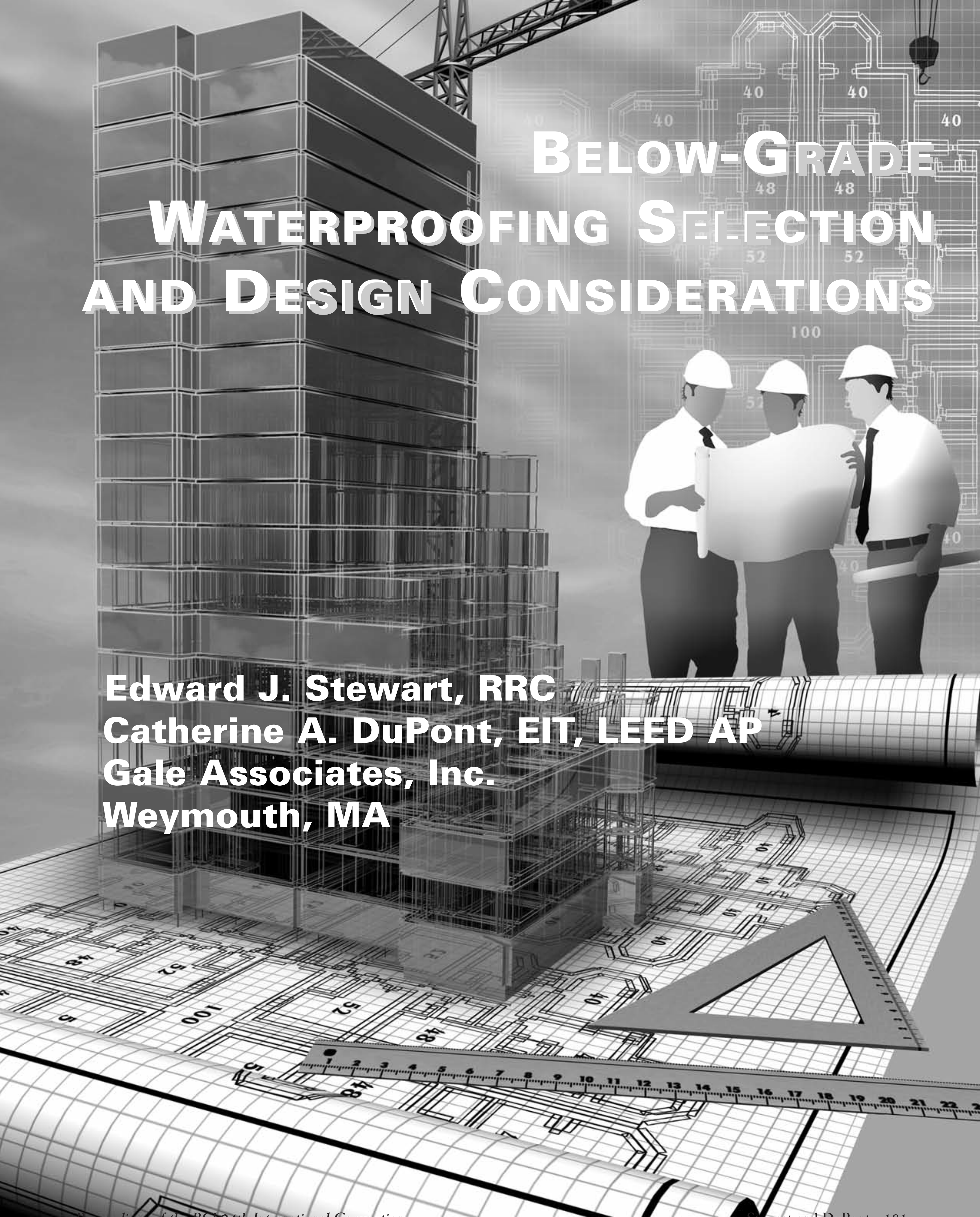

Below-Grade Waterproofing Selection and Design Considerations

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ABSTRACT

This presentation will educate the audience about the fundamentals of below-grade waterproofing. With high costs, many functions are being placed in below-grade locations. Classrooms, laboratories, auditoriums, and other critical occupancies require a completely water-tight environment. This presentation will discuss the various below-grade waterproofing options available, along with recommended materials and installation methods. Below is an outline of the presentation:

SPEAKER

Edward Stewart is a Registered Roof Consultant and certified construction supervisor. He has specialized in building renovation projects for 25 years and has extensive experience in evaluating and designing roofs, walls, windows, plaza decks, green roofing, and weatherproofing systems. Mr. Stewart has given numerous educational presentations at client and peer associations throughout the U.S. He is a member of the National Roofing Contractors Association, the U.S. Green Building Council, and RCI.

