Care & Feeding of Your Engineer on Shotcrete Projects

By Christoph Goss

Most readers of this article have probably had some terrific — and some less than terrific — experiences on shotcrete construction projects. While some projects just sailed along smoothly with everyone wanting to work together again, others were a miserable slog that might have ended up in lawsuits. Often the project experience is driven by the relationship between the engineer and the contractor. As an engineer working at an engineering company and spending a lot of time on job sites, I would like to share some thoughts aimed at contractors who would like to have more effective communication with their engineers.

STARTING OFF WELL

One of the defining characteristics of engineers is that they dislike risk. As Scott Adams's *Dilbert* once stated, "It is the goal of every engineer to retire without getting blamed for a major catastrophe." This attitude likely came from engineering design, where you come up with every possible way something can fail and design to avoid that. Concrete can fail in a variety of ways; including shear, compression, diagonal tension, bending, and debonding.

Designing to avoid these failure modes requires assumptions for the calculations of concrete strength, thickness, and bond. Once the calculations are complete, the engineer prepares drawings and specifications for bidding and construction. These specifications then typically require submittals and testing, both before and during construction, to show that what is being built matches the assumptions in the calculations.

"I love submittals" is a phrase that no one has ever said. Submittals are tedious to prepare and review, but they are also vital to effective construction communication between the contractor and engineer. In submittal packages, contractors describe how they will build the designed project, who will build it, the materials that they will use, and how it will be tested. By describing how and with what the project will be built, the engineer can verify assumptions, and the contractor can propose value engineering options. It is much cheaper and more effective for all parties to do this before mobilization than in the middle of construction.

THOUGHTS ON CONCRETE MIXTURE DESIGN

Concrete mixture designs are one of the key submittals on a shotcrete placement project. While the engineer is most concerned with the final in-place specifications (strength, sometimes permeability or shrinkage), the mixture must be effective for shotcrete placement. That means it must:

Fig. 1: If a dozer runs over your panel, throw it out

- Be pumpable for the project delivery line setup;
- Give enough working time, and;
- Be shootable for the specific project needs

For example, some mixtures are optimized for overhead placement, others for pools, others for thick highly congested reinforced walls, and others for small repair patches. There is no single perfect concrete mixture. During the preconstruction submittal phase, it is best to get several mixtures approved for flexibility and fewer delays — ideally from different suppliers in case a plant is unavailable. Another good idea is to have prepackaged bags of an approved mixture on site that can be mixed and used when no off-site supply is available.

Fig. 2: Shooting test panels

Specifications typically require the mixture design to include information on the various components because small details can have a major impact. For aggregate, this includes sizing and mineral properties for potential alkali-silica reaction problems. For cement, the type (C-150 I-V or C-595 1L) along with supplementary cementitious materials like fly ash, slag, and silica fume are critical. For chemical admixtures, the focus should be on compatibly between both the chemical admixtures and the cementitious materials. For underground projects, dosage and rapid-set accelerator compatibility with the rest of the mix is critical. The intent is to avoid unpleasant surprises in the field. If you are on a state DOT or some federal projects, find out if they require special testing or pre-approval by their labs.

WHAT IF THE SPECIFICATIONS ARE BAD?

As an engineer, I find bad specifications appalling; fortunately, there is an effective solution. The American Concrete Institute (ACI) publishes the following guides, tech notes, and specifications for shotcrete placement:

- ACI PRC 506-22: Shotcrete - Guide
- ACI PRC 506.1-21: Fiber Reinforced Shotcrete - Guide
- ACI SPEC 506.2-13 (18): Specification for Shotcrete
- ACI PRC 506.4-19: Guide for the Evaluation of Shotcrete
- ACI PRC 506.5-22: Specifying Underground Shotcrete - Guide
- ACI PRC 506.6-17: Visual Shotcrete Core Quality Evaluation - Tech Note
- ACI PRC 506.7-23: Shotcrete Preconstruction Mockup - TechNote

If you find a section of the project specification unpalatable, look up that section in the ACI documents and politely point out the discrepancy to the engineer. In most cases, the engineer will agree that following these recommendations is acceptable. For bonus points, check out ASA's searchable *Shotcrete* magazine archive (**shotcrete.org/articles**) and share with the engineer some similar projects where shotcrete placement and your approach were successful.

