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Elastomeric Waterproofing Membranes for Parking Garage Decks

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The slab of a parking garage serves as a structural diaphragm and wearing surface. It also must provide protection for the space below. Those functions require a deck to be impervious to liquids and stop water from seeping through cracks. Depending on the type of structure, North American Standards require, as a minimum, sealing the top surface of the deck with penetrating sealers or elastomeric traffic bearing membranes, with or without epoxy coated reinforcing steel. Elastomeric membranes are widely used to prevent the ingress of water and chloride ions, both for new and existing structures. The durability of membranes is affected by a number of factors, including poor installation, variation in product uniformity, and exposure to adverse in-service conditions. A study of six proprietary membranes showed many degradative agents encountered in the parking garage environment affected critical properties, seriously reducing short- and long-term performance of the membranes.

In repairing and restoring parking garages, the general approaches include patching and waterproofing; replacing the deteriorated surface with concrete overlays; cathodic protection; and crack injection with polymeric materials such as epoxies.[1,2]

Patching and waterproofing offer a medium term solution to deck deterioration problems. Delamination and spalls are repaired by removing the affected concrete to below the level of the top steel, cleaning and coating the exposed surfaces with a corrosion inhibiting primer, and back filling with fast setting, high-strength concrete. After patching is completed, a surface barrier (such as a elastomeric membrane or a penetrating sealer) is applied. This substantially reduces the penetration of moisture and chloride ions.[1-3]

Elastomeric membranes provide an impervious barrier to the concrete surface, bridge cracks, and respond to thermal cycling without rupture. Sealers reduce moisture and chloride ion ingress by filling the concrete pores below the level of the concrete surface. An advantage of elastomeric membranes is that they are thin adhesive coatings, that are easy to apply and provide a good seal of the concrete surface, cracks, joints, and drains, regardless of the geometry of the structure.[2,4]

Moisture barriers for parking garages are classified into two types, thin systems 0.7 to 1.5 mm (elastomeric adhesive coatings) and thick systems (asphalt mastics). This article discusses the composition, properties, performance, durability, criteria for selection, and quality control of the thin systems. Performance and durability characteristics are illustrated by results obtained from a study involving six elastomeric coating systems.[5]

Categories of Elastomeric Membrane Systems

Elastomeric parking garage membrane systems vary in chemical composition, types of wear resistant top coats, and method of application. Various types available on the market include one component, moisture-cured polyurethane, two component catalyzed polyurethane, two component flexibilized epoxy-urethane, and water-based neoprene.

Many systems are liquid elastomers, usually cold applied in thin coats. Typically, the system consists of a primer, followed by the waterproofing coating, 30 to 60 mil (0.75 to 1.50 mm) thick overcoated with an abrasion resistant 60 mil wear coat containing aggregate. A tie coat is then sprayed over the aggregate to firmly bond it (Figure 1).[2]

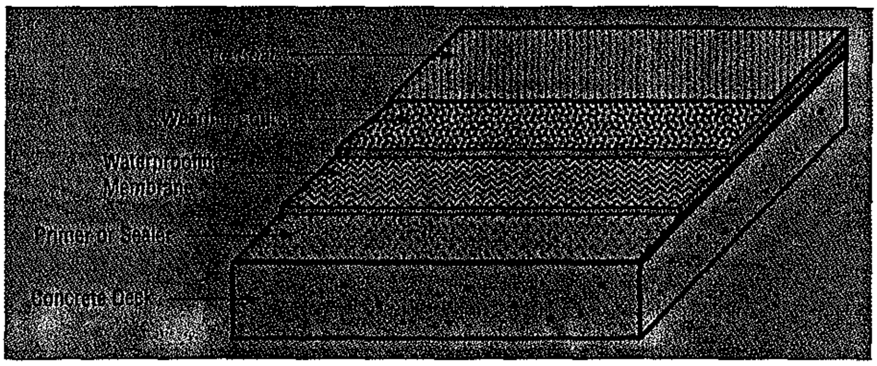

FIGURE 1
Typical configuration of a parking garage coating.

Membrane Properties

Properties critical to a membrane's performance and durability are tensile strength, elongation, adhesion, resistance to heat, UV, chemicals, and freeze/thaw (F/T) cycling.

