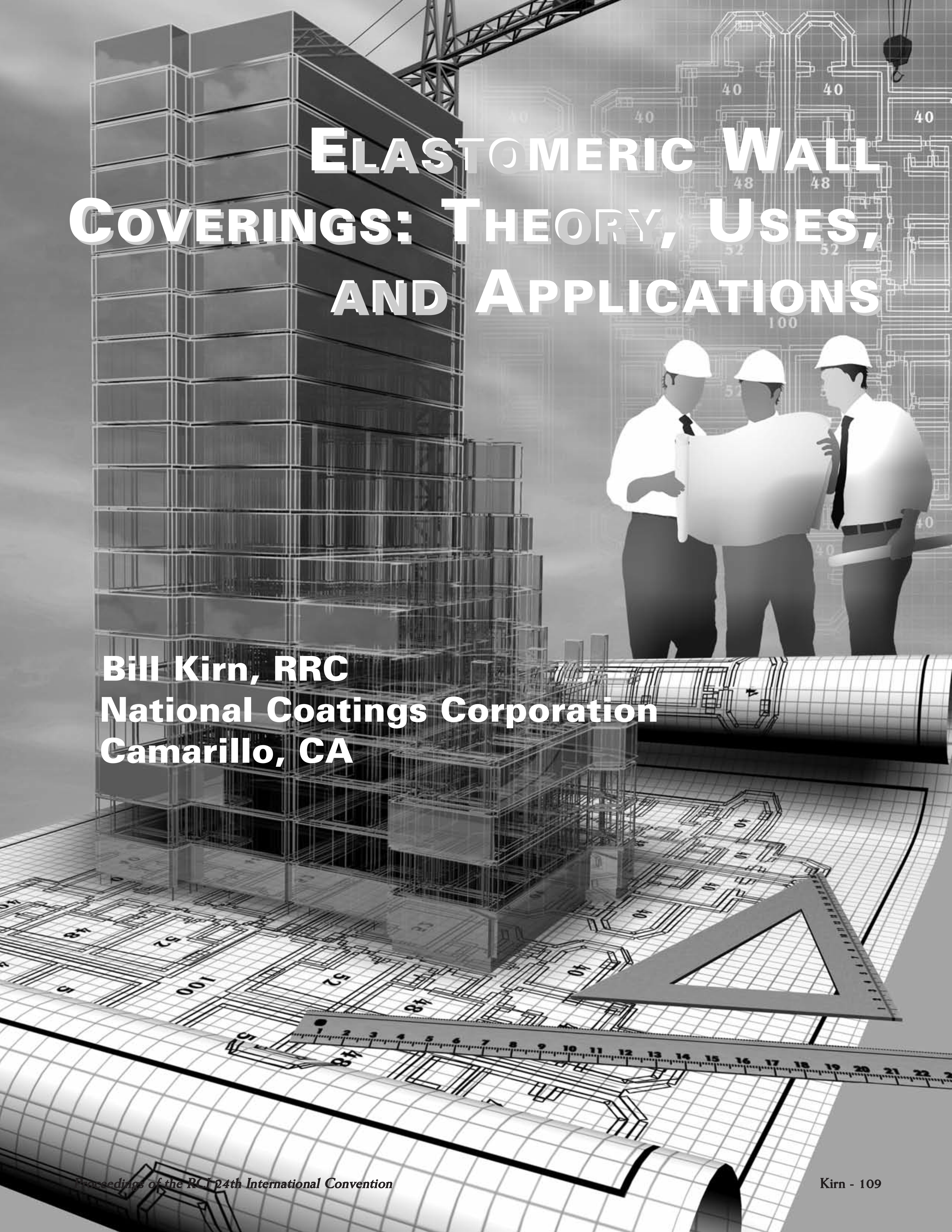

ELASTOMERIC WALL COVERINGS: THEORY, USES, AND APPLICATIONS

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ABSTRACT

Elastomeric wall coatings are an integral part of above-grade waterproofing and masonry-wall restoration. They are designed to provide functional performance and crack bridging over all types of masonry construction. A unique and novel test apparatus called the "Climate Drive Durability Tester" will be described that provides weathering and membrane movement under in-service conditions. The need for coating permeance and the phenomenon of carbonation, (i.e., corrosion attack on metal rebars by atmospheric CO_2 and moisture, will also be described. The attendee will gain a fundamental understanding of the technology that underlies elastomeric wall coatings. Case histories will be used to exemplify the basic concepts.

SPEAKER

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Elastomeric Wall Coverings: Theory, Uses, and Applications

ABSTRACT

Elastomeric wall coatings are an integral part of above-grade waterproofing and masonry wall restoration. This paper will begin with a review of the fundamental research on elastomeric wall coatings. A novel mathematical model for determining the crack bridging requirements for elastomeric coatings as a function of a building's geographic location will be elucidated. A unique and novel test apparatus, called the "Climate Drive Durability Tester," will be described, which provides weathering and membrane movement under in-service conditions. The need for coating permeance and the phenomenon of carbonation, (i.e., corrosion attack on metal rebars by atmospheric CO^2 and moisture), will also be described. This paper will provide the reader with a fundamental understanding of the technology that underlies elastomeric wall coatings and will provide solutions to above-grade waterproofing problems. Case histories are included to exemplify the basic concepts.

