Fundamentals of Traffic-Bearing Membranes

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Figure 1 – Chloride exposure.

Figure 2 – Corrosion of reinforcing steel.

Concrete structures such as parking garages and stadiums are sometimes exposed to harsh environmental conditions. Exposure to deicing salts and other chlorides, high humidity levels, and carbonation can lead to corrosion of reinforcing steel (*Figures 1* and *2*).

Traffic-bearing membrane systems (TBMs) are used to protect horizontal concrete surfaces from deterioration by preventing moisture and deicing salts from reaching the reinforcing steel. TBMs also help protect property below (i.e., vehicles in a parking garage) by preventing moisture from migrating through the slab (*Figures 3* and *4*). Beyond their functional purposes, a TBM often provides an aesthetic upgrade to its bare concrete surface counterpart (*Figures 5* and *6*).

TBMs are most commonly used to protect horizontal surfaces in high vehicular or pedestrian traffic areas such as parking garages, stadiums, and balconies. Areas over occupied space—such as plaza decks or mechanical rooms—can be candidates for TBMs. However, scenarios such as these, where a TBM is used as the primary waterproofing system to protect against water leakage, should be treated with caution. TBMs can also be used over concrete slabs-on-grade. However, the waterproofing benefits of a TBM over slabs-on-grade are often minimal. Other criteria, such as the presence of a vapor retarder below the slab and the type of reinforcement in the slab, should be closely evaluated prior to applying a TBM over slabs-on-grade.

Figure 3 – Moisture migration through slab.

Figure 4 – Vehicle damage.

Before selecting a TBM material, it is important to understand the characteristics of the surface where a TBM will be applied. The age of the concrete, moisture content in the slab, and crack configuration are factors that can affect TBM selection and performance.

Bond strength is the most important characteristic for a durable TBM system. A TBM system will not bond well to a wet surface. Furthermore, TBMs create a vapor retarder that prevents moisture vapor emissions. This is only exaggerated in floor assemblies that have another vapor retarder elsewhere

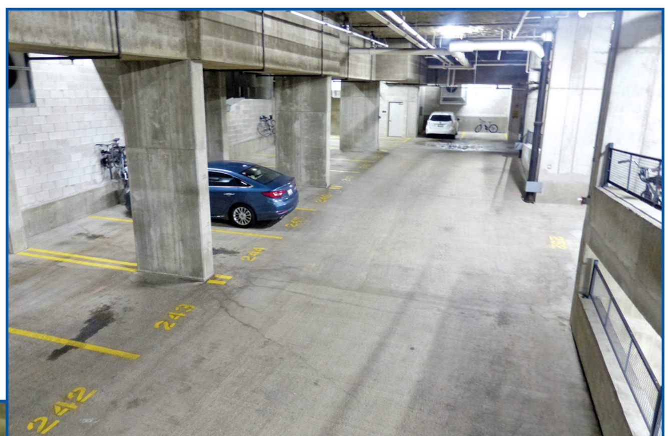

Figure 5 – Parking garage slab prior to TBM application.

Figure 6 – Parking garage slab after TBM application.

Figure 7 – ASTM F1869 moisture emission testing.

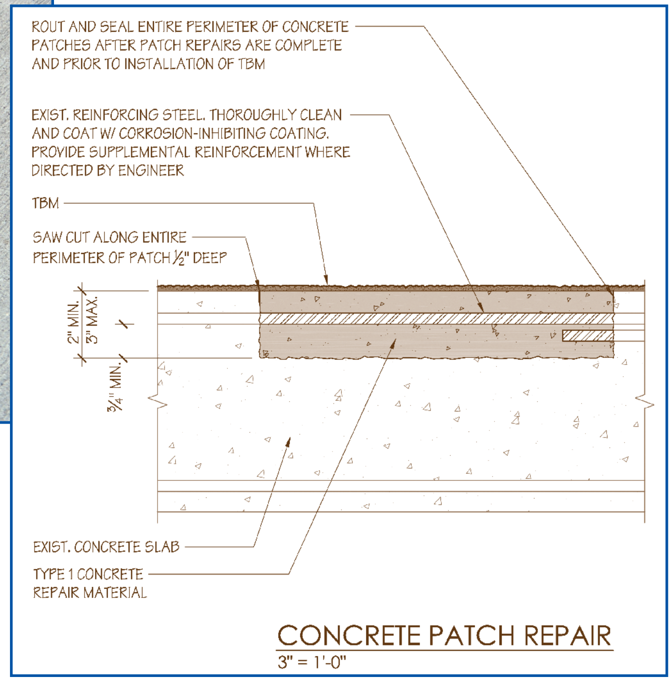

Figure 8 – Concrete patch repair.

in the assembly. As an example, steel decking in composite decks can act as a vapor retarder (unless the deck is vented). Split slab construction is another example where the waterproofing membrane—sandwiched between the structural slab and topping slab—acts as a vapor retarder. Even though many TBM manufacturers permit it, using TBMs for these applications may not allow the slab to dry sufficiently.

