Waterproofing with elastomeric membranes

Mailvaganam, N. P.; Collins, P.

Publisher’s version / Version de l'éditeur:

Construction Specifier, 45, Dec. 12, pp. 97-105, 1992-12-01

Waterproofing with elastomeric membranes

NRCC-34067

Mailvaganam, N.P.; Collins, P.

December 1992

A version of this document is published in / Une version de ce document se trouve dans:
Construction Specifier, 45, (12), Dec., pp. 97-105, December-01-92

by Noel P. Mailvaganam and Peter G. Collins

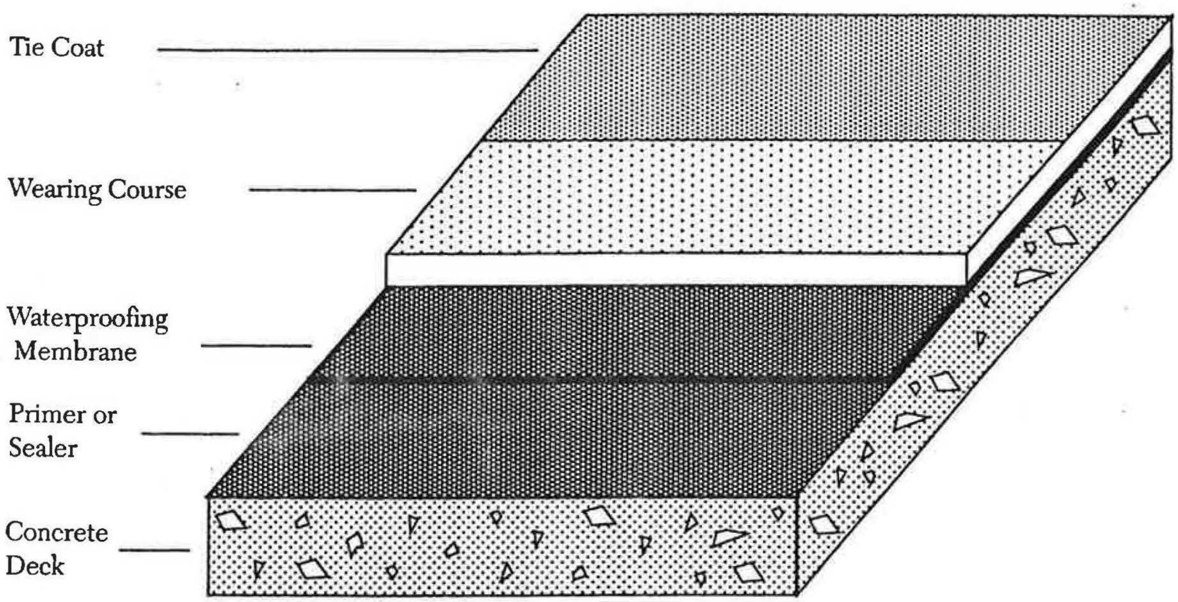
Waterproofing with Elastomeric Membranes

Acquaint yourself with elastomeric membranes' critical properties before selecting one to protect parking decks.

During the winter, many tons of deicing salts are spread on roads. These salts produce large quantities of concentrated chloride solution, which cars bring into parking garages. Some of this solution percolates through the concrete deck, entering fine cracks in the surface and promoting corrosion of reinforcing steel. Waterproofing membranes applied to decks can help prevent moisture and salt ingress and subsequent rebar corrosion.

Elastomeric waterproofing membranes in temperate climates are subject to rigorous temperature extremes, exposure to damaging chemicals, and high wear. A membrane's ability to withstand these harsh conditions depends on critical characteristics tied to the physical and chemical properties inherent in the polymer resin from which the membrane is made. Properties such as abrasion resistance are provided by layered, composite membrane systems.

Figure A. Schematic of a typical membrane system



Critical Properties

Most of the waterproofing systems used in parking garage decks are cold liquid-applied self-adhering elastomers. These systems are usually applied in relatively thin coats, bonded continuously to the substrate, and cured to form a seamless elastomeric waterproof barrier. Typically, the systems consist of a primer, followed by a cold liquid-applied membrane 0.75 to 1.50 mm (30 to 60 mils) thick. The primer is coated with an abrasion-resistant, 60-mil wear coat. *Figure A* shows a cross section of the various coats of a typical thin adhesive membrane system. Membrane systems vary in chemical composition, type of top coat, and application method, and individual properties of membranes are governed by the many factors peculiar to each material. Membrane types include one-component urethanes, two-component urethanes, two-component solvent-borne epoxy-urethane blends, one-component waterborne neoprenes, and rubberized asphalt mastics.

