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# Repair of Damaged Glazed Terra Cotta Surfaces: A Comparative Study of Remedial Coatings for Their Effectiveness on Areas of Glaze Loss in Temperate Maritime Weathering Conditions

Jessica Amy Sloop  
*University of Pennsylvania*

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## **Disciplines**

Historic Preservation and Conservation

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REPAIR OF DAMAGED GLAZED TERRA COTTA SURFACES:  
A COMPARATIVE STUDY OF REMEDIAL COATINGS  
FOR THEIR EFFECTIVENESS ON AREAS OF GLAZE LOSS  
IN TEMPERATE MARITIME WEATHERING CONDITIONS

Jessica Amy Sloop

A THESIS

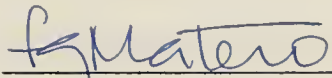
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Historic Preservation

Presented to the Faculties of the University of Pennsylvania in  
Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

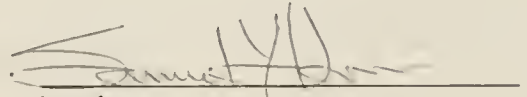
1996



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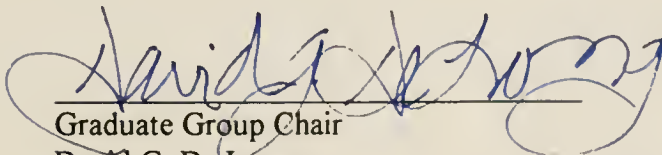
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## Introduction

From the beginning of the 20th century to the early 1930s in the United States, glazed terra cotta was one of the most widely used building materials.<sup>1</sup> Its aesthetic properties of moldability and colorability, and its practical qualities of lightness, ability to be duplicated easily, resistance to weather and fire, and ease in cleaning, made it an attractive and cost-effective cladding material for a wide range of buildings. Unfortunately, the material's newness and increasing use in such a short span of time did not allow for proper installation standards to be field-tested or enforced until after many structures were already erected. A lack of sufficient experience in building with architectural terra cotta and an over-reliance on its superior material qualities resulted in improper or careless installation causing the terra cotta of these early buildings to deteriorate. In addition, precisely at the time when these buildings were beginning to show their faults, new mass-produced cladding materials like metal, glass, and reinforced concrete were introduced and attracting attention because they were inexpensive, available in much shorter periods of time, and less labor intensive to use than hand molded terra cotta. These factors led to the eventual decline of the glazed terra cotta industry in the United States, and although many of the great glazed terra cotta structures are now gone, those that remain are often in need of conservation.

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<sup>1</sup> Robert C. Mack, "The Manufacture and Use of Architectural Terra Cotta in the United States," in *The Technology of Historic American Buildings: Studies of the Materials, Craft Processes, and the Mechanization of Building Construction*, ed. H. Ward Jandl, (Washington: Foundation for Preservation Technology, for the Association for Preservation Technology, 1983), 120.





Much of the deterioration of glazed terra cotta buildings occurs at the glaze layer. The condition of glaze loss not only impairs the aesthetic integrity of the building, but also provides a vehicle for further deterioration by exposing the porous terra cotta substrate to the damaging effects of weather. Although some field work and research has been conducted in the area of applying coatings *in situ* for glaze loss repair, much of the conservation of damaged glaze surfaces thus far has taken the form of total replacement.<sup>2</sup> The current literature concerning repair methods for damaged glazes indicates that a proven solution to the problem of glaze loss has not yet been found. Architectural conservators who were consulted for this study related various philosophies with regard to glaze repair. While some considered coatings to be the most viable option, others deemed them aesthetically unacceptable. Those that had employed coatings cited a variety of coating types and brands which have been used, but it is clear that no consensus has been reached yet as to which coatings are the most effective or what their long-term performance will be. These observations justify the need for more research directly targeting the use of coatings for glaze repair.

The experimental program of this thesis was an attempt to address unanswered questions related to the issue of *in situ* glaze repair. The tests conducted evaluate remedial coatings

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<sup>2</sup> Two case studies which involved replacement include: Stephen J. Kelley and Jerry G. Stockbridge, "The Railway Exchange Building, A Terra Cotta Renovation," *Association for Preservation Technology Bulletin* 20 (No. 3, 1988): 15-22; and James Marston Fitch, "Renovation of Alwyn Court, New York City: Restoring the Facades & Improving Public Spaces," *Technology & Conservation* 5 (Summer 1980): 24-27. This option will be discussed further in Chapter 4.



for their effectiveness in protecting exposed areas of the clay body and in replicating certain glaze characteristics when subjected to weathering conditions typical of a temperate maritime climate. In order to build on previous research this program examined the same five coatings which were tested earlier,<sup>3</sup> with several modifications in the testing program. Four of the five coatings were used in their pigmented versions assuming that for covering peeled or spalled areas, these would be the most appropriate. Accelerated aging tests, performed in a QUV/SE/SO Accelerated Weathering Tester at the Architectural Conservation Laboratory at the University of Pennsylvania, included simulations of alternating exposures to ultraviolet light and condensation combined with high temperatures and relative humidity. Water vapor permeability was also tested to determine the compatibility of these coatings to the original glaze and ceramic core, and water absorption rates of the coated samples were measured and compared to the absorption rate of the exposed terra cotta substrate. In addition, this program evaluated the coatings' performances when applied to the terra cotta substrate and to a terra cotta restoration mortar patch. This dual application was intended to simulate repairs necessary for the two most commonly found conditions of glaze loss: peeling and spalling.

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<sup>3</sup> Ricardo Julio Viera, "Cold Glazing Terra Cotta: The Repair of Damaged Glazed Surfaces" (Master's thesis, Columbia University, 1992).



## CHAPTER 1

### Historical Overview

There is no shortage of early or recent literature to testify to the fact that the development of glazed terra cotta was rapid and widely publicized by the manufacturers. Numerous articles in trade magazines such as *The Architect and Engineer*, *Brickbuilder*, *American Architect and Building News*, and *The Architectural Review* detail why glazed terra cotta was one of the “most superior materials”<sup>4</sup> for building in the early twentieth century.<sup>5</sup> More recent publications also review the early history of the material and in addition, describe the reasons for glazed terra cotta’s increased use in more recent times.<sup>6</sup>

Although unglazed architectural terra cotta emerged as a popular building material in the mid to late 1800s, glaze technology for architectural terra cotta did not take root in the United States until the very end of the nineteenth century. Walter Geer reported that the Perth Amboy Terra Cotta Company, with the expertise of T. C. Booth, began

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<sup>4</sup> H. L. Fitzsimmons, “Terra Cotta in Building Construction,” *The Architect and Engineer* (November 1914): 95.

<sup>5</sup> Some of the most salient articles include: Herbert D. Croly, “Glazed and Colored Terra-cotta,” *Architectural Record* 19 (April 1906): 313-323; Oswald Speir, “Architectural Terra Cotta,” *The Architect and Engineer* (October 1915): 77-83; Samuel Howe, “Glazed and Lustered Terra-cotta,” *American Architect and Building News* 101 (1912): 237-242; and Samuel Howe, “Polychrome Terra-cotta,” *American Architect and Building News* 101 (1912): 99-105. In addition trade journals published by the terra cotta manufacturers were constantly singing the praises of their material for building. For instance, *Atlantic Terra Cotta*, the monthly magazine published by the Atlantic Terra Cotta Company of Staten Island, New York, included articles about all the merits of terra cotta as a building material, spotlighting a specific characteristic or building each month.

<sup>6</sup> Michael Stratton, *The Terra Cotta Revival* (London: Villiers House, 1993) and Susan Tunick, “Introduction” in Gary F. Kurutz, *Architectural Terra Cotta of Gladding, McBean* (Sausalito: Windgate Press, 1989) are two recent publications which give excellent summaries of the history of the terra cotta industry from its beginning until today.



experimenting with glazes for exterior architectural terra cotta in 1894. At first, they were able to produce a cream white glaze which could be sandblasted to imitate marble.<sup>7</sup> By 1898, colors were introduced and used in large scale projects, and in 1906 polychrome glazed terra cotta got perhaps its most important endorsement when it was employed by McKim Mead and White in their Madison Square Presbyterian Church.<sup>8</sup> The church, primarily attributed to Stanford White, sat on a prominent Manhattan street corner surrounded by skyscrapers including the towering Metropolitan Building. The Atlantic Terra Cotta company called it the “first building of importance for which Atlantic Polychrome was used,” and also said, “its success opened up a field scarcely dreamed of before.”<sup>9</sup> The church was adorned with matte colors of golden yellow at the base course and entrances and stronger colors such as sienna, blue and green, in features further from eye level.<sup>10</sup> Geer called the church a “triumph in restrained color.”<sup>11</sup>

The same year of the erection of the Madison Square Presbyterian Church, Herbert D. Croly claimed in *Architectural Record* that, of all the advantages of terra cotta

its comparative lightness, the possibility of moulding it before hardening, its strength, its ability to resist fire, and finally, the chance it offers of obtaining an agreeable texture and colored surface . . . those that are most inimitable and most beyond competition are the result of glazing and coloring.<sup>12</sup>

Croly related the value of glazes for the future of terra cotta when he stated

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<sup>7</sup> Walter Geer, *The Story of Terra Cotta* (New York: Tobias A. Wright, 1920), 208.

<sup>8</sup> *Ibid.*, 205-211.

<sup>9</sup> “The Atlantic Terra Cotta Church: Dr. Parkhurst’s Madison Square Presbyterian Church,” *Atlantic Terra Cotta* 2 (No. 5, March 1915).

<sup>10</sup> *Ibid.*

<sup>11</sup> Geer, 212.

<sup>12</sup> Herbert D. Croly, “Glazed and Colored Terra-cotta,” *Architectural Record* 19 (April 1906): 314.





to secure an aesthetic polychromatic effect, there is nothing like glazed and colored terra cotta, and it cannot be doubted that the great future success of terra cotta in this country will be associated with its enlarged and improved use as highly colored material.<sup>13</sup>

He admitted though, in 1906, that the methods and processes were still subject to improvement to make glazes more reliable and to expand the range of colors. At the time of the article, cream was a commonly used color; shades of blue, green, yellow, and gray were available, and efforts were being made to create a red.<sup>14</sup> Ten years later, in 1916, the Atlantic Terra Cotta Company advertised the availability of “practically every color that could be wanted in architecture - even a bright red and a lustrous gold.”<sup>15</sup> In 1924, over 100 Atlantic colors were available,<sup>16</sup> and in 1926 the claim was made that the “experimental stage of polychromy is passed”<sup>17</sup> Finally, by 1932, color development had reached its climax, and Atlantic Terra Cotta reported that

nearly two hundred standard tones of blues, buffs, greens, etc., ranging from soft pastel shades to brilliant polychrome effects are now the everyday choice of the designer. Ceramic finishes, such as gold and silver and bronze, are also available.<sup>18</sup>

The application of glazes was seen as a great additional benefit to a material which was already quite popular due to the qualities suggested by Croly above. The addition of color in architecture was attractive to the architectural public especially in this period in which architects were turning to polychromy in order to add interest to their structures.

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<sup>13</sup> Ibid., 315-316.

<sup>14</sup> Ibid., 317-318.

<sup>15</sup> “The Adaptability of Atlantic Terra Cotta,” *Atlantic Terra Cotta* 3 (No. 4, February 1916).

<sup>16</sup> “The Della Robbia School of Today: Childs Restaurant, Coney Island, New York, Dennison & Hiron, Architects,” *Atlantic Terra Cotta* 7 (No. 2, September 1924).

<sup>17</sup> “Architectural Treatment,” *Atlantic Terra Cotta* 8 (No. 8, May 1926).

<sup>18</sup> “Recent Advances in Terra Cotta Manufacture,” *Atlantic Terra Cotta* 11 (No. 3, November 1932).



“beauty as often means color as it does proportion or ornament,” claimed Samuel Howe in a 1912 article in *The American Architect and Building News*.<sup>19</sup> Some glaze colors and textures were created to imitate stone such as marble and granite. In this respect, terra cotta provided an economical way to clad and detail a building which was intended to look like stone. Frequently stone was used for the base or first few stories of a building, and then terra cotta to match was used for the main body and the modeled detail which would otherwise be very costly to execute in stone.

There was, however, considerable antagonism towards using terra cotta in imitation of stone.<sup>20</sup> Opponents to imitation saw colored glazes as the vehicle for terra cotta to have its own identity. Advocating this point of view, Herman Plusch wrote, “When architectural terra cotta branches out into the polychrome field, it is no longer an

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<sup>19</sup> Samuel Howe, “Polychrome Terra Cotta,” *The American Architect and Building News* 101 (1912): 99.

<sup>20</sup> Three specific examples of this emphatic opposition are cited below.

Oswald Speir relates, “Terra cotta is not a substitute for stone. Under certain conditions and for certain architectural effect terra cotta should not be used. Under other conditions and for other architecture effects, stone of one kind or another should be used . . . The comparative use of the two materials is confused by the fact that terra cotta is cheaper and more flexible material than stone and that consequently it is often used as a substitute for stone, not because the architect wants use terra cotta but because he cannot afford to use stone. . . and the manufacturer of terra cotta is required to produce a ‘sham’ material in which the substantial and characteristic merits of each material is sacrificed for the sake of putting up a false appearance.” In Oswald Speir, “Architectural Terra Cotta,” *The Architect and Engineer* (October 1915): 80.

Samuel Howe states, “Glazed terra cotta is no imitator! By no stretch of the imagination can anyone be justified in accepting it in this light. To think of it for one moment as a reproduction or copy of another building material must surely be realized as a serious mistake, a grave error of judgment . . . terra cotta has its own individuality, its own language, its own character.” In Samuel Howe, “Polychrome Terra-cotta,” 101.

Fitzsimmons states, “Terra cotta is not imitation stone and should not be used as such . . . it should not be employed in such a way that it will appear as an imitation of, or as cheap substitute for some more expensive material.” In H. L. Fitzsimmons, “Terra Cotta in Building Construction,” *The Architect and Engineer* (November 1914).



imitation or substitute for stone, but a building material, complete in itself . . .”<sup>21</sup> As a material that had the strength and durability of stone and could also be coated in the colors of the rainbow, terra cotta was unrivaled in the building industry. The Atlantic Terra Cotta Company advertised “colorability” as a major benefit offered by glazed terra cotta for entrances, office buildings, theater fronts, and apartment buildings. They claimed it would “give a plain facade a touch of interest” and add “life and spirit” to a stone building.<sup>22</sup> Its ability to take on either a matte or glossy finish made it versatile in terms of adaptability to different tastes and designs. Although in 1912 Howe related that there was a preference for the matte surface, he acknowledged that the lustered or glossy surface “is one of the charms of terra cotta.”<sup>23</sup>

In addition to the decorative qualities such as the color and texture glazes provided, they also imparted practical qualities to a terra cotta body. One of the most widely touted was durability. Samuel Howe noted that

. . . stone perishes, that marble requires repolishing every once in awhile or it deadens and dulls, granite endures, surrendering however its distinction and gets both greasy and filthy, but in glazed tile, brick or faience there is a material that defies the destructive acids in the air.<sup>24</sup>

Walter Geer claimed that terra cotta was “without doubt the most durable material known . . . unaffected by age or climatic change.”<sup>25</sup> Glazes were vitrified upon burning at very

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<sup>21</sup> Herman A. Plusch. “Polychrome Glaze Decoration in Architecture,” *Transactions of the American Ceramic Society* 9 (1907): 476.

<sup>22</sup> “The Atlantic Terra Cotta Entrance,” *Atlantic Terra Cotta* 1 (No. 10, August 1914); and “Possibilities” *Atlantic Terra Cotta* 7 (No. 8, May 1925).

<sup>23</sup> Howe, “Polychrome Terra Cotta,” 105.

<sup>24</sup> Samuel Howe, “Glazed and Lustered Terra-cotta,” 242.

<sup>25</sup> Geer, 218.



high temperatures in the kiln which made them impervious to absorption of moisture and “beyond the possibility of fading even if exposed to centuries of sunlight.”<sup>26</sup> Their smooth surface also made them less subject to the deposition of soot and pollutants in the environment.<sup>27</sup> Thus, they stayed cleaner and more intact than their counterparts in the stone and metal families. In an advertisement for black matte glazed spandrels, Atlantic Terra Cotta vouched for their superiority to iron by claiming that the glazed terra cotta spandrels “. . . cannot rust; they do not deteriorate; they will never need painting or any other maintenance.”<sup>28</sup>

Ease in cleaning was another highly marketable and, in fact, excessively promoted, quality of glazed terra cotta. Manufacturers claimed that it’s slick, smooth, waterproof surface, not only prevented dirt from accumulating or being absorbed into the piece, but also made the terra cotta surface easily cleaned with a simple solution of “ordinary soap and water.”<sup>29&30</sup> This method was inexpensive and did not require especially skilled workmen to carry out, allowing building owners to maintain pristine and attractive facades throughout the year. The commercial benefits of this quality of terra cotta were

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<sup>26</sup> “No Variation in Color,” *Atlantic Terra Cotta* 2 (No. 8, June 1915).

<sup>27</sup> “The Place of Terra Cotta in Post-War Building with Special Reference to the Problem of Atmospheric Pollution,” *British Clayworker* 53 (1944): 76.

<sup>28</sup> “The Spandrels,” *Atlantic Terra Cotta* 6 (No. 4, September 1923).

<sup>29</sup> Geer, 230.

<sup>30</sup> Recent research indicates that in actuality, cleaning may not have always been that simple. C.B. Moynihan, et al. report that, “The pattern of external soiling is, in many ways, similar to that of sandstone; some dirt appears to be bonded to the surface with a siliceous matrix that is not readily released by conventional washing systems.” In addition, soiling resulting from water migration within the terra cotta piece would commonly lie under the fireskin or glaze which would be “difficult to remove without some loss of surface.” From C.B. Moynihan, et al., “Surface Analysis of Architectural Terracotta,” *Journal of Architectural Conservation* (No. 1, March 1995): 58-59.





exploited by terra cotta manufacturers in the trade literature. In *General Building Contractor*, William Lockhardt wrote, “Terra cotta is the recourse of the modern owner with a building to keep clean and attractive to prospective tenants under the most adverse conditions.”<sup>31</sup> Atlantic Terra Cotta even advertised that, “the busiest housewife will have a hard time to keep her apartment rivaling the exterior of the [glazed terra cotta] building in cleanliness.”<sup>32</sup> They touted their lustrous glazed terra cotta as the “cleanest building material in the world” with their matte glazed finish in a close second.<sup>33</sup> The possibility of harmoniously constructing an addition to a glazed terra cotta building was also a selling point attributed to easy and effective cleaning. The addition could be made to match the existing terra cotta while the original part could be cleaned “to look like new.”<sup>34</sup>

The commercial aspect of terra cotta as a building and decorative material was further enhanced by its suitability and effectiveness for floodlighting. This quality was specifically attractive for theaters which needed to be illuminated at night and to office buildings to advertise their corporate images and to allow them to stand out at night as well as during the day. *General Building Contractor* reported in 1931 that, “. . .today we lean heavily on the proven superiority of terra cotta for buildings to be given exterior night illumination.”<sup>35</sup> Tests done by the General Electric Company in 1927 and

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<sup>31</sup> William Lockhardt, “Architectural Terra Cotta,” *General Building Contractor* (January 1931).

<sup>32</sup> “The Apartment House of Moderate Size,” *Atlantic Terra Cotta* 2 (No. 3, January 1915).

<sup>33</sup> *Ibid.*

<sup>34</sup> “Old and New Atlantic Terra Cotta,” *Atlantic Terra Cotta* 2 (No. 12, October 1915).

<sup>35</sup> Lockhardt.



published by the National Terra Cotta Society illustrated that terra cotta was clearly the best material for this purpose. Results showed that glazed and unglazed terra cotta had the highest reflection coefficients and lowest absorption coefficients of any building material. Glaze colors were reported to show up perfectly under white light, as evidenced in the illuminated polychrome details on the Fred French building in Manhattan.<sup>36</sup>

Combined with all the aforementioned qualities of glazed terra cotta, its comparative cost made it an extremely popular material. Architectural form, color, and texture could be had for a much lower price than they could be had in stone. The economy came from the requirement of making only one mold from which many repeated details could be created. This allowed for a larger quantity of ornamentation as well as for the potential to employ more elaborate decoration. Terra cotta's light weight compared to that of stone, also allowed the superstructure of the buildings to be smaller and significantly decreased shipping costs, thus substantially lowering the total cost of a building. For example, the Atlantic Terra Cotta company claimed that it produced capitals for the State Education Building in Albany, New York for one sixth of the price they would have cost in the marble with which the columns were made.<sup>37</sup> This amounted to a great savings for owners.

Terra cotta manufacturers were successful in their attempts to convince architects to use

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<sup>36</sup> "Night Architecture," *Atlantic Terra Cotta* 9 (No. 8, May 1928).

<sup>37</sup> "A Supplementary Use of Atlantic Terra Cotta," *Atlantic Terra Cotta* 2 (No. 12, October 1915).



their materials. Michael Stratton claims that “terra cotta became the rule rather than the exception in downtown areas.”<sup>38</sup> Illustrating the value of the glaze in this feat, Robert C. Mack states that, “in this glazed form, terra cotta became one of the most popular building materials for exterior surfaces of buildings.”<sup>39</sup> Yet, in the 1930s, a sharp decline in the use of terra cotta began. New mass-produced materials like metal and glass panels, and reinforced concrete were introduced and attracting attention because they were less expensive to manufacture, available in much shorter periods of time, and less labor intensive to use than hand molded terra cotta. During World War II, skilled labor shortages resulted in decreased production. Moreover, after the war, the material began to exhibit its weaknesses. Mostly due to problems of improper installation and maintenance, these deterioration problems added to the gradual disappearance of the use of terra cotta as a building cladding. By 1947 only seven of the 24 companies that previously dominated the market were still in operation.<sup>40</sup> Although many of the terra cotta buildings in America have been lost to demolition, what is left is primarily of glazed finish in a variety of colors, but mostly in white and cream glazes which were popular for downtown areas.

In the last 15 years or so, however, terra cotta has experienced somewhat of a resurgence of interest by architects in the United States. According to architect Robert Venturi,

Opportunities abound for using terra cotta for the sensual enrichment of

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<sup>38</sup> Stratton, 189.

<sup>39</sup> Mack, 119.

<sup>40</sup> Susan Tunick, “Introduction” in Gary F. Kurutz, *Architectural Terra Cotta of Gladding, McBean* (Sausalito: Windgate Press, 1989), 10.



architecture . . . Because of its easy repetitiveness and inherent refinement, terra cotta can be a means of creating small-scale articulation as a counterpoint to the big size of many of our buildings today . . . it is a way to bring back . . . color and ornament.<sup>41</sup>

Venturi's Seattle Art Museum (December 1991) which employed glazed terra cotta in yellow, white and black has been instrumental in promoting the revival of terra cotta and the terra cotta manufactories.<sup>42</sup> This revival can also be attributed to restoration projects. Now that surviving terra cotta buildings are between 60 and 100 years old, most are in desperate need of some form of conservation. As a result, remaining companies, such as Gladding McBean, are now being called upon to make terra cotta replacement pieces for these buildings.<sup>43</sup>

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<sup>41</sup> Ibid., 11.

<sup>42</sup> Stratton, 225.

<sup>43</sup> Tunick, 11.





## CHAPTER 2

### Glaze Manufacture and Application

#### 2.1 Glaze Manufacture

Simply stated, a *glaze* is, “a glassy covering applied to a ceramic material.”<sup>44</sup> More technically, it may be described as

the prepared mixture of materials, which is either a powder or a suspension in water, ready for application to ceramic ware by dipping or spraying. After suitable heat treatment this powdered mixture vitrifies and develops specific properties appropriate to the designed use of the glaze on the ceramic body. The composition of the glaze is chosen to ensure certain well-defined properties, such as adhesion to the substrate, correspondence of thermal expansion, transparency or opacity, surface texture and resistance to chemical attack, are possessed by the glasslike coating.<sup>45</sup>

Glazes were applied after drying and before firing of a piece. Often an *underslip* or liquid suspension of fine clay particles in water, or an *engobe* which contained clay, flux, and metallic oxides, was applied before the glaze. These intermediate layers improved adhesion of the glaze, provided opacity to hide the color of the body, and protected the body from tensions produced by the glaze.<sup>46</sup>

Common ingredients for glazes included feldspar, clay (ball clay or china clay, usually), flint, zinc oxide, barium carbonate, magnesium carbonate, and lead. Each imparted particular qualities to the coating. Flint supplied silica which forms a glass when heated.

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<sup>44</sup> David Hamilton, *The Thames & Hudson Manual of Architectural Ceramics* (London: Thames and Hudson, 1978), 177.

<sup>45</sup> J. R. Taylor and A. C. Bull, *Ceramics Glaze Technology* (New York: Pergamon Press, 1986), 1

<sup>46</sup> Hewitt Wilson, “Monograph and Bibliography on Terra Cotta,” *Journal of the American Ceramic Society* 5 (February 1926): 114.



but has an extremely high melting point. To lower the melting point, a flux, such as magnesium carbonate was added. Feldspar and clay supplied aluminum which increases the viscosity and facilitates adherence to the body. Zinc was used to improve whiteness and opacity of opaque glazes, reduce the coefficient of thermal expansion, and improve the chemical durability of some compositions. Finally, the inclusion of lead imparted low surface tension, low viscosity, resistance to chipping, and a high gloss surface.<sup>47</sup> The composition of the glaze depended on the composition of the body and the aesthetic effects desired. Compatibility with the mechanical and chemical properties of the body was essential to ensure proper fit and durability.

Glaze colors were imparted by adding minerals or stains to the glaze mix. Generally a chemist was employed by the company to formulate glaze recipes for a variety of colors. Hewitt Wilson reported that the most common colors in 1922 were variations of white, cream and gray. White was made by the addition of tin oxide sometimes mixed with a little cobalt sulfate. Creams could be formed with dilute iron oxide, rutile and antimony for yellower creams, and uranium oxide for brownish creams. Grays were formed by adding a black stain to a white glaze. Black stains were made by mixing cobalt blue, manganese brown, nickel and iron, and chromium green. Tans could be formed from chromium oxide mixed with a zinc glaze and manganese browns, varied with the cream producing materials noted above.<sup>48</sup>

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<sup>47</sup> Taylor and Bull, 15-37.

<sup>48</sup> Wilson, "Monograph and Bibliography," 124-125.



Polychrome colors, used more for ornamental work were also commonly made. Cobalt diluted in a white glaze produced blue. For fainter blues, soluble cobalt sulfate or nitrate was precipitated in the glaze after mixing with soda ash. Greens were produced with copper oxide or chromium oxide, or by mixing cobalt (blue) and uranium (yellow). For example, one common chromium green stain contained chromium oxide, cobalt oxide, flint, and borax.<sup>49</sup> A chrome-tin-lime combination was the most commonly used recipe for pink or rose colors, and finally, blacks were made by mixing dark colors such as iron chromate, nickel oxide, cobalt oxide, chromium oxide, and red lead.<sup>50</sup>

Granite finishes were very popular and required a more involved process to produce. The most successful way to replicate a granite surface on terra cotta was to apply a black slip, cover it partially by spotting a white underslip leaving only small spots of black exposed, and spraying a glaze coating over this to produce the glossy appearance of polished granite.<sup>51</sup>

Once the appropriate recipe was determined, preparation was relatively simple. All the materials were mixed with water to form a smooth paste which was sieved through a 150 to 200 mesh sieve and brought to the appropriate pint weight for the clay which was to be glazed.<sup>52</sup>

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<sup>49</sup> Ibid., 126-127.

<sup>50</sup> Ibid., 127

<sup>51</sup> Ibid., 128-129.

<sup>52</sup> Hamilton, 166.



## 2.2 Glaze Application

The method of glaze application was determined by the nature of the pieces to be glazed. If only one color was to be used, the glaze was sprayed on using compressed air sprayers. Glaze was poured into funnels or tanks or elevated in pails so that it flowed by gravity into the sprayers below. For spraying, pieces were placed on revolving stands or conveyer belts which enabled the sprayers to reach all sides without touching the pieces themselves. When using an underslip and then a glaze, the underslip was applied and allowed to dry, first. Then the glaze, in a firm powder form, was applied into the ornamental parts by holding the nozzle close to the piece and blowing out the excess glaze with air from the nozzle. The rest of the piece was then sprayed with the nozzle farther away from the surface.<sup>53</sup>

For more intricate pieces containing polychrome details, application required more attention. The method used depended on the size of the colored areas, the number of colors on the piece, the shape and finish of the outline of the colored areas, and the colors to be applied. The first method was to paint the glazes on with a brush. This was reportedly slow and caused streaking due to variation in thickness and brush marks. The second method, spraying using a plaster, metal, or paper shield to protect portions of the piece while others were being sprayed, was useful for large areas in repeating designs. Finally, colored metallic compounds could be blended in water solutions and painted with

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<sup>53</sup> Wilson, "Monograph and Bibliography," 113.





glycerine to dried glaze surfaces only in the areas where color was desired.<sup>54</sup>

### **2.3 Drying and Firing**

Some glazes required drying before going into the kiln while others could go immediately to be fired. Architectural terra cotta was normally fired in a gas fired muffle kiln at temperatures of between 2000° F and 2500° F. Glazes required uniform temperatures in the kiln to ensure uniform results of color, texture and vitrification.<sup>55</sup> These kilns employed combustion gases to heat the ware by radiation. The gases never came in contact with terra cotta which prevented discoloration of the finishes. Some kilns were 50 feet in diameter, held 30 tons of terra cotta and took a full two weeks to turn over. Within these two weeks three stages of burning took place. First, slow fires were used to burn off excess moisture still in the terra cotta. Second, hot fires were burnt until the finishing temperature was reached. The ware would burn at this temperature for a specified period of time, and then temperatures would be lowered gradually for cooling to take place.<sup>56</sup>

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<sup>54</sup> Ibid., 129-30.

<sup>55</sup> Ibid., 132.

<sup>56</sup> Mack, 135.



## CHAPTER 3

### Characterization of Glaze Failures and Causes of Deterioration

Treatment of the problem of deterioration and loss of terra cotta glazes is relatively new to architectural conservation. Although some early publications, such as the *Reports Relating to the Technical Work of the National Terra Cotta Society*<sup>57</sup> and *Investigations into the Durability of Architectural Terra-Cotta and Faience*,<sup>58</sup> discuss glaze failure, most of the discussion among building professionals has been in the last 20 to 25 years. Due to the fact that commercial glazed terra cotta was introduced to the United States in the first decade of the 20th century, the buildings that incorporated this material have only recently begun to show the effects of weathering, causing concern among architects

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<sup>57</sup> Of the reports from the National Terra Cotta Society the author was able to locate the following: *Summary and Index of Reports One to Eight Relating to the Technical Work of the National Terra Cotta Society* (New York: National Terra Cotta Society, April 1, 1927); *Twelfth Report* (June 10, 1926); *Thirteenth Report* (November 5, 1926); *Fourteenth Report* (June 2, 1927); *Fifteenth Report* (November 15, 1927); *Sixteenth Report* (May 10, 1928); and *Seventeenth Report* (December 1928). Manufacturing faults and tests were addressed in the testing and observations done by the National Terra Cotta Society from 1926-1929. While they also performed tests comparing the terra cotta of several large manufacturers, an informative part of the study involved observations of terra cotta in service. 1260 buildings were monitored for signs of deterioration and evaluated as to how their terra cotta reacted to the different climates. Observations provided interesting insight into the nature of terra cotta deterioration as related atmospheric weathering.

<sup>58</sup> W. A. McIntyre, *Investigations into the Durability of Architectural Terra-Cotta and Faience*, Department of Scientific and Industrial Research, Building Research Special Report No. 12 (London: Building Research Station, 1929).

