



## Form-and-Pour to Shotcrete

By Ross King

In today's increasingly competitive and challenging structural concrete marketplace, the need for innovative solutions to challenging forming issues is greater than ever. Old standbys aren't the answer for increasingly complex requirements. These challenging issues require new and better solutions.

Not too long ago, form-and-pour methodology completely dominated the forming marketplace, but that's changing. Today, the marketplace is seeing structural shotcrete gain far greater acceptance as a more logical and efficient option for structural concrete applications. And with today's increased emphasis on sustainability and environmental responsibility, structural shotcrete is well-positioned to make further inroads and experience increased demand and growth.

Shotcrete for structural needs was first adopted on the west coast of North America beginning in California and

then eventually moving north to Washington state. Until relatively recently, however, shotcrete was rarely used in thick, heavily reinforced structural concrete applications east of the Rockies in the United States or in any parts of Canada. Over the last 5 years, however, recognition and acceptance of structural shotcrete in thick, heavily reinforced sections has now extended to the east coast and across Canada as well. This growth has been driven by the efficiency of one-sided shotcrete formwork panels for buildings and civic structures and the ability to produce high-quality concrete in place using wet-mix shotcrete placement.

The greatest barrier to acceptance in the early stages of adoption was a resistance by structural engineers, architects, and project owners to consider shotcrete as a viable alternative. The hard work and persistence of structural shotcrete pioneers on a prove-it-as-you-go basis, however, has steadily helped dispel concerns that existed in the past. Today, the acceptance of structural shotcrete as an option to concrete poured into two-sided forms built to contain high fluid pressures is commonplace. Structural shotcrete placement is now routinely included in project specifications for a wide variety of high-quality concrete structures.

Structural shotcrete offers several compelling advantages that are now coming to light and driving its growth in the construction marketplace:

- Substantially less formwork is required;
- The formwork that is required is substantially lighter in weight;



Fig. 1: Tall segmented radius, one-sided "shoot panels" for curved wall forming



Fig. 2: Architectural reveals and recessed panels on single reskinned shoot panels for curved wall prior to reinforcing bar placement

- Greater square footage (m<sup>2</sup>) per day can be delivered consistently;
- Project schedules are accelerated because of productivity and efficiency gains;
- Faster project completion translates into substantial cost savings;
- The inherent flexibility of shotcreting versus pouring reduces the complexity of many structural forming challenges; and
- More surface finishing options are available.



Fig. 3: Complex forming for architectural "Y" columns, using one-sided shoot panels



Fig. 4: Retaining wall with an architectural pattern of radiating reveals, with alternating broom-and-polished finish

## LESS FORMWORK

All vertical, two-sided formwork is designed to withstand a minimum of 600 lb/ft<sup>2</sup> (2900 kg/m<sup>2</sup>) of concrete head pressure. The resulting forms are substantial and heavy to carry this high internal pressure. With shotcrete applications, however, a one-sided form is all that is required and this form only needs to withstand 50 lb/ft<sup>2</sup> (240 kg/m<sup>2</sup>) of pressure. This reduced pressure requirement is a direct result of



Fig. 5: Complex shoot panel formwork for a church; notice the lack of internal bracing required in the window breakout



Fig. 6: Finished shotcrete structure using only one-sided shoot panels, eliminating the risk of voids in the slender pillars that can occur when using form-and-pour

the high-velocity, pneumatic application of the concrete impacting over a small area, as opposed to pouring in a form that has fluid pressure along the entire form length.

There's far less pressure at the bottom of a one-sided shotcrete form and the pressure resistance requirement is only to keep the form from moving or vibrating during the shotcrete placement. With the dramatic decrease in form pressure, forms can be much lighter and thinner than traditional form-and-pour panels. And with the need for only a one-sided form rather than a two-sided form factored in,



*Fig. 7: Tall, light one-sided shoot panels with pinwheeled corners and uneven base; not possible with form and pour*

overall formwork materials can be reduced by up to 75%. In addition, the reduction in form pressure means that details for corners, intersections, fillers, and bulkheads are easier to produce, resulting in significant material and labor savings.