ELASTOMERIC WALL COATINGS: THE BASICS

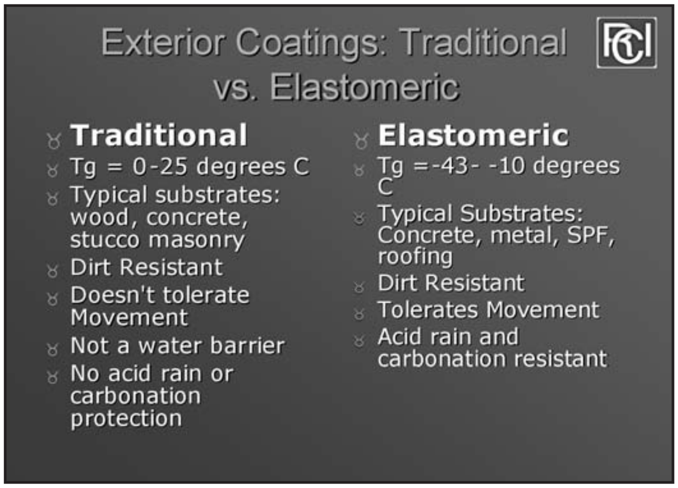
Elastomeric wall coatings (EWCs) are designed to coat vertical masonry surfaces such as concrete masonry unit (CMU), tilt-up concrete, block, EIFS, and stucco. While they are classified as "coatings", they have attributes of both coatings and sealants. EWCs can be classified into two categories: penetrating sealers and barrier coatings. Penetrating sealers are usually silicone- or siloxane- based and employ an organic solvent as the carrier. These materials have high surface tension and cause water to "bead" when in contact. However, these sealers have surprisingly high water permeance and will easily allow the passage of water through the sealer and into the underlying substrate. Because these materials are silicone-based, it is difficult to achieve adhesion to them when a nonsilicone coating is applied. The remaining portion of this paper will be devoted to barrier coatings.

Barrier coating types are exemplified by either acrylic or silicone. Most acrylic EWCs are waterborne, while silicones can either be water- or solvent-borne. These coatings are comprised of several classes of key ingredients. The first is the binder or polymer. This provides the adhesion to the coating substrate and also "binds" the individual discrete pigment particles to the coating matrix. The second is the pigment. This may include several types of pigments, such as high hiding pigments (e.g. titanium dioxide and zinc oxide), and extenders such as silica or calcium carbonate. Other "additives" are included that provide in-can stability, coating rheology (doesn't slump when applied in thick films), and mildewcides to prevent mildew growth.

PAINTS VERSUS ELASTOMERIC COATINGS

There are key performance requirements that differentiate these two coating classes. The most notable is the ability of an elastomeric wall coating to tolerate substrate movement and crack bridging at low service temperatures. Typically traditional architectural coatings or house paints have polymer Tg's between 0° and 25°C. By contrast, EWCs have Tg's between -40° and -10°C. The polymer Tg is an approximate temperature at which the coating becomes glassy or brittle. There are other key distinctives that differentiate these uniquely different coatings.

The polymer can be described physically as a spring with its ends attached to individual pigment particles. The polymer "spring" provides the elastomeric properties and also adheres to the pigment to the coating matrix and to the substrate, preventing the particle from becoming dislodged. The higher the polymer level, the more flexible or elastomeric the



Exterior Coatings: Traditional vs. Elastomeric

Traditional
- Tg = 0-25 degrees C
- Typical substrates: wood, concrete, stucco masonry
- Dirt Resistant
- Doesn't tolerate Movement
- Not a water barrier
- No acid rain or carbonation protection

Elastomeric
- Tg =-43- -10 degrees C
- Typical Substrates: Concrete, metal, SPF, roofing
- Dirt Resistant
- Tolerates Movement
- Acid rain and carbonation resistant

Figure 1

coating and the better the adhesion. The higher the pigment level, the better the hiding or coating opacity, the poorer the adhesion, but the higher the tensile strength of the coating. *Figure 1* compares some of these properties in more detail.

These properties will be discussed in greater detail throughout this paper.

PRODUCT SELECTION: TRADITIONAL PAINT VS. EWC

It is important to understand the distinctions and proper uses for traditional coatings (paints), elastomeric coatings, and sealants. *Figure 2* compares the recommended film thickness and crack bridging ability of these coatings. Because EWCs must have the ability to expand and contract as hairline cracks moves, they are applied at dry film thicknesses at 3-5 times the thickness of paint.

