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Eames House Conservation Project

Cemesto Panel Investigations Phase I

Research Report

Getty
Conservation
Institute

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The Getty Conservation Institute (GCI) works internationally to advance conservation practice in the visual arts—broadly interpreted to include objects, collections, architecture, and sites. The Institute serves the conservation community through scientific research, education and training, field projects, and the dissemination of information. In all its endeavors, the GCI creates and delivers knowledge that contributes to the conservation of the world's cultural heritage.

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Cover image: Close up of Eames House residence's east elevation, 2023. A combination of stucco, different types of glass, and opaque infill panels made of Cemesto, both painted and unpainted, add color, texture, and visual interest to the building's facade. © J. Paul Getty Trust

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PREFACE

In 2011, the Getty Conservation Institute (GCI) began working with the Charles and Ray Eames House Preservation Foundation (Eames Foundation) on the Eames House Conservation Project. This is the first field project under the GCI's Conserving Modern Architecture Initiative (CMAI), which seeks to advance the practice of conserving twentieth-century heritage. The project was developed to demonstrate the practical application of international best practices at the Eames House. The first step for the Eames House Conservation Project was to understand the conditions of the house by focusing on areas where deterioration was evident or suspected.

Over the next five years, the GCI conducted on-site investigations and assessments on a variety of topics by either conducting its own work or hiring consultants with expertise in specialized fields. The results of those investigations were published by the GCI in a volume titled *Eames House Conservation Project: Investigations 2011 to 2016* (Matarese, McCoy, and Ostergren 2019). In addition, the GCI developed a Conservation Management Plan (CMP) for the Eames House, published in 2018, which was intended to provide the Eames Foundation with practical guidance for managing the house in a way that highlighted and protected that which made it significant. The CMP was also meant to be a model planning document that can help others who manage modern heritage properties.

As part of *Arts and Architecture* magazine's Case Study House Program, the Eames House was designed using off-the-shelf products to showcase new and affordable materials and demonstrate how these materials could be used to create modern, livable homes. One of the materials the Eameses selected was Cemesto, a fiber-cement panel considered to be an affordable and easy-care exterior material. Cemesto was incorporated into the steel-framed exterior window-wall system to provide areas of opacity in the mostly glazed facade.

The CMP for the Eames House identified the Cemesto panels as having exceptional significance. However, the CMP also noted that their asbestos content poses health risks to humans because of its toxicity, contributing to the site's vulnerabilities. Hence, the GCI focused on researching and investigating Cemesto, knowing that although it was a common building material, it may present potential safety hazards, particularly as elements deteriorate, and little had been written about its history, durability, or how to manage it over time. The results of this research and investigation are the subject of this report. As with the previous GCI publications on the Eames House, we share our research and investigation with the conservation community in hopes that others who work with Cemesto or other similar midcentury building materials will find this useful.

The GCI wishes to acknowledge the extensive commitment of the Eames Foundation to our partnership and to the conservation and stewardship of the Eames House for future generations. In particular, we would like to thank Lucia Dewey Atwood for supporting our work on Cemesto, the Eames Foundation staff for their assistance during the on-site investigations, and John Kishel for loaning resources from his collection of materials related to the Eames House. We acknowledge the work done by Laura Matarese, who was on the staff of the GCI from 2014 to 2018 and spearheaded the initial historical research and condition assessment of the panel faces , and Anna Flavin, GCI Lead Photographer, who generously shared her expertise and provided support in the photographic recording. Thanks also go to GCI Associate Scientist Joy Mazurek for her testing of the surface staining and soiling found on the panels. The GCI is grateful to the conservation team at WJE, who carried out laboratory studies that included light microscopical examination, X-ray diffraction analysis, and scanning electron microscopy. We also thank Drew Barnhart, GCI graduate intern, who, in addition to her role in drafting appendix III of this volume, has provided assistance in fieldwork and the preparation of this report. Finally, we acknowledge the contributions of former GCI staff members Cynthia Godlewski, Chelsea Bingham, and copy editor Dianne Woo for their work in finalizing this document and readying it for publication.

INTRODUCTION

Completed in 1949, the Eames House, also known as Case Study House No. 8, is one of the most intact and internationally recognized and published works designed under *Arts and Architecture* magazine's Case Study House Program. It served as the residence and studio of its renowned designers, Charles and Ray Eames, throughout most of their career, and embodies their reflective, iterative approach to design and their evolving understanding and appreciation of the natural qualities of the site. In doing so, the Eames House provides evidence of the Eameses' humanization of industrial modernism. Today, it is a place of international pilgrimage for architects and designers and has had an exceptional continuity of ownership, occupation, and ongoing care, including the continued practice of welcoming visitors, which honors Charles and Ray's way of living and socializing and communicates their spirit of a place.

The Getty Conservation Institute has been working with the Eames Foundation on preserving this icon of twentieth-century modernism for more than a decade. Efforts have included the practical application of internationally recognized conservation methodology to understand and assess the condition of the Eames House residence and studio, its contents, and its setting through a variety of on-site scientific investigations; to design and implement conservation measures; and to develop a CMP. After adoption of the CMP, the GCI has continued its collaboration with the Eames Foundation to carry on the study of the Cemesto panels, an essential and culturally significant component of the building enclosure at the Eames residence and studio.

Cemesto is a brand name for an insulating panel manufactured by the now-defunct Celotex Corporation in the United States. It consists of a core of laminated bagasse fiberboard surfaced on both sides with thin asbestos-cement sheets bonded with a bituminous adhesive. The building material gained tremendous popularity during and after World War II, which witnessed an unprecedented need for innovation in construction and new structures, including large housing developments, some of which were associated with the war industry, such as Aero Acres in Maryland and Oak Ridge in Tennessee. Cemesto was marketed as a suitable and durable material with sufficient structural strength, thermal insulation properties, and aesthetic appeal for interior and exterior facing walls, even when left unfinished. Its popularity waned as increased awareness and litigation related to the toxicity of asbestos led many manufacturing companies, including the Celotex Corporation, to file for bankruptcy.

At the Eames House residence and studio, the Cemesto panels, typically supplied in 4-by-8-foot (1.22 by 2.44 meter) sizes, were trimmed and rabbeted to fit the various configurations of the steel frame, including fixed units, operable awning and hopper windows, and the narrow spandrels around the perimeter of each building, in a quasi-artisan process. The resulting panels were installed and secured in place with the aid of nails, wood shims, and glazing-like putty.

Investigation of the Cemesto panels is divided into two phases. The first phase of the study, the focus of this report, documents historical and technical research, in situ visual condition assessment, and limited material testing and characterization. The second phase, which is ongoing, involves reviewing applicable guidance, understanding the limitations of preserving hazardous materials, and developing suitable conservation treatments, including repair and replacement.

Specifically, this report aims to accomplish the following:

- Describe the history of Cemesto, its manufacture, and its use at the Eames House and in the United States.
- Assess the significance of the Cemesto panels as an element of the Eames House.
- Identify, describe, and document the location of the Cemesto panels at the Eames House.
- Present the methodology and summarize the results of the visual condition assessment of the Cemesto panels, the sealants, and the steel frame that encloses the panels on the exterior and interior of the residence and studio.
- Analyze the results of the condition assessment and diagnose mechanisms of deterioration.

CHAPTER 1

HISTORY, MANUFACTURE, AND INSTALLATION CONSIDERATIONS

1.1 Introduction to the Material and Its Properties

Cemesto, manufactured by the Celotex Corporation, was one of several brands of insulated panels that entered the US market in the 1930s, marketed either as a stand-alone material, such as Transite-Encased Insulating Board (later rebranded as Transitop), or as a part of prefabricated systems and standardized designs, such as the Pyrestos panels used in the Motohome by American Houses Inc.

Cemesto was advertised as a functional exterior wall insulating material consisting of a laminated bagasse fiberboard called Celotex—the Celotex Corporation's flagship building material—bonded on one or two sides to asbestos-cement sheets with a waterproof, highly vapor-resistant bituminous adhesive (fig. 1.1). In a single thickness, the material provided a replacement for typical wall construction characterized by the use of various layers comprising siding, sheathing, building paper, insulation, and lath and plaster. Other suggested applications included ceilings and partitions in residential architecture and low-temperature dryers, air ducts, roof decks, and interior linings in industrial structures.

Although the panel length could range up to 12 feet (3.66 meters) by the late 1940s, it was commonly manufactured in a standard 4-by-8-foot (1.22 by 2.44 meter) size and various thicknesses depending on the number of layers of Celotex sheets forming the core. Typical panels were faced with ⅛-inch (3.2 millimeters) asbestos-cement sheets, but ¼-inch (6.35 millimeters) surfaces could be ordered as well. The surface had a smooth, light gray speckled appearance defined as pleasant in look and feel and generally not requiring further treatment or painting. If a color was desired, water-based or oil paints with a lime-proof primer were recommended (Dietz 1949, 11).

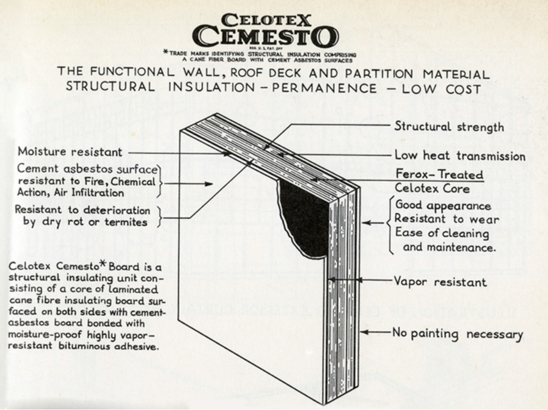


FIGURE 1.1 *Illustration showing the composition and benefits of a typical Cemesto panel. From* Cemesto Design and Construction Application Data, *AIA File 19-D, File 5000, Celotex Corporation, 1950.*

The standard thicknesses and sizes available in 1950 (one year after the Eames House was completed) are shown in table 1.1.

TABLE 1.1

Size, thickness, and other properties of Cemesto based on data from the manufacturer (Celotex Corporation 1950).

Overall Thickness (in.)	Insulating Board Core Thickness (in.)	Weight (lb. per sq. ft.)	"U"-Values for Exterior Walls*	"U"-Values for Roof Decks*	Standard Panel Sizes for All Thicknesses**
1⅛	⅞	3.9	0.28		4'0" × 6'0" 4'0" × 8'0" 4'0" × 9'0" 4'0" × 10'0" 4'0" × 12'0"
1⁹⁄₁₆	1⁵⁄₁₆	4.7	0.20	0.19	
2	1¾	5.4	0.16	0.15	

"U" = BTU per hour per sq. ft. per degree Fahrenheit difference in temperature between the air on the two sides, wind at 15 mph.

**⅛ in. or ¼ in. less than these dimensions could be ordered as well.*

Overall Thickness (cm.)	Insulating Board Core Thickness (cm.)	Weight (kg. per sq. m.)	"U"-Values for Exterior Walls (W/m$^{2}\cdot$°K)	"U"-Values for Roof Decks (W/m$^{2}\cdot$°K)	Standard Panel Sizes for All Thicknesses (m.)
2.86	2.22	19.04	1.589		1.22 × 1.83 1.22 × 2.44 1.22 × 2.74 1.22 × 3.05 1.22 × 3.66
3.97	3.33	22.95	1.135	1.078	
5.08	4.44	26.36	0.908	0.851	

Cemesto panels used vertically would transmit typical design loads up to 30 pounds per square foot (146.5 kilograms per square meter) to the perimeter supports without appreciable deformation. Laboratory tests conducted as described in the ASTM standard of the period demonstrated that Cemesto provided a fire-resistance rating of one hour. One of the factors contributing to this resistance was the asbestos-cement facings, which would support the fire safety claims made by the product's advertising. Laboratory tests also demonstrated that rain would penetrate the asbestos-cement sheets up to, but not through, the bituminous adhesive layer, which validated its function as a moisture barrier. In addition, the bond created between the asbestos-cement and the bagasse by this adhesive was greater than the strength of the bagasse internal bond, which would break within itself under tensile load (Celotex Corporation 1952).

Before exploiting its use in housing, the company advertised the material as suitable for industrial applications where insulation, structural strength, and a high degree of fire-retardant properties were required. The fact that it could be cut easily with standard tools was also a characteristic promoted at the time (*Cotton* 1931, 28).

Although secondary sources have indicated that the Celotex Company, as the Celotex Corporation was then known, introduced Cemesto to the market in 1937, advertising of this building material dates back to 1931,[1] the same year that the US Patent Office received the application for the trademark and one year after the company filed the patent application. In 1931, the company reportedly tested the product for the construction of the Travel and Transport Building, a pavilion at the 1933 Chicago World's Fair (Schrenk 2007, 147).

Press clippings show that plants in Metuchen, New Jersey, and Marrero, Louisiana, were producing the Cemesto panels by the 1940s (*Architectural Record* 1943, 76). Whereas the Metuchen plant was built in the late 1930s, the story of the Marrero facility went back to the first Celotex insulation bagasse fiberboard and the creation of the Celotex Company by Bror G. Dahlberg, Carl G. Muench, and others in the early 1920s, a time when insulation was a rarely used and expensive building material (Lathrop 1930, 449).

One may think that both the insulation core and the asbestos-cement sheets were formed separately as finished products and then bonded together under pressure. However, contrary to what one would expect, the patent[2] suggests that the asbestos-cement sheets, barely formed and still wet, were applied and bonded to the Celotex directly, creating an integral bond. Applying pressure eliminated excess moisture, compacted the sheets, and attached both materials firmly and securely by means of the bituminous adhesive. After the board was formed and achieved its initial set, it was removed from the press and stored for the curing of the asbestos-cement surfaces.

The building material and the fabrication process shared similarities with the composite material known as Transitop, whose patent had been assigned to Johns-Manville Corporation in 1932.[3] Transitop, as the archival records show, was used as a replacement material at the Eames residence and studio as early as the 1970s.

1.2 Celotex Fiberboard

Fiberboard is defined as follows:

> A rigid building material composed primarily of wood fiber or other vegetable fiber. Manufactured in various densities and thicknesses, this material has been used to insulate, sheathe, and finish building exteriors and interiors. Often referred to generally as wallboard, fiberboard falls into three basic categories: insulation board, medium-density fiberboard, and hardboard. These boards were either laminated or homogeneous compositions of grasses, reeds, rag, straw, bagasse (sugarcane waste), jute, flax, and hemp. Manufacturers also used waste materials such as sawdust, bark, oat hulls, spent hops, newspaper, and peanut shells, although most fiberboard was mechanically or chemically produced from wood pulp (Gould et al. 2014, 89).

It should be noted that fiberboard and plywood are different. Plywood is an assembly of hardwood or softwood veneers, bonded together with an adhesive (Jester 2014, 101).

The first fiberboard was developed in late eighteenth-century England (Jester 2014, 89). After several decades of experimentation, fiberboard was mass produced and readily available by 1910 (Gould et al. 2014, 89). Medium- and low-density fiberboards were often used as insulation in walls and roofs, and hardboards (i.e., high-density boards) were used for walls or furniture. Both low- and medium-density fiberboards made from newsprint (e.g., Homasote, from the Agasote Millboard Company) and bagasse (e.g., Celotex, from the Celotex Corporation) were successfully produced in the United States by 1910 and by the 1920s, respectively, and hardboards were successfully manufactured by the 1920s.

Fiberboards could be laminated, with multiple layers of the material glued together with some type of adhesive. Adhesives were also used to bond the fibers together. The adhesives used in fiberboard manufacture included dextrin; asphalt; flour paste; a mixture of powdered clay and waterglass, the common name for silicate of soda; and other types of glues. Improvements made in the manufacture of fiberboards in the 1950s increased speed of production and resulted in a stronger product. Regardless of the type of manufacture, fiberboards were typically treated chemically to prevent dry rot, fungal growth, and termites (Gould et al. 2014, 90).

In the United States, Carl G. Muench was one of the individuals involved in early efforts to find an alternative to the use of paper by-products in the insulation board industry. These alternatives included bagasse, the dry, pulpy, fibrous by-product left from the stalks of sugarcane (*Saccharum officinarum*) after the sugar had been extracted.[4] Often used as a fuel in sugar production, it was a readily available and inexpensive waste product. Hence, locating the Celotex plant in Marrero was no coincidence. The close proximity of the sugarcane industry ensured an ample supply of raw materials at a reasonable cost, and, as the use of other fuels proved to be more advantageous in sugar processing, bagasse became the basis for the Celotex insulation fiberboard.

FIGURE 1.2 *Photo showing bales of bagasse drying prior to delivery to the manufacturing plant. Photo: Robert Yarnall Richie, Celotex, Marrero, Louisiana (12/38) for* Fortune *magazine. Robert Yarnall Richie Photograph Collection. Ag1982.0234. DeGolyer Library, Southern Methodist University.*

Bagasse was delivered to the fiberboard plant in the form of bales (fig. 1.2) that underwent a number of steps to make the insulation, which included:

- Breaking down the bales
- Cooking, cleaning, and shredding the bundles to soften the fibers and create an appropriate size and mixture of long, short, thick, and thin fibers (figs. 1.3 and 1.4)
- Draining, forming, and felting the fibers into continuous sheets (fig. 1.5)
- Drying the sheets in ovens
- Cutting, trimming, and fabricating the material into various products depending on need and packaging (fig. 1.6)

Different authors describe the above steps in sources dated 1930, 1936, 1939, and 1947. Their descriptions indicate that these manufacturing steps remained

FIGURE 1.3 *A worker operating equipment in which the bagasse is heated, or cooked, to soften the fibers. Photo: Robert Yarnall Richie, Celotex, Marrero, Louisiana (12/38) for* Fortune *magazine. Robert Yarnall Richie Photograph Collection. Ag1982.0234. DeGolyer Library, Southern Methodist University.*

FIGURE 1.4 *The cooked and cleaned fiber mixture in the process of being shredded to a soupy consistency using mechanized rotating hammers. Photo: Robert Yarnall Richie, Celotex, Marrero, Louisiana (12/38) for* Fortune *magazine. Robert Yarnall Richie Photograph Collection. Ag1982.0234. DeGolyer Library, Southern Methodist University.*

almost invariable over the years. Improvements were perhaps limited to the introduction of new types of machines or changes in existing ones, at least in earlier decades.

Sugarcane bagasse has two main components: pith and rind. Pith is the inner part of the bagasse; rind is the outer part. The existent pith in the bagasse would play a significant role in the density and the water absorption of the cane base fiberboard. Being of small particle size, pith has the advantage of filling in around larger particles to produce a dense structure. However, this feature is largely offset by the fact that pith has a high water-absorption rate. Therefore, the removal of pith is desirable. Depithing requirements are similar whether bagasse is to be used in the manufacture of paper or board products.

The sterilized fibers were waterproofed to provide some water resistance throughout the thickness of the entire board and were chemically treated to prevent decay. The latter treatment was widely advertised as Ferox, an integral treatment toxic to termites and fungi developed by the Celotex Corporation's Research and Development Department about a decade after introducing Celotex on the market.

In the 1930s, the *Survey of American Chemistry* stated that the bagasse fibers were protected by incorporating "an insoluble colloidal complex including arsenious acid absorbed in freshly formed ferric hydroxide" (West 1934, 223). According to the patent, a solution of 1% arsenious acid (AS2O3) would be added to a fluid suspension of fibers at about 0.75% concentration. Next, a certain amount of ferric chloride in the ratio of Fe to As of approximately 1:1¼ was added. The ferric chloride would oxidize in solution, forming hydrous ferric oxides. A solution at pH 6 was preferred for this process. The arsenious acid would then be absorbed by the freshly formed ferric hydroxide and deposited on the fibers as they passed through the screens.[5] The Ferox treatment did not alter the physical properties of the fiberboard, nor did it interfere with other operations (*Journal of the Franklin Institute* 1934, 746).

Regarding the chemical treatment for waterproofing the clean bagasse fibers, no detailed information was found. However, the patent mentioned above suggests that the Ferox treatment was applied after the fibers underwent a sizing treatment with rosin and alum, which is known to confer hydrophobic properties, and was used in the paper manufacturing process.[6] Dahlberg and Muench were likely familiar with this treatment, since both had backgrounds in the paper and wallboard industry.[7]

Besides the sizing solution of rosin and alum, shredding the fibers included the addition of a wood-fiber filler (*Fortune* 1939, 80). More recently, the production process involved the mixing of the

FIGURE 1.5 *Workers passing the fiber mixture through rollers that felt the fibers together, squeezing the water out and causing the fibers to adhere into a continuous sheet. Photo: Robert Yarnall Richie, Celotex, Marrero, Louisiana (12/38) for* Fortune *magazine. Robert Yarnall Richie Photograph Collection. Ag1982.0234. DeGolyer Library, Southern Methodist University.*

FIGURE 1.6 *Workers handling sheets of cut bagasse after drying in ovens. Photo: Robert Yarnall Richie, Celotex, Marrero, Louisiana (12/38) for* Fortune *magazine. Robert Yarnall Richie Photograph Collection. Ag1982.0234. DeGolyer Library, Southern Methodist University.*

fibers with newspaper waste. It is not clear when the latter started to be used in the manufacture of Celotex.

According to trade catalogs and commercial literature, it was claimed that Celotex was virtually 85% air. For instance, a half-inch thickness of Celotex weighs 600 pounds per 1,000 square feet (272.15 kilograms per 92.9 square meters). This made it lightweight compared to other fiberboards. A fiberboard made of pine would weigh 2,000 pounds per 1,000 square feet (907.18 kilograms per 92.9 square meters).

