Dealing With Reinforcing

by James Warner

Shotcrete frequently contains reinforcing steel, and in the case of structural applications, reinforcing bars can be of a large size and closely spaced. Heavy structural shotcrete has not yet been practiced in many parts of the world, and until recently, even the American Concrete Institute in their "Guide to Shotcrete" stated: "Good practice dictates that small bar sizes be used, with #5 (No. 15M) bar being the maximum size." This notwithstanding, the fact is that literally tens of thousands of heavily reinforced shotcrete applications with large diameter reinforcing bars have been successfully completed over the last half century.

Figure 1: With the wet mix process, the nozzle can be discretely directed into and through the reinforcing.

Leadership for such use came from California as a result of the need for seismic strengthening and repair of earthquake damage. Such applications started in response to a mandate to strengthen school and hospital buildings following the 1933 Long Beach earthquake. As the practice evolved, ever larger and more heavily reinforced sections were required, and it is now common to see multiple layers of reinforcing and individual bars as large as 1.7 in. (43 mm) in diameter. Nozzlemen do, however, require training to properly complete such work.

As the projected stream of shotcrete hits the relatively hard surface of the reinforcing, the larger particles tend to ricochet back as rebound. With well spaced small size bars, the quantity of this is minimal; however, as the bars become larger and the spacing tighter, the amount increases significantly. Rebound will tend to gather behind the reinforcing, particularly where large bars or multiple layers exist. Prevention of rebound embedment is thus required as is complete filling around the reinforcing bar. To accomplish this, well established procedures are available.

Whereas the techniques are similar for either the dry- or wet-mix process, use of wet mix offers substantial advantages in heavily reinforced work. Unlike dry mix, dispersal of the material as it strikes the receiving surface is not required, as wet mix is uniformly blended prior to entering the gun or pump. As a result, manipulation of the nozzle

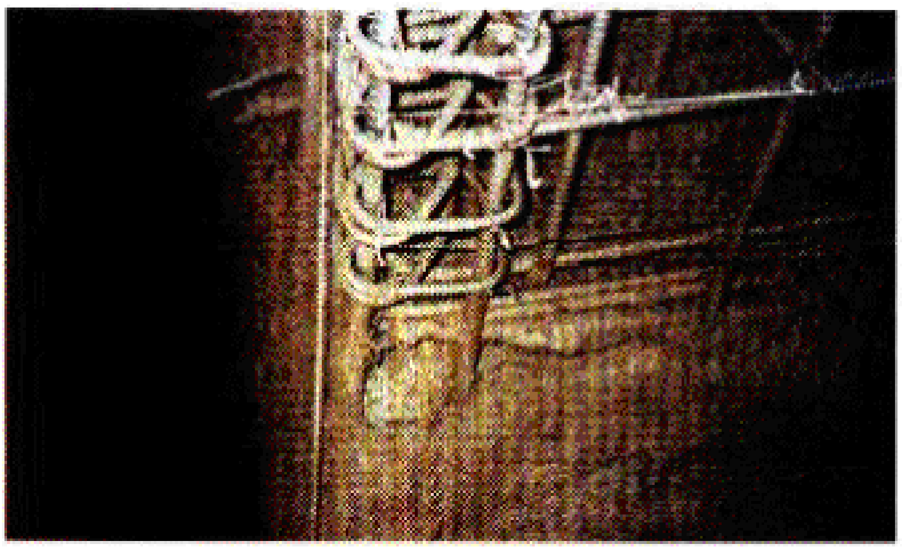


Figure 2: Ground wire delineates finish of a corner without restriction of nozzle trajectory.

Figure 3: Small diameter steel rod delineates final curvature contour of a bridge pier.

Figure 4: Nozzle is actually pushed into the reinforcing in order to completely fill this thick, heavily reinforced section.