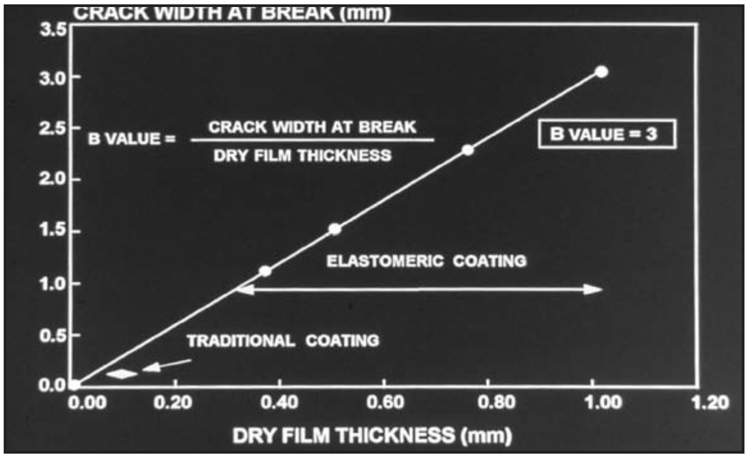


Figure 2

DYNAMICS OF CRACK BRIDGING

Any masonry construction begins as a continuous, crack-free substrate. During its life, the cementitious material develops cracks. These cracks are the result of stress relief caused by the thermal and/or seismically induced expansion and contraction of the masonry substrate. Even if a wall is properly designed with sufficient expansion joints, cracks often develop. As the wall is continually exposed to natural weathering, the size and depth of the cracks continue to propagate and grow. The diagram in *Figure 3* describes the evolution of these cracks.

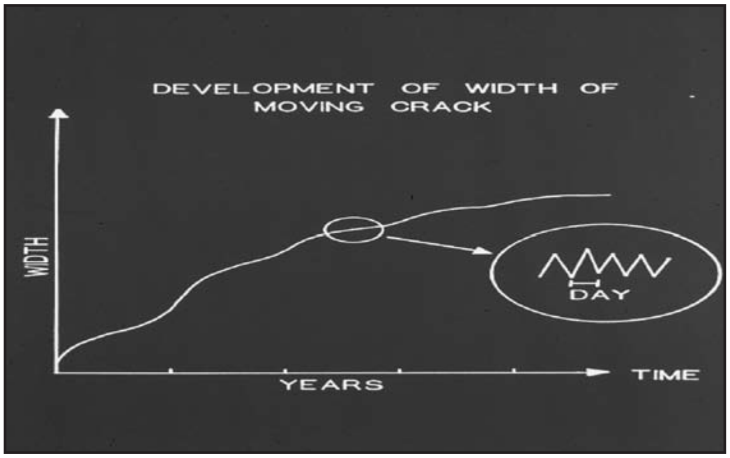


Figure 3 – Dynamics of crack-bridging, an effect of weathering.

Since the crack width is governed by the physical property of the coefficient of expansion and contraction, the theoretical crack movement can be calculated.[1]

$$a=1/L\ dL/dT$$

where:

a = coefficient of linear expansion of the construction material (concrete)

L = length

T = temperature

HOW WIDE IS A "HAIRLINE CRACK?"

While this question sounds rather simplistic and almost silly, it underscores the need for sealing even these very narrow openings in the wall system. Consider the following example:

1. A 16-ft-high wall that has a hairline crack.
2. The crack is 1/16-in wide in the winter, and smaller in the summer.
3. Question: How large is that opening?
4. Answer: It is the same as a 3-in x 4-in hole in the wall: Twelve square inches!

A hole this size in the wall would immediately be observed, and proper maintenance techniques using sealants or cementitious materials would be used to close the opening. This further validates the need to use these coatings to seal and protect the interior of the building to prevent moisture penetration, air movement, and insect infestation.

FIELD EVALUATION AND DYNAMICS OF CRACK BRIDGING

A comprehensive series of measurements were taken in the expansion joint on south-facing exterior wall on this project in Pennsylvania. Crack width and temperature measurements were taken daily for one year. A photo of the wall is shown in *Figure 4*.

The data were plotted on the graph in *Figure 5*, which shows

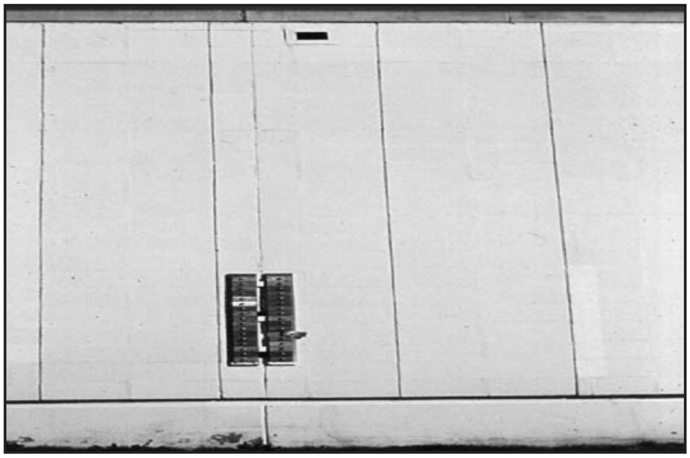


Figure 4

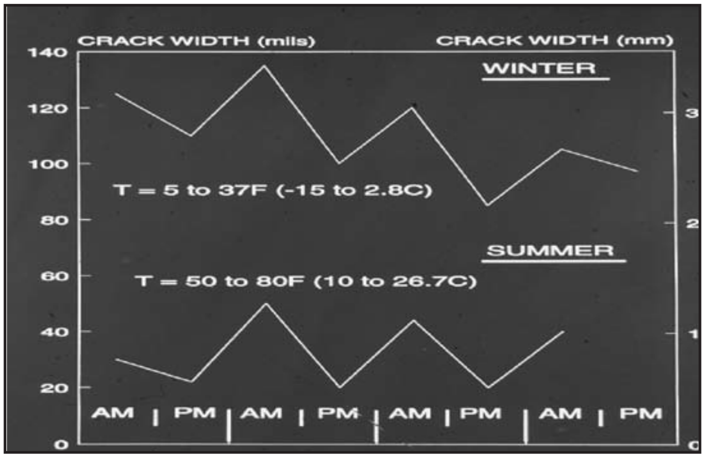


Figure 5

the crack movement for the coldest days in the winter and the warmest days in the summer.

