



Shotcrete—The Blindside Waterproofing Solution

By Ross King

The large cities of the world are growing and being rebuilt like never before. This city rebuilding and densification is increasing below-grade construction complexity and challenges due to smaller sites, close proximity to adjacent buildings, and traffic congestion. One of the most recent and rapidly growing solutions to deal with this boom in urban basement construction is the use of structural shotcrete. A particularly efficient and economical use is in place of traditional form-and-pour concrete construction for one-sided walls built at the building perimeter against excavation shoring tight to property lines, also known as blindsided wall construction.

The performance demands for blindsided waterproofing increase as the uses of these below-grade structures change. More buildings situated downtown are using the below-grade areas not just for parking, but for finished, occupied spaces that are far more sensitive to water intrusion (refer to Fig. 1). Add to this the boom in urban condominium construction and a resident lawyer on every condominium council, and water leaks can become very costly.

A new challenge in below-grade construction is rising in cities such as Toronto and Seattle, where the city is prohibiting groundwater discharge from basement drainage systems, or imposing an expensive metered charge



Fig. 1: Downtown high-rise hospital, below-grade blindsided walls, with shoring rakers and densely reinforced high-strength pilasters supporting 20 floors

on lift pumps to discharge into the city sewer mains. This will become more common as cities grow because existing storm or combined storm/sanitary sewers are not designed for the increasing density and are becoming overloaded and nearly impossible to upgrade.

The solution is to “bathtub” waterproof the below-grade structure, meaning not just the blindside walls but also the basement floor. This bathtub, or essentially a concrete tank, resisting the outside groundwater with no hydrostatic drainage relief, increases the need for more competent blindside wall waterproofing.

I see using structural shotcrete in combination with a proper blindside waterproofing system as a solution over traditional form-and-pour to address these new challenges by creating watertight and dry, below-grade concrete structures in our growing cities.

There is a wealth of information available on blindside waterproofing for both form-and-pour and structural shotcrete. Unfortunately, much of this information is written based on a long history of using form-and-pour and with a lack of knowledge of the structural shotcrete process. As a result, the information on the finished product typically relates to traditional form-and-pour. Also, most information and articles have been written from the waterproofing side, with at times the obvious lack of knowledge of concrete construction methods regardless of form-and-pour or structural shotcrete methods.

The goal of this article is to address and clarify the similarities and differences of both these methods of placing concrete in reinforced concrete structures while focusing on blindside walls below-grade to dispel the myths and show the advantages of using structural shotcrete in building construction.

To compare and show the advantages of structural shotcrete, the following points need to be addressed:

- Shotcrete is concrete;
- Form-and-pour versus structural shotcrete;
- Site conditions and building dynamics; and
- Types of blindside waterproofing.

SHOTCRETE IS CONCRETE

Many times, the structural shotcrete process is referred to as a product, as though we are substituting an alternative concrete mixture for ready mixed concrete. Builders and consultants need to realize that the concrete mixture used in wet-mix shotcreting is very similar. Whether for a small-diameter line pump or in a heavily reinforced, high-strength core wall, both require reduced aggregate size and a higher cement content. The only difference is that when they use these mixtures in form-and-pour placements, they need to have higher slumps, as compared to shotcrete placement that needs a lower slump (with the benefit of a lower water-cementitious materials ratio [w/cm]) depending on the stack rate, reinforcement density, and wall thickness.

Given that shotcrete is concrete, the next typical question is, “What are the differences in construction joints,

details, and sequencing?” The answer is, “none.” Construction joints, control joints, and placing sequences are not altered and use the same construction details as traditional form-and-pour.

Structural shotcrete experiences drying shrinkage as it matures and gains strength, the same as form-and-pour. This rate of concrete material shrinkage varies based on many factors. The major influences are aggregate size, w/cm , and curing. There are several ways to design for this shrinkage, including admixtures, reinforcement, and control joints. In the end, concrete cracks in different ways, sizes, and spacing, and at times induced by the overall structure settlement.