TESTING IS PROGRESSING

During or upon completion of the submittal process, other pre-construction qualifications are carried out. This typically involves the shotcreters demonstrating that they can shoot what is required for the project with preconstruction panels. In some cases, it is just a material test panel to confirm the concrete's hardened properties, while for projects with complex geometry or congested reinforcement, a mockup panel representing the most challenging configuration is required. The material or mockup panel should be shot using the proposed concrete mixture and shotcreting equipment. Material test panels are normally shot vertically. Mockup panels are generally shot in the same orientation as needed on the project. Get the number and type of panels required sorted prior to construction.

Once construction begins, the field quality control (QC) program is used to demonstrate that the shotcrete placement meets the design requirements. The QC plan should be a submittal describing what kind of panels will be shot at what intervals, as well as how and by whom they will be tested. Check the plan against both the project specifications and the ACI recommendations or requirements. Keep an eye out

for specific requirements — for example, instead of using standard shotcrete material test panels, is it acceptable to take concrete material cylinders at the truck, or is coring of in-place material required? Testing requirements must be clear before the project starts construction.

EDUCATE EVERYONE

The next suggestion is a hard one: Consider educating the inspector to be a growth opportunity for all, instead of a shouting match that makes your ready-mix trucks time out. If you have regular inspectors on site, take the time to teach them about shotcrete placement and the ACI recommendations. Even better, let them know about the ACI Shotcrete Inspector Certification. ASA's "Quality Shotcrete – Know It When You See It" seminar is more than just the education that supports ACI's Shotcrete Inspector program; it also provides knowledge about industry standard shotcrete practice you can use in your efforts to educate. Having an ACI-Certified Shotcrete Inspector on your team also makes sense: It ensures your crew delivers high-quality shotcrete placement on every project while also giving you the credibility to show your project owner or less experienced inspector what quality shotcrete placement should look like. If you already have the required work experience, add this credential to your company's offerings as well, starting at **shotcrete.org/inspector**.

MATCH TO KEEP MOMENTUM

During construction, ensure that the shotcrete placement matches what you documented in the submittals and QC plan: Engineers hate discrepancies and will call you out. Use the right material and equipment, and make sure that the crew has the lighting, ventilation, access, and safety equipment to let them do a good job safely and efficiently. Empower your crew, particularly the shotcreter, to stop work if the material is not right or the equipment is malfunctioning. It is much less expensive to send away a truck or have the crew on standby than to spend several shifts removing defective concrete.

Invite the engineer and inspector to watch the placement and show them how the shotcreter controls the placement sequence, distance, and angle. If you see the crew doing something incorrectly or unsafely, stop the shotcreting in front of the engineer and correct it. Proper placement the first time is in the best interest of all.

During placement, have an effective method of measuring shotcrete thickness and share that with the engineer. It can be a grade line, internal template, monitoring nails, pattern rock bolts with constant hardware stick-out, or pre- and post-placement Lidar scans.

Compare the theoretical volume to the actual volume and see if they make sense. If you are using a rapid-set accelerator, check the actual volume used for each truck and compare that to the mixture design and preconstruction testing: Too little accelerator will make the shotcreted concrete more likely to fall or have low early strength, whereas too much accelerator will weaken it.

For materials testing, make sure that test panels are protected for at least 24 hours and then carefully taken to the lab: In colder weather, significantly more than 24 hours may be required to have adequate strength to tolerate moving to the testing lab. You want to make sure that they reflect what you are doing in the field. Also, confirm that the lab knows

Fig. 3: Shooting underground on a platform with good light and ventilation

Fig. 4: Use guides for alignment and thickness

how to sample panels and test shotcrete. Get the results to the engineer promptly, but check the results before you pass them on. If a tested sample does not meet the specification requirements, figure out why, point it out, and have some corrective measures ready — do not wait for the engineer to tell you that a test failed, because it suggests that you are hiding something.

YOU'RE ON THE SAME TEAM

If you have a better or different way of doing the work, explain well in advance why your way is better, and with lots of detail.

- Get technical and document your assertions; provide data (the more the better), testing (standardized), and experience.
- Reference ACI shotcrete documents or ASA's *Shotcrete* magazine articles to prove your recommendations have been used successfully.
- Present facts, not vague thoughts — certainly not sales pitches — and be transparent about what you know and do not know.
- Be realistic about the pros and cons.
- Give the engineer time to digest the data and do independent research.

If you are not sure what the engineer is looking for, read the specifications and plans. Get the engineer onboard with your approach, and the project will go more smoothly.

Throughout the project, keep in mind that the contractor, owner, suppliers, and engineer all want the same thing: A project built correctly and within budget.

Disclaimer: These are my thoughts and do not necessarily reflect those of Schnabel Engineering.

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