To protect concrete effectively, a waterproofing membrane and wearing surface must have five critical properties. It must be able to

- recover from elongation
- retain flexibility at low temperatures
- adhere to concrete
- bridge cracks
- remain stable with freeze/thaw cycling.

Recovery from elongation is the ability of a membrane to return to its original dimensions after it has been subjected to continuous load and deformation. Tests require a minimum of 85 percent recovery after loading to demonstrate the stress-relaxation capacity of the polymeric matrix.

Testing is done on free film specimens with benchmarks. The sample is stretched to 100 percent elongation (based on the benchmarks) and held for one hour. The load is then removed and the specimen allowed to relax. After 15 minutes, the distance between benchmarks is measured.

Some of the membrane types listed above do not pass this test (see *Table 1*). Those that fail may be unable to retain their integrity with low-temperature cycling, causing reflective cracking in the field, as will be shown later.

Retaining flexibility in cold weather. All membranes stiffen in the cold and undergo gradual crystallization at very low temperatures, i.e., -25°C (-13°F) or below. Such embrittlement will reduce the membrane's ability to withstand static loading and dynamic shock without cracking. The change in performance that results from embrittlement is measured by determining tensile strength and elongation capacity of free film specimens.

Figures B and *C* present the trends in variation of tensile strength and elongation capacity as the temperature is decreased to -40°C (-40°F). Tensile strength increases and elongation decreases with decreasing temperature. Percentage elongation values at -20°C (-4°F) for urethane 1 and the solvent-borne epoxy-urethane blend, neoprene, and asphaltic mastic samples are extremely low, showing a considerable decrease from room temperature values. The better response of urethane 3, however, is typical of long chain polyurethane rubber-based elastomers.

The results show the drastic reductions in elongation and tensile strength at temperatures below -20°C (-4°F). These changes may significantly increase the strain at the bond interface during low-temperature cycling, promoting debonding or tearing of the membrane.

Table 1. Tensile strength and elongation of free film membrane samples

Membrane System	Tensile Strength (MPa)	Elongation at Failure (%)	Recovery from Elongation (%)
Urethane 1 (S1)	22.7	300	87.1
Urethane 2 (S2)	3.2	370	98.5
Urethane 3 (S3)	3.0	700	93.7
Epoxy-urethane blend (S4)	4.8	140	58.0
Neoprene (S5)	8.6	760	69.4
Asphaltic mastic (S6)	0.18	1070	88.0