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Below-Grade Waterproofing Selection and Design Considerations

The goal of a properly designed and executed below-grade waterproofing system is to prevent passage of water into occupied space or structural building components. When designing a waterproofing system, specific guidelines should be followed to ensure long-term performance. Product selection will often depend on a number of environmental factors, including water sources and the presence of soil contaminants. A waterproofing design professional should be included on the building envelope and structural design team so as to develop an interconnected waterproofing system. Successfully designed and installed waterproofing will protect interior finishes and equipment, reduce the weatherization of structural concrete and masonry, and provide a comfortable indoor air quality environment for building occupants. While each project varies in site conditions and building configuration, the following basic concepts should be considered during the selection and design of a waterproofing system.

Photo 1 – View of compacted, engineered backfill material prior to application of waterproofing and pouring of the concrete foundation slab in a blindside application.

REVIEW OF AVAILABLE INFORMATION

The first step in designing an effective waterproofing system is to review various sources of information that can typically be provided by the architect, geotechnical engineer, and structural engineer. Each of the following will ultimately influence the designer's waterproofing system selection:

Water Sources

Water sources, including capillary action, hydrostatic pressure, and gravitational water, are typically encountered in below-grade applications. Capillary action can be defined as the act of water wicking through or into a porous substrate via tiny voids in the material. Hydrostatic pressure on a vertical surface occurs due to the weight of the water in the soil above a point. Water passage under hydrostatic pressure is of special concern, as it travels through the path of least resistance, and therefore, any defects or areas of weak termination may be a path for travel. Gravitational water is allowed passage through soil by means of gravity (e.g., rainwater that collects on the ground's surface and percolates down through the soil due to gravity). A geotech report is a priority so as to determine the height of water tables, presence of subgrade systems, or even the effect of tides on a water table.

Environmental Conditions

Environmental conditions to be considered generally include the presence of soil contaminants, high acidic content in soil, and chemical contaminants. Material selection is critical, since particular salts, acids, or alkalis present in soils can inhibit bentonite clay's ability to swell. In some cases, the soil itself (such as marine clays) can shrink and swell and could influence performance. Over recent years, waterproofing materials such as PVCs have been developed to be more resistant to common soil contaminants, including salts, alkali, petroleum, and sulphates.

Structural Drawings

Structural drawings should be obtained from the architect and/or structural engineer prior to considering a waterproofing system. Structural drawings will indicate if both horizontal and vertical surfaces are to be waterproofed or if blind-side waterproofing is required. Often, accessibility will limit the type of products that are suitable for use. A combination of various waterproofing materials may be required to address varying conditions on the same site. The number of penetrations and complexity of building transition details can also be determined during the structural drawing review. A large number of penetrations and overly complicated detail transitions may affect the designer's decision to use a liquid, or spray-applied waterproofing versus a sheet membrane.

Soil and Geotechnical Reports

Soil and geotechnical reports, in conjunction with a structural analysis, will indicate any anticipated settlement of the structure. Where soft soils are present and slab settlement is anticipated, the waterproofing material should have the ability to accommodate limited amounts of differential movement and bridge any cracking and expansion joints. The type of soil to be used for backfill, whether it be the existing soil on site or a well-graded backfill material, should be reviewed by the design professional. Typically, aggregate should not be less than ¾ inch to provide a well-drained soil environment surrounding the waterproofing. Additionally, soil with large or sharp "rocks" should not be used for backfilling applications, as damage to the waterproofing material may occur. Post consolidation of backfill can be a major problem, so attention during backfill operations is extremely important. Backfill should be specified to be compacted to the manufacturer's requirements and in accordance with ASTM D 1557, "Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort."

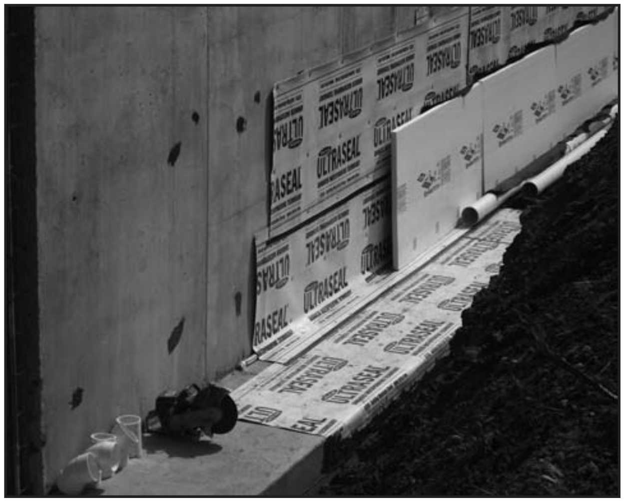

Photo 2 – Installation of a positive-side waterproofing system.