So, comparing the slight difference between concrete mixtures placed by form-and-pour and structural shotcrete to see whether the cracking occurs at 12 ft (3.7 m) on center or 14 ft (4.3 m) on center doesn’t really matter when comparing blindside waterproofing options. Stopping water flowing from any crack regardless of spacing is the goal, not by what method the concrete was placed.

When making critical blindside waterproofing choices, it is important for the waterproofing and building construction industries to address concrete crack control by making sure that control joints are properly detailed and spaced with adequate reinforcement.

Another factor I see that is rarely taken into consideration when choosing a blindside waterproofing system is linear shrinkage of the overall structure below grade. Proof of this often-overlooked movement is that buildings over a certain length commonly have delay strips or gaps designed into the structure to allow for contraction caused by shrinkage and are only filled in 28 days later. Common sense says that this shrinkage occurs in both horizontal directions regardless of the length, and pulls inward toward the center point of the structure, not just one way from the delay strip. This inward shrinkage, mostly restrained by the floor slabs, decreases the confining pressure against the excavation shoring substrate, which in turn can create issues for blindside waterproofing systems requiring confining pressure to work.

STRUCTURAL SHOTCRETE VERSUS FORM-AND-POUR

I have found when introducing the relatively new shotcrete process for placing concrete in blindside walls that the builders, engineers, and especially the waterproofing industry really don’t fully understand how the process works, nor the finished product. Because of this lack of overall knowledge and myths about the shotcrete process, and at times even the process of concrete placement for form-and-pour, incorrect statements and decisions are made when considering blindside waterproofing.

The number-one factor and myth to dispel is that it’s all just about the nozzle men. Over my 40 years of experience in the form-and-pour industry, it’s also been all about the vibrator man. The skill and necessity of these designated skilled persons is the same for either placement method, and the first major step to achieving high-quality cast-in-place concrete blindside walls. Proper compaction is essential.

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The next most important step required for quality blind-side walls is using a placement-specific mixture design with properly spaced reinforcement, maintaining required reinforcing bar clearance from formwork and to the finished surface. The formwork must also be constructed to create proper access for concrete placement and consolidation.

The only way to achieve all these steps to quality is by using a qualified concrete contractor who uses properly trained people, the correct placement equipment, and plans ahead with the on-site team to make sure the concrete is placed correctly.

Everything stated in the previous three paragraphs applies completely to both form-and-pour and structural shotcrete placement. The needs for both processes are the same, and the quality of concrete placement with blindside waterproofing depends on the experience of the concrete contractor, whether it is shotcrete or form-and-pour. The opportunity and risk to place poor-quality concrete is equal between both methods (refer to Fig. 2(a) and (b)). The ability to achieve the required concrete quality for blindside waterproofing is also equal with both placement methods.

Just as there are similarities, there are also differences between both placement methods:

- Form-and-pour subjects the waterproofing to puncturing or splitting open seams from internal vibration. The formwork industry slang for this is “vibrator burn,” which commonly occurs when a vibrator head snakes between the exterior reinforcing bar curtain and the form plywood, gouging out multiple layers of veneer from the plywood—this also happens to the blindside waterproofing on the outside of the wall 50% of the time!

- Most blindside form-and-pour is not placed using an elephant trunk or tremie drop pipe; instead, the concrete is dropped full height. This creates two major issues:
 1. Impact energy commonly dislodges the waterproofing attachments, and the horizontal impact force from the “big blob” effect can tear open seams, especially at deviations in the shoring substrate. Additionally, segregation of aggregate and paste from dropping concrete through reinforcing bar (pinball effect) occurs on form-and-pour projects always! This commonly creates unconsolidated pockets of gravel at the bottom of wall joint to the floor slab, a critical location when it comes to blindside waterproofing and a water-tight below-grade structure. Properly placed structural shotcrete employs the use of a blow pipe along this initial bottom of the wall pass, which basically eliminates the common form-and-pour rock pockets. Many cores and saw-cut testing of floor-wall joints have proven the superior performance of this method; and
 2. Walls over 8 ft (2.4 m) tall are poured at a rate of usually 4 ft (1.2 m) high per hour to control form pressure, meaning the taller a wall, the more time to complete the pour. This delayed pour process creates a dried cement paste buildup on the blindside waterproofing, which can affect certain waterproofing systems’ bonding performance. I have been recently surprised to hear from major waterproofing suppliers, consultants, and installation contractors that they were unaware of this phenomenon! Properly installed structural shotcrete does not create this paste buildup issue. During lift placement and at the top of the wall,