Felting bagasse provided the basis for a homogeneous structure of closely interlinked fibers. Celotex would absorb about 12% of water by volume when immersed one inch for 72 hours and would withstand up to 1,200 pounds (544.31 kilograms) in pulling tests.

Major Celotex products available in the 1930s included insulation boards for both residential and industrial applications, as well as specialty products for a wide range of insulating needs from carpet lining to radio baffles and even acoustic panels (Lathrop 1930). The product was advertised as an interior and exterior finish, and trade literature highlighted both its insulation and sound-deadening properties. An example would be the *Celotex Insulating Lumber* booklet published by the company in 1929, which briefly described the material and showed examples of homes in which the product had been used, accompanied by positive testimonials from clients.

Celotex was used in the 1930s to insulate the roofs of the White House in Washington, DC, and the Rockefeller Center in New York City. At the 1939 World's Fair, also in New York, Celotex's acoustical insulation products were used in the Perisphere, designed by Wallace Harrison and J. Andre Fouilhoux. Medium-density fiberboards and hardboards possessed structural strength and rigidity suitable for sheathing but did not work as well for insulation. Products such as Celotex's Building Board were used as exterior finishes or as sheathing under roofing materials (such as ceiling tiles) or as supports for brick siding, stucco, and roof shingles (Gould, Konrad, and Milley 1995).

Although the company changed hands, bagasse-based Celotex continued to be produced at Marrero until early 2007, when the plant was shut down because of impacts from Hurricane Katrina and the collapse of the construction industry (Watkins and Varble 2008, 1).

1.3 Cemesto Fiber Cement

Although the commercial application of asbestos dates back to the mid-nineteenth century, the first US patent for manufacturing a composite material combining asbestos and cement was issued in 1904 to the Austrian industrialist and inventor of the process, Ludwig Hatschek. The addition of asbestos to a cement matrix improved the fire resistance, durability, and mechanical properties of the resulting product. Appreciation of these qualities, along with a relatively low cost, minor maintenance requirements, and lack of awareness of its hazardous nature, granted the mixture a bright future, as reflected in a myriad of materials developed or adapted throughout the twentieth century (Maines 2005, 42). By the 1930s, asbestos-cement products on the market included boards, corrugated shingles (for siding and roofing), pipes, floor tiles, and decorative moldings (Woods 2000, 78).

Asbestos was used extensively in the construction and manufacturing industry for more than half of the twentieth century. It was popular because of its low cost, mechanical strength and flexibility, resilience to wear and tear, and effectiveness as a fire retardant. Asbestos refers to a group of minerals that can be separated into individual flexible filaments because of its fibrous nature. It can withstand very high temperatures, hence its fire-retardant properties, which were echoed in the trade literature. Laboratory analysis showed that chrysotile, a fibrous form of the mineral serpentine, was the fiber used in the fabrication of Cemesto asbestos-cement. Chrysotile is "a hydrated magnesium silicate that may have minor quantities of iron, manganese, nickel, or aluminum." Its fibers are "the longest and vary in length from an average of ¹⁄₁₆ to ¾ inch [1.58 to 19.05 millimeters] to as long as 12 inches [30.48 centimeters] in rare specimens. The fibers are very flexible and have a high tensile strength…and a high resistance to heat" (Hornbostel 1961, 59).

Asbestos use was largely phased out in the United States and other parts of the world in the latter part of the twentieth century as the hazardous nature of its friable form became more broadly known. With the passage of the 1970 Clean Air Act, the US Environmental Protection Agency began to regulate asbestos as a hazardous material.

In rigid materials, such as asbestos-cement siding and floor tiles, asbestos fibers are bonded to a matrix and are considered relatively stable. However, this type of material can still pose a health risk in the case of weathering, age, or disturbance such as cutting, drilling, or accidental breakage (Vogt-O'Connor 1999, 1).

1.4 Applications

In the 1930s, economic and building activity had declined in the wake of the Great Depression, reducing the number of manufacturers of building materials. Those that survived, such as the Celotex Corporation, expanded, consolidated, and aggressively promoted their products to remain viable (Tomlan 2014, 6).

Cemesto was exhibited in New York at the 1939 world's fair in the Town of Tomorrow pavilion, which featured several houses that were constructed of newly invented materials. The use of Celotex and Cemesto was displayed throughout the Celotex House, known as Demonstration Home No. 17 (Kargon and Molella 2010, 76–77).

A shortage of materials and an increased need for buildings precipitated shifts in the building industry during and after World War II. Newer materials were needed to meet demand, including Cemesto, which was heavily used throughout the United States during this building boom (Tomlan 2014, 7).

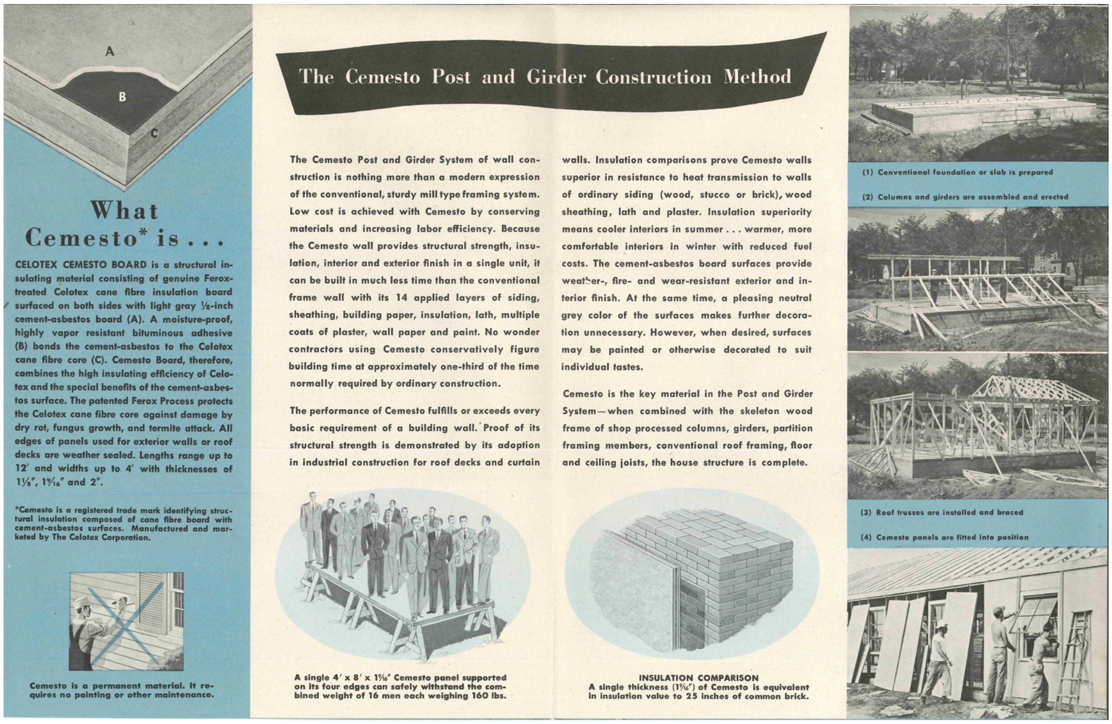
In the 1940s, the Celotex Corporation worked with the John B. Pierce Housing Foundation to develop a prefabricated kit-of-parts system to construct houses and other types of buildings using Cemesto. The Pierce Foundation's primary focus at this time was supporting research and development for wartime and postwar housing. One goal was to create mass-produced construction systems so that comfortable housing could be speedily constructed (John B. Pierce Foundation 2012). The foundation developed the Pierce construction system, which featured walls of single Cemesto panels within wooden frames; this system was used to build houses throughout the country (Breihan 2008, 7).

In 1941, the aforementioned Aero Acres, a defense housing community for the Glenn L. Martin Aircraft Company, was developed outside Baltimore. It was designed by Skidmore, Owings & Merrill (SOM), a commercial affiliate of the John B. Pierce Foundation. SOM used Cemesto and the Pierce construction system for the rapid construction of low-cost modular housing (Breihan 2008; Hales 1997, 51). That year, 600 Cemesto houses were erected at Aero Acres, laid out on wide streets with sidewalks, and the following year an additional 400 were built. Aero Acres survives today, although many of its Cemesto homes have been altered (Marks 2012).

With the success of Aero Acres, the same approach was used at Oak Ridge, Tennessee, in the establishment of a housing community to support the Manhattan Project. Beginning in 1942, houses, schools, and shops were assembled using Cemesto (Hales 1997, 83). The modular residential units came in different forms, characterized alphabetically from type A to type F. Type A houses were the smallest, square-shaped with two bedrooms; the larger type B houses took on a rectangular shape; type C extended the rectangle into an L shape; and so on. Peter Hales, an architectural historian, characterizes these houses as "brilliantly innovative" in the use of building materials and construction techniques, while also remaining conservative in form and adhering to a traditional town-planning layout (Hales 1997, 83) (fig. 1.7). Thousands of Cemesto houses were eventually built at Oak Ridge. Originally designed for a life of twenty-five years, many of these homes remain in use today (Johnson and Jackson 1981, 21; Kamin 2011).

After the end of World War II, traditional building materials—brick, stone, and steel—were in short supply, and there was a housing shortage. These two factors contributed to reinvigorating the

FIGURE 1.7 *Aerial photograph of Hillside Road in the defense housing community at Oak Ridge, Tennessee, showing Cemesto houses and site layout (Hales 1997). Photo: James E. Westcott, US Army Corps of Engineers, Manhattan Engineer District, Oak Ridge, Tennessee.*



What
Cemesto* is . . .

CELOTEX CEMESTO BOARD is a structural insulating material consisting of genuine Ferox-treated Celotex cane fibre insulation board surfaced on both sides with light gray ⅛-inch cement-asbestos board (A). A moisture-proof, highly vapor resistant bituminous adhesive (B) bonds the cement-asbestos to the Celotex cane fibre core (C). Cemesto Board, therefore, combines the high insulating efficiency of Celotex and the special benefits of the cement-asbestos surface. The patented Ferox Process protects the Celotex cane fibre core against damage by dry rot, fungus growth, and termite attack. All edges of panels used for exterior walls or roof decks are weather sealed. Lengths range up to 12′ and widths up to 4′ with thicknesses of 1⅛″, 1$\frac{9}{16}$″ and 2″.

*Cemesto is a registered trade mark identifying structural insulation composed of cane fibre board with cement-asbestos surfaces. Manufactured and marketed by The Celotex Corporation.

Cemesto is a permanent material. It requires no painting or other maintenance.

The Cemesto Post and Girder Construction Method

The Cemesto Post and Girder System of wall construction is nothing more than a modern expression of the conventional, sturdy mill type framing system. Low cost is achieved with Cemesto by conserving materials and increasing labor efficiency. Because the Cemesto wall provides structural strength, insulation, interior and exterior finish in a single unit, it can be built in much less time than the conventional frame wall with its 14 applied layers of siding, sheathing, building paper, insulation, lath, multiple coats of plaster, wall paper and paint. No wonder contractors using Cemesto conservatively figure building time at approximately one-third of the time normally required by ordinary construction.

The performance of Cemesto fulfills or exceeds every basic requirement of a building wall. Proof of its structural strength is demonstrated by its adoption in industrial construction for roof decks and curtain walls. Insulation comparisons prove Cemesto walls superior in resistance to heat transmission to walls of ordinary siding (wood, stucco or brick), wood sheathing, lath and plaster. Insulation superiority means cooler interiors in summer . . . warmer, more comfortable interiors in winter with reduced fuel costs. The cement-asbestos board surfaces provide weather-, fire- and wear-resistant exterior and interior finish. At the same time, a pleasing neutral grey color of the surfaces makes further decoration unnecessary. However, when desired, surfaces may be painted or otherwise decorated to suit individual tastes.

Cemesto is the key material in the Post and Girder System—when combined with the skeleton wood frame of shop processed columns, girders, partition framing members, conventional roof framing, floor and ceiling joists, the house structure is complete.

A single 4′ x 8′ x 1$\frac{9}{16}$″ Cemesto panel supported on its four edges can safely withstand the combined weight of 16 men each weighing 160 lbs.

INSULATION COMPARISON
A single thickness (1$\frac{9}{16}$″) of Cemesto is equivalent in insulation value to 25 inches of common brick.

(1) Conventional foundation or slab is prepared

(2) Columns and girders are assembled and erected

(3) Roof trusses are installed and braced

(4) Cemesto panels are fitted into position

FIGURE 1.8 *Advertisement from a Celotex Corporation catalog detailing the construction of a Cemesto and wood frame house (Celotex Corporation 1940). Courtesy of Stock Plan Books Collection, Northwest Architectural Archives, University of Minnesota Libraries.*

prefabricated, factory-built, low-cost housing industry (Hales 1997, 82). Modern building materials such as Cemesto were plentiful and readily available, and the advances in construction systems and techniques allowed Cemesto houses to be quickly built. The construction system for these units was advertised in a Celotex Corporation catalog as the “Cemesto Post and Girder System” and was offered in a range of traditional and modern styles (Celotex Corporation 1940) (fig. 1.8).

Charles and Ray Eames were not the only designers to use Cemesto. The Strutt House in Ottawa, Canada, built in 1956 by architect James Strutt, used timber framing and large Cemesto panels in a unique design. Architect Harwell Hamilton Harris used Cemesto and Celotex insulation in several of his designs in California (Muchnic 1984). Frank Lloyd Wright also used Cemesto in his “standardized Usonian automatics and pre-fabs” work in the 1950s, as well as in his designs for the Carlson House in Phoenix, Arizona, and the Louis Penfield House in Willoughby, Ohio (Pyron 1963, 23, 24). In 1953, Wright used Cemesto, along with concrete block and glass, in the construction of a temporary art pavilion next to the Solomon R. Guggenheim Museum in New York (Louchheim 1953, 23). The pavilion, covering 10,000 square feet (929 square meters), was constructed for an exhibition of the architect’s work, including a full-scale, fully furnished two-bedroom residence.

It is assumed that the Celotex Corporation continued to produce Cemesto until the 1980s, although archival research could not locate references to the material beyond the mid-1960s. By this time, it was known that asbestos was harmful to human health, and litigation was present. Later, by the 1990s, the United States had placed a partial ban on the manufacture, import, processing, and distribution of some asbestos-based products, prohibited new uses of the material, and begun to regulate asbestos-abatement industries to protect the health of workers.[8]

CHAPTER 2

CEMESTO PANELS AND THEIR SIGNIFICANCE AT THE EAMES HOUSE

The Eames House uses a number of prefabricated building materials developed during the twentieth century. Cemesto panels were installed within Truscon steel frames and window units (figs. 2.1 and 2.2) and are found in areas where the Eameses desired an opaque rather than translucent or transparent material in the steel window frames (stucco was used elsewhere within the steel frame). A 1949 *Arts and Architecture* article describes the panels as follows: "A novel feature is the adaptation of Celotex Cemesto Board as insulating panels in some sections of the exterior walls. This multifunction Celotex product provides structural strength, insulation, and maintenance free exterior and interior finish in a single thickness. Its use on this house fits nicely into this interior type of design" (*Arts and Architecture* 1949b, 11). There are eighty-seven infill panels, either Cemesto panels or their replacements made from Transitop (a similar material) or plywood. The panels are located on the east, north, and west elevations of the residence and on the east, west, and south elevations of the studio (figs. 2.3–2.8). Some of the panels on the exterior of the residence and studio are painted, but many retain their natural, mottled gray color. On the interior, the panels remain unpainted, with the exception of four panels in the studio that had been replaced with plywood.

FIGURE 2.1 *Photo of Eames House studio exterior showing various types of glass, stucco, and Cemesto and replacement panels (painted and unpainted). Photo: Joshua White, 2016. ©Eames Office.*

FIGURE 2.2 *View of the interior faces of the Cemesto and replacement panels (painted and unpainted) shown in figure 2.1. Note the open-tread staircase that partially conceals them and the Plyon window panels in custom-designed wooden frames that provide light control. Photo: Joshua White, 2016. ©Eames Office.*

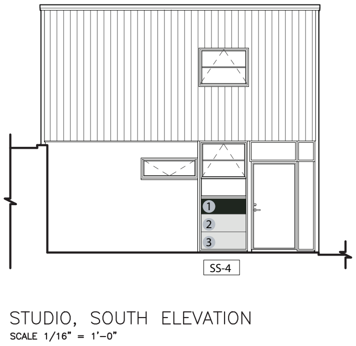


FIGURE 2.3 *Eames House studio, south elevation, showing Cemesto panels and panel identification numbers. Drawing by Getty Conservation Institute, 2015, adapted from Historic American Building Survey CA-2903, Library of Congress, Prints & Photographs Division.*

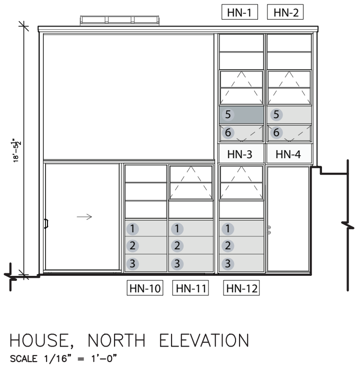


FIGURE 2.4 *Eames House residence, north elevation, showing Cemesto panels and panel identification numbers. Drawing by Getty Conservation Institute, 2015, adapted from Historic American Building Survey CA-2903, Library of Congress, Prints & Photographs Division.*

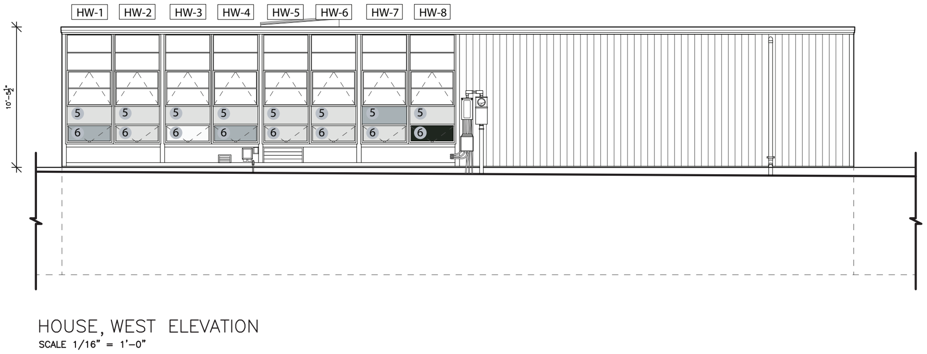


FIGURE 2.5 *Eames House residence, west elevation, showing Cemesto panels and panel identification numbers. Drawing by Getty Conservation Institute, 2015, adapted from Historic American Building Survey CA-2903, Library of Congress, Prints & Photographs Division.*

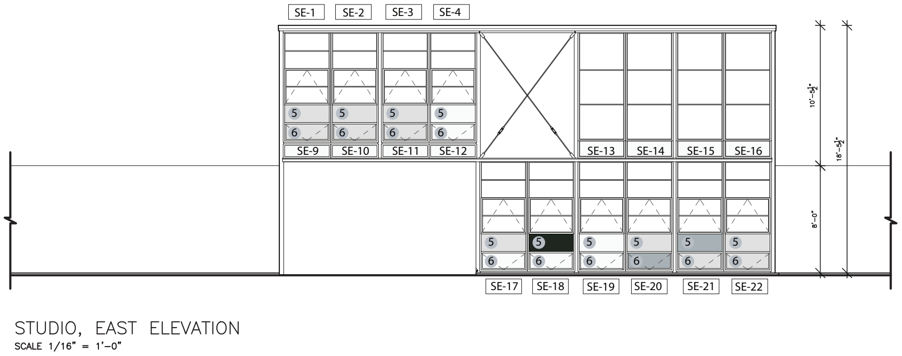


FIGURE 2.6 *Eames House studio, east elevation, showing Cemesto panels and panel identification numbers. Drawing by Getty Conservation Institute, 2015, adapted from Historic American Building Survey CA-2903, Library of Congress, Prints & Photographs Division.*

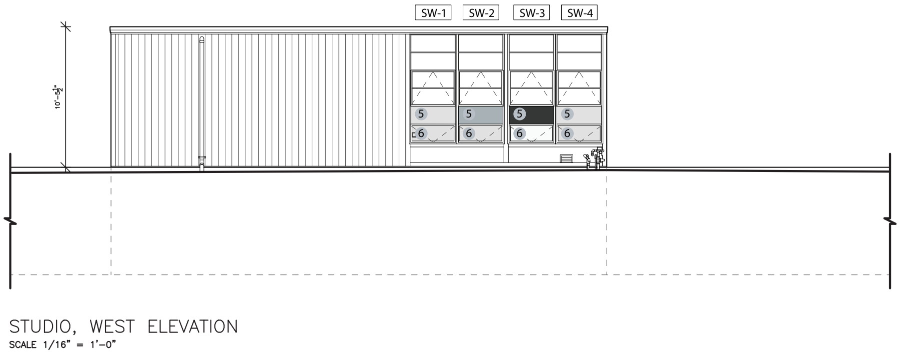


FIGURE 2.7 *Eames House studio, west elevation, showing Cemesto panels and panel identification numbers. Drawing by Getty Conservation Institute, 2015, adapted from Historic American Building Survey CA-2903, Library of Congress, Prints & Photographs Division.*

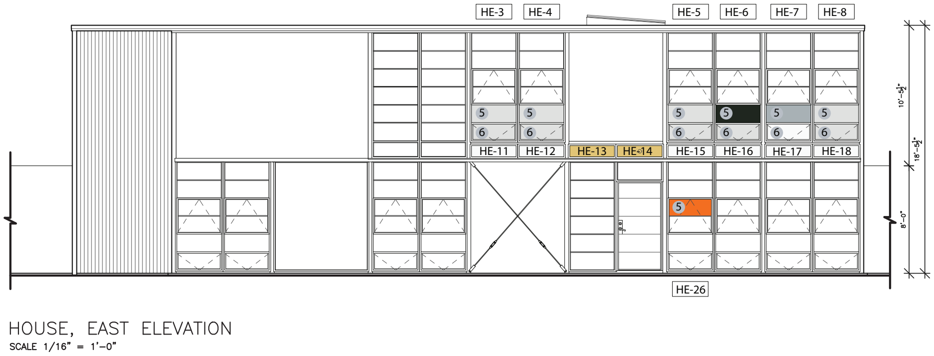


FIGURE 2.8 *Eames House residence, east elevation, showing Cemesto panels and panel identification numbers. Drawing by Getty Conservation Institute, 2015, adapted from Historic American Building Survey CA-2903, Library of Congress, Prints & Photographs Division.*

Though the Cemesto panels were a prefabricated, off-the-shelf product for building construction, they were customized by the Eameses for the Eames House. Typically, full-size Cemesto panels were used as wallboard per the manufacturer's recommendations. They were nailed to wood framing and their edges made watertight using gaskets and sealants. The Eameses, however, customized the panels by cutting them down to fit into the Truscon steel window frames or spandrels.

