Polymer rubber gel technology for waterproofing underground structures

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ABSTRACT: Using Polymer Rubber Gel (PRG) technology for waterproofing underground structures is an effective method and has been proven to meet the unique challenges of underground construction. This technology has excelled in the requirements for successful waterproofing of below grade construction for cut and cover applications. The key characteristics for Polymer rubber gel waterproofing systems are adhesion to the substrate, responsiveness to substrate movement, non-curing, self-healing and chemical resistance. This newly developed material, polymer rubber gel, exhibits exceptional adhesiveness, self healing attributes and continuous flexibility. Polymer rubber gel combined with a durable, flexible laminate such as LLDPE or PVC creates a dynamically responsive composite waterproofing assembly that excels in waterproofing effectiveness. Recently, this technology and method has been successfully used for waterproofing large scale infrastructure tunnels in the state of California. This paper will describe polymer rubber gel's unique physical characteristics, its various waterproofing assemblies and a case history of application on a large scale infrastructure application.

1 Introduction

Cut and cover waterproofing poses distinct challenges in design and application. Proper selection of the waterproofing system and appropriate engineering details are essential to the success of any cut and cover waterproofing application. Two distinct methods of application are used for waterproofing a cut and cover structure. Positive side application is generally considered the application of the waterproofing membrane directly to the surface of a concrete substrate. Blind side application is generally considered the application of waterproofing to the soil support of excavation i.e. sheet pile wall, secant pile wall, CDSM, etc. For blind side applications, the structural wall is formed against the waterproofing membrane.

<table>
<thead>
<tr>
<th>Waterproofing Method</th>
<th>Description</th>
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<tbody>
<tr>
<td>Positive Side Waterproofing</td>
<td>Applying waterproofing directly to a concrete substrate</td>
</tr>
<tr>
<td>Blind Side Waterproofing</td>
<td>Pre-applying waterproofing to the soil support of excavation</td>
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Proper tie-in details between positive side waterproofing and blind side waterproofing are necessary for the effective application of the cut and cover structure, most notably at the horizontal invert base slab, vertical structural walls and lid.

The preferred method for waterproofing has been the direct application of waterproofing to the exposed concrete substrate - positive side application. This method is preferred because it allows the installer to see the substrate that is receiving the waterproofing and to ensure that proper membrane detailing and proper adhesion of the membrane to the substrate is achieved. However, overexcavation of the cut and cover structure may be impractical due to adjacent lot lines and is
typically more costly than utilizing a soil support of excavation method which necessitates the use of a blind side waterproofing assembly. Utilizing a blind side waterproofing assembly reduces the amount of excavation necessary for site construction. Typically, blindside waterproofing of cut and cover structures has been accomplished utilizing bentonite clay panels or more recently composite bentonite panels with sheet laminate. Bentonite requires hydration and compaction for effective waterproofing ability. Care must also be taken to protect the exposed membrane prior to concreting from pre-hydration caused by environmental conditions such as rain or site runoff. Within the last decade, preformed HDPE laminate pressure sensitive adhesive membranes have also been used to varying degrees of success for blindside applications. These preformed blindside membranes do not require compaction or hydration. Various challenges are inherent for both systems, including adhesion, flexibility, environmental

Through innovative developments in waterproofing materials, the industry has adopted a new state-of-the-art waterproofing system for both positive side and blind side membranes for cut and cover construction. With the introduction of polymer rubber gel, new hybrid composite waterproofing systems have been developed that attain superior waterproofing performance for cut and cover structures. A new concept in waterproofing, polymer rubber gel composite waterproofing system effectively wraps the cut and cover structure in a monolithic layer of flexible, self healing, non-curing gel. Polymer rubber gel’s unique physical characteristics were specially formulated to effectively retain the integrity of the waterproofing envelope through exceptional adhesive properties, continuous flexibility and self healing properties.

2 Requirements for effective waterproofing of cut and cover structures

2.1 Design requirements and waterproofing system selection

Many factors must be considered for effective waterproofing of cut and cover structures. First, a water tightness criteria must be identified for the structure. A waterproofing system selection process should then be based on the water tightness criteria considering both physical site conditions and type of construction chosen for the cut and cover structure. The substrate for which the blind side waterproofing system is to be applied should be considered during the soil support of excavation design process. A relatively smooth surface with sufficient rigidity should be specified to prevent the risk of cavitations, tears or punctures in the waterproofing system subsequent to concrete placement. For example, with sheet pile walls, a protection board with some sort of structural fill behind the board in the flutes is necessary to prevent blowouts in the waterproofing system during concrete placement. For DSM or secant pile walls, the substrate should either be shotcreted to a relatively smooth surface or the face of the DSM/secant pile walls should be shaved flush with the face of the soldier beams. Protrusions or cavitations in the excavated DSM/secant pile walls will need to be smoothed to create an acceptable substrate for the application of the blind side waterproofing system. All waterproofing systems require careful consideration of the substrate prior to application.