The decreased volume of formwork materials required on the jobsite further reduces storage needs and crane requirements. The number of forms that must be stored offsite and transported to and from the jobsite is lessened; that also reduces costs while accelerating scheduling. By reducing the amount of formwork required and thus eliminating a substantial portion of transport requirements, a shotcrete application reduces the environmental impact of a project and contributes to more sustainable construction.

### LABOR AND SCHEDULE SAVINGS

When the quantity, size, weight, and complexity of onsite formwork are reduced, labor requirements are also minimized. The level of required labor skill is usually also lowered and this often allows skilled labor to be used in other high-demand project areas that are commonly strained during busy times.

When labor requirements decrease, schedules accelerate. Schedule acceleration reduces site overhead, which results in less consumption and greater sustainability.

The reduction of formwork requirements is especially advantageous in tight urban project sites. Fewer deliveries and materials onsite reduces crane time and frees up lifts for other critical operations, further contributing to schedule



*Fig. 8: Tall shoot panels braced from the shot side due to property line constrictions*

acceleration. As an additional bonus, fewer deliveries means less traffic congestion and in some cities, that equates to significant savings on lane closure fees associated with extended loading and unloading requirements.

On remote sites, the reduction in transport time and lessened crane requirements also reduces project completion timing and transport costs.

## SHOTCRETE ADVANTAGES IN SPECIALTY APPLICATIONS

With the combined savings achievable in materials, labor, and site logistics, structural shotcrete offers new forming opportunities not available or associated with two-sided form-and-pour methodology:

- Shooting or finishing a wall from both sides with stay-form or insulation in the middle;
- Laminating over an existing structure that is tight to the floor and ceiling with no access from above to pour concrete into traditional two-sided forms;
- Creating curved walls without the cost of building complicated two-sided curved formwork;
- Easily creating tapered concrete sections that provide the exact concrete thickness where needed;
- Creating shotcrete wall finishes similar to architectural floor finishes with color, stamping, carving, and offset facing not possible with traditional form liners; and
- Hoisting or formwork moving challenges encountered in constricted spaces such as subways and tunnels are mitigated or eliminated when the form panel size and weight is reduced, or rendered unnecessary.

## ENVIRONMENTAL IMPACT—SUSTAINABILITY

All areas of the construction industry are being impacted by increased pressure to contribute to more sustainable and environmentally friendly work processes—and rightly so. And while it's a challenge for many segments of the industry, this increased awareness and subsequent demand represents another significant opportunity for structural shotcrete to position itself as a better application alternative and continue to grow and flourish.

Wet-mix shotcrete placement creates a fresh concrete surface that can be a troweled, smoothly finished surface free of bug holes, lift lines, and form tie holes. The surface is denser and can be treated like an industrial floor. The result is a longer life cycle with added protection against freezing and thawing, chloride penetration, abrasion, and wear from environmental conditions. These characteristics enhance the overall sustainability of the shotcrete application methodology. Structures that last longer have less overall impact on the environment.

Rebound and waste concrete can be turned into a usable retaining wall and barrier blocks. This recycling of waste into marketable by-products further contributes to the sustainability of structural shotcrete in a significant and tangible way.



Fig. 9: Finish troweled curved wall, with post saw-cut architectural reveals



Fig. 10: Rebound and waste shotcrete cast onsite into useable retaining wall and barrier blocks, further contributing to the sustainability of shotcrete

From the offsite prefabrication and delivery stage right through to cleanup at the end of the project, structural shotcrete can increase sustainability and result in a more durable, longer life structure that requires less maintenance in the future.

When you add the sustainability benefits of structural shotcrete to the significant cost savings and schedule advantages it creates, it's not hard to see that structural shotcrete applications will continue to gain ground and truly represent a bright future for the construction industry.



**Ross King** is Vice President of Business Development for Torrent Shotcrete Group in Toronto, ON, and Vancouver, BC, Canada. He has more than 40 years of experience as a Principal in the heavy concrete construction business.