Mechanical Properties—Tensile Strength and Percent Elongation

Membranes must endure stresses imposed by traffic without damage. Mechanical properties must remain satisfactory at all temperatures likely to be encountered in the parking garage. Mechanical properties are usually determined by measuring changes in tensile strength and elongation of free film and composite specimens.Results are expressed as a percent of the control value.[5-6]

TABLE 1
Chloride Ion Permeability of Coated and Uncoated (Control) Concrete Specimens According to AASHTO T227-831

Coating System	Initial Charge (Coulombs) w/c = 0.45 Air Entrained	w/c = 0.45 Nonair Entrained	w/c = 0.55 Air Entrained	w/c = 0.55 Nonair Entrained
PDM1	<1	10	36	<1
PDM2	2	1	1	<1
PDM3	<1	223	24	143
PDM4	2	0	0	17
PDM5	135	3	502	2
PDM6	<1	<1	<1	<1
Control	7,815	4,170	10,940	8,695

Intercoat Adhesion and Adhesion to the Concrete Substrate

Good intercoat adhesion and adhesion to the substrate is a primary requirement that should be satisfied under normal, humid, or other specific conditions to which the deck will be subjected. Adhesive strength of the concrete coating was evaluated using a tensile bond test. Bond strengths varied with the type of concrete due to the macro structural effects of the concrete surface on adhesion.[1,4,7]

In general, lower values were obtained with air entrained concrete. Concretes made with water:cement (W/C) ratios exceeding 0.55 may produce varied results, depending on the difference in viscosity of the membranes. Lower viscosity materials penetrate the pores of the concrete and provide mechanical interlocking. This increases bond strength. Lower values obtained with air entrained concrete was probably due to a fatty acid film on the surface of the cement and aggregate particles. Most air entraining admixtures are fatty acid based. The film they produce on mortar and aggregate reduces adhesion of the membrane to such substrates.[5]

Water Vapor and Chloride Ion Permeability

The whole system (including seals curbs and joints) should be impervious to water and chloride ions under all anticipated conditions. Applying the waterproofing membrane reduces water vapor permeance of the concrete. However, the degree to which permeance is reduced depends on the type of coating and concrete substrate.

Waterproofing properties are usually determined through permeability tests conducted on composite samples consisting of the waterproofing and wear coat. Tests were conducted on samples in which the coating was applied to air entrained and non-air entrained concrete at two different W/C ratios. These tests determined the effect of concrete surface characteristics on coating film formation, and hence moisture vapor transmission. The result (expressed as percentage permeance) was obtained by comparing the test values to the control value—that produced from uncoated concrete samples. Reduced percentage permeance values were obtained for samples made with air-entrained concrete as well as those with the higher W/C ratio.[6] Reduced percent permeance values observed in the air entrained and higher W/C ratio specimens was due to thicker resinous coats formed on the more porous surface of such concretes.[3,5,7]

The efficiency of the coating in reducing chloride ion permeability was measured by the chloride permeability test AASHTO T-831, based on the total electric charge passed. Most results obtained from this test showed the coating significantly reduced chloride ion permeability into the concrete substrate. Some coatings applied to air-entrained and higher W/C ratio concrete substrates gave higher permeability values (Table 1).

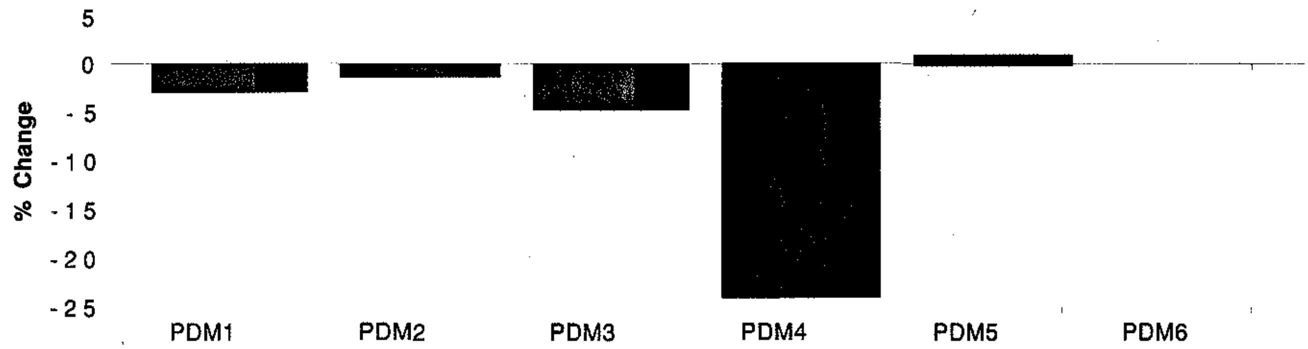

FIGURE 3
Resistance to heat aging: weight changes after 28 days' exposure to 100°C.