The data were then compared to the calculations using the formula above. Note the excellent correlation of the experimental to theoretical data.

Using this model, the evaluated wall with its dynamic crack could be "mathematically relocated" to any geographic location in the world. Using weather data, the crack movement could be predicted. These calculations were carried out for Miami, FL; San Juan, PR; Minneapolis, MN; Denver, CO; Phoenix, AZ; and Seattle, WA.

TESTING EWCS

Bench performance testing of these coatings is considerably different from that of architectural coatings or paints, as these coatings actually create a fluid-applied membrane formed in-situ on the masonry substrate.

These tests include:

- Mechanical properties/tensile strength and elongation
  - Room and low-temperature environments
- Hairline crack bridging
- Wind-driven rain TTC-555B
- Alkali resistance
- Low temperature flexibility
- Dirt pickup resistance
- Permeance

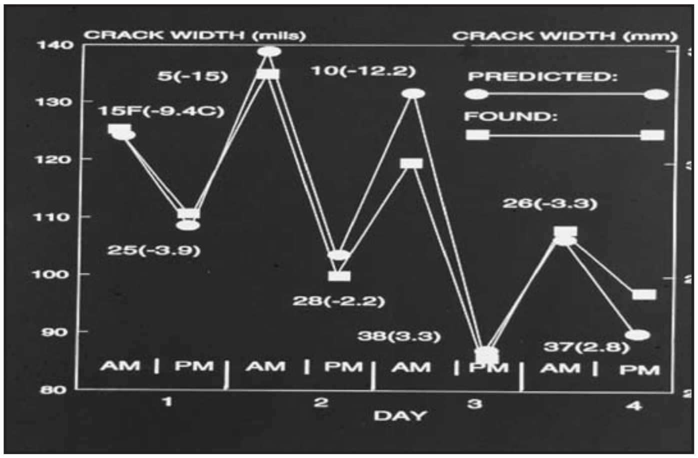


Figure 6

While the measurement of tensile strength and elongation is a common test used to evaluate the mechanical properties of membranes and coatings, this test does not simulate the ability of the coating to span dynamic cracks in the wall. Typical gauge length of 0.5-1.0 inches (distance between the jaws of the Instron) is obviously too large to simulate the hairline cracks associated with masonry construction. By contrast, a dynamic crack may be coated in the summer when it is completely "closed up." During the colder winter months, however, the crack will open. This situation is totally unlike a typical sealant installation, where there is a gap between the CMU sides, and the sealant is installed. The EWC problem is sometimes called the problem of infinite elongation, where in the equation:

$$\textbf{Percent elongation} = \frac{L_t}{L_o} \times 100$$

The L_o is zero; hence, the name "infinite elongation."

A novel test method called "hairline crack bridging" has been developed. It utilizes a piece of rigid PVC sheet that is scored to create crack in the film. The coating to be tested is applied at the proper film thickness over the cracked PVC. After curing/drying, the composite is tested in an Instron-type tester. The results are reported as length to break, known as "B" value, and tensile strength. *Figure 7* shows the composite under extension with the

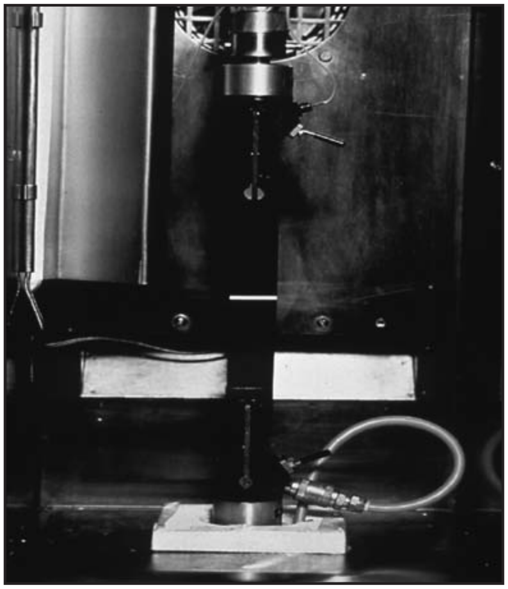


Figure 7 – Hairline crack bridging "B" value.

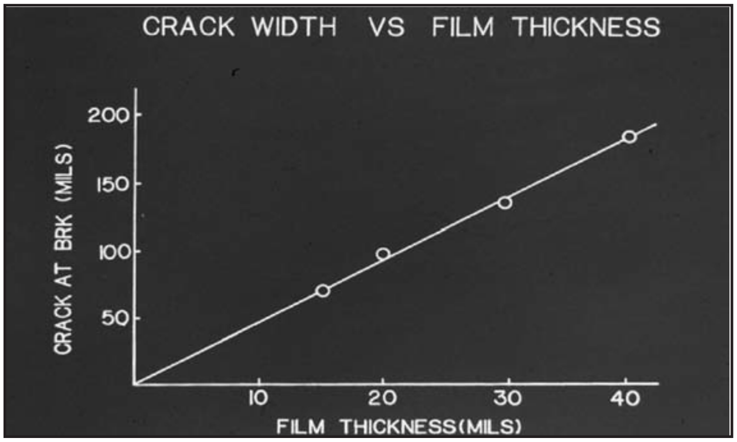


Figure 8 – Crack-bridging ability of a representative EWC.