Fig. 2(a) and (b): Honeycomb and voids in form-and-pour (left) and dense sharp-edged structural shotcrete (right)

the shotcrete process uses a blow pipe to continuously clean the top of wall and the waterproofing as placement progresses. Using the blow pipe is much easier when shotcreting because there is no formwork protruding above the pour line. This would also make cleaning off the waterproofing membrane virtually impossible when using form-and-pour.

- Another urban shotcrete myth is that cold joints are created from multiple lift placements. Refer to a previous *Shotcrete* magazine article, “Shotcrete Placed in Multiple Layers does NOT Create Cold Joints,” by Charles Hanskat (www.shotcrete.org/media/Archive/2014Spr_Technical_Tip.pdf), which dispels this myth and explains how proper shotcrete lifts are achieved. Form-and-pour is also placed in lifts but the risk of a cold joint is certainly greater and happens when concrete placement is delayed by pump or crane malfunctions, or just simply a late concrete truck, which happens often in a busy city. Once the vibrator cannot penetrate the previously placed lift of cast concrete, a cold joint occurs. This is a blindside waterproofing issue that does not happen with properly placed structural shotcrete.
- Liquid head pressure within formwork can reach 600 to 800 lb/ft² (2900 to 3900 kg/m²), exerting extremely high lateral pressure on the waterproof membrane, and forcing it against uneven shoring substrates and the sharp anchor points. This often damages the waterproofing. Structural shotcrete exerts only 15 to 25 lb/ft² (73 to 120 kg/m²), helping the waterproofing to bridge irregularities and not warping the smoothing materials added behind the waterproofing in extreme conditions.
- One-sided forms require form tie anchorage to resist form pressure created by each placement lift (refer to Fig. 3). Many projects don't use “A-frame” one-sided forms due to availability, cost, height, shoring raker/strut projections, or complex shapes. The only alternative is to install numerous formwork tie anchor points attached to the shoring substrate, creating many penetrations in the waterproofing. This requires a lot of attention to detail for successful performance, and many opportunities for the penetration to leak. The structural shotcrete process requires far less anchorage to the substrate. Shotcrete placement is comparable to safely restrained reinforcing bar curtains used with “A-frame” formwork. These reinforcing bar anchorage points are at much greater spacing than form tie anchorage. Having a greatly reduced number of penetrations in the waterproofing substantially reduces the chances of leakage in the system.

SITE CONDITIONS AND BUILDING DYNAMICS

Many different site conditions can affect the performance between the cast-in-place concrete blindside walls and the waterproofing system, depending on



Fig. 3: Form-and-pour requires far more form tie anchor penetrations in the blindside waterproofing than reinforcing bar stabilization for shotcrete

which type of waterproofing is used. The following should be taken into consideration when selecting a blindside waterproofing system:

- Shoring subsidence, especially with wood lagging, where the hand-packed fill material settles behind the lagging or is washed out by groundwater flowing down the backside of the lagging, carrying the fines away, and creating a loss of density, resulting in movement that decreases the confining pressure between the concrete wall and the shoring substructure. This can be an issue for some types of waterproofing that rely on confining pressure.
- Differential settlement can occur between the building and the shoring system, caused by the building compressing the ground beneath and the anchored shoring system staying in place. This shearing movement can negatively affect the blindside waterproofing if not planned for.
- Substrate smoothness is always a factor and can affect the performance of any blindside waterproofing, except for integral waterproofing admixtures.

