the Construction Specifier

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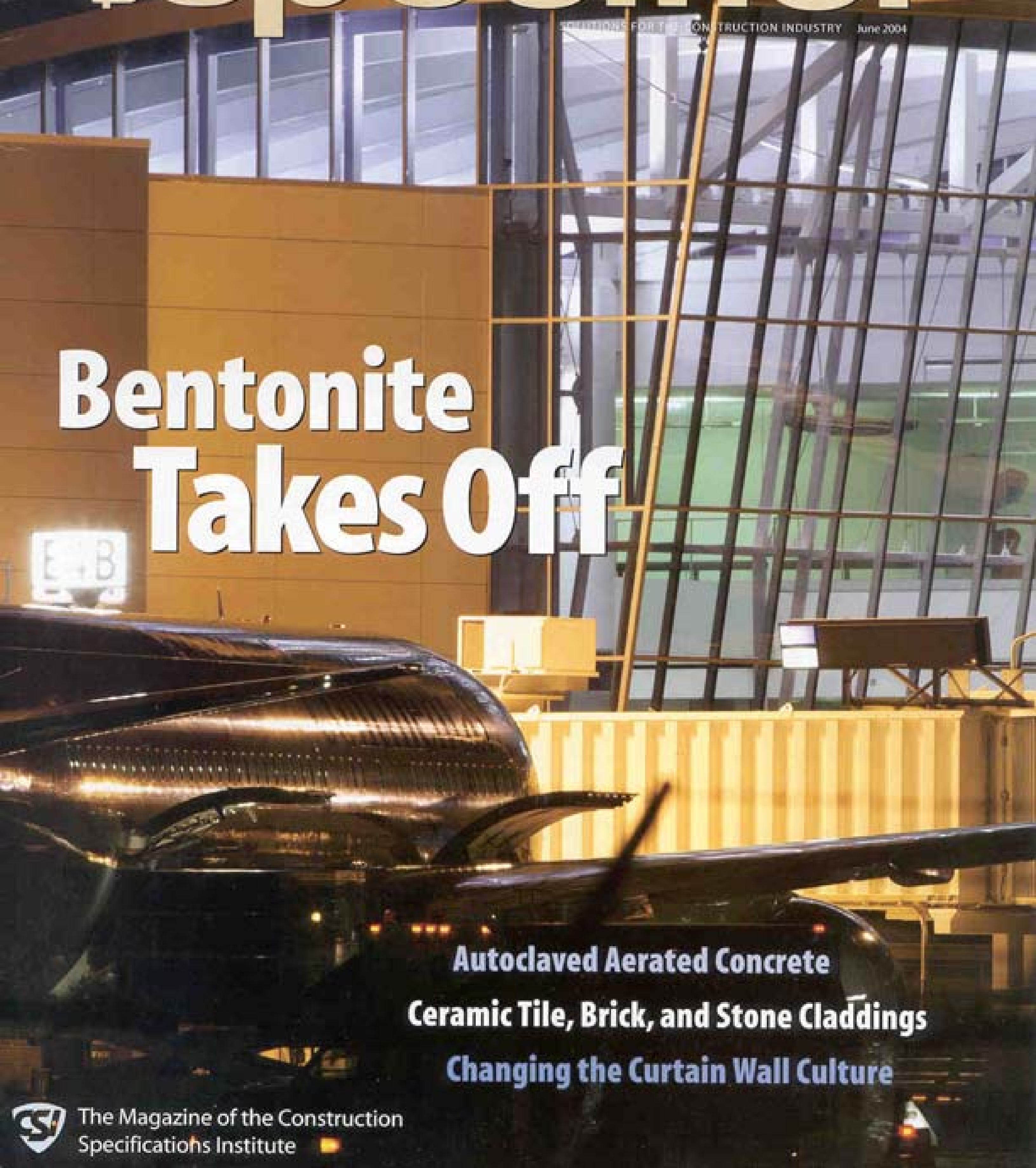

Bentonite Takes Off

Autoclaved Aerated Concrete

Ceramic Tile, Brick, and Stone Claddings

Changing the Curtain Wall Culture

The Magazine of the Construction Specifications Institute

The Construction Specifier

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In This Issue

Houston, Texas' George Bush Intercontinental Airport is in a constant state of growth. Its 55,742-m^2 (600,000-sf) Terminal E will serve international flights after next year's completion of the adjacent Federal Inspection Services (FIS) building. To prepare the nation's eighth largest passenger airport for even further expansion, its inter-terminal train tunnel has already been extended under the FIS construction site. The project involved waterproofing with lagging walls and a several-foot-thick bentonite underslab, poured in 30.5-m (100-ft) long sections.