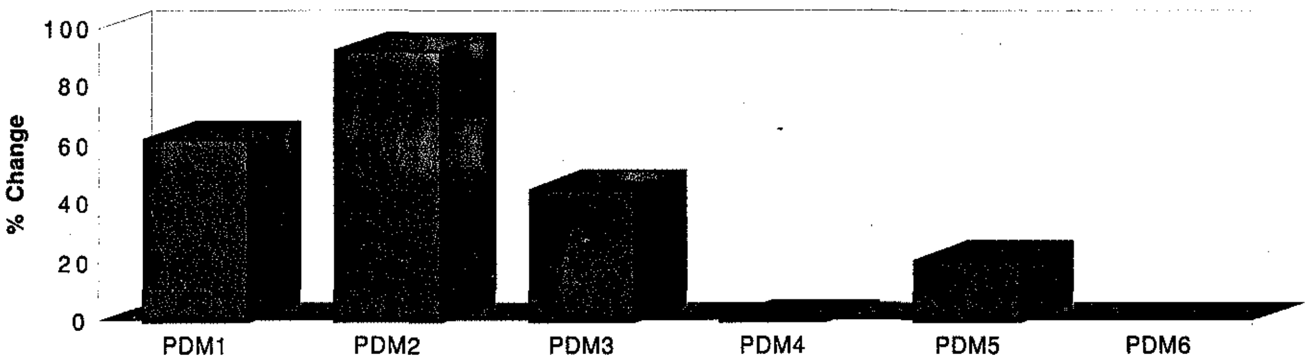

FIGURE 4
Resistance to heat aging: retention of elongation after 28 days' exposure to 100°C.

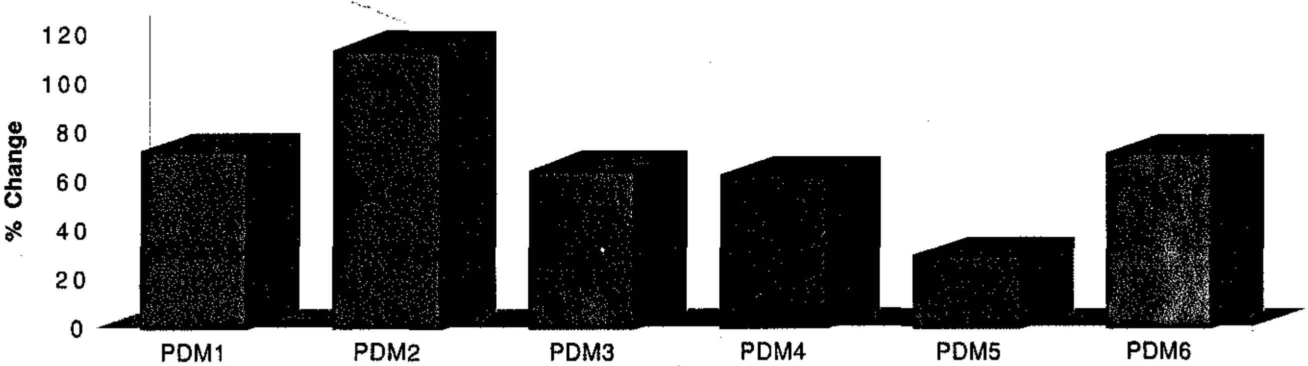

FIGURE 5
Resistance to UV radiation: retention of elongation of free film specimens.

Exposure to motor oil produced small reductions in tensile strength, while elongation capacity decreased in a number of membranes. Membranes immersed in ethylene glycol showed significant tensile strength reduction. ASTM C-957 has no requirements for elongation capacity, but requires a 70% retention of tensile strength. Some of the membranes did not meet these requirements.[2,5-6]

Abrasion Resistance

Wear characteristics are usually determined with a Taber Abrader†. Results are presented in terms of the wear index, defined as the mass in grams of material worn away by the action of a rotating wheel after 1,000 cycles. Membranes with the lowest wear index were the most wear resistant (Figure 6).[3,6] Some membranes were readily worn away, raising concern about their performance in cer-