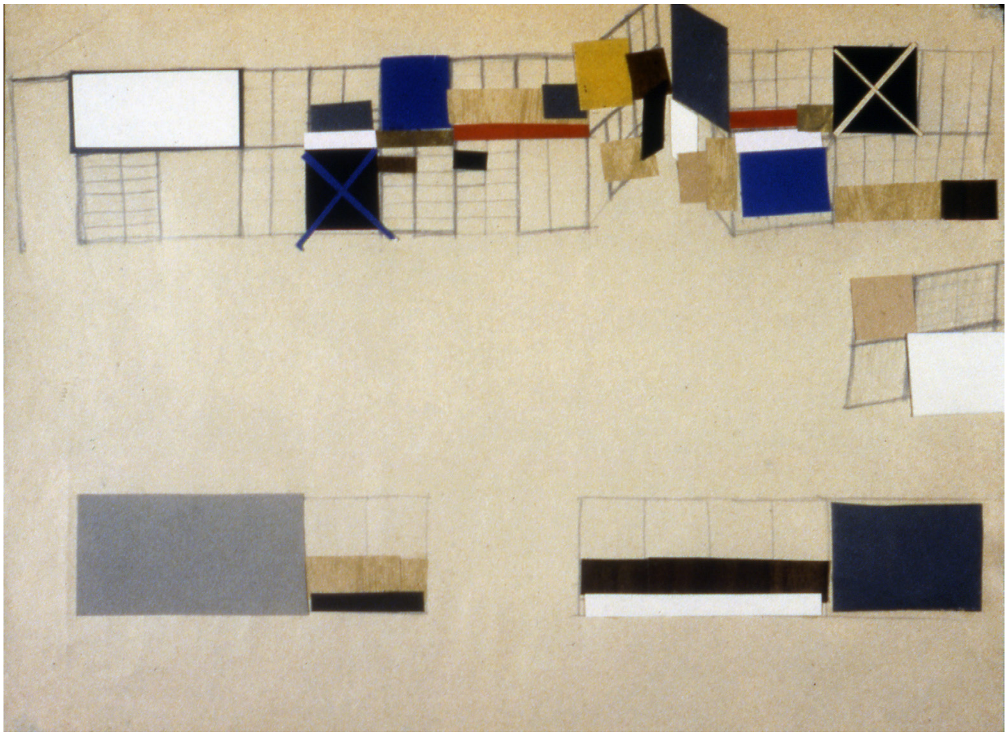
Even when cut down to size, additional customization was required. Charles noted that Cemesto panels were "about ¼ inch [19.05 millimeters] too thick to use in the sash without [rabbeting]"; therefore, each panel had to be cut around the edges (Eames 2015, 70).[9] The panels were held in place in the frame with the aid of glazing putty, wood shims, and nails that typically went through existing nail holes in the upper part of the frame and reached only to the Celotex core, rather than through the full panel. On the operable hopper windows, nailing was noticed on the lower part of the frame as well. Whether the frames were predrilled or the holes were drilled on-site is unknown.

The installation of the panels was undertaken by the Los Angeles firm of Lamport, Cofer, and Salzman, the general contractor on the construction of the Eames House. Various members of the Eames Office, who were involved in the construction of the house, might have also participated in the installation of the panels.

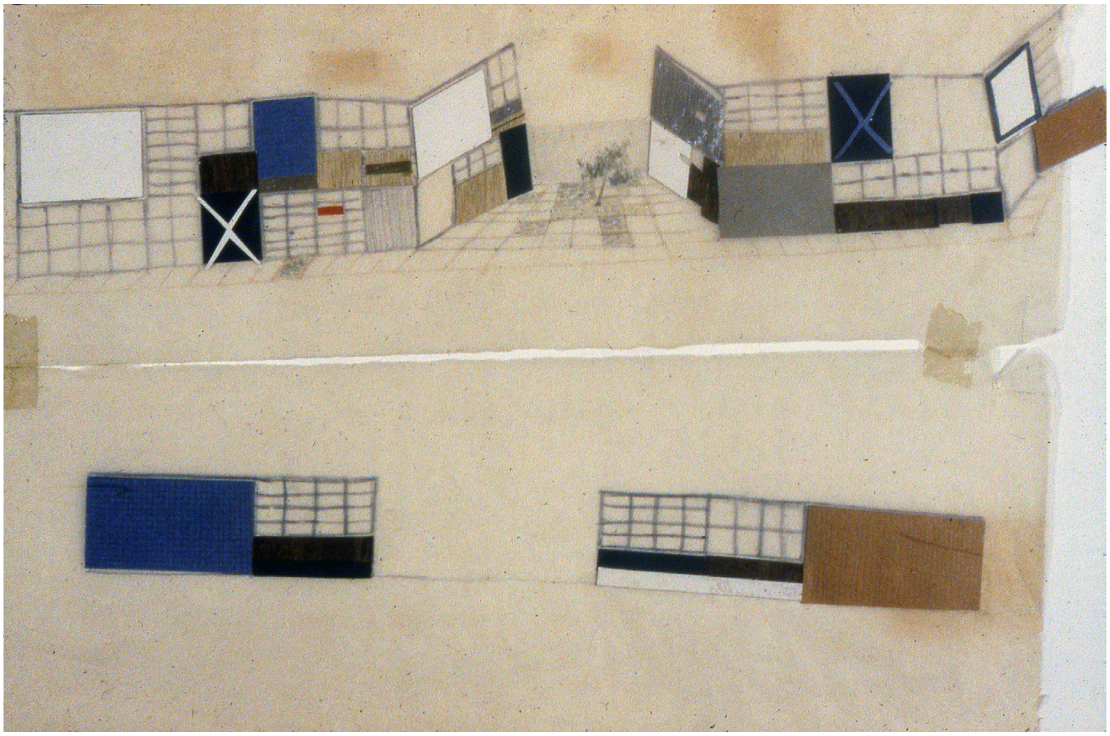
The first painting campaign of the Eames House relied on paints purchased from a Sears, Roebuck and Company department store, and despite the Eameses' intention to experiment with the use of color, they ultimately made few changes to the initial paint scheme. According to Ray, they "could try a color and see its relationship to others," then "simply change it" if they didn't like it (quoted in Kirkham 1990, 136). In drawings that are undated but presumed to predate the construction of the Eames House, Ray experimented with different colors and color placements for the design of the residence and studio, including the treatment of the Cemesto panels (figs. 2.9a and 2.9b). About the initial scheme, Charles explained: "Color was planned and used as a structural element, and while much concern was given to its use in the various structural planes, the most gratifying of all the painted surfaces is the dark, warm gray that covers the structural steel and metal sash. The varying thickness and constant strength of this line does more than anything else to express what goes on in the structural web that surrounds the building. It is also this gray web that holds in a unit the stucco panels of white, blue, red, black, and earth" (*Arts and Architecture* 1949a, 30). Subsequent painting campaigns have attempted to visually match this image, which has become "fixed in the mind of the architectural community and taken to be the architecture" (Colomina 1997, 132).

Maintenance records from the Eames Foundation indicate that a number of damaged or deteriorated Cemesto panels have been repaired or replaced with similar materials:

- In October 1975, Charles Eames ordered two Transitop panels from Industrial Building Materials, which were delivered in November of the same year. The order indicates these were 4 by 8 feet (1.22 by 2.44 meters) and 1⅛ inches (2.86 centimeters) thick (Eames Foundation records, purchase order dated October 30, 1975, and delivery ticket dated November 13, 1975). It is unclear if these Transitop panels were used in 1975 or shortly thereafter, or if they were stored and used at a later date.
- In 1977, Ray Eames prepared a condition assessment of the panels. On the same document, she recorded that panels in the residence had been replaced in 1977, 1981, and 1982. The replacements were recorded as being installed on the lower part of the north elevation of the residence and on the lower part of the east elevation of the studio.
- Several pages of notes and questions dated December 10, 1981, include questions about ordering a number of "transitop asbestos panel[s]," querying if they could be ordered from Industrial Building Materials and if the supplier could cut the panels to size. Specific cutting details for the edges (specifically, the "rabbeting" customization undertaken for the original panels) are included, as are various measurements and cost estimates. On one page, the number to be ordered is six panels and, on another page, fourteen panels. It is unclear how many were ordered and if these replacement panels were installed. These notes most likely refer to the repairs undertaken in 1981 or 1982 mentioned in the bullet point above.
- Former Eames Foundation staff member Shelley Mills recalls nine panels on the north elevation of the residence being repaired in the late 1990s or early 2000s (panel nos. HN10-1 to 3, HN11-1 to 3, and HN12-1 to 3). She relays that these nine panels were taken out of their steel frames and repaired by removing the water-damaged Celotex core from the asbestos-cement sheet and replacing it with a rigid blue insulation or extruded polystyrene foam board. It is assumed that the replacement core material was fixed to the cement-asbestos sheets using an adhesive. Once the panels were reassembled by adhering the asbestos-cement sheets to the new core material, the panels were reinstalled.[10]



(A)



(B)

FIGURES 2.9A, 2.9B *Studies of exterior elevations by Ray Eames showing different fenestration configurations and color schemes, 1949. ©Eames Office.*

- In 2012, four Cemesto panels on the lower part of the east elevation of the studio were replaced by the Eames Foundation with plywood, because of deterioration of the Celotex core (panel nos. SE17-6, SE18-5, SE18-6, and SE19-6).
- In early 2017, several Cemesto panels (or their replacements) were damaged by heavy rainfall. An exterior asbestos-cement board fell off a panel located on the east elevation of the studio. Other panels were damaged as moisture and rainfall infiltrated the panel, causing the fiberboard core to expand. This expansion caused the exterior asbestos-cement sheet to detach from the core and sit forward from the frame.

It is not known if additional repair or replacement of Cemesto panels was carried out at the Eames House, other than the instances recorded above. Additionally, painting campaigns in 1958, 1966, 1974, 1976–1978, 1989, and 2003 may have included the repainting of the panel faces, as well as the replacement or repair of sealants between the steel frames and the Cemesto panels (Eames Foundation records).

2.1 Current Historic Status of the Eames House

The Eames House is listed on several historic registers and has the following designations:

- The US Secretary of the Interior declared the Eames House (Case Study House No. 8) a National Historic Landmark (NHL) on September 20, 2006. NHLs are places of national significance that are designated for their "exceptional value or quality in illustrating or interpreting the heritage of the United States in history, architecture, archaeology, engineering and culture" (US National Park Service 1999, 9). An NHL is the highest level of designation in the United States.
- Because of its designation as a National Historic Landmark, the Eames House was automatically listed on the National Register of Historic Places and on the California Register of Historical Resources.
- "Case Study House No. 8—The Eames House and Studio and Grounds" was designated a City of Los Angeles Historic-Cultural Monument (HCM #381) on July 15, 1988, in accordance with the Los Angeles Cultural Heritage Ordinance.

The latter listing, by the City of Los Angeles, brings with it specific regulations. Under the ordinance, exterior alterations *must* comply with the *Secretary of the Interior's Standards for the Treatment of Historic Properties*, and proposed substantial alterations to a property are reviewed by the city's Cultural Heritage Commission for compliance. To assist with compliance, the city's Office of Historic Resources provides technical assistance to owners of HCMs, who are entitled to apply the California Historical Building Code when carrying out work.

The Eames House has also received other awards and recognitions. In 1978, the "Charles Eames House" was the recipient of the American Institute of Architects' Twenty-Five Year Award. International recognition came in 1979, when the Royal Institute of British Architects awarded its Royal Gold Medal to the Office of Charles and Ray Eames.

2.2 Significance of the Cemesto Panels at the Eames House

The NHL designation affirms the site as having significance because of its association with the Case Study House program, its association with Charles and Ray Eames, and its status as "an exceptionally important work of postwar Modern residential design and construction" (Historic Resources Group and National Park Service, 2005, 9). The local heritage designation does not call out the specific significance criteria under which the Eames House was listed, but it appears that, at a minimum, the site was designated for its architectural significance and as a notable work of a master designer.

The *Eames House Conservation Management Plan* (Burke et al. 2018) also provides a current assessment of the heritage significance of the Eames House, including the building complex, its landscape and setting, and its contents and collections. The CMP takes into account the significances identified in the heritage designation in addition to other values that have become known through research and investigation. Using the CMP's statement of significance, this section examines how the Cemesto panels contribute to the overall significance of the Eames House.

In addition to being an outstanding example of postwar design, as noted above, the Eames House has been assessed as exhibiting "many of the hallmarks of the period [including an] innovative selection and use of industrial materials in a residence, an honest expression of materials and structure; and an emphasis on the use of prefabricated and experimental construction materials" (Burke et al. 2018, 3).

The Cemesto panels were an innovative use of an experimental construction material at the Eames residence and studio. Charles and Ray took a material that had been used in prefabricated housing in the 1940s and handcrafted the panels by tailoring their shape by cutting large panels down to smaller sizes and detailing them to fit within the steel-frame structures. This is an example of the Eameses' "interplay between craft and machine work" and "evidence of the Eameses' humanization of industrial modernism" (Burke et al. 2018, 9). With more than half of the exterior faces and all of the interior panels left unpainted, the Cemesto panels stand as an honest expression of materials. Yet the panels on the exterior of the buildings also provided an important canvas for the Eameses to incorporate color in their design.

2.3 Integrity Evaluation

To receive a heritage designation, a site or property must possess integrity and the ability to convey its significance. One measure of integrity is the wholeness or intactness of the site. Other measures are evaluated on retention of location, design, setting, material, feeling, workmanship, and association. The NHL designation for the site states that the "Eames House retains an extraordinarily high degree of material integrity" (Historic Resources Group and National Park Service 2005, 7).

Based on historical information, most of the Cemesto panels at the Eames House are original. As noted above, some have been repaired or replaced during and after the Eameses' lifetimes. Specifically, several panels were replaced with an in-kind product (such as Transitop) prior to Ray Eames's death in 1988. Thereafter, nine panel cores were repaired or replaced, and some panels were removed and replaced with plywood.

The panels that were originally painted remain and have been repainted with the same colors over the years. The panels that were originally unpainted also remain so. Overall, the panels maintain a high degree of integrity when measured in terms of intactness and retention of location, design, setting, material, feeling, workmanship, and association, although the panels with a foam core arguably have much less material integrity.

2.4 Levels of Significance

Elements of a heritage place are often ranked on a scale of exceptional, high, moderate, or little significance, or as intrusive. Site elements may have different levels of significance based on their integrity and the extent to which they embody or demonstrate the key heritage values of the site. Loss of integrity may contribute to a diminished level of significance. In the case of the Eames House, most components are exceptional, with a few being moderate, and fewer still being intrusive (Burke et al. 2018).

Burke et al. (2018) assess the Cemesto panels as being of exceptional significance. Panels that have been replaced with in-kind materials while the Eameses were alive, such as those of Transitop, are assessed as having high significance. Substitute components or materials that have been installed since Ray Eames's death in 1988 are assessed as having moderate significance. Based on additional information gathered as part of this report, the plywood panels that were installed in the studio in 2012 by the Eames Foundation are assessed as having little significance.

CHAPTER 3

CAUSES AND MECHANISMS OF DETERIORATION

3.1 Methodology

The results in this chapter are largely based on a condition assessment, including photographic recording, of the Cemesto panels undertaken in summer 2015 and winter 2022, complemented by limited laboratory analyses conducted between 2018 and 2020 to understand some of the recorded conditions and their underlying causes. Laura Matarese, Chandler McCoy, and Anna Flavin from the GCI, with assistance from Eames Foundation staff, performed the condition assessment and photographic recording on July 8, 13, 27, and 29, 2015, and on August 5, 12, and 19, 2015. In January 2017, Matarese and McCoy recorded additional photographic documentation of several panels that had been damaged by heavy winter rainfall.

The condition assessment included the visual inspection of the current condition of the panels, including the sealants and surrounding steel frame. No panels were removed from the frame or taken apart. It was impossible, therefore, to visually inspect the fiberboard core, other core materials, or adhesives located between the asbestos-cement facings.

In total, there are eighty-seven exterior infill panels consisting of Cemesto or replacement materials. A numbering system established by Escher GuneWardena Architects for a documentation project in 2012 was used to identify the panels. The system envisions the elevation as a combination of columns and rows. Each panel is designated by two letters and up to three numbers depending on the location. The first letter is an H or an S (House or Studio), and the second letter marks the exposure (E, East; W, West; N, North; S, South). Each column section is identified with up to two digits, and each row is identified with a number (see figs. 2.3–2.8). In this way, HE-8-5 refers to an infill panel located in the house, east elevation, in the eighth column in the fifth position. Condition assessment information was recorded in an Excel spreadsheet and included the following:

- Panel number
- Date of recording
- Finish (painted or unpainted)
- Paint color (if applicable)
- Overall initial visual assessment of panel face condition (rated as poor, fair, or good)
- Condition assessment of the steel frame
- Condition assessment of the sealant between the Cemesto panel and the steel frame, including evidence of a sealant, the type of sealant, and the sealant condition
- Condition assessment of each panel, identifying any soiling (dirt), stains, crack impacts, or missing pieces

Photographs were taken of each Cemesto panel on the exterior and, where accessible, the interior faces (fig. 3.1). A photographic log documented the date, image number, panel number, and other

FIGURE 3.1 *Front to back: Laura Matarese, Anna Flavin, and Chandler McCoy of the GCI photographing the Cemesto panels on the upper level of the Eames House residence, 2015. Photo: Lucia Dewey Atwood.*

details such as face location. This information was also recorded in the metadata of each image. During postprocessing, photographs were color corrected and spatially rectified, and metadata were added in Adobe Bridge and Photoshop CS6.

On February 8, 10, and 24, 2022, McCoy and GCI colleagues César Bargues Ballester and Drew Barnhart inspected selected panels, including perimeter sealants and steel frames. The fieldwork included the revision and update of the 2015 condition assessment, which was used as a baseline to conduct a comparative analysis and assess additional deterioration occurring over the course of seven years.

3.2 Findings of the 2015 Condition Assessment

The panels, sealants, and surrounding steel frame exhibited a range of conditions, including soiling (dirt), various types of stains, fading, cracks, dents, missing pieces, rusting of the steel frame, and deterioration of sealants. The conditions of the panels of the residence and studio in the 2015 assessment, exterior and interior, are summarized in tables 3.1–3.4.

In 2015, more than half of the exterior panel faces on the residence and studio were assessed as being in good condition, 60% and 74%, respectively; 19% and 17% were in fair condition; and 21% and 9% were in poor condition. The interior panel faces of the residence and studio were mostly in good condition, 54% and 66%, respectively; and 2% and 17% were in fair condition. Figure 3.2 details the initial condition assessment. Several panel faces on the interiors of both buildings were not assessed because they are located behind built-in furniture or concealed by structural framing, as is the case with the spandrels. Based on historic documentation and a visual assessment, four panels have been replaced with plywood. These were in poor to fair condition when surveyed in 2015, and in 2017, after heavy winter rains, all were in poor condition.

On the exterior of the residence, twenty panels were painted, and thirty-two panels remained unpainted. On the studio exterior, eighteen panels were painted, and seventeen remained unpainted. None of the interior panel faces were painted, with the exception of the four plywood panels.

All the exteriors were soiled to some degree, and some showed fungal growth. Many of the dirtiest panels were close to the ground on the west elevation of the buildings and the east elevation of the studio. Several of the panels on the upper levels of the buildings were also heavily soiled; in most cases, the heaviest soiling appeared on the upper half of the panel (fig. 3.3). All the interior panel faces had very little to no soiling (fig. 3.4); however, several were stained or marked. Unlike the unpainted panels, the painted surfaces appeared to be less soiled.

Most of the panels on the exterior and interior of the structures showed evidence of staining or marks. For the purposes of the assessment, “stains” appear to be permanent, but “marks” appear to be removable. The ability or need to remove the stains and/or marks would require further investigation.

The stains included white streaks that may be water or cleaning stains, paint stains, yellow-brown stains, and rust stains (exterior only), as well as various gray to brown drip-like marks (figs. 3.5 and 3.6). The majority of panel faces on the interior and exterior of both buildings exhibited these stains and marks to varying degrees. For example, some panels were covered with white stains and others simply had a small mark of paint near the edge. Several letters (A or B) written in chalk from an unknown date were found on some interior panel faces (fig. 3.7).