Tests and observations made from 1926-1928 in England revealed that most glazed terra cotta in service was in "a perfect state of preservation," but noted that they were also very young. Basic conclusions made from the study were as follows:

(1) The chief agent of destruction of terra cotta is crystallization of salts within materials; (2) Thermal expansion and frost produce effects too small to be serious singly, although acting in conjunction with other factors may produce total stresses sufficient to cause rupture; (3) The glaze acts as protective coating on the face of a piece; (4) Crazeing will not necessarily increase the liability of body to atmospheric attack; and (5) When water penetrates to the interior of a glazed piece, the glaze reduces rate of evaporation and causes the material to become saturated beyond a safe limit. In this case, evaporation from face is confined to cracks on the glaze, and, in turn, the crystallization of salts tends to be intensified in these positions.



and conservators. The primary glaze defects observed in the literature are described as pinholing, crazing, spalling, and peeling. All of these failures occur as a result of one or a combination of the following factors: manufacturing faults, excessive weathering or, most commonly, improper installation. In 1915, Oswald Speir recognized that “terra cotta which has been properly put together and burnt, is more durable than stone.”<sup>59</sup> It was becoming obvious even then that installation problems, not the material or manufacturing faults, were the major cause of terra cotta failure.

### 3.1 Pinholing

Pinholes, “small tongues of underslip rising through the glaze and leaving a clean hole to the body,”<sup>60</sup> were the subject of two articles in the *American Ceramic Society Transactions* in the early 1900s,<sup>61</sup> but have not been addressed as a problem to a great extent in the recent literature. They are caused primarily in the manufacturing stages and do not form as a result of weathering. Although Thomasen and Searls mention that pinholes may facilitate circular spalling,<sup>62</sup> and earlier sources report that they are collection places for dirt and water, they do not cause significant damage to the pieces in service. Other deterioration problems, discussed below, are more prevalent and require attention.

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<sup>59</sup> Speir, 81.

<sup>60</sup> Hewitt Wilson, “Note on Pinholing and Peeling on Terra Cotta,” *American Ceramic Society Transactions* 19 (1917): 209.

<sup>61</sup> These include Wilson’s article cited above and H. J. Knollman, “An Unusual Case of Pinholing of Glazes,” *American Ceramic Society Transactions* 17 (1915):165-172;

<sup>62</sup> Sven E. Thomasen and Carolyn L. Searls, “Diagnosis of Terra-Cotta Glaze Spalling,” in *Masonry: Materials, Design, Construction, and Maintenance, ASTM STP 922*, ed. H. A. Harris (Philadelphia: American Society for Testing and Materials, 1988): 228.



### 3.2 Crazing

Crazing is defined as “a cracking of the glaze after solidification on cooling caused by excessive tension”<sup>63</sup> (fig. 3.1). These fine hairline cracks may occur as a direct result of cooling in the kiln, but can also be caused much later when the piece is subjected to rapid changes in temperature in the environment. Crazing may occur in one layer of the glaze, through several layers, or may continue into the depth of the body.<sup>64</sup> Crazing is frequently seen, and has been acknowledged as a problem by ceramics experts since glazed ware was first manufactured. Crazing is caused by differing coefficients of thermal and moisture expansion and contraction between the body and glaze. When the body expands upon hydration or temperature rise, the glaze relieves tension by crazing. Crazing may also be caused by pressure exerted when the body deforms more than the glaze upon loads in service.<sup>65</sup>

There is debate regarding the effects of crazing on the durability and impermeability of the glaze layer. While some claim that it does not affect the absorptive capabilities of the terra cotta through the glaze, others claim that crazing may allow water to enter the piece, causing further damage or discoloration.<sup>66</sup> There is a general agreement, however, that

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<sup>63</sup> Wilson, “Monograph and Bibliography,” 118.

<sup>64</sup> Ibid.

<sup>65</sup> *Sixteenth Report Relating to the Technical Work of the National Terra Cotta Society*, 73.

<sup>66</sup> John Fidler writes, “Unless the cracks extend from the surface down to the clay body itself the phenomenon should not be regarded as being a serious material failure. It does however tend to increase the water absorption risks of the whole unit and to effect the staining and discolouration of the terracotta over time.” In “The Conservation of Architectural Terracotta and Faience,” *Friends of Terra Cotta Newsletter* (Spring 1984): 12.





the greater the depth of the cracks, the greater the potential damage.

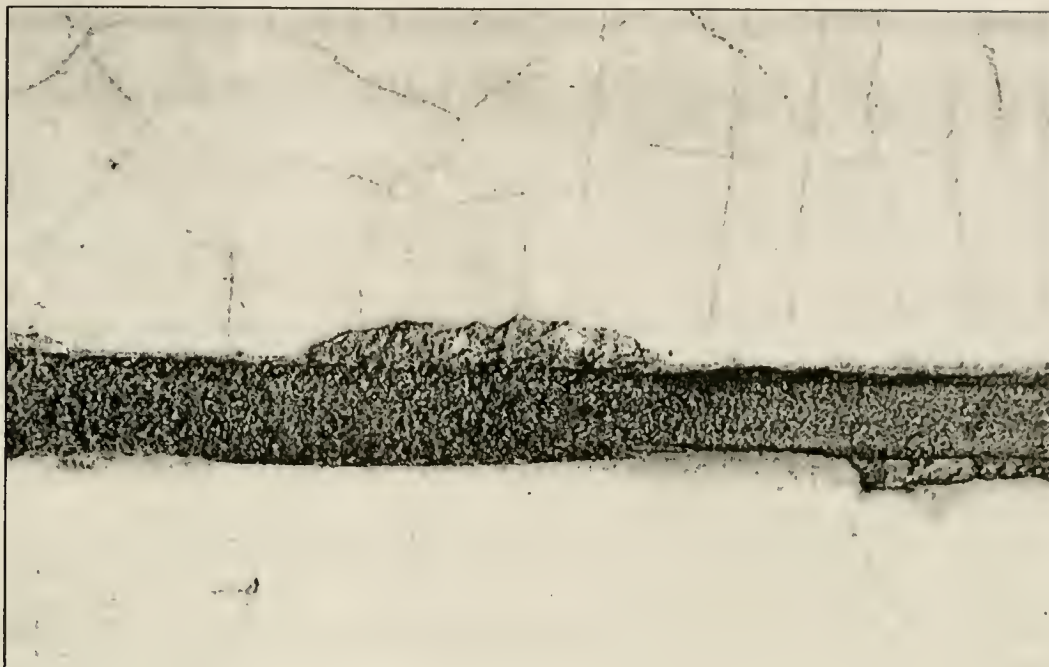


Figure 3.1 Glaze crazing, Berkeley Building, Boston, Massachusetts (Codman & Despradelle, 1905).

### 3.3 Spalling

Spalling is defined as a separation of the glaze with portions of the body attached<sup>67</sup> (fig. 3.2). In other words, the failure has occurred within the body of the piece, not at the glaze to body interface. This problem is probably the most frequently seen in buildings

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Theodore Prudon reports that cracks formed from crazing “eventually will alter a building’s appearance by their fostering the conditions necessary for other deterioration to occur. That is, they provide the possibility for moisture to pass through the otherwise impervious layer of glaze into the porous terra cotta body.” In “Architectural Terra Cotta: Analyzing the Deterioration Problems & Restoration Approaches,” *Technology & Conservation* (Fall 1978): 33.

Susan Tindall writes, “very little moisture permeates through the face of a crazed terra cotta unit. Jerry Stockbridge at Wiss, Janney, Elstner in Northbrook, Illinois estimates that, ‘unless a crack goes all the way through the glaze into the body, no more water is absorbed than through the face of an unglazed or slip coated unit. Almost all significant amounts of water are absorbed through imperfect bonds of the mortar joint.’” In “Technical Notes,” *Friends of Terra Cotta Newsletter* (Spring 1984): 4.

<sup>67</sup> Wilson, “Monograph and Bibliography,” 118.



today and is the most damaging and disfiguring. Water infiltration and moisture related mechanisms are the main cause of spalling. When water is allowed to enter the terra cotta substrate through means discussed below, it may become trapped due to the impermeability of the glaze layer. Water or water vapor stored in the pores of the masonry or between the glaze layer and substrate is then subject to the effects of freeze-thaw action causing expansion and contraction of the water molecules. When these molecules expand within the pores of the terra cotta, they cause strains and eventual failure. In addition, soluble salts from the mortar, fill, or terra cotta, may have been picked up by the water. These salts travel in solution until they reach the impermeable glaze layer. When the water evaporates, salt crystallization occurs. Upon hydration and dehydration, the salt crystals expand and contract, exerting pressure upon the walls of the pores in which they are trapped. This mechanism also causes stress in the material and eventually spalling of the outer layers occurs. In addition, infiltrated water can promote biogrowth in detached areas behind the glaze layer which causes strains and can fracture the body and glaze.

Water infiltration can occur through faults in fabrication, installation, and environmental weathering. Fabrication faults such as inadequate firing and a thin glaze layer increase permeability allowing water vapor to enter and become trapped in the piece. Improper pressing may also produce microcracks and weak areas in the substrate which lead to spalling when the piece is exposed to other weathering elements.





Figure 3.2 Glaze spalling, Ventnor City Hall, Ventnor, New Jersey (Vivian Smith, 1928-29).

Improper installation is a major cause of water infiltration and other stresses which induce spalling. Many terra cotta buildings did not include provisions for movement in the frame. In the absence of this provision, when differential movement occurs, the outer shell of terra cotta may crack in both the mortar and within the substrate. These cracks, in turn, allow water ingress. In addition, because of the builders' reliance on the glazed terra cotta's increased resistance to water penetration, weep holes were often excluded. This omission creates problems when water inevitably gets into the system. Having no planned means of escape, it builds up in voids causing additional strain through hydrostatic pressure. One drastic consequence of water build up is the corrosion and expansion of ferrous anchors. Their expansion from corrosion causes strains which lead to spalling, micro-cracking, and eventual unit loss. Finally, incomplete anchoring is



another installation fault which causes cracking and spalling due to inadequate support of the terra cotta pieces.

Water infiltration can also occur as a result of environmental weathering. Pollutants in the air weaken and make the mortar porous, allowing water to migrate into the substrate.<sup>68</sup>

Additionally, inappropriate maintenance may facilitate or worsen the possibility for water related damage. One common problem occurs when vapor impermeable sealants are used to cover damaged mortar joints. These sealants block the normal escape route for water vapor through the mortar and cause it to be trapped behind the glaze layer. Improper coatings applied to the surface of the terra cotta are also culprits for trapping moisture and causing pressure beneath the glaze layer. Finally, chemical cleaning treatments can damage the glaze layer allowing water infiltration and the exposure of the substrate to other weathering elements.<sup>69</sup>

### **3.4 Peeling**

Peeling is the separation of the glaze from the body without any damage to the body itself<sup>70</sup> (fig. 3.3). This condition occurs as a result of causes similar to those described above for spalling when water, water vapor, or soluble salts get trapped between the body

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<sup>68</sup> Thomasen and Searls, 228-233.

<sup>69</sup> *Ibid.*, 233.

<sup>70</sup> Wilson, "Monograph and Bibliography," 117.





and the glaze causing strains and eventual separation at this interface. Manufacturing faults may also cause peeling. For example, in the initial manufacturing process, soluble salts from the clay may have formed a coating on the surface of the substrate upon drying. These salts prevent underslip from adhering properly, but this condition may not materialize until the piece is in service for many years. In addition, proper adhesion of the glaze may also be hampered by the content of the glaze or underslip.<sup>71</sup>

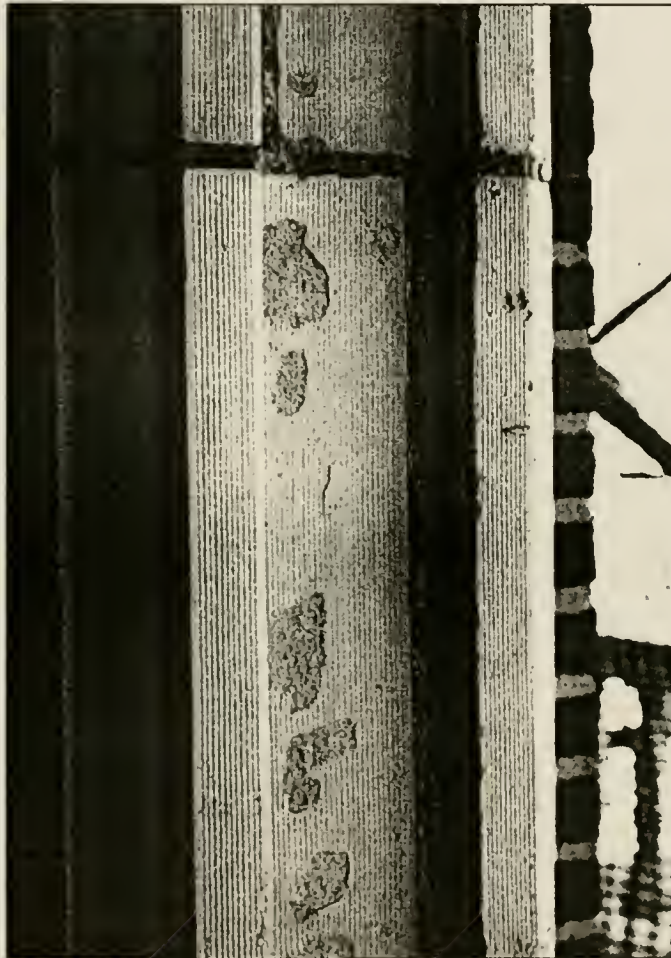


Figure 3.3 Glaze peeling, Ventnor City Hall, Ventnor, New Jersey (Vivian Smith, 1928-29).

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<sup>71</sup> Ibid.



All of these defects can lead to glaze loss which exposes the unvitified surface of the terra cotta body to elements to which it was never intended to be exposed. Further weathering and degradation occurs as a result of the initial glaze loss. This condition requires attention so that deterioration does not continue to spread throughout the surface of the piece. Conservation alternatives for glaze loss will be discussed in Chapter 4.



## CHAPTER 4

### Review of Repair Methods for Glaze Loss

Maintenance of fireskin, slipstain and glazed surfaces is critical to the well-being of terracotta and faience as the clay bodies they protect are far less durable. Their degradation can lead to one of the most complicated failure systems of all materials.<sup>72</sup>

The importance of repairing damaged glazed surfaces in order to protect the health of the rest of the building system is a well known fact among architectural conservators. Depending on the damage, repairs can come in the form of patching, coating, or total replacement.

#### 4.1 Published Literature on Coatings and Patching Materials

The first mention of remedial coatings for glaze loss of exterior cladding appears in the *Fifteenth Report on the Technical Work of the National Terra Cotta Society* issued on November 15, 1927.<sup>73</sup> The discussion begins with a disclaimer which states, “It is impossible to restore peeled terra cotta to its original condition and the only manner in which this can be prevented in the future is by manufacturing terra cotta which will not peel.”<sup>74</sup> In the study, eight lacquers and cements were tested as repair materials. These included: Ripolin gloss white enamel (Glidden and Company, Cleveland, OH), Vitralite Cement Coating (Pratt and Lambert, Inc., Long Island City, NY), Valspar white enamel

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<sup>72</sup> John Ashurst and Nicola Ashurst, “Repair and Maintenance of Terracotta and Faience,” *Brick, Terracotta and Earth 2, Practical Building Conservation* (New York: Halsted Press, 1988), 70.

<sup>73</sup> *Fifteenth Report Relating to the Technical Work of the National Terra Cotta Society*, 13-15.

<sup>74</sup> *Ibid.*, 13.



(Valentine and Company, NY), Duco brush white (E. F. DuPont DeNemours and Company, Parlin, NJ), Duco Green 281253 (E. F. DuPont DeNemours and Company, Parlin, NJ), White zinc lead paint (one part zinc oxide with one part white lead plus oil composed of one part turpentine and ten parts raw linseed oil), Zinc oxychloride cement, and nitro-cellulose solutions (nitrated cotton in amyl acetate, Van Schaack Bros. Chemical Works, Inc., Chicago, IL). All coatings were applied on unglazed tiles, and the nitro cellulose solutions were applied over the zinc oxychloride cement over the terra cotta to impart a gloss to the cement surface. The results after four months exposure to weather showed that the Vitralite white enamel and zinc lead paint were the most suitable for coating. The zinc oxychloride cement also seemed promising and could be made glossy with a coating of the Vitralite enamel.<sup>75</sup>

The current literature concerning repair methods for damaged glazes on the exterior surface of buildings does not allow for a much more hopeful outlook than provided in the National Terra Cotta Society's disclaimer and indicates that the solution to the repair of glaze loss has not yet been found. As the following review will show, the literature is limited and inconsistent, signaling the need for more conclusive research on this issue. Much of the conservation thus far has taken the form of total replacement of damaged pieces rather than *in situ* repair of localized damaged areas which has only begun to be explored in the field and in recent research.

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<sup>75</sup> Ibid.





A 1978 publication mentioning glaze loss reports that, “painting areas of terra cotta where the glazed surface has failed will alter the visual appearance because of the paint’s uniform look. Also, there is strong probability that the paint will fail in a short period of time.”<sup>76</sup> In the restoration of the spalled terra cotta on the Woolworth Building in New York City clear sealers with color added were applied, in lieu of paint, to match the existing glaze and to prevent further deterioration through the area of glaze loss.<sup>77</sup> Conformal Stain, a solvent based acrylic coating, was used in this case.<sup>78</sup>

While coating or sealing areas of glaze loss to prevent water entry were generally acknowledged as appropriate and necessary methods of repair, by 1979 another publication reports that no permanently effective reglazing materials were available. The only recommendations were (unspecified) acrylic-based proprietary products and masonry paints which could be tinted to match the original glaze color. No explanation was offered as to why this particular generic type was recommended over others. For repair of spalling, the application of these coatings for upper stories (which are not especially visible from the street) and complete replacement in easily observed locations were recommended. Patching was emphatically denounced with the claim that there was no material which is compatible enough with the terra cotta to form an appropriate

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<sup>76</sup> Theodore H. M. Prudon, “Architectural Terra Cotta: Analyzing the Deterioration Problems and Restoration Approaches,” *Technology and Conservation* 3 (Fall 1978): 35.

<sup>77</sup> Prudon, 37 and Theodore Prudon and Jerry Stockbridge, “Renovation of the Facade of the Woolworth Building,” in *Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures*, ed. Ganjan Sabnis (Detroit: American Concrete Institute, 1985), 217.

<sup>78</sup> Theodore H. M. Prudon, telephone conversation with author, 28 March 1996.



patch.<sup>79</sup>

Yet another view was expressed by John Fidler in 1981.<sup>80</sup> He recommended the application of a gloss polyurethane ‘varnish’ with an iron oxide filler for color or acrylic for coating repairs, but cautioned that these coatings are “quite impermeable” and therefore should not be used if there is a risk of migrating salts appearing behind them, which is generally the case. He also mentioned that epoxy coatings could be used since epoxy resin containing mortars have been successful in plastic repairs in England, but again warned that with plastic coatings migrating salts will be a problem in addition to their poor resistance to ultra violet radiation which may cause chalking, powdering, or yellowing over time. Fidler also stated that patching is only desirable for small areas, citing the difficulty of obtaining a finish that will not be altered over time. Included for mortar patching were recipes based on cement, lime and sand; hydraulic lime and sand; and lime, brick or terra cotta dust, and sand.<sup>81</sup>

In 1988, Ashurst and Ashurst described a range of treatment methods for terra cotta glaze failure.<sup>82</sup> They first stated, “mimic glazes are rarely a total success and for this reason special consideration should be given to replacement of all but the most superficially

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<sup>79</sup> de Teel Patterson Tiller, “The Preservation of Historic Glazed Architectural Terra-Cotta,” *Preservation Briefs* 7, (Washington, D.C.: U. S. Department of the Interior, Technical Preservation Services Division: 1979), 7.

<sup>80</sup> John Fidler, “The Conservation of Architectural Terra Cotta and Faience,” *Friends of Terra Cotta Newsletter* (Fall/Winter 1984): 23-24. Reprinted from the *Association for Studies in the Conservation of Historic Buildings Transactions* 6 (1981).

<sup>81</sup> *Ibid.*, 24.

<sup>82</sup> Ashurst and Ashurst, 81-82.



damaged blocks.”<sup>83</sup> In addition, gloss polyurethane ‘varnish’, acrylic paint and clear epoxide coatings had all been used to alleviate the problem of glaze loss, but had not been evaluated as to long-term use. All three are reportedly susceptible to ultraviolet degradation, but ultraviolet resistant polyurethanes were apparently available and were beginning to be used around 1988. According to Ashurst, polyurethanes, acrylics and epoxies have low viscosity which requires a great deal of care in application; acrylic resins can be made up as a 10% solution in acetone or industrial methylated spirit (1:1) as consolidants for deteriorating glazes in localized areas. For small plastic repairs, cellulose nitrate, polyester pastes or epoxy putties were recommended. For larger areas, feather-edged mortar has been used, but again, they related that these repairs are invariably vulnerable to weathering which makes them unsightly over time. In the case of a large spall, it was recommended that a repair be done in which a square is cut around the area of damage and a mortar patch is inserted. The suggested mortar should consist of aggregate of at least 50% sharp sand and a binder of masonry cement.

In 1989, Hunderman and Slaton recommended cementitious patches covered with breathable masonry coatings for the repair of glaze loss.<sup>84</sup> Martin Weaver supported their view four years later when he reported excellent results produced by “the careful application of breathable masonry coatings based on silicates.” He cited Keim Granital (Keimfarben GmbH) and Breathable Masonry Coating (ProSoCo, Inc.) as cases in point.

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<sup>83</sup> Ibid., 82.

<sup>84</sup> Harry J. Hunderman and Deborah Slaton, “Terra Cotta Analysis and Repair,” *The Construction Specifier* (July 1989): 55.



For clear or tinted glazes he also mentioned successes with ultraviolet stable polyurethane resins, acrylic resins, and clear non-yellowing epoxy resins.<sup>85</sup>

It is apparent from a review of the published literature that there is no commonly accepted solution to the problem of remedial coatings for *in situ* glaze repair. While some sources recommend acrylic resins, others recommend mineral based coatings, and yet others claim that coating is not even an acceptable solution. Because of the lack of published projects and the relative infancy of this technique, several architectural conservators, architects and coating manufacturers were consulted to determine the latest trends in glaze repair.<sup>86</sup> Information gathered from practitioners further justified the need for further research on glaze repair with coatings. Although all agree that the coating should be breathable, aesthetically compatible with the surrounding glaze, and water repellent, a variety of products are being specified including acrylic elastomers, solvent-based acrylic emulsions, polyurethane-based emulsions, and potassium silicates.<sup>87</sup> While different climatic conditions and site specific deterioration mechanisms play a part in the

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<sup>85</sup> Martin E. Weaver, *Conserving Buildings, A Guide to Techniques and Materials* (New York: John Wiley, 1993), 130.

<sup>86</sup> Author conducted telephone conversations with the following: Karen Reed, Watson & Henry Associates, Bridgeton, NJ, 26 March 1996; Ricardo Viera, Building Conservation Associates, New York, NY, 26 March 1996; Joel Snodgrass, Integrated Conservation Resources, New York, NY, 27 March 1996; Deborah Slaton, Wiss, Janney, Elstner Associates, Inc., Chicago, IL, 28 March 1996; Theodore H. M. Prudon, Swanke, Hayden, Connell Architects, New York, NY, 28 March 1996; Carolyn L. Searls, Wiss, Janney, Elstner Associates, Inc., Emeryville, CA, 2 April 1996; and Dale Frens, Frens & Frens Architects, Westchester, PA, 2 April 1996.

<sup>87</sup> These products include: Elasto Wall 351 (acrylic elastomer), Edison Chemical Systems, Inc., Waterbury, CT; Aquathane UA-210H (polyurethane-based emulsion), Edison Chemical Systems, Inc., Waterbury, CT; Breathable Masonry Coating 55 (acrylic emulsion), ProSoCo, Inc., Kansas City, KS; Keim Granital (potassium silicate), Keimfarben GmbH, Germany; Thorosheen and Thoroglaze H (solvent-based acrylic emulsions) Thorosystem Products, Jacksonville, FL; Conformal Stain (solvent-based acrylic) Chemprobe Corp., Garland, TX..





selection of different coatings, there still seems to be a great deal of uncertainty as to which products perform the best and if they will be effective in the long-term.

Because the technique is relatively new for terra cotta, very little research and testing has been done directed specifically at this use. The experimental program of this thesis was a continuation of a number of recent studies attempting to provide useful data towards evaluating the use of coatings as a repair method for this common terra cotta problem. Other thesis research which has preceded the present study is discussed below.

## **4.2 Theses**

Two M.S. theses which deal specifically with the issue of architectural terra cotta glaze repair have been written recently. In 1989, Judith Jacob tested the effectiveness of six proprietary masonry paint systems for inpainting areas of glaze loss. Her tests determined the water vapor transmission rates of the six paint systems applied on Type O mortar samples (ASTM C 270-87a). The paint systems Jacob tested represented silicate, silicone, acrylic and alkyd paints, some which are organic solvent-based resin solutions and others, water-based emulsions. All of the coatings produced a matte finish and one was combined with a clear coating to impart a glossy finish. The results of the water vapor transmission tests put Keim Granital (Keimfarben GmbH, Germany; potassium silicate) and Breathable Masonry Coating (BMC) (ProSoCo, Inc., Kansas City, KS; acrylic emulsion) at the top with the highest rates followed by Thorosheen (Thorosystem Products, Jacksonville, FL; acrylic emulsion), Conformal Stain (Chemprobe



Technologies, Inc., Garland, TX; solvent-based acrylic), Thorosheen with Thoroglaze II (Thorosystem Products, Jacksonville, FL; solvent-based acrylic) and Pentaflex House Paint 114 (Benjamin Moore & Co., Montvale, NJ; alkyd). Although this work provided a good starting point for testing remedial coatings, it left much to still be tested with respect to coating performance, such as adhesion to an actual terra cotta substrate and to a mortar patch, hiding power, and weather resistance.<sup>88</sup> Additionally, no statistical analysis was carried out to substantiate the results of the tests.

In 1992, Ricardo Viera also attempted to find a coating suitable for the repair of glaze loss. Viera applied coatings directly to the exposed surface of a terra cotta body and over the entire surface of the glaze. He tested five coatings chosen after initial evaluation of nine original selections. After eliminating epoxy coatings due to their poor resistance to ultraviolet radiation, inorganic coatings due to their impermeability to water vapor, and mineral based coatings due to their poor adhesion to glazed surfaces, he chose three acrylic and two urethane based coatings. These included Breathable Masonry Coating 911 Primer and Breathable Masonry Coating 55 (ProSoCo, Inc., Kansas City, KS; acrylic emulsion), Elasto Wall 351 (Edison Chemical Systems, Inc., Waterbury, CT; waterborne acrylic elastomer), Conformal Stain (Chemprobe Technologies, Inc., Garland, TX; solvent-based acrylic), CPU-CII Protective Safety Sealer (Chemique, Inc., Moorestown, NJ; urethane polymer), and Edison Aquathane UA-210H (Edison Chemical Systems,

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<sup>88</sup> Judith M. Jacob, "Inpainting Areas of Glaze Loss on Architectural Terra Cotta: A Study of Six Proprietary Masonry Paint Systems" (Master's thesis, Columbia University, 1989).



Inc., Waterbury, CT; polyurethane-based emulsion). Viera's tests examined the coatings' performances in accelerated weathering for ultraviolet resistance (light and heat) and resistance to freeze/thaw cycling. Of the five coatings tested, the three which yielded the best overall results were the Breathable Masonry Coating 55/911 Primer combination, Conformal Stain, and Elasto Wall 351.<sup>89</sup>

The limitations of Viera's tests included his use of only one sample per coating per test, which does not allow for random results which would be filtered out when using replicates. In addition, the weathering chamber built for the accelerated UV tests did not maintain the temperature specified in ASTM G-53, nor did it provide a source of condensation, which is proven to be an essential component in order to obtain a high level of agreement with degradation seen outdoors.<sup>90</sup> Four of the five coatings tested were clear, intended for coating both spalled areas without glaze and areas of crazed glaze. Spalled areas, however, necessitate a pigmented coating which may react differently to the tests performed because of the pigment additives contained in it. Finally, Viera's tests did not include the variable of mortar patching, often used in conjunction with coatings to fill areas of loss.

With these limitations in mind, Viera's results remain informative, but there is still a need

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<sup>89</sup> Ricardo Julio Viera, "Cold Glazing Terra Cotta: The Repair of Damaged Glazed Surfaces" (Master's thesis, Columbia University, 1992).

<sup>90</sup> Gregory R. Fedor and Patrick J. Brennan, "Comparison Between Natural Weathering and Fluorescent UV Exposures: UVA 340 Lamp Test Results," In *Durability Testing of Non-Metallic Materials. ASTM STP 1294*, Robert J. Herling, ed. (Philadelphia: American Society for Testing and Materials, 1996).



for testing pigmented versions of these coatings for their durability in other weathering conditions. It would also be useful to test their compatibility with appropriate patching mortars.

The issue of material patching for terra cotta was addressed in 1993 by Daniel Allen who tested four repair mortars including M100-101 Terra Cotta Restoration Mortar (HHO Jahn, Cathedral Stone Products, Jessup, MD), Edison Custom System 45 (Edison Chemical Systems, Inc., Waterbury, CT), SikaTop 123 (Sika Corp., Lyndhurst, NJ), and a Type S Mortar (ASTM C270-89).<sup>91</sup> Allen tested samples of the mortar to see how weathering (freeze/thaw, UV radiation, and soluble salt crystallization) affected modulus of rupture and water absorption. He also measured inherent mechanical and physical properties - curing shrinkage, coefficient of thermal expansion, moisture absorption, vapor permeability, and adhesion/bond strength. He found that the two polymer modified mortars, Edison Custom System 45 and SikaTop 123, had excessively strong moduli of rupture for use in repairs to historic terra cotta. The Edison product, however, was reported in the product literature to have a low modulus of elasticity which may counter this. In addition, accelerated weathering under the conditions of freeze/thaw, ultraviolet radiation, and soluble salt crystallization had no effect on the moduli of rupture for any of the mortars. The same two products were found to have lower absorption rates than terra cotta, and again weathering had no effect on the absorption rates of any of the products.

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<sup>91</sup> Daniel Allen, "An Evaluation of Mortars for the Plastic Repair of Architectural Terra Cotta" (Master's thesis, Columbia University, 1993).





Although none of the products had a curing shrinkage deemed problematic, the Edison Custom System 45 had the lowest and the SikaTop 123 had the highest shrinkage. Similarly, the thermal expansion rates of the four mortars did not indicate a problematic degree of movement, but the Jahn M100-101 exhibited the closest rate to terra cotta while the Type S mortar and Edison Custom System 45 rates were twice that of the terra cotta. In terms of moisture expansion, Edison Custom System 45 showed the least change, but all four products had a higher moisture expansion than the terra cotta. For water vapor transmission, the polymer modified Edison and Sika mortars had rates too low to report (indicating that they were not permeable enough for use with terra cotta) while the Jahn and Type S were closer together at around  $2.00\text{g/h}\cdot\text{m}^2$ . Finally, bond strength tests were inconclusive.<sup>92</sup>

The present study combined the results of Viera's coating tests with Allen's mortar results by applying replica glaze coatings to both terra cotta and one successful repair mortar, Jahn M100-101 Terra Cotta Restoration Mortar,<sup>93</sup> and testing their performance as a system.

### **4.3 Other Repair Methods: Replacement**

As stated above, many conservators advocate total replacement as the only option for

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<sup>92</sup> Ibid., 104-124.

<sup>93</sup> Jahn M100 was found to be compatible with terra cotta measurements of modulus of rupture, thermal expansion, and water vapor transmission. Its absorption and curing shrinkage met acceptable levels. Its moisture expansion rate was high, but all four mortars tested had greater expansion than published values for terra cotta.



repairing spalled, peeled or crazed terra cotta pieces. For reasons already mentioned, such as aesthetic compatibility with the surrounding areas, unsightly weathering of repair coatings and mortar patches, and the difficulty of obtaining mechanical compatibility between patching and coating materials and the original glazed surface, replacement of the entire damaged piece is often the solution reached. Obviously, the most appropriate replacement material is terra cotta; however, due to the cost of reproducing molds and surface finish, and the difficulty of finding skilled labor to work in this somewhat custom production material, terra cotta is not often chosen. Other options cited in the literature include fiberglass reinforced plastic, fiberglass reinforced concrete, cast aluminum, acrylic resin compounds, and precast concrete.<sup>94</sup> Of these, there is one reference to acrylic resin compounds being used to replicate ornamental details,<sup>95</sup> but the great majority of published case studies employed precast concrete.