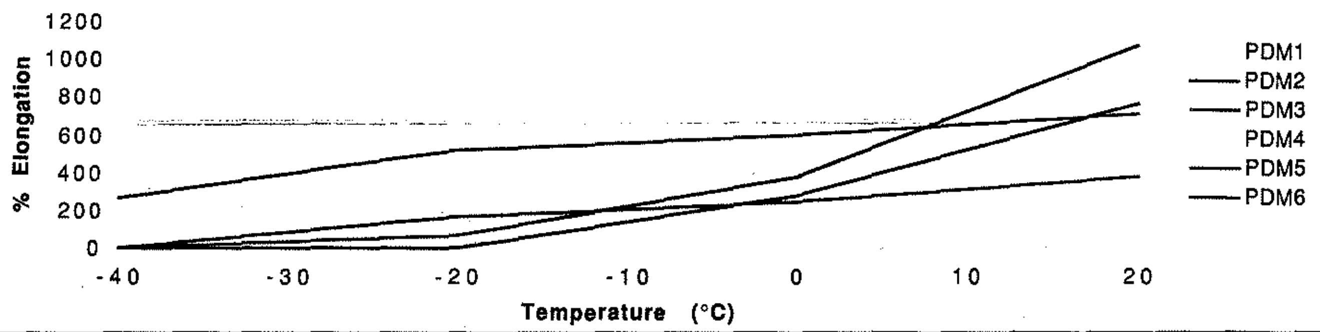

FIGURE 2
Effects of cold temperatures on elongation characteristics of different types of coatings.

Durability of the Coatings

The materials should not show any detrimental heat or photochemical aging effects, such as an increase in brittleness. They should be unaffected by F/T cycles and a variety of chemicals encountered in the parking garage environment. Durability depends on the interaction of the material with degradative factors, including temperatures in excess of 100°C, UV radiation, cyclic movement at low temperature, abrasion, automotive chemicals, and F/T cycling. Degradation caused by these factors was assessed by determining the change in the following critical coating properties:

- cold temperature crack-bridging character,
- heat aging,
- resistance to UV radiation,
- chemical resistance (to automotive fluids),
- abrasion resistance, and
- F/T resistance.

The manner in which critical properties are affected by the degradative factors encountered in the parking environment is described by a discussion of results obtained from the previously mentioned study. In the discussion, test results were compared to values obtained from specimens not exposed to degradative conditions.[3,5-8]

Cold Temperature Crack-Bridging Character

The membrane should bridge cracks not exceeding 3 mm without tearing. This capability (which should be retained at temperatures down to −26°C) is usually evaluated by determining the elongation capacity of free-film samples at various temperatures. Low temperature behavior of most waterproofing coatings, measured by crack bridging and low temperature elongation, appeared to be poor (Figure 2). The elongation capacity of most membranes was drastically affected at temperatures at which crack-bridging character was determined. This indicated that cracks which develop in the concrete after the coatings is installed, tend to reflect through those coatings with insufficient low-temperature elongation capacity.[2-4,7]

Heat Aging Characteristics

Heat aging characteristics are important because most exterior decks of parking garages attain high surface temperatures. Car tires, depending on the distance traveled, can further increase the temperature in excess of 100°C. High temperatures can drastically alter properties by a change in molecular structure or a loss of volatile components.

Exposure to 100°C produced a drastic reduction in elongation capacity, particularly in some coatings. The dramatic loss of elongation capability of membranes can be related to the large weight loss—possibly volatile components, such as plasticizers (Figures 3 and 4). Loss of plasticizer decreased the flexibility of the material, reducing it's capacity to accommodate low temperature movement.[3,6-7] Some membranes melted at the test temperature.

Resistance to UV Radiation

Polymeric materials exposed to sustained UV radiation (as in exposed roof decks) may undergo photochemical aging due to the increased cross-linking. Such degradation was accelerated in black coatings because of the increased absorption of light, which raised the temperature of the coating. As the material's temperature rose, increased thermal energy caused bond cleavage and breakdown of the polymer structure.[2]

The effects of UV degradation were determined on both the free film and composite samples, so the shielding effect of the wearing course, and the rate of deterioration of the waterproofing coating with no protection (as in situations where the wearing coat is pried off), could be determined. Results for free film coupons, showed exposure to UV caused a reduction in elongation capacity of a number of coatings (Figure 5). In the composite systems, a significant reduction in the adverse effects due to UV was observed. A shielding effect due to the wearing coat, was evident.[3,5,8-9]

Resistance to Automotive Chemicals

Automobiles drip antifreeze, battery acid, motor oil, and water on parking decks. Resistance to those chemicals was determined by immersing cured free film coupons in motor oil, ethylene glycol, and water. After a period of immersion, retention of both tensile strength and elongation capacity were determined.