See feature page 36.

Photo courtesy Alcan Composites USA Inc.
Photo © Charles Davis Smith.

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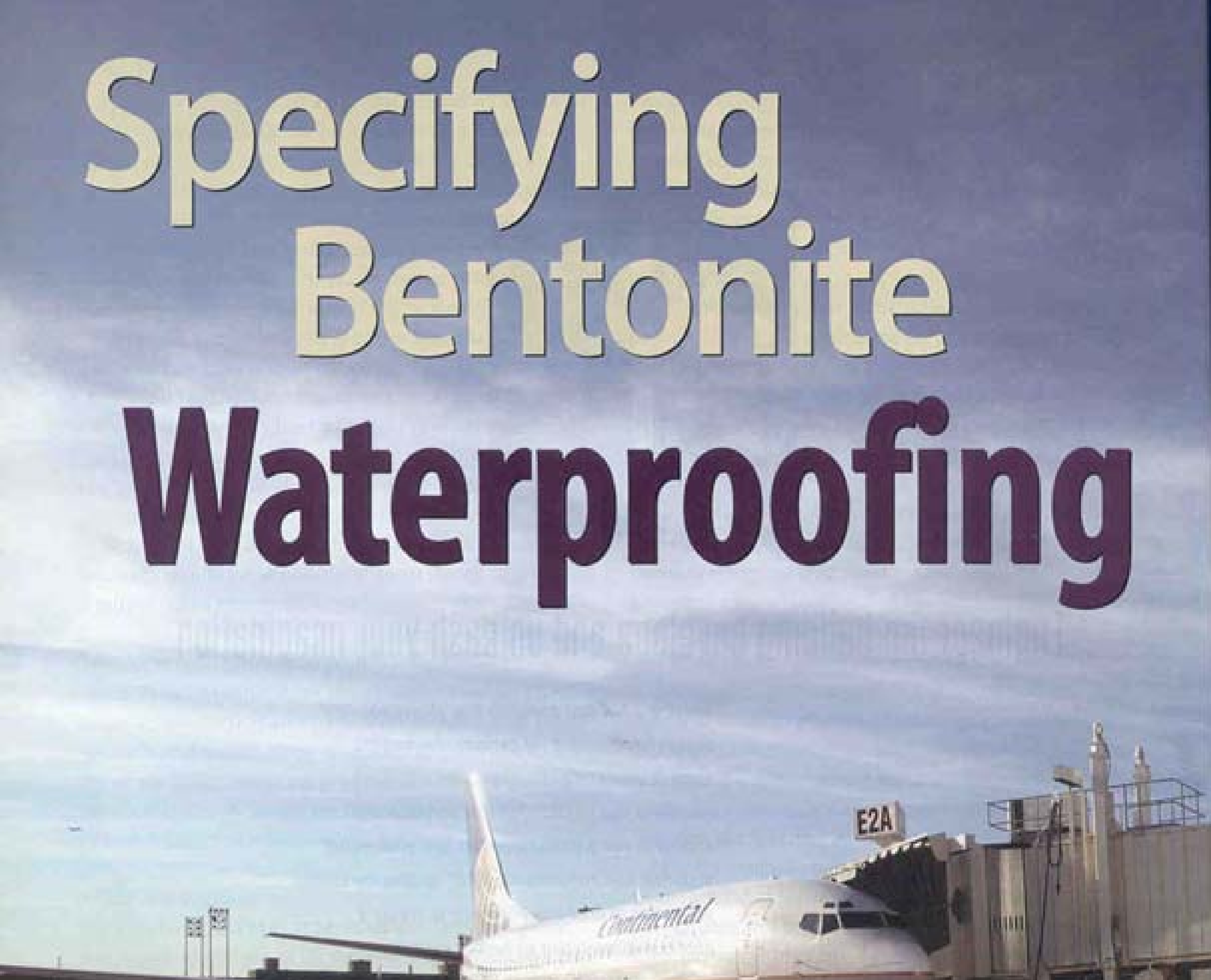
Specifying Bentonite Waterproofing



by Stacy Byrd, CDT

Since the early 1900s, bentonite has been used to seal and contain water; it has been employed for decades as a solution for zero-lot line foundation construction sites and structural slabs under hydrostatic conditions. It was not until the development of the first commercial products in the early 1960s, however, that bentonite systems became available as specified products for architects/engineers (A/Es) for below-grade waterproofing.