Vapor pressure from trapped moisture will result in blistering and/or a failed membrane. This is primarily a concern in new construction applications during the curing process. While a 28-day cure is a common benchmark used in concrete construction, there are many other factors besides time that will affect the moisture emission rate of the concrete. Moisture emission can and will still occur well beyond a 28-day cure time. As such, it is important to verify that the moisture emission rate is within the TBM manufacturer's acceptable limits before TBM application begins, regardless of the age of the concrete. Moisture emission can be measured using various test methods, including ASTM D4263 (*Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method*), which provides qualitative results, and ASTM F1869 (*Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride*), which yields quantitative rates of moisture emission (*Figure 7*). ASTM F2170 (*Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in Situ Probes*) is another useful test method that measures the relative humidity within the slab.

SURFACE PREPARATION

Bond strength is also dependent on the appropriate preparation of the substrate surface. There are many TBM material and manufacturer options. Recommendations for surface preparation vary from material to material, and from manufacturer to manufacturer. As such, it is important to follow the manufacturer's written recommendations for surface preparation. At a minimum, TBMs should only be applied to sound concrete. Surfaces that will receive the TBM should be sounded (i.e., hammer sounding or chain dragging) to locate loose or delaminated concrete. Proper concrete repair methods and materials should be used to repair areas where loose or delaminated material is located (*Figure 8*). Moisture emission rates should again be verified at repaired areas prior to applying a TBM.

Most TBMs will require some degree of roughening of the substrate in order to promote adhesion. The International Concrete Repair Institute (ICRI) has developed criteria for defining various levels of concrete surface profiles (CSPs). These criteria, as defined in ICRI's Technical Guideline 310.2R, range from a nearly flat surface (CSP-1) to a surface amplitude of more than ¼ inch (CSP-10). Table 7.1 in Technical Guideline 310.2R lists protective system materials that are commonly applied to concrete surfaces and the recommended CSP range for each (*Figure 9*). Table 7.2 lists the various preparation methods that can be used to achieve each CSP level (*Figure 10*). A more detailed description of each preparation method can be found in Table 3.3.2 from ACI 546 – *Guide to Concrete Repair*. Of the protective systems listed, TBM systems would be considered high-build coatings.

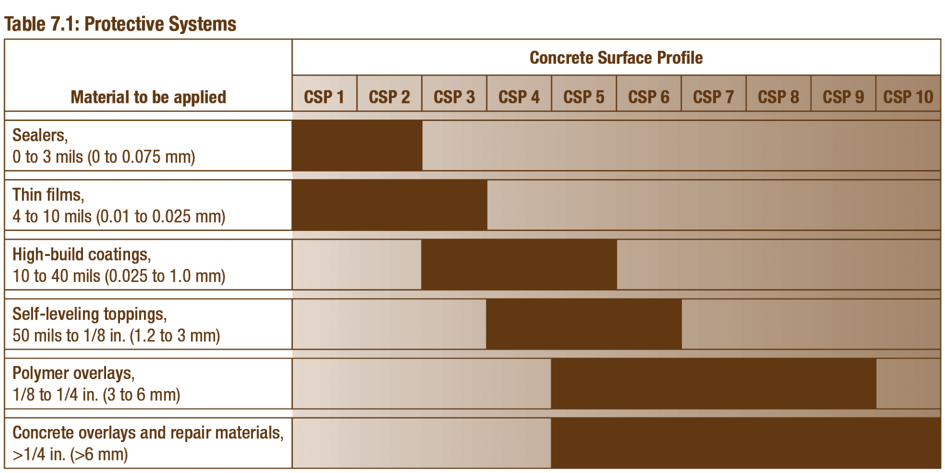

Figure 9 – Table 7.1, ICRI 310.2 R.