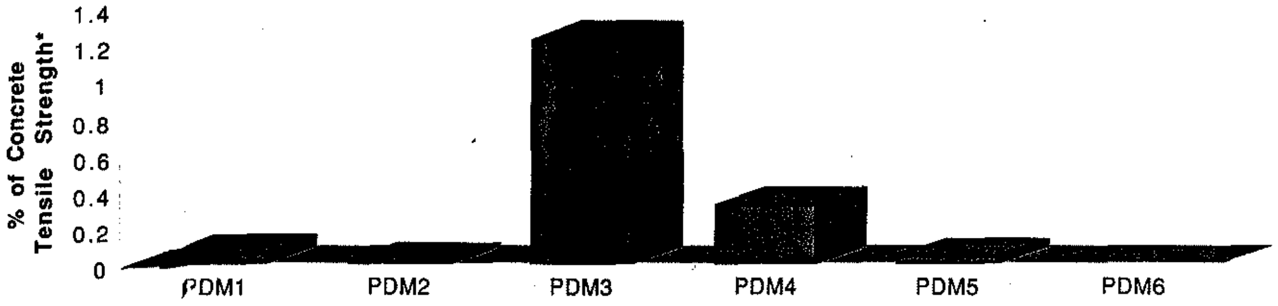

FIGURE 6
Abrasion resistance: wear index of free film specimens with H-10 wheels.

TABLE 2
Length Change After 100 Freeze/Thaw Cycles (%)

Coating System	% Length Change			
	w/c = 0.45		w/c = 0.55	
	Air Entrained	Nonair Entrained	Air Entrained	Nonair Entrained
PDM1	0.004	1.323	0.041	1.047
PDM2	0.003	0.006	0.003	0.006
PDM3	–0.023	–0.028	–0.013	–0.017
PDM4	0.01	0.628	0.019	1.371
PDM5	–0.012	0.017	–0.018	–0.031
PDM6	12.721	(A)	12.712	(A)

(A)Sample completely deteriorated.

tain locations of the parking garage (such as the isles) where they will be subjected to constant abrasive stresses from braking vehicles and spinning car tires.

F/T Resistance

Many parking garages in Canada and the U.S. have exposed decks damage due to F/T. Cycling is of particular concern. Damage to the membrane can result if water saturates concrete/membrane interface. Subsequent exposure to freezing conditions will cause the membrane to flake off. It is important to determine the F/T durability of the membrane/concrete interface to ensure integrity of the system. F/T durability was determined by the percentage increase or decrease in length of coated concrete prisms observed after 100 cycles of freezing and thawing (Table 2). It was generally accepted that increases over 0.1% in length represented the onset of fracturing in mortar specimens.[3,6]

All membrane systems improve the F/T durability of air entrained concretes. For nonair entrained concretes, only some coatings improve the F/T durability of the concrete substrate, indicating water ingress can occur due to pinhole and blister formation.

Material Specification for Intended Job

Selection of a material for a particular job should be based on a match of the material's field performance to the specific service conditions of the parking garage environment. Criteria for selection must include:[7-9]

- degree of structural movement,
- extent of traffic loading (commercial vs residential),
- designed live load capacity, height and weight restrictions, and
- for exposed decks, resistance to heat and UV radiation.

Specifications should define the membrane type and quality of the installed system. It should include type and thickness to suit in-service conditions; limitations imposed by weather conditions; surface finish of the concrete required; exclusion of materials (such as curing membrane) that interfere with adhesion; installation by applicator certified by membrane manufacturer; and test area for appraisal.[7-8]

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Quality Control

Performance of the final product depends on material properties and on the care excised during installation. Good on-site control is necessary. Samples obtained for acceptance tests should be retained for comparison to material delivered during the course of the installation. This also will be useful for repair. Membrane thickness should be monitored during application using a wet mill thickness gauge. Samples should be obtained from noncritical areas to verify that dry-film thicknesses are being met. During application, coupons for testing of tensile strength and elongation should be obtained by spraying on boards. Values obtained from these tests indicate the efficiency of the mixing and spraying process as well as the consistency of the product being installed.[5,7,9]

Concluding Remarks

Elastomeric membranes restrict the ingress of moisture and chloride ions into the concrete deck. A number of the systems were vulnerable to deterioration when subjected to most of the degradative agents encountered in the parking garage environment. Poor installation aggravates inherent problems by producing defects which affect waterproofing characteristics. In view of the limitations of certain membranes, selection should be based on a serious consideration of the location and in-service conditions, rather than basing it on cost.

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