Shotcrete Nozzleman Basics—Vertical Wall Construction

Why Specific Techniques at the Footing to Wall Joint Are Essential to Product Quality

By Oscar Duckworth

Shortly after the wall was built, it began to leak. Although the owner was unhappy, the crew thought that it was not much of a problem. Coring of the work revealed more trouble than anyone could have imagined.

Placing shotcrete at the construction joint of a concrete footing is a typical procedure. To a nozzleman, this step may appear simple. Begin at the bottom—no big deal. As basic as this may appear, there is much more to the initial shotcrete placement step than you may think. A closer look at the first moments of shotcrete placement will reveal that there are critical—and often overlooked—placement techniques that must be used by the nozzleman and crew to avoid creating hidden structural defects. Specific placement techniques are required to generate satisfactory in-place material at the footing to wall joint. To be effective, the nozzleman must be knowledgeable in these techniques. The long-term performance and durability of the wall depends on it.

Why the Bottom Matters

To understand the critical nature of shotcrete applied along the footing to wall joint, it is important that the nozzleman know more about what is required of the shotcrete material. Concrete and shotcrete are essentially the same material, differentiated by their placement methods. Engineers know that concrete displays behavioral properties that are unique to the product. Concrete can be designed to possess very high compressive strength, but concrete does not perform well in tension. In simple terms, concrete is difficult to crush but can be pulled apart quite easily.

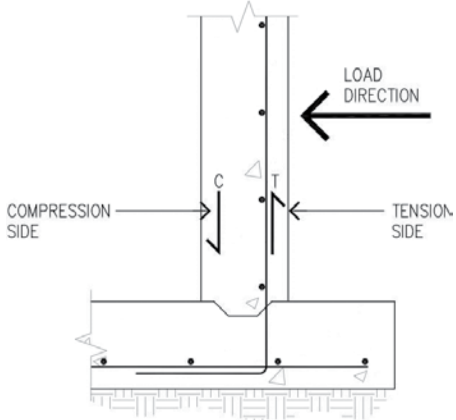


Fig. 1: Concrete compressive strength, f'_c=4000 psi (27.6 MPa). Tensile strength, 8 to 13% of f'_c

Engineers must design around concrete's unique physical properties. Most structural concrete elements are designed to use the reinforcing steel embedded within the concrete to carry the required design loads of the structure. These standard design criteria require the concrete for two main purposes. The concrete must permanently retain the reinforcement at a specific position within the element and must provide the reinforcement with long-term corrosion protection. Traditional wall designs incorporate embedded reinforcement locations that place the concrete at the bottom of a wall within its naturally occurring strong direction (refer to Fig. 1). Loads applied to this wall configuration will force the concrete on the face side of the wall into compression and the reinforcement steel into tension. Concrete works well under compressive loads and steel performs well in tension. For this design to function, the wall's lower areas cannot contain low-compressive-strength concrete or loose materials that can transmit moisture to the reinforcement. Pneumatically applied shotcrete wall designs mirror these standard design parameters because shotcrete is essentially concrete placed through a nozzle.

Why Is Shotcrete Different?

Although the plastic and hardened properties of concrete and shotcrete are similar, the placement procedures of each discipline can strongly affect those mixtures' long-term performance characteristics. This is especially true at the footing to wall joint. By comparison, standard concrete placement operations use mechanical vibration or the use of self-consolidating mixtures to place and encase reinforcement at the bottom of a formed wall. Dense, high-quality concrete must be in place here. The design parameters of the job depend on it.

Shotcrete placement methods use nozzle velocity and impact energy at the receiving surface to achieve required encasement and consolidation of the material. During initial shotcrete placement, impact energy from the high-velocity nozzle stream unintentionally separates some of the mixture's large aggregates as they strike, then rebound off the receiving surfaces along the construction joint. Rebounded aggregates are generated by nozzle velocity; therefore, rebound cannot be prevented. These rebounded aggregates tend to accumulate in the joint during placement (refer to Fig. 2).

Loose aggregates lack sufficient paste to develop required strength and do not provide necessary moisture resistance to protect the reinforcement. Loose rebound cannot be tolerated within this critical area of the wall. By far the most preventable cause of moisture-related defects or reduced service life of a structure is accumulated rebound lenses and loose, unconsolidated rebound pockets within the in-place work (refer to Fig. 3).

If It Is Predictable, It Is Preventable

Rebound is predictable. Experienced nozzlemen use techniques to limit rebound development and remove rebound simultaneously during shotcrete placement. Dense, well-consolidated in-place material within the footing to wall joint is essential to product quality. Professional shotcrete crews use well-proven techniques to prevent trapped rebound from accumulating within this critical area.

