Managing Groundwater Using Shotcrete

By Michael Klemp

Managing groundwater using shotcrete placement involves integrating structural reinforcement with effective waterproofing strategies to ensure durability and prevent water ingress in underground or below-grade structures.

KEY TECHNIQUES FOR GROUNDWATER MANAGEMENT WITH SHOTCRETE

DRAINAGE SYSTEMS

In areas with active groundwater flow, it's essential to install drainage mechanisms before applying shotcrete. This typically involves drilling weep holes and inserting short pipes filled with quick-set mortar to redirect water away from the receiving surface. Drainage mat systems can also be used to control groundwater at the receiving surface. These drainage mats are placed on the wall before shotcrete placement, and depending on the groundwater flow rate, 20 to 100% of the wall may be covered.

WATERPROOFING MEMBRANES

- Spray-Applied Membranes: These are essentially coatings applied directly onto the substrate to create a seamless barrier that prevents water from flowing through and withstands the high-velocity shotcrete application of concrete.
- HDPE Dimple Sheets: High-density polyethylene sheets with a dimpled surface to provide a somewhat roughened surface to enhance the bond of the shotcrete placement and provide drainage channels for groundwater behind the sheet.
- Bentonite-Based Sheets: Comprised of sodium bentonite between geotextiles, these membranes swell upon contact with water, sealing potential leaks and accommodating minor movements in the structure.

SHOTCRETE APPLICATION

After installing the waterproofing system, shotcreted concrete is applied in layers. The initial layer may be thinner to lessen the impact and provide support of the system, while subsequent layers provide the structural strength of the concrete section. The final layer can be finished as required, from a gun finish to a floated or even a carved finish. Proper sequencing of the shotcrete placement with careful attention to maintaining the integrity of the waterproofing membrane is key to a successful project.

Fig. 1: Shooting soil nail wall with drainage behind

ADDITIONAL SEALING OF THE CONCRETE

Some specifiers also like to decrease the effective natural permeability of the placed concrete. Though quality concrete with 28-day compressive strengths over 4000 psi (28 MPa) and proper placement is functionally watertight, there are concrete admixtures that can further reduce permeability. Though these permeability-reducing admixtures (PRA) are often called "waterproofers", as they help fill the natural pores in the concrete matrix and thus reduce permeability, they do not, however, make concrete entirely impermeable against water. Most of these admixtures are crystalline-based, but supplementary cementitious materials, such as silica fume, fly ash, and slag, will also help reduce the permeability of concrete. ACI PRC 212.3-16 *Report on Chemical Admixtures for Concrete* is a good reference for PRAs.

CRYSTALLINE PERMEABILITY REDUCING ADMIXTURES

Some of the most common PRA in concrete are crystalline materials. The crystalline materials are hydrophilic (attract water), and exposure to water causes them to increase the density of the cement hydration products and generate

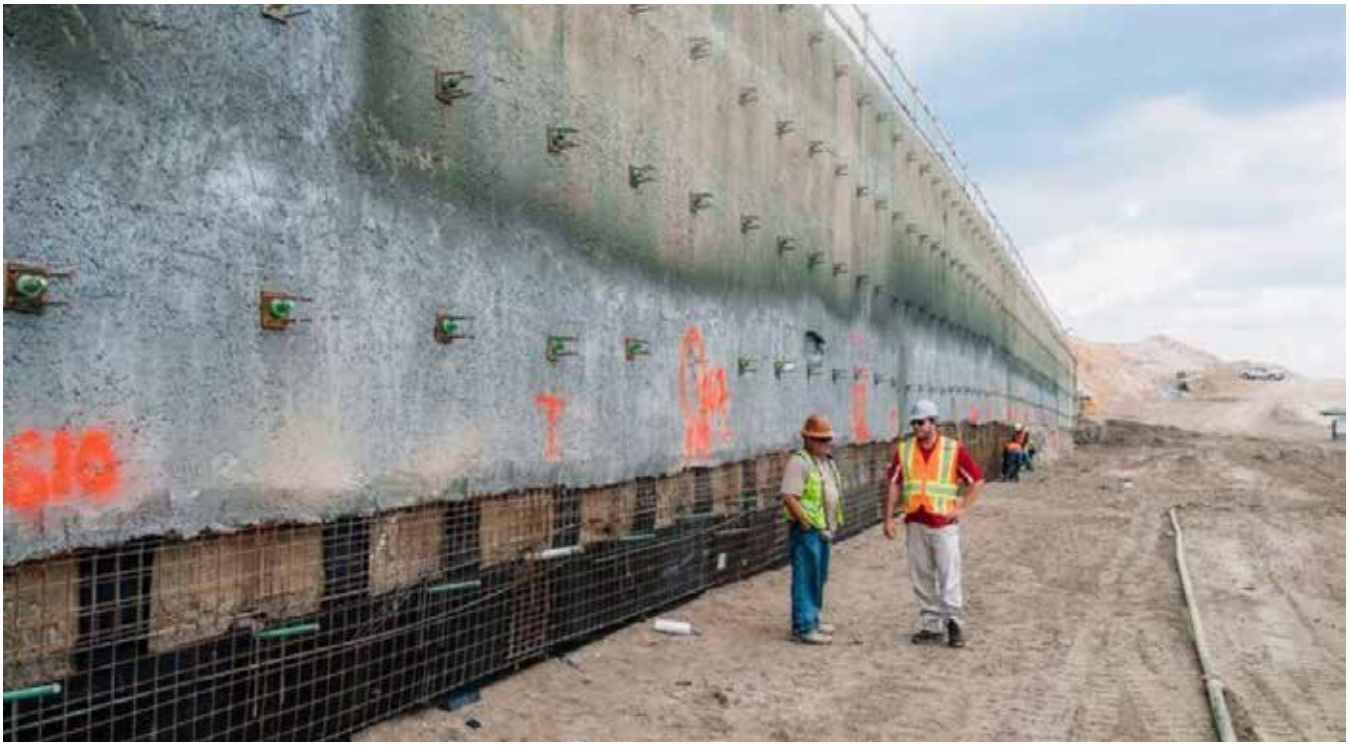

Fig. 2: Tall soil nail wall shot from top to bottom

additional deposits to help fill the pores in the concrete. The result of the materials "growing" in the concrete matrix can also help to fill existing microcracks and capillaries.