For effective waterproofing of cut and cover structures below the watertable, the entire building envelope of the cut and cover structure must be continuously enveloped in the waterproofing system. Proper detailing for tie-ins to other structural waterproofing systems, penetrations, protrusions (such as tiebacks in secant pile walls), transitions, terminations and seams within the waterproofing system are essential for maintaining the integrity of the continuous waterproofing envelope. Maintaining the same waterproofing system throughout the structure is preferred so as to limit any issues of either incompatibility or difficult tie-in details. A single source manufacturer waterproofing system warranty is also preferred.

2.1 Constructability and installation

Constructability should also not be overlooked in the system selection process. Oftentimes, waterproofing systems used on large scale cut and cover applications will be exposed to the elements for extended periods of time prior to placement of concrete. In addition, follow on trades must work in direct proximity and in the case of the mud slab, on top of the in place waterproofing system. The environmental and physical durability of the exposed waterproofing membrane is important to prevent potential damage to the waterproofing system prior to concreting and backfill. Preconstruction meetings with the waterproofing applicator and project general contractor should be conducted to
ensure proper work staging to limit the exposure. Waterproofing systems that are easily damaged or require extensive protection can cause project delays due to the necessity for repairs and/or complicated protection schemes. Manufacturer approved applicators skilled and experienced in the installation of the specified waterproofing systems are essential to the positive outcome of any waterproofing installation. Onsite QA/QC for the waterproofing work should also be provided to document and help ensure that the waterproofing system is installed per spec and plans.

2.2 Important physical requirements of the waterproofing system

After successful installation and proper detailing, a waterproofing system’s ultimate performance is based on its physical attributes. The following is a list of physical attributes that are important to the long term watertightness of a cut and cover waterproofing system.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Benefit to waterproofing</th>
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<tr>
<td>Adhesion to concrete</td>
<td>Adhesive bond of the waterproofing to the substrate it is protecting ensures no path for water migration.</td>
</tr>
<tr>
<td>Elongation</td>
<td>The ability to bridge cracks in concrete and construction joints without debonding ensures water tightness</td>
</tr>
<tr>
<td>Hydrostatic pressure resistance</td>
<td>The system must have the durability to withstand continuous hydrostatic pressure without rupture</td>
</tr>
<tr>
<td>Self healing/sealing capability</td>
<td>Mitigates failure of the system with the ability for it to self heal if punctured or penetrated</td>
</tr>
<tr>
<td>Chemical resistance</td>
<td>Prevents degradation of the waterproofing system from soil contamminates</td>
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2.3 Additional water mitigating components to the waterproofing system

In addition to a cut and cover structure’s primary waterproofing system, additional consideration must be given to accessory waterproofing components such as prefabricated drainage composites and various types of waterstops. For cut and cover structures that are not below the watertable or where additional water control measures are desired, prefabricated drainage composites may be a suitable addition to the waterproofing system. A drainage system removes direct hydrostatic pressure from the waterproofing membrane. It is also advisable to utilize waterstops on critical construction joints as a last means of defense against water inflow. Regroutable injection tubes should also be considered for critical interfaces, such as between subway stations, structures, and tunnels. There are many various forms of drainboards, waterstops and regroutable waterstops. An in depth explanation of these systems is beyond the scope of this paper.

3 Contribution of polymer rubber gel to cut and cover waterproofing

3.1 Introduction

Polymer rubber gel waterproofing systems have excelled in meeting the requirements of challenging cut and cover waterproofing applications. Developed specifically for the waterproofing industry, polymer rubber gel is comprised of a modified rubberized asphalt emulsion. However, unlike typical rubberized asphalt materials, polymer rubber gel’s polymers never completely cross link. This retains the gel in a semi-cured state. This innovation enables polymer rubber gel to act as an exceptionally flexible, adhesive, continuously self healing membrane. A new concept in waterproofing, composite waterproofing systems utilizing a polymer rubber gel component exhibit superior elongation properties, adhesion and self healing ability. A polymer rubber gel waterproofing system is comprised of a layer of polymer rubber gel at minimum thickness of 2.5mm +/- .5mm combined with a sheet membrane laminate such as LLDPE or HDPE. Varying manufacturer produced viscosities of polymer rubber gel allow for multiple delivery methods including spray applied, trowel applied and preformed waterproofing sheet applied. The flexible, non-curing, highly adhesive polymer rubber gel and the
durable, chemical resistant, hydrostatic pressure resistant LLDPE or HDPE sheet are combined to create a dynamically responsive high performance waterproofing system for cut and cover construction. Application of a polymer rubber gel system is efficient and economical.