Over the last 20 years, bentonite has been combined with geomembranes and geotextiles, forming composite membranes with greater performance, durability, and economy. Today, it is increasingly being used on backfilled foundation walls, plaza decks, and tunnels on sites without hydrostatic conditions.

A tunnel expansion below the George Bush Intercontinental Airport (Houston, Texas) relies on the impermeable properties of sodium bentonite for below-grade waterproofing.

Photo courtesy Alcan Composites USA Inc. Photo © Charles Davis Smith.

The material

Sodium bentonite is a non-toxic mineral found primarily in the Blackhills region of the United States. It consists largely of a plastic-type clay known for its absorption, expansion, cohesion, and sealing characteristics.

When hydrated in an unconfined condition, sodium bentonite swells 10 to 15 times its dry volume. When constrained against the below-grade foundation's exterior, however, its swell capacity is restricted, and it transforms into a thick, water-impermeable gel. Most manufacturers also add polymers and other chemicals to processed bentonite, enhancing its resistance to salts and other contaminants. (These additives can enhance the mineral's impermeability a hundredfold.)

oto courtesy CETCO

A look at the slab edge of the tunnel construction project at George Bush Intercontinental Airport.

Products and applications

Bentonite-based products have advantages and limitations. Although material cost is typically more than asphaltic sheets and fluid-applied elastomeric products, the total installed expense can be less, as bentonite requires neither substrate priming nor protection courses.

Bentonite is a positive-side waterproofing treatment (in direct contact with hydrostatic pressure). It can be installed under reinforced slabs, on backfilled walls's exteriors, as part of split-slab deck construction, earth-covered tunnel roofs, or zero-lot line shoring walls before concrete placement. Bentonite products include:

1. Cardboard panels
2. Geomembrane sheets
3. Geotextile mats
4. Rubber compound membranes
5. Polymer alloy composites
6. Remedial injection grout
7. Waterstops

The material requires no on-site blending, and is free of volatile organic compounds (VOCs). It can be applied to poured concrete as soon as the forms are removed, and/or in freezing temperatures. The membranes are typically mechanically attached with washer-head fasteners (usually temporary until backfill placement) or concrete casting against shoring walls.

Under reinforced concrete slabs

Site conditions allowing, bentonite can be installed directly over a compacted substrate without requiring a site working (mud) slab. When necessary, bentonite can be applied directly over a mud slab before the reinforcing slab is cast. For hydrostatic conditions, bentonite systems are applied under footings and grade beams, thereby wrapping the entire structure.

Geotextile bentonite mats form a mechanical bond to the structural slab's underside, rather than being adhered to the thin concrete mud slab. The mat should be kept in direct contact with the slab's bottom to give it the opportunity to seal any concrete cracks as they form, and prevent water migration between the protection course and slab. (A protection course should not be applied over the bentonite mat.)

A concrete protection slab over geomembrane sheets can protect the system from premature hydration during steel reinforcement placement. When a protection slab is specified, it should be at least 76-mm (3-in.) thick to provide proper temporary confinement. Furthermore, a bentonite strip waterstop should be installed atop the protection slab, around the site perimeter, and all slab penetrations at that level. To provide additional leak localization protection, an 8-m (25-ft) grid of bentonite strip waterstops should be installed over the protection slab's entirety.

Most underslab applications require a slab thicker than 152 mm (6 in.), and reinforced concrete slabs should be doweled into the surrounding structural walls. However, bentonite is unsuitable for raised slab perimeter joints isolated from the foundation walls with a fiber compression board, especially under hydrostatic conditions.

Zero-lot line construction

Bentonite systems are extensively used as blind-side waterproofing with zero-lot line foundation construction. Below-grade structural walls are cast against the shoring of heavy timber placed between steel H-piles anchored into the surrounding soil (the soldier pile and lagging method). In this situation, the waterproofing is applied directly onto the shoring wall before the building's structural wall is formed and cast.