Although crystalline PRA can potentially seal static, non-moving cracks in concrete, it is less effective against moving cracks. Cracks in concrete sections exposed to temperature swings are not static, non-moving cracks and will open and close due to the thermal volume change in the concrete.

There are two primary methods for using crystalline PRA in shotcrete placement: admixture or surface applied. Proper mixing and curing are essential to activate crystalline growth, and shotcrete application must ensure complete coverage and compaction.

ADMIXTURE METHOD

The PRA is blended directly into the concrete mixture during batching. This is desirable for wet-mix shotcrete, as it is part of the concrete matrix, reducing permeability from within. Depending on the manufacturer, the dosage typically ranges from 0.8% to 2% by weight of cementitious material.

SURFACE TREATMENT METHOD

For existing or exposed shotcreted surfaces, a slurry with a high concentration of the PRA is applied as a brush-on or dry-pack. It is suitable for dry-mix or where integral PRA was not used, and helps to seal static cracks and surface pores post-application.

SUMMARY

Shotcrete placement with quality concrete materials and proper application creates concrete sections with high strength and inherently low permeability. Many designers specify the use of membrane systems (spray-applied, sheet, or bentonite) to provide a primary barrier to groundwater contact or to relieve pressure against the shotcreted concrete. Crystalline PRAs may be used with the concrete shotcreted against the membrane systems. The PRAs can also be used in applications where a membrane system is not needed, but a lower permeability or ability to seal small, static cracks and voids is desired.

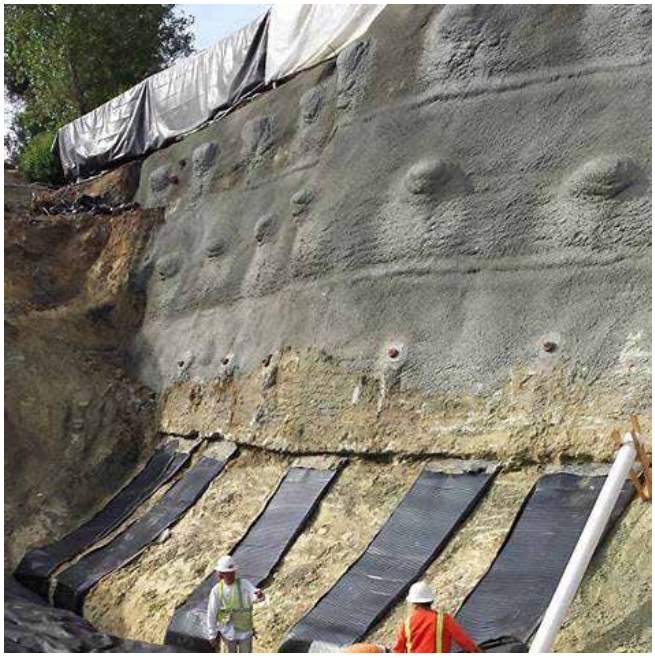

Fig. 3: Soil nail wall with drainage panels to be shot in next

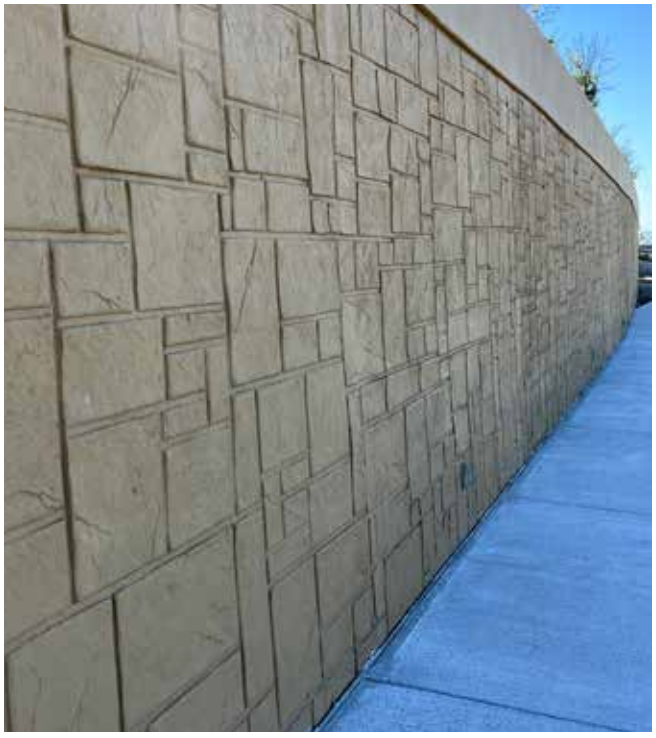

Fig. 4: Final carved soil nail wall

All these groundwater control techniques benefit from shotcrete placement's ability to eliminate formwork and easily adapt to irregular surfaces, while providing structural integrity, and longevity in challenging environments.

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