In tests done during the Woolworth Building restoration, Theodore H. M. Prudon, of the Ehrenkrantz Group, tested two fiberglass reinforced materials and found that fiberglass reinforced plastic did not meet fire code and the fiberglass reinforced concrete had a large water absorption rate, which put its long term durability into question. Fiberglass containing products have also been reported to have poor weathering and aging properties in addition to problems with color compatibility.<sup>96</sup> Accordingly precast concrete

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<sup>94</sup> Hunderman and Slaton, 57.

<sup>95</sup> Anne Rogers and Doyle Wilhite, "Exterior Restoration of the West Virginia State Capitol: Cleaning and Structural Stabilization Procedures, *Technology & Conservation* 4 (Spring 1979): 16.

<sup>96</sup> Tiller, 8.



masonry units were selected for the Woolworth Building. The conservators performed accelerated weathering tests specified by the Portland Cement Association and evaluated the materials' durability, water permeability over time, color change over time, and specular reflectance over time.<sup>97</sup> Their tests stressed the importance of testing foreign substitute materials for compatibility with the original material. If incompatible, the combination of old material with new may cause further damage. The precast concrete was color matched to the existing glaze, but clear coatings were used over the precast concrete to replicate the degree of reflectivity of the original matte glaze.<sup>98</sup> Without the coating, the replacement material would have been aesthetically incompatible with the remaining glazed surfaces.

A 1980 restoration of Alwyn Court in New York City also used precast concrete to replicate the cream matte finish of the damaged terra cotta pieces. The chemical composition and fabrication methods were such that they achieved a material that matched the color, texture and finish of the terra cotta. These blocks were attached by cement partering on wire mesh supported by stainless steel pins in epoxy, a common technique for replacing corroded pins as well.<sup>99</sup> In the 1985 St. Louis Railway Exchange Building renovation, precast concrete was found to have a similar coefficient of expansion and lower compressive strength and rate of absorption than the surrounding

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<sup>97</sup> Prudon and Stockbridge, 215. Tests performed included freezing to -30°F, immersion in 5% salt solution, immersion in 3.5 pH acid solution, exposure to ultraviolet and infrared lamps, exposure to wind blown dirt, and soaking in water before introduction into freezing chamber again - 1 cycle every 25 hours for 30 cycles.

<sup>98</sup> Theodore H. M. Prudon, telephone conversation with author, 28 March 1996.

<sup>99</sup> Fitch, 25.



terra cotta. Replicas of damaged terra cotta pieces were made here as well.<sup>100</sup>

#### **4.4 Summary**

Just as there is the possibility of remedial coatings being aesthetically and physically incompatible with the original glazed terra cotta over time, there is also the likelihood that materials used for complete replacement will prove incompatible. Based on the accepted tenets of conservation, which demand that the least amount of intervention and greatest retention of original fabric occur when repairing a building, it would be preferable to use coatings to retrieve minimal glaze loss where the terra cotta unit is still structurally sound. If suitable glaze replacement coatings are found, this method allows for the most sensitive and least invasive repair of glaze spalling and peeling.

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<sup>100</sup> Kelley and Stockbridge, 20.





## **CHAPTER 5**

### **Remedial Coatings**

#### **5.1 Coating Requirements**

In order to be effective, coatings to repair glaze loss and replicate the original glaze layer must impart aesthetic properties compatible with the original glaze and physical properties to prevent further damage. These qualities: adhesion, cohesive strength, stability with age, optical compatibility, spreadability, and protection, must be considered when choosing a repair coating. Variables such as the extent and location of the damage on the building, the location of the building and specific weathering conditions to which it is subjected, and the other materials being employed in conjunction with the coating should also be considered in the selection process, for certain qualities may be more important in particular situations and less so in others. Because of the variability of the building conditions, these properties cannot be prioritized uniformly. They are discussed below in no particular order.

First, the coating must possess good adhesion, flexural strength, and abrasion resistance. It is important that the coating adhere well to the terra cotta substrate, to patching mortar, and to the original glaze. Since spalling occurs within the surface of a piece, the original glaze is often surrounding the area of loss. Merely inpainting the area of loss without overlapping the glaze at all may eventually leave a separation at the juncture where the coating meets the glaze. To achieve an adequate connection, the coating should overlap



the glaze to a minimal degree. In addition, if patching mortar is used to fill a deep spall, the coating must adhere to it as well. The strength of the coating is important to provide resistance to dirt pick-up and abrasion by wind blown particles. Flexural strength is also necessary to allow the coating to resist stresses incurred by thermal or moisture differentials itself or between the coating and the substrate or patching mortar. If it cannot endure these stresses, failure will occur.

Satisfactory aging properties of the coating are the second essential requirement. The most damaging element in terms of aging of outdoor coatings is ultraviolet radiation which typically causes yellowing or chalking (specific means will be discussed below). The coating must be stable enough to resist these effects or it will be faulty both aesthetically and as a protective feature.

The optical qualities - color, finish, and texture - possessed by the coating are essential to provide aesthetic compatibility with the original glaze. Since part of the purpose of the coating is to restore aesthetic unity of a damaged surface, these qualities are important. Of course, an exact match with the original glaze would be ideal, but since this is probably not feasible, there are variables which allow for a less than perfect match. For instance, the location of the damage may determine the level of compatibility required. Repairs made on the upper stories of a structure are not as visible to an observer on the street as those made closer to the ground. Upper story repairs, therefore, may be acceptable with less compatible coatings. Lower story repairs, however, demand as close



to perfect match as possible. A survey of the coatings available indicates that custom color matching is available, and many coatings can be ordered to cure to either a glossy or matte finish.<sup>101</sup>

Spreadability is a quality that is both aesthetic and practical. The viscosity of the coating determines whether it can satisfy this requirement. To replicate surrounding glaze, a remedial coating should spread evenly and uniformly without showing brush strokes. Since most applications of these coatings are made on vertical surfaces and surfaces with sculptural details, the coating must also be of a viscosity that allows application without dripping, puddling, or sagging. These two requirements are in conflict since a thicker coating tends to show brush strokes but will adhere without dripping, while a thinner coating will not show brush strokes, but is more prone to drip. A viscosity which balances these two must be achieved. If a coating does not possess appropriate viscosity, levelling agents can be added.

Finally, the coating must possess protective qualities. Of foremost importance, the coating must be water repellent in order to prevent water infiltration. Since water inevitably finds its way into the terra cotta in other locations, though, it is equally important for the coating to be vapor permeable. In order to allow water vapor to escape from within the piece, primarily the coating must possess a water vapor transmission rate great enough to allow water vapor to pass through itself without failure. Additionally, the

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<sup>101</sup> See "Selected Coatings" below.



coating must have a permeability rate greater than or equal to that of the surrounding glaze so it does not promote further damage to the original material. In addition to protection from water infiltration, the coating must prevent dirt and biogrowth from recurring in the area.

## 5.2 Weathering of Coatings: Ultraviolet Light and Condensation

“Climate, in all its aspects, is one of the fundamental causes of the decay of buildings, through failure of their materials which in turn affects the structure.”<sup>102</sup> Weathering, defined as “the effect of outdoor exposure on a material’s properties and service performance,” is caused by many factors in the environment.<sup>103</sup> Its effects challenge the essential qualities described above. Factors such as water in the form of condensation or precipitation, wind, atmospheric pollution, sunlight, and temperature all participate in the deterioration of building materials. Coatings, due to their location as the first line of defense on a building’s surface, are especially susceptible to weathering. They suffer chemical and physical reactions when exposed to levels of these conditions which are greater than they can withstand. These reactions can cause chemical decomposition of plasticizers or pigments, oxidation of susceptible components, and breakage of polymer chains which may result in chalking, discoloration, cracking, and overall degradation of the coating. Two of the most damaging weathering factors for coatings and those that were explored in the experimental program, are ultraviolet energy and moisture

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<sup>102</sup> Bernard M. Feilden, *Conservation of Historic Buildings* (London: Butterworth and Co., 1982), 91.

<sup>103</sup> R. M. Holsworth, “Overview-On the Weathering of Organic Coatings,” In *Permanence of Organic Coatings. ASTM STP 781* (Philadelphia: American Society for Testing and Materials, 1982), 4.





condensation.

### 5.2.1 Ultraviolet Light

Along with frost, solar radiation has been deemed one of the two worst natural enemies of building materials.<sup>104</sup> In fact, because the resistance of building materials to climatic agents of decay decreases with their exposure to these agents, solar radiation is reported to be more destructive even than frost in temperate zones.<sup>105</sup> Electromagnetic energy from the sun is divided into infrared energy, visible light, and ultraviolet light. Ultraviolet light, which consists of radiation below 400 nm on the spectrum, is credited with causing most damage to exposed polymers, due to its high energy.<sup>106</sup> Most ultraviolet damage occurs when the sun is high in the sky, which is around noon during the summer months. In latitudes nearer to the equator, ultraviolet damage is more prevalent because the average sun angle is higher. Therefore in tropical, maritime climates, deterioration of coatings due to ultraviolet light is more rapid, and a greater factor in their overall performance, than in other locations.

The mechanism for ultraviolet damage is photochemical degradation which occurs when the material is exposed to light with wavelengths short enough to break its chemical bonds. All chemical bonds in a material have a critical threshold wavelength of light.

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<sup>104</sup> Hewitt Wilson, "Monograph and Bibliography." 134.

<sup>105</sup> Feilden, 91.

<sup>106</sup> Douglas M. Grossman, "Know Your Enemy: The Weather and How to Reproduce it in the Laboratory," *Q-Panel Company Bulletin U-B21* (Cleveland: Q-Panel Company, 1989).



Light with a wavelength shorter than the threshold wavelength will break the bond while light with a longer wavelength will not. Because ultraviolet light consists of the shortest wavelengths of sunlight to reach the earth's surface, its wavelengths are shorter than the thresholds of many chemical bonds in polymeric coatings and, hence, cause degradation.

Ultraviolet light is subdivided by the International Commission on Illumination (CIE) into UV-A, UV-B, and UV-C light. UV-A light, which consists of wavelengths between 315 and 400 nm, is reported to cause polymer damage, while UV-B light which ranges from 280 to 315 nm causes more severe polymer damage due to its shorter wavelengths.<sup>107</sup> This difference is an important factor in selecting the appropriate lamps to use in accelerated weathering tests which will be discussed in the next chapter.

### **5.2.2 Condensation**

Condensation results when a material is cooler than the surrounding air or below the dewpoint temperature of the air. It generally occurs at night when the sun's radiant heat is lost from the object making it cooler than the ambient air. Dew deposited on the surface is saturated with oxygen which causes damage to coatings through oxidation of their materials. This results in certain components of the coating being extracted and deposited on the surface causing both an aesthetically unsatisfactory appearance and a possible detrimental effect on the coating's durability. Droplets of dew which may

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<sup>107</sup> Patrick Brennan and Carol Fedor, "Sunlight, UV, & Accelerated Weathering," *Q-Panel Company Bulletin L-822* (Cleveland: Q-Panel Company, 1987).



remain when solar radiation is present will also magnify the effects of ultraviolet light described above in a process called photo-oxidation.<sup>108</sup>

### 5.3 Characterization of Coating Failures

Upon weathering, coatings exhibit several typical failures which will be described in detail below. Terminology used to describe paint and coating defects is not uniform. The terms used below reflect definitions from two sources which were in agreement - *Annual Book of ASTM Standards, Volume 6.01 Paint - Tests for Formulated Products and Applied Coatings* and "Paints and Coatings," Chapter 10 by Frank G. Matero in *Conserving Buildings, A Guide to Techniques and Materials*.<sup>109</sup>

*Peeling* or *blistering* involves a general loss of adhesion between the substrate and the coating. Its causes include improper surface preparation and stresses caused by trapped water or water vapor behind the coating.

*Crazing*, *checking*, and *surface microcracking*, small cracks on the surface of the coating, generally occur when the coating has become brittle and is unable to withstand stresses of expansion and contraction of the substrate or itself due to changes in temperature and

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<sup>108</sup> Holsworth, 5 and *Adhesives and Coatings. Science for Conservators* 3 (London: The Conservation Unit of the Museums & Galleries Commission, 1983), 102.

<sup>109</sup> ASTM definitions taken from ASTM D659-86, ASTM D660-87, ASTM D661-86, and ASTM D772-86, *Annual Book of ASTM Standards, Vol. 6.01, Paint-Tests for Formulated Products and Applied Coatings* (Philadelphia: American Society for Testing and Materials, 1990). These are supplemented by definitions from Frank G. Matero, "Paints and Coatings," Chapter 10 in Martin E. Weaver, *Conserving Buildings, A Guide to Techniques and Materials* (New York: John Wiley, 1993), 222.



humidity. ASTM distinguishes checking from cracking. Checking is described as breaks in the film that do not penetrate through the final coat while cracking is described as a break extending through the coated surface.

These small scale defects are followed by two conditions. *Alligatoring* or open cracks which create a discontinuous layer of coating involves the further opening of cracks without detachment. *Flaking* is a phenomenon resulting from the actual detachment of pieces of the film from the substrate or from previous layers.

*Chalking*, defined as the formation of a pigmented coating of a friable powder evolved from the film itself at or just beneath the surface, is caused by a breakdown of the binder through photochemical degradation. This is usually caused by ultraviolet light through the mechanisms described above.

*Staining* and *discoloration* may be caused by topical agents such as biological attack, pollution of the environment, dirt, or water staining from precipitation. It may also be caused by internal agents like rusting of metal anchors or water seepage.

#### **5.4 Selected Coatings**

The five coatings selected for the experimental program included two urethane-based and three acrylic-based materials. These two general types are the most commonly used in the industry because of their good adhesive properties, strength, and superior aging





performance in adverse external environments. They are also capable of pigmentation and some can be either glossy or matte. Epoxies were explored for inclusion in the program, but excluded due to their inevitable breakdown over time in exterior weathering conditions. Several manufacturers including Shell Chemical Company, CIBA Geigy, and SIKA Corporation were consulted, but none deemed their epoxy based coatings appropriate for external use where aesthetic properties were important. All claimed that their products would undoubtedly yellow and break down upon weathering, and recommended either urethanes or acrylics.<sup>110</sup>

The patching mortar, Jahn M100-101 Terra Cotta restoration Mortar was selected based on the results of Daniel Allen's tests (detailed in Chapter 4). Although his tests did not rank the mortars in the final assessment, this selection performed satisfactorily on the most critical tests, and was therefore chosen as an exemplary material.

#### **5.4.1 Urethane-Based Coatings**

General properties which make urethanes applicable to glazed terra cotta repair are toughness, abrasion resistance, flexibility, good chemical resistance and good adhesion.

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<sup>110</sup> James J. Pease, SIKA representative (610) 783-5604; David Helfand, CIBA Geigy staff scientist (914) 785-3116; and Gary Hunter, Shell Chemical Co., telephone conversations with author, 6 December 1995. James Pease of SIKA claimed that their epoxies would chalk, peel, and blister after three or four years of exposure and that they are not vapor permeable. He recommended an acrylic for exterior use of architectural quality. David Helfand of CIBA-Geigy explained that epoxies would yellow and lose gloss upon outdoor exposure of five or six years. He recommended using a polyurethane or polyester based coating. Gary Hunter of Shell also did not recommend epoxies for this use, explaining that they would undoubtedly yellow and chalk over time. He suggested urethanes for their lasting qualities and ability to retain gloss.



They can cure at low temperatures which is extremely important for this situation in which buildings needing repair may be in cold climates. In addition, aliphatic-based urethanes absorb practically no ultraviolet radiation, thus will not yellow or discolor, chalk, or lose gloss over time.<sup>111</sup> One source specifically cites their importance for objects which are “too large to fit in a baking oven,” illustrating that urethanes possess the qualities of coatings which are fired like terra cotta glaze.<sup>112</sup>

*Edison Aquathane UA-210H.* Edison Aquathane UA-210H, manufactured by Edison Chemical Systems, Inc., is an aliphatic-polyurethane-based emulsion with additives, surfactants, pigments and modifiers. Edison describes it as “breathing, low in odor, non-flammable and fast drying,” and it is available as clear or pigmented, gloss or satin finishes. Product literature claims that Aquathane has chemical resistance to solvents and water, compatibility with many substrates and other coatings, durability, and high abrasion resistance. It is also non-flammable and has low hazard when used with appropriate ventilation. Edison recommends it as a sealer for concrete and masonry surfaces, and specifically notes that its “gloss level and color control allows it for use as a breathable terra cotta glaze repair or replacement system.”<sup>113</sup> In 1982, Aquathane was used successfully on the glazed terra cotta of the Pennsylvania Station in Pittsburgh.

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<sup>111</sup> G.P.A. Turner, *Introduction to Paint Chemistry and Principles of Paint Technology*, 3d ed. (London and New York: Chapman and Hall, 1988), 209 and Dr. M. Dahm et al., “PU Paints and Coatings,” in *Polyurethane Handbook*, 2d ed. (Cincinnati: Hauser/Gardner Publications, Inc., 1993), 562.

<sup>112</sup> Dahm, 562.

<sup>113</sup> “Edison Aquathane UA-210 High Performance Waterborne Polyurethane Coatings” and “Restoration Products,” Edison Chemical Systems, Inc., 25 Grant Street, Waterbury, CT, 06704



Pennsylvania.<sup>114</sup>

*CPU-CII® Protective Safety Sealer.* CPU-CII, manufactured by Chemique, Inc., is described in product literature as “a combination of urethane polymers and a colloidal dispersion that produces a durable, flexible coating.” It reportedly has excellent adhesive and cohesive properties, high abrasion and chemical resistance, and is unaffected by ultraviolet light, weathering, staining, and acid rain. CPU-CII contains an aqueous polysiloxane emulsion for long term water repellency and will not yellow with age. It dries clear, but can be added to synthetic emulsion paints (one pint per gallon of paint) for a coating which will possess all of its qualities with a colored finish. The literature recommends it for use on “new or cleaned” stucco, concrete, cinder block, waylite block, limestone, and wood, but it does not specifically mention terra cotta.<sup>115</sup>

#### 5.4.2 Acrylic-Based Coatings

Acrylic coatings also possess excellent weathering resistance including resistance to ultraviolet light. In addition, they are attractive because of their ease of application and clean-up, low toxicity and low flammability.<sup>116</sup>

*Breathable Masonry Coating 55.* Breathable Masonry Coating 55 (BMC™), produced by

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<sup>114</sup> Ricardo Viera, Building Conservation Associates, telephone conversation with author, 26 March 1996.

<sup>115</sup> Product Information Sheet, “CPU-CII Protective Safety Sealer,” Chemique, Inc., 315 N. Washington Ave., Moorestown, NJ, 08057.

<sup>116</sup> W. M. Edwards, “Acrylic Resins,” in Charles R. Martens, ed., *Technology of Paints, Varnishes and Lacquers* (New York: Reinhold Book Corporation, 1968), 127.



ProSoCo, Inc., is an acrylic emulsion reported to possess “excellent adhesion and long-lasting durability.” Its 55% water vapor transmission rate allows vapor to escape from behind while preventing liquid water from entering the masonry body, thus reducing blistering and eventual spalling. Product literature claims that BMC™ 55 is “especially suitable for protecting surfaces exposed to extreme weather and harsh atmospheric pollutants.” Tests performed by the manufacturer report that it has good salt spray and humidity resistance, excellent color retention, ultraviolet resistance, and good flexibility and adhesion. BMC™ 55 dries to a flat finish, is available in 15 colors, and can be custom matched.<sup>117</sup> ProSoCo, Inc. deems it suitable for use on masonry surfaces including brick, and reports that it has been used on terra cotta.<sup>118</sup> Viera tested BMC™ 55 with BMC™ 911 Primer, a low-solid siloxane, but noted that this combination was not recommended for glazed terra cotta because the primer would not adhere to the glaze bordering the area of glaze loss.<sup>119</sup> Current product literature states that the 911 primer is used to improve adhesion of BMC 75 and 95 and to provide additional water repellency. It is not specified for use with BMC™ 55 though because BMC™ 55 contains a special acrylic binder for adhesion and durability.<sup>120</sup> Accordingly the 911 Primer was not used in this testing program.<sup>121</sup>

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<sup>117</sup> Product Data sheet, “Breathable Masonry Coating 55,” ProSoCo, Inc., P. O. Box 171677, Kansas City, KS, 66117.

<sup>118</sup> “Breathable Masonry Coating” brochure and Project Listings, ProSoCo, Inc., Kansas City, KS.

<sup>119</sup> Viera, 25.

<sup>120</sup> Product Data Sheet, “911 Primer,” ProSoCo, Inc., P. O. Box 171677, Kansas City, KS, 66117.

<sup>121</sup> Carolyn Searls, telephone conversation with author, 2 April 1996. Ms. Searls, of Wiss, Janney, Elstner Associates, Inc., reported that for projects where algae and slime mold are commonly found in glaze spalls and under the edges of remaining glaze, the 911 primer or other ProSoCo water repellents (i.e. SL100 liquid water repellent) are applied under the BMC 55. In addition, she stated that on buildings that have extensive glaze crazing as well as spalling, the 911 Primer is applied to the entire surface of the terra cotta





*Conformal® Stain.* Conformal® Stain, manufactured by Chemprobe Technologies, Inc., is described as a “solvent based acrylic formulated with a color flattening fumed silica and colored with non-fading inorganic oxide pigments” for concrete, masonry, brick and stucco walls. It resists water intrusion, stain damage, freeze-thaw spalling, efflorescence, and color fading. Conformal® Stain comes in ten standard colors and can also be custom matched.<sup>122</sup> The finish is a satin/matte texture which can be made glossy by adding one coat of Conformal® Clear Anti Graffiti on top.<sup>123</sup> Product representative, Van Burriss, claimed that Conformal® Stain “works well for terra cotta” and would last for at least 15 years on a terra cotta substrate.<sup>124</sup> It was used on the Woolworth Building restoration in 1985 and the San Francisco Ritz Carlton Hotel in 1988.<sup>125</sup>

*Elasto Wall 351.* Manufactured by Edison Chemical Systems, Inc., Elasto Wall 351, is a “high solids, internally plasticized, waterborne acrylic elastomer . . . designed to waterproof and decorate vertical and above-grade surfaces including . . . glaze-crazed terra cotta.” Product literature reports that it has excellent elongation which allows the

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and then BMC 55 is applied over the primer to areas of total glaze loss. In these cases, the 911 primer must effectively bond with the glaze coating.

<sup>122</sup> Spec Data sheet, “Conformal Stain,” Chemprobe Technologies, Inc., 2805 Industrial Lane, Garland, TX, 75041.

<sup>123</sup> Conformal® Clear Anti Graffiti, also produced by Chemprobe Technologies, Inc., is a clear protective coating produced to resist marring, scratching, and stains. It prevents penetration of graffiti markings and allows for their easy removal. Product information included in Spec Data sheet for Conformal® Stain (see appendix).

<sup>124</sup> Van C. Burriss, President, Capricorn Industrial Sales Co., Inc., Distributor for Chemprobe Technologies, Inc., (610) 429-5301, telephone conversation with author, 21 November 1995.

<sup>125</sup> Carolyn Searls, Wiss, Janney, Elstner & Associates, telephone conversation with author, 2 April 1996.



coating to expand and contract with the substrate upon temperature and volume changes and also prevents rupturing due to impact. Elasto Wall 351 allows water vapor transmission while preventing liquid water from entering from the exterior. Testing by the company found that in accelerated weathering there was no yellowing, swelling, blistering, chalking, cracking or fading. Elasto Wall 351 is available in Standard and Custom colors and textures.<sup>126</sup>

### 5.4.3 Patching Mortar

*Jahn M100-101 Terra Cotta and Brick Repair Mortar.* Jahn M100-101 Terra Cotta and Brick Repair Mortar is cementitious based, free of chlorides, metal compounds, leachable constituents, and synthetic bonding agents. Product literature claims that the mortar remains porous when cured allowing water vapor transmission, that it is frost resistant and shrink proof, and that it can withstand “extreme climatic conditions.” It comes in standard off white and yellow, and custom colors can be made on request. Jahn M100-101 has been used on various terra cotta buildings including the Rookery Building in Chicago, Illinois and the Oakland City Hall in Oakland, California.<sup>127</sup>

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<sup>126</sup> “350 - Series Waterborne Elastomeric Coatings,” Edison Chemical Systems, Inc., 25 Grant Street, Waterbury, CT, 06704.

<sup>127</sup> “Cathedral Stone, Washington, D. C. Products & Services for Stone & Masonry Restoration: Jahn Restoration Mortars,” Cathedral Stone Products, Inc. 8332 Bristol Court, #107, Jessup, MD 20794.



## CHAPTER 6

### Experimental Program

#### 6.1 Overview

It was the goal of the experimental program of this thesis to evaluate the film forming properties of remedial coatings for their effectiveness in protecting exposed areas of the terra cotta clay body and in replicating certain glaze characteristics when subjected to weathering conditions typical of a temperate maritime climate. Conditions related to sunlight, high humidity, and liquid water were examined since they are prevalent in this type of climate. Interviews with building conservators and an observation of the wide variety of coatings currently being used indicate that there is still a need for further research and evaluation on their applicability and performance. In order to build on previous research, this program examined the same five coatings which were tested by Ricardo Viera in 1992, with several modifications in the testing program. All coatings, with the exception of CPU-CII Protective Safety Sealer, were used in their pigmented versions assuming that for covering spalled areas, these would be the most appropriate.<sup>128</sup> In addition, this program evaluated the coatings' performances when applied to the terra cotta substrate and to a terra cotta restoration mortar patch. This dual application was intended to simulate repairs necessary for the two most commonly found conditions of glaze loss: peeling and spalling.

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<sup>128</sup> CPU-CII is only made in a clear version. See Chapter 5 for specifications for mixing with paints.



Accelerated aging tests, performed in a QUV/SE/SO Accelerated Weathering Tester at the Architectural Conservation Laboratory at the University of Pennsylvania, included simulations of alternating exposures to ultraviolet light and condensation at high temperatures and high relative humidity. The effectiveness of each coating was evaluated based on visual examination of its surface qualities after 624 hours of weathering. Water vapor transmission of the coatings was also tested to determine if they would fail or induce damage to the remaining glaze due to trapped moisture. Finally, water absorption rates of the coatings were measured and compared to the absorption rate of the exposed terra cotta substrate to determine which coatings would be the most effective in preventing water infiltration.

## 6.2 Accelerated Weathering

Accelerated weathering has as its objective, “the prediction of long-term effects by the use of short-term tests.”<sup>129</sup> According to R. M. Holsworth it “is intended to provide quick answers on weathering effects by establishing general trends.”<sup>130</sup> Although accelerated weathering cannot accurately reproduce all the variables in all climates and locations, testers are available now that can produce repeatable results while simulating specific conditions as close to natural exposures as possible. In a paper presented at the Society of Plastics Engineers Automotive RETEC in November, 1987, Patrick Brennan and Carol

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<sup>129</sup> G. A. Zerlaut. “Accelerated Weathering and Precision Spectral Ultraviolet Measurements,” In *Permanence of Organic Coatings. ASTM STP 781* (Philadelphia: American Society for Testing and Materials, 1982), 10.

<sup>130</sup> Holsworth, 6.





Fedor related that the “real usefulness of accelerated testers is that they can give reliable, *relative* [original italics] indications of which material performs best under a specific set of conditions.”<sup>131</sup>

There are two ways to accelerate aging. Although both methods have limitations, the first, to subject the materials to continuous exposure to weathering conditions rather than duplicating the intermittent effects of natural exposure, is the preferred method. The second method, to increase the severity of exposure above the natural level, is not recommended because it may produce degradation that would not normally occur at the lower intensities of natural outdoor exposure.<sup>132</sup> In addition, the choice of accelerated weathering tests for evaluating the performance of a certain material must be based on two fundamental tenets. First, acceleration of deteriorating factors must be reasonably related to natural conditions to obtain meaningful results. Second, there must be an understanding of the fundamental processes involved in the deterioration of the material in order to formulate an accurate accelerated test.<sup>133</sup>

### 6.3 QUV/SE/SO Accelerated Weathering Tester

The QUV/SE/SO Accelerated Weathering Tester, manufactured by the Q-Panel Company, was used in this testing program to simulate the effects of ultraviolet light and

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<sup>131</sup> Brennan and Fedor, 8.

<sup>132</sup> Holsworth, 6.

<sup>133</sup> H. E. Ashton, “Evaluating the Performance of Organic Coatings and Building Materials,” In *Permanence of Organic Coatings. ASTM STP 781* (Philadelphia: American Society for Testing and Materials, 1982), 84.



condensation on the remedial coatings. As described above, these two weathering conditions are appropriate to the materials being tested because they are proven to be directly responsible for the natural degradation of these types of coatings. In order to answer the question posed by this thesis, which coatings perform best in a temperate maritime climate, these conditions provided an appropriate simulation of prevalent conditions of this particular climate, high ultraviolet radiation levels, high relative humidity and temperature, and moisture condensation.

Ultraviolet light was simulated by Fluorescent UVA-340 lamps with peak emission at 340 nm. As their name suggests, the emission range is primarily in the UV-A region of the electromagnetic spectrum. These lamps, introduced in 1987 to enhance correlation in accelerated testers, are excellent simulators of sunlight below 360 nm in the region of the spectrum which causes most polymer damage. The fact that they do not produce light in the range lower than 295 nm (solar cut-off) will allow them to produce “better, more accurate results.”<sup>134</sup> Commonly used UVB lamps which emit a range of wavelengths including lower wavelengths than those that actually reach the earth’s surface cause damage that would not naturally occur, while UVA-340 lamps have been proven to produce good correlation with outdoor test results. They are recommended for comparison tests between generically different materials including plastics.<sup>135</sup>

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<sup>134</sup> Brennan and Fedor, 3 and 8.

<sup>135</sup> *QUV Accelerated Weathering Tester with Solar Eye Irradiance Control & Spray Option, Model QUV/SE/SO Operating Manual* (Cleveland: The Q-Panel Company, 1993), 16.



Besides the type of lamps used in the tester, the irradiance level, or the rate at which light energy falls on a unit area of surface, is another variable factor. Control of irradiance is important for two reasons. Changes in light intensity affect the speed of degradation, and changes in wavelength or Spectral Power Distribution (SPD) may also affect the speed and type of degradation of the material. Through the use of sensors and regular calibration, the QUV/SE/SO is able to maintain a constant level of irradiance, and will alert the user if irradiance is not reaching set levels.

The QUV/SE/SO allows the user to manually set the irradiance level. “Solar Maximum” irradiance, which replicates global, noon sunlight, on the summer solstice, at normal incidence, is the most severe condition met in outdoor service. For the UVA-340 lamps, the Solar Maximum is  $0.83 \text{ W/m}^2/\text{nm}$ . Although this level is shown to be the closest to actual sunlight, higher levels of irradiance have proven to produce accurate results in shorter periods of time. In tests performed by Gregory R. Fedor and Patrick J. Brennan, results gained from irradiance levels of  $1.35 \text{ W/m}^2/\text{nm}$  were compared to those from  $0.83 \text{ W/m}^2/\text{nm}$  and to actual outdoor exposures. They reported that, “in no case was agreement sacrificed due to high irradiance.”<sup>136</sup> In the interest of time, this testing program used the  $1.35 \text{ W/m}^2/\text{nm}$  irradiance set point.