BLINDSIDE WATERPROOFING TYPES

A brief and simple explanation of blindside waterproofing can be broken down into five types of membranes, either sheet- or liquid-applied:

1. **Unbonded hydrophilic** sheet membranes, such as bentonite, swell when exposed to water and permanently rely on the confining pressure between the exterior concrete wall face and the shoring substrate.
2. **Mechanically bonded** systems rely on a fabric or hair-like structure to bond with the concrete wall during initial set. This in turn is attached to various waterproofing materials, including bentonite sheeting.

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3. **Chemically bonded** waterproofing relies on an adhesive activated by heat and minimal contact pressure. This type of system does not rely on confining pressure and stops water from traveling laterally along the wall face to a crack, creating a leak.
4. **Integral crystalline** waterproofing admixtures are added to ready mixed concrete. Once the concrete has cured, cracking occurs and leads to water infiltration; the crystalline waterproofing grows internally to fill in non-moving cracks and voids to seal off the passageways for potential water leaks.
5. **Post-groutable fabric membrane** is a newly developed waterproofing system that takes full advantage of the unique properties offered by the structural shotcrete process. A fabric with an attached woven geo-like grid is attached to the shoring substrate. After the reinforcing bar is installed, grout tubes are connected to the fabric grid and project slightly past the final wall face. Later, these tubes are used to inject grout to fill the curtain wall fabric to completely seal the blindside of the basement wall. This injection grouting is done after much of the concrete shrinkage has occurred, with an elastomeric, hydrophilic adhesive, two-part grout.

SHOTCRETE THE BLINDSIDE SOLUTION

The use of structural shotcrete for blindside walls is rapidly expanding and is becoming a common solution on tight urban sites, with fast-track schedules that require a water-tight below-grade structure. Once all the players of these projects fully understand the similarities and differences of

form-and-pour and structural shotcrete, and get past the misconceptions, they can benefit from these advantages to create a better blindside waterproofing assembly:

- Speeds up the concrete placement schedule because little or no formwork is needed, thus freeing up the workforce and crane time, and requiring less on-site formwork storage.
- Steel trowel final finish on the exposed surfaces, requiring far less touchup than form-and-pour.
- The ability to place concrete for blindside walls around obstructions such as shoring struts and rakers while still addressing tall, complex wall configurations.
- The unique ability to shoot around properly spaced in-place control joint inducers, which helps to meet ACI requirements to reduce wall thickness by 20 to 25% at control joints (refer to Fig. 4).
- Shotcrete delivers concrete to the bottom of the wall without the segregation of concrete dropping through the reinforcement and with no formwork in the way, enabling complete consolidation at the bottom of the wall and creating a better construction joint for the blindside waterproofing.
- Shotcrete can achieve better concrete consolidation in walls with dense reinforcement because greater access is available with no formwork in the way, making it easier to create a denser surface for the blindside waterproofing integrity.
- With much lower concrete pressure and no impact dropping concrete from the top of a form, shotcrete inherently has far less risk of damaging the waterproofing system.

