What's the Hurry?

Effective tools to determine the correct stack rate

By Oscar Duckworth

Apparently, seeing the concrete truck arrive does not bring out the best in people.

I know seasoned concrete professionals who suffer painful anxiety on pour day in the agonizing moments before they must place tall form-and-pour walls. Experienced concrete workers know first-hand what may happen as enormous fluid pressures are contained within tall concrete formwork. Most days, the pour is uneventful and workers quickly return to their boisterous selves.

With the shotcrete process, placement of tall walls tends to be a little less stressful. That is because only momentary impact pressure over a small area must be carried by the form, whereas, in the form-and-pour approach, the full fluid head pressure must be carried along the entire length of the cast section.

Although placement of tall walls tends to be less risky with shotcrete placement, nozzlemen must be aware that shotcreted materials can be stacked in vertical lifts too quickly. When this occurs, internal stacking pressures can quickly escalate to levels potentially damaging concrete that has not yet reached sufficient strength to support the weight of the concrete above. Similar to the traditional form-and-pour operations, placing materials in very tall lifts can increase the risk of a failure, potentially collapsing large sections of freshly placed material. All nozzlemen know that stacking a wall in excessively tall lifts is a gamble, but collapse is only one of the potentially destructive effects that can occur.

Nozzleman Checklist

- Aggressive stack rates do not save time. The risk of injury, fallouts, waste, and damage to in-place work is completely avoidable.
- Movement can cause hidden cracks and delaminations of the in-place material. Learn to avoid potential trouble by recognizing the subtle cues of an excessive stack rate.
- Completely cut out and reshoot materials that exhibits signs of cracking, sags, or delaminations.
- Prior to placement, check reinforcement rigidity by giving it a firm tug. Visually validate that there is sufficient anchorage between front and rear curtains and to the substrate surface.
- Use the best tools available to you—your hands, eyes, and experience—to determine a safe stack rate.
- Plan to give in-place materials sufficient time to reach initial set before proceeding.

UNDERSTANDING THE STACK RATE

Ask a nozzleman to identify the correct stack rate. Most will reply: as high as possible. But experienced nozzlemen can describe, usually from their personal experience, a collapse caused by stacking a wall too quickly. Shotcrete should never be stacked excessively before the in-place material below reaches a sufficient set to support its own weight without deforming. Nozzlemen know this as the

Fig: 1: Moments after a potentially dangerous collapse of plastic material caused by stacking a wall too quickly

material's stack rate. Numerous job-specific placement conditions will influence how tall a given wall may be safely stacked per hour.

To enhance productivity and minimize hose movements, nozzlemen tend to attempt the tallest stack rate possible. Unfortunately, nozzlemen and other in-field workers may not be aware of the potential damage that can occur to the in-place work from overly aggressive stack rates.

SUBTLE CLUES OF TROUBLE

The obvious risk shotcrete crews encounter when building up too quickly is the risk of creating fallouts or a dangerous collapse (Fig. 1)—at minimum, fallouts, sags, and cracks caused by aggressive stacking waste material and time. Many times, vertical wall fallouts can create a risk of injury to workers. Even small fallouts may weigh several hundred pounds (kg). Because a fallout can occur unexpectedly, workers may not realize that they are at risk. Head, neck, and shoulder injuries—even potentially deadly scaffold failures—have occurred due to fallouts.

Far less obvious is the risk to in-place material quality from aggressive stack rates. Shotcrete nozzlemen who stack a wall too quickly negatively affect in-place quality well before the work is at risk of a fallout. Reinforcements specified for shotcrete placement must be firmly secured to remain in place and resist movement while the material is in its plastic state (Fig. 2).

Aggressive stack rates subject reinforcement and formwork to strong downward pressures from immense weight. Freshly placed materials are vulnerable to cracking, sags, or delamination damage from internal movement due to the weight of higher levels being carried through the fresh concrete that has not yet reached enough set (and strength) to carry the loads (Fig. 3).