In addition to the results comparing irradiance levels above, Fedor and Brennan proved that moisture (condensation) must be included in the exposure cycle in order to obtain an

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<sup>136</sup> Fedor and Brennan.



accurate level of agreement with natural outdoor exposure.<sup>137</sup> In the QUV/SE/SO, condensation is achieved through heating water in a tray in the bottom of the machine to produce 100% relative humidity and to maintain a high temperature. During the cycle the inner surface temperature of the specimens is higher than the outer surface. Dew forms on the coated surface of the specimens, lies on the materials for the four hour cycle, and is allowed to permeate through the coating and possibly dissolve and damage its components. The dew created in the QUV is pure and distilled, thus simulating exactly the purity of natural condensation.

The complete exposure cycle included four hours of condensation followed by eight hours of ultraviolet light, each occurring separately, as they do in nature.<sup>138</sup> Temperatures were substantially higher than natural, 50° C for condensation and 60° C for UV, in order to facilitate the accelerated result. As discussed above, correlation of the total exposure time to natural exposure is difficult to predict. Due to variations in regional climates, local terrain, seasonal conditions, yearly weather, and how samples are mounted in natural outdoor weathering, a wide range of comparisons could be made. Therefore, it was the intention of this testing program to determine how the five coatings performed in relation to one another, not to predict how long they would endure actual weathering conditions before failure.

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<sup>137</sup> Ibid.

<sup>138</sup> Exposure times recommended to author by technical staff of Q-Panel Company.





## 6.4 Salt Resistance

The effects of salt are an additional weathering factor to which surface materials are subjected in temperate maritime climates. Maritime salts, such as sodium chloride, as surface deposits transported by sea air in itself do not cause disintegration, but they are able to, by hydration and dehydration, facilitate the disintegration of surface coatings by their action on other salts present.<sup>139</sup> Salts contained in water vapor can also enter a glazed terra cotta piece. If water is allowed to enter the piece, these salts are picked up and transported to the outer layers of the piece. When the liquid water evaporates within the piece, subfluorescence occurs and may cause damage through expansion and contraction of the crystals upon hydration and dehydration. Although, omitted from this testing program, the effects of salt laden aerosol and salts deposited behind the coating should be examined in further study of remedial coatings for glaze loss.

A search of available testing standards revealed the lack of an appropriate laboratory test for the effects of salt laden aerosol on masonry coatings. Although ASTM B 117-90 “Standard Test Method of Salt Spray (Fog) Testing” appeared to be relevant, further research indicated that, in fact, this test which was developed to evaluate the performance of metallic coatings on metal, is not necessarily applicable to non-metallic coatings.<sup>140</sup> It

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<sup>139</sup> Feilden, 105.

<sup>140</sup> On p. 69, Ashton relates the following:

The salt spray test is the preeminent example of misapplication of a test. ASTM Salt Spray Testing [B117-73(1979)] . . . was developed to evaluate the performance of metallic coatings on metal, especially chrome-plated steel. Evidently it did a reasonable job in that field so its use was extended to organic coatings without considering the fact that most anticorrosion primers protect steel by a different mechanism (passivation) than zinc (sacrificial) and other metallic coatings (barrier) do. Since then, use of the test has become so widespread that coatings for concrete and



specifies that samples be continuously exposed to high temperature and relative humidity while being sprayed with a saturated salt mist, but does not account for the need for intermittent wetting and drying, the main condition which induces salt damage to coatings in actual exposures.<sup>141</sup>

Alterations to ASTM B-117 have been suggested, though, using a machine in which temperature and humidity are cycled. The recommended cycle for organic coatings is two hours of cooling at 4.5° C, raising the temperature to 32 ± 3°C in warm, moist air, maintaining the high temperature and humidity for five hours. The cycle continues by lowering the temperature to 23° C and the relative humidity to 35% over four hours, thus drying off the specimens. This type of cycling has been shown to produce more realistic failures.<sup>142</sup> As this cycling presents a complicated regimen to carry out without access to a specialized weatherometer like the QUV, it was not possible to perform in the scope of this thesis. It is recommended, though, that this test or some modification of it be used in the future to evaluate the performance of these coatings to salt laden aerosol exposure.

Although no test devised specifically for evaluating the effects of subfluorescence on coatings has been found, the effects of salts trapped under the coating may be tested by adopting several standardized tests used for other materials. Three tests with similar

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masonry are now being reported as resisting the salt spray test for thousands of hours. It would be surprising if they didn't because the substrate does not rust and sodium chloride is most detrimental to concrete at freezing temperatures, not at the 35°C (95°F) of the test.

<sup>141</sup> Ibid., 68.

<sup>142</sup> Ibid., 76.



methodologies include ASTM C88-90 “Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate,” RILEM 25 P.E.M. Test V 1b “Crystallisation Test by Total Immersion (for Treated Stone),” and British Research Establishment Report, Crystallization Test, 1992. All three include successive cycles of immersion in a salt solution with oven drying to simulate the effects of solubilization and recrystallization of salts.

### 6.5 Sample Preparation

Samples were obtained from the Ventnor City Hall in Ventnor, New Jersey (1928-1929, Vivian Smith, Architect) located one block west of the Atlantic Ocean (fig. 6.1).



Figure 6.1 Ventnor City Hall

The pieces were taken from various parts of the building including cornices, lintels, and



other details. Each piece was glazed with a gray matte finish simulating limestone. Although the pieces obtained were not spalled themselves, this building exhibits most of the typical glaze defects previously mentioned, and is currently under construction to repair these failures. Of particular importance is the fact that naturally weathered glazed terra cotta was used in the testing program. Since coatings will have to perform in relation to weathered materials in real-life conservation projects, it is important that laboratory testing replicate this condition to achieve accurate results.

The terra cotta pieces were cut into three shapes to accommodate the apparatus and tests. For the QUV Accelerated Weathering Tester (ASTM G53-88), samples were cut to 3" x 4" x 3/4". Four sample replicates per coating were prepared for statistical accuracy. Because of the varied shapes of the pieces from the building, some samples did not have a flat surface. To ensure uniformity between the groups, each specimen group contained the same combination of flat and curved surfaced samples. The glazed surface of the samples was divided into three sections. The center section retained the original glaze layer. One flanking section was stripped using a Metabo grinder with a stone grinding wheel, of just its glaze layer to simulate the exposed surface resulting from peeling. The other flanking section was abraded down approximately 1/2" to simulate a spalled condition. Before repair materials were applied, all samples were cleaned using water and a nylon scrubbing brush. Subsequently, the sections with glaze loss only were coated and sections with body and glaze loss were patched and coated (fig. 6.2). According to manufacturers instructions, two coats of all coatings were brush applied as this method





gives the applicator the most control.<sup>143</sup> Coatings were applied to the exposed area and overlapped the glaze section approximately 1/8" to prevent failure at the junction between the coating and glaze.<sup>144</sup>

For the water vapor transmission test (ASTM E 96-80), pieces were cut into round disks, 1 5/8" diameter x 5/8" thick. Glaze was removed from fifteen disks and 1/2" of substrate was removed from ten disks. The samples were cleaned as described above, and each coating was applied directly to the terra cotta substrate on the fifteen unglazed disks, and the patching mortar and coating combination was applied to the ten remaining disks (fig. 6.3).

For the water absorption tests (ASTM C67-83), samples 1" x 1" x 3/4" were used. The required five unglazed specimens were made to test the water absorption of the terra cotta substrate, and three replicate specimens per coating were prepared. These specimens contained two coats of the respective coating on all six sides.

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<sup>143</sup> For application instructions see Appendix A.

<sup>144</sup> Due to the lack of prior experience using these coatings for glaze repair, manufacturer's representatives were unsure as to whether to overlap the glaze or not. Some thought their coating would not adhere to glaze, but none had definite instructions for this use. It was determined that in actual use, the coatings would need to overlap the surrounding glaze to prevent weathering (water ingress, biogrowth, etc.) at the seam between the coating and glaze.



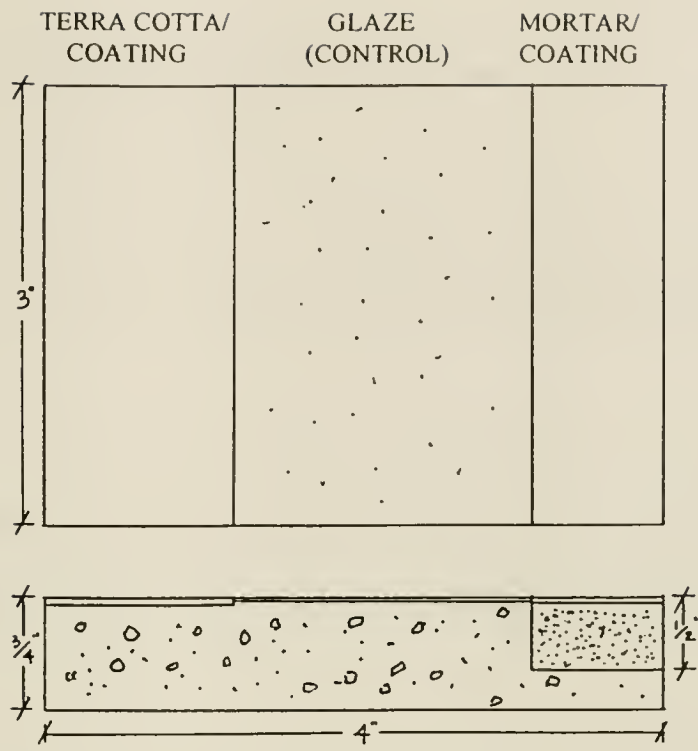


Figure 6.2 Specimen design for QUV Accelerated Weathering Tester (ASTM G 53-88)

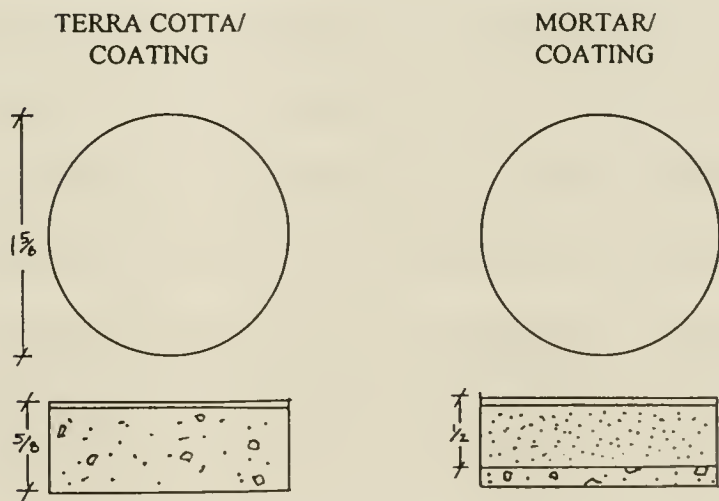


Figure 6.3 Specimen design for Water Vapor Transmission Test (ASTM E 96-80)



## 6.6 Tests

### 6.6.1 Ultraviolet Light-Exposure and Water-Exposure

#### *Standardized Test Used*

ASTM G 53-88: Standard Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials

#### *Purpose*

To simulate conditions caused by water as dew and the ultraviolet energy in sunlight, and to predict the relative performance of the remedial coatings when subjected to these two conditions.

#### *Significance*

Visually, ultraviolet light and condensation may alter the appearance of the coatings in terms of color, texture, and gloss. Materially, these conditions may cause physical break down of the coatings in the form of chalking, blistering, or cracking. Ideally, remedial coatings would replicate the glaze layer characteristics, including resistance to ultraviolet light and condensation, so that they serve as appropriate protective repair materials for areas where the original glaze has been lost. If these materials do not perform well under these conditions, they may be more detrimental to the structure than the exposed substrate would be.



## *Methodology*

Fifteen 3" x 4" x 3/4" samples (3 per coating as described above) were mounted in the specimen racks of the QUV/SE/SO Accelerated Weathering Tester with the treated surface facing the lamps. Blank panels filled the empty racks in the machine to maintain test conditions. One prepared sample per coating was retained without weathering as a control to provide a means of comparison to the weathered samples. One cycle was set at eight hours of ultraviolet exposure at 60° C and four hours of condensation at 50° C. Samples were rotated horizontally each week to account for possible variations in exposure within the machine, and they were inspected and conditions of the coatings recorded after every six cycles (72 hours). Qualities evaluated were color change, blistering, cracking, and chalking all assessed through visual observation and comparison with controls. The total exposure time of the test was 52 cycles (624 hours).

## *Results*

### **1) Edison Aquathane UA-210H**

*Application:* Aquathane is a very thin coating which did not spread evenly over the surface of the specimen. On the samples that were not completely flat, it tended to puddle in lower areas of the surface and remain thin in higher areas. In this program the coatings were applied to a horizontal surface so the viscosity of the Aquathane did not pose as much of a problem as it will when applied onto a vertical surface. It is anticipated that uniform covering would be difficult on a





vertical or sculpted surface. One coat did not provide an opaque finish and in some cases two coats did not completely obscure the surface of the sample. The coating also bubbled upon application and produced small pinholes upon drying. After complete drying, a glossy dark gray coating, Munsell 10B 5/1, appeared.

*Performance:* Aquathane failed consistently on both the terra cotta and mortar substrate and also failed to adhere to the original glaze layer (Appendix B, fig. B.1-B.32) After six cycles (72 hours), small whitish spots appeared on the terra cotta and mortar substrate discoloring the coating. On sample 1A, large white stains appeared on the bottom half of the terra cotta section. This sample also exhibited blisters with cracks exposing the first layer of coating or terra cotta substrate beneath. The mortar sections exhibited map cracking, and although there was no flaking of the coating, some cracks separated enough to reveal the mortar beneath. Some of the cracks appeared to be associated with depressed areas which had a heavy application of coating. In addition, on the edges where it overlapped, the Aquathane began to lift from the original glaze layer.

After 12 cycles (144 hours), cracking and lifting continued in the areas where it began earlier, and after 18 cycles (216 hours) these conditions worsened further. Additional cracks appeared on the terra cotta sections of all the samples. Again, these cracks were associated with areas where the coating was thicker. In addition, the Aquathane began to lift from the bottom edge of sample 1A where it



had been wrapped over the side of the terra cotta. In all cases, the coating continued to peel back from the original glaze.

Most of the damage occurred by cycle 18. After this cycle, existing cracks and conditions continued to worsen, but only to a minimal degree.

## 2) CPU-CII Protective Safety Sealer

*Application:* CPU-CII was also a thin coating, but it seemed to spread well and evenly. This coating was the only clear coating in the program, and when applied, it minimally darkened the surfaces. It also added a gloss to the mortar substrate. After drying the terra cotta surface was Munsell 10YR 8/4 and the mortar surface was Munsell 5Y 8.5/1.

*Performance:* No changes were witnessed due to weathering.

## 3) Breathable Masonry Coating 55

*Application:* BMC is a thick coating which spread uniformly. Its color completely obscured the substrate color in one coat (although two were applied for consistency with the other coatings). When applied, some bubbles appeared on the mortar repair and brush strokes were visible. Upon drying, the brush strokes disappeared and a light gray matte finish, Munsell 5Y 8.5/1, was produced.



*Performance:* The only change exhibited on the BMC samples was after cycle 12 (144 hours). Five brownish stains appeared on the terra cotta side of sample 3B. These stains, however, disappeared by the next check at cycle 18 (216 hours). Otherwise, the BMC exhibited no alterations due to weathering.

#### **4) Conformal Stain**

*Application:* Conformal Stain was thicker than CPU-CII but thinner than BMC 55 allowing it to spread evenly and uniformly and also to show the underlying texture of the substrates. Its color successfully obscured the substrate color producing a matte gray color, Munsell 5Y 7/1.

When the coating dried on specimen 4C, it exhibited chalking and hairline cracking. This specimen was not completely flat, and the damage occurred in the depressed area where the coating may have been thicker. This condition facilitated further weathering discussed below.

*Performance:* With the exception of minimal hairline cracking and chalking, the Conformal Stain performed relatively well. After six cycles (72 hours), specimen 4A exhibited hairline cracks on the terra cotta side with a small amount of chalking. After 12 cycles (144 hours), the hairline cracks on specimen 4C began to flake exposing a small area of the substrate (Appendix B, fig. B.33, B.34).



Specimens appeared relatively stable until cycle 30 (360 hours) when chalking was exhibited on all three, but no further damage occurred after this cycle.

#### 5) Elasto Wall 351

*Application:* The thickest of the coatings, Elasto Wall spread evenly but tended to hold the brush strokes. Specks of solid particles appeared throughout and once dry some appeared as bubbles. Its matte gray color, Munsell 5Y 8/1, completely obscured the substrate color.

*Performance:* No changes were witnessed due to weathering.





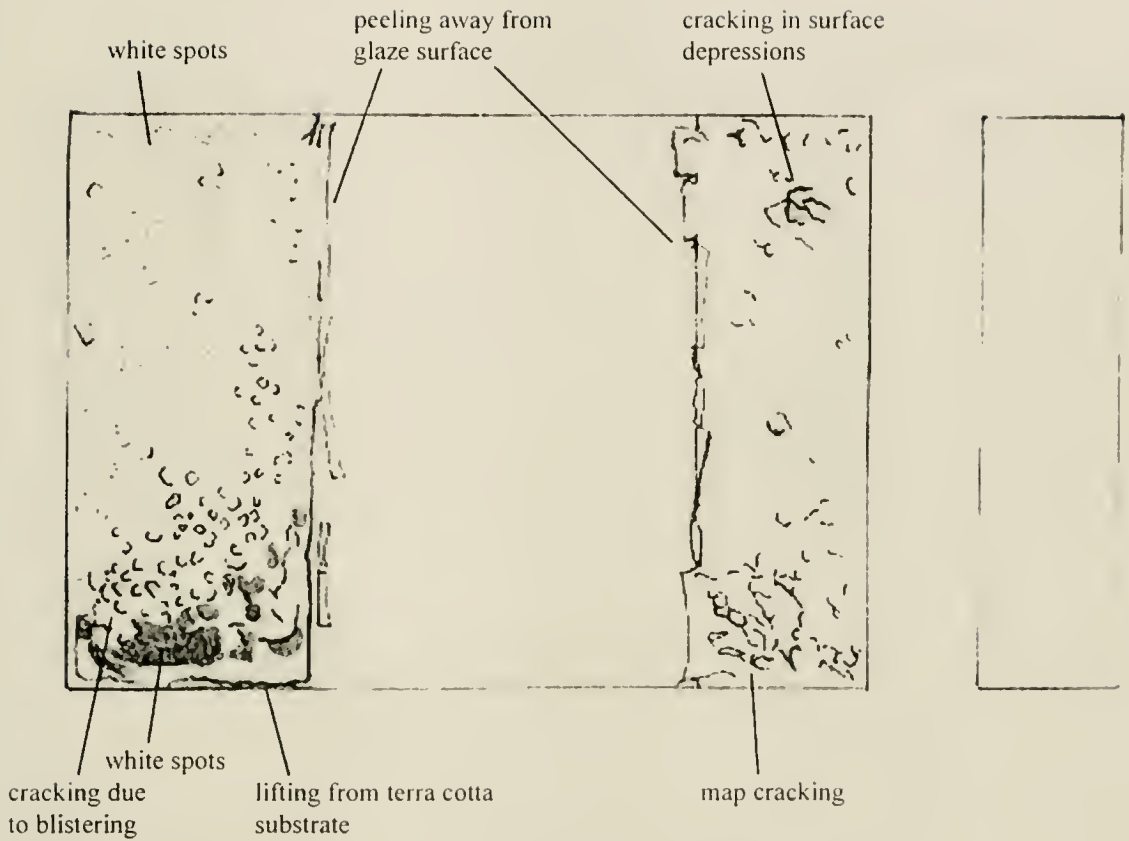


Figure 6.4 Edison Aquathane UA-210H specimen 1A after 52 cycles (624 hours)



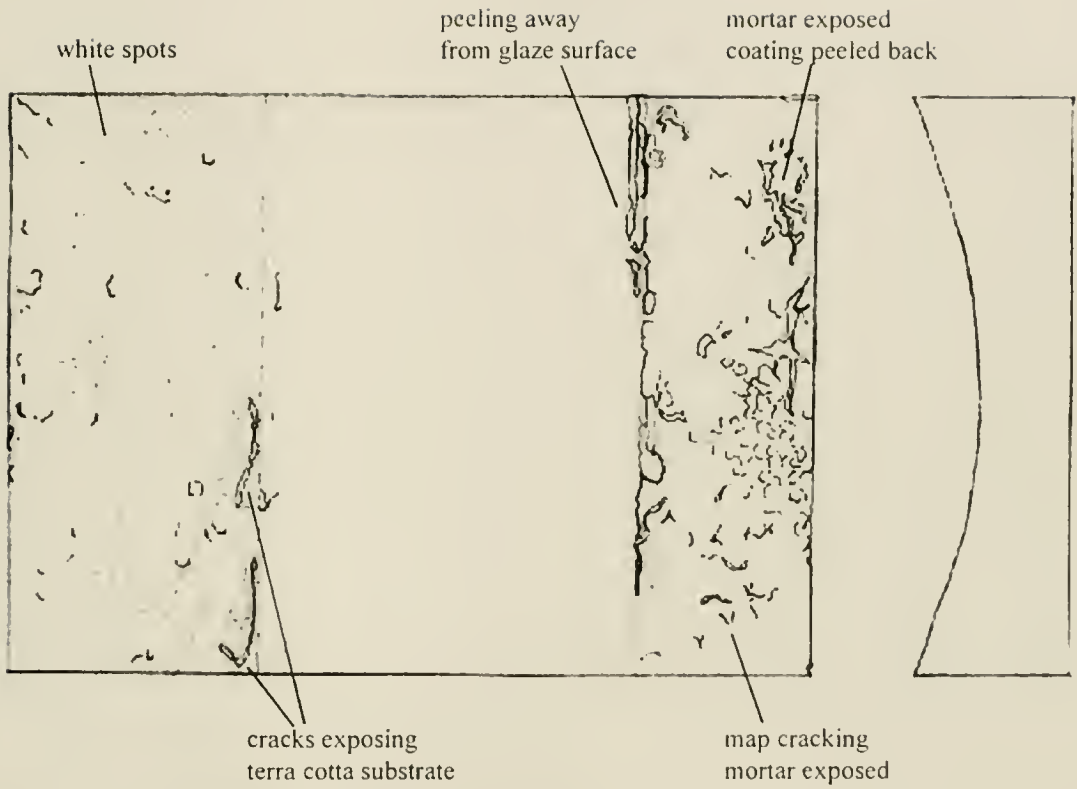


Figure 6.5 Edison Aquathane UA-210H specimen 1B after 52 cycles (624 hours)



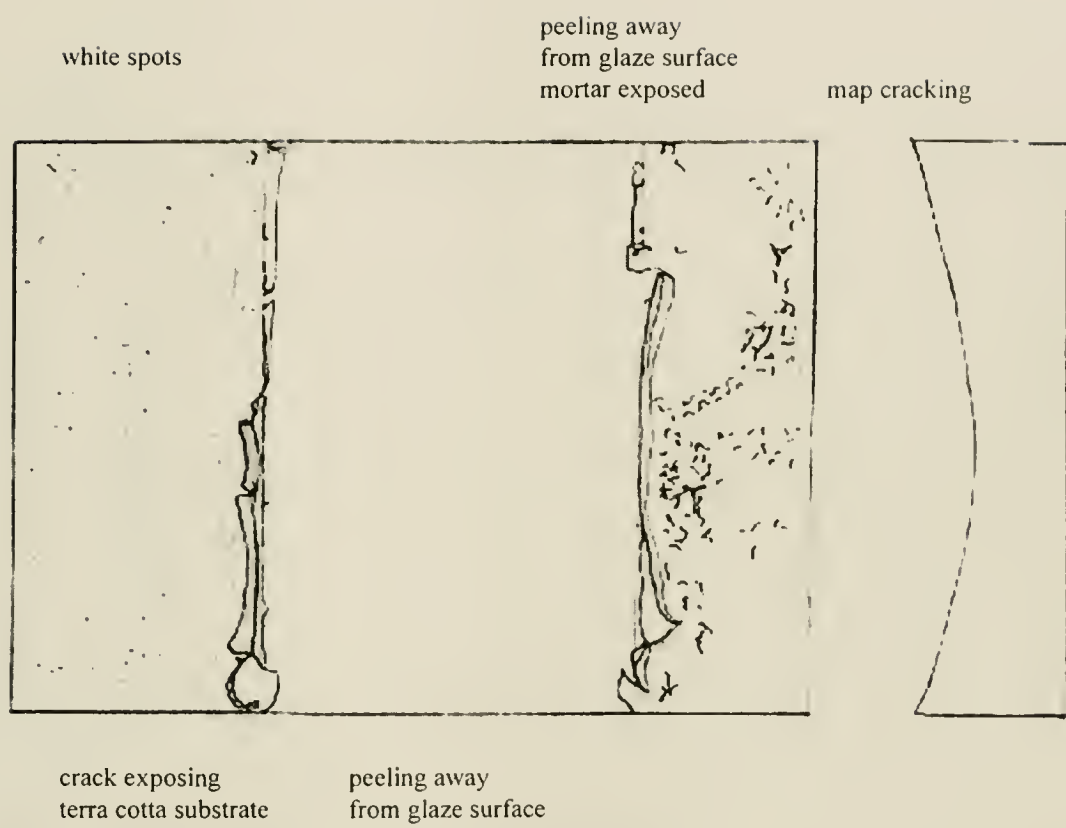


Figure 6.6 Edison Aquathane UA-210H specimen 1C after 52 cycles (624 hours)



map cracking

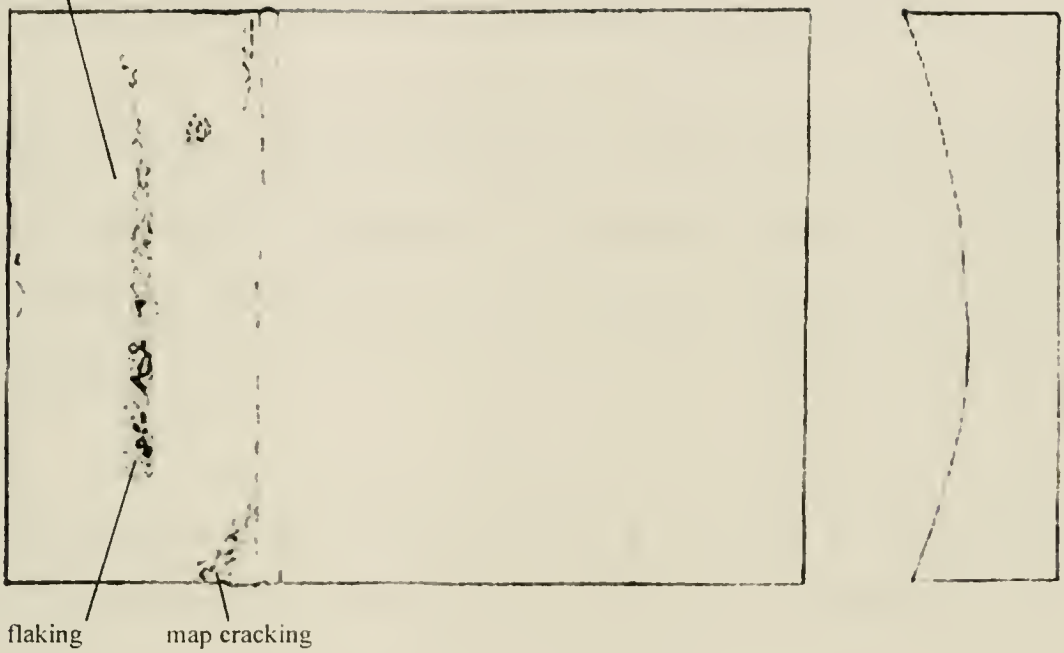


Figure 6.7 Conformal Stain specimen 4C after 12 cycles (144 hours)





### *Discussion and Conclusions*

Rating the coatings by the amount of failure witnessed due to weathering, the coating that performed the best overall of the urethane-based was CPU-CII Protective Safety Sealer, and of the acrylic-based products, BMC 55 and Elasto Wall 351 performed the best. Of the pigmented coatings, the two acrylic-based coatings, BMC 55 and Elasto Wall 351, were the most effective. In addition, application of these two coatings posed no problems due to their adequate thickness for vertical application and uniform spreading.

In order to be properly compared with the other two CPU-CII would have to be mixed with a pigmented paint as instructed by the manufacturer, and tested accordingly. In combination with a pigmented coating, its performance may not have been the same as shown here.

Aquathane failed in both application and weathering. Conformal Stain, although it did not exhibit drastic failures, showed weaknesses which may cause problems in service.

Although the Aquathane UA-210H was the only coating which showed a noticeable color change, a more accurate method is necessary for measuring this change. Spectrophotometry provides an accurate method for measurement of color change by determining the CIELAB color coordinates for hue, value and chroma of weathered and unweathered specimens. (ASTM D2244-89). Unfortunately, the cost of the apparatus for this test was prohibitive so it was not used in this testing program.



Application procedures may have affected the results of this test, as well. It is possible that in the area where the coating overlaps the glaze, that the glaze may need to be etched or roughened more than it was in this case. When sanding off the glaze from the section of the specimen to be coated, often the edge of the remaining glaze was left rough, but because of the sanding mechanism, it may not have been rough enough to facilitate a strong bond between the coating and the glaze. Failures at the glaze interface consisted of peeling from the edge of the coating. Once the edge was lifted, there appeared to be no bonding capacity. Failures on the body of the terra cotta or on the mortar repair, however, consisted mainly of cracks which eventually produced peeling. These failures were more contained, though, and did not make the entire surface peel away.



## 6.6.2 Water Vapor Transmission

### *Standardized Test Used*

ASTM E 96-80: Standard Test Methods for Water Vapor Transmission of Materials:  
Water Method

### *Purpose*

To measure the water vapor transmission (WVT) rate of the terra cotta substrate coated with the remedial coatings and the terra cotta substrate-patching mortar-coating assembly in relation to that of samples coated with the original glaze; to determine which, if any, coatings are significantly more permeable than others; and to determine if the patching material affects the water vapor transmission. “Water vapor transmission rate” is defined as “the steady water vapor flow in unit time through unit area of a body, normal to specific parallel surfaces, under specific conditions of temperature and humidity at each surface.”

### *Significance*

Although these coatings are intended to replicate the characteristics of a glaze layer, it is of utmost importance that they are not as impermeable as the glazes. Because water invariably enters the terra cotta, through cracks in the mortar or otherwise, it is important that the coatings allow for more vapor transmission than the glaze so that this water vapor will escape through the remedial coating rather than getting trapped behind the surrounding glaze layer and coating. Water vapor trapped behind the glaze or coating



will cause water-related deterioration of the terra cotta, glaze, and/or coating. Since it is unlikely that any coating could be as impermeable as fired glazes, the water vapor permeability of the coating is largely to protect the coating, itself, from failure due to these mechanisms. If the coating fails, it no longer performs its purpose which is to protect the exposed terra from the weather.

### *Methodology*

Five round sample disks per coating, as described above, were used. The samples measured 1 5/8" (4.1 cm) in diameter and were 5/8" (1.6 cm) thick with a surface area of 2.41" (0.13 cm<sup>2</sup>) per side. On three of the five, the coating was applied directly to the terra cotta substrate, and on the other two the patching mortar was applied, and its surface was coated. Three disks with the original glaze were used as controls.

A total of 28 disposable 50 ml beakers were each filled with 15 ml of deionized water. The edge of the each specimen was covered with electrical tape and the disks were sealed to the mouths of the plastic beakers with microcrystalline wax. The assemblies were weighed and placed onto racks in a glass tank which was then sealed with a glass lid. Two trays of Drierite, an anhydrous calcium sulfate desiccant, were placed on the floor of the tank maintaining a relative humidity of 36% ± 3%. A thermometer placed in the tank measured the temperature which ranged from 19.5° C to 22° C. Readings of the temperature, relative humidity and weights of the samples were taken daily until a rate





was determined (Appendix B, Tables B.1-B.12). After each reading the assemblies were rotated to accommodate for any conditional variations in the tank. Because the scale slipped from calibration easily, a 295.0g weight was weighed on the scale prior to the weighing of the samples, and the data collected each day was corrected according to the error in the reading of the 295.0g weight.