With the steel sheet piling method, bentonite systems are secured onto the piling's interior surface, as the geotextile mats/composites conform to its angular transitions. Should water penetrate the sheet piling knuckles during construction, bentonite grout can be injected down the exterior side to seal them off.

Property line excavations descending into rock formations generally require the irregular surface to be treated with shotcrete or cementitious grout to provide a uniform surface for bentonite installation. Another method for providing an acceptable substrate involves building a plywood form wall to the rock face's interior and filling the gap between the two with cement slurry. Similarly, auger-cast concrete caisson piles should be grouted between caissons to provide a monolithic surface to secure the bentonite.

Shotcrete can create difficult conditions for ensuring a below-grade waterproofing system's performance. Improperly mixed or placed shotcrete can create voids between itself and the waterproof membrane, or force open poorly sealed seams. Therefore, extra fasteners should be used to secure the overlap seams and down the sheet's center to hold the membrane firmly against the shoring. The shotcrete's force should not cause the bentonite membrane to move or vibrate.

Backfilled foundation walls

Bentonite systems have been used extensively on backfilled walls, installed on the exposed structural walls's exterior after concrete forms are removed. If an insulation board or prefabricated drainage sheet is specified, the waterproofing membrane should be applied directly on the concrete substrate, before being covered by the insulation or drainage sheet. A water discharge system is required at the base, especially when sheet drainage is used to collect water on the wall.

At the wall's base, the first bentonite sheet course should be installed horizontally oriented to reduce the overlaps at the critical wall/footing transition. Here, bentonite-filled tubes should be positioned under geotextile mats and placed atop the bentonite corrugated panels. The bentonite sheets should be extended onto the footing at least 152 mm (6 in.) and, when applicable, underslab waterproofing should be overlapped to form a continuous system.

Comprising clean, compactable soils or aggregate no greater than 19 mm (0.8 in.), backfilling should commence as soon as the bentonite system has been installed and inspected. Following standard industry practices, the backfill should be placed in shallow lifts and compacted to a minimum 85 percent modified proctor density. Protection board (*i.e.* sheet drain composite) is generally not required, but can be used to reduce possible damage to the bentonite layer, both during construction and backfilling.

Cardboard filled panels are not recommended for installation on below-grade masonry walls, even when a cementitious parge coat is first applied. At least one manufacturer does not recommend bentonite geotextile mats for use on below-grade masonry block walls. Instead, it suggests bentonite butyl rubber composite sheets, adhered with a water-based primer. For masonry block projects, all membrane overlap seams require taping.

Over the past five years, insulated concrete forming (ICF) has become much more common in light commercial construction. However, until applicable construction standards and installation methods can be further tested and reviewed, it may be prudent to contact the manufacturer to clarify if its system is approved for use with ICF construction and if special detailing is required.

Plaza decks

Generally, bentonite is used with split-slab plaza deck construction with a minimum 76-mm (3-in.) thick

Special zero-lot line detailing methods

Blind-side waterproofing requires special detailing. Tieback anchor heads create difficult flashing details for the membrane's integration, and can also form void cavities due to anchor rod placement. Before the waterproofing can proceed, these gaps must be filled with cementitious grout or compacted soil.

Tieback head use typically involves tightly installing the waterproof membrane, covering the head with a cut membrane section, and detailing with trowel-grade bentonite mastic. Manufacturers are starting to incorporate solid EPDM (ethylene propylene diene monomer) and galvanized sheet metal covers, filled with a bentonite mastic/granules mix, which tightly fits over and provides a seamless cover to waterproof the tieback heads. Alternatively, the heads can be recessed into the shoring, before filling the cavity, and applying the waterproofing course.

Conventional cast-in-place concrete formwork methods stabilize a one-sided form with through-ties before concrete placement. Shotcrete methods require the reinforcing steel to be stabilized with anchor rods secured to the shoring wall. Both the form through-ties and the rebar anchor rods create penetrations through the waterproof membrane that must be detailed with accessory products. These conditions require a thick, trowel-grade bentonite mastic flashing and a bentonite waterstop strip wrapped around the penetration's outer end.

At grade, local building codes generally require the lagging timbers and the top of the steel H-piles be removed to a depth of 1 m to 2 m (4 ft to 5 ft) for accommodating mechanical penetrations. As part of the waterproofing work, a 13-mm (0.5-in.) thick cementitious wallboard should be specified over the H-pile—to the required excavation depth—for membrane protection from being burned or damaged during the removal.

concrete wearing slab placed over a bentonite membrane system. Brick and stone pavers—at least 51-mm (2-in.) thick, and placed within a setting bed of sand or cementitious grout—offer an alternative wearing surface.