Panel Damage

A few panels showed damage such as cracks, dents, and missing pieces (figs. 3.8a–d). On the exterior of the buildings, six of the eighty-seven panel faces had small to large cracks in the asbestos-cement facing, three had small dents in the facing, and ten had small to large missing pieces where part of the facing and fiberboard core had broken off. The interior panel faces of both structures had no cracks, four panels had dents, and four panels had missing pieces.

TABLE 3.1

Panel face condition assessment summary of the Eames residence exterior, 2015.

Total number of panel faces: 52		Painted	20 (38%)
		Unpainted	32 (62%)
Initial assessment of the panel face condition based on visual inspection		Good	31 (60%)
		Fair	10 (19%)
		Poor	11 (21%)
Asbestos-cement facing condition	Appearance	Soiling	Varied from minimal dirt to heavy dirt appearance
		Staining and marks	Various, including paint stains, sealant stains, white streaks, rust stains
		Leaching	Present on unpainted faces on east and west elevations
	Damage	Crack	4 have cracks (3 also have missing pieces)
		Dent	3 on west elevation
		Missing piece	6 (2 on west elevation and 4 on north elevation)
Potential indicators of fiberboard core and adhesive deterioration	Panel expansion	Flush	28 (54%)
		Expanded	24 (46%)
	Firmness	Some looseness	7 (13%)
		Firm	32 (62%)
		Unknown (unable to reach/access panel)	13 (25%)
Steel-frame condition	Corrosion	Present	10 (19%)
		Not present	42 (81%)
Sealant condition	Type	Most sealant appears to be silicone, with some areas of older, drier sealant or caulking.	
	Degree of deterioration	Intact	24 (46%)
		Partially deteriorated	19 (37%)
		Unknown (unable to reach/access panel)	9 (17%)

TABLE 3.2

Panel face condition assessment summary of the Eames studio exterior, 2015.

Total number of panel faces: 35		Painted	18 (51%)
		Unpainted	17 (49%)
Initial assessment of the panel face condition based on visual inspection		Good	26 (74%)
		Fair	6 (17%)
		Poor	3 (9%)
Asbestos-cement facing condition	Appearance	Soiling	Moderate dirt on upper part of panel faces; splotchy appearance around edges
		Staining and marks	Various, including scuff-like marks and white and brown streaks.
		Leaching	Present on unpainted faces on east and west elevations
	Damage	Crack	2 (6%)
		Dent	None
		Missing piece	4 (12%)
Potential indicators of fiberboard core* and adhesive deterioration	Panel expansion	Flush	23 (66%)
		Expanded	12 (34%)
	Firmness	Some looseness	5 (15%)
		Firm	19 (54%)
		Unknown (unable to reach/access panel)	11 (31%)
Steel-frame condition	Corrosion	Present	6 (17%)
		Not present	29 (83%)
Sealant condition	Type	Mixed; harder (possibly older) and silicone-based	
	Degree of deterioration	Intact	18 (51%)
		Partially deteriorated	14 (40%)
		Unknown (unable to reach/access panel)	3 (9%)

**Nine panels have had their core replaced with blue foam on the north elevation of the residence.*

TABLE 3.3

Panel face condition assessment summary of the Eames residence interior, 2015.

Total number of panel faces: 52		Painted	None
		Unpainted	37 (71%)
		Unknown (unable to reach/access panel)	15 (29%)
Initial assessment of the panel face condition based on visual inspection		Good	28 (54%)
		Fair	1 (2%)
		Poor	None
		Unknown (unable to reach/access panel)	23 (44%)
Asbestos-cement facing condition	Appearance	Soiling	Varied, from very minor to minor dirt
		Staining and marks	Various types; white streaks, yellow/orange/brown stains, gray stains, brown stains
		Leaching	Imperceptible
		Unknown (unable to reach/access panel)	23 (44%)
	Damage	Crack	None
		Dent	3 (6%), 2 on east elevation (in main bedroom) and 1 on west elevation (second bedroom)
		Missing piece	3 (6%), 2 on east elevation (in main bedroom) and 1 on west elevation (second bedroom)
		Unknown (unable to reach/access panel)	23 (44%)

continued on next page

TABLE 3.3 ***continued***

Panel face condition assessment summary of the Eames residence interior, 2015.

Potential indicators of fiberboard core and adhesive deterioration	Panel expansion	Flush	4 (8%)
		Expanded	19 (36%)
		Unknown (unable to reach/access panel)	29 (56%)
	Firmness	Some looseness	22 (42%)
		Firm	4 (8%)
		Unknown (unable to reach/access panel)	26 (50%)
Steel-frame condition	Corrosion	Present	28 (54%)
		Not present	8 (15%)
		Unknown (unable to reach/access panel)	16 (31%)
Sealant condition	Type	Mostly hard (possibly older) cracking or missing; one panel face (HE-26-1) exhibits more recent repairs (silicone based).	
	Degree of deterioration	Intact	2 (4%)
		Partially deteriorated	27 (52%)
		Unknown (unable to reach/access panel)	23 (44%)

TABLE 3.4

Panel face condition assessment summary of the Eames studio interior, 2015.

Total number of panel faces: 35		Painted	4 (11%) (plywood replacement only, 3 white, 1 black)
		Unpainted	27 (78%)
		Unknown (unable to reach/access panel)	4 (11%)
Initial assessment of the panel face condition based on visual inspection		Good	23 (66%)
		Fair	6 (17%)
		Poor	None
		Unknown (unable to reach/access panel)	6 (17%)
Asbestos-cement facing condition *Note that 4 are plywood; this is included in the panel assessment for appearance and damage.	Appearance	Soiling	Varied from minimal to none
		Staining and marks	Various, including white streaks, paint stains, rust stains, dark marks, chalk (letters *A* and *B*)
		Leaching	Imperceptible
	Damage	Crack	None
		Dent	1 on east elevation
		Missing piece	1 on west elevation due to cables and wires
		Unknown (unable to reach/access panel)	4 (11%)
Potential indicators of fiberboard core and adhesive deterioration *Note that 4 are plywood and are not included in this assessment.	Panel expansion	Flush	11 (31%)
		Expanded	17 (49%)
		Unknown	7 (20%)
	Firmness	Some looseness	1 (3%)
		Firm	18 (51%)
		Unknown (unable to reach/access panel)	16 (46%)

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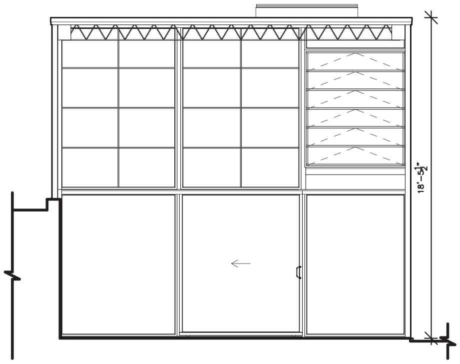
TABLE 3.4 *continued*

Panel face condition assessment summary of the Eames studio interior, 2015.

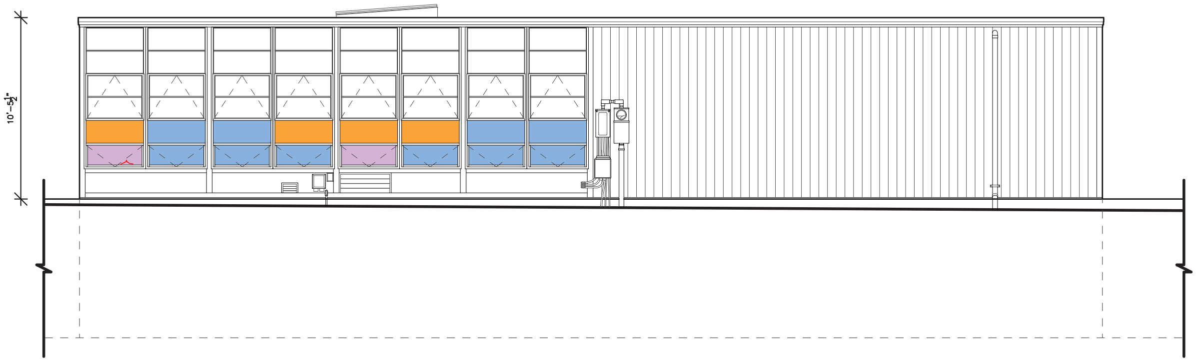
Steel-frame condition	Corrosion	Present	29 (82%)
		Not present	2 (7%)
		Unknown	4 (11%)
Sealant condition *Note that 4 are plywood and have no sealant and are not counted in this assessment.	Type	Mixed; harder (possibly older) and silicone based. Most sealant appears to be silicone based, with some areas of older, drier sealant or caulking.	
	Deterioration	Intact	4 (11%)
		Partially deteriorated	14 (40%)
		Unknown (unable to reach/access panel)	17 (49%)

Initial condition assessment, 2015 (Revised in 2018).
Exterior elevations

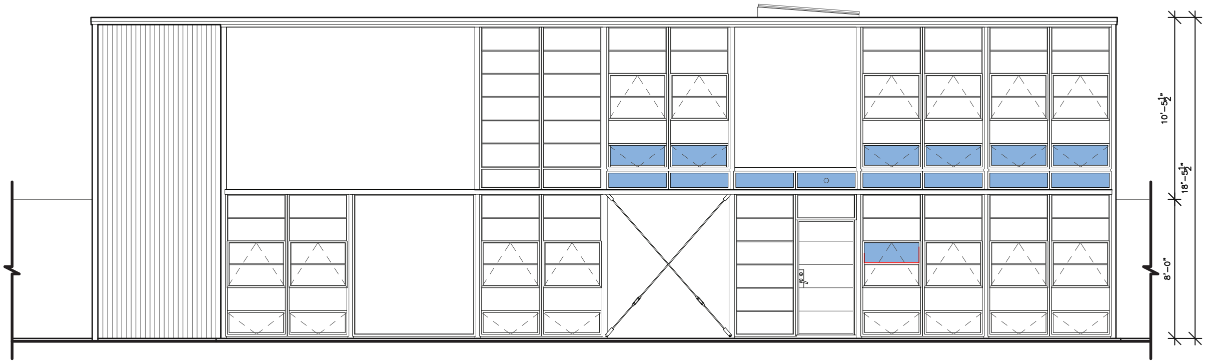
HOUSE, NORTH ELEVATION
SCALE 1/16" = 1'-0"



HOUSE, SOUTH ELEVATION
SCALE 1/16" = 1'-0"

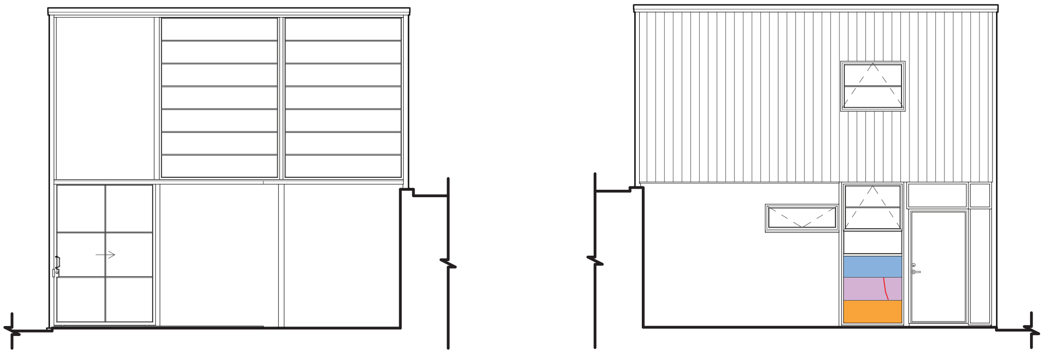


HOUSE, WEST ELEVATION
SCALE 1/16" = 1'-0"



HOUSE, EAST ELEVATION
SCALE 1/16" = 1'-0"

Legend: 🟦 Good 🟧 Fair 🟪 Poor ━ Crack



STUDIO, NORTH ELEVATION
SCALE 1/16" = 1'–0"

STUDIO, SOUTH ELEVATION
SCALE 1/16" = 1'–0"

STUDIO, WEST ELEVATION
SCALE 1/16" = 1'–0"

STUDIO, EAST ELEVATION
SCALE 1/16" = 1'–0"

FIGURE 3.2 *Elevations showing the initial condition assessment of the exterior Cemesto panel faces of the Eames residence and studio. Drawing by Getty Conservation Institute, 2018, adapted from Historic American Building Survey CA-2903, Library of Congress, Prints & Photographs Division.*

FIGURE 3.3 *Photo of Eames residence exterior, east elevation, showing heavy soiling on panels HE-8-5 and HE-8-6. Photo: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

FIGURE 3.4 *Photo of Eames House studio interior, east elevation, showing no soiling and the natural mottled gray color of the asbestos-cement board. Photo: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

FIGURE 3.5 *Photo showing white streaks on panel HE-3-5. Photo: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

FIGURE 3.6 *Photo showing brown marks on panel SW-1-5. Photo: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

FIGURE 3.7 *The letter* B *written in chalk in the center of the asbestos-cement facing of a lower panel in the Eames studio interior. Note broken lower left corner, possibly caused during the installation of telecommunication and internet wires. Photo: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

(A)

(B)

(C)

(D)

FIGURES 3.8A–D *Examples of damage to panels at the Eames residence and studio: (a) a small crack in the asbestos-cement facing on the studio interior, east elevation; (b) a large crack in the asbestos-cement facing on the studio exterior, south elevation; (c) a small dent in the asbestos-cement facing on the studio exterior, west elevation; and (d) a panel with a large piece missing, exposing the Celotex fiberboard core, on the studio exterior, west elevation. Photos: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

Fiberboard Core and Replacement Core Materials

The fiberboard core and adhesives were generally not visible and thus could not be assessed. In some cases, however, the core was visible because the panel was protruding from the steel frame, the sealant was insufficient or deteriorated, or pieces of the asbestos-cement facing were missing. For example, the blue foam replacement core in several panels at the residence (ground level of the north elevation) remained exposed because of missing pieces of asbestos-cement sheeting and a lack of sealant in the joints.

The condition of the adhesives and core materials was assessed using two potential indicators: whether or not the asbestos-cement board of each panel was flush with the frame and whether the panel face was firm (hard and secure) or loose when pressed (areas of the panel face yielded to some degree). These observations may indicate if the core had expanded because of water infiltration, if the core had deteriorated and therefore shrunk, and if the adhesives were still functioning effectively. It has been noted that these indicators are potentially flawed: the looseness of a panel may not indicate poor conditions of the adhesive and core materials, and any observed protruding or expansion from the frame may be the result of the width of the panel being larger than the frame or the way the panels were originally installed. Further methods are needed to accurately determine the condition of the core materials and adhesives.

On the exterior of the residence and studio, more than half of the panel faces felt firm to the touch and less than a quarter were loose. The rest could not be reached or accessed. The interior conditions showed more variation. Half of the interior panel faces of the residence were not accessible, with the remaining panels mostly feeling loose to the touch. Similarly, half of the studio interior panel faces could not be accessed; however, the majority of those evaluated were firm.

More than half of the panel faces on the exterior of the residence and studio appeared to be flush with the frame. Nearly half of the exterior panel faces showed evidence of some protrusion from the frame. Typically, the asbestos-cement board protrudes (with or without the core material intact) up to approximately ⅛ inch (3.2 millimeters) at the corners of the panel.

Many of the interior panel faces in the residence could not be assessed because of access issues. However, most of the remaining panels showed evidence of protrusion. In half of these, the asbestos-cement facings were observed either to protrude all the way around the panel with the fiberboard core visible and intact (which may indicate an issue with the thickness and installation of the panel) or to have expanded and apparently detached from the fiberboard core on the lower corners of the panel (figs. 3.9 and 3.10). Half of the panels on the interior were protruding to some extent from the frame. Of these, the asbestos-cement facings were protruding all the way around the panel, although several showed evidence of protrusion only at the top. It was difficult to determine by visual inspection if the core materials still adhered to the asbestos-cement panels or if they were intact.

Frame Condition

Several types of Truscon steel-frame units had infill panels within them, such as fixed and hopper windows and spandrel frames. Typically, the steel frames surrounding the panels were all in good condition, and all had been painted. Corrosion was the primary deterioration condition that was observed.

FIGURE 3.9 *Panels on the studio interior, west elevation, shown protruding from the frame, exposing the Celotex fiberboard core. Photo: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

FIGURE 3.10 *Panel on the residence exterior, north elevation, showing the outer asbestos-cement facing detaching from the fiberboard core and sealant on the lower corners. Photo: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

Less than 20% of the panel frames on the exterior of the residence and studio showed evidence of minor corrosion, 19% and 17%, respectively. The interior frames, however, showed corrosion on more than half of the panel frames at the residence and studio, 54% and 82%, respectively. Corrosion was consistently observed on the bottom and in the lower left- and right-hand corners of the frame, with minor corrosion evident on the upper part of a few frames (fig. 3.11). Corrosion on the steel frame varied from minimal to extensive and presented throughout the residence and studio on the upper and lower levels of the buildings. The exterior steel frames around the panels typically showed minor corrosion; the interior steel frames, however, had minimal to extensive corrosion.

FIGURE 3.11 *Example of rust in the lower corners of a steel frame surrounding Cemesto panels. Photo: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

Sealant Condition

At least three types of sealant have been used in the past between the asbestos-cement board and the steel frame: two were soft and likely silicone-based, and one consisted of a whitish, hard material, which was characterized as a fish oil–based putty by gas chromatography/mass spectrometry (GC/MS). The latter is assumed to be the original glazing putty used at the time of construction and appears to be older than the softer, silicone-based sealants. This glazing putty was observed on all elevations and on both interior and exterior. It is often painted, and it underlies the silicone-based sealant. It appears that at least two silicone-based sealants have been used at the

Eames House. The first silicone-based sealant is located on the exterior of both buildings. For the interior, evidence of the material was found only on the lower east elevation of the studio. The second silicone-based sealant is located only on the exterior and interior of the three panels adjacent to the studio kitchen door. The GCI was informed that Shelley Mills, former Eames Foundation staff member, carried out the application of this particular sealant in the late 1990s or early 2000s.[11]

The glazing putty located on the interior of the studio and residence is partially deteriorated and, in a few instances, absent. Whether these panels ever had any sealant is impossible to determine through visual inspection. The soft, silicone-based sealant observed on the exterior of the studio and residence is intact on approximately half of the panels, with some deterioration of the sealant on the other half, including cracking, uplift, or missing pieces.

Assessment of the Panels after Heavy Rainfall

In early 2017, extensive rain fell in the area over several weeks, following several years of drought. Several panels and frames were affected by water infiltration, and in one case water infiltrated the Eames residence itself.

At least two of the asbestos-cement facings on the exterior of the residence, on the upper north elevation and west elevation, were observed to be protruding from the steel frame, with the core material no longer attached to the asbestos-cement sheet. The fiberboard core appeared to have absorbed water and expanded outward, having broken away from the adhesive and asbestos-cement sheet (fig. 3.12). Damage was sustained by the replacement plywood boards, which also absorbed water and expanded to both the exterior and interior within the frame. Some delamination of the outer wood veneer was observed in the corners of these panels.

FIGURE 3.12 *Panel on the residence exterior, north elevation, damaged after heavy rainfall in 2017. The outer asbestos-cement facing has been pushed out and detached from the Celotex fiberboard core, adhesive, and outer sealant. Photo: Laura Matarese and Chandler McCoy, 2017. ©J. Paul Getty Trust.*

Water appeared to have infiltrated the residence's kitchen through the panels on the lower part of the north elevation, adjacent to the kitchen base cabinets. A pool of water was observed on the kitchen floor tiles next to the sliding door, which was closed at the time and had a tight seal. There is no sealant between the Cemesto panels—whose cores had been replaced—and the frame at this location.

Finally, the asbestos-cement facing of panel SE-11, located on the studio exterior, upper level of the east elevation, had separated from the core material and sealant and fallen onto the path below, leaving the fiberboard core exposed. In the 2015 condition assessment and photographic documentation, this panel was evaluated as being in fair condition overall, though it showed signs of cracking at the top of the panel and signs of breaking away from the silicone-based sealant (fig. 3.13). The damage in 2017 provided an opportunity to assess the interior of the panel and how it was installed. The exposed fiberboard core was found to be saturated with water. It was also observed that wood shims had been placed around the edges of the panel, most likely to hold the panel in place in the steel frame during the original installation (fig. 3.14). Wood shims were likely used elsewhere in both the residence and the studio.

FIGURE 3.13 *Panel SE-11, studio exterior, east elevation, in 2015, prior to detaching and falling off in 2017. Note the signs of cracking and breaking away at the top of the panel. Photo: Laura Matarese and Chandler McCoy, 2015. ©J. Paul Getty Trust.*

FIGURE 3.14 *Panel SE-11 in 2017, showing damage after heavy rainfall. The Celotex fiberboard core, exposed when the exterior asbestos-cement facing fell off, was saturated with water. Wood shims were found to have been installed around the panel to hold it in place, as shown here under the exposed core. Photo: Laura Matarese and Chandler McCoy, 2017. ©J. Paul Getty Trust.*

3.3 Diagnosis of the 2015 Condition Assessment

This section analyzes the results of the 2015 condition assessment and posits several likely causes of deterioration of the Cemesto panels (and their replacements), core materials, sealants, and the surrounding steel frame. A major cause of deterioration of the panels is moisture infiltration into the core and the steel frame. Other causes include soiling, staining, leaching, and damage from impacts.