3.2 **Unique physical characteristics of polymer rubber gel**

Polymer rubber gel exhibits many unique physical characteristics that make it an ideal component to a composite waterproofing system. The physical characteristics that are unique to polymer rubber gel are principally the gel’s ability to remain in an uncured state and also it’s extreme cohesion and adhesion attributes. Polymer rubber gel’s elongation to break is greater than 350% (ASTM C1135). Polymer rubber gel’s adhesion to concrete is rated one (1) for excellent (ASTM D412-98). Polymer rubber gel’s self healing ability has been tested to 3.0 bar of direct hydrostatic head (2mm thickness of polymer rubber gel membrane).

![Figure 1. Polymer rubber gel's exceptional elongation property](image1)

3.3 **Advantages of polymer rubber gel waterproofing systems**

Shear force of the waterproofing membrane against the concrete substrate caused by either seismic activity, foundation settlement, vibration, thermal expansion and contraction or shrinkage cracks in concrete can cause traditional waterproofing membranes to debond from the substrate and fail. Since polymer rubber gel is a non-cured flexible gel it effectively creates a ball bearing effect that allows it to dynamically respond to the movement of two substrates moving independently of one another. This non-cured, flexible bond retains the integrity of the waterproofing envelope better than traditionally fully adhered, cured waterproofing systems.

![Figure 2. Polymer rubber gel's ball bearing effect](image2)
Due to polymer rubber gel’s non-curing characteristic, it has the unique ability to repeatedly self heal under direct hydrostatic pressure. This ability helps mitigate some common pre-construction waterproofing system damages such as accidental form work penetrations, construction site debris (nails, fasteners, etc.) or applicator installation mistakes. This allows for a greater “margin of error” in the waterproofing system resulting in a system that achieves a higher level of predictable performance.

![Figure 3. Testing polymer rubber gel’s self healing ability](image)

Polymer rubber gel also does not require substrate conditioners and can be applied to freshly stripped concrete, eliminating a 28 day cure time prior to waterproofing application. Since the gel never completely cures, there is no cure wait time for application of other components to the waterproofing system and concreting can be completed immediately after application of the waterproofing system. These easy surface preparation conditions speed a project’s time to completion by eliminating waterproofing as the critical path.

![Figure 4. Field application of polymer rubber gel composite waterproofing system](image)

4 Polymer rubber gel waterproofing assemblies and design considerations for cut and cover structures

4.1 Positive side assembly and blind side assembly

For cut and cover construction, polymer rubber gel waterproofing systems have two basic assemblies, positive side and blind side. The positive side assembly is applied on the mud slab underneath the base slab for box construction of cut and cover construction and also to the roof slab. The blind side assembly is applied to the soil support of excavation for cut and cover construction that is utilizing soil support of excavation methods to form the box construction. Each assembly is comprised of a composite system of protection sheet combined with polymer rubber gel. The durability of the sheet combined with the flexibility of the gel creates the dynamically responsive waterproofing system. For the blind side assembly, an additional protection sheet is applied to the negative face of the system to
protect this installed waterproofing system from job site contamination or damage. The protection layer is UV stable and offers environmental protection of the waterproofing system for up to three months. This duration of protection allows greater flexibility for timing of pours in a cut and cover application. The base slab positive side assembly is robust enough to serve as a trafficable surface. However, a thin topping slab is recommended to improve durability and to add enhanced protection prior to backfilling for the ceiling slab and prior to the invert pour for the base slab.

![Figure 5. Polymer Rubber Gel Positive Side Assembly](image)

Preparation of the soil support of excavation substrate for blind side application of the polymer rubber gel system may require the application of a plywood protection board or application of a shotcrete smoothing layer to create a sufficiently rigid and smooth substrate for the mechanical attachment of the waterproofing sheet. Typical applications where this would be necessary are for sheet pile walls or some types of deep soil mix walls. Care must be taken to prevent the possibility of protrusions from the wall or cavitations that could damage the waterproofing assembly either during assembly or at the time of concrete pour.