Figure B. Effects of cold temperature on elongation

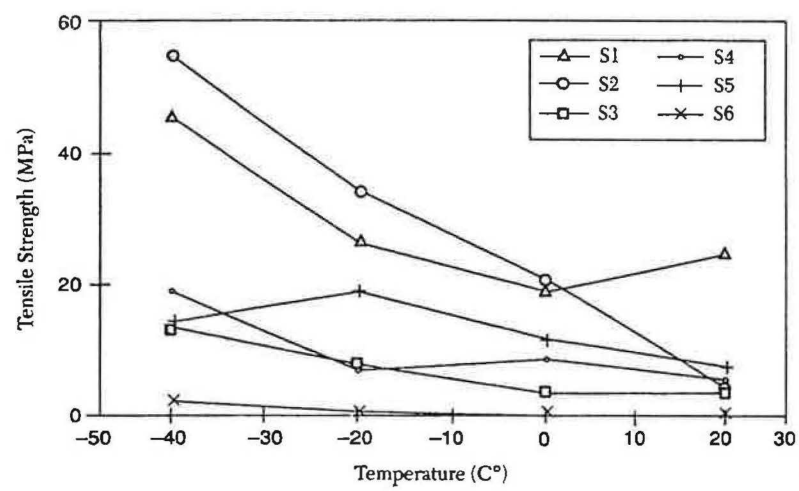


Figure C. Effects of cold temperature on tensile strength

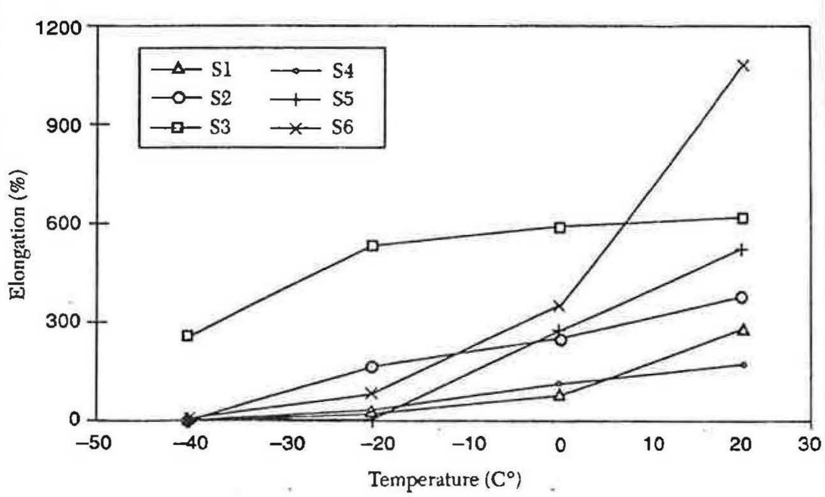


Figure D. Relationship between coating thickness and crack-bridging ability

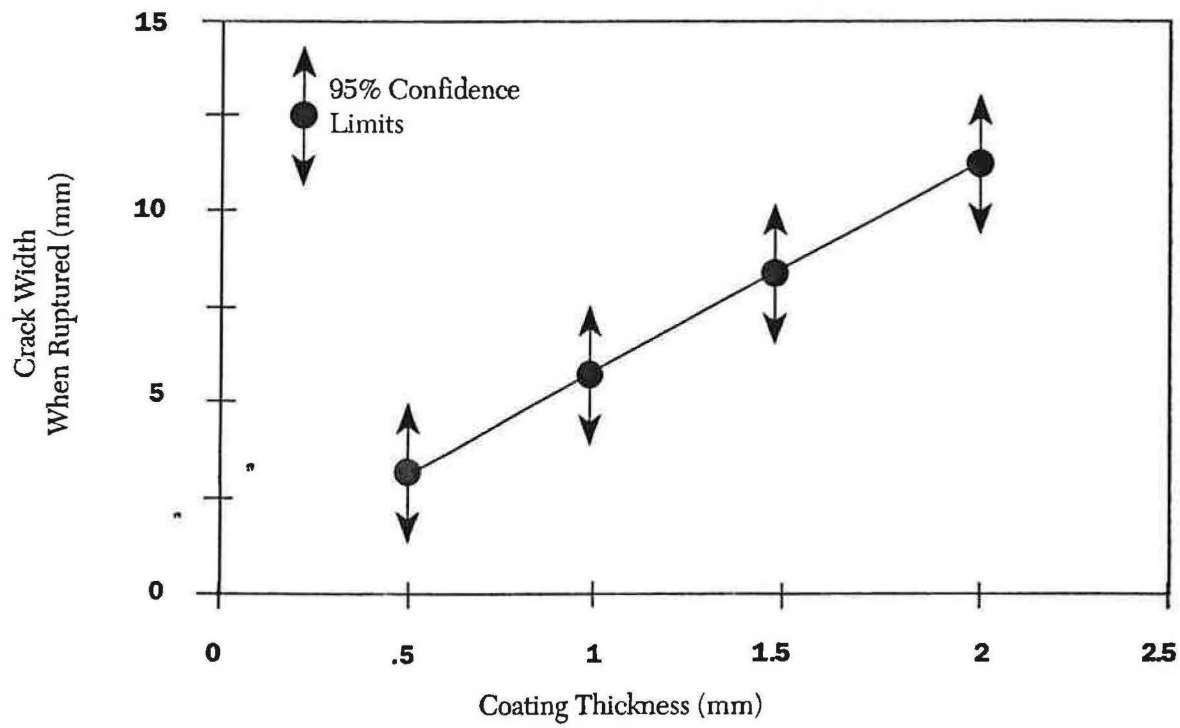


Table 2. Tensile adhesive strength to concrete (MPa)

Membrane	Concrete Substrate w/c = 0.45 Adhesive Strength, MPa		Concrete Substrate w/c = 0.55 Adhesive Strength, MPa	
	Air Entrained	Non Air Entrained	Air Entrained	Non Air Entrained
Urethane 1 (S1)	4.88	4.27	3.47	4.88
Urethane 2 (S2)	2.36	1.45	2.25	1.80
Urethane 3 (S3)	1.85	1.59	1.36	1.56
Epoxy-urethane blend (S4)	3.82	3.31	3.42	3.16
Neoprene (S5)	3.75	3.56	2.55	2.88
Asphaltic mastic (S6)	0.26	0.26	0.14	0.11
Control	4.88	4.88	4.32	4.88

Adhesive strength to concrete. Waterproofing membranes must adhere well to concrete. Consequently, many job specifications stipulate proper surface preparation according to membrane manufacturers' instructions and require that the acceptance of the concrete surface texture and cleanliness be subject to the approval of the applicator.