Moisture as the key cause of deterioration can be traced to the way the Eameses customized the Cemesto panels, which deviated from the Celotex Corporation's recommendations. The manufacturer had developed architectural specifications for the construction of houses using Cemesto as a primary building material for interior and exterior walls. These specifications included installing large Cemesto panels at their full size using wood framing, gaskets, and sealants and nailing the panels into the frame (through the entire width of the panel) so that the edges of the panels would always be covered. This ensured that the panels in the frame would be airtight and watertight. However, the Eameses cut the panels down in size and employed their own installation method: they cut the panels and rabbeted the edges to fit within the frame; used a glazing putty as a sealant and wood shims to hold the panels in place; and secured the panels to the steel frame by driving nails into the fiberboard core only, not through the width of the panel.

Moisture

The following types of deterioration of the panels were assessed as having been caused by moisture infiltration:

- Saturation of the fiberboard core, causing the core to rot and/or to expand and possibly crack the asbestos-cement sheets in the corners and edges (on the interior and exterior sides of the panels)
- Corrosion of the surrounding steel frame on the interior and exterior sides of the panels, found in areas where moisture accumulates, that is, in the lower corners of the steel frame and occasionally along the head and the sill of the frame

Sources of moisture at the Eames House include rain, fog (often called "the marine layer" in Southern California), humidity, watering of the landscape and potted plants, and groundwater.

The panels were not effectively sealed within the surrounding steel frame, allowing moisture to infiltrate the core of the panel and accumulate between the panel and the frame. As the evidence shows, infiltrated moisture can contribute to various degrees of corrosion of the steel frame.

The edges of the panels, after being cut to size and rabbeted, were not waterproofed, leaving the core material and adhesive exposed and vulnerable to moisture. In some elevations, panels protruded forward from the frame, either because of expansion of the fiberboard core from moisture or because the actual thickness of the panel was greater than the depth of the frame, thus exposing the frame, adhesive, and core. Several locations had no sealant between panel and frame; in other areas, the existing sealant had partly deteriorated and appeared to be ineffective at keeping moisture out. It is not known if the first sealant applied was ineffective at the time, or if its gradual deterioration allowed moisture into the panel and frame.

The steel frame surrounding the panels comes in a number of configurations—including frames with sashes (for glass windows), frames without sashes, and spandrels—and the thickness, detailing, and profile of the frame contribute to moisture accumulation in the panel and frame. Frames with sashes have holes in the sash used to nail panels in place and may be an entry point for moisture infiltration. Panels installed in frames without sashes—for example, the north elevation of the residence and the south elevation of the studio—and without an effective sealant exhibit significant problems attributable to moisture infiltration, including corrosion, water stains, cracks, saturated core materials, and leaks into the kitchens of the residence and studio. Several painted Cemesto panels on the exterior spandrels of the buildings are cracked around the edges. This condition appears to be caused by moisture infiltrating the panel, saturating the fiberboard core material and wood shims, and potentially causing the asbestos-cement sheet to separate from the rest of the panel, as seen in 2017 (see fig. 3.13).

Soiling

The degree of soiling on the exterior facings appears to correlate with the location of the panels and adjacent uses. Soiling of the panels appears to be primarily dirt with no biological growth, while a limited number of panels show a fungal-like growth on their outdoor facings. While soiling is visually unappealing, it does not appear to be causing damage or deterioration to the panels.

The lower panels on the east elevation of the studio are adjacent to a pathway with potted plants and to the meadow. The Eames Foundation has noted that in the past, plants were placed close to the structures, which may have caused some splashing of water and dirt onto the panels. Similarly, the lower panels on the west elevation of the studio and residence may accumulate dirt, as they are located in an area that is often used to store gardening and other materials and that is adjacent to a dirt-and-pebble pathway with potted plants that are watered with a garden hose.

All the panels on the upper-level elevations of the residence and studio are soiled along their top edges. The cause may be dirt accumulated on the upper part of the surrounding frame; during fog, rainfall, or other wet conditions, water carries the dirt from the frame onto the top of the panels.

Regarding the fungal-like growth visible on the outdoor facing of some panels, light microscopy with an oil immersion (100× objective) revealed the presence of numerous small fungal spores. These spores have a morphology similar to that of the fungus previously found on the teak wood elements at the Salk Institute for Biological Studies, La Jolla, California—another GCI conservation field project—and identified as coming from decaying eucalyptus leaves. This suggests that the fungus was likely from the order Capnodiales, which feeds on decaying plant matter such as leaves and wood (see appendix I).

Staining and Marks

Stains on the interior and exterior of the residence and studio appear to be mostly from spills or splashes of paint, adhesive, or sealants and likely occurred during their application. Rust stains on panels originate from the deterioration of the steel frame. White or yellowish drip-like stains may have been caused by moisture (for example, rainfall that may have entered the building through an open window).

A laboratory analysis with FTIR (Fourier transform infrared spectroscopy) conducted by GCI Science staff on samples of white streaks taken from an indoor Cemesto panel identified the presence of calcium carbonate and silica. FTIR results on a sample of brown streaks were inconclusive, indicating that the sample was composed of organic material, the best match of which was a plant gum or polysaccharide.

Leaching

As may be inferred from the above descriptions, the visual investigation showed that the double exposure of the unpainted panels had caused a differential aging likely due to diverse environmental factors between the interior and the exterior.

A petrographic analysis conducted in 2020 on a Cemesto sample taken from a deteriorated, unpainted panel that had fallen off from its original location concluded that no significant deterioration or alteration had occurred on the asbestos-cement sheets, except for minor surficial leaching and discoloration. The color alteration and surface staining appeared to be mainly related to a diverse group of causes: soiling, biological growth, differential surficial leaching, and subsequent formation of carbonate and low-calcium high-silica gel, as well as the presence of iron oxides/hydroxides on the exposed surfaces. The leaching and localized cement paste erosion or loss had caused the exposure of asbestos strands that could potentially be a health hazard. The limitations to obtaining additional samples prevent us from extrapolating the results to all the panels. Yet, they provide a good understanding of the deterioration mechanisms that may occur in this type of fiber cement (see appendix II for the full report of the laboratory analysis).

Impact Damage

Cracks, dents, and missing pieces on the exterior panel facings of the residence and studio appear to be caused primarily by physical impacts and other wear and tear. On the west elevation of the residence, dents are located adjacent to a gas meter and to plants in large terra-cotta pots. Impacts to the panels may have been caused by the installation of the gas meter or by moving the terra-cotta pots. The exterior face of one of the panels on the west elevation of the studio exhibits an area that broke away, possibly during the installation of telecommunications and internet wires (see fig. 3.7).

It is not known what caused the dent and missing pieces on two other panels on the west elevation of the studio exterior, but they were likely caused by physical impacts such as an object hitting the panels. Large cracks on panels on both the exterior and interior of the residence and studio appear to be due to mechanical impacts. Damage to a panel in the residence on the second floor, east elevation, adjacent to the corner of a bed, may have been caused by the movement of objects or people in this tight space.

3.4 Comparative Assessment of 2015 and 2022 Findings and Conclusion

In winter 2022, thirty-seven of the eighty-seven infill panels were inspected, including both exterior and interior faces, if accessible, and the east and west elevations of both the residence and the studio. Compared to the 2015 inspection, little change was observed in the appearance of the panel faces. Various amounts of leaching, soiling, and staining are visible across panels, as was observed in 2015. Notwithstanding, comparisons between the 2015 and 2022 data reveal a substantial increase in the evidence of corrosion on the surrounding exterior frames, namely in the form of localized surface corrosion that is likely linked to deterioration of the paint coatings. In at least four instances in the interior of the residence, corrosion is visible in areas where the sealant is missing and the joints stand open, suggesting evidence of concealed corrosion. These conditions were not noted in 2015.

In four more instances, the exterior asbestos-cement facings are detached or partially detached from the core, two on the studio and two on the residence; and five infill panels exhibit additional expansion. An increased number of areas of "looseness" or "softness" were noticed, which may indicate that deterioration affecting the bagasse core has advanced. This condition is likely the result of the fact that sealants between the panel and the surrounding steel frame are rarely intact, and, consequently, these open joints allow water infiltration during wetting episodes. It must be noted that at the time of inspection, some areas of the infill panels were covered with plastic sheeting as a temporary measure to prevent this very issue. A significant gap was observed between the spandrel top frame of HE-11 and the steel profile behind it. More sealant deterioration was noted on the interior, particularly inside the residence.

Based on the findings, moisture infiltration continues to be the primary cause of deterioration at the Eames House. Because both the 2015 and 2022 GCI condition surveys involved only visual inspections, GCI staff are hesitant to make a definitive diagnosis of the condition of the steel window frames that hold the panels in place. Evidence of surface corrosion on the steel frames may or may not indicate that severe corrosion is present at the hidden parts of the window frames; if it is present, it is likely to be affecting some steel frames more than others. GCI researchers suggest removing some panels to investigate this issue further. To prevent further deterioration, the GCI recommends repainting the steel frame selectively, as long as it is capable of receiving a new paint layer, and resealing the joints between the panel and the steel.

Endnotes

1 See, for example, advertisements in *Heating and Ventilating*, vol. 28, no. 12, December 1931; and *Asbestos*, vol. 13, no. 1, July 1931. These advertisements might be linked to product development and trademark registration processes. Surprisingly, one advertisement claimed Cemesto was also sold by the Ruberoid Company under the name of Eternit-Celotex board, which was produced at the Eternit plant in St. Louis (*Asbestos*, vol. 13, no. 2, August 1931, p. 57). No further reference to this fact has been found.

2 Treadway B. Munroe and George E. Swenson, Structural material, US Patent 1,976,684, filed November 11, 1930, and granted October 9, 1934.

3 Charles J. Beckwith, Laminated sheet building material, US Patent 1,883,485, filed February 27, 1928, and granted October 18, 1932.

4 Reportedly, bagasse fibers are very similar to wood fibers in size and structure. They are composed of cellulose, hemicellulose, and lignin in different proportions. See Suchsland and Woodson 1986, 80.

5 Elbert C. Lathrop and Fergus A. Irvine, Preservation of fibrous products, US Patent 1,935,196A, filed June 27, 1930, and granted November 14, 1933.

6 For a brief explanation of the use of the rosin size, see Suchsland and Woodson 1986, 88.

7 In 1914, Muench developed Insulite and its manufacturing method for the Minnesota & Ontario Paper Company in International Falls, Minnesota. Insulite was a type of insulation board made from ground wood and sulfite screenings; Muench 1947, 49.

8 Updated information on existing regulations and related information, including ongoing efforts, can be found on the US Environmental Protection Agency's dedicated website: www.epa.gov/asbestos.

9 While Eames correctly spelled "rabbeting" in his original letter, now held at the Library of Congress, it was misspelled "rabbitting" in the published transcript.

10 Shelley Mills, video communication with Laura Matarese, July 2015. Recorded by the Eames Foundation.

11 Shelley Mills and Laura Matarese, personal communication, Eames House, July/August 2015.

GLOSSARY

Conservation Management Plan (CMP)

A document that "sets out what is significant about a place and from this, what policies are appropriate to enable that significance to be retained as part of its future use and development" (Kerr 2013, 1). In most cases, a CMP deals with the ongoing care of a place and management of change.

Cultural significance

The "aesthetic, historic, scientific, social or spiritual value for past, present, or future generations. Cultural significance is embodied in the place itself, its fabric, setting, use, associations, meanings, records, and related objects. Places may have a range of values for different individuals or groups" (Australia ICOMOS 2013, article 1.2). Cultural significance may change over time and with use. Used interchangeably with "heritage significance" and "cultural heritage significance" or "value." Frequently shortened to "significance."

Integrity

The "measure of the wholeness and intactness" of a place and its attributes (UNESCO World Heritage Committee 2016, article IIE.88). In the United States, "authenticity" and "integrity" are often used interchangeably. The National Park Service defines "historic integrity" as "the authenticity of a property's historic identity, evidenced by the survival of physical characteristics that existed during the property's historic or prehistoric period," such as its location, design, setting, materials, workmanship, feeling, and association (US National Park Service 1983).

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APPENDIX I

GCI Materials Characterization Analyses and Findings

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Science Department

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Analysis Report

Organic Analysis Laboratory

Date: December 19, 2018

Site: The Eames House, Charles and Ray Eames, 1949

Address: 203 Chautauqua Boulevard, Pacific Palisades, CA 90272

Project: The Eames House

Prepared for: Cesar Bargues Ballester and Chandler McCoy

Prepared by: Joy Mazurek, Assistant Scientist

Introduction

This report summarizes the preliminary results of samples analyzed and taken November 28th, 2018 at the Eames House by Joy Mazurek, Getty Conservation Institute (GCI), Science Department. Select samples were analyzed by Fourier-transform infrared spectroscopy (FTIR) for general materials characterization, Ion Chromatography (IC) for soluble salts, Electron Microscopy (ESEM) for elemental analysis, Gas Chromatography/Mass Spectrometry (GC/MS) for oils waxes, and resins, and light microscopy for microbiological imaging. Tables 1 and 2 summarizes the results and images 1 to 4 show sample locations. Appendix 1 contains ESEM results in greater detail.

Results and Discussion

A white drip-like material was removed with a scalpel from an indoor Cemesto panel (image 1). IC analysis identified 10% by weight soluble salts (7% calcium and 3% sodium), however counter ions such as sulphate, nitrate, and chloride were not detected. FTIR identified calcium carbonate and silica, indicating that the counter ion could be carbonate. Carbonate is not detectable by IC and the Cemesto panel is composed of calcium carbonate and silica, so the interpretation is difficult. The white drip-like material can be described as a soluble salt of calcium and sodium, and the counter ion is likely carbonate but this is not confirmed. Sample 2 is a white powder on the floor (below the drip-like Cemesto panel), and it does not contain soluble salts. FTIR identified silica, and ESEM shows that it also contains unusual elements such as aluminum and minor amounts of barium (table 1). The likely source of this powder is not known at this time.

Sample 3 is wood putty from outside the Cemesto panel with white drip-like material. It does not contain detectable levels of soluble salts. FTIR analysis identified calcium carbonate, however drying oil was not detected by GC/MS, as suggested by Cesar Ballester. The lack of an oil binder is perhaps due to the fact that organic material was no longer detectable due to degradation, or the binder may be something completely different such as milk casein. Further testing by GC/MS for the analysis of proteins would be necessary.

Sample 6 is a small piece of a cross section of a Cemesto panel (image 4). A thick black layer in the middle was isolated and GC/MS identified hopene, indicating bitumen. Sample 8 is a brown drip-like material from an indoor Cemesto (office area, top floor) as shown in image 3. FTIR results were inconclusive only indicating that the sample is composed of organic material, best matching a plant gum or polysaccharide, i.e. a polymer composed of sugars. Further GC/MS analysis is necessary in order to fully characterize the material.

Sample 4 is a fungal-like growth visible on an outdoor Cemesto panel (image 1). Light microscopy with an oil immersion 100x objective showed many small fungal spores, approximately 5 micrometers in diameter (figure 5). It has similar morphology to the fungus previously identified on the teak wood and decaying Eucalyptus leaves from the Salk institute. This suggests the fungus is likely from the Capnodiales order, also known as sooty mold fungus. It is not a human pathogen, and its food source is decaying plant matter such as leaves and wood.

Sample 7 appears to have a speckle like pattern all over the Cemesto (image 4), however microscopic examination did not show evidence of fungal spores. This indicates that the dark speckle-like pattern is not from microbiological activity, and is likely the result of an unknown material used in the manufacturing process

Sample Descriptions

Image 1. Black fungus-like surface deposit on outdoor Cemesto panel. Sample 4.

Image 2. White stripes on surface of indoor Cemesto panel (HE-35). Sample 1.

Image 3. Brown drip-like stripes from indoor Cemesto, top office. Sample 8.

Image 4. Dark speckle-like pattern on outdoor Cemesto panel. Sample 7.

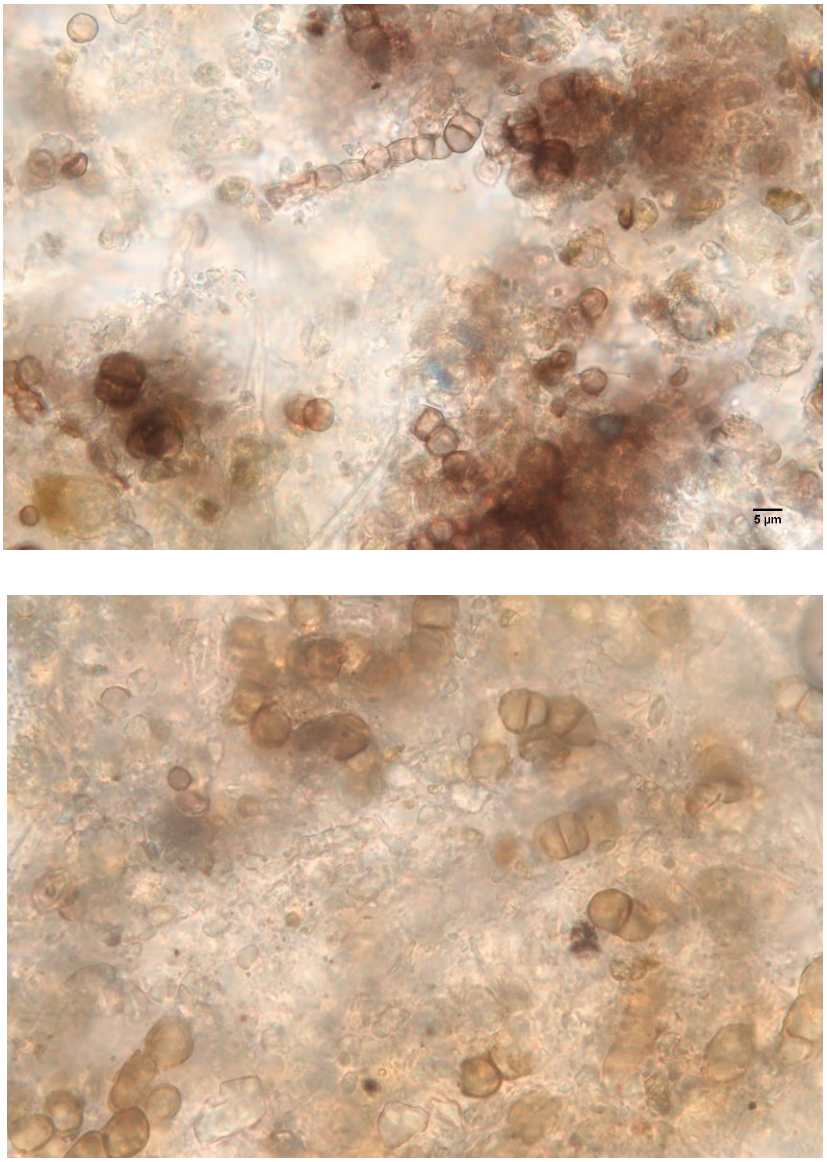


Figure 5. 100X objective, oil immersion.

Results

Table 1. Summary ESEM.