The principal design concept for a cut and cover structure with a polymer rubber gel waterproofing system is to achieve a complete monolithic building envelope of the gel system. This requires proper detailing of the transitions from base slab to walls and walls to ceiling. Special attention to detailing at these transitions is essential for the integrity of the waterproofing envelope. Typically, it is at these transitions that leaks can occur, especially at the base slab transition where most of the hydrostatic pressure will occur.

Accessory waterproofing system products, such as prefabricated drainage composites and waterstops are compatible with polymer rubber gel waterproofing systems and should be evaluated for use based
on specific site and construction conditions. Water table, adjoining construction and expected hydrostatic pressure against the positive side of the cut and cover structure should be taken into account when evaluating the use of accessory waterproofing products.

5 Polymer rubber gel waterproofing system case study: Presidio Parkway, CA

5.1 Introduction

Renovations are underway to improve the seismic, structural and traffic safety of the approach leading to the Golden Gate Bridge in San Francisco. On one of the most iconic roadways in the United States, major improvements in design will open up enhanced views of San Francisco Bay, support rehabilitation of endangered tidal marshlands and improve pedestrian networks throughout the Presidio of San Francisco. The replacement of Doyle Drive with the Presidio Parkway is a collaborative effort led by the California Department of Transportation, the San Francisco County Transportation Authority, and the Federal Highway Administration. Segregated into two phases, phase one was completed April 2012. The first phase included the construction of a seismically stable replacement viaduct and tunnel. Phase two of the project started Fall of 2012. Scheduled completion is for 2016. The second phase of the project was structured as a P3 contract, the state of California’s first P3. The concessionaire will maintain the project for 30 years. Special consideration was given to both design and materials selection to help mitigate maintenance related issues for the coming decades. Total project cost is calculated at $928 million USD.

Figure 7. Presidio Parkway scope of work

A polymer rubber gel waterproofing system was specified for use on all tunnels within the scope of work. Project design calls for the construction of four highway tunnels, constructed utilizing the open cut method. Phase 1 (tunnel portion) was designed by Parsons Brinckerhoff/Arup. HNTB is responsible for Phase 2 design. Phase 1 consisted of the South Bound Battery Tunnel, a substation building beneath the tunnel, southbound high viaduct and other structures and roadway work. Total square footage for all installed waterproofing is greater than 1,000,000 sq. ft. Because of the significance of this particular project and the first time use of this product on the State Highway System, a pre-evaluation was completed and construction evaluation is ongoing of the polymer rubber gel waterproofing system by the California Department of Transportation.

5.2 Polymer rubber gel waterproofing selection

Many waterproofing systems were evaluated for specification for the Presidio Parkway project including typical bentonite panel and pressure adhesive systems. However, known limitations with these systems in seismic areas precluded their use. Structural engineers were particularly concerned with improving seismic performance of the construction. Polymer rubber gel’s superior flexibility and self healing characteristics help ensure that the tunnel waterproofing system can better withstand seismic events. Designers also specified polymer rubber gel because it provided the owner with a performance guarantee that covered both labor and materials for 15 years of watertight performance.
5.3 Polymer rubber gel waterproofing system application

Concrete columns with embedded steel beams provided the support of excavation for the trench cut. The face of the columns were shaved flush with the beam flange and a 3” smoothing layer of shotcrete was applied. Construction required a blind side waterproofing system as the structure was not over-excavated. The structural walls of the tunnel were formed directly against the shotcreted walls. Because the structure was not expected to withstand constant hydrostatic pressure, a prefabricated drainage composite was applied to the shotcreted walls. The blindside polymer rubber gel assembly was applied directly to the prefabricated drainboard composite. The positive side assembly was applied to a mud mat on the base slab and directly to the ceiling slab, both covered with a 3” protection slab.

![Figure 9. Presidio Parkway view from above construction](image1)

6 Conclusion

Polymer rubber gel waterproofing systems are proven and effective for cut and cover construction applications. Other large scale infrastructure applications for this technology include projects such as subway stations for Bay Area Rapid Transit, San Francisco Muni and Toronto Transit Commission. Polymer rubber gel’s unique physical characteristics enhance composite waterproofing assemblies. Given proper design consideration and specification of composite polymer rubber gel waterproofing assemblies, the state-of-the-art within the cut and cover construction industry has advanced.

7 References

<www.presidioparkway.org/project_docs/fact_sheets.aspx>.