Table 7.2: Preparation Methods

Surface preparation method	Concrete Surface Profile									
	CSP 1	CSP 2	CSP 3	CSP 4	CSP 5	CSP 6	CSP 7	CSP 8	CSP 9	CSP 10
Detergent scrubbing	■									
Low-pressure water cleaning	■									
Grinding	■	■								
Acid etching	■	■	■							
Needle scaling		■	■	■						
Abrasive blasting		■	■	■	■	■	■			
Shotblasting		■	■	■	■	■	■	■	■	
High- and ultra-high-pressure water jetting			■	■	■	■	■	■	■	■
Scarifying				■	■	■	■			
Surface retarder (1)					■	■	■	■	■	■
Rotomilling						■	■	■	■	
Scabbling							■	■	■	
Handheld concrete breaker							■	■	■	■

(1) Only suitable for freshly placed cementitious materials

Figure 10 – Table 7.2, ICRI 310.2R.

As such, ICRI recommends that the surface be prepared between a CSP-3 and a CSP-5. Shotblasting is a popular preparation method to achieve the desired surface profile because it is an efficient way to remove contaminants and produce relatively uniform surface characteristics (*Figures 11* and *12*). However, other

Figure 11 – Shotblasting.

Figure 12 – Shotblasted surface.

Figure 13 – Cracks in concrete.

Figure 14 – Routed and sealed cracks.

Figure 15 – Sealant at horizontal-to-vertical transitions.

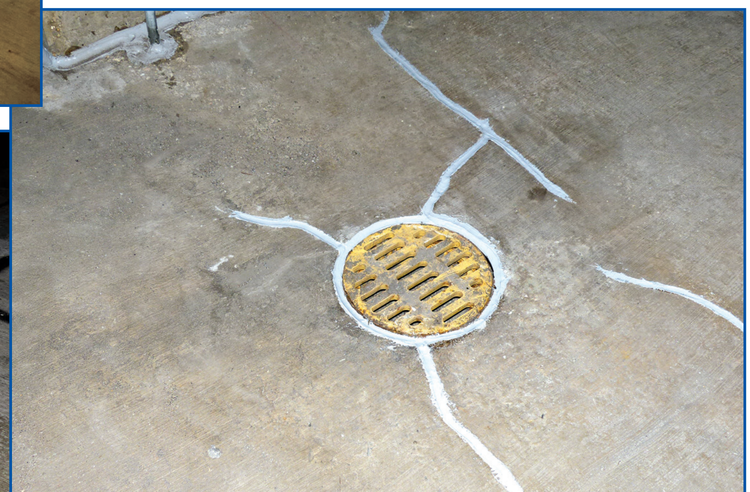

Figure 16 – Sealant at drain perimeter.

surface preparation methods may be more suitable, depending on the TBM material selected and the surrounding conditions. The TBM manufacturer should be consulted for appropriate surface preparation methods for each project.

The final piece of the surface preparation puzzle is the treatment of cracks, which are inevitable in concrete construction (*Figure 13*). The extent and pattern of cracking should be evaluated prior to applying a TBM system. It is also important to verify the cracks are not indicative of more significant issues (i.e., structural deficiencies, corrosion of existing reinforcing steel, etc.).

Some narrower, static cracks can be treated with additional base coat material (often referred to as pre-striping). Wider cracks and cracks where dynamic movement is anticipated should be routed and sealed with an elastomeric sealant prior to applying a TBM (*Figure 14*). Polyurethane sealant is recommended because fluid-applied membrane materials do not typically adhere well to silicone sealants. TBM systems are often wrapped up vertical surfaces a specified distance (approximately 4 to 6 in.) to create a bathtub effect. TBM manufacturers also recommend applying polyurethane sealant at horizontal-to-vertical transitions such as walls, columns, steps, etc. to create a concave surface to adhere to instead of a sharp 90-degree corner (*Figure 15*). This is similar to the function of a cant strip in roofing. Sealant application is also important at horizontal terminations of the TBM, such as floor drains (*Figure 16*).

TBM MATERIAL OPTIONS

There are many TBM system material options. As such, it is important to understand the advantages and disadvantages of each option. Common TBM materials include the following:

- Polyurethane
- Polyurea
- Epoxy
- Methyl methacrylate
- Cementitious

Polyureas have superior material properties when compared to polyurethane. However, application requires costly spray equipment and can only be applied over small areas at a time because the material sets up quickly. Epoxies can have good waterproofing characteristics. However, many epoxy formulations on their own are too rigid to accommodate thermal movements and will not maintain their color when exposed to UV rays. Other materials, such as polyurethanes, are often used in conjunction with epoxies to provide better elastic properties and to be more UV-stable. Methyl methacrylates have excellent UV resistance, and can be manipulated more easily to achieve greater hardness or flexibility. However, their material properties vary with temperature, and the materials themselves are highly volatile and more costly than some of the other options. As such, there are more variables that need to be considered during the design phase than with other materials. Cementitious materials are more permeable and provide more options for aesthetics. However, cementitious materials do not have the elongation properties that some of the more elastic materials have. Polyurethane is the most common material used in TBM application and will be the main focus of this article going forward.