Due to equipment failure, weight readings for the first 27 days of the test were deemed invalid. As a dense material like terra cotta generally needs at least 30 days to stabilize and establish a steady rate, the rate was determined in the next 15 days, using effective equipment. Hence, the total test time was 42 days.

### *Results*

The daily rate of water loss due to vapor transmission (WVT, expressed in  $\text{g/h}\cdot\text{m}^2$ ) was determined for each specimen, and then the mean value and standard deviation were calculated within each coating group. From the mean values, the percentage differences in the WVT rates of the coated samples compared to the glaze control samples were also calculated (Table 6.1).



Table 6.1 Mean Water Vapor Transmission rates and percentage difference with respect to glazed control specimens<sup>145</sup>

MEAN WVT RATES & STANDARD DEVIATIONS						
	GLAZE	AQ	CPU	BMC	CS	EW
<b>COATING ONLY</b>						
Mean (g/h·m <sup>2</sup> )	1.60	1.98	2.70	1.63	2.10	1.92
Standard Deviation	±0.22	±0.28	±0.26	±0.37	±0.28	±0.15
% Difference	0.0%	+24%	+69%	+1.9%	+31%	+20%
<b>MORTAR/COATING</b>						
Mean (g/h·m <sup>2</sup> )		invalid	1.55	1.34	1.75	1.84
Standard Deviation		invalid	±0.049	±0.016	±0.34	±0.15
% Difference		invalid	-3.1%	-16%	+9.4%	+15%

As indicated in Table 6.1, one significant failure occurred during the test. The coating on both of the mortar patched samples coated with Edison Aquathane UA-210H exhibited blistering and cracking as of day 28 of the test. The coating was cracked and lifted, exposing the mortar beneath. Due to this failure, the results from these two samples were excluded from the water vapor transmission test. This outcome is significant, though, in that it illustrates that the Aquathane coating may not be suitable for coating a mortar patch of this type. There are two plausible explanations for this failure. First, water vapor passing through the substrate and mortar may have been trapped beneath the coating causing it to fail. This condition was not witnessed on the Aquathane samples without patching mortar, so it is possible that the combined water vapor transmission rate of the mortar and coating was too low for vapor to pass through. Second, an incompatibility in bonding at the mortar-coating interface may have caused the failure.

<sup>145</sup> AQ=Edison Aquathane UA-210H, CPU=CPU-CII Protective Safety Sealer, BMC=Breathable Masonry Coating 55, CS=Conformal Stain, EW=Elasto Wall 351.



Because only two replicates were used, further testing with a greater number of sample replicates is necessary to determine if this result represents a typical condition.

The F-test and the Student t-test were used to statistically analyze the test results. Using the F-test, the standard deviations of the five coating groups were compared to the standard deviation of the glaze control group to determine if their precisions were significantly different. At the 95% confidence level, all test values were less than the critical value, so no significant difference was found between the precisions of the coated samples and the glaze control samples. Using the t-test, the means of the coating groups were compared to the mean of the glaze control group to determine if there were significant differences in the WVT rate of the products. At the 90% confidence level, significant differences were found between the means of CPU-CII coating only group and the glaze control group and between the means of Conformal Stain coating only group and the glaze control group. The levels of probability of significant differences between the means of the sample groups are reported in Table 6.2.

**Table 6.2 Significant Differences in the mean water vapor transmission rates of treatment groups compared to glaze control group**

<b>SIGNIFICANT DIFFERENCES IN MEAN WVT RATES AT 90% CONFIDENCE LEVEL (10% LEVEL OF PROBABILITY) COATING &amp; MORTAR/COATING GROUPS VS. GLAZE CONTROL GROUP</b>		
<b>TREATMENT GROUP</b>	<b>HYPOTHESIS TEST RESULT</b>	
	<b>COATING</b>	<b>MORTAR/COATING</b>
<b>AQ-GLAZE</b>	Not significant	Not significant
<b>CPU-GLAZE</b>	Significant	Not significant
<b>BMC-GLAZE</b>	Not significant	Not significant
<b>CS-GLAZE</b>	Significant	Not significant
<b>EW-GLAZE</b>	Not significant	Not significant



An analysis was done comparing the coating only groups to each other and mortar/coating groups to each other. For the coating only groups an F-test revealed that there were no significant differences in their precisions. A t-test found a significant difference in the means of all coatings compared to the mean of CPU-CII and a significant difference in the means of BMC 55 and Conformal Stain (Table 6.3). For the mortar/coating groups, an F-test revealed no significant differences in their precisions and a t-test revealed no significant differences in any of the means.

**Table 6.3 Significant differences in the mean water vapor transmission rates between coating only groups**

<b>SIGNIFICANT DIFFERENCES IN MEAN WVT RATES AT 90% CONFIDENCE LEVEL (10% LEVEL OF PROBABILITY) COATING ONLY GROUPS</b>	
<b>TREATMENT GROUP</b>	<b>HYPOTHESIS TEST RESULT</b>
AQ-CPU	Significant
AQ-BMC	Not significant
AQ-CS	Not significant
AQ-EW	Not significant
CPU-BMC	Significant
CPU-CS	Significant
CPU-EW	Significant
BMC-CS	Significant
BMC-EW	Not significant
CS-EW	Not significant

To determine if the mortar component significantly affected the water vapor transmission, a statistical analysis was done between the coating only group and mortar/coating group within each treatment group. An F-test found no significant differences in the precisions of the standard deviations between the coating and mortar/coating groups, so a t-test was





performed to determine if there were any significant differences in their means. Although, it appeared that the mortar lowered the WVT rate in all treatment groups, the only significant difference found was between the CPU-CII coating only group and mortar/coating group (Table 6.4).

**Table 6.4 Significant Differences in the mean water vapor transmission rates of coating only groups compared to mortar/coating groups**

<b>SIGNIFICANT DIFFERENCES IN MEAN WVT RATES AT 95% CONFIDENCE LEVEL (5% LEVEL OF PROBABILITY) COATING GROUPS VS. MORTAR/COATING GROUPS</b>	
<b>TREATMENT GROUP</b>	<b>HYPOTHESIS TEST RESULT</b>
<b>AQ Coating - AQ Mortar/Coating</b>	Not significant
<b>CPU Coating - CPU Mortar/Coating</b>	Significant
<b>BMC Coating - BMC Mortar/Coating</b>	Not significant
<b>CS Coating - CS Mortar/Coating</b>	Not significant
<b>EW Coating - EW Mortar/Coating</b>	Not significant

### *Discussion and Conclusions*

According to the test results above, only the CPU-CII Protective Safety Sealer (CPU) and Conformal Stain (CS) applied directly to the terra cotta body, were found to have significantly higher water vapor transmission rates than the weathered original glaze. This indicates that CPU-CII and Conformal Stain provide the greatest water vapor transmission of the five coatings and hence the greatest durability in relation to trapped moisture. No significant difference exists between the WVT rates of CPU-CII and Conformal Stain, so theoretically their performance would be similar. The two products, however, do not provide the same aesthetic characteristics. While CPU-CII is a clear, unpigmented coating, Conformal Stain is pigmented. As has been discussed above, CPU-



CII must be mixed with or painted over a synthetic emulsion paint in order to be appropriately compared to the four other pigmented coatings in this study. Further testing of this combination is necessary.

Since, statistically, three of the five products' WVT rates were found not to be significantly different than that of the glaze, their rates are neither significantly higher *nor lower* than that of the controls, indicating that they would still perform adequately. It is assumed that their rates are close enough to the glaze rate to be considered adequate repairs. In addition, a knowledge of glaze technology suggests that it is unlikely that any of these coatings could actually be as impermeable as a terra cotta glaze, even in its weathered state.

Because no significant difference was found in the precisions of any of the data, comparisons between the coating groups were also made to determine if any coatings performed significantly better or worse than another. Of importance is the fact that the coating only assemblies within each coating group compared to the mortar/coating assemblies within each coating group revealed no significant difference in three of the four groups. According to the results of this test, BMC 55 (BMC), Conformal Stain (CS), and Elasto Wall 351(EW) used atop a mortar patch would not have a WVT rate significantly different than if they were used directly on the terra cotta substrate. The addition of mortar to the assembly coated with CPU-CII significantly decreased the water vapor transmission rate, but since the CPU-CII mortar/coating rate was not significantly



lower than that of the glaze control, it is still an adequate solution.

Comparisons made between products in the coating only group revealed that CPU-CII had a significantly higher WVT rate than the other four coatings, meaning it would perform the best where water vapor transmission is a concern. Among the other four coatings, the only significant difference was that the Conformal Stain had a significantly higher WVT rate than the BMC 55. One factor affecting CPU-CII's comparatively high WVT rate may be the absence of components which would provide a pigment. It is possible that in the absence of pigmenting materials, the coating allows the water vapor to pass more readily than it can through the four other pigmented coatings

Three factors in the testing program may have contributed to the fact that the water vapor transmission rates of the coatings and the glaze controls were so close. First, the terra cotta substrate, used so that comparison between the coatings and the glaze could be possible, may have prevented a significant amount of water vapor from actually reaching the coating layer. The inclusion of a group of unglazed terra cotta specimens would have established the role of the substrate in determining the water vapor transmission. Second, the sample number used to establish each mean was small (3 for coating & 2 for mortar/coating). A greater number of replicates may provide enough data to indicate significant differences between the means of these coatings and the glaze. Third, because weathered glazed terra cotta was used as a control, the existence of microcracks in the surface of the weathered glaze most likely allowed more water vapor to pass than an



intact glaze would. This factor may have made the water vapor transmission rate of the control samples approach the rate of the coated samples which is presumed to be higher than that of an intact glaze.

Finally, comparisons made between products in the mortar/coating group revealed no significant differences between the WVT rates of any of the coatings. All would be equally effective. Since the addition of mortar to the assembly was uniform, one would expect to see the same differences between the coating groups as were seen between coating groups on the terra cotta substrate. It is possible that the use of only two replicate specimens, one less than the number used for the coating only assemblies, affected the outcome of the test. A larger number of replicates may reveal greater differences between the products when applied over a mortar patch.

The main issues of water vapor transmission are first, to insure that the repair itself lasts under the influence of trapped water vapor, and second not to induce further glaze damage at the interface of the glaze and substrate. The combined results of all statistical analysis reveal that, with respect to water vapor transmission, CPU-CII and Conformal Stain allow the greatest water vapor transmission and therefore least possibility of damage from trapped moisture to either themselves or to the surrounding glaze. Elasto Wall 351, Aquathane UA-210H, and Breathable Masonry Coating 55 are less water vapor permeable, but still equal to or slightly more vapor permeable than the weathered glaze surface. These three will also perform adequately with respect to trapped moisture.





### **6.6.3 Water Absorption**

#### *Standardized Test Used*

ASTM C 67-83 Standard Methods of Sampling and Testing Brick and Structural Clay Tile. Section 7: 24 hour Submersion Test

#### *Purpose*

To measure the absorption rate of uncoated, unglazed terra cotta as compared to terra cotta coated with remedial coatings.

#### *Significance*

Areas where spalling and peeling have occurred on a terra cotta piece expose the substrate to liquid water which may be absorbed into the piece causing water-related deterioration and continued failure of body and glaze. Ideally, these coatings will prevent liquid water from being absorbed into the terra cotta substrate in areas where the glaze is lost. The coated terra cotta should have a lower absorption rate than the glaze-free, uncoated specimen.

#### *Methodology*

Twenty samples of terra cotta, 1" x 1" x 3/4" were cleaned and dried in an oven at 115° C for 24 hours until two successive weighings at intervals of 2 hours showed an increment of loss not greater than 0.2% of the last determined weight of the specimen. The



specimens were then cooled for 4 hours in a glass tank with trays of Drierite in the bottom. Each coating was applied to three specimens, covering all six sides. The coatings were allowed to dry as per manufacturers instructions, and each specimen was weighed. The five remaining unglazed samples were left uncoated as controls for comparison of the absorption of the uncoated terra cotta to that of the coated terra cotta.

Samples were then submerged in a glass tray filled with deionized water at a temperature of 25° C for 24 hours. They were removed, wiped off with a damp cloth, and weighed (Appendix B, Table B.13).

Absorption was calculated as follows:

$$\text{Absorption, \%} = 100 (W_s - W_d) / W_d$$

where:  $W_d$  = dry weight of the specimen, and

$W_s$  = saturated weight of the specimen after 24 hour submersion

### *Results*

The absorption as a percent of the dry weight of each specimen was calculated, and then the mean value and standard deviation were calculated within the substrate group and each coating group (Table 6.5).



**Table 6.5 Mean absorption percentages and standard deviations**

<b>MEAN ABSORPTION PERCENTAGES &amp; STANDARD DEVIATIONS</b>						
	<b>Control</b>	<b>AQ</b>	<b>CPU</b>	<b>BMC</b>	<b>CS</b>	<b>EW</b>
<b>Mean Absorption (%)</b>	13.48%	13.16%	13.49%	6.341%	4.911%	8.450%
<b>Standard Deviation</b>	±0.7516	±0.07382	±0.9371	±3.184	±5.166	±6.570

The F-test and Q-test were used to statistically analyze the data. Using the F-test, the standard deviations of the five coating groups were compared to the standard deviation of the unglazed, uncoated terra cotta group to determine if their precisions were significantly different. Significant differences were found in the precisions of all groups except the CPU-CII, so no t-test could be used to compare the means of the groups. A Q-test performed on the suspect value of the F-test results, showed that these results are acceptable.

### *Discussion and Conclusions*

Although the results could not be statistically compared using a t-test, a visual comparison illustrates that all of the coatings affect the liquid water absorption capacity of the terra cotta. While the Aquathane UA-210H and CPU-CII do not affect water absorption very much, the BMC 55, Conformal Stain, and Elasto Wall 351 significantly decrease the absorption percentage. This indicates that these coatings will provide added protection against liquid water penetration when applied to areas of glaze loss where the terra cotta substrate is exposed.



It is important to note that application procedures may greatly affect the outcome and performance of these coatings in terms of water absorption capacity. The greater the number of coats applied, the greater the water repellency. This may have been a factor in the variability of the absorptions within the coating groups tested. In addition, in climates where moisture is prevalent, additional water repellents can be used underneath these coatings as primers to provide another layer of protection.





## 6.7 Conclusions

The results of the three tests conducted in this testing program indicate that no one coating is effective in performing under all three conditions (Table 6.6). The coatings that performed best, as judged by their resistance to cracking, blistering, chalking, and discoloration, in the ultraviolet light/condensation accelerated weathering test were the Breathable Masonry Coating 55, Elasto Wall 351, and CPU-CII Protective Safety Sealer. The Conformal Stain was adequate but not satisfactory because of minimal flaking and chalking; and the Aquathane UA-210H was not adequate due to failure in all judging criteria. Conformal Stain and CPU-CII Protective Safety Sealer exhibited the highest water vapor transmission and therefore would show the least vulnerability to damage due to trapped moisture. Finally, Breathable Masonry Coating 55, Conformal Stain, and Elasto Wall 351 significantly reduced the water absorption when applied to exposed terra cotta, hence would provide the most effective protective layer in terms of water infiltration.

Table 6.6 Final results of experimental program.

FINAL RESULTS				
Product	Performance Ratings			Overall Performance Rating
	Property Tested			
	Ultraviolet light & Condensation Exposure	Water Vapor Transmission	Water Absorption	
Aquathane UA-210H	3	2	3	8
CPU-CII*	1	1	2	4
BMC 55	1	2	1	4
Elasto Wall 351	1	2	1	4
Conformal Stain	2	1	1	4

1 = Satisfactory, product significantly satisfies the desired result  
 2 = Adequate, product minimally satisfies the desired result  
 3 = Inadequate, product fails to satisfy the desired result

\*CPU-CII is not pigmented.



Sources of error in the water vapor transmission test indicate that further testing with more replicates and possibly a thinner terra cotta substrate may provide different, more accurate results. Excluding the results of this test, the Breathable Masonry Coating 55 would be the recommended product.

Although Conformal Stain failed in the accelerated weathering test, it only failed on one of the three replicates. Because of its satisfactory performance in both the water vapor transmission test and the water absorption test, further examination of this coating is necessary to determine if it will fail regularly under ultraviolet light and condensation exposure due to intrinsic factors.

In summary, of the two generic types of coating, acrylic and urethane, the acrylic coatings perform better. Although CPU-CII, a urethane, performed well in accelerated weathering and in water vapor transmission, the fact that it is not pigmented prevents it from being accurately compared with the other four coatings. Edison Aquathane UA-210H was ineffective in all three tests. Breathable Masonry Coating 55 and Conformal Stain, both acrylic-based products performed well on the whole.



## 6.8 Suggestions for Further Research

As in most research projects, limitations, observations, and results of this program have raised further questions as to the materials tested and glazed terra cotta repair methods in general. Various suggestions for further testing in this area have been included in the text. Other suggestions follow below.

- Although it may give indications of relative performance, lab testing cannot substitute for actual outdoor exposure testing. All coatings should be tested on damaged terra cotta surfaces in varying climates over extended periods of time before their performance can be accurately determined.
- Additional weathering tests such as salt crystallization and water spray should be performed to determine the coatings' effectiveness in other damaging conditions they may encounter in a temperate maritime climate. Salt tests have been discussed in the text, and the QUV/SE/SO is capable of producing water spray to test the effects of mechanical and thermal damage on materials.
- CPU-CII Protective Safety Sealer should be mixed with variety of synthetic emulsion paints and tested for its effectiveness as a pigmented coating. Although, in its clear state, it may be used effectively to seal crazed pieces of glazed terra cotta, for repairing areas of total loss of glaze, it must be pigmented.
- Micro investigation of the coatings before and after weathering may prove instructive. For example, thin sections could be taken of the coatings before weathering and after,



and they could be examined for microcracking or other small scale damage not visible to the naked eye. Scanning Electron Microscopy should also be performed to view small scale changes.

- The role of microcracking on the surface of weathered glazed terra cotta should be examined for its effect on the properties of the surface. This condition is especially important in relation to the water vapor transmission of the original surface as compared to that of a surface which has been repaired with a remedial coating.
- Additional coatings should be tested. Several possible alternatives were made known to the author too late for their inclusion in this program. Others, excluded from earlier studies for various reasons, should be included in future testing. Some examples include, Thorosheen and Thoroglaze H (Thorosystem Products), Keim Granital (Keimfarben GmbH), and VIP Umbrella Coat (Flood Coatings).
- Additional patching mortars should be tested in conjunction with these and other coatings. In addition to Jahn M100-101, one commonly used terra cotta mortar which also performed well in Daniel Allen's tests is Edison Custom System 45 manufactured by Edison Chemical Systems, Inc.





## Conclusion

Although the present study did not definitively prove the effectiveness of any one coating over another when subjected to temperate maritime weathering conditions, it is notable that the three coatings which were the most effective in these tests were also the most effective in the earlier study by Ricardo Viera. Combined, these results indicate that the three acrylic-based coatings, Breathable Masonry Coating 55, Conformal Stain, and Elasto Wall 351, may all be appropriate for treating damaged glazed terra cotta surfaces. In addition to testing these coatings for resistance to other weathering conditions such as salt spray and water spray, the next step should be to substantiate the results of the laboratory tests by testing the products in actual exposures. All three of these coatings were cited by practitioners as having been used on projects in the recent past.<sup>146</sup> Through these projects, the coatings' outdoor weathering tests have effectively begun. In order to determine if the coatings are effective in natural weathering conditions, though, it is crucial that their performance on these buildings be monitored and evaluated on a regular basis. Only a few of the architectural conservators and architects interviewed for this study had evaluated their treatments once since installation, and none had monitored them on a regular basis.

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<sup>146</sup> Breathable Masonry Coating 55: Russ Building, San Francisco, CA, current; Los Angeles City Hall, Los Angeles CA, current.

Conformal Stain: Ritz Carlton Hotel, San Francisco, CA, 1988; Woolworth Building, New York, NY, 1978.

Elasto Wall 351: 770 Chapel Street, New Haven, CT, 1984; Bank Center South, Savannah, GA, 1991-92.



Several significant issues were introduced during the present study which deserve mention. First, the effectiveness of these remedial coatings is dependent on the proper application. Because this repair technique is relatively new to architectural conservation, detailing of repairs is not standardized. Further research and testing is needed to determine the most appropriate application methods. Second, color matching and color durability using specified pigments and colorants must be tested for each of the coating systems. The properties of the pigments and issues related to color have not been investigated in the present study or in the preceding ones. Third, different coatings or different combinations of coatings and primers may be necessary depending on the location of the building. Local climate and site specific conditions must be considered because they invariably affect the necessary requirements of a coating. There will never be one specific coating applicable to all locations. For this reason, site testing is of utmost importance before any treatment is applied to areas of glaze loss. Finally, because these coatings do not have a long track record in this use, they require regular monitoring and maintenance. Although they may provide temporary protection, it is known that they will not last forever. Just as a coat of paint needs recoating after a certain amount of time, it should be expected that these coatings will need maintenance as well.

Although a solution is not apparent yet, this study has increased the probability that remedial coatings can be an effective solution to the problem of terra cotta glaze loss. Through the generation of comparative performance results using standard methods of



weathering according to ASTM and through examining the relationship between different coatings on both the terra cotta substrate and a mortar repair, this thesis has made a significant contribution to the furthering of the research in this field. The application of remedial coatings provides the least invasive method of repair for glaze spalling and peeling. This fact alone justifies the need for continued research to ensure that the limited population of glazed terra cotta structures remaining will be able to retain their distinct character.



**APPENDIXES**





**APPENDIX A**  
**Product Information**



**Table A.1 Product Information**

<b>PRODUCT</b>	<b>GENERIC TYPE</b>	<b>MANUFACTURER/ DISTRIBUTOR</b>
<b>Aquathane UA-210H</b>	Aliphatic polyurethane-based emulsion with additives, surfactants, pigments and modifiers	Edison Chemical Systems, Inc. 25 Grant Street Waterbury, CT 06704 (203) 597-9727 fax (203) 597-8044 Leah & Michael Edison
<b>CPU-CII® Protective Safety Sealer</b>	Combination of urethane polymers & a colloidal dispersion	Chemique, Inc. 315 N. Washington Ave. Moorestown, NJ 08057 (800) 225-4161 (609) 235-4161 Ed Drazga
<b>Breathable Masonry Coating (BMC™) 55</b>	Water-based acrylic emulsion.	ProSoCo, Inc. P.O. Box 171677 Kansas City, KA 66117 (800) 255-4255 (913) 281-2700 fax (913) 281-4385 J. R.
<b>CONFORMAL® Stain</b>	Acrylic resin solution. Solvent-based acrylic, formulated with color flattening fumed silica & colored with non-fading inorganic oxide pigments	Chemprobe Technologies, Inc. 2805 Industrial Lane Garland, TX 75041 (214) 271-5551 fax (214) 271-5553  Local Distributor: Capricorn Industrial Sales Co., Inc. P. O. Box 494 West Chester, PA 19381 (610) 429-5253 fax (609) 429-5301 Van Burriss
<b>Elasto Wall 351</b>	Waterborne acrylic elastomer emulsion	Edison Chemical Systems, Inc. 25 Grant Street Waterbury, CT 06704 (203) 597-9727 fax (203) 597-8044 Leah & Michael Edison
<b>Jahn M100-101 Terra Cotta &amp; Brick Repair Mortar</b>	Cementitious-based with no acrylics, polymers, or metal constituents	Jahn International Restauratietechnieken BV Rijksstraatweg 243 3222 KD Hellevoetsluis The Netherlands fax 31-1883-20602  Distributor: Cathedral Stone Products 8332 Bristol Court, #107 Jessup, MD 20794 (301) 317-4658 fax (301) 317-4670 Jim Hanlon/Keith Matney



Table A.2 Product Application Procedures

PRODUCT	CLEANING	APPLICATION	CURING
Edison Aquathane UA-210H	Surface must be dust free & clean Temperature above 50° F	One or two coats (depending on color) Brush, pad, roller, low pressure airless spray Apply evenly and moderately	Allow first coat to dry for 12 hrs. before applying second Reaches full strength at 48 hrs. May be accelerated by heating to 175° F for 20 min. after drying
CPU-CII Protective Safety Sealer	Surface must be clean and dry Recommends using ION-417 or BAC-2-NU for cleaning then rinsing and drying	Two coats: recoat after 20-30 min. Airless spray, low pressure spray, roller, brush, or lambs wool applicator	Allow 20-30 minutes between coats
Breathable Masonry Coating (BMC™) 55	Surface must be clean Temperature above 40° F	Two coats: 5 mils wet first coat, mils for second coat or approx. 3 mils dry Brush, roller, airless spray, may need back rolling Mix well before application	Allow 2 hours between coats 24 hours for complete drying
CONFORMAL® Stain	Surface must be clean and dry Temperature above 50° F 60-70% Relative Humidity	One or two coats (by color) Airless spray, brush, deep nap roller	Allow 5 hours between coats
Elasto Wall 351	Surface must be clean, damp or dry	One coat for uncracked substrates Two or Three where greater waterproofing or crack bridging are required Dry film thickness = 8-10 mils., wet = 15-18 mils./coat Spray, roll, or brush	Allow 4 hours between coats
Jahn M100-101 Brick & Terra Cotta Repair Mortar	Temperature above 40° F Substrate must be cut away to at least 1/2" depth Surface must be cleaned of dust using clean water and scrub brush Pre-wet substrate, re-wet just before applying patching material	Mixing: Mix amount of material that can be used in 30 min. 5 parts dry material to 1 part water, mix well Application: Use trowel in series of lifts; Without waiting between layers, use light pressure to build up mortar so that it is slightly above adjacent masonry surface Set for 15-30 minutes (longer if cool), then scrape off excess material with straight edge	Lightly mist patch with water to wet entire surface 30 min. to 1 hour after completion (sunny day) or 2 hours (cool day) For 28 day cure: Mist at least once a day (as often as possible) on two days after installation For 14 day cure: Mist twice a day for first seven days after inst.



# AQUATHANE UA-210

## HIGH-PERFORMANCE WATERBORNE POLYURETHANE COATINGS

### Description:

**EDISON AQUATHANE UA-210** products are multi-purpose, high-performance, waterborne polyurethane-based coatings. They are breathing, low in odor, VOC-Compliant and fast drying. They are reactive, single component products which cure to tough, flexible films which resist abrasion and intermittent exposure to water and many chemicals.

### Applications:

Applications for **EDISON UA-210** products include:

- ✓ Anti-Graffiti Coatings - Interior or Exterior
- ✓ Stain Resistant Wall Coatings & Treatments
- ✓ Wood, Stone and Concrete Sealers
- ✓ Terra Cotta Glaze Replacements
- ✓ Over Many Previously Coated Surfaces

### The UA-210 System:

**AQUATHANE UA-210F** Floor Sealer  
The most economical of the **UA-210** series formulas is a self-crosslinking urethane and acrylic copolymer, designed for sealing of hard floor surfaces. **Type F** provides a tough, clear, traffic resistant film for sealing and dustproofing concrete floors and providing resistance to intermittent exposure to a variety of chemicals. On porous surfaces, **AQUATHANE UA-210F** may also be used as a lower cost sealer/primer for subsequent applications of **AQUATHANE UA-210H**.

**AQUATHANE UA-210H** General Use  
The heart of the **UA-210** series is a high-solids, reactive polyurethane emulsion designed for use in a wide range of challenging applications. It is a heavy duty, chemical resistant, self-crosslinking aliphatic urethane for use in interior or exterior concrete floor and deck coating, wood finishing, maintenance coating - and many other specialty coatings applications. Clear **UA-210H** is USDA-accepted for use on incidental food contact surfaces in federally inspected meat and poultry packing plants. Available in standard gloss clear or white tint base formulations, the product is compatible with many commonly used waterborne pigment dispersions. Optional "Flatted" formula provides a low luster finish. Custom colors may also be factory blended.

**AQUATHANE UA-210H-A/G** Anti-Graffiti  
Similar in composition and appearance to regular **AQUATHANE Type H**, the **H-A/G** formulation incorporates special stain-release agents to prevent adhesion and facilitate removal of spray paints, inks, crayons, markers and other coatings. Unlike traditional urethane graffiti inhibitors, **AQUATHANE UA-210H-A/G** does not darken or discolor most surfaces, and odorless application permits easy use and touch-up in interior applications such as school buildings, residential hallways, underground parking structures, elevators and many institutional settings. Available in clear or color, gloss or flatted finishes, the product resists hydrocarbon solvents typically incorporated in paints, markers and other coatings, allowing removal by use of similar solvents or proprietary cleaners.

### Features:

**Chemical Resistance:**  
Resists solvents, paints, markers, fuels, oils & water

**Compatibility:**  
May be applied over a wide variety of substrates and previous coatings.

**Durability:**  
Tough, flexible, hard, abrasion resistant, UV stable

**Fast Drying: (70°F, 50% RH)**  
Dry to touch: 30-60 minutes  
Through dry: 60-120 minutes

**Rapid Hardness Development: (% of ultimate)**

4 hrs. : 25%	8 hrs.: 35%	24 hrs.: 60%
7 days: 100%	Force Cure: 20 mins. @ 180°F	

**Safety:** Low odor, non-flammable, low VOC, moderate pH; low hazard when used with adequate ventilation and when care is taken in handling to avoid eye and prolonged skin contact.

### Limitations:

**AQUATHANE** products are not intended for use in continuous submersion or continuous high humidity exposures. For continuous immersion/high humidity services, we recommend using **AQUEPOXY 250**, **FLEXI-GARD 500-S**, or **FLEXI-DECK 500-U** coating and membrane systems.

**AQUATHANE** products must not be applied at

Figure A.1.a Edison Aquathane UA-210H product literature.





temperatures below 50°F(10°C), as improper or damaged films may result.

## Properties:

### Composition:

Aliphatic polyurethane emulsion with additives, catalysts, surfactants, pigments, resins and modifiers.

### Appearance:

Clear, White, or custom colors; Gloss or satin finish.

### Adhesion:

Concrete, masonry, wood, steel, aluminum and many previous coatings. Primers required for some substrates and exposures.

### Chemical Resistance\*: (After 7-day air dry)

Toluene, 24 hr. immersion:	No effect
Gasoline, 24 hour immersion	No effect
1N NaOH, 1' hour spot test	No effect
Methanol, 24 hr. immersion	Softens, Recovers
Isopropanol, 24 hr. Immersion	Softens, Recovers
Water, 90-day immersion	Swells, Recovers
M.E.K. Rub Resistance	150+ Passed

### Corrosion Resistance\*:

Humidity (100°F, 100% RH, 1000 hrs.)	
Rusting (ASTM D-610)	No effect
Blistering(ASTM D-714)	No effect
Loss in Gloss	No effect

Tensile Strength at yield 6000 psi

Ultimate Elongation 70%

UV Stability (Fadeometer) 1500 hrs.

Abrasion Resistance, Taber Abraser, CS-17 Wheel, 1000 cycles, 1000g load 6 mg loss

Impact Resistance (Dir/Rev) 160/160 lb Pass

60° Gloss, Gardner 91

Sward Hardness 48

\* Values shown are for clear UA-210H

## Application:

1. Surface preparation: AQUATHANE UA-210 is supplied ready to use, and should not be thinned. Surfaces should be dust free and clean. Remove all grease, oil and other contaminants and roughen previous coatings to the extent required to get good wetting of the substrate. Prior to large-scale application, particularly over plastics, questionable surfaces or previous coatings, apply an inconspicuous test area to confirm adhesion and compatibility. If adhesion is inadequate, consult Edison Coatings, Inc. regarding use of an adhesion-promoting primer.

2. Application: Apply AQUATHANE UA-210 at 200 - 400 sq. ft./gallon by brush, pad, roller or low pressure airless spray. Apply evenly and moderately, avoiding rundown or ponding. Avoid excessive

agitation or pressure, and avoid whipping air into the product as this may generate foam. A second coat may be applied, if needed, at any time following through-drying of the first coat. Do not apply at temperatures below 50°F (10°C) or when temperatures may fall below 50°F before through-drying.

NOTE: Temperature, humidity and air movement all effect drying and curing times. When working at marginal conditions, allow sufficient extra dry and cure times to compensate.