When selecting the waterproofing location, two applications are considered:

- Negative side applies to the face of the structure which is not directly exposed to water or hydrostatic pressure. Negative-side waterproofing is typically used for property-line construction, where excavation of the site is not feasible. Negative-side waterproofing that is accessible from the interior of the building can be beneficial, since it allows for repair access. However, under hydrostatic conditions, the waterproofing system is susceptible to failure, as it is not confined by a structure or backfilled soils.
- Positive (blind) side is the face of the structure exposed to water or hydrostatic pressure. Positive-side waterproofing applications are widely accepted by industry professionals as a more effective system, as they act as barrier systems preventing water from entering the structural components and thus reducing the potential for corrosion of embedded steel in concrete. Additionally, in a positive-side application, the waterproofing system is "sandwiched" between the backfill soil or mud slab and the structure and can be either partially to fully adhered or loosely fastened.

Photo 3 – View of unconfined and prematurely hydrated bentonite waterproofing. Bentonite waterproofing can swell up to 15 times its dry volume.

DESIGN SELECTION CRITERIA

The process of selecting an effective and feasible waterproofing system will also depend on a number of other factors. The design professional should consider the following:

Construction Sequencing

- How long will concrete have to cure prior to waterproofing installation?
- Will backfilling occur immediately after waterproofing installation?
- Who will be responsible for substrate preparation?
- What is the acceptable application temperature?

Installation

- Is the local workforce experienced with applying specified materials?
- How will difficult building transition details or flashing configurations be addressed?
- Will the waterproofing be applied to cast-in-place concrete, pre-cast concrete, or lagging?

Nontechnical Provisions

- What is the cost?
- What type of manufacturer warranty is available to the owner?

Unfortunately, poor construction sequencing can result in damaged waterproofing that may ultimately require costly removal and replacement. For example, a one-week delay in backfilling over a bentonite-based waterproofing system applied to a horizontal surface exposed to rain may result in prematurely hydrated clay. Hydrated bentonite, when not under confinement pressure provided by a compacted backfill, is beyond repair and requires removal and replacement.

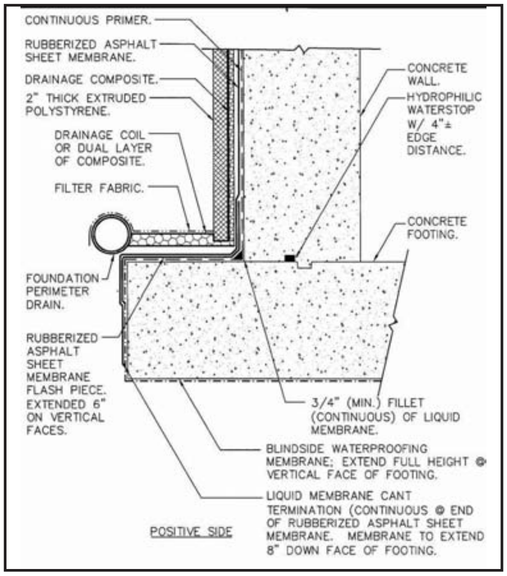

Figure 1 – Typical cross section of positive-side waterproofing system components.

WATERPROOFING SYSTEM COMPONENTS

Although not all components referenced in *Figure 1* are required for a complete waterproofing system, all are commonly utilized within the industry. Depending on on-site characteristics, including the height of the water table, code requirements, and the use of sub-drainage systems, the designer may consider a combination of the following components to be included in his or her waterproofing design:

- Surface primer
- Waterproofing membrane
- Protection layer
- Drainage composite
- Insulation
- Site slope and sub-grade drainage options
- Filter fabrics (as required for sub-grade drainage systems)

DETAILING AND INSTALLATION

The majority of waterproofing failures occur not through material deficiency or failure, but from poor workmanship or inappropri-

Photo 4 – Ribbed polyvinyl chloride (PVC) waterstop embedded in concrete.

Photo 5 – Preparation of substrate by blowing debris from concrete footing.

ate detailing by the design professional. The waterproofing and building envelope components need to act as one system, with each component affecting the overall performance. Detailing and building transitions require close attention from design professionals. Construction joints, expansion joints, penetrations and terminations are all "weak" points where the likelihood of leakage is the greatest on a below-grade waterproofing system.