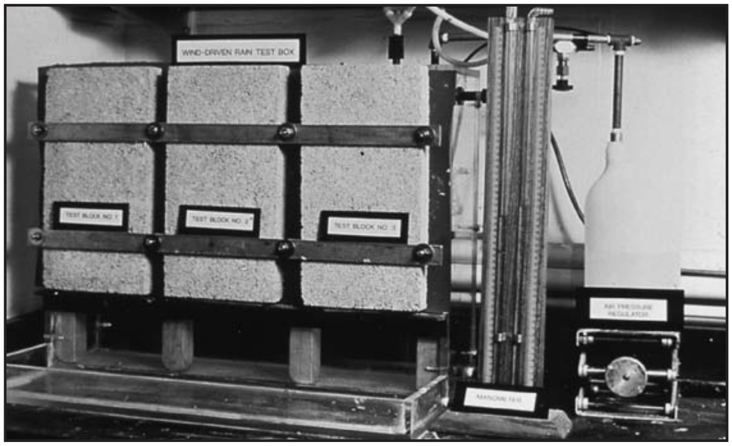


Figure 9 – Wind-driven rain tester Fed Spec TTC-555B.

white EWC clearly visible.

This apparatus can serve as a valuable research tool for understanding the performance limits of a specific EWC. If a series of coated PVC samples having increasing film thickness are prepared and tested, the ability of the coating to tolerate expansion can be elucidated and quantified. The graph in *Figure 8* shows the performance profile of one representative coating.

Another important test is called "Wind-Driven Rain," also known as Federal Specification TTC-555B. In this test, concrete blocks are coated and installed in an apparatus designed to simulate rain at a velocity of 105 mph. The weight gain of the block is reported. If the back side of the block is wet, the coating has failed the test. Recently, this test method has been eliminated from the Federal Specifications and has been replaced by ASTM D6904 "Standard Practice for Resistance to Wind-Driven Rain for Exterior Coatings Applied to Masonry." This method has no minimum performance requirements.

Another important test unique to this type of coating is alkali resistance. It is not uncommon for an EWC to be applied to fresh concrete where the pH of the substrate is >12. Some coatings are susceptible to attack from these high pH environments. Typical tests are to immerse the coating in a saturated calcium hydroxide $Ca(OH)_2$ solution, measure weight gain, and observe any membrane deterioration.

Low temperature flexibility is another common test conducted on EWCs. This is a more expedient and less costly test than measuring the mechanical properties at low temperature. While not as quantitative, it does provide valuable information about the ability of the coating to tolerate movement at low service temperature.

CLIMATE DRIVE DURABILITY TESTER ... OR "MOVING WALL" INSTRON

All laboratory bench tests are designed to measure some facet of the expected performance demands placed on any construction material. Adhesion, low temperature flexibility, and artificial weathering are some of the key properties that must be measured and proven. We have developed an innovative test methodology for measuring adhesion, tolerance for expansion and contraction of the substrate, alkali resistance, and weathering durability that is simple, cost-effective, and virtually labor free. First, an expansion joint that is dynamic (i.e., actually moves during the hot/cold, summer/winter cycle) must be identified. Then a clamping device as shown in *Figures 10* and *11* must be attached to each side of the joint. The device holds test specimens that are made from unglazed cement asbestos (UGCA) panels coated with the EWC under investigation. Like the PVC samples, the UGCA panels are butt joined with coating applied to the top face. *Figure 11* shows the basic design.

The close-up in *Figure 11* reveals the performance of various smooth and textured coatings tested. Note how some of the coatings are performing satisfactorily, while others have cracked. It is noteworthy that "smooth" EWCs demonstrate better tolerance for movement than their "textured" counterparts.

As can be seen, the apparatus creates expansion and contraction demands on the coatings. The apparatus tests adhesion to a high pH cementitious substrate and the samples are exposed 24/7, 365 days per year to all weather conditions; hence, the name "Climate-Driven Durability Tester."

The permeance of the coating is measured using one of the protocols described in ASTM E-96. Theoretically, permeance is defined as the passage of bulk water or water vapor through the coating film. Permeance < 1.0 is considered a vapor retarder and not a "breather." However, for EWCs, a somewhat higher degree of permeance is needed to allow the wall to exhaust trapped moisture.