On porous surfaces, UA-210 generally will require 2 or more coats. Gloss may be increased by applying additional coatings as required for particular job conditions. In anti-graffiti applications, sufficient material must be applied to build a continuous surface film. Generally two coats will be adequate, but deeply textured or highly porous surfaces may require additional coatings. Multiple coatings (three or more) may limit capacity of the coating to "breathe", or transmit vapor.

On wood surfaces, AQUATHANE UA-210 may exhibit slight grain-raising tendencies. For smoothest finish, sand lightly between first and second coats. On hardwood floors, cedar siding or other natural wood surfaces, staining may be desired prior to AQUATHANE UA-210H application. While the product is compatible with many oil and waterborne stains following overnight drying, compatibility testing in an inconspicuous area is always recommended. Some highly porous or moisture-sensitive fiberboards or simulated wood products may require the use of a 100% solids sealer/primer such as FLEXI-DECK 500-L/501-L before application of AQUATHANE UA-210.

On steel, galvanized steel and aluminum surfaces, abrasive cleaning is required to remove rust, loose scale or other corrosion products before coating. This should be followed by application of a corrosion-inhibiting, adhesion-promoting primer AQUAPRIME 211.

3. Curing: AQUATHANE UA-210 requires curing time before developing full traffic and chemical resistance. Graffiti resistance roughly parallels strength development, indicated above. Protection of surfaces from vandalism for at least 24-48 hours following application is recommended when possible. Cure may be accelerated by heating to 175°F for 20 minutes, following drying. Do not subject uncured films to heavy moisture or standing water.

4. Graffiti Maintenance: AQUATHANE UA-210H-A/G is intended to withstand repeated cleanings before reapplication is required. Most markers and spray enamels can be removed using Xylene or SYSTEM 100 without damage to the AQUATHANE coating. If stronger removal is required, methyl ethyl ketone may be used. Proprietary cleaners should be tested before use. Some highly durable stains may require the use of methylene chloride paste paint remover. When using strong removal agents, some loss of gloss in the AQUATHANE film may occur. This may be restored by light reapplication in the affected areas. After repeated cleanings, if the film appears rough or uneven, it is time for application of an additional AQUATHANE UA-210H-A/G seal coat.

CAUTION! Many solvents and cleaners commonly used for removing graffiti are hazardous chemicals requiring special care in storage and handling. Refer to manufacturers' Material Safety Data Sheets before using any chemical product.

5. Storage and Handling: KEEP FROM FREEZING. Keep container closed when not in use. Use with adequate ventilation. Avoid splashing into eyes or prolonged skin contact. Wash thoroughly after use. Clean tools and applicators immediately after use with warm water. Avoid depositing on shrubbery, windows, cars and other surfaces or property. In case of eye contact, flush with clean water for at least 15 minutes and consult physician. In case of ingestion, give water, do not induce vomiting. Keep out of reach of children. Observe all safety and handling guidelines as detailed in the Material Safety Data Sheets supplied with this product.

For Commercial and Industrial Use.

 Edison Coatings, Inc.

25 GRANT STREET · WATERBURY, CT. 06704 · (203) 597-9727

Figure A.1.b Edison Aquathane UA-210H product literature.





Chemique®

## PRODUCT INFO

# CPU-CII®

Protective Safety Sealer

### Description

CPU-CII is a permanent, single component, water based, safety sealer for interior or exterior applications, in industrial, commercial or residential environments. C-II is a combination of urethane polymers and a colloidal dispersion that produces a durable, flexible coating. When cured, C-II has excellent adhesive and cohesive properties and high abrasion and chemical resistance. It is unaffected by ultra-violet light, weathering, staining and acid rain.

C-II is a high solids, penetrating, low maintenance product that dries crystal clear and will not yellow with age. For added protection, an aqueous polysiloxane emulsion is incorporated for long term water repellency.

### Uses

CPU-CII is designed for new or cleaned stucco, concrete, cinder block, waylite block, limestone, wood, including cedar, pine and redwood. As a paint additive, CII will extend the life of any latex paint by adding one pint per gallon of paint. It also prevents out-gassing on most surfaces.

### Coverage & Preparation

Two coats is recommend on most surfaces. Coverage rates vary but average 300 square feet per gallon for the first coat and 400 square feet per gallon for the second coat.

All surfaces being treated, should be thoroughly cleaned to remove dirt, grease, stains, mildew and other contaminants with ION-417® or BAC-2-NU®.

### Properties

Appearance	Clear liquid
Odor	Slight ammonia
Flash Point	N/A
pH	8.0 - 8.5
lbs/gallon	8.4 - 8.6

### Application

CPU-CII can be applied by airless sprayer, low pressure sprayer, roller, brush or lambs wool applicator. Before applying, surface must be clean and thoroughly dry.

When finished, immediately purge spray equipment with ION-417®. Brushes and roller sleeves cannot be reused.

### Packaged

CPU-CII is available in gallons (6/case), 5 gallon pails, 15 and 55 gallon drums.

### Safety and Handling

For specific information, please refer to the material safety data sheet. CPU-CII is a non-hazardous, non-flammable sealer.

### Storage and Shelf Life

Store in a cool dry room. CPU-CII can withstand 3-4 freeze/thaw cycles; however, it is recommended that it is protected from freezing. The shelf life for CPU-CII is indefinite in closed containers.

### Ordering Information

CHEMIQUE, INC.  
315 N. WASHINGTON AVE.  
MOORESTOWN, NJ 08057  
TEL: 800 225 4161 NJ 609 225 4161

Figure A.2 CPU-CII Protective Safety Sealer product literature.



# PRODUCT DATA

## BREATHABLE MASONRY COATING 55

BMC™

### DESCRIPTION AND USE

BMC™ 55 coating is an economical, general purpose, pigmented water-base product for interior and exterior surfaces. BMC™ 55 contains a special acrylic binder for excellent adhesion and long-lasting durability. It also provides good moisture vapor permeability. This easy-to-use coating has a water vapor transmission of 55%, allowing destructive moisture vapor to escape, but it stops water from entering the masonry. Because of its breathability, BMC™ 55 reduces peeling and blistering that can occur with conventional paints.

BMC™ 55 is especially suitable for protecting surfaces exposed to extreme weather and harsh atmospheric pollutants. It protects against atmospheric staining, leaching, efflorescence and mildew. BMC™ 55 is suitable for use on a variety of masonry and nonmasonry surfaces including brick, concrete block, stucco, natural stone, and wood.

BMC™ 55 is available in white and 15 other popular colors that dry to a flat finish. Custom colors are also available.

#### ADVANTAGES

- Excellent coverage
- Good salt spray and humidity resistance
- Excellent color retention
- Meets VOC requirements
- Good water vapor transmission
- Compatible with BMC™ Blok-It®
- Easy to apply; cleans up with water
- Ideal for interior/exterior surfaces
- High elongation, good flexibility
- Low cost

### APPLICATION INFORMATION

#### PREPARATORY WORK

Do not apply in temperatures below 40°F, or when temperature is expected to fall below 40°F within 24 hours. Surface temperatures should not exceed 95°F at the time of application.

Protect all surrounding surfaces, which are not to be coated, with drop cloths or other proven protective material.

Glazed or gloss surfaces should be roughened or abraded, and chalky surfaces should be cleaned prior to application. All surfaces need to be clean and sound. Efflorescence and moisture-related stains should be cleaned from the surface using the appropriate Sure Klean® cleaner. The cause of the condition should be determined and the appropriate corrective measures taken. All algae or mildew must be thoroughly removed for good performance of the coating. For information on surface preparation, contact your BMC™ representative or distributor.

Always test before application. BMC™ 55 comes ready-to-use. Material should be stored in sealed containers and kept away from extreme heat. Protect from freezing. Storage life is one year.

Figure A.3.a Breathable Masonry Coating 55 product literature.



<b>EQUIPMENT</b>	Material can be applied by brush, roller or airless spray, depending on the size of the area and substrate. Porous substrates may need to be back-rolled to ensure a satisfactory application and good coating performance.
<b>THINNING</b>	Mix well before applying. For some spray applications, it may be necessary to thin the coating slightly. Use only clean water and sparingly; never more than 5%, since thinning affects color density. Always test to ensure coating is covering completely.
<b>APPLICATION</b>	BMC™ 55 may be applied on interior or exterior surfaces. Surfaces must be dry and absorbent prior to application. Allow first application to dry 2 hours before application of the second coat. Protect from rain for at least 6 hours. After the coating has dried completely (24 hours), BMC™ 55 needs no special maintenance.
<b>RECOMMENDED COVERAGE</b>	<ul style="list-style-type: none"> <li>• Apply two coats; 5 mils wet first coat, 3 mils for second coat or approximately 3 mils dry.</li> <li>• Theoretical coverage rate for BMC™ 55 applied to smooth, dense surfaces is equal to 375 - 425 sq. ft./gal. per coat.</li> <li>• When estimating coverage rates, allow for surface porosity, texture and profile. (e.g. Measured coverage rate for BMC™ 55 applied to smooth, porous concrete block is equal to 205 sq. ft./gal. per coat.)</li> </ul>
<b>CLEAN UP</b>	Equipment used for application of the material should be cleaned with warm water and mild detergent. If coating is thoroughly dried, the use of solvent paint thinners may assist in removal.

TEST METHOD	Exposure	Results	Date
Q-U-V Accelerated Weathering Test FS-40 (ASTM G 53)	1,008 hrs.	ΔE 1.94	2/89
Accelerated Weathering Test Federal test method 141,6152 Carbon ARC	600 hrs.	ΔE 2.37	2/89
Salt Spray Resistance (ASTM B 117)	504 hrs.	no change	2/89
Humidity Resistance (ASTM D 2247)	504 hrs.	no change	2/89
Tensile Strength (ASTM D 412)	————	107 psi	10/88
Elongation (ASTM D 412)	————	2,106%	10/88
Water Vapor Transmission (ASTM E 96)	————	55%*	7/89
Adhesion by Tape Test (ASTM D 3359)	————	no peeling/removal	7/89

\* Percentage reflects the amount of water that passes through the treated sample versus the untreated sample(100%).

### TECHNICAL INFORMATION

<b>GENERIC TYPE:</b>	Acrylic emulsion	<b>WEIGHT PER GALLON:</b>	11.65 lbs.
<b>PIGMENT:</b>	Titanium dioxide rutile Inorganic and organic colored pigments	<b>FLASH POINT:</b>	None
<b>BINDER:</b>	Modified-acrylic polymer	<b>DRYING TIME:</b>	(Normal 77°F, 50% R.H.) Touch: 35 minutes Recoat: 2 hours
<b>PERCENT SOLIDS BY WEIGHT:</b>	56.0%	<b>REDUCTION SOLVENT:</b>	Water
<b>PERCENT SOLIDS BY VOLUME:</b>	37.5%	<b>CLEAN UP SOLVENT:</b>	Water
<b>PERCENT PIGMENT BY WEIGHT:</b>	36.8%	<b>TYPE OF CURE:</b>	Coalescence

Figure A.3.b Breathable Masonry Coating 55 product literature.





**1. PRODUCT NAME**

CONFORMAL® Stain, acrylic stain for concrete, masonry, brick and stucco walls; CONFORMAL® Clear Anti Graffiti, protective coating against graffiti

**2. MANUFACTURER**

Chemprobe Technologies, Inc.  
2805 Industrial Lane  
Garland, TX 75041  
Phone: (214) 271-5551  
FAX: (214) 271-5553

**3. PRODUCT DESCRIPTION**

**Basic Use:** CONFORMAL® Stain adds permanent color to concrete and masonry surfaces without disturbing the natural texture. CONFORMAL® Stain is available in ten (10) standard colors as well as custom colors matched to a specific need. On porous surfaces, it forms a breathable coating which allows the release of water vapor. Effectively repels water from dense surfaces such as precast panels, and from masonry and porous surfaces when used with PRIME A PELL® 200.

**Advantages:**

- One coat application
- Custom color matching
- Can be factory thinned to leave aggregate exposed
- Compatible with caulking and sealing compounds

**Resists:**

- Water intrusion
- Stain damage
- Freeze-thaw spalling
- Efflorescence
- Color fading

CONFORMAL® Clear Anti Graffiti is a clear protective coating for brick, concrete, stucco, masonry and natural stone surfaces. It provides vertical surfaces with an excellent mar, scratch, impact, grease, and stain resistant

coating. The protective film prevents penetration of graffiti markings and spray paints allowing a much faster and easier removal than from untreated surfaces.

**Advantages:**

- Nondestructive coating
- Graffiti markings removable with water soluble paint remover

**Resists:**

- Graffiti paint
- Marring
- Scratching
- Grease
- Water intrusion

**Limitations:** CONFORMAL® Stain was developed to retain the beauty of substrate texture and does not close the open pores of concrete block units. Concrete block and split face units must receive a first coat of PRIME A PELL® 200 for effective water repellency. When completely changing the color of lightweight products, two coats may be necessary. A test application is always recommended. CONFORMAL® Clear Anti Graffiti when used alone or with PRIME A PELL® will darken the substrate one shade.

**Composition and Materials:** CONFORMAL® Stain is a solvent based acrylic formulated with a color flattening fumed silica and colored with non-fading inorganic oxide pigments.

CONFORMAL® Clear Anti Graffiti is a solvent based meth-

# SPEC DATA®

This Spec-Data sheet conforms to editorial style prescribed by The Construction Specifications Institute. The manufacturer is responsible for technical accuracy.

acrylate copolymer also containing a fumed silica as a flattening agent.

**4. TECHNICAL DATA**

Refer to Table I.

**5. INSTALLATION**

**Preparatory Work:** The surface to be treated must be sound, dry and free of cracks, dirt, oils, paint or other contaminants which may effect the appearance or performance of CONFORMAL® Stain or CONFORMAL® Clear Anti Graffiti. For best performance and coverage rate, wall and air temperatures should be above 50° F (10° C). Application at lower temperatures may substantially reduce coverage rates. New masonry must be allowed to cure for fifteen to thirty days (depending on weather conditions) before application.

**Precautions:** Use only in well ventilated or open areas. Keep away from open flame or extreme heat. Avoid breathing vapors, repeated contact with the skin and contact with eyes. The use of an organic mask and eye protection during application is recommended. Overspray should be removed immediately with lacquer thinner or acetone. Shield and protect from overspray; plants and shrubs, glass, painted surfaces, wood frames and anything

Table I: Technical Characteristics

	CONFORMAL® Stain	CONFORMAL® Clear
Flash Point	105° F (40.5° C)	105° F (40.5° C)
Weight per Gallon	9.0 lb/gal (1078 g/l)	8.25 lb/gal (988 g/l)
Solubility in Water	None	None
Solids Content	25% +/-5%	22%
Abrasion Resistance	Excellent	Excellent
Appearance	Liquid Stain Color	Semi-Opaque Liquid
Storage	Not above 120° F (49° C)	Not above 120° F (49° C)

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0990C

Figure A.4.a Conformal Stain product literature.



else that is not to be coated and is subject to overspray

**Application:** CONFORMAL® Stain and CONFORMAL® Clear Anti Graffiti can be applied using an airless spray, brush, or deep nap roller. For airless spray application use a 0.015 or 0.018 fan spray tip and reduce pressure to a point of minimal misting or fogging to produce a wet application. These products should be used as supplied by the manufacturer. Do not dilute or thin. Coverage rates are dependent upon substrate porosity and degree of color change desired. Light weight materials may require two coats to fully change colors. A test application should be done to determine exact coverage rate. For best performance and coverage rate, wall and air temperatures should be above 50° F (10° C). Application at lower temperatures may substantially reduce coverage rate. Refer to Table II for approximate coverage rates of various substrates.

For the best anti-graffiti results on lightweight or porous substrates, apply two coats of CONFORMAL® Clear Anti Graffiti at an average coverage rate of 100 to 125 square feet per gallon. Allow a minimum of five (5) hours between coats. If color is desired a single coat of CONFORMAL® Stain and a single coat of CONFORMAL® Clear is sufficient. Graffiti is removed using a water soluble gel type paint remover. Turpentine or paint thinner (not lacquer thinner) might be necessary on tougher stains. These cleaners are nondestructive to the protective coating.

#### 6. AVAILABILITY AND COST

**Availability:** CONFORMAL® Stain and CONFORMAL® Clear Anti Graffiti are available in 1, 5 and 55 gallon containers from distributors throughout the United States. Contact Chemprobe for the distributor nearest you

CONFORMAL® Stain comes in ten standard colors. Custom color matching is also available from the Chemprobe laboratory. Color charts and samples will be provided upon request.

**Cost:** Material cost is dependent on container size and geographical location. Prices are available from your local distributor or our sales office in Garland, TX

#### 7. WARRANTY

Chemprobe will provide a written limited warranty against product failure. Chemprobe also warrants that its products are free from defect in materials and workmanship. Liability of Chemprobe under all warranties, expressed or implied, shall be limited to the replacement of product.

#### 8. MAINTENANCE

None required. If reapplication of CONFORMAL® Stain or CONFORMAL® Clear Anti Graffiti is requested, it will blend into itself and not leave a layered look

#### 9. TECHNICAL SERVICES

Complete technical assistance and information is available from select Chemprobe distributors or our Technical Department in Garland, TX. Phone: (214) 271-5551 or FAX: (214) 271-5553.

#### 10. FILING SYSTEMS

• SPEC-DATA® II

Table II: Approximate Coverage Rates for CONFORMAL® Stain

	sq ft/gallon	meter <sup>2</sup> /liter
Concrete Block (Light Weight)	75-100	1.8-2.5
Concrete Block	100-125	2.5-3.1
Stucco	100-125	2.5-3.1
Brick (Fired)	150-200	3.7-4.9
Concrete Panels	150-200	3.7-4.9

\*Two coats may be required to drastically change the color of a substrate.  
 \*\*Coverage rates are approximate. A test application should be done to determine exact coverage rates for the desired color

# CHEMPROBE TECHNOLOGIES, INC.

2805 Industrial Lane • Garland, TX 75041 • (214) 271-5551 • FAX (214) 271-5553

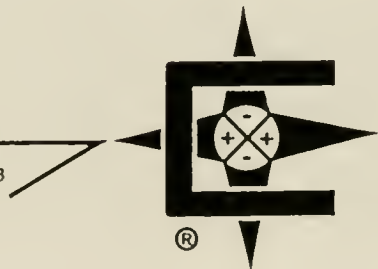


Figure A.4.b Conformal Stain product literature.



# 350 - SERIES

## Waterborne Elastomeric Coatings

**ELASTO DECK 350**

**ELASTO MASTIC 352**

**ELASTO WALL 351**

**ELASTO TONE 353**

### Description:

*350-Series* coatings are high-solids, internally plasticized, waterborne acrylic elastomers with exceptional water and weather resistance. They offer an opportunity to accomplish three major objectives in one process:

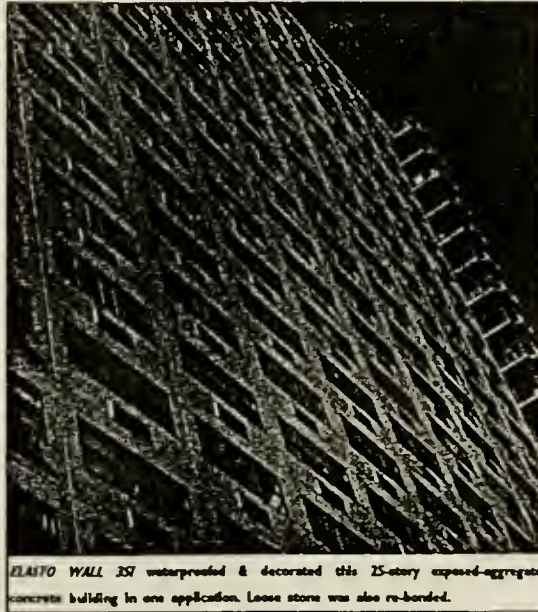
- ✓ 1. Seal small working cracks
- ✓ 2. Waterproof porous surfaces
- ✓ 3. Provide highly decorative finishes

Their combination of high build, outstanding exterior durability, and low temperature flexibility make the *350-Series* the coatings of choice for the most demanding

applications. Advanced waterborne formulation represents the state of the art in handling convenience, safety, low odor and low V.O.C.'s. The result is a high-performance coating system that is both *User and Environmentally Friendly*.

*ELASTO DECK 350* is designed for use on properly pitched or drained roof surfaces which may intermittently accumulate puddles or ponded water. It may be applied over a wide range of substrates, including concrete, plywood, polystyrene foam, metal, and many types of existing roofing materials.

*ELASTO WALL 351* is designed to waterproof and decorate vertical and sloped above-grade surfaces, including porous block, exposed aggregate concrete panels, polystyrene foam, exterior stucco/insulation



*ELASTO WALL 351* waterproofed & decorated this 25-story exposed-aggregate concrete building in one application. Loose stone was also re-banded.

systems, and glaze-crazed terra cotta, including walls exhibiting small working cracks. It has somewhat higher vapor permeability and elongation than *ELASTO DECK 350*, which offers better ponded water resistance.

*ELASTO MASTIC 352* is a knife-grade, higher solids formulation designed for pre-treatment of surface defects and cracks prior to general coating application. Depressions and defects are simply "spackled", and then a *350-Series* coating is applied after drying.

*ELASTO TONE 353* is a color finish system designed for economical, decorative and "touch-up" applications. Based on the same chemistry as

*ELASTO WALL 351*, it features high elongation and low temperature flexibility, while offering greater economy, due to lower build and higher application rate. It is ideally suited to cosmetic renewal of older *ELASTO WALL 351* applications.

### Features:

**Appearance:** *350-Series* coatings are available in a wide range of other Standard and Custom colors. Custom color matching is also available. In addition, *350 & 351* are available in textured versions, some of which simulate natural stone finishes. Products are non-chalking, non-yellowing, and resistant to dirt pick-up.

**Elongation:** Permanent flexibility, and low temperature flexibility, even at -30°F (-34°C) is assured through

Figure A.5.a Elasto Wall 351 product literature.



plasticizer-free formulation. High build and elongation allow the coatings to expand and contract with substrate temperature and volume changes, even on surfaces with small working cracks. Products also resist impact and vibration without fatigue or rupturing.

**Breathing:** Moisture vapor is allowed to escape through the film, preventing coating failure and substrate damage which may otherwise result from moisture entrapment.

**Safety:** Products are non-flammable, essentially non-toxic, non-corrosive and free of solvent odors. Eye contact and prolonged skin contact may produce some irritation, and should therefore be avoided.

**Environmental:** At VOC < 250 g/l, complies with regulations for architectural coatings.



Textured Uimestone ELASTO WALL 351 provided a new stone-like finish without complete abrasive removal of existing paint from this church's cast stone elements.

### COVERAGE RATES:

Typical coverages are 100-120 sq.ft./gal. per coat for "average" surfaces. Rough surfaces and textured formulations yield lower coverage rates. For decoration, 1 coat is usually adequate. For crack bridging and waterproofing two coats are recommended.

### PROPERTIES:

	350	351	352	353
Density: (lbs/gal)	12.9	12.3	13.6	11.5
Solids, %: (by wt.)	72%	69%	84%	55%
Elongation at break: (20 mils DFT @ 70°F)	290%	330%	330%	330%
Tensile Strength:	280 psi	250 psi	250 psi	250
Low Temp. Flexibility:	PASS 180° Bend at -30°F (-34°C)			
Breathing: (ASTM E-96-80)	5 - 8 perms @ 20-30 mils DFT			
Accelerated Weathering: 1000 hrs. (ASTM G-53-84)	No yellowing, fading, swelling, blistering, chalking or cracking			
Adhesion:	Concrete	Concrete	Concrete	Wood
	Polyurethane Caulk	Polyurethane Foam	Polystyrene Foam	Stucco
	Concrete Block	Asphalt Roof Shingles	Galvanized Metal	Brick
	Terra Cotta Glaze	Latex-modified Patch & Overlays	Many Previously Coated Surfaces	Stone
				B.U.R.

### Application:

1. **Surface Preparation:** 350-Series products are applied to clean, sound substrates free of grease, oil, chalk, dirt, efflorescence, and unsound or incompatible previous coatings. Surfaces may be damp or dry, but do not apply to saturated surfaces or where moisture has accumulated. Pre-patch unsound substrates prior to application. For repairs to concrete or masonry surfaces, refer to product data for SYSTEM 44 and Custom SYSTEM 45. Some applications, particularly on highly porous or chalky surfaces, require use of #342 primer. Consult your Edison Coatings technical representative.

2. **Application:** 350-Series coatings are high-build systems which resist sagging on vertical applications. Accordingly, application procedure will directly affect finished appearance. Spraying, rolling and brushing are acceptable application methods, within this limitation. Products are supplied ready to use and require no thinning, but up to 4 ounces per gallon of clean water

Figure A.5.b Elasto Wall 351 product literature.





may be added, if required, to facilitate spreading. Monitor film build particularly closely when water is added for thinning purposes.

Clean runs, spills and equipment with warm water and soap immediately. Coatings which have been allowed to "set" will resist water cleanup. If significant interruptions in spray application will occur, immerse gun or tip in clean water during interruption.

*ELASTO DECK 350* should be applied in two to three coats, at 100 sq. ft./gallon per coat to a total dry film thickness of 20 - 30 mils. A wet film thickness gauge should be used to control application rate at 16 - 20 wet mils per coat. Allow thorough drying, typically overnight, between coats.

*ELASTO WALL 351* can be applied in one coat, on uncracked substrates, at 100 sq.ft./gal., or in 2-3 coats where greater waterproofing and crack bridging are required (Dry film thickness= 8 - 10 mils. Wet film thickness= 15 - 18 mils per coat.)

*ELASTO MASTIC 352* is knife-applied to fill surface voids and defects, and to detail cracks before coating.

*ELASTO TONE 353* is applied in one or two coats at 200 sq.ft./gal. to achieve color uniformity and continuous, water-resistant films. (8 - 12 wet mils per coat are applied to achieve 4 - 6 dry mils per coat.)

### Crack Detailing:

Cracks less than 1/16" wide can be bridged by spackling with *ELASTO MASTIC 352*. Cracks up to 1/8" wide should be grooved out to a width of 1/4" to 3/8" and should be filled with *ELASTO MASTIC 352* or *HYDROSPAN EC-401*. Cracks wider than 1/8" should be cut out and shaped in accordance with proper expansion joint detailing and geometry, and should be sealed with *HYDROSPAN ES-400* or *EC-401* polyurethane sealants. Sealants should be cured a minimum of 24 hours before coating.

### LIMITATIONS:

*350-Series* coatings are not designed for continuous water

submersion, below-grade installation, against hydrostatic pressure, or against high constant humidity differentials where moisture originates from behind the coating (negative side waterproofing).

*ELASTODECK 350* is designed for use in light to moderate foot traffic areas. Higher traffic surfaces will require more frequent reapplications. Use on vehicular traffic surfaces is not recommended. For continuous submersion or more severe chemical exposures, use *FLEXI-DECK 500-U* elastomeric membrane.

*ELASTO MASTIC 352* is not a replacement for proper expansion joint sealants. Joints, windows, vents and other penetrations should be caulked with *HYDROSPAN 400-Series* sealants.

*350-Series* coatings are suitable for exterior or interior application.

### Storage & Handling:

**KEEP FROM FREEZING.** Store in tightly closed containers. Use with adequate ventilation. Avoid eye or prolonged skin contact. Wash with soap and water after use and before eating, drinking or smoking. Avoid breathing spray mists. Use mist filter when spraying. In enclosed areas, use supplied air respirator. In case of eye contact flush with clean water for 15 minutes. If irritation persists, see physician. Do not ingest. Observe all safety and handling guidelines as detailed in the Material Safety Data Sheets supplied with these products. **KEEP OUT OF REACH OF CHILDREN.**

### Color Selection:

*ELASTO-WALL 351* & *ELASTO-TONE 353* are available in a wide range of standard and custom colors. Refer to the Edison Restoration Colors chart, or the Edison Color Selector fan deck. Custom color-matching is also available.

*ELASTO-DECK 350* is available in White, Medium Grey, or a variety of custom colors.

*ELASTO-MASTIC 352* is available in a "neutral" off-white color only.

Figure A.5.c Elasto Wall 351 product literature.



Cathedral Stone Products is not just a product supplier. Our extensive background in the restoration and reconstruction marketplace gives us a clear advantage. We have the experience to evaluate a product that is not only good in theory, but also practical for use in the field. We test our products on actual restoration projects before we recommend them for general use.

## Jahn Restoration Mortars 04520 Masonry Restoration

### 1.00 General 1.01 Description

## Patching and Unit Casting

Jahn Restoration mortars are intended for the repair of architectural masonry including brick, bluestone, cast stone, concrete, granite, limestone, marble, plaster, sandstone, slate and terra-cotta. Jahn Mortars are preblended, no field adjustments or coloring is needed.

## Injection Grouts

Jahn injection grouts are intended for crack sealing and void filling in the stabilization of any masonry material. Jahn injection grouts produce excellent penetration and bond strength with no chlorides, metal compounds or leachable constituents.

### 2.00 Products

#### 2.01 Product Composition

Cathedral Stone carefully formulates each mortar to match, as closely as possible, the physical properties of the masonry material

being repaired. Close attention is devoted to color, texture, hardness and moisture permeability of each mortar. Careful selection of aggregates, cements and other proprietary mineral ingredients improve job site quality control and promote consistent product performance.

The complete line of Jahn M-Series mortars are cementitious based, with no acrylics, polymers, or metal constituents present. No bonding agents should be added, or applied to surfaces, prior to mortar application.



Jahn mortars are very durable and can withstand extreme climatic conditions. The mortars come in many different standard compositions and colors and can be customized when adequate site samples are supplied.

### 3.00 Execution

#### 3.01 Patching

The application and finishing techniques are different from more traditional methods and should be taught to new users. When properly applied the mortars will weather naturally as the original masonry and therefore ensure a quality repair.

Jahn patching mortars can be applied directly in considerable thicknesses without the need for layering. Minimum depth of application should be 1/4". Finishing should be done by scraping the excess material down to the desired surface level. Detailing can be done while the material is still damp. The mortars bond so well that if additional finishing is required it can be done once the repair has cured. These mortars can also be cast for unit replacement.

#### 3.02 Injection Grouts

Jahn cementitious injection grouts are easily applied by various standard injection techniques. These injection grouts are suitable for low or high pressure application. Choice of equipment and method depends on the construction to be injected.

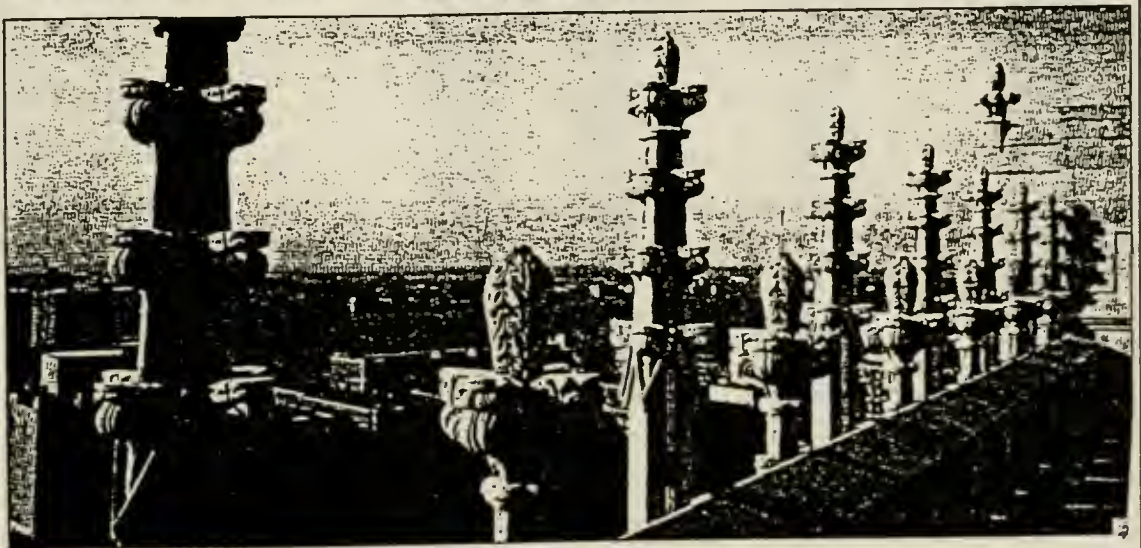
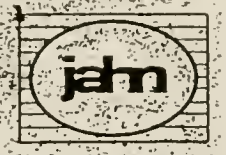
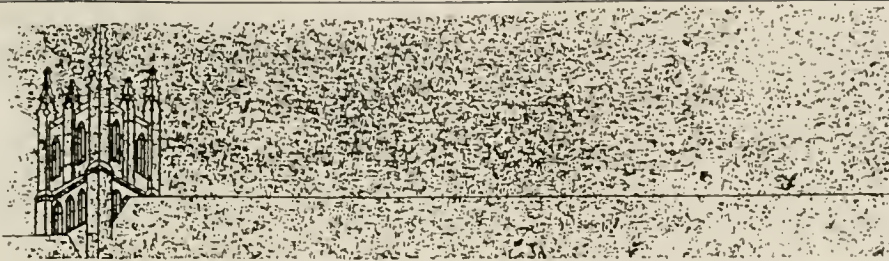


Figure A.6.a Jahn M100-101 Brick & Terra Cotta Repair Mortar product literature.