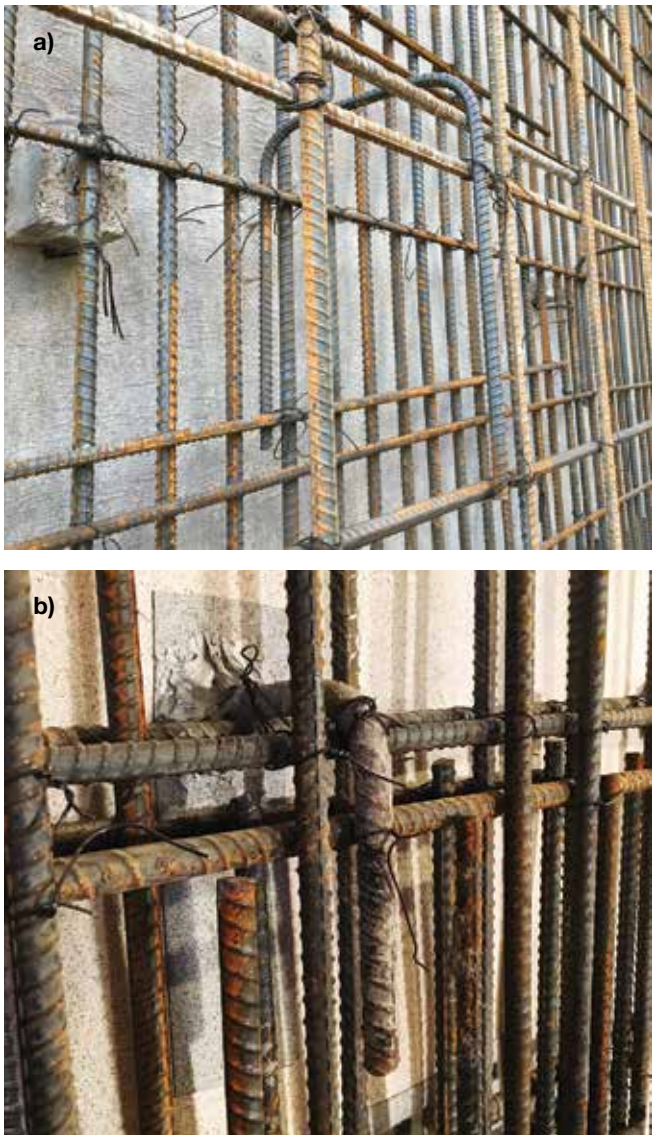

Fig. 2: Reinforcements must be sufficiently rigid to resist movements as loads are transferred to them from the stacking of plastic materials. Note: (a) inverted U-shaped transfer bars between curtains; and (b) rigid anchorage to the substrate

Fig. 3: (a) Visual evidence that excessive downward pressure has caused cracks within the plastic material; and (b) sagging materials have lost their bond with reinforcements and the substrate surface. These cracks, sags, or delaminations must be cut out and reshot

Downward force imparts pressures that act powerfully against the in-place materials, the receiving surface, and the reinforcement. As pressure increases, these pressures tend to distort the supporting previously placed concrete and embedded reinforcement. This can often push curtains of reinforcing apart and force them away from the receiving surface. The effects of the deformation and subsequent movement, whether within the material, forms, or reinforcement, tend to produce cracks and delaminations along the reinforcement within the work that will not reconsolidate (Fig. 4).