Sample	ESEM
Sample 1. White stripe on Cemesto (Image 2) **spectrum 23**	**Mg, Si,** Ca, *Fe, Al*
Sample 1. **spectrum 24**	**Ca,** *Si, Fe, Al*
Sample 1. **spectrum 25**	**Ca, Si,** *Fe, Al, Mg*
Sample 1. **spectrum 26**	**Ca, Si,** *Al, Mg, Fe*
Sample 1. **spectrum 27**	**Ca, Si,** *Al, Mg*
Sample 2. Floor sample white powder, beneath white stripe area. No image **Spectrum 19**	**Al, Si,** *Mg, Ba*
Sample 3. Wood putty outside panel **Spectrum 20**	**Ca,** *Si*
Sample 7. Dark speckle like pattern (Image 4) **Spectrum 21**	**Ca, Si,** *Mg, Al, Zn*
Sample 7. **Spectrum 22**	**Ca, Si, Mg,** *Al*

Bold text (major component), *Italics* (minor component)

Table 2. Summary of FTIR, GC/SM and IC results

Sample	**FTIR**	**Oil, wax, resin**	**IC**
Sample 1. White stripe on Cemesto (Image 2)	*CaC03 and silica*	*NT*	3% Na, 8% Ca
Sample 2. Floor sample white powder, beneath white stripe area	Silica	*NT*	1% Na
Sample 3. Wood putty outside panel	CaC03	Palmitic, stearic	1% Ca
Sample 4. Black surface deposit, fungal? (Image 1)	CaC03 and Silica	*Palmitic, stearic, oleic*	*NT*
Sample 6. Black interior of Cemesto,	*Bitumen?*	*Bitumen*	*NT*
Sample 7. Dark speckle like pattern on Cemesto. (Image 4)	*CaC03 and Silica*	*ND*	*NT*
Sample 8. Brown drip from interior office (Image 3)	Polysaccharide?	*ND*	*NT*

NT=Not Tested, ND=Nothing Detected

Description	**Sample**	**pH**	**Amount in mg**	**H_2O in l**	**Concentration in Solution in mg/l**									
					Na^+	NH_4^+	K^+	Mg^{2+}	Ca^{2+}	F^-	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
White stripe	Eames 1	NT	0.12	0.001	3.9	0.0	0.0	0.0	9.2	0.0	0.3	0.0	0.0	1.1
Floor white	Eames 2	NT	0.411	0.001	3.8	0.0	0.0	0.0	1.1	0.0	0.4	0.0	0.2	1.0
Cemesto	Eames 7	NT	1.22	0.001	0.9	0.0	0.4	0.2	12.6	0.0	0.6	0.0	1.1	4.9

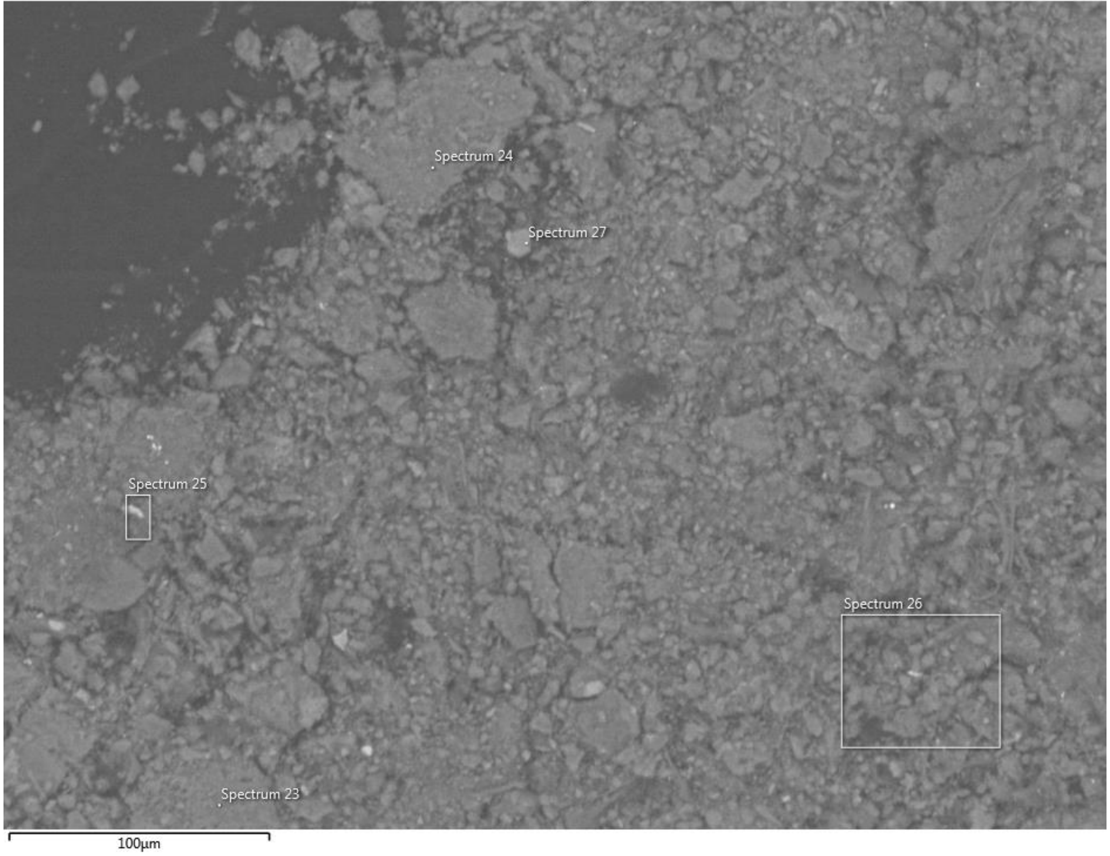
Sample	**Concentration in Sample in mass-%**										
	Na^+	***NH_4^+***	***K^+***	***Mg^{2+}***	***Ca^{2+}***	***F-***	***Cl-***	***NO3-***	***PO43-***	***SO42-***	***Total %***
Eames 1	3.25	0.00	0.00	0.00	7.67	0.00	0.00	0.00	0.00	0.00	10.92
Eames 2	0.92	0.00	0.00	0.00	0.27	0.00	0.01	0.00	0.00	0.01	1.21
Eames 7	0.07	0.00	0.03	0.02	1.03	0.00	0.10	0.00	0.00	0.03	1.29

Sample	**MICROEQUIVALENTS PER GRAM**									
	Na+	***NH4+***	***K+***	***Mg2+***	***Ca2+***	***F-***	***Cl-***	***NO3-***	***PO43-***	***SO42-***
Eames 1	1413.7	0.0	0.0	0.0	3825.7	0.7	0.2	0.0	0.0	0.9
Eames 2	402.2	0.0	0.0	0.0	133.6	0.9	3.4	0.0	0.0	1.2
Eames 7	32.1	0.0	8.4	13.5	515.4	1.5	29.5	0.0	0.0	5.7

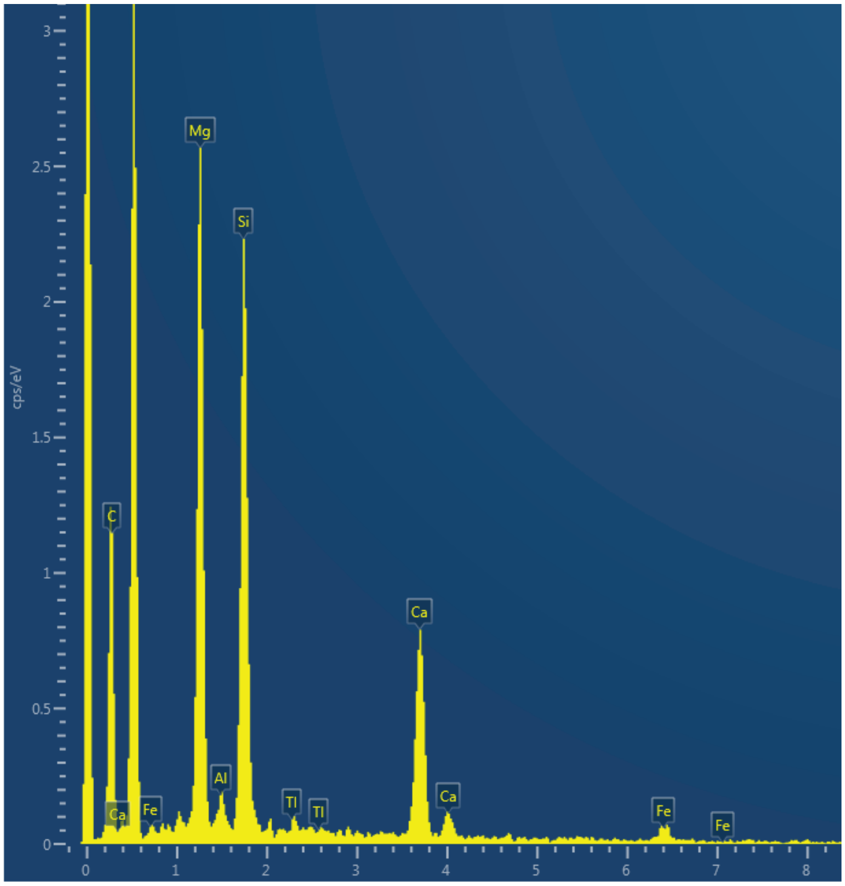
Appendix 1.

ESEM report

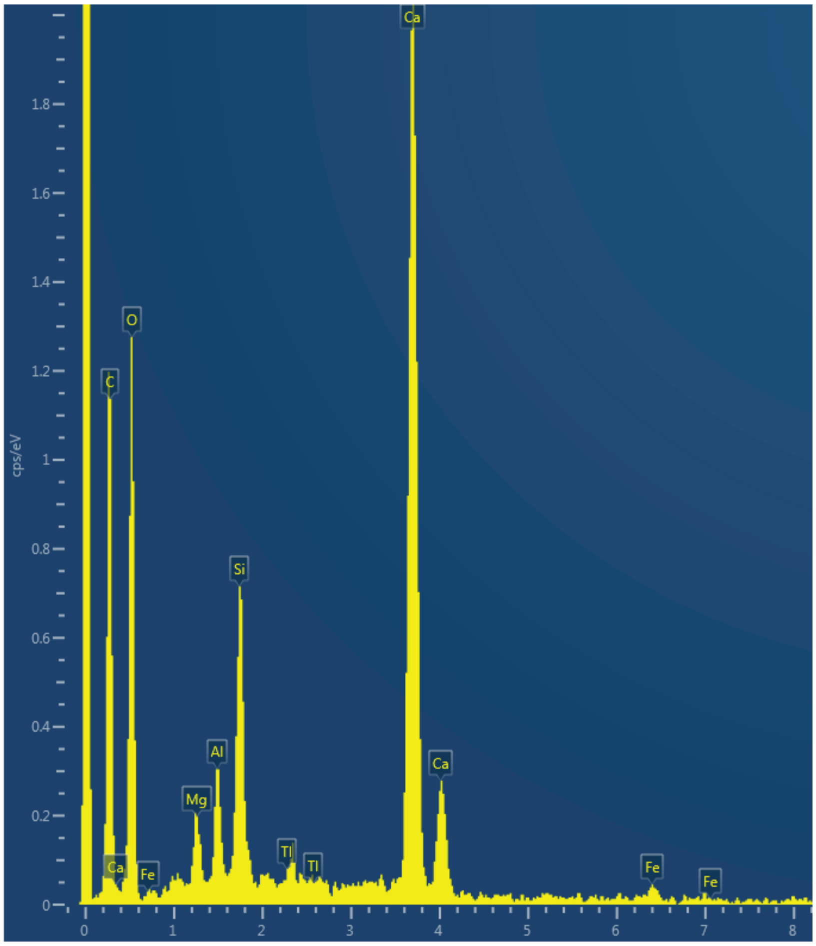
Electron Image 14



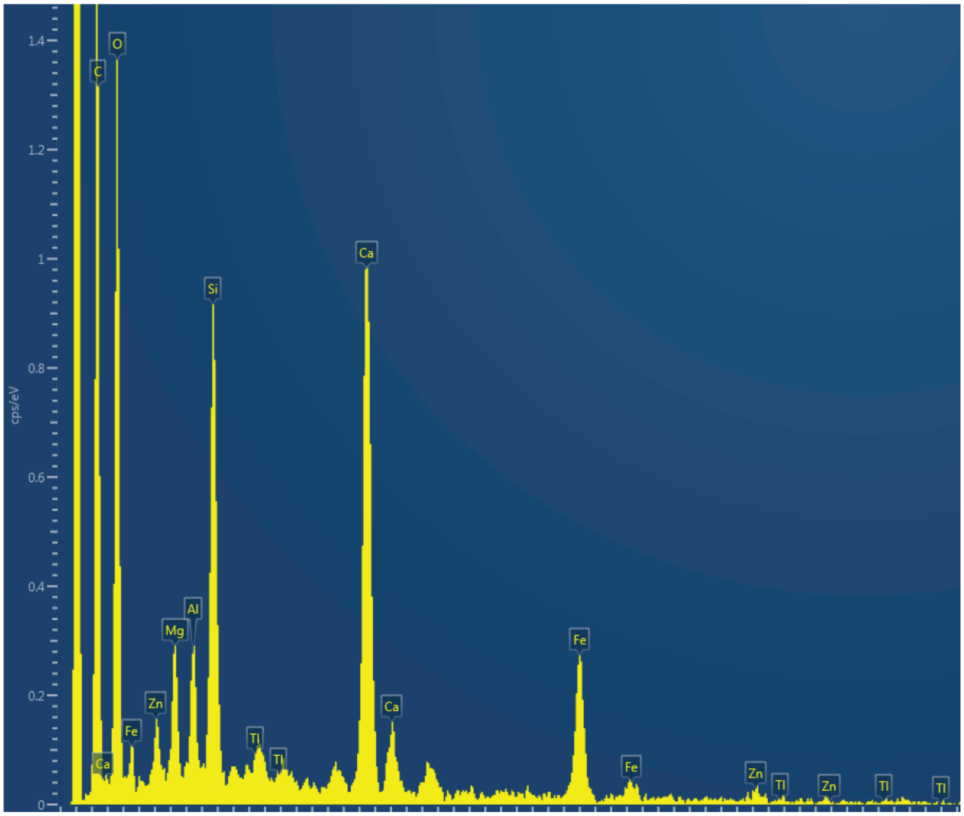
Sample 1. White stripe on Cemesto



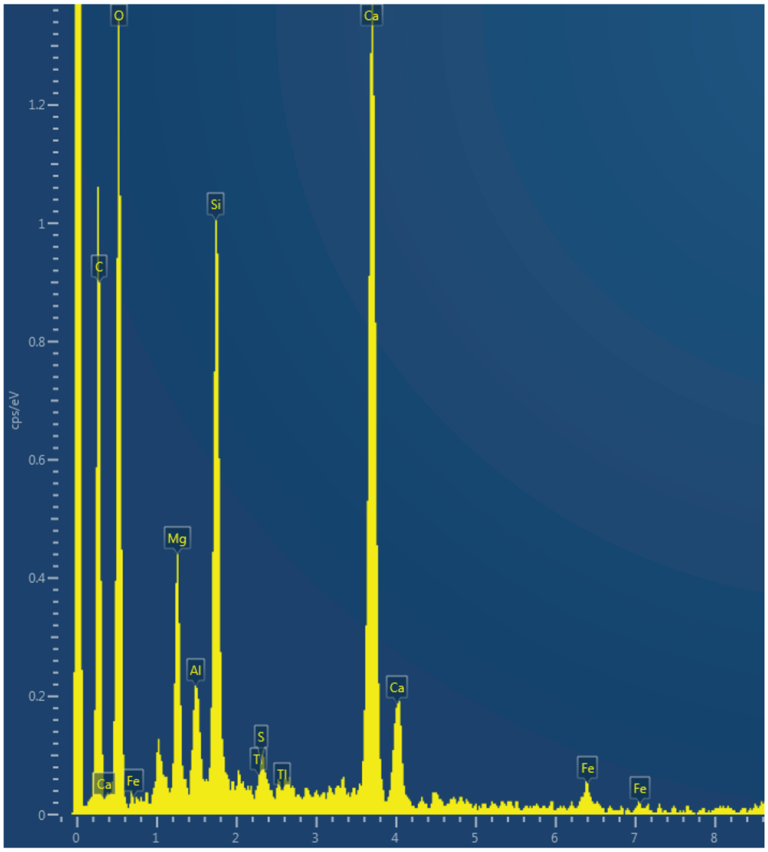
Sample 1. White stripe spectrum 23. Mg, Si, Ca, *Fe, Al*



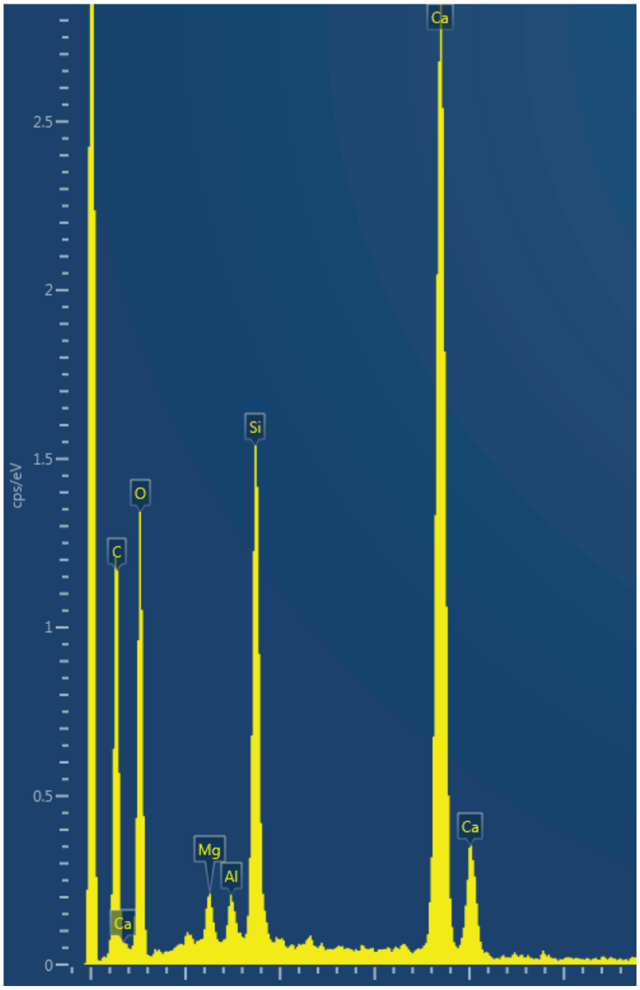
Sample 1. White stripe spectrum 24. Ca, *Si, Fe, Al*



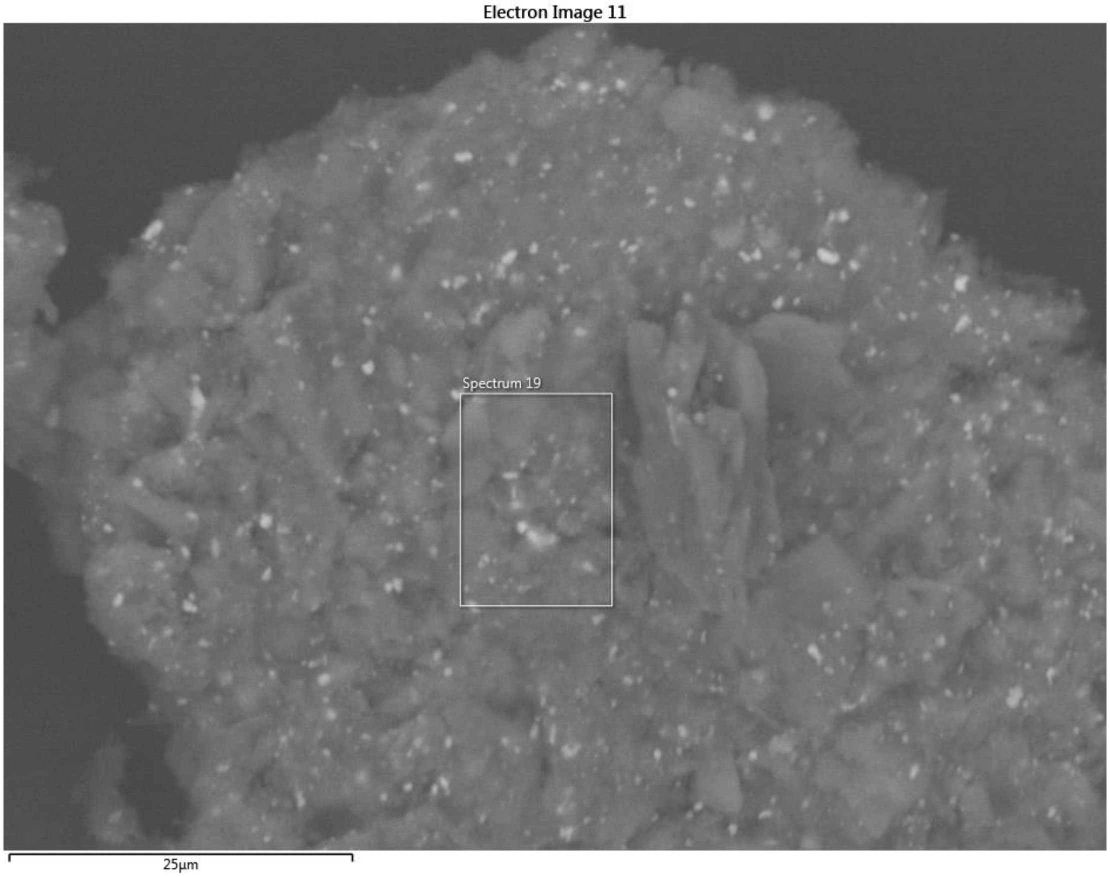
Sample 1. White stripe spectrum 25. Ca, Si, Fe, Al, Mg



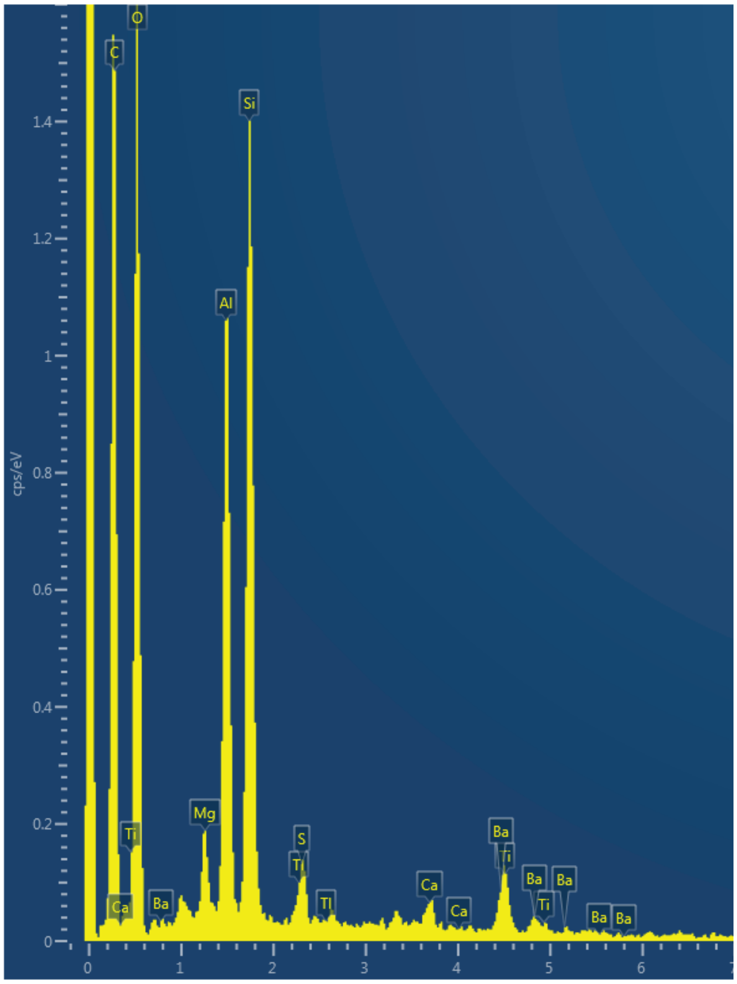
Sample 1. White stripe spectrum 26. Ca, Si, Al, Mg, Fe