Fig. 2: Loose aggregates collect along the construction joint ahead of the nozzle flow

Fig. 3: Dramatic example of loose rebound trapped within a corner

Professional Nozzlemen Prevent Accumulated Rebound by:

1. **The continuous use of a blow pipe**. The continuous use of a blow pipe is by far the most efficient method to eliminate rebound from accumulating in the construction joint. Its full-time use is required in many specifications. Rebound is always created. Without a blow pipe, rebound will accumulate in the joint area and create loose lenses or pockets. Contrary to what many believe, nozzle energy itself is insufficient to remove rebound once the material initially congregates. Therefore, if rebounded material is not immediately removed by a blow pipe, it will be covered by the following stroke, permanently encasing loose, unconsolidated masses within the work. Continuously use a blow pipe to keep the bottom of the wall clean and free of rebound as the nozzleman applies shotcrete at the construction joint (refer to Fig. 4).

Fig. 4: A blow pipe operator continuously removes rebound as a nozzleman places material at the construction joint

Fig. 5: A nozzleman following a blow pipe operator and using proper techniques at the construction joint

Fig. 6: Build corners higher than adjacent areas to minimize trapped rebound

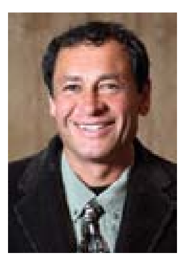
2. **Advanced nozzle techniques must be used at the joint**. Place the initial shotcrete layer by carefully developing a bench-shaped puddle of shotcrete along the bottom joint. Expert nozzlemen avoid shooting directly toward reinforcements or hard surfaces that are likely to generate excess rebound. They develop a puddle of in-place material that absorbs, rather than rebounds, the mixture's larger aggregates. Keep the nozzle close and shoot into, not away from, the puddle. Do not shoot with a nozzle angle that is perpendicular to the wall. Instead, direct the nozzle at an angle to shoot perpendicular to the puddle's receiving surface. The nozzle stream will strike the fresh puddle, not the hard surfaces of the footing or form. This nozzling technique will not eliminate rebound development but will diminish rebound dramatically. Keep an angled taper to all benched shotcrete. This will help rebound roll out, not into a wall section (refer to Fig. 5).
3. **Start in the corners first**. Work from the corners first to keep rebound and other loose material from becoming trapped. Create a bench that simultaneously works up both sides of a corner higher than the adjacent area to minimize trapped rebound (refer to Fig. 6).
4. **Properly encase water stops**. Water stops are common details at many construction joints (refer to Fig. 7). A nozzleman must exercise caution when encasing water-stop products during initial placement. Water stops can move or fold over from nozzle stream velocity. Water stops are likely to trap excessive rebound due to their location within the construction joint. Reduce air delivery at the nozzle to avoid deforming or dislodging the

water stop. Continuously blow rebound and loose materials out of the "shadow area" created by the water stop. An installation-related water-stop failure cannot be easily repaired. The nozzleman must visually validate the water stop's shape, location, and cleanliness as it is being encased.

5. **Watch your work**. Prior to placement, ensure that the footing to wall joint is free of dirt, construction debris, or standing water. Roughened surfaces in saturated surface-dry (SSD) conditions at the footing joint will promote bond of the fresh layer. During placement, use your eyes and watch for rebound accumulation and react accordingly. You are the only person who can see the material as it is placed. A skilled nozzleman's leadership skills, visual observations, and attention to details are critical at the construction joint. If rebound accumulates, direct the crew to cut suspected rebound pockets out of the fresh work and reshoot them. Skilled nozzlemen know that the bottom of a wall can be the most challenging area to correctly place shotcrete material. Specific nozzleman placement techniques to control rebound accumulation at the footing to wall joint are critical to attaining a quality product.

Poor workmanship does not simply disappear—it gets covered over. Accumulated rebound lenses at the footing to wall joint can lead to serious long-term structural issues that can come back to the shotcrete placement company as a costly repair. Fortunately, rebound-related flaws are completely avoidable through the use of proven placement techniques that effectively remove rebound and limit its development.

Fig. 7: Properly installed water-stop products are important components to wall construction designs



*ACI Certified Nozzleman **Oscar Duckworth** is an ASA and American Concrete Institute (ACI) member with over 15,000 hours of nozzle time. He has worked as a nozzleman on over 2000 projects. Duckworth is currently an ACI Examiner for the wet- and dry-mix process. He is also on the ASA Board of Direction and Chair of the ASA Safety Committee. He continues to work as a shotcrete consultant and certified nozzleman.*