Bentonite systems should not be used under pavers perched on pedestals, as this does not provide the required uniform confining ballast. Bentonite should also not be used under thin set tile flooring or other similar thin wearing surface material.

The wearing surface design should provide positive slope to a sufficient number of drains. Inadequate slope is the most common deficiency in plazas with leakage and wear surface deterioration—industry practice dictates a deck slope of 3 mm to 6 mm (0.13-in. to 0.25-in.) per 305 mm (12 in.).

It is extremely important to provide drainage at the membrane level below the wearing surface, to avoid deterioration and freeze-thaw heaving. It is also important the subsurface drain assembly has many large weep holes to permit sufficient water flow and reduce clogging.

Membranes on decks should be installed with the bentonite component side down, directly against the structural slab surface, geomembrane liner side up. The membrane should be installed from the lowest to the high point across the fall line so that laps shed water like roof shingles. The overlapped membrane edges should be sealed with the manufacturer's specific seam tape, which protects the installed membrane from pre-hydration prior to the topping slab placement, and completes an outer membrane barrier during service. Penetrations, transitions, drains, slab edges, etc., should be treated with proper accessory products before membrane installation.

Around the deck perimeter, the deck-to-wall transition corner should be detailed with an elastomeric mastic cant, extending the mastic out onto the deck a minimum 152 mm (6 in.), and the vertical wall surface to just below the wearing surface's finished height. The bentonite membrane should not extend up the perimeter wall if joint fiberboard is installed, as it deteriorates over time and does not provide proper confinement.

Bentonite membranes should not be installed all the way to subsurface drains, rather, they should be detailed around the drain, minimum 305 mm (12 in.), with a trowel grade elastomeric waterproofing mastic to ensure the bentonite edge does not extrude and clog drain weep holes.

Precast concrete decks, common to parking structures, have many joints prone to movement, particularly at the ends of precast elements and beside joints lacking positive connections. As a result, precast decks joints should be grouted and striped with a reinforced elastomeric coating prior to the bentonite system installation.

For pedestrian plywood decks and balcony walkway areas, a minimum 0.8-mm (0.03-in.) thick fluid-applied elastomeric membrane should be installed prior to the bentonite membrane. (A bentonite system should not be placed directly over a plywood deck.) Tongue and groove plywood should be screwed and not nailed, and the joints treated with a geotextile-reinforced, elastomeric mastic strip prior to the full elastomeric coat. As with concrete plaza deck design, drains need to be provided, along with a minimum 76-mm (3-in.) thick concrete wearing surface for ballast.

For earth-covered decks, most bentonite systems require a minimum 457-mm (18-in.) soil layer compacted to 85 percent modified proctor density. Where required, the membrane can be protected from landscaping placement and future removal by installing a protection course over it.

Sometimes granular bentonite is used under loose-laid waterproofing membranes installed over a deck. Water penetrating a break in the loose-laid membrane system can flow considerable distances on the concrete deck before leaking into the building, therefore, the bentonite provides a seal or leak localization.

Since open concrete block cells do not provide proper confinement, a fluid-applied elastomeric waterproofing should be specified to run uniformly under any block walls constructed on the deck. To overlap with the bentonite system, elastomeric mastic—at least 2-mm (0.1-in) thick—needs to extend outward a minimum 305 mm (12 in.) from both sides.

Expansion joints are a common leakage problem in plaza deck waterproofing, but they can be elevated above the membrane level through raised curbs to install the expansion joint material. Additionally, a properly sloped deck should drain water away from expansion joints, rather than over them. (Removable concrete pavers set into a sand bed can be placed above the elevated curb for easier access to the expansion joint should leakage occur.)

Limitations

Bentonite's biggest limitation is its need for confinement. Although the material has great swelling properties, most manufacturers limit its crack sealing to the industry standard established by self-adhering sheet membranes—no greater than 1.5 mm (0.06 in.)—making it an inappropriate expansion joint sealer.

Bentonite's swelling action can be hindered by strong, acidic chemical conditions in the groundwater. Wherever this possibility exists, water samples should be sent to the manufacturer to test for saline content, pH, and free swell loss as compared to deionized water to determine the appropriate action. Bentonite should also never be installed in the presence of free-flowing underground streams.