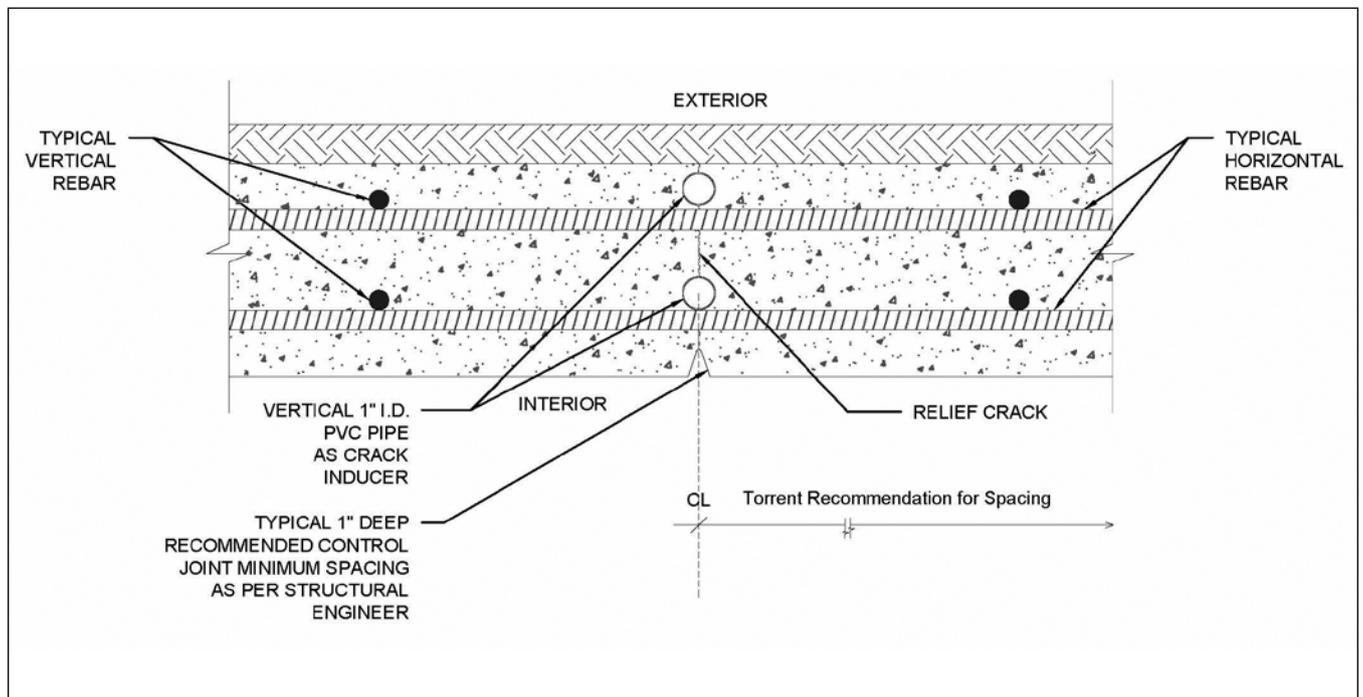


Fig. 4: In-place crack control inducer (two pipes for thicker walls) is only possible with structural shotcrete. Concrete placement in form-and-pour would wash pipes away

- Shotcrete is placed in short, visible lifts, with overspray blown off the blindside waterproofing continuously until the end of placement. There is no additional risk for both mechanical and chemically bonded waterproofing degradation due to a buildup of dry concrete paste, which typically happens in form-and-pour.
- Shotcrete reinforcing bar stabilization requires far fewer anchorage penetrations than most one-sided formwork systems, therefore requiring less detailing, and reduces the risk of leakage.
- Structural shotcrete now creates the opportunity to use a post-grouted hydrophilic curtain wall fabric, which accommodates shrinkage cracking, and other irregularities that can occur in any concrete placement (refer to Fig. 5). This system cannot be used with form-and-pour because the fabric grid would be crushed by the form pressure, vibration would force cement paste into the fabric, and the injection tubes would be knocked off by the concrete drop placement and vibration. Also, no concrete contractor would approve several holes drilled through expensive formwork, let alone trying to fish the pipes through the holes in the form while closing the form panel.

CONCLUSIONS

My opinion, after many years of experience in the form-and-pour industry and more recently in the rapidly growing structural shotcrete sector, is that structural shotcrete is THE solution to improving blindside waterproofing. We need to toss aside all the silly misconceptions and incorrect details that have been presented for blindside waterproofing projects and objectively consider the total performance of the completed concrete walls when using shotcrete placement.



Fig. 5: Large highway tunnel project in Seattle, WA, with over 750,000 ft² (69,677.28 m²) of structural shotcrete, completely done with a post-injected hydrophilic membrane/textile composite system for blindside waterproofing



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