS is of such a claimed benefit, why is an incentive necessary?” Authorities who shared their experiences with P-BS stated that the contractors all achieved bonus. Some authorities admit to setting the bar low so that a positive experience on initial contracts would be readily achieved, then the bar could be raised later. It is interesting to reflect on how bonus/penalty could be worked into a shotcrete contract. As for concrete, however, bonus could simply result from meeting the prescriptive criteria.

The matter of service life needs further exploration. It is now common for authorities to require 75 years for infrastructure projects. Then there is the challenge of defining how much maintenance is included in the calculation of life. The writer is not aware of any shotcrete projects where service life was specified or assessed by the design engineer. However, there is no reason why shotcrete could not be modeled in the same way that concrete is currently treated. Given that much of today’s shotcrete contains silica fume, and all service life models of concrete with silica fume show great advantages, the service life of shotcrete could be long with proper design and construction. Interestingly, according to Marc Jolin of the University of Laval, Quebec, QC, Canada, the university is now undertaking a project to evaluate the service life of various common shotcrete mixes.

To model a shotcrete mixture, it would be necessary to shoot a panel of the proposed mixture and core samples from it. The samples would be tested for diffusion and other transport properties required for the model. These properties would then be fed into the model with parameters of the structure and the projected service life would result.

Claimed Benefits of P-BS

The fundamental justification for P-BS in concrete construction is that it opens the door for innovation by the contractor (and concrete supplier) and now possibly a shotcrete sub-contractor. This is certainly true. Unfortunately, in some cases, this has translated into opening the door to construction or material choices that are simply cheaper and not necessarily in the interest of concrete performance. The justification assumes that the parties are capable of taking advantage of the benefits of P-BS through their technical abilities.

Innovation results in the use of materials and construction systems that are more suited to the project’s shotcrete environmental exposure; and

A bonus/penalty provision. This is stated by current users to be a necessary incentive for the contractor.

Acceptance Criteria

Those using P-BS all acknowledge that establishing acceptance criteria is a major challenge. Included in the criteria must be the required sampling plan, typically defining some form of core extraction. Such plans would be fundamental parts of the QMS.

Consider the example of acceptance of concrete compressive strength. Current codes require sampling at the end of the concrete truck chute for concrete acceptance (also sometimes for wet-mix shotcrete). For P-BS, the sampling for the owner’s purposes would likely be in-place, which would lead to testing of as-delivered concrete to the contractor’s or ready-mixed supplier’s quality control. This is a logical separation of responsibilities, but it would be necessary to define those responsibilities in a contract between the customer and supplier. Would failure of compressive strength be the result of the mixture, the consolidation in placing, or the subsequent curing?

Following are examples of some acceptance criteria that might be considered for shotcrete work (Table 1). In all cases, there is a challenge to define the “what if” the acceptance criteria are not met. This is where the penalty provisions have been used in some contracts. Many of these criteria measured by testing could not be confirmed until the service-life structure was months old. For most tests, it is necessary to define the required average value and also some minimum/maximum. This accounts for the within-test variations and isolated local lower-quality shotcrete. The spread between average and minimum/maximum can be varied with the precision of the particular test. As an example, the current ACI 318 code defines for compressive strength acceptance as having the average strength of cores greater than 85% of the specified strength with no single core less than 75% of that strength.
Table 1: Acceptance Criteria for Shotcrete