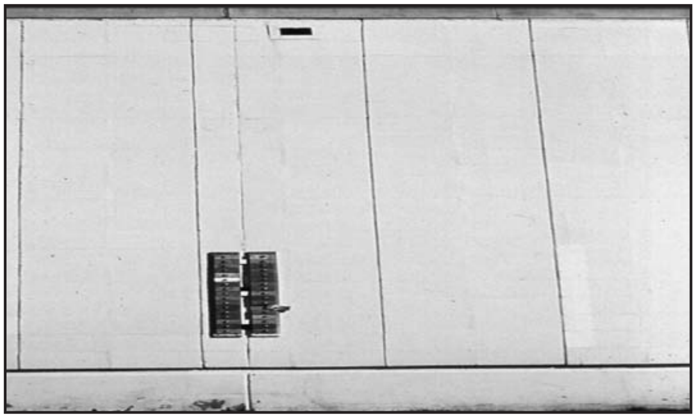


Figure 10

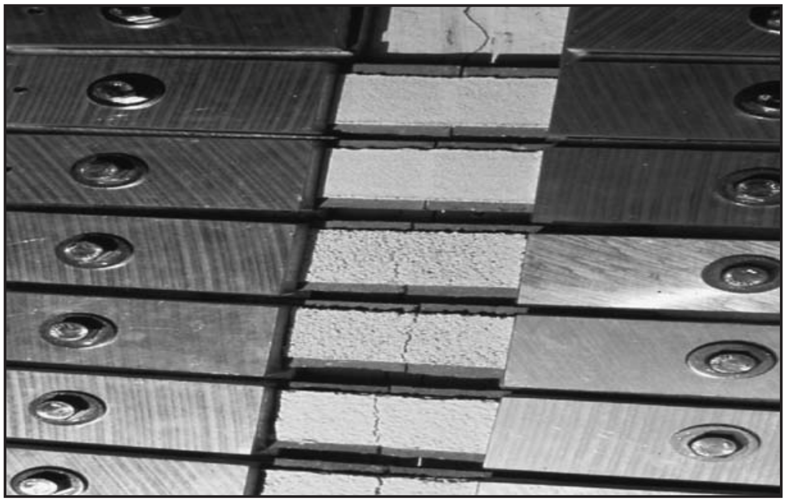


Figure 11

ASTM E-96 BW
Liquid Water in Contact with Coating
"B" method used for EWC 's

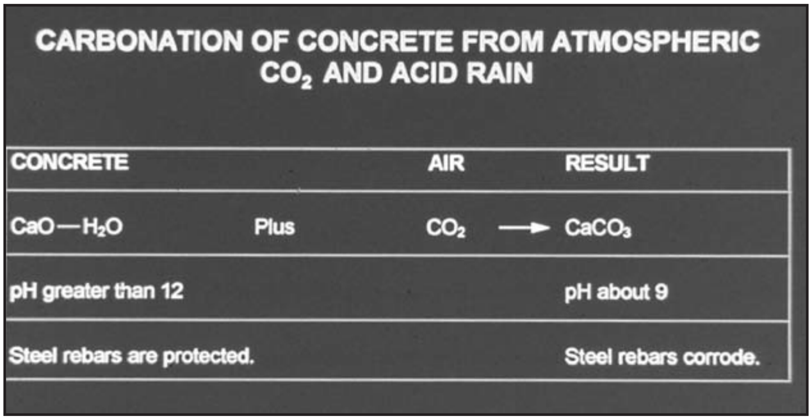
Figure 12

REBAR CARBONATION

Reinforcing bars (rebars) are incorporated into concrete construction to increase the flexural strength of the CMU. When the rebar is surrounded by concrete, it is considered "passivated" and the bar will not corrode due to the high pH of the concrete. However, if the pH of the area surrounding the bar drops, the bar will corrode. The corrosion is caused by the presence of water and carbon dioxide. A solution of these two compounds forms carbonic acid, which effectively lowers the pH of the area surrounding the rebar and causes rust to form.

The physical manifestation of carbonation is the rust-stained concrete that spalls from the affected area. The formation of the rust is approximately seven times greater than the volume of the steel (iron) from which it was formed. This expansion process causes the concrete to expand and crack.

To be effective in preventing carbonation, the EWC must act as a barrier to carbon dioxide and water. Besides the standard test for water permeance described previously, there is a standard test for CO_2 permeance used to qualify EWCs that are designed to prevent carbonation. These EWCs


CARBONATION OF CONCRETE FROM ATMOSPHERIC CO_2 AND ACID RAIN

CONCRETE		AIR		RESULT
$CaO-H_2O$	Plus	CO_2	$\longrightarrow$	$CaCO_3$
pH greater than 12				pH about 9
Steel rebars are protected.				Steel rebars corrode.

Figure 13

are sometimes called “anti-carb coatings.” This problem is being exacerbated by the increasing levels of CO_2 in the atmosphere. The levels of CO_2 are tracked by the National Oceanographic and Atmospheric Administration (NOAA). Maps showing CO_2 concentrations can be found at **www.esrl.noaa.gov/gmd/ccgg/carbontracker/**. This problem is further compounded when locally generated acid rain falls on a reinforced concrete structure.

DIRT PICKUP RESISTANCE

The aesthetics of an EWC are an important property and must be considered when specifying products. Properties such as color, texture, and aggregate incorporation all drive the decision to specify one coating versus another. One very important property is dirt pickup resistance. Although the coating is clean when it is newly applied, it may quickly pick up dirt and mildew. Mildew accumulation is greatest in warm, moist climates and on the north or shady sides of buildings. Properly formulated EWCs have inherent dirt pickup resistance and are formulated with mildewcides to prevent discoloration caused by mildew.