### Anchor Setting—M80

- For securing anchors in new construction or retrofit applications
- High compressive strength
- Safe and easy to use, mixes with water
- Can be custom colored

### Structural Concrete—M90

- For repair of structural reinforced concrete
- Easily applied with a trowel
- Good for high traffic areas
- Can be custom colored

### Brick and Terra-Cotta—M100

- For repair of common and ornamental clay red masonry.
- Can be used on some marbles
- Excellent cost saving alternative to unit replacement

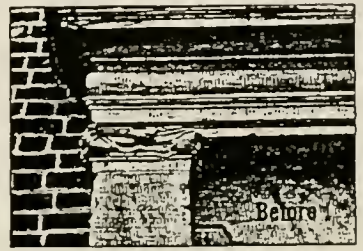
- Surface resembles a matt finish
- Repairs can be coated to simulate glaze
- Several standard colors are available
- Can be custom colored

### Special Dry Casting Mortar—M150

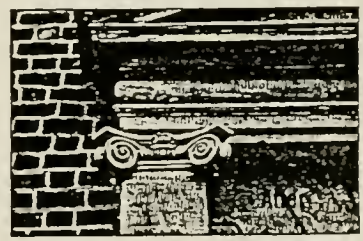
- For mold casting of replacement masonry units
- Can be used with most mold making techniques
- Extremely low water to mortar ratio stops shrinkage
- Fast setting—can be turned out within 48 hours
- Standard grey mortar color
- Can be custom colored and/or stained

### Granite—M160

- For repair of granite
- Slow curing with water
- Can be custom colored
- Can be stained to match



*Pohick Church, Ft. Belvoir, V.A.  
Cast replacement capitals using Jahn M150 - special dry casting mortar*



### Product Selection Chart

	BLUESTONE	BRICK	CONCRETE	GRANITE	LIMESTONE	PLASTER	PRECAST	SANDSTONE	STUCCO	TERRACOTTA
Injection Grout M30	◆		◆		◆		◆	◆	◆	
Injection Grout M40			◆		◆		◆	◆		
Injection Grout M50			◆		◆		◆	◆		
Stucco M60						◆			◆	
Stone Patch M70	◆				◆		◆	◆		
Anchor Grout M80	◆		◆		◆		◆	◆		
Concrete Patch M90			◆				◆			
Brick/TC Patch M100							◆			
Dry Cast Mortar M150	◆		◆		◆		◆	◆		

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Figure A.6.b Jahn M100-101 Brick & Terra Cotta Repair Mortar product literature.



**APPENDIX B**  
**Experimental Program Data**





**APPENDIX B**  
**Experimental Program Data**



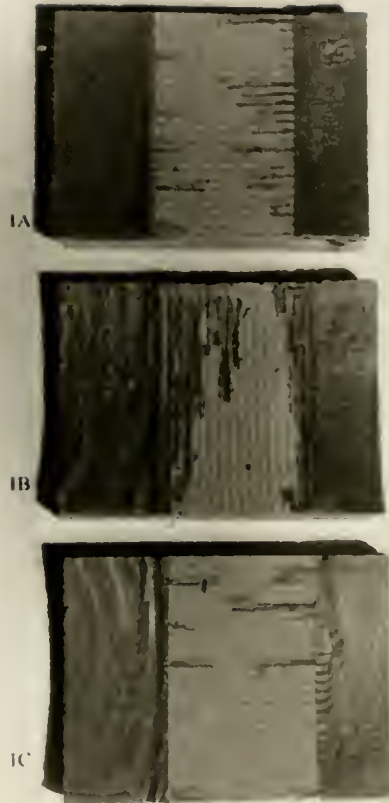


Figure B.1 Edison Aquathane UA-210H specimens before weathering.



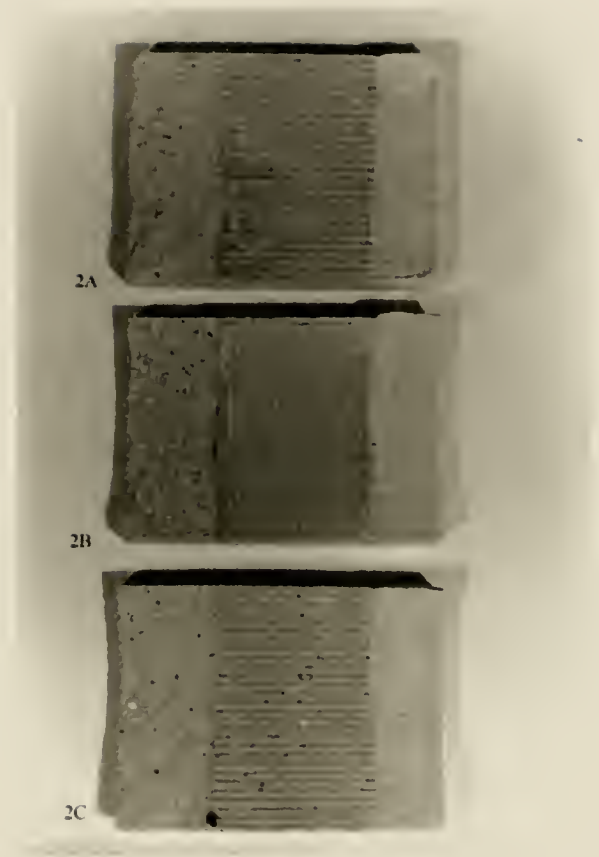


Figure B.2 CPU-CII Protective Safety Sealer specimens before weathering.



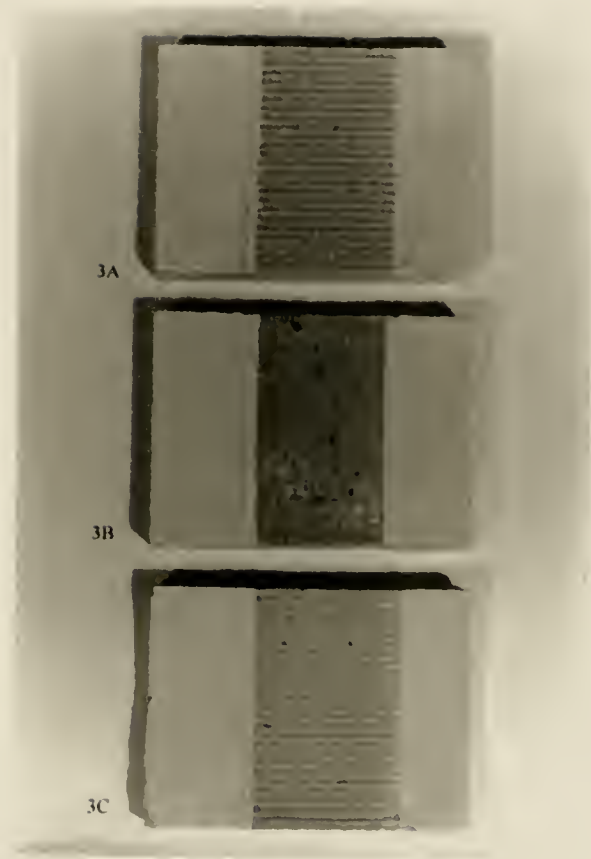


Figure B.3 Breathable Masonry Coating 55 specimens before weathering.





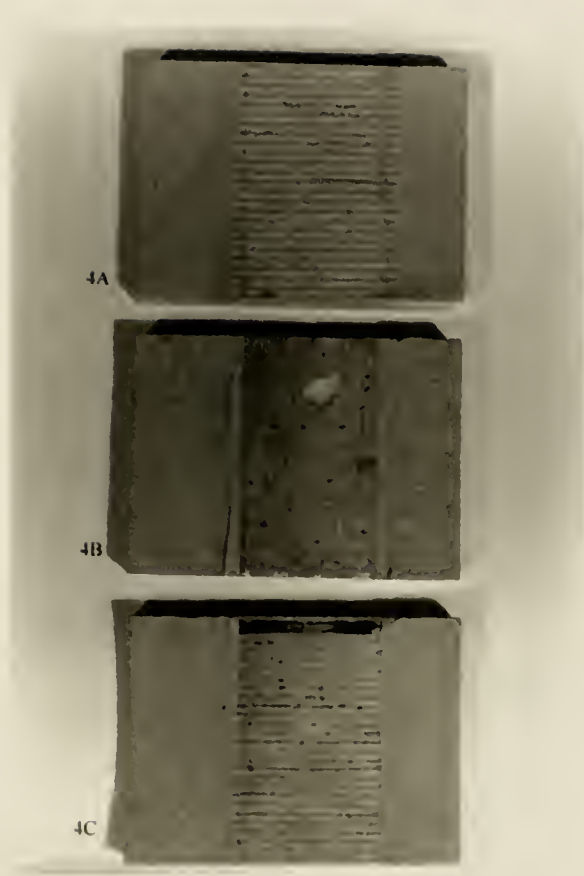


Figure B.4 Conformal Stain specimens before weathering.



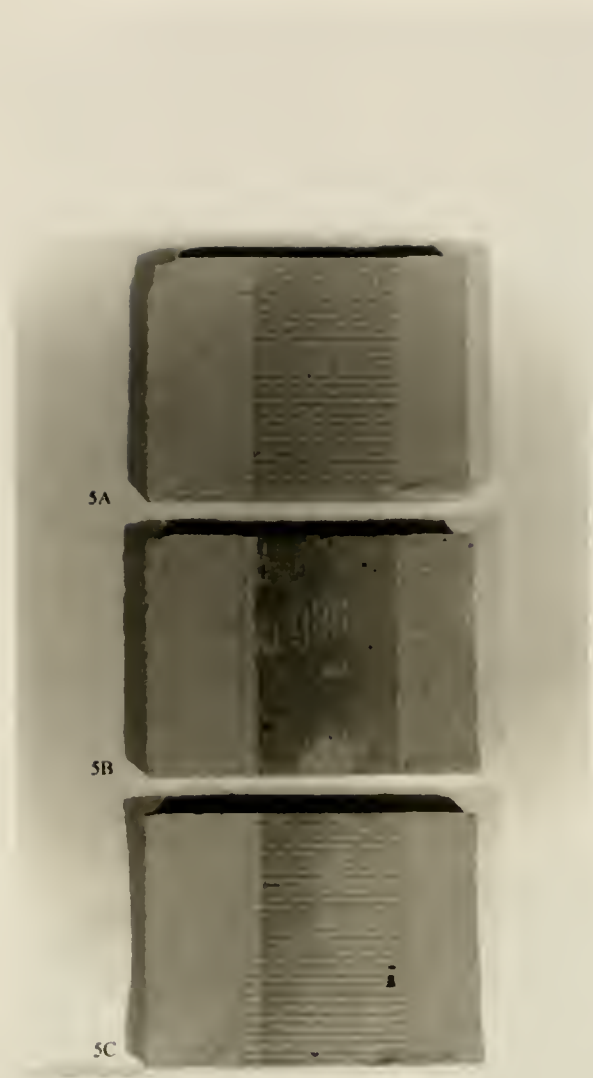


Figure B.5 Elasto Wall 351 specimens before weathering.



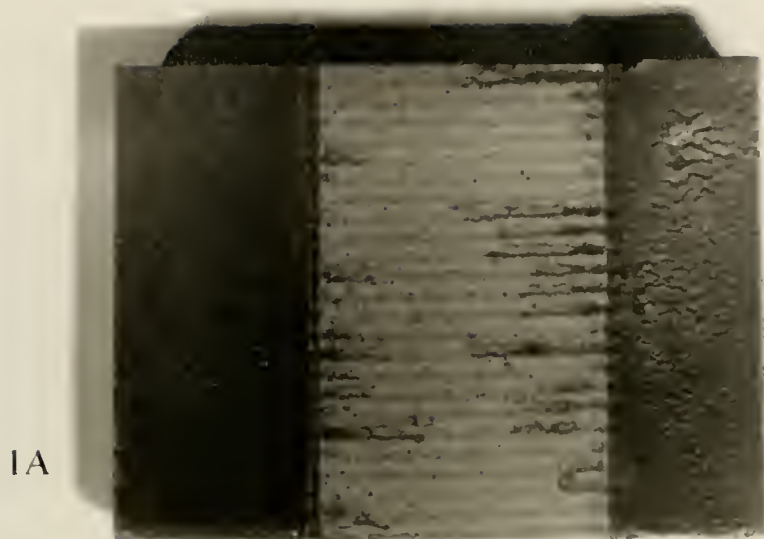


Figure B.6 Edison Aquathane UA-210-H specimen 1A before weathering.

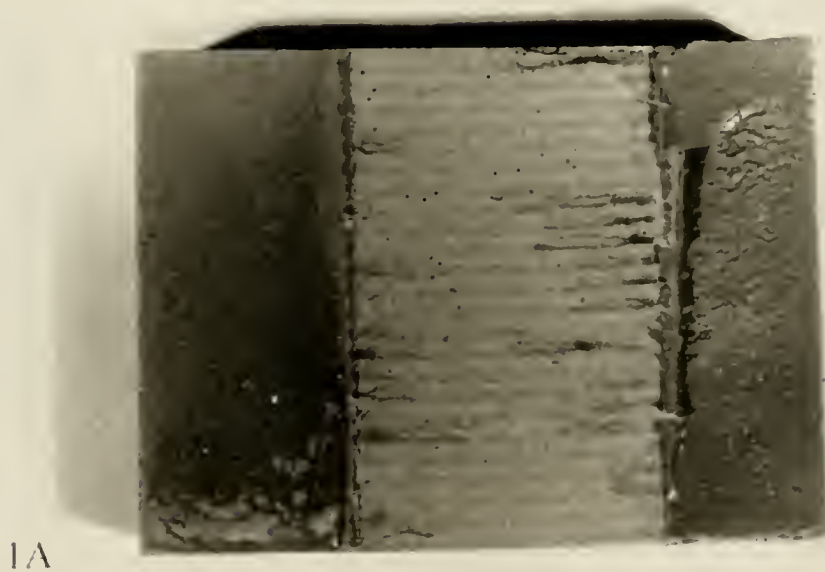


Figure B.7 Edison Aquathane UA-210-H specimen 1A after 6 cycles. Note peeling of coating from glaze surface, white spots on both coated surfaces, and minor cracking.



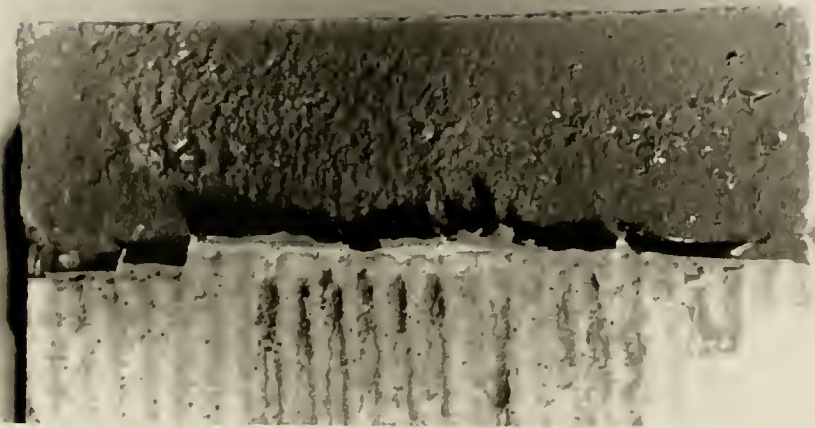


Figure B.8 Edison Aquathane UA-210-H specimen 1A mortar after 18 cycles. Note further peeling of coating from glaze surface, exposed mortar, and further cracking.

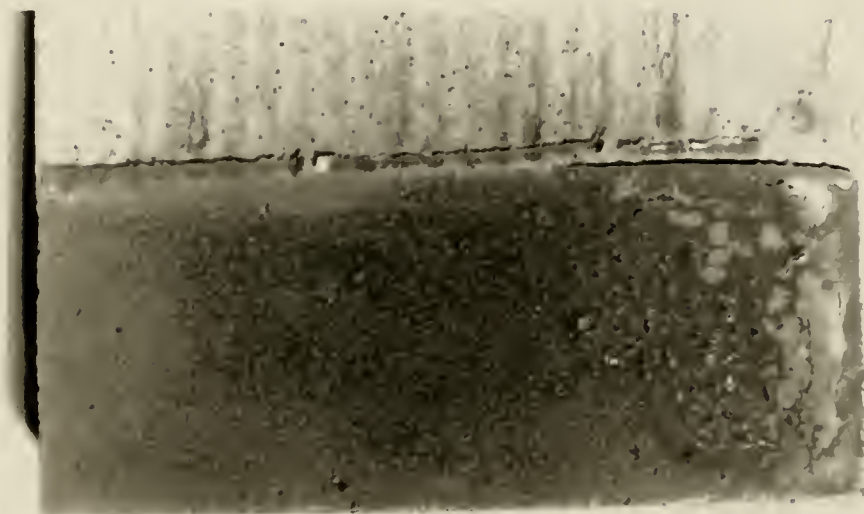


Figure B.9 Edison Aquathane UA-210-H specimen 1A terra cotta after 18 cycles. Note cracking, white staining, and coating lifted from glaze surface.





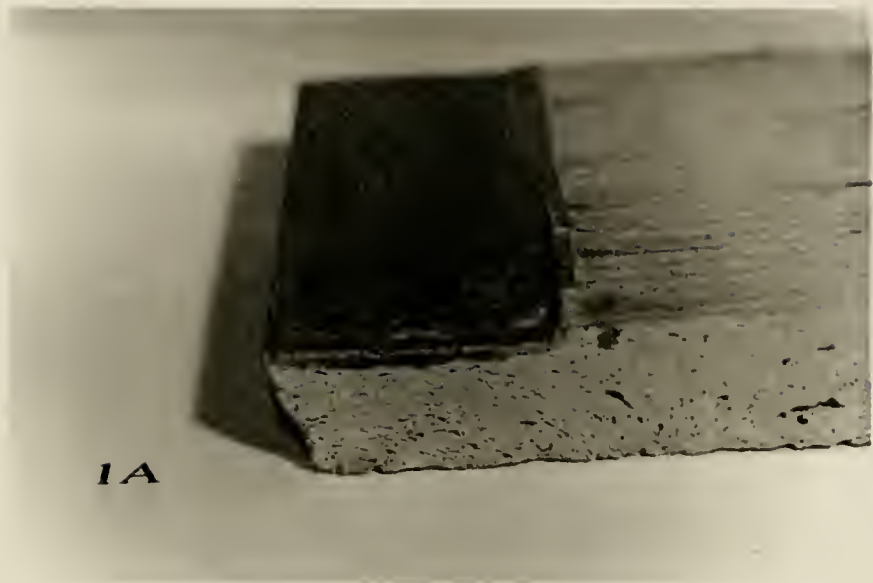


Figure B.10 Edison Aquathane UA-210-H specimen 1A terra cotta after 18 cycles. Note coating separated from edge of specimen.

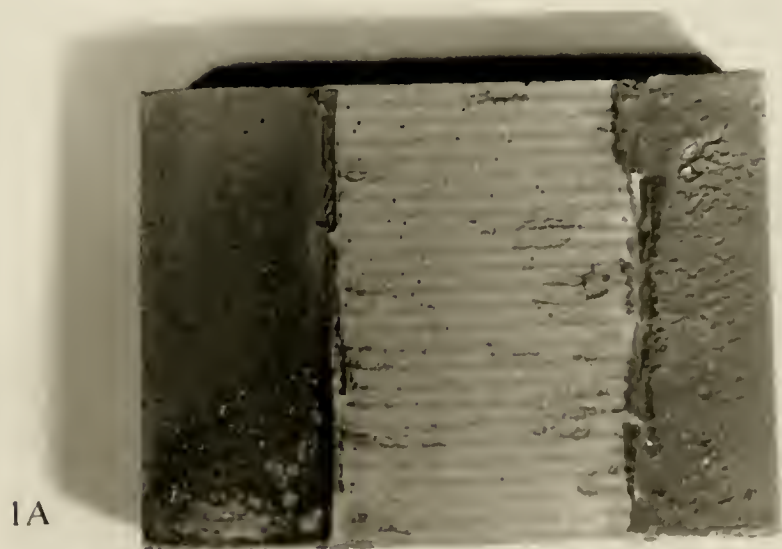


Figure B.11 Edison Aquathane UA-210-H specimen 1A after 52 cycles. Note continued weathering of all previous conditions.



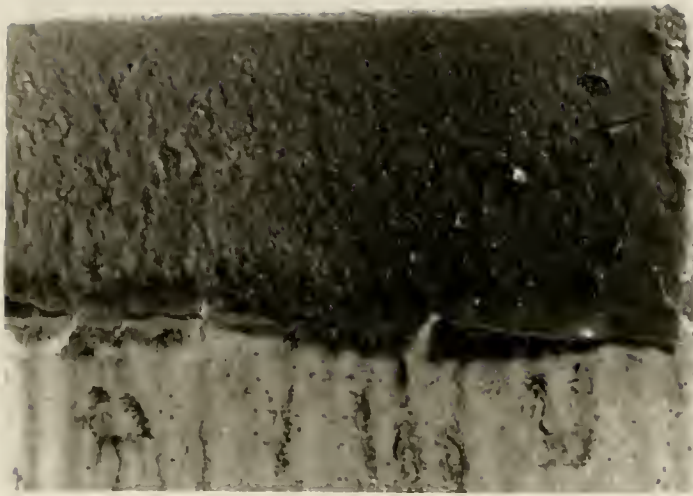


Figure B.12 Edison Aquathane UA-210-H specimen 1A mortar after 52 cycles. Note cracking and peeling of coating.

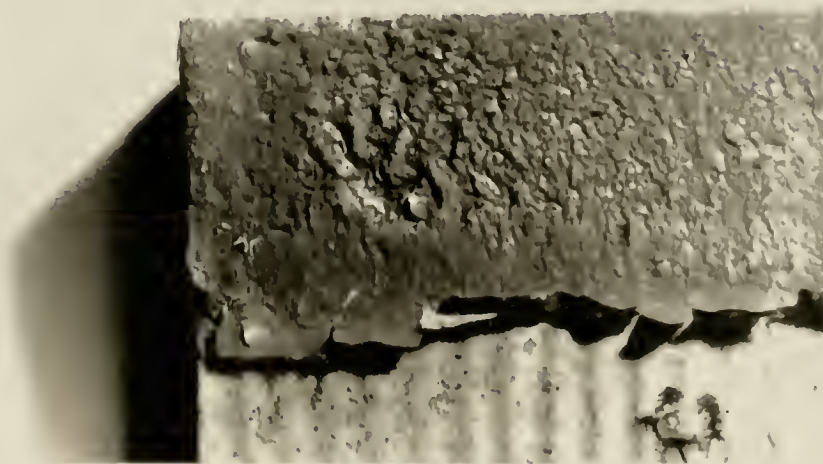


Figure B.13 Edison Aquathane UA-210-H specimen 1A mortar after 52 cycles. Note cracking and peeling of coating.



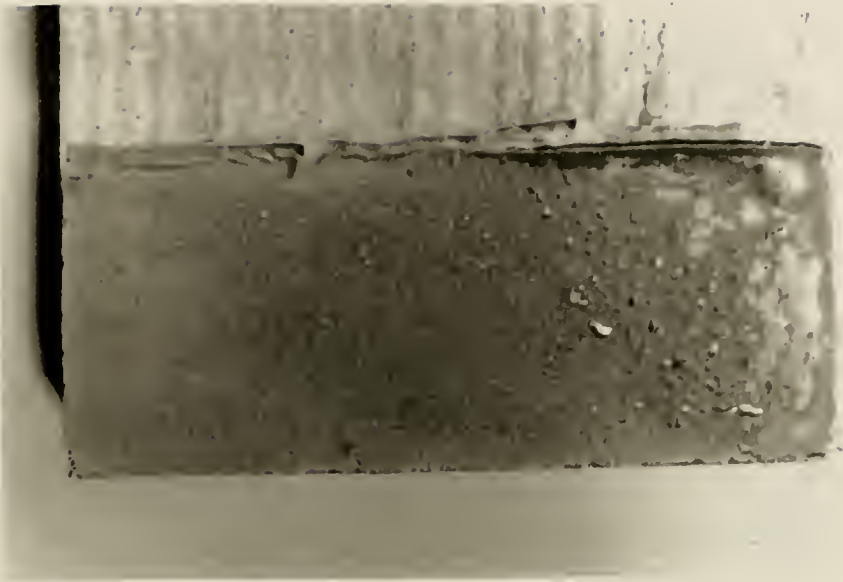


Figure B.14 Edison Aquathane UA-210-H specimen 1A terra cotta after 52 cycles. Note continued cracking, white staining, and coating separated from glaze surface.



Figure B.15 Edison Aquathane UA-210-H specimen 1A after 52 cycles. Note coating further separated from edge of specimen.



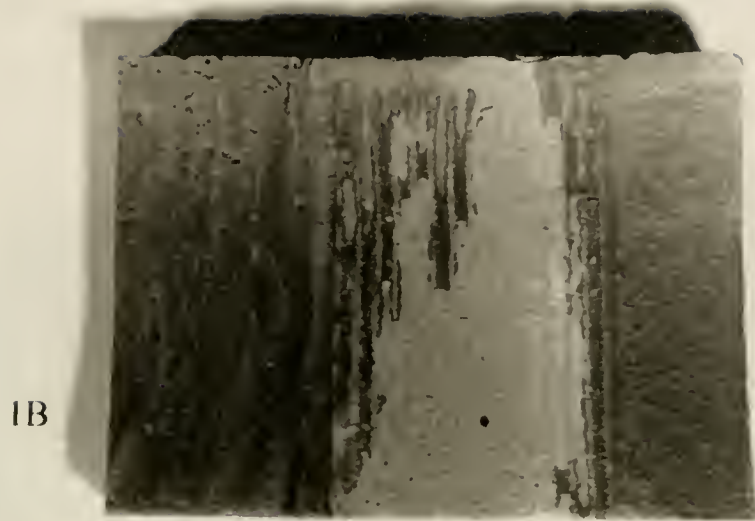


Figure B.16 Edison Aquathane UA-210-H specimen 1B before weathering.

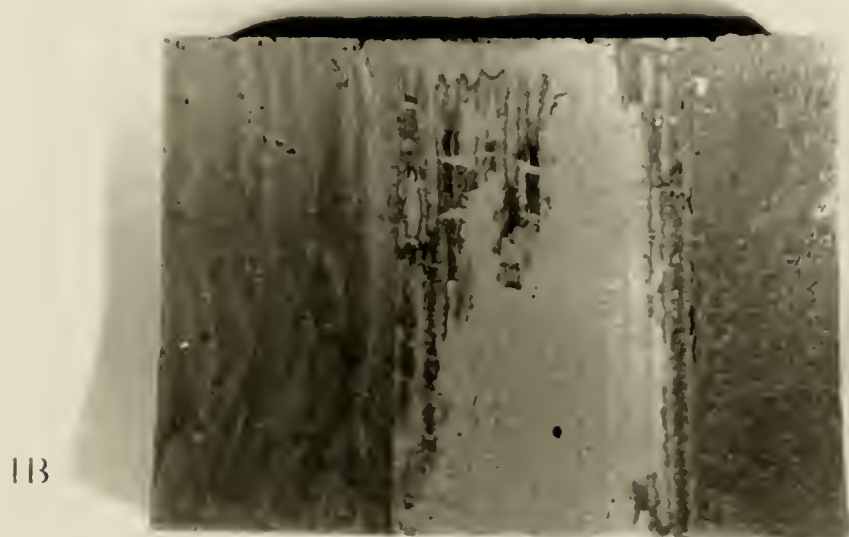


Figure B.17 Edison Aquathane UA-210-H specimen 1B after 6 cycles. Note minor cracking and lifting of coating from glaze surface on mortar side.





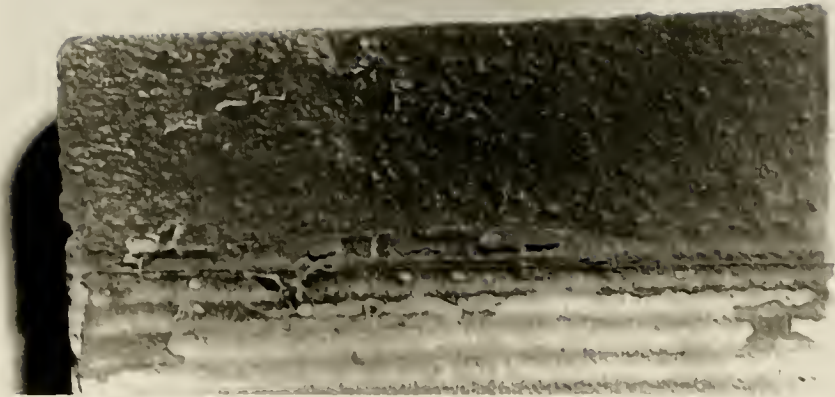


Figure B.18 Edison Aquathane UA-210-H specimen 1B mortar after 12 cycles. Note cracking and lifting from glaze surface.



Figure B.19 Edison Aquathane UA-210-H specimen 1B mortar after 18 cycles. Note continued cracking and greater areas of mortar exposed.



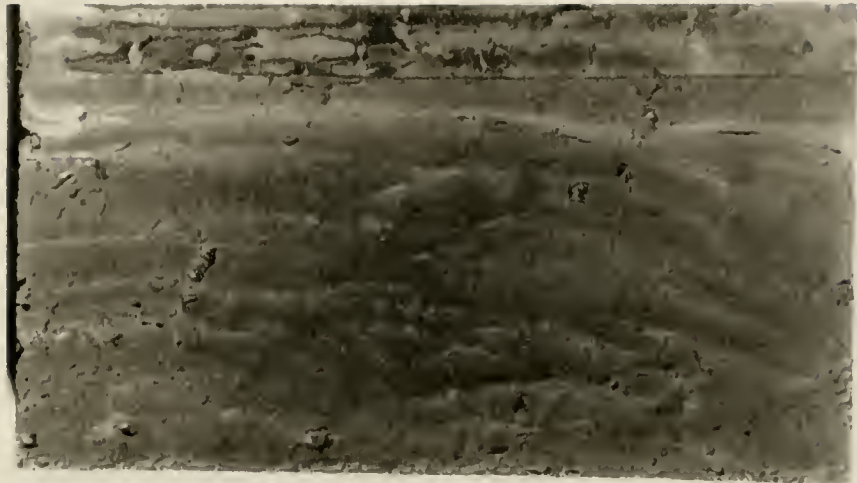


Figure B.20 Edison Aquathane UA-210-H specimen 1B terra cotta after 18 cycles. Note minor cracking at junction between glaze surface and terra cotta substrate surface.



Figure B.21 Edison Aquathane UA-210-H specimen 1B terra cotta after 30 cycles. Note continued cracking in same areas as above.