<table>
<thead>
<tr>
<th>Property</th>
<th>Criteria</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensional tolerance</td>
<td>Easily defined. ACI 117 is a guide. The main interest may be shotcrete thickness.</td>
<td>Need to define the type, amount, and frequency of measurement.</td>
</tr>
<tr>
<td>Surface finish</td>
<td>Common criteria are those in prescriptive specifications. Hard to quantify as performance.</td>
<td>No problem for as-shot.</td>
</tr>
<tr>
<td>Compressive strength</td>
<td>Criteria well established. Would probably require in-place sampling as well as panels for quality control.</td>
<td>Only an indirect measure of durability.</td>
</tr>
<tr>
<td>Absorption</td>
<td>Acceptance criteria well established and recognized in the industry.</td>
<td>Can be used as both a qualification and quality control test.</td>
</tr>
<tr>
<td>Water-cementitious material ratio (w/cm)</td>
<td>This is currently the base for durability assessment of concrete in all codes.</td>
<td>Some are measuring this in the field with the microwave test. Presumably that test could be used for both wet- and dry-mix.</td>
</tr>
<tr>
<td>Resistance to chloride ion penetration</td>
<td>General criteria for acceptance now available.</td>
<td>Test not commonly conducted on shotcrete but it could be done. Test normally conducted on concrete at 28 to 56 days or later age.</td>
</tr>
<tr>
<td>Diffusion, surface, and bulk</td>
<td>Test procedures established, but no quantified acceptance generally recognized.</td>
<td>Considerable research ongoing. A few authorities have used diffusion for qualification and even quality control.</td>
</tr>
<tr>
<td>Freezing-and-thawing resistance</td>
<td>Criteria for acceptance well established.</td>
<td>Test seldom conducted on shotcrete. Beam samples would have to be cut from shot panels. Qualification test only. Test can take 6 months.</td>
</tr>
<tr>
<td>Bond to substrata</td>
<td>Test procedure available, and there is a general agreement on achievable values for shotcrete.</td>
<td>Test results highly variable, requiring a large number of tests and proper interpretation.</td>
</tr>
<tr>
<td>Reinforcing bar encapsulation</td>
<td>This would have to be defined by the designer.</td>
<td>The use of core grades in the current ACI 506.2 standard is being discontinued for all applications except nozzlemen certification, so new criteria has to be developed. ACI 506 is addressing this.</td>
</tr>
</tbody>
</table>

Note that a number of these tests would only be used for qualification of the mixture. Consid- erable lead time would be required to complete them. Such lead time is seldom available in most current contracts.

Also, Table 1 shows that a significant challenge in acceptance is in defining workmanship properties.

Application of P-BS to Shotcrete Work

The requirement to use in-place samples for assessment of the end product can readily be accommodated in shotcrete.

The pending revised ACI 506.2, “Specification for Materials, Proportioning, and Application of Shotcrete,” has many of the elements that would be required for compliance with a P-BS contract. Examples include:

- The shotcrete industry has embraced the ACI Nozzleman Certification and most experienced shotcrete contractors can readily provide certified nozzlemen. Close to 50% of the shotcrete mixtures in the world are purchased through nozzlemen. The specifications for this certification are being updated. The use of nozzlemen would essentially allow for a P-BS type of verification of quality with the nozzleman as the key control person.

- Shotcrete is used in a large number of projects, large and small. It is not always possible to have in-place samples for assessment, although it is highly desirable. The use of precast concrete panels for precast shotcrete animals is increasing. The recent ACI Committee 502.19 has a guideline for quality control of precast shotcrete, i.e., “Guideline for Quality Control of Precast Shotcrete (ACI 502.19R-99),” American Concrete Institute, Farmington Hills, MI, 2003, 10 pp.

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P-BS is ideal for design-build projects because, by definition, these projects are performance-based. It is possible that increases in design-build projects will lead to the development and adoption of P-BS.

A Look to the Future

P-BS is not for all projects. Most projects, however, could benefit from hybrid specifications that combine prescriptive and performance-based specifications.

Projects where P-BS are currently being used are not those that would commonly be undertaken by shotcrete contractors, except perhaps as a subcontractor. However, there is no reason why the shotcrete portion of a large contract could not be performance-based.

This is an evolving process and, as the industry becomes more sophisticated, it is probable that some shotcrete contractors will look to P-BS to take advantage of their innovative approaches to common concrete construction challenges. Innovative uses of shotcrete can also result in substantial advances in sustainability of the final concrete structure.

References


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