Sample 1. White stripe spectrum 27. Ca, Si, *Al, Mg*

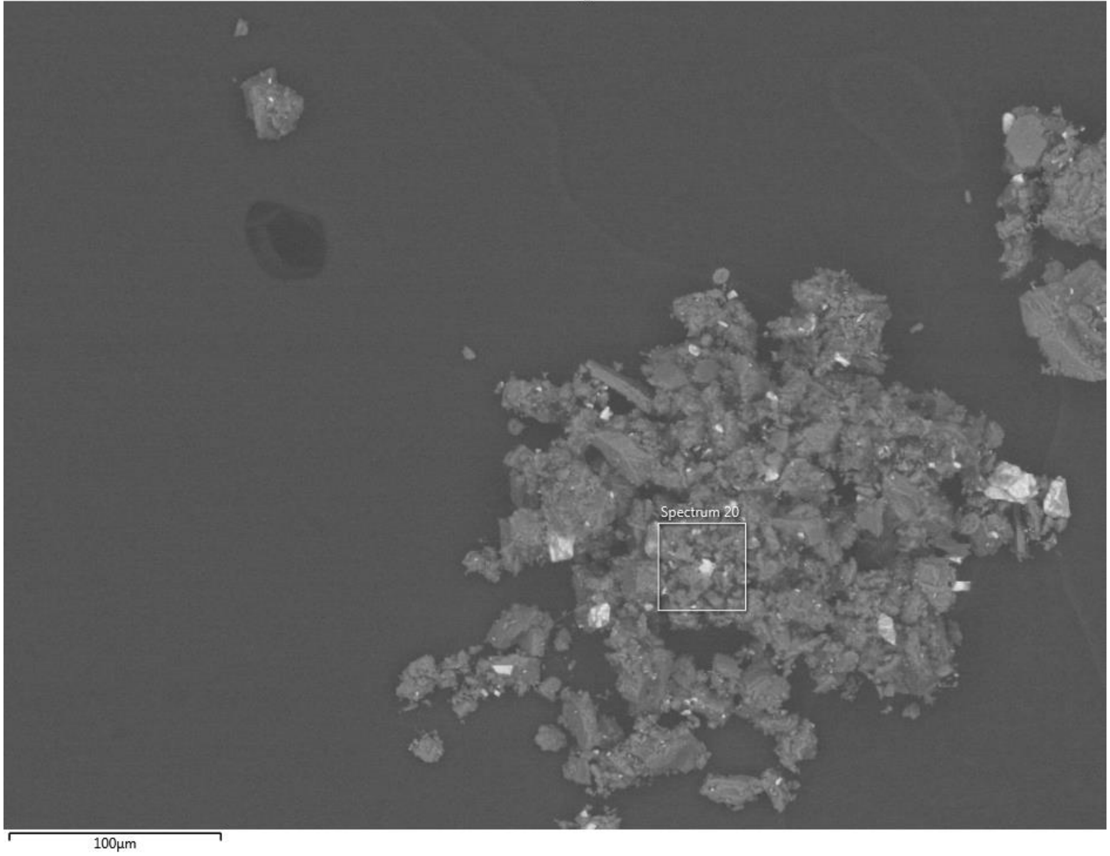


Sample 2 floor white powder

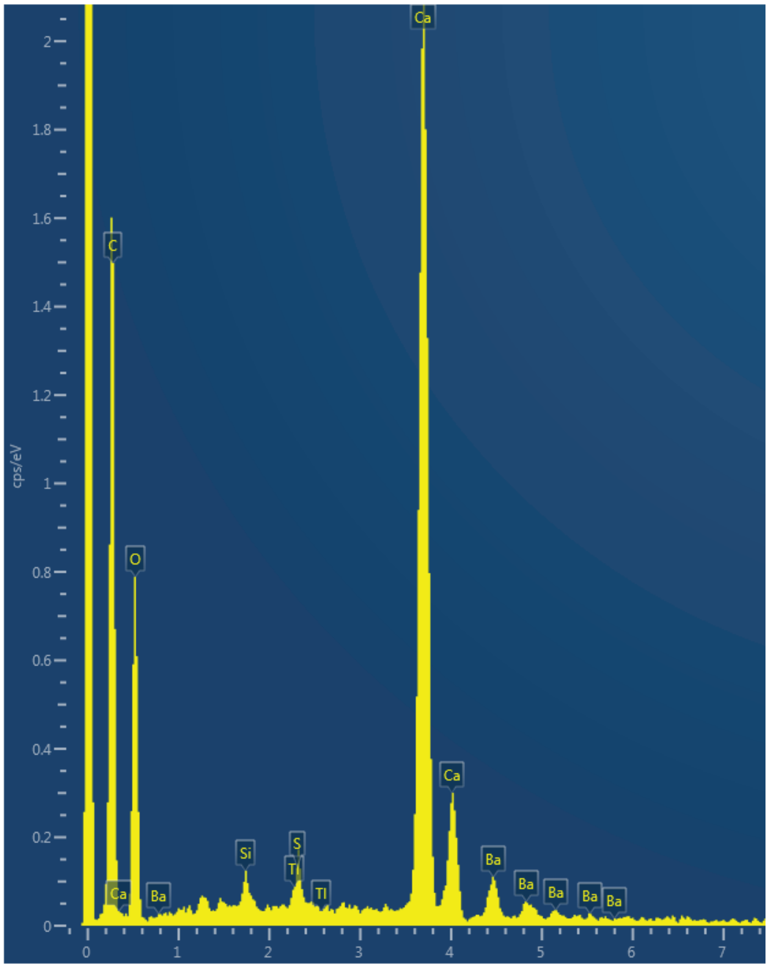


Sample 2. White powder on floor beneath sample 1 Cemesto. Spectrum 19. Al, Si, *Mg, Ba*

Electron Image 12

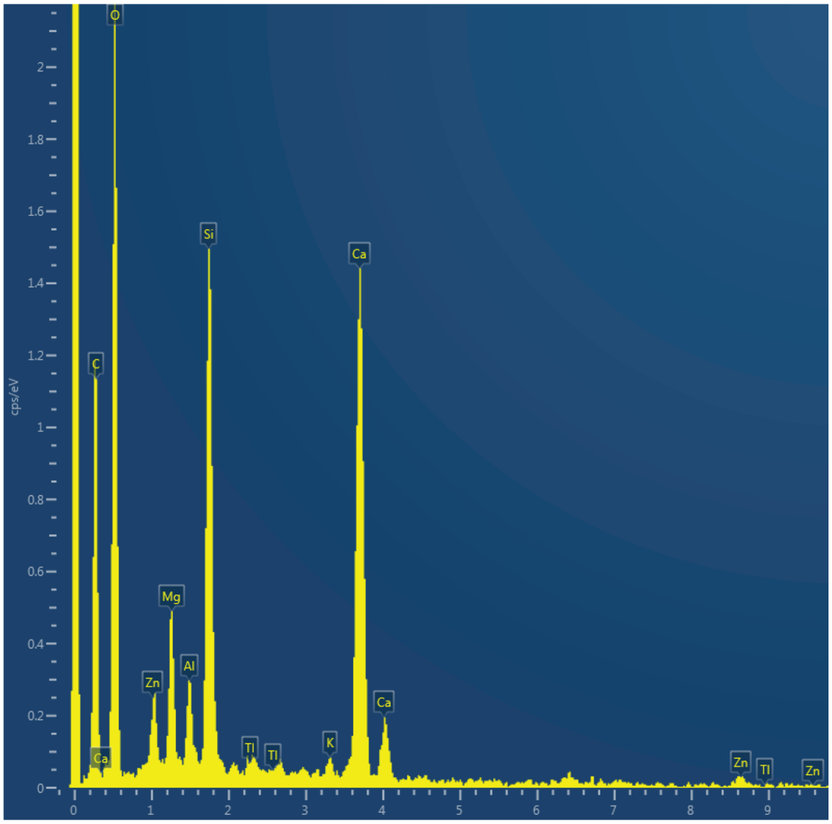


Sample 3 wood putty

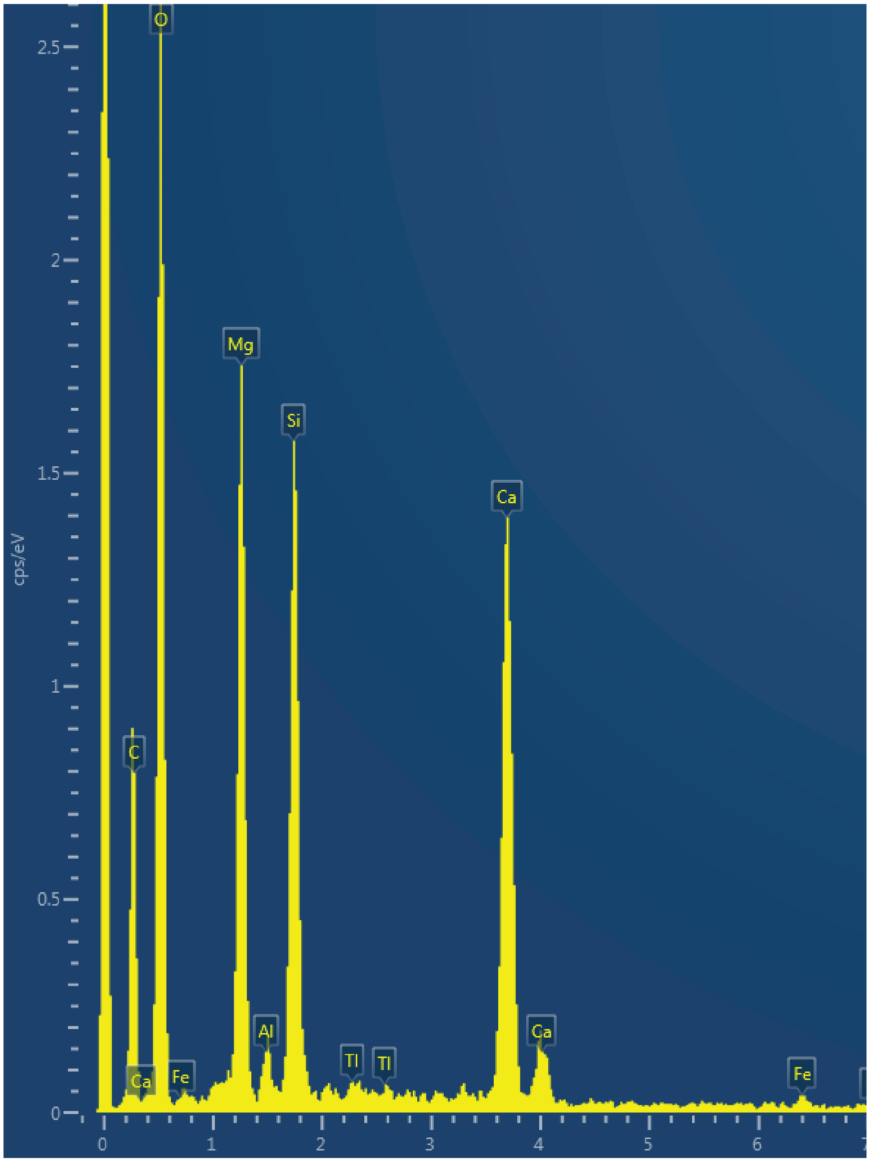


Sample 3 wood putty. Spectrum 20. Ca, *Ba,Si*

Sample 7 Cemesto



Sample 7 Cemesto. Spectrum 21. Ca, Si, *Mg, Al, Zn*



Sample 7 Cemesto. Spectrum 22. Ca, Si, Mg, *Al*

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Analysis Report

Materials Characterization Laboratory

Date: February 25, 2019

Site: The Eames House, Charles and Ray Eames, 1949

Address: 203 Chautauqua Boulevard, Pacific Palisades, CA 90272

Project: The Eames House

Prepared for: Cesar Bargues Ballester and Chandler McCoy

Prepared by: Joy Mazurek, Assistant Scientist

This report summarizes results of a white putty supplied by Cesar Ballester. The sample is from an unknown location. It was analyzed for Gas Chromatography/Mass Spectrometry (GC/MS) for oils, waxes, and resins[1]. The sample contains oil, most likely fish oil. It is identified as fish oil due to the presence of myristic acid, and odd numbered fatty acids that indicate animal origin (C15, C17, and C19 fatty acids).

Oils are identified on the basis of fatty acid (FA) composition. Palmitic (P), stearic (S), and azelaic (A) acids are used to identify different types of drying oils; for example the P/S ratio for walnut is around 3, poppy is around 5, and linseed is around 1.5. A/P ratios around 1 or higher indicate the presence of a drying oil. However, A/P ratios are generally very low in dried fish oil.

Sample	Oil, wax, resin
White putty supplied by Cesar.	Fish Oil P/S =1.3, A/P=0.14

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[1] Add 1:2 Meth-Prep II:toluene to vial. Inject into GC/MS. A ZB-5HT Inferno (30 M x 0.25 mm x 0.1µm) capillary column was used for the separation. Helium carrier gas was set to a linear velocity of 15.68 psi. Split injection was used 50:1, and was set to 320°C. The MS transfer line was set to 320°C. The GC oven temperature program was: 80°C for 2 min; 10°C/min to 340°C; isothermal for 12 min; 20°C/min to 360°C; isothermal for 5 min.

APPENDIX II

WJE Laboratory Studies and Findings

WJE

Wiss, Janney, Elstner Associates, Inc.
225 South Lake Avenue, Suite 500
Pasadena, California 91101
626.696.4650 tel
www.wje.com

June 19, 2020 rev

Mr. Chandler McCoy
Senior Project Specialist
Getty Conservation Institute
1200 Getty Center Drive
Los Angeles, California 90049

The Eames House Cemesto Panel Sample
Laboratory Study and Findings
WJE No. 2020.2121

Dear Mr. McCoy:

At the request of the Getty Conservation Institute (GCI), Wiss, Janney, Elstner Associates, Inc. (WJE) has completed review and laboratory analysis of a Cemesto panel sample removed by the GCI from the Eames House. This letter presents our findings and has been revised based on clarifications provided by GCI.

BACKGROUND

The Eames House is located at 203 North Chautauqua Boulevard in the Pacific Palisades neighborhood of Los Angeles and was constructed in 1949. The home is part of a group of five houses on a five-acre parcel and located on a bluff overlooking of the Pacific Ocean. Built by American designers Charles and Ray Eames, the house was designed under the influential Case Study House Program, initiated by John Entenza, editor of *Arts & Architecture* magazine. The house was an experiment in the use of prefabricated materials and mass–produced, off-the-shelf products to rapidly construct a residential structure. The use of industrial materials, including the Cemesto panels, for home building was unique at the time.

The Cemesto panels at the Eames House are reported to be a mixture made of asbestos fibers (chrysotile), portland cement, and possibly additives. The panel's name of "cemesto," a linguistically blended word from cement and asbestos, represents a popular composite construction material in the 1940s. Information concerning the raw materials and formulations used in the production of the fiber asbestos cement was proprietary and is not available.

Visual investigation by GCI shows that the double exposure of the panels (both interior and exterior faces) has caused a differential aging due to diverse environmental factors. The cement asbestos face exposed to the outside environment shows surface dirt, discoloration, and localized biological growth. The interior face shows signs of material aging, but this is less evident. It presents white or brown drip-like staining that could be caused either by past or current moisture infiltration through the windows and steel frames; moisture condensation may also be migrating along the inside faces of glass panes although this issue does not appear to be active.

GCI Science staff sampled the interior face of a Cemesto panel and characterized the white drip-like staining as likely calcium carbonate. The brown drip-like staining is leaching from an organic-based substance possibly used to encapsulate the cut edges of the asbestos-cement. However, there is currently no information about the exterior Cemesto face regarding the signs of discoloration (a yellowish hue) and the water leaching deposits.

LABORATORY STUDIES

As requested, laboratory studies were conducted on a fiber reinforced cement panel sample to determine its major composition and deterioration. The laboratory studies included light microscopical examination, X-ray diffraction analysis, and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM/EDX). These studies were conducted in general accordance with applicable ASTM or other relevant professional standards.

Sample

The sample was a saw-cut 6-inch section sent to WJE for review and examination. As reported by the GCI, the sample was removed and prepared by H.M. Pitt Labs from the Eames House. The appearance of the as-received sample at the WJE laboratory in Northbrook, Illinois, is shown in Figure 1 through Figure 5, including close-up views of the surfaces. The sample is composed of a plant fiber insulation core faced on both sides with cementitious sheets. The exterior exposed surface was overall very light gray to pale tan color, mottled with small black to medium gray or beige discolored areas (Figure 2, Figure 4). The interior surface exhibited an overall light brown tint or a soiling appearance compared to the exterior exposed surface (Figure 3, Figure 5). The laboratory studies focused on the asbestos-cement sheets and their surfaces that are exposed to the environment at the interior and exterior of the Eames House[1].

Laboratory Test Methods

Light Microscopy

Optical microscopy was conducted on the panel based on the guidelines of ASTM C856, *Standard Practice for Petrographic Examination of Hardened Concrete*. The panel was first briefly examined in as-received condition. A small representative cross section was cut and embedded in epoxy to facilitate subsequent preparation. The embedded cross section was then cut in a direction perpendicular to the panel planar surfaces. The cross section was ground using progressively finer silicon carbide abrasives to achieve a fine matte finish suitable for examination with a stereomicroscope (Figure 6 and Figure 7). A thin section was prepared from the embedded block. Lapped cross sections and as-received surfaces were examined using a stereomicroscope at magnifications up to approximately 50X. The thin section was examined using a petrographic (polarized-light) microscope at magnifications ranging from 50X to 500X. Both microscopes were equipped with a digital camera and a calibrated reticle to measure a layer thickness.

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[1] The exterior surface is used throughout the report to refer to the surface of the outer asbestos-sheet exposed to the outdoor environment. The interior surface refers to the surface of the inner sheet facing the indoor environment. Both surfaces are often referred to as “exposed surfaces”.

SEM/EDX Examination

The Cemesto panel sample was examined using scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM/EDX), using a JEOL JSM 6010LA instrument with methods described in ASTM Standard C1723-10, *Guide for Examination of Hardened Concrete Using Scanning Electron Microscopy*. Both the cross section surface perpendicular to the panel and the planar as-received, exposed sheet surfaces (away from the insulation core) were examined.

In SEM analysis, a beam of electrons is generated, focused, and scanned across a small area of the sample. The electrons interact with the sample in many ways, which can be used to image and analyze the sample. Two imaging modes are possible: backscattered and secondary. During backscattered electron (BE) imaging, the electron beam bombards the sample, and some electrons are backscattered or elastically scattered by the elements in the sample based on their atomic weight. Heavier atoms in the sample scatter the beam electrons more than lighter atoms; hence phases with a higher average atomic weight appear brighter in the resulting image than phases with a lower average atomic weight, providing compositional information within the image. Secondary electron (SE) imaging uses lower energy electrons that are emitted from the sample as a result of inelastic interactions with the beam. SE images provide information related to the topography of the specimen; cracks and crystals deposited on the surface will be well defined. The interaction of beam electrons with the sample also generates characteristic x-rays. The energy of the characteristic x-rays can be measured using an energy dispersive x-ray spectrometer, and the elements present in the sample can be identified. EDX can only identify elements heavier than boron (carbon through uranium); therefore lighter elements, such as hydrogen, do not appear in the spectrum. EDX data can be collected from a point of a few microns across, or over a larger area of the sample. The panel sample was examined without coating and mainly in the BE mode.

X-Ray Diffraction Analysis (XRD)

The Cemesto panel sample was also examined using XRD analysis on the exterior surface and the interior surface of the panel. A 1.2-inch square specimen was cut from the exterior sheet and the interior sheet. XRD patterns were directly collected from the exposed planar surfaces (opposite or away from the insulation core) to assess material composition on each surface. XRD is generally not sensitive in detecting poorly crystalline or amorphous phases. Well-crystallized phases tend to exhibit sharp and strong peaks on an XRD pattern while poorly crystalline phases show low broad peaks or wide humps.

LABORATORY OBSERVATIONS AND FINDINGS

General Composition

The panel represented by the sample is composed of a fiber insulation core faced on both sides with an asbestos-cement sheet. The panel has a total thickness of approximately 1-1/8 inches (Figure 6 and Figure 7). The cement sheet on each side was approximately 1/8-inch thick and the two sheets appeared to be similar overall in material composition and texture. The sheet consisted of asbestos reinforced portland cement paste (Figure 6 through Figure 13). Asbestos was identified as chrysotile by different techniques used in the study. Estimated asbestos content was roughly 7 to 15 percent by volume. The asbestos strands were up to tens of mils thick and half inches long. Individual fibrils were much thinner.

Bond between the fiber strands and the cement paste appeared to be tight overall. No gap or separation was observed except on the exposed surfaces (as described in the next section). Each sheet exhibited small directional or aligned indentations that likely represented imprints from the casting manufacture process (Figure 4 and Figure 5).

The insulation core fiber was plant-based and distinct cellulose texture was visible (Figure 14 and Figure 15). It is likely a bagasse. A bagasse refers to the dry pulpy fibrous residue that remains after sugarcane or sorghum stalks are crushed to extract their juice. Other major findings are summarized below and illustrated in attached figures.