As with any material, one must also review any additional limitations imposed by the manufacturer with regards to application and field conditions.

Specifications

One of the most difficult aspects of successful waterproofing is creating comprehensive construction documents, which take into account and detail site conditions and building designs. With so many factors to consider, many architects and owners enlist an independent waterproofing consultant.

A below-grade waterproofing system's installation cost is relatively low when compared to future repair expenses. Overburden removal/replacement costs alone can easily exceed the price of repairing a defective or improperly detailed waterproofing system a hundredfold. Due to the potentially high repair cost, design professionals should approach the tasks involved with an extremely conservative attitude.

Perhaps the most common problem stems from copying verbatim a manufacturer's guideline specification, which inevitably overlooks the project's unique aspects. Adapting a manufacturer's specification to include provisions for unique

Photos courtesy CETCO

(Above) When hydrated, bentonite expands and conforms to penetrations and irregular surfaces, sealing small concrete cracks. (Right) Bentonite systems can be installed directly onto compacted soil or gravel substrate without a working mud slab.

site construction and or conditions is an acceptable practice, as is deleting the parts of the work execution section not applying to the particular project. (As a cautionary note, it is important to discuss any specification revisions and detail adaptations with the manufacturer to confirm full compliance with application and warranty requirements.)

Far too often, superseded manufacturer's product literature is used as a basis for drafting project documents, resulting in discontinued products/installation guidelines being specified. Another problem is when the specification is based on a membrane from one manufacturer but incorporates accessory products from another, causing confusion by introducing proprietary requirements. An even worse situation occurs when no specific system is specified, and the only references to waterproofing on the drawings are cryptic notations such as 'W/P Membrane.' Since this leaves the waterproofing system selection to the contractor, such ambiguous specifications should be avoided.

The team should also be wary of value engineering (VE) the waterproofing system—simply put, the amount saved by using an inferior waterproofing system can quickly evaporate and turn into enormous expenses when repairs are required.

Specification coordination

Specifications for waterproofing fall under the Construction Specifications Institute's (CSI's) *MasterFormat*™ Division 7, Thermal and Moisture Protection, with bentonite systems further grouped under that division's Section 07170–Bentonite Waterproofing.

Part One–General

Reference all appropriate sections in Division 2, Site Construction, and Division 3, Concrete. Under quality assurance, require a pre-installation meeting for waterproofing scheduled before site excavation. The architect, owner (or his representative), inspector, general contractor, and manufacturer's representatives should attend this meeting, along with the subcontractors for waterproofing, concrete-casting, backfill, formwork, and excavating.

Require the owner to retain an independent inspector for full-time monitoring and the daily submission of reports on work completed with the location and scope noted on drawings, photographs, and weather information. Require that waterproofing subcontractor is a manufacturer-approved applicator, to comply with warranty guidelines. Have the contractor submit applicator certification at bid time.

Under Submittals, require shop drawings and manufacturer's product literature—drawings should indicate all conditions, transitions, and penetrations, while literature should include installation instructions. Require Material Safety Data Sheets (MSDSs) be submitted and kept on site.

Part 2–Products

Identify the specific bentonite waterproofing system and specify accessories. List the membrane's physical and performance properties with an applicable test method standard.

Part 3–Execution

Require substrate inspection to ensure suitable texture, soundness, and dryness, prior to any waterproofing work. Specify that the concrete or masonry contractor shall fill honeycombs, rock pockets, indentations, and tie holes with non-shrink cementitious grout.

Under surface preparation, require the removal of all contaminants, dust, dirt, rocks, debris, and laitance on surfaces to which waterproofing will be applied.

Provide a specific section to the execution for each site condition requiring the use of waterproofing and accessory products as needed by manufacturer's guidelines and per project drawing and documents. Protect the system from prehydration, and replace/repair damaged materials prior to backfill or concrete placement.

Activity in other divisions, notably Divisions 2 and 3, has a major impact upon the waterproofing work. Therefore, the appropriate specification sections in the divisions must be coordinated with the waterproofing specification.