A successful membrane must be able to wet out the concrete surface (even the laitance) to achieve adhesion. This requirement should be satisfied under normal, humid, or any other conditions to which the deck will be subjected.

Tensile bond strength values for concrete coated with waterproofing membranes are presented in *Table 2*. Generally, the adhesive strength of the waterproofing membrane is considerably less than the tensile strength of the concrete. Bond strengths vary with concrete type, typically decreasing with an increase in the water-cement ratio or with air entrainment.

With the exception of the values obtained for the asphaltic system, the results show that thin adhesive-type membranes provide an adequate bond to the concrete substrate.

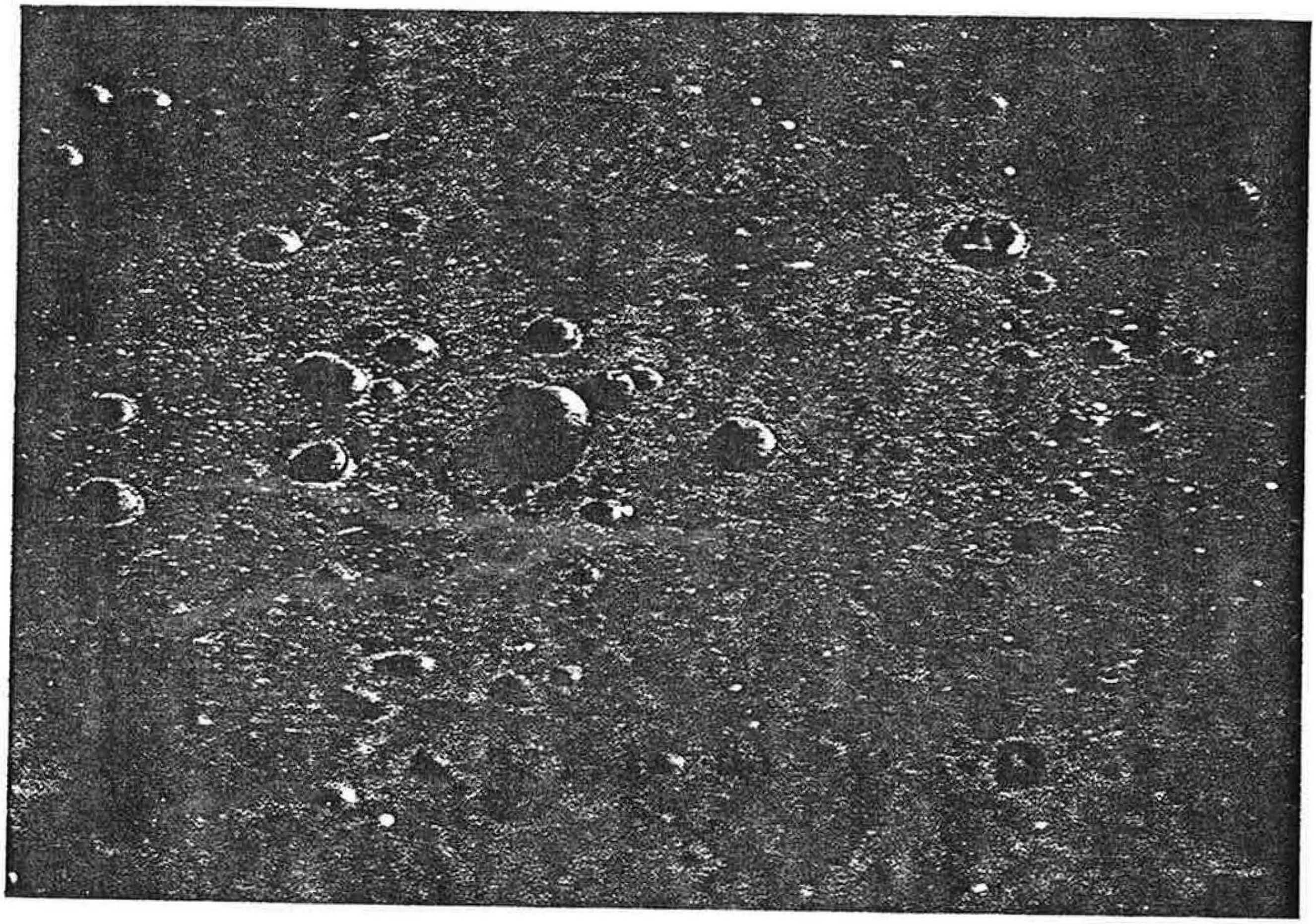


Table 3. Crack-bridging ability

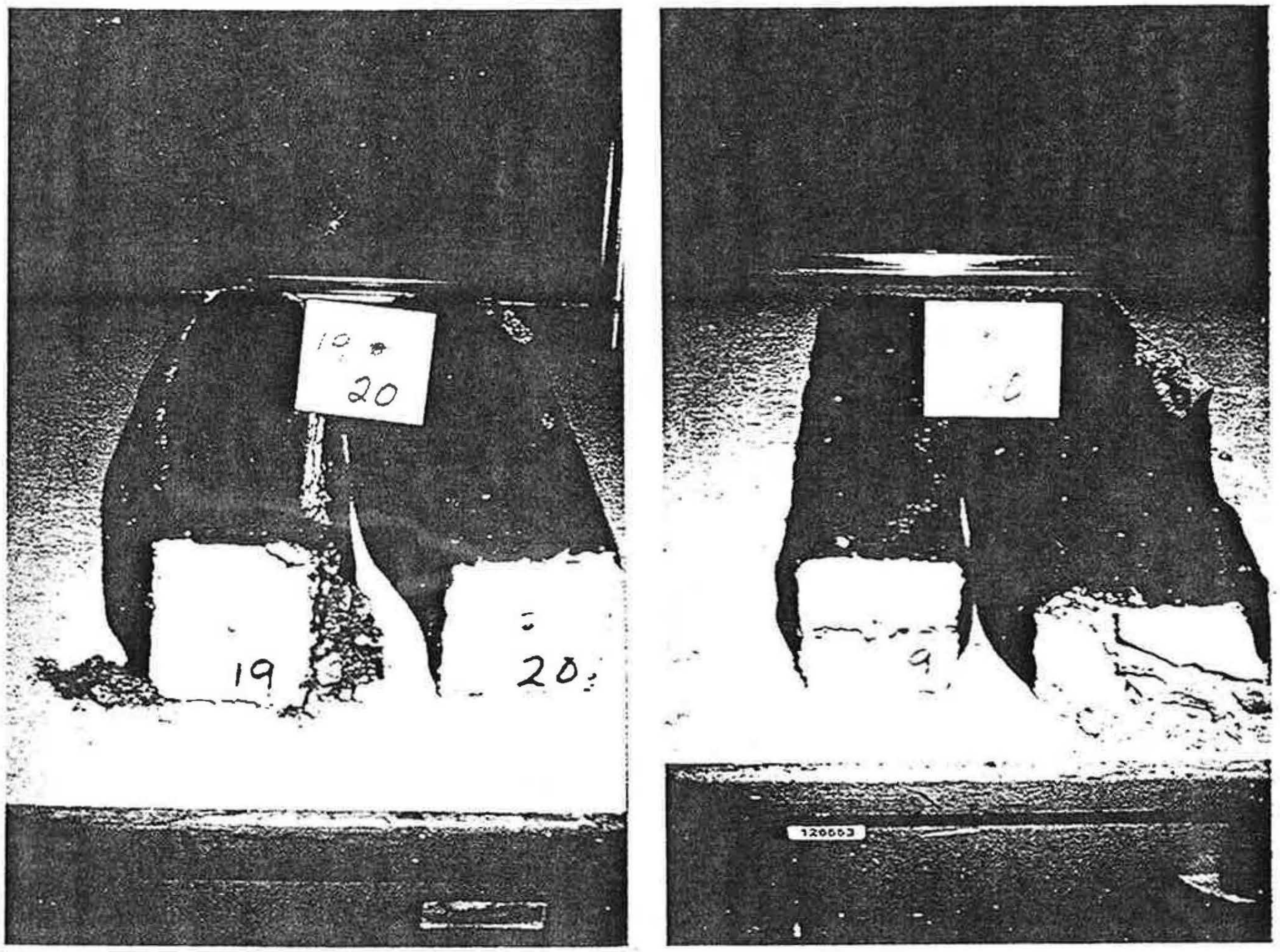
Membrane	Concrete Substrate w/c = 0.45		Concrete Substrate w/c = 0.55	
	Air Entrained	Non Air Entrained	Air Entrained	Non Air Entrained
Urethane 1 (S1)	fail	fail	fail	fail
Urethane 2 (S2)	pass	pass	pass	pass
Urethane 3 (S3)	pass	pass	pass	pass
Epoxy-urethane blend (S4)	fail	fail	fail	fail
Neoprene (S5)	pass	pass	pass	pass
Asphaltic mastic (S6)	fail	fail	fail	fail

Notwithstanding their inherent capability to bond well to concrete, poor surface preparation and adverse application conditions can cause dry or liquid-filled blisters to form. Debonding invariably follows.