Currently, there is an ASTM Task Group within the D08.06 Subcommittee to develop a laboratory method for measuring dirt pick resistance.

One method currently used is to “soil” coated panels with brown iron oxide pigment, rinse the samples with water, and visually compare the dirt pickup resistance of the samples. Results of this test can be seen in *Figure 14*.

APPLICATION CONSIDERATIONS OF EWCS

While prudent selection of a quality EWC is vitally important for a successful wall-coating project, proper surface preparation is an equally important consideration. Key points regarding surface preparation and application include:

- Pressure wash to remove salts, dirt, and chalk.
- Repair wide cracks using elastomeric sealant.
- If still chalky, use a primer/sealer. However, priming is no substitute for proper cleaning. Use the “masking tape test” when in doubt. Apply a piece of 2-in masking tape to the cleaned surface. If it adheres well, so will the coating. If it comes off easily and has “chalk” or dirt adhered to it, the coating will have unsatisfactory adhesion.
- Apply the coating in two coats via spray, roller, or brush.

  * Roller may be required for irregular surfaces.
- Follow manufacturer's directions!
- 28-day cure may be required before the EWC can be applied to allow the pH to drop sufficiently.

  * Beware of “hot concrete.”
- Beware of efflorescence on interior or exterior walls.

  * May be a roof/parapet leak.

  * Observed as water-filled coating blisters in coating.

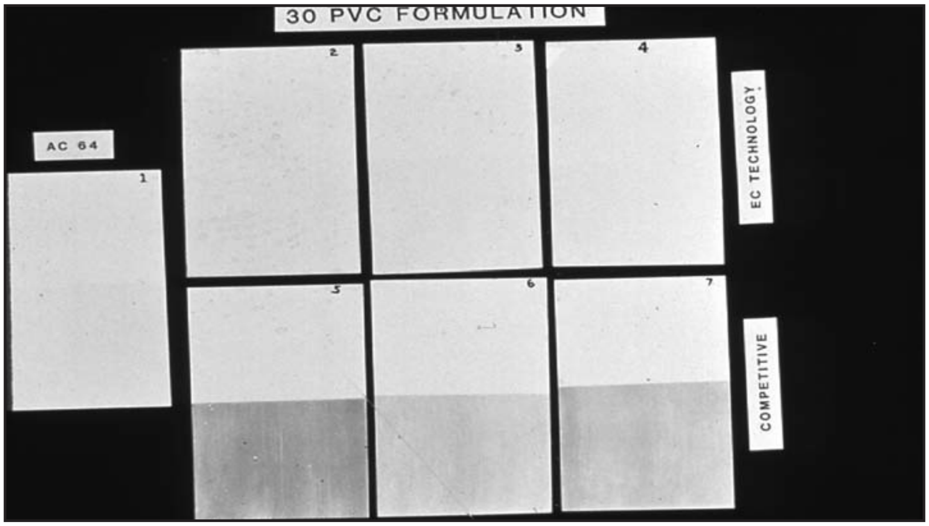


Figure 14

WHAT CONSULTANTS NEED TO KNOW ABOUT SPECIFYING AND SELECTING EWCS

One key performance criteria for EWCs is the ability of the coating to tolerate movement at low service temperatures. The term "low service temperature" has a different meaning if the building is located in Minneapolis, MN, or in Miami, FL. This was made obvious in the graphs in the preceding section of this paper. Thus, this key information must be obtained from the manufacturer. A product that has a successful track record in Miami, FL, may not perform satisfactorily in a much colder climate, such as Minneapolis. In fact, some architectural coatings are repackaged and sold as "elastomeric" coatings in Florida, and perform fully satisfactorily. However, these coatings will crack if applied on a moving hairline crack in a colder climate.