Division 2 coordination

As bentonite's performance depends on proper confinement, specify the following in the appropriate Division 2 sections:

1. Underslab: Require site substrate, if soil, to be compacted to a minimum 85 percent modified proctor density. If aggregate substrate, require aggregate to be no larger than 20 mm (0.8 in.) and properly compacted.
2. Shoring systems: With soldier pile and lagging, require lagging timbers be installed with the interior face monolithically, with gaps between timbers no larger than 25 mm (1 in.). Require that all voids and cavities behind the lagging timbers be filled with compacted soil or cementitious grout, including any voids behind the tieback heads.
   - Cut face rock: Require surface to be smoothed with shotcrete or grout.
   - Auger-cast caissons: Require recesses between members to be grouted smooth with outer caisson face.
3. Backfilled walls: Require backfilling as soon as the waterproofing system is installed. Limit backfill lift height to a maximum 305 mm (12 in.) and require soil compaction to minimum 85 percent modified proctor density. If aggregate backfill, require unwashed aggregate with fines no larger than 20 mm (0.8 in.), placed in shallow lifts and compacted.

Division 3 coordination

As successful waterproofing requires proper concrete placement and consolidation, specify the following in the appropriate Division 3 sections:

1. For slabs and zero-lot line construction, require concrete placement as soon as possible after the waterproofing system installation.
2. Require bentonite strip waterstops be installed in all applicable concrete construction joints, including around pipe penetrations through slabs and walls, around structural steel H-piles through the slab, and encircling reinforcing steel in pile caps.
3. Require concrete decks, both the structural slab and wearing course, to be designed with adequate slope and drains.

4. For cast-in-place walls, require the concrete contractor to grout honeycombs, rock pockets, and form tie holes, and also remove any raised form lines.
5. For shotcrete, require an experienced crew place it in strict accordance with American Concrete Institute's (ACI's) 506.2-95, *Specification for Shotcrete*, and include:
   - gunning all walls from the bottom up to their full design thickness in a single application;
   - limiting the lift height to a maximum 1.2 m (4 ft);
   - dampening absorptive substrates before placing shotcrete;
   - removing rebound and sand pockets;
   - encasing steel reinforcement; and
   - wet curing the shotcrete installation.

   Also, require all heavily reinforced columns be formed and cast-in-place, and specify temporary protective sheeting be installed over adjacent waterproofing substrate to protect from shotcrete overspray contamination.
6. For shotcrete, require the owner to retain an independent inspector for full-time installation monitoring. Require the inspector to submit a daily report of work completed with the location and scope noted on a drawing, photographs, and weather information.
7. Require the contractor notify the waterproofing contractor, in writing, if the waterproofing is damaged during steel reinforcement or concrete work.

Other divisions requiring coordination are Division 15, Mechanical, and Division 16, Electrical, as pipes or conduit may penetrate the building's foundation. Require these subcontractors notify the waterproofing contractor, in writing, if the waterproofing is damaged during their work so the system can be repaired.

Final words

Before writing warranty requirements, specifiers should learn about any limitations imposed by the manufacturer. A warranty's duration should not be the deciding factor in product/system selection, as it does not necessarily ensure either satisfactory performance or potential service life. Instead, decisions should be based on whether the product is suitable for the intended application.

Waterproofing warranties rarely include overburden removal/reinstallation, which can range from easily removed brick pavers in a sand bed to the costly excavation of backfill against a foundation. For this reason, manufacturers often exclude overburden removal/replacement from their warranties, limit them to the cost of just replacing defective materials, or keep silent on the subject.

Warranty coverage varies between manufacturers, but most do not cover consequential damages to interior materials from water infiltration. Several bentonite manufacturers provide joint warranty coverage for a specified period (up to 10 years), requiring leaks to be repaired with a method determined by the manufacturer. The repair methods for below-grade waterproofing are typically performed from the structure's interior, which include a polyurethane or bentonite grout injection through the wall at the leak's location. One should be very skeptical about warranties offering to only replace defective material, especially when one also has to provide access to the repair location.

The waterproofing process requires unique coordination among design professionals and contractor principals. A complete and detailed specification provided by the specifier is the first step toward ensuring success.

Additional Information

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A1030–Slabs on Grade
A2020–Basement Walls
B3010–Deck Horizontal

Key words

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Bentonite
Shotcrete
Waterproofing

Abstract

This article looks at waterproofing and thermal protection techniques involving bentonite clay panels or sheets. Largely a misunderstood material, bentonite is increasingly finding its way into projects—an educated specifier needs to understand its suitable applications and proper detailing.