Bistering is in fact one of the most common causes of failure related to adhesion. Blistering is usually caused by the penetration of moisture through the coating into areas of poor adhesion. Other conditions that can cause blisters are incompatibility between topcoat and base coat, solvent entrapment, and use of the wrong primer.

There are two types of blister: (1) those formed from the substrate, with the coat separating from the substrate, and (2) those formed between coats, e.g., where the top coat separates from

Photo 1, top. Blistering is usually caused by penetration of moisture through the coating in areas of poor adhesion.



Photos 2 and 3. These specimens failed due to the asphaltic membrane's inability to withstand freeze/thaw action.

an undercoat (circular blisters). The latter type is shown in *Photo 1*, page 101.

Crack-bridging ability. Concrete substrate cracks can move, affecting the performance of membrane systems by reflecting through the membrane and allowing water to penetrate to the deck. Liquid-applied membranes are susceptible to this problem because of their continuous adhesion to the substrate. They are subjected to tremendous stresses when a moving crack develops where none existed at the time of application.

These problems are likely to occur when the cast-in-place structure is exposed to direct sunlight and the membrane is applied before sufficient time has passed for all shrinkage cracks to occur. Other factors that influence a membrane's crack-bridging characteristics are low-temperature flexibility and film thickness. The importance of membrane thickness to crack bridging is shown in *Figure D*, page 100.

Low-temperature flexibility is tested at temperatures of -26°C (-15°F). A 1.5 mm (0.06 in.) coating is applied to a pair of mortar blocks, allowed to cure, then tested as the opening between the blocks changes from zero to 2 mm (1/16 in.). Materials that survive 10 cycles without cracking or losing adhesion are considered to have passed the test.

Data in *Table 3*, page 101, shows that three waterproofing membranes—urethane 1, the epoxy-urethane blend, and the asphaltic mastic—failed after 10 cycles of elongation, which is not surprising since these membranes do not readily accommodate movement at low temperatures (see *Figure C*, page 99).

This is a laboratory test, and while it is severe and should be a good predictor of field success, membranes that pass it are still subject to reflective cracking. Such failure is probably due to the defects incorporated into the membrane by substrate movement during its early curing. When elastomeric membranes are applied under field conditions, they are likely to be subjected to movement in the early curing stages, prior to developing full elastomeric properties. Consequently, defects that will serve as potential sites for deterioration develop. Furthermore, initial daily thermal cycling can increase the number of defects within the membrane before it is fully cured.

Freeze/thaw stability. Exposed concrete decks need to be protected from corrosion-related deterioration as well as