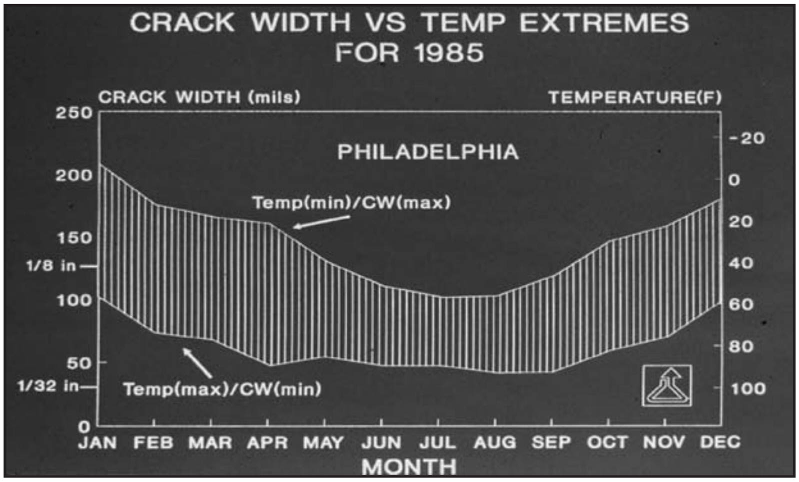


Figure 15

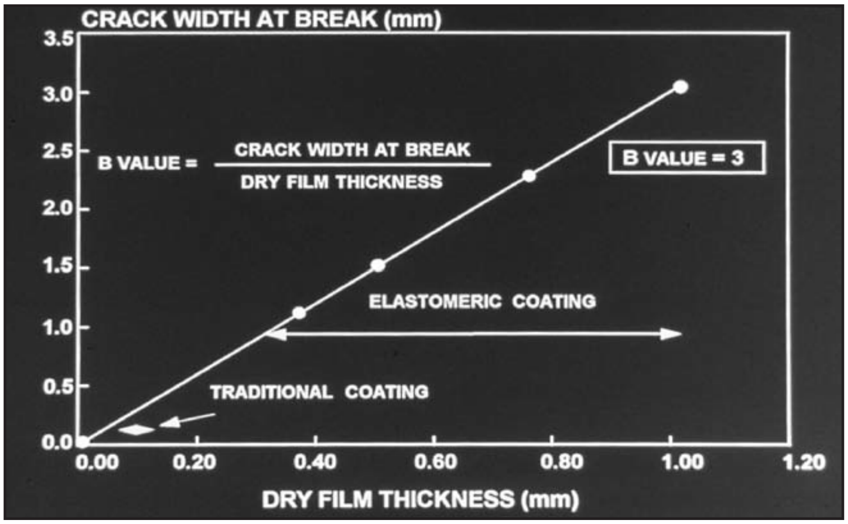


Figure 16

Sufficient film thickness is a key requirement for an EWC. Obviously, the thicker the coating applied over a dynamic crack, the better able the coating is to tolerate repeated cyclic movement of the underlying crack. While the manufacturer's recommended film thickness provides a proxy for film thickness recommendations, there is a more accurate method for determining the required film thickness for a coating. This will be described in greater detail in the following section.

Dirt pickup resistance is a key performance requirement for any exterior coating. This term encompasses not only dirt pickup, but also mildew and algae growth that may propagate on the wall coating. Properly formulated EWCs are designed to prevent or retard dirt accumulation and mildewcides to prevent bacterial growth.

Adhesion to the underlying substrate is another obvious requirement for an EWC. However, the specifics of the underlying substrate must be fully understood. Is the surface stucco? Block? Tilt-up? Acrylic modified stucco? Is the surface coated with an architectural coating? Is the coating acrylic? Silicone? Urethane? Epoxy? It is important that the EWC has acceptable adhesion to that specific substrate.

Underlying all these requirements is a fundamental question that can be posed by the consultant to the manufacturer: What is the performance track record of this coating in the same geographic location and over the same substrate as my project? There is no substitute for successful "proof statements" or case histories.

The term "semi-elastomeric" has been recently "spotted" on some manufacturers' Web sites and product data sheets. (Author's note: I have absolutely no idea what this means!) However, the key to proper EWC selection is to work closely with the coating manufacturer and establish what the key performance criteria and product requirements are, and allow the manufacturer to assist in coating selection, and wall surface preparation and application recommendations. This will ensure a successful project.

HOW THICK SHOULD THE EWC BE? MANUFACTURER'S DIRECTION? ...OR IS THERE A BETTER WAY?

Coating application film thickness requirements are usually included on the manufacturer's product data sheets. These recommendations are based on the EWC's performance history. However, if we consider the functional (elongation and compression) requirements imposed on the coating, simply reading the PDS may not be sufficient. Previously in this paper, it was shown that the size of any crack is a function of geography (summer and winter temperatures). The graph in *Figure 15* shows the crack history for the building in Spring House, PA.

Figure 15, together with *Figure 16*, showing the crack-bridging ability for a specific coating, will provide the recommended film thickness for the EWC.

The required film thickness is ~40 dry mils for this product. Other products may require more or less coating, depending on their mechanical (tensile strength and elongation) properties.

WHEN NOT TO USE EWCS

Consider the photo in *Figure 17*. There is evidence of efflorescence (presence of water) on the wall. An immediate solution to the problem would be to apply an EWC to prevent moisture intrusion into the block and efflorescence discoloration on the wall. However, upon further investigation, the problem is more complex. *Figure 18* shows the problem in better detail. The efflorescence begins below the weep holes. Ideally, by design, any water trapped in this cavity wall is diverted using a drainage system to the weep holes and out of the building. However, in this case, the water flows beneath the diverters and slowly migrates through the CMU below the weep holes and is evidenced as the white efflorescent stain. The root cause and the severe effloresence may be related to factors such as lack of a watertight transition between the roof and wall, improper flashing within the wall cavity, or blocked weep holes. Obviously, in each case, EWC application would not be the proper repair for this problem. The root cause must be identified before any coating option is considered.

Figure 17

Figure 18

CASE HISTORIES

SUMMARY

Elastomeric wall coatings are different from traditional architectural coatings. They not only serve aesthetic functions, but also have functional properties and the ability to tolerate dimensional substrate movement at low service temperatures. They are typically applied three to five times thicker than a regular house paint to achieve these properties. They must have the ability to bridge hairline cracks in the wall under repeated cyclic movement. They must also be alkali resistant and have the ability to "breathe" and allow moisture vapor to transpire. They also have dirt pickup and mildew-resistant requirements.

The successful installation of an EWC is the result of using the correct product for the unique climatic environment and installing it properly. This is the "recipe for success" when selecting any product for construction applications.

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CASE HISTORIES