Polyurethane TBM systems are generally divided into two groups: Single-component systems and two-component systems. Single-component systems are solvent-based materials with low solids content. Their curing mechanism is moisture-based, which leaves them highly dependent on environmental conditions. The strong odors commonly associated with single-component systems are not ideal for poorly ventilated and/or confined spaces.

Two-component systems are solvent-free materials with a high solid content and relatively low odor. The materials are chemically cured and, therefore, less dependent on environmental conditions. This can lead to a more predictable schedule. However, there is more labor involved in mixing the components.

Figure 17 – Primer application.

Figure 18 – Pre-striping.

Figure 19 – Base coat application.

TBM SYSTEMS

TBM systems typically include the following layers:

1) Primer (where required by manufacturer): Roller-applied over properly prepared concrete surface (*Figure 17*).
2) Pre-striping: Roller-applied base coat material over non-moving cracks and cracks less than 1/16 inch (*Figure 18*).
3) Base coat: Spread with a notched squeegee and back-rolled with rollers (*Figure 19*). Note: Since walking through wet materials is unavoidable during TBM application, applicators typically wear spiked footwear as depicted in *Figure 19*.
4) Intermediate coat with aggregate (for heavier-duty applications): Spread with a notched or flat squeegee and back-rolled with rollers (*Figure 20*).
   a. Aggregate is added for slip resistance and most commonly

Figure 20 – Intermediate coat application.

Figure 21 – Aggregate.

Figure 22 – Finish coat application.

consists of rounded silica sand (*Figure 21*). Less-common materials include walnut shells or rubber. Aggregate can be applied using the refusal method or the broadcast and back-roll method.

b. High-friction areas will wear faster. As such, thicker TBM systems are usually specified for high-traffic areas (i.e., turning lanes).

5) Top coat(s) with aggregate: Same material and application methods as intermediate coat (*Figure 22*).

POST-APPLICATION

Cure time will vary from manufacturer to manufacturer. However, TBM systems can be opened to pedestrian and/or vehicular traffic as soon as 24 hours after top coat application in some cases. TBM surfaces can be cleaned with a pressure washer, provided the TBM manufacturer is consulted regarding maximum pressures that can be used to avoid abrasively damaging the membrane. TBM manufacturers offer a variety of warranty options. Some warranties include periodic reviews of the TBM system by the manufacturer with recommendations for maintenance and repairs. TBMs can be patched in localized areas. The top coat wears from heavy traffic. Top coats can be reapplied periodically, provided the TBM manufacturer confirms that the remainder of the TBM system is in good condition.

CONCLUSION

TBM systems are appropriate for protecting horizontal concrete elements with pedestrian and vehicular traffic. In order to ensure durability of the TBM system, it is important to evaluate the existing conditions and verify appropriateness and compatibility of desired materials. Once a material is selected, following the manufacturer's recommendations for surface preparation and TBM system application is critical to the performance of the system. Proper maintenance after application will also help extend the life of the TBM system.

REFERENCES

ACI 302.1R-15 – Guide to Concrete Floor and Slab Construction. American Concrete Institute.

ACI 564R-14 – Guide to Concrete Repair. American Concrete Institute.

ACI 546.3R-14 – Guide to Material Selection for Concrete Repair. American Concrete Institute.

K. Farahmandpour. "Does a Traffic-bearing Membrane Constitute a Proper Waterproofing System Over Occupied Spaces?" *RCI Interface*. RCI, Inc. February 2006. p 44.

K. Farahmandpour. "Failure Mechanisms in Liquid-Applied Waterproofing Systems." Building Technology Consultants, PC.

K. Farahmandpour and T. Willems. "Evaluation of Liquid-Applied Waterproofing Systems: Case Histories." *RCI Interface*. RCI, Inc. October 2001. pp. 21-31.

K. Farahmanpour. "How Dry Should Concrete Decks Be...for Application of Liquid-applied Waterproofing Membranes?" *RCI Interface*. RCI, Inc. October 2001. pp. 14-17.

Emily R. Hopps and Peter E. Nelson. "Avoiding Flooring Failures: 10 Things You Need to Know." Good Technical Practice. *Durability + Design*. January 2014. pp. 21-28.

Technical Guideline No. 310.2R-2013 – Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair. International Concrete Repair Institute.

Technical Guideline No. 710.2-2014 – Guide for Horizontal Waterproofing of Traffic Surfaces. International Concrete Repair Institute.

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