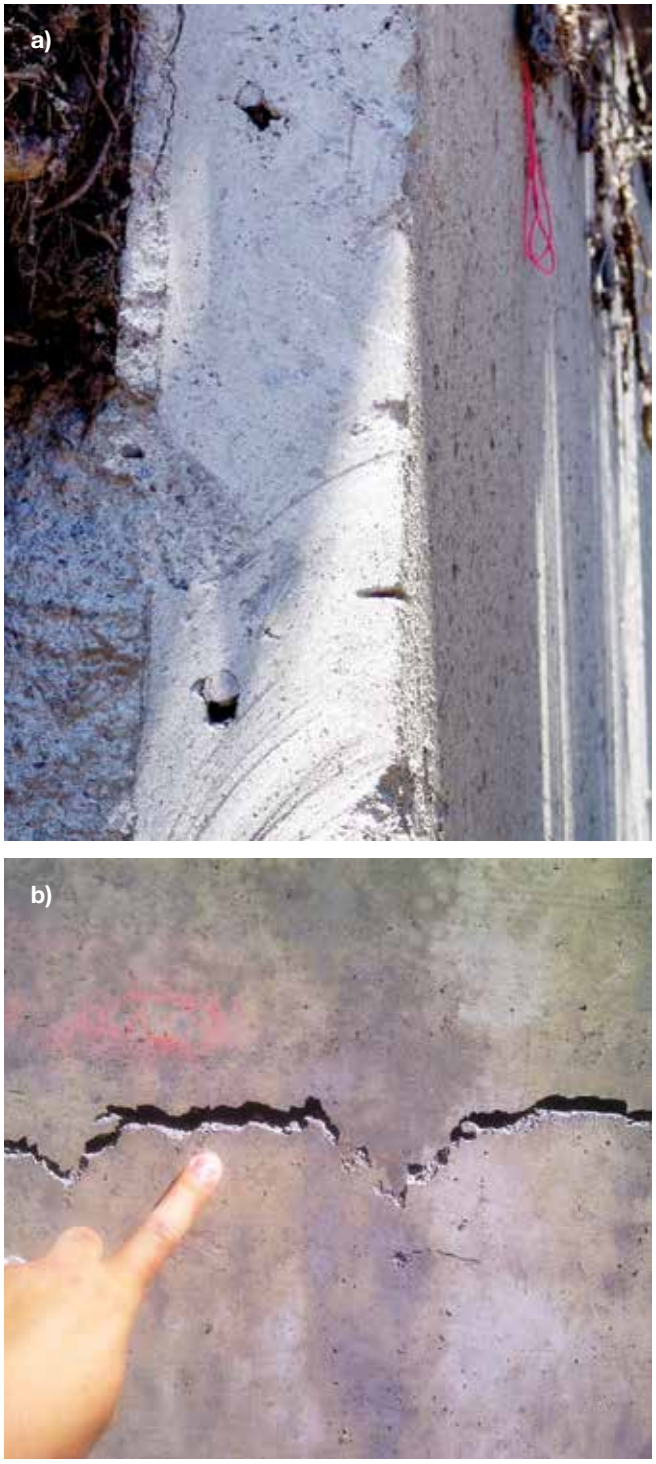

Fig. 4: (a) Saw cut reveals delaminations beneath reinforcements caused by downward movement; and (b) substantial crack visible from formed surface caused by excessive weight

Freshly placed materials that exhibit sags, cracks, or other delaminations lack structural properties and must be identified, completely cut out, and reshot before final set.

Choosing the proper stack rate should not be guesswork. The best stack rate gauges are the nozzleman's hands, eyes, and experience.

Damage and risk due to aggressive stack rates are caused by the actions of the nozzleman. Rather than shoot a very tall lift, then hope for the best, nozzlemen should choose the appropriate stack rate by using all the tools available to them. Placement condition variables invalidate simple 3 to 6 ft/h (1 to 2 m/h) stack rate guidelines. Cold weather, concrete mixture, substrate surface, reinforcement, low nozzle velocity, or excessively thick elements are just a few of the varying conditions that require nozzlemen to limit the stack rate.

Nozzlemen must determine the project's safe stack rate by using keen sensory skills, their hands, eyes, and experience rather than simply reaching "as high as possible." Prior to placement, nozzlemen should use their hands to tug the reinforcements and validate they are properly retained. During placement, they should feel in-place material, constantly validating sufficient set has occurred prior to placing additional shotcrete above previously placed material. Nozzlemen should keep a watchful eye for signs of movement within the reinforcement and the area below where fresh material is being stacked, and immediately stop if movement is noted. Nozzlemen should diminish risk by planning to allow more time for in-place materials to reach proper set before building additional height. Give in-place materials time by slowing the placement volume rate, increasing the horizontal length of a bench, or stop and move to another location.

It is important to remember that choosing the proper stack rate is the nozzleman's responsibility. Any efficiencies gained by shooting very tall lifts will be quickly erased by sagging, fallouts, or by hidden damage to in-place work.

*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 processes. He serves on the ASA Board of Direction and as Chair of ASA's Education Committee. He continues to work as a shotcrete consultant and certified nozzleman.*