Construction Joints

Where penetrations and construction joints or "cold joints" exist in a below-grade structure, waterstops should be installed as a means of preventing the transmission of water through that location. Even with the installation of full positive-side waterproofing, waterstops must be included as "redundancy" to the primary waterproofing system. Waterstops come in a variety of shapes and materials, including polyvinyl chloride (PVC), neoprene, thermoplastic rubber, bentonite clay, asphalt, plastic, and hydrophyllic materials. Waterstops should be installed on the "wet" side of the reinforcing steel to act as a barrier against corrosion. Care should be taken by the designer to ensure that waterstops are specified and installed at all cold joint and penetration locations. A combination of an embedded PVC and swellable bentonite or hydrophilic waterstops is recommended. The redundancy of a waterproofing membrane and waterstop to prevent transmission of water is critical to a successful waterproofing system.

Surface Preparation

Most waterproofing membranes are applied to concrete or wood surfaces. With the majority of waterproofing being applied to concrete surfaces, surface preparation is critical to obtain a well-adhered, nonpuncture-susceptible waterproofing membrane. Design documents should include manufacturers' expectations of what is acceptable with regards to substrate preparation. Although various manufacturers opinions may differ, concrete should typically be smooth and clean from loose debris. Bugholes, honeycombs, and voids in the concrete should be patched with a non-shrink grout or an acceptable patching cement. Poorly compacted concrete, typically found at the base of the wall, should also be filled. Small cracks in a concrete wall may require grinding and patching or a reinforcement application of the waterproofing sheet membrane. Note that specific substrate preparation methods and details are product- and manufacturer-dependent. The design professional should consult with the manufacturer's representative for typical substrate preparation requirements.

Waterproofing Material Selection

Based on the site conditions, owner expectations, and costs associated with installation, the selection of the waterproofing material and composition may vary. Typical waterproofing systems include but are not limited to the following:

- Fluid-Applied Systems, which are typically water- or solvent-based, cure to a monolithic, rubberized solid. Fluid-applied systems are typically installed cold; however, hot-applied, asphalt-based products are available. These systems have a number of derivatives including urethane, rubber, asphalt, and coal tar. Many applicators and designers prefer a fluid-applied system for a structure with overly complicated penetrations, and detail transitions as these products are typically "self-flashing." They also tend to accommodate structural movement, as they are considered to be highly resilient. However, obtaining an acceptable dry-film thickness of the finished product is imperative for product performance and may be workmanship-dependent. Additionally, the cured, fluid-applied system can be susceptible to punctures on the job site and requires a protection board to be installed once curing is complete. Some fluid-applied systems are not considered suitable for high hydrostatic head conditions on negative-side applications. It is recommended that concrete be allowed to cure for a minimum of seven days, preferably 28 days. Blistering may occur if water is trapped beneath the membrane.
- Sheet Membrane Systems, including but not limited to

thermoplastic, elastomeric, and rubberized asphalts, are typically installed in a single-ply membrane application. While sheet membrane systems are manufactured to a uniform thickness, high quality workmanship is required when detailing penetrations, joints, and seams. Unlike fluid-applied systems, sheet membranes should be shingled when installed to allow for the shedding of water. While sheet seam preparation and detailing differs, based on the manufacturer, a sufficient material lap and/or reinforcement sheet is typically required. Sheet-applied systems are also susceptible to fishmouths and blisters during the installation and alignment of the sheets. Sheet membrane systems can be loose-laid or fully adhered.

- Bentonite or natural clay systems have the ability to swell when exposed to water. Under proper confinement and when applied to properly prepared concrete, bentonite can be self sealing and act as an excellent barrier to water. Exposure to water activates the clay. Phased construction, where the clay may be exposed to weather for long periods, is not recommended, and backfilling immediately after installation is preferred. However, bentonite sheet waterproofing is favorably utilized in blind-side applications for foundation slabs where the concrete is poured directly onto the laid waterproofing sheets. The curing of the concrete in conjunction with the bentonite clays creates a strong bond. It should be noted that a geotech report is critical in determining the presence and locations where subgrade streams and tidal water tables exist, since such conditions can wash out or cause wet-dry cycle failures of bentonite.

Photo 6 – Blister in a fluid applied waterproofing application.

CONCLUSION

For a below-grade waterproofing system to be successfully executed, the design professional should review all available materials related to site conditions, structural detailing, and interior usage.

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