Figure 5: The working face should always slope in both directions to enable rebound to roll off.

to complete mixing is not necessary, and the nozzle can thus be discretely directed through and behind the reinforcing bar, resulting in reduced rebound and facilitating the filling of isolated areas behind and around the individual bars (Fig. 1).

The reinforcing must be thoughtfully designed, specified, and placed. The particulars will depend upon which shotcrete process is used. Because nozzle manipulation is required to complete mixing in dry-mix work, individual bars in multilayer installations should be offset. Conversely, in the use of wet mix, which enables discrete nozzle movement, it is usually best to stack the bars of multilayer installations. This is especially so in the case of bars that are very large, closely spaced, or where many layers exist. To minimize congestion, lap splices should be avoided. This is easily accomplished by the use of mechanical splices. The selection of mechanical splices should consider the amount of space they will occupy, and only those that are most compact should be used. In extreme cases, the layer of reinforcing nearest the shooting face might be prefabricated but not installed until after the more distant shotcrete has been placed.

A fundamental requirement is to provide the maximum possible latitude for nozzle trajectory to facilitate filling around and behind the reinforcing, allow for the unimpeded escape of air and rebound, and minimize the opportunity for rebound to accumulate. Because of the greater importance of these factors in structural work, special procedures must be used, and in many cases a departure from otherwise common practice is required. The use of forms and/or rigid guides for alignment control should be avoided in order to broaden available nozzle access. For alignment control, ground wires (Fig. 2), which contribute virtually no interference with nozzling, should be used. For curved surfaces, 0.25 in. (6.4 mm) "pencil rod" can be installed to the required configuration (Fig. 3).

When encasing large or congested reinforcing, the nozzle must be aimed so as to fill behind the reinforcing bars, and is often positioned at unusual angles to the plane of the work. This is contrary to the preferred practice of maintaining an angle of impingement of about 90 degrees, but is nonetheless necessary. Also, it will usually be held much closer than in traditional work, and will often be held very close to the reinforcing, and in some cases actually penetrate the outer bars, as seen in Fig. 4.

The nozzleman must be ever alert to minimize the rebound amount, and most importantly, prevent entrapment of that which occurs. The amount will vary, but will always grow as the density or congestion of reinforcing increases. Shooting should start at corners or ends of a section, and the working face should always slope away therefrom. Thick sections should be built up in layers that slope toward the face at an angle of about 45 degrees, so that any rebound will tend to roll off (Fig. 5). The top of the individual placement layers should always terminate between horizontal reinforcing bars.

Regardless of the nozzleman's skill, rebound will tend to accumulate behind the reinforcing and on the working surface. This must be removed and is best blown away with oil-free compressed air immediately as it gathers. A blowpipe operator equipped with a blowpipe

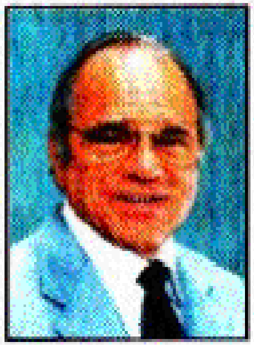
Figure 6: Use of a blowpipe constantly following the nozzleman is essential to prevent rebound accumulation in heavily reinforced work.

Figure 7. Construction joints should be located between horizontal rebar and sloped toward the face, to enable easy escape of rebound in succeeding work.

(Fig. 6) should follow the nozzle movement at all times and promptly blow off any accumulated rebound.

In order to facilitate the nozzling of subsequent placements, and to minimize the risk of rebound entrapment when shooting continues, construction joint locations and configuration should be judiciously selected. As a general rule, joints should be located between reinforcing bars and in areas of minimal reinforcement congestion, to the greatest extent possible. To reduce the risk of entrapping air and rebound in the succeeding work, horizontal joints should be inclined toward the face at an angle of about 45 degrees, as seen in Fig. 7.

With these procedures, which are well established and routinely used, quality shotcrete, even for very heavily reinforced sections, can be readily constructed.



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