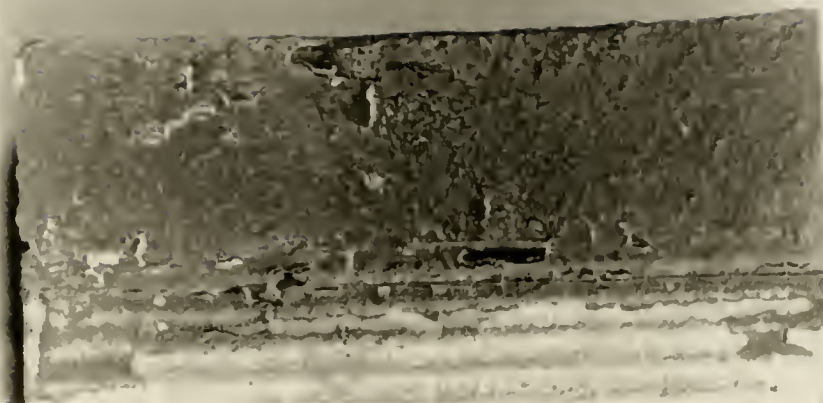


Figure B.22 Edison Aquathane UA-210-H specimen 1B mortar after 30 cycles. Note continued cracking and greater exposure of mortar.



Figure B.23 Edison Aquathane UA-210-H specimen 1B mortar after 52 cycles. Note excessive map cracking, mortar exposure, and coating peeled from glaze surface.





Figure B.24 Edison Aquathane UA-210-H specimen 1B terra cotta after 52 cycles. Note cracking.

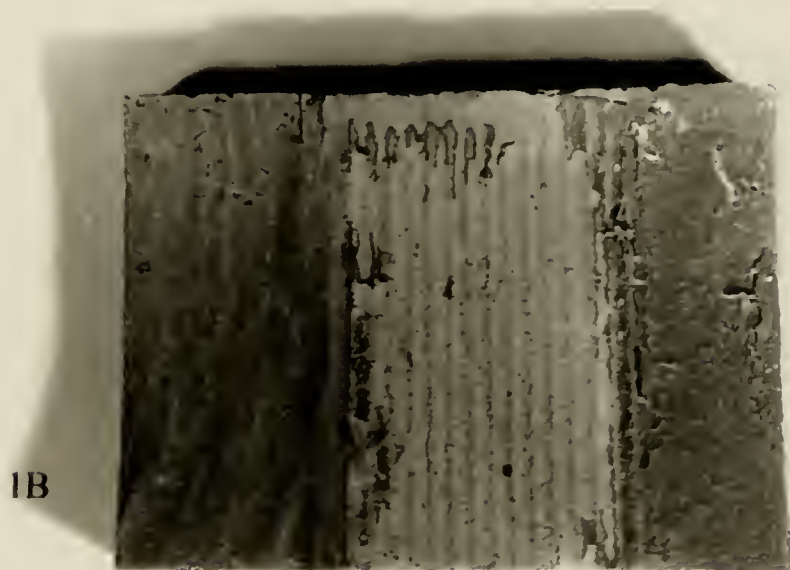


Figure B.25 Edison Aquathane UA-210-H specimen 1B after 52 cycles.







Figure B.26 Edison Aquathane UA-210-H specimen 1C before weathering.



Figure B.27 Edison Aquathane UA-210-H specimen 1C after 6 cycles. Note coating peeled away from glaze surface.





Figure B.28 Edison Aquathane UA-210-H specimen 1C mortar after 30 cycles. Note continued peeling of coating from glaze surface and map cracking.

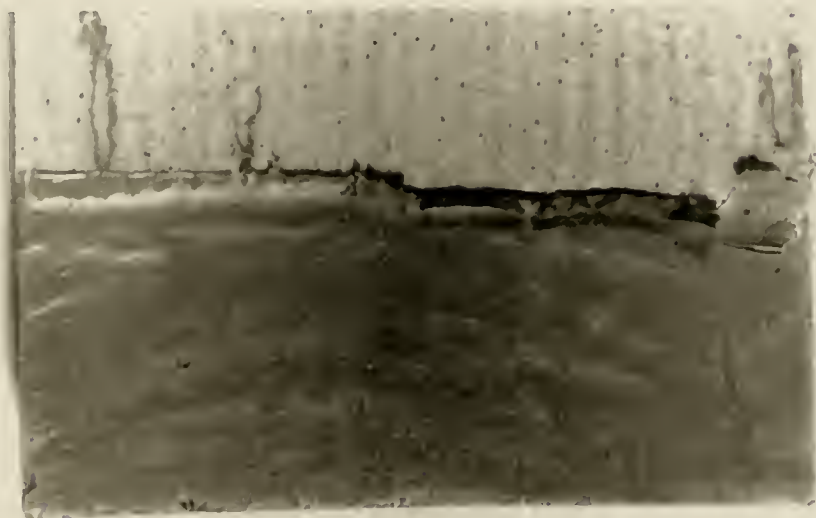


Figure B.29 Edison Aquathane UA-210-H specimen 1C terra cotta after 30 cycles. Note continued peeling of coating from glaze surface and small crack in coating at junction between glaze and terra cotta substrate.



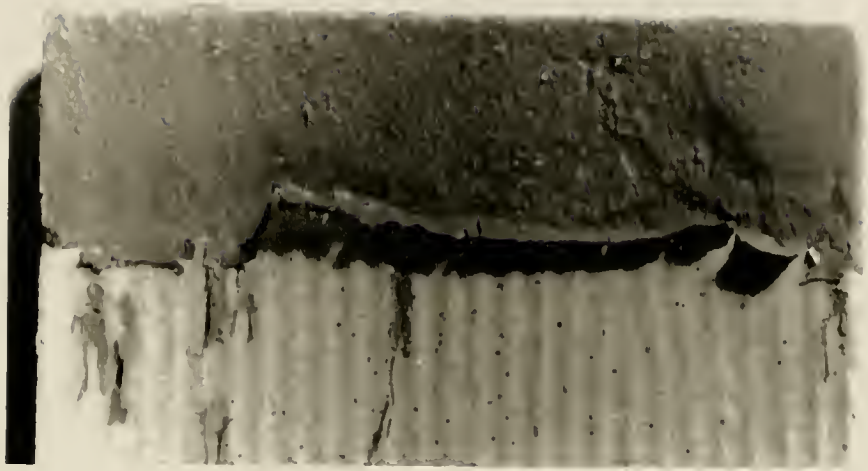


Figure B.30 Edison Aquathane UA-210-H specimen 1C mortar after 52 cycles. Note continued peeling of coating from glaze surface exposing mortar beneath.

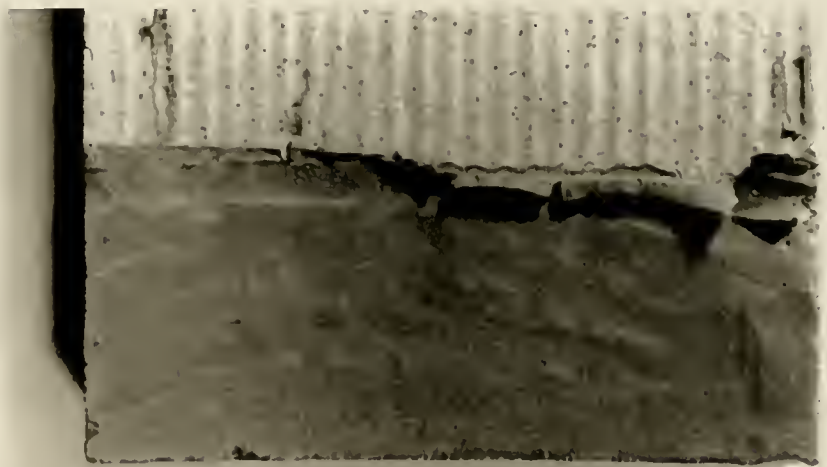


Figure B.31 Edison Aquathane UA-210-H specimen 1C terra cotta after 52 cycles. Note continued peeling of coating from glaze surface exposing terra cotta beneath.





Figure B.32 Edison Aquathane UA-210-H specimen 1C after 52 cycles.

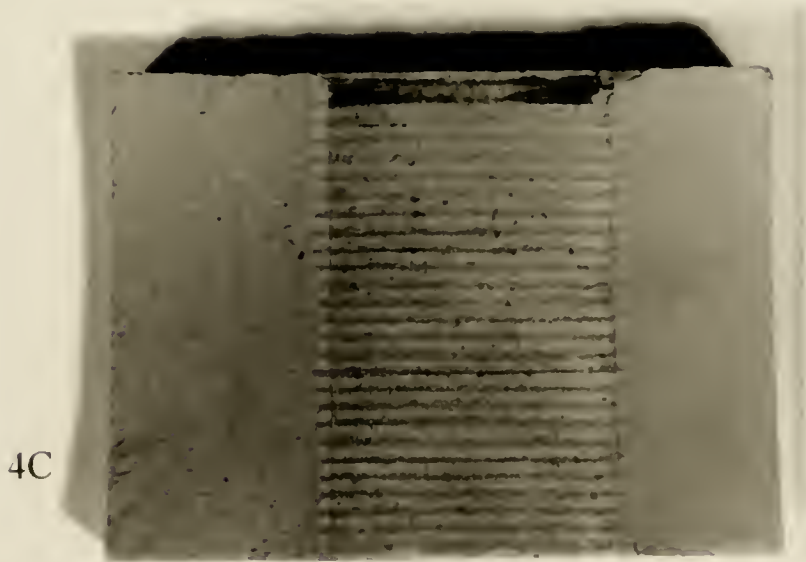


Figure B.33 Conformal Stain specimen 4C before weathering.





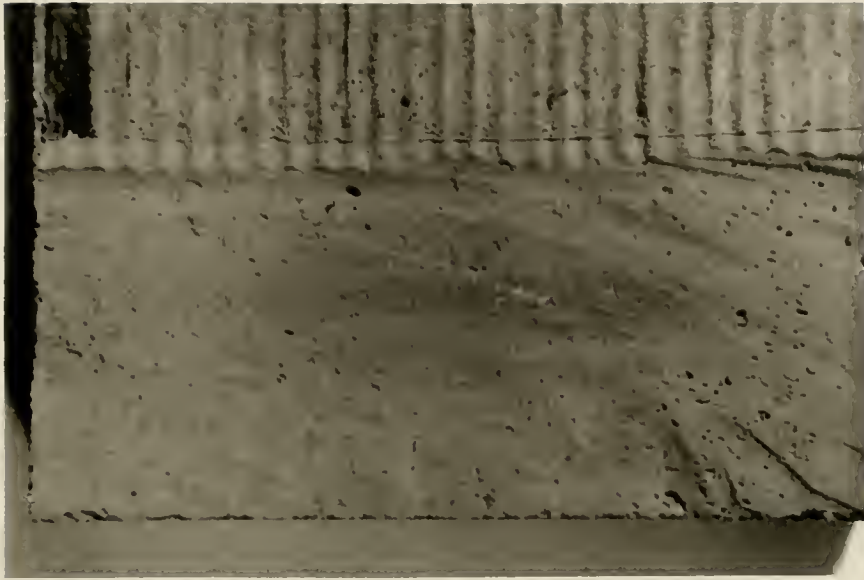


Figure B.34 Conformal Stain specimen 4C after 12 cycles. Note hairline cracking and flaking.

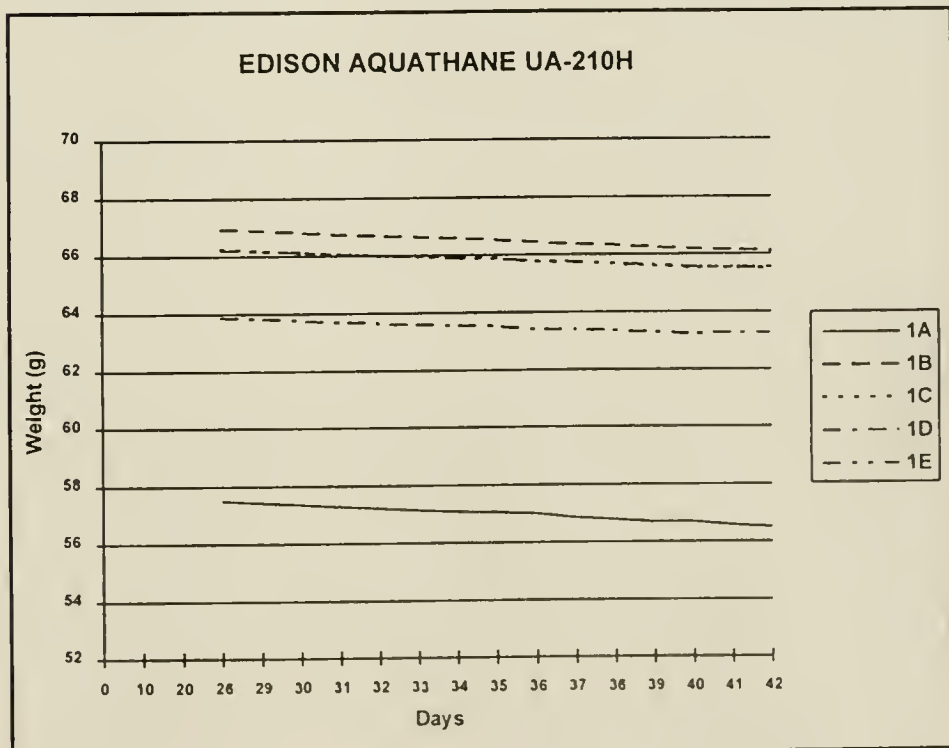


**Table B.1** Measurements of weight loss of specimens coated with Edison Aquathane UA-210H

EDISON AQUATHANE UA-210H - WVT DATA					
Day	1A Wt.	1B Wt.	1C Wt.	1D Wt.	1E Wt.
28	57.51	66.95	66.25	63.87	66.22
29	57.44	66.89	66.18	63.83	66.17
30	57.37	66.83	66.12	63.77	66.12
31	57.29	66.74	66.06	63.70	66.06
32	57.22	66.69	65.99	63.65	65.99
33	57.15	66.63	65.94	63.60	65.96
34	57.09	66.59	65.88	63.55	65.90
35	57.06	66.54	65.86	63.53	65.90
36	57.01	66.44	65.75	63.41	65.77
37	56.86	66.37	65.76	63.39	65.73
38	56.79	66.33	65.66	63.36	65.69
39	56.69	66.25	65.58	63.29	65.62
40	56.59	66.18	65.52	63.24	65.56
41	56.58	66.15	65.55	63.25	65.50
42	56.51	66.11	65.49	63.25	65.54

A, B, C = coating only; D, E = mortar/coating.

**Table B.2** Water Vapor Transmission of specimens coated with Edison Aquathane UA-210H

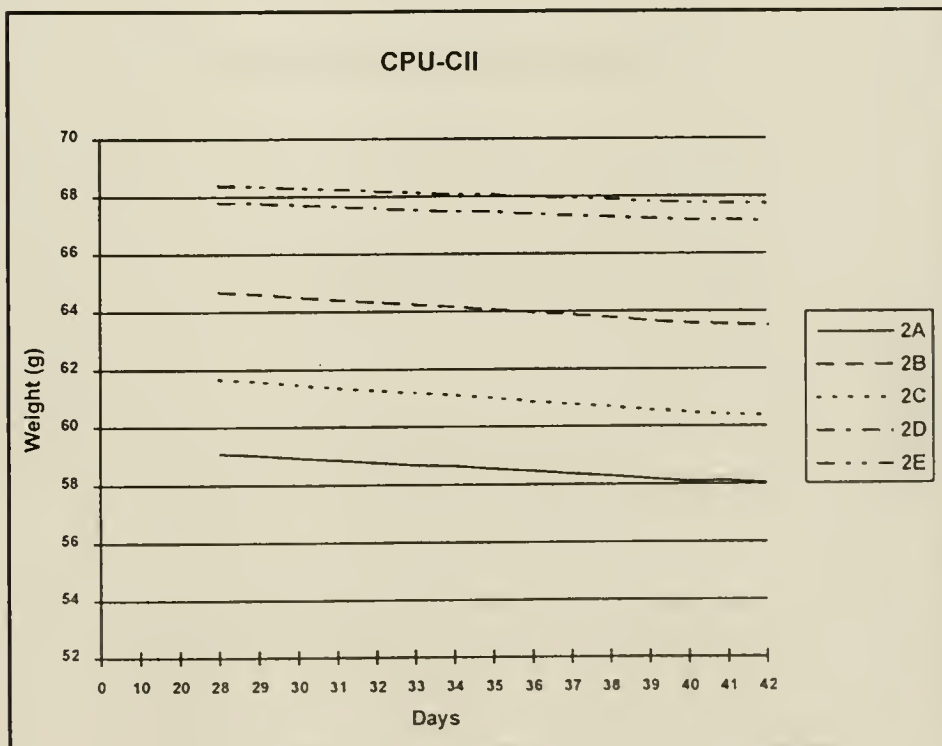




**Table B.3** Measurements of weight loss of specimens coated with CPU-CII Protective Safety Sealer

CPU-CII - WVT DATA					
Day	2A Wt.	2B Wt.	2C Wt.	2D Wt.	2E Wt.
28	59.10	64.69	61.66	67.82	68.40
29	59.03	64.61	61.58	67.77	68.36
30	58.94	64.51	61.46	67.71	68.30
31	58.86	64.40	61.34	67.66	68.24
32	58.77	64.32	61.26	67.59	68.20
33	58.69	64.24	61.18	67.54	68.14
34	58.65	64.17	61.10	67.48	68.08
35	58.56	64.08	61.00	67.47	68.07
36	58.47	63.96	60.87	67.39	67.98
37	58.38	63.88	60.77	67.33	67.94
38	58.30	63.79	60.68	67.28	67.89
39	58.20	63.67	60.57	67.22	67.82
40	58.11	63.59	60.48	67.16	67.78
41	58.13	63.55	60.40	67.18	67.75
42	58.04	63.49	60.38	67.13	67.74

**Table B.4** Water Vapor Transmission of specimens coated with CPU-CII Protective Safety Sealer

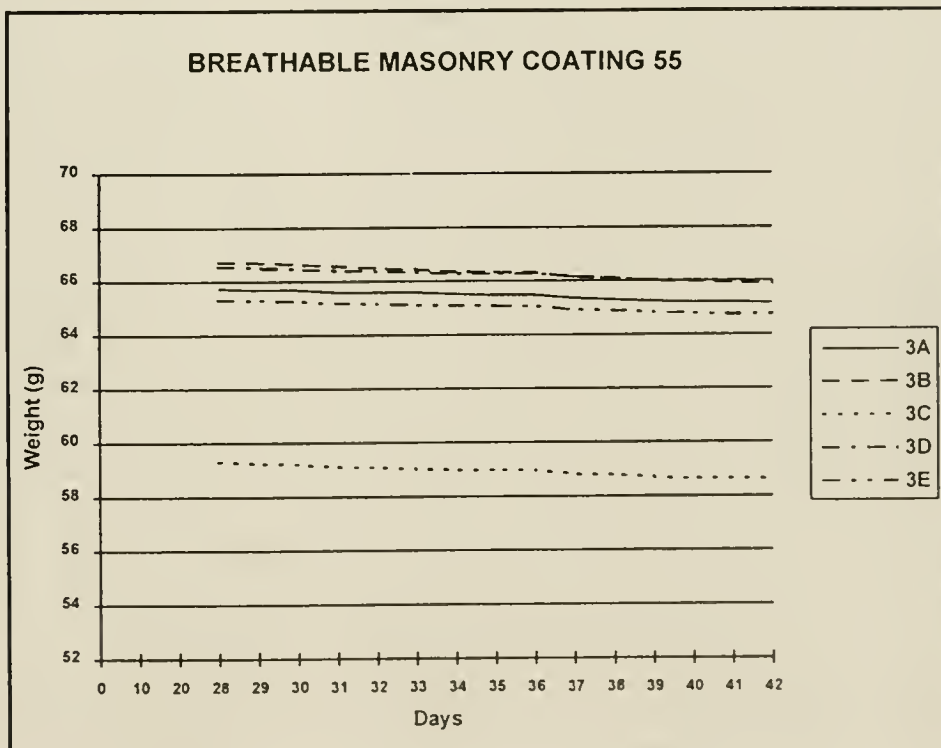




**Table B.5** Measurements of weight loss of specimens coated with Breathable Masonry Coating 55

BREATHABLE MASONRY COATING 55 - WVT DATA					
Day	3A Wt.	3B Wt.	3C Wt.	3D Wt.	3E Wt.
28	65.74	66.77	59.30	66.55	65.32
29	65.69	66.70	59.24	66.51	65.29
30	65.68	66.64	59.20	66.45	65.25
31	65.60	66.55	59.10	66.39	65.17
32	65.58	66.49	59.08	66.36	65.15
33	65.63	66.43	59.02	66.32	65.10
34	65.52	66.34	58.97	66.27	65.07
35	65.47	66.32	58.96	66.26	65.06
36	65.47	66.30	58.95	66.27	65.05
37	65.35	66.15	58.82	66.14	64.92
38	65.30	66.10	58.78	66.09	64.88
39	65.24	66.00	58.70	66.02	64.81
40	65.19	65.95	58.63	65.99	64.77
41	65.20	65.91	58.63	66.02	64.73
42	65.16	65.88	58.63	65.96	64.74

**Table B.6.** Water Vapor Transmission of specimens coated with Breathable Masonry Coating 55.



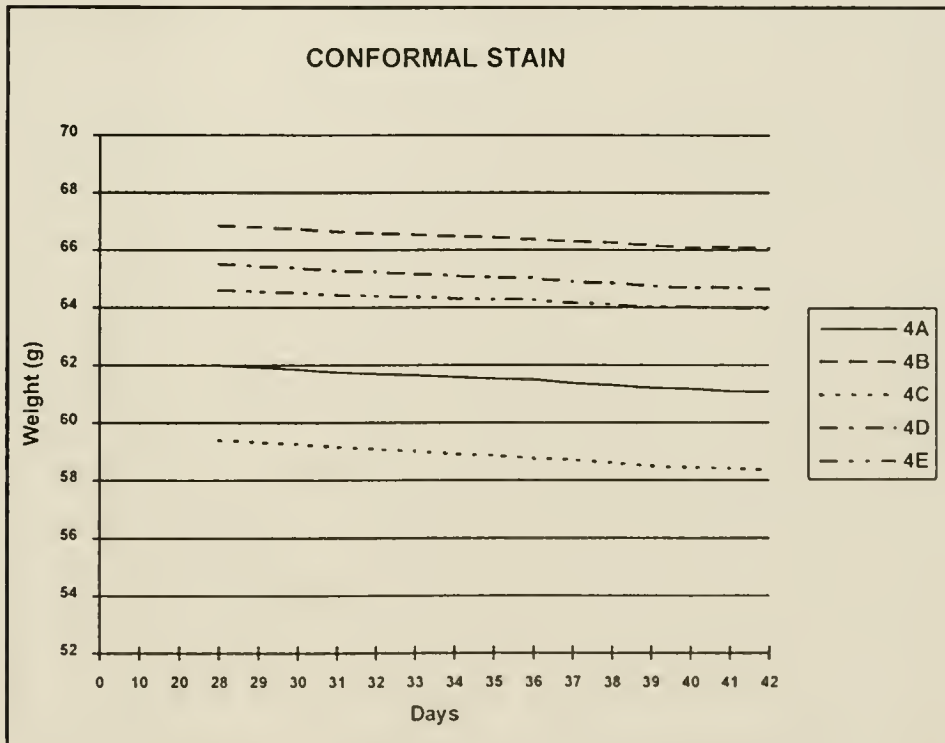




**Table B.7.** Measurements of weight loss of specimens coated with Conformal Stain.

CONFORMAL STAIN - WVT DATA					
Day	4A Wt.	4B Wt.	4C Wt.	4D Wt.	4E Wt.
28	61.99	66.86	59.39	65.51	64.61
29	61.92	66.80	59.32	65.44	64.55
30	61.85	66.75	59.25	65.38	64.51
31	61.76	66.65	59.15	65.27	64.43
32	61.70	66.59	59.08	65.22	64.39
33	61.65	66.55	59.00	65.16	64.36
34	61.59	66.48	58.91	65.09	64.31
35	61.53	66.45	58.86	65.05	64.28
36	61.50	66.38	58.75	65.02	64.27
37	61.37	66.30	58.71	64.89	64.15
38	61.31	66.26	58.60	64.85	64.11
39	61.22	66.17	58.49	64.75	64.03
40	61.18	66.09	58.44	64.68	64.02
41	61.10	66.11	58.40	64.69	63.99
42	61.08	66.06	58.35	64.64	63.95

**Table B.8** Water Vapor Transmission of specimens coated with Conformal Stain

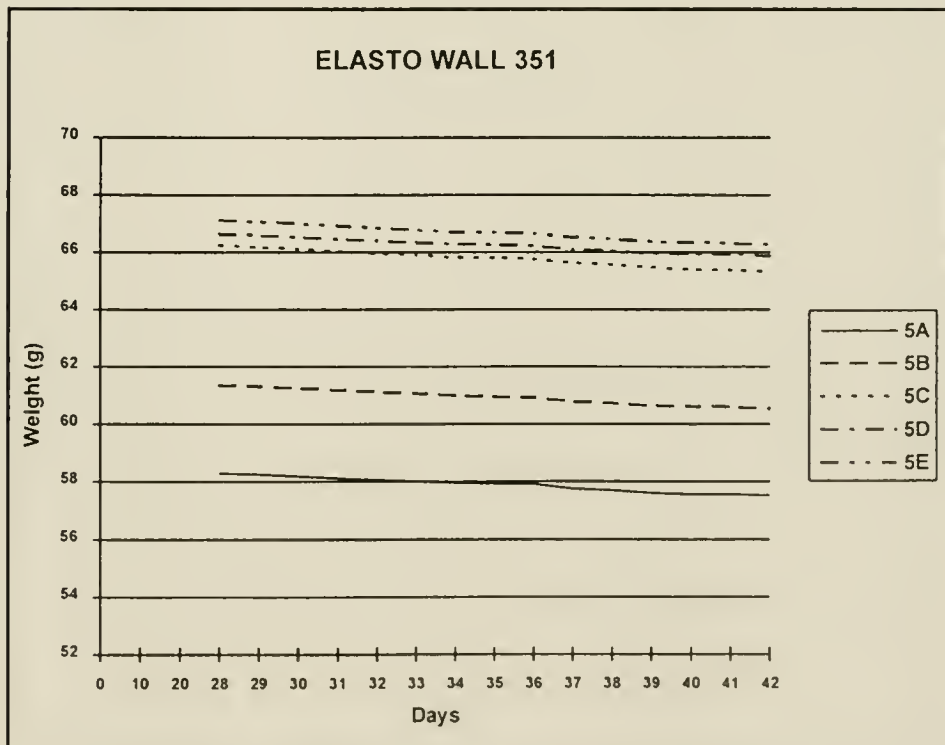




**Table B.9** Measurements of weight loss of specimens coated with Elasto Wall 351

ELASTO WALL 351- WVT DATA					
Day	5A Wt.	5B Wt.	5C Wt.	5D Wt.	5E Wt.
28	58.30	61.35	66.24	66.63	67.12
29	58.25	61.30	66.17	66.58	67.06
30	58.19	61.25	66.11	66.52	67.00
31	58.12	61.18	66.03	66.45	66.92
32	58.07	61.13	65.96	66.40	66.85
33	58.01	61.06	65.90	66.34	66.78
34	57.96	61.99	65.81	66.28	66.69
35	57.92	61.95	65.80	66.25	66.68
36	57.91	61.92	65.76	66.22	66.65
37	57.76	61.79	65.62	66.09	66.51
38	57.70	61.73	65.56	66.05	66.46
39	57.62	61.64	65.47	65.96	66.38
40	57.56	61.60	65.39	65.93	66.33
41	57.57	61.59	65.38	65.92	66.32
42	57.52	61.53	65.33	65.87	66.27

**Table B.10** Water Vapor Transmission of specimens coated with Elasto Wall 351

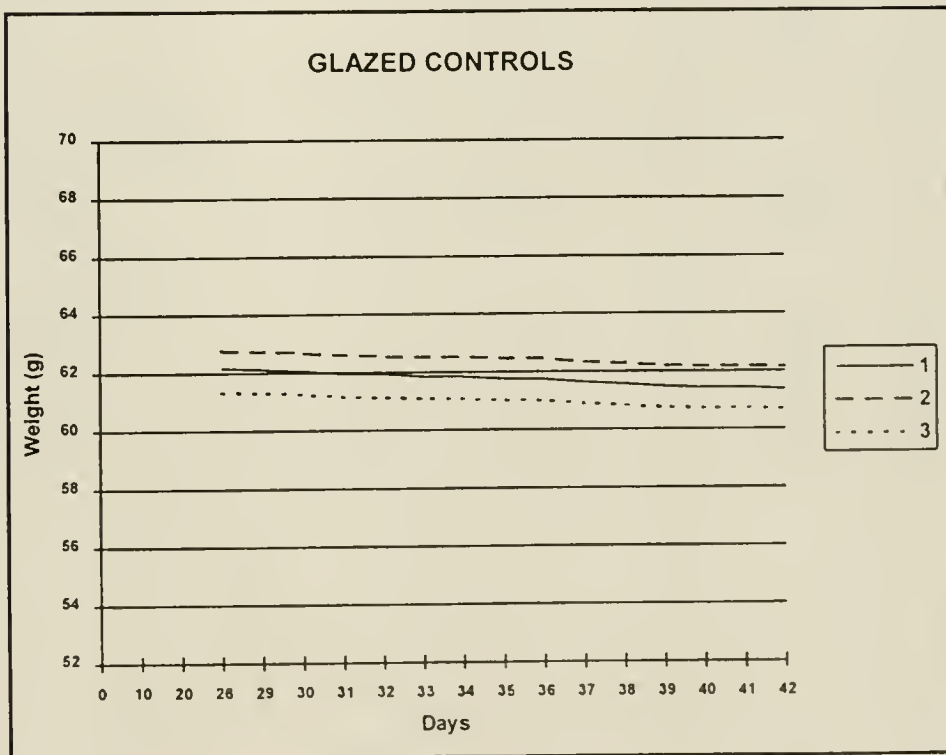




**Table B.11** Measurements of weight loss of glazed control specimens

GLAZED CONTROLS - WVT DATA			
Day	C1 Wt.	C2 Wt.	C3 Wt.
28	62.18	62.78	61.33
29	62.13	62.73	61.30
30	62.06	62.69	61.26
31	61.96	62.60	61.16
32	61.94	62.56	61.13
33	61.86	62.52	61.08
34	61.84	62.52	61.06
35	61.77	62.45	61.02
36	61.75	62.45	61.00
37	61.63	62.33	60.89
38	61.57	62.27	60.83
39	61.48	62.21	60.75
40	61.43	62.16	60.71
41	61.44	62.16	60.71
42	61.37	62.13	60.69

**Table B.12.** Water Vapor Transmission of glazed control specimens.





**Table B.13.** Measurements of weight gain of specimens after 24 hour submersion test based on ASTM C67-83, Section 7.

<b>24 HOUR SUBMERSION DATA</b>		
	<b>W<sub>d</sub> (g)</b>	<b>W<sub>s</sub> (g)</b>
<b>AQUATHANE UA-210H</b>		
1A	44.93	50.88
1B	40.22	45.49
1C	48.52	54.89
<b>CPU-CII</b>		
2A	43.13	49.38
2B	48.05	54.12
2C	47.62	53.98
<b>BMC 55</b>		
3A	43.64	47.29
3B	45.57	49.21
3C	48.31	49.60
<b>CONFORMAL STAIN</b>		
4A	43.39	44.39
4B	46.54	47.27
4C	50.00	55.43
<b>ELASTO WALL</b>		
5A	45.46	51.15
5B	48.25	54.02
5C	42.76	43.13
<b>CONTROLS</b>		
C1	42.58	48.70
C2	45.83	51.67
C3	49.39	56.14
C4	37.43	42.17
C5	43.05	49.05





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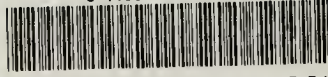
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