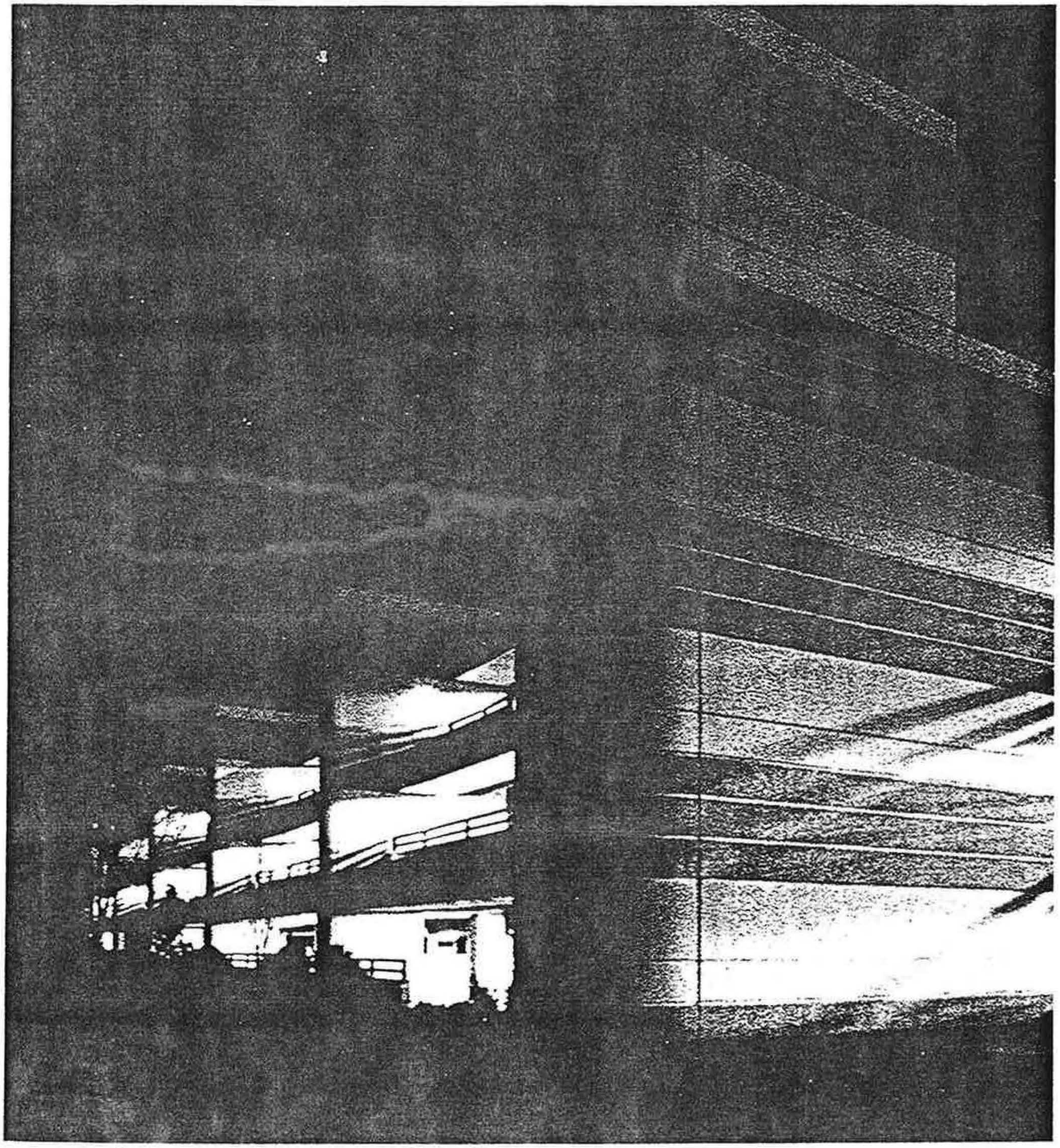
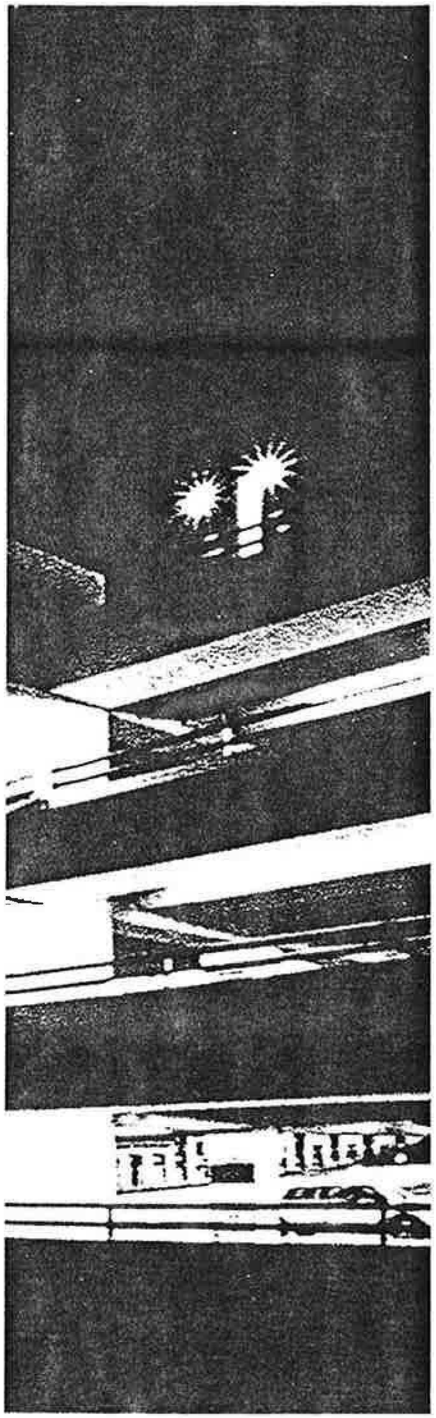


Table 4. Length change after 100 freeze/thaw cycles (%)

Membrane	w/c = 0.45		w/c = 0.55	
	Air Entrained	Non Air Entrained	Air Entrained	Non Air Entrained
Urethane 1 (S1)	1.323	0.004	1.047	0.041
Urethane 2 (S2)	0.006	0.003	0.006	0.003
Urethane 3 (S3)	–0.038	–0.023	–0.017	–0.013
Epoxy-urethane blend (S4)	0.628	0.010	1.371	0.019
Neoprene (S5)	0.017	–0.012	–0.031	–0.018
Asphaltic mastic (S6)	*	12.721	*	12.712



Before choosing elastomeric membranes to protect concrete slabs in parking garages, specifiers should not fail to evaluate products' field performance.

the surface scaling that results from freeze/thaw cycling of saturated concrete. Damage to the membrane can result if water penetrates it and saturates the concrete/membrane interface. Subsequent exposure to freezing conditions will cause the membrane to flake off, with a thin layer of concrete adhering to its underside.

Also, moisture movement through the concrete to the surface may push off the membrane under similar circumstances. Thus, the membrane/concrete interface must remain as dry as possible to ensure the system remains intact and impermeable to water under all expected conditions.

The percentage increase or decrease in length of coated concrete prisms observed after 100 cycles of freezing and thawing is presented in *Table 4*. It is generally accepted that increases in length above 0.1 percent represent the onset of fracturing in mortar specimens.

With the exception of asphaltic mastic, all the membrane systems investigated here improved the freeze/thaw durability of air-entrained concrete. Only urethanes 2 and 3 and the neoprene sample improved the durability of non-air-entrained concrete, however, indicating that water ingress may have occurred in urethane 1 and in the solvent-borne epoxy-urethane blend due to pinhole and blister formation. *Photos 2* and *3* (page 102) illustrate the poor resistance of the asphaltic membrane.

Evaluation

The foregoing discussion was intended to draw attention to the critical properties of elastomeric membranes used to protect concrete slabs in parking garages. Membrane selection should always be based on a careful study of material properties. And before a product is chosen, the specifier should not fail to evaluate its performance under field conditions similar to those expected in the job at hand. ◆

References

"A Guide to the Use of Waterproofing, Dampproofing, Protective and Decorative Barrier Systems for Concrete," Report ACI 515.1R-79. *Manual of Concrete Practice*, pt. 5. Detroit, Michigan: American Concrete Institute, 1984.

Evaluation of Elastomeric Membrane Systems Used in Parking Garage Protection, Client Report CR 6145.3. Ottawa, Canada: Institute for Research in Construction, National Research Council of Canada, February 1992.

Evans, R.M. "Test Methods Used in ASTM Specifications for Liquid-Applied Elastomeric Membranes for Waterproofing Concrete." *Building Deck Waterproofing*, ASTM STP 1084. Philadelphia, Pennsylvania: American Society for Testing and Materials, 1990.

Hunnicut, J.M. "Parking Deck Deterioration: The Reasons Why" (*Concrete Construction* 21, no. 9).

Jacobson, N.G., Jr. "A Case Study of Parking Deck Deterioration Methods" (*Parking*, Winter 1982).

Mailvaganam, N.P. "Elastomeric Parking Deck Membranes" (*Concrete International*, 8, no. 10).

Monroe, D.C. "Reflective Cracking and Cold, Liquid-Applied Elastomeric Deck Coating and Membrane Systems: Practical Considerations from Field Observations." *Building Deck Waterproofing*, ASTM STP 1084. Philadelphia, Pennsylvania: American Society for Testing and Materials, 1990.

Oosterbroek, M. Lammers, R.J., and Ven der Van, L.G.J. "Crack Formation and Stress Development in an Organic Coating" (*Journal of Coatings Technology*, June 1991).

Waterproof Membranes for Protection of Concrete Bridge Decks, Laboratory Phase (Project 12-11), National Cooperative Highway Research Program Report no. 165. Washington, D.C.: Transportation Research Board, National Research Council, 1976.

NOEL P. MAILVAGANAM is a senior research officer with the Canadian National Research Council's Institute for Research in Construction (IRC). Mr. Mailvaganam, who is head of the Polymer Group, has co-authored and edited three books on chemical admixtures and on concrete repair and protection. **PETER G. COLLINS, BSC,** is a technical officer with the IRC's Polymer Group.