- No sand was observed in the asbestos-cement sheets (Figure 6 through Figure 10).
- No asbestos fibers were observed in the insulation core.
- A layer of black, asphalt-like (carbon-rich) binder or adhesive was present between the sheet and the insulation core (Figure 7). The layer was tested hydrophobic. Water droplets beaded on the black material. It likely served as a waterproof membrane. The insulation bagasse appeared to contain a minimal amount of the same asphalt-like binder (Figure 14).
- Residual portland cement particles in the sheet were large in size, frequently greater than 50 microns (2 mils) and up to 100 microns (4 mils) or even greater. The size of the portland cement was consistent with the reported age (1949), before and during which time portland cement was coarsely ground.
- Large portland cement particles were partially or poorly hydrated and might have served as a sand filler or aggregate in functionality.
- The distribution of portland cement was not uniform on a microscale, likely indicating non-uniform mixing or locally varying water-to-cement ratios (w/c).
- Elongated, irregularly-shaped air voids were observed. The elongation direction was parallel to the planar surface, consistent with a pressing and dewatering of the sheets during manufacture process. Estimated air content was 5 to 8 percent (Figure 7). The voids within the asbestos-cement sheets were generally empty and free of significant amounts of secondary deposits.
- The cement sheets were partially carbonated throughout the cross sections of the sheets, more frequently along voids and asbestos fibers. Many uncarbonated patches were observed (Figure 8, Figure 9, Figure 10), generally consistent with localized low w/c regions. The exposed surfaces were generally carbonated, as indicated by a phenolphthalein solution test. The surfaces remained the same color as prior to the application of the phenolphthalein and no pink staining was observed.

Deterioration

No major cracks or fractures were observed on the asbestos-cement sheets. Microcracks were infrequent. No major material deterioration or alteration was observed to the asbestos-cement sheets. XRD and microscopical examinations identified mainly carbonate (both calcite and vaterite, secondary deposits), low calcium high silicon gel, and chrysotile, with trace to small amounts of residual cement phases, clay, iron oxides/hydroxides, and gypsum. Major difference between the exterior surface and interior surface appeared to be greater amounts of exposed asbestos on the exterior surface, and a greater but overall small amount of gypsum on the interior surface.

Surficial deterioration was observed and manifested mainly as paste leaching, localized cement paste erosion/loss, and subsequent exposure of asbestos fibers. The exterior surface contained greater amounts of exposed asbestos strands compared to the interior surface, based on both microscopical observations and XRD analysis (Figure 4, Figure 5, Figure 11, Figure 12 and Figure 13) consistent with a harsher environmental exposure on the exterior. It should be noted that comparisons were not made to unexposed attic stock to understand the frequency of exposed asbestos fibers in the as-manufactured panels. Evidence of leaching and associated decalcification of cementitious paste was also observed in the surface region and appeared to be more severe in the exterior sheet as well. The paste in the surface region of the exterior sheet frequently contained lower calcium but higher silicon than the paste in the greater depth of the sheet, consistent with decalcification by leaching.

No residue of paint was observed. Color variations or color non-uniformities were observed on both exposed surfaces as described above, and were likely caused by one or a combination of following factors:

- Dirt or soil of varying amounts on the surfaces. Trace amounts of clay were detected on both surfaces based on the XRD patterns (Figure 13).
- Biological growth that directly caused the black spots or small areas of discoloration, more abundant on the exterior surface (Figure 4).
- Large cement particles that contained abundant ferrite and exhibited a brown to orange color (Figure 9), more abundant on the exterior surface.
- Iron oxides or iron hydroxides of unknown origin that were observed on the exposed surfaces, appearing to be more abundant on the interior surface (Figure 12).
- Leaching, erosion, and subsequent precipitation of calcite/vaterite, formation of low-calcium high-silicon gel, and exposure of asbestos strands. Calcite and vaterite were detected on the exposed surfaces and across the sheets (Figure 8, Figure 9, Figure 10, Figure 13). Leaching appeared to be more severe on the exterior surface. Differential leaching may have contributed to the color variation within an exposed surface and between the two exposed surfaces.
- Localized staining by the asphalt-like binder was also observed, mainly in the asbestos-cement sheets near the insulation (Figure 6, Figure 7). Potential degradation of the binder along a crack could cause staining/discoloration of the exposed surfaces.

Asbestos strands did not appear to exhibit alteration or chemical interaction with the portland cement paste within the interior of both sheets. Chrysotile is reportedly resistant to strong bases and is thus stable in high pH pore solution of portland cement paste. The fibers, however, can be affected by acids. Detection of increased magnesium in the near-surface paste and the leaching might be consistent with acid dissolution (Figure 11, Figure 12). The small amounts of gypsum detected by XRD (Figure 13) possibly represents a reaction product of acid rain and the portland cement paste. However, gypsum appeared to be marginally greater in content on the interior surface. It therefore could have originated from other sources.

The bagasse insulation core exhibited material loss and moisture-related staining or discoloration as received. The staining and discoloration appeared to be overall more severe near the exterior sheet side.

CONCLUSIONS

The laboratory studies revealed that the Cemesto panel is a composite material consisting of bagasse-based insulation core faced on both sides with a 1/8-inch thick chrysotile asbestos-gray portland cement sheet bonded with likely a moisture-proof asphalt/bituminous adhesive to the core. No major cracks or significant materials-related distress was observed in the asbestos-cement sheets, except for frequently exposed asbestos strands on the exterior surface, minor surficial leaching, and discoloration. The discoloration and surface staining appeared to be mainly related to dirt/soiling, biological growth, differential surficial leaching, and subsequent material redistribution (formation of carbonate and low-calcium, high-silica gel), and presence of iron oxides/hydroxides on the exposed surfaces. The asbestos-cement sheets appeared to be in overall fairly good condition, considering their age. However, the exposed chrysotile asbestos could be a health hazard. The bagasse insulation appeared to be in fair condition based on the examination of the sample, apart from minor section loss that could be the result of sample extraction.

While it is not known if this panel is representative of the Cemesto panels at the Eames House, remediation and conservation of the panels may include encapsulation and consolidation of the exposed chrysotile asbestos and protection of the bagasse from continued moisture intrusion. The development of a conservation approach should include consideration of the materials of the panels, the overall aesthetic considerations, protecting existing conditions from continued moisture intrusion, as well as preservation of historic fabric. Trial repairs should be completed as part of the development of the conservation approach.

We appreciate the opportunity to work with the GCI on this unique project and are available to the GCI assist in the development of a conservation strategy that incorporates encapsulation while repairing the panels.

Sincerely,

WISS, JANNEY, ELSTNER ASSOCIATES, INC.

Ann Harrer, P.E.
California License C80977
Project Manager

Hugh (Xiaoqiang) Hou, Ph.D
Petrographer

c: Paul Gaudette, WJE

FIGURES

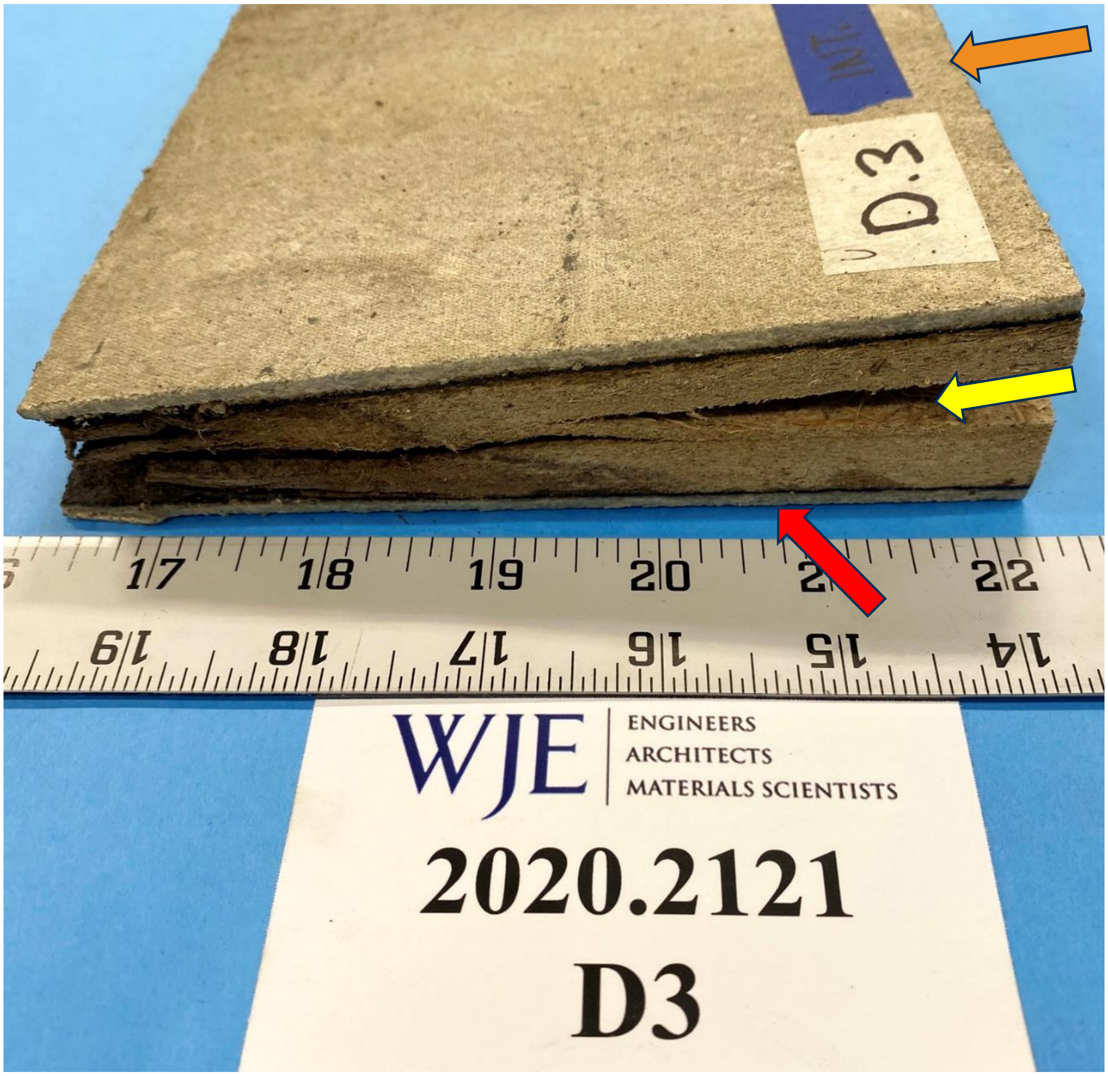


Figure 1. Sample D3. View of the interior surface (orange arrow), exterior surface (red arrow), and cross sectional surface (yellow arrow), as received. The sandwiched central strand core/board was disrupted. The exterior and interior surfaces are further shown below.

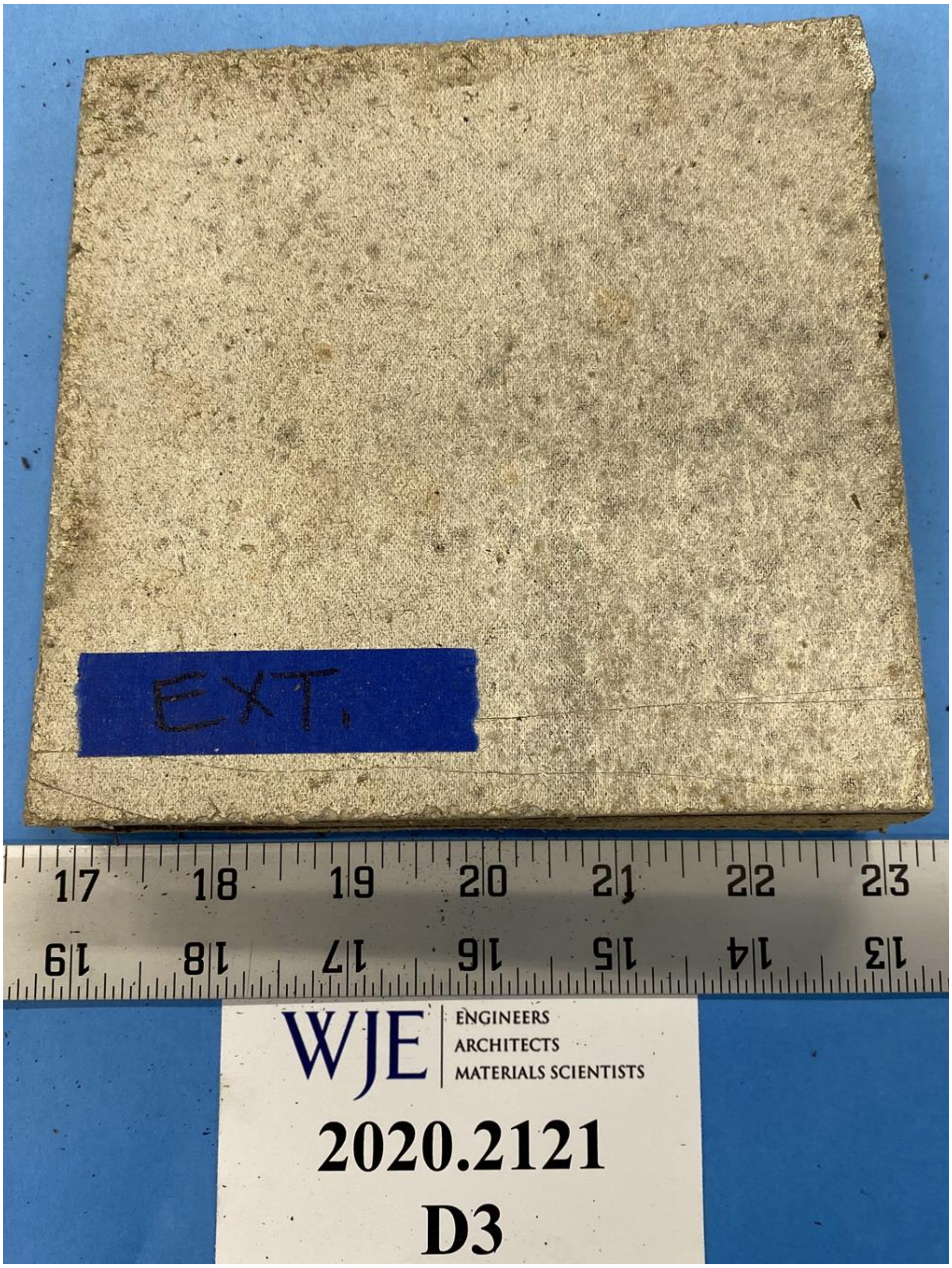


Figure 2. Sample D3. Exterior surface, as received.

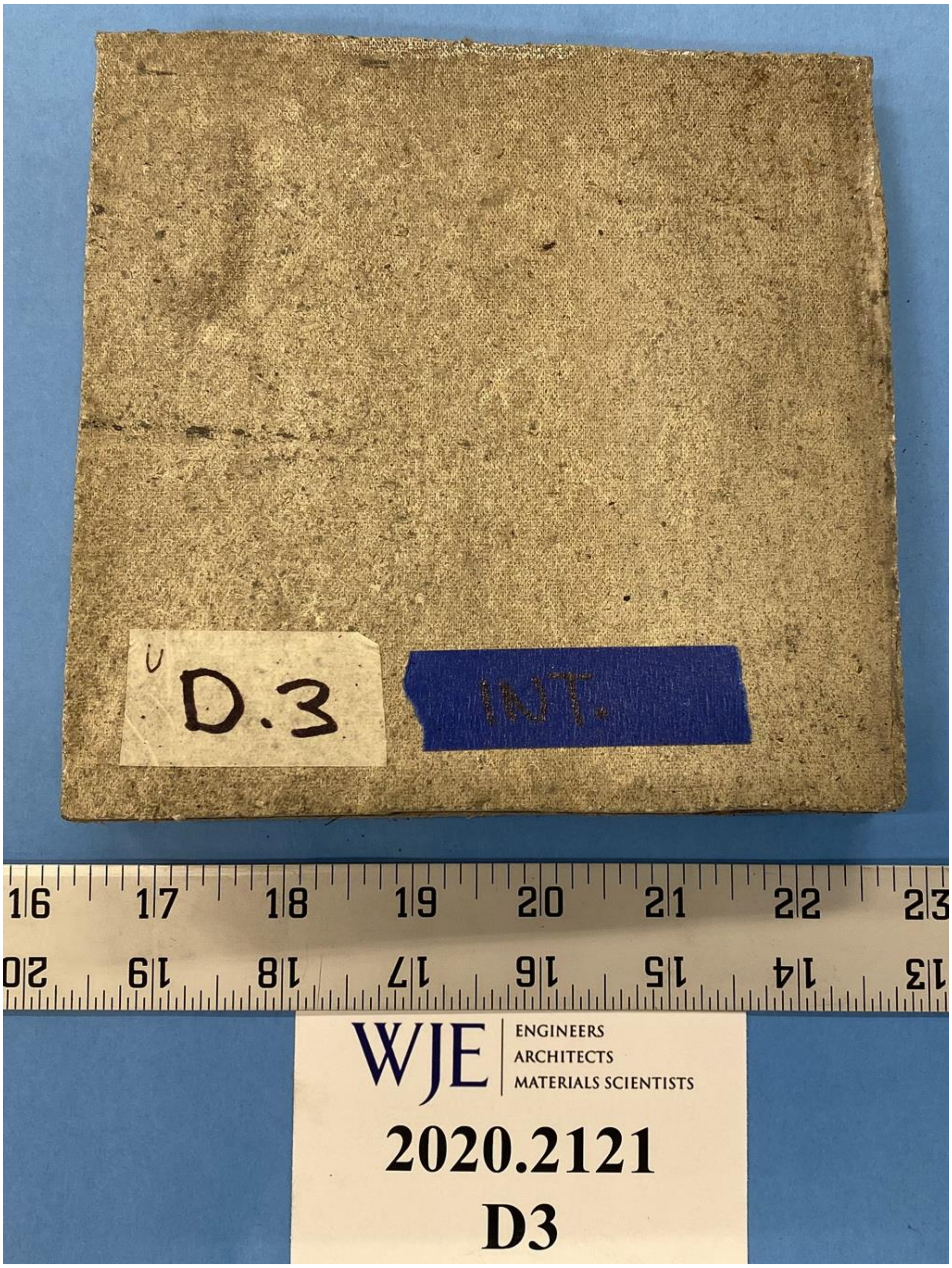
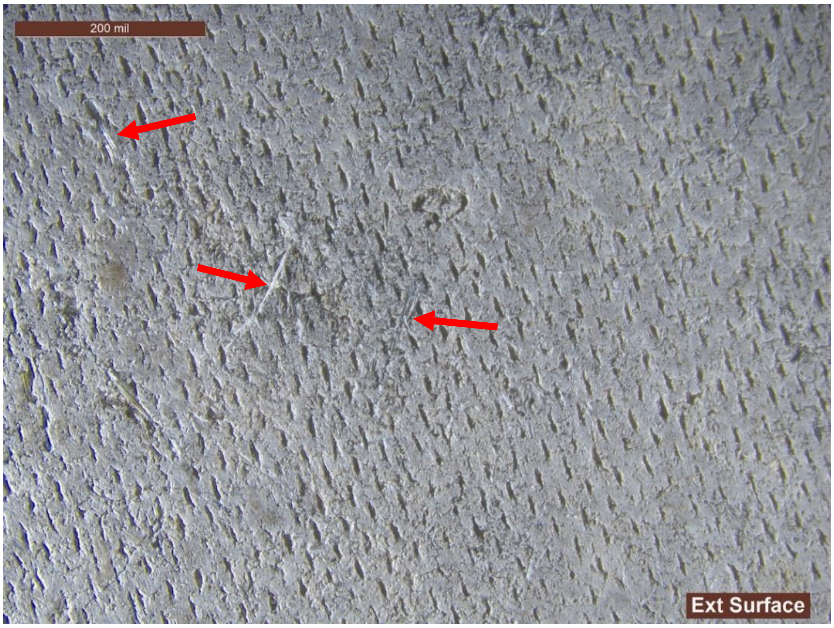


Figure 3. Sample D3. Interior surface, as received.



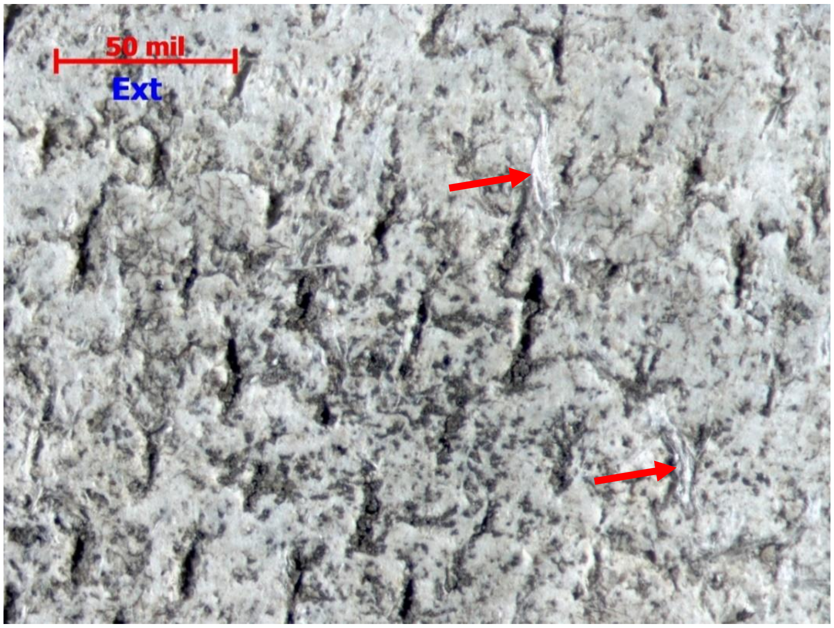


Figure 4. Sample D3. Close-up views of the exterior surface, as received. The black debris or spots were identified as residue of biological growth. Asbestos strands were often exposed (arrows). Thin, short, parallel indentations were cast from manufacturing and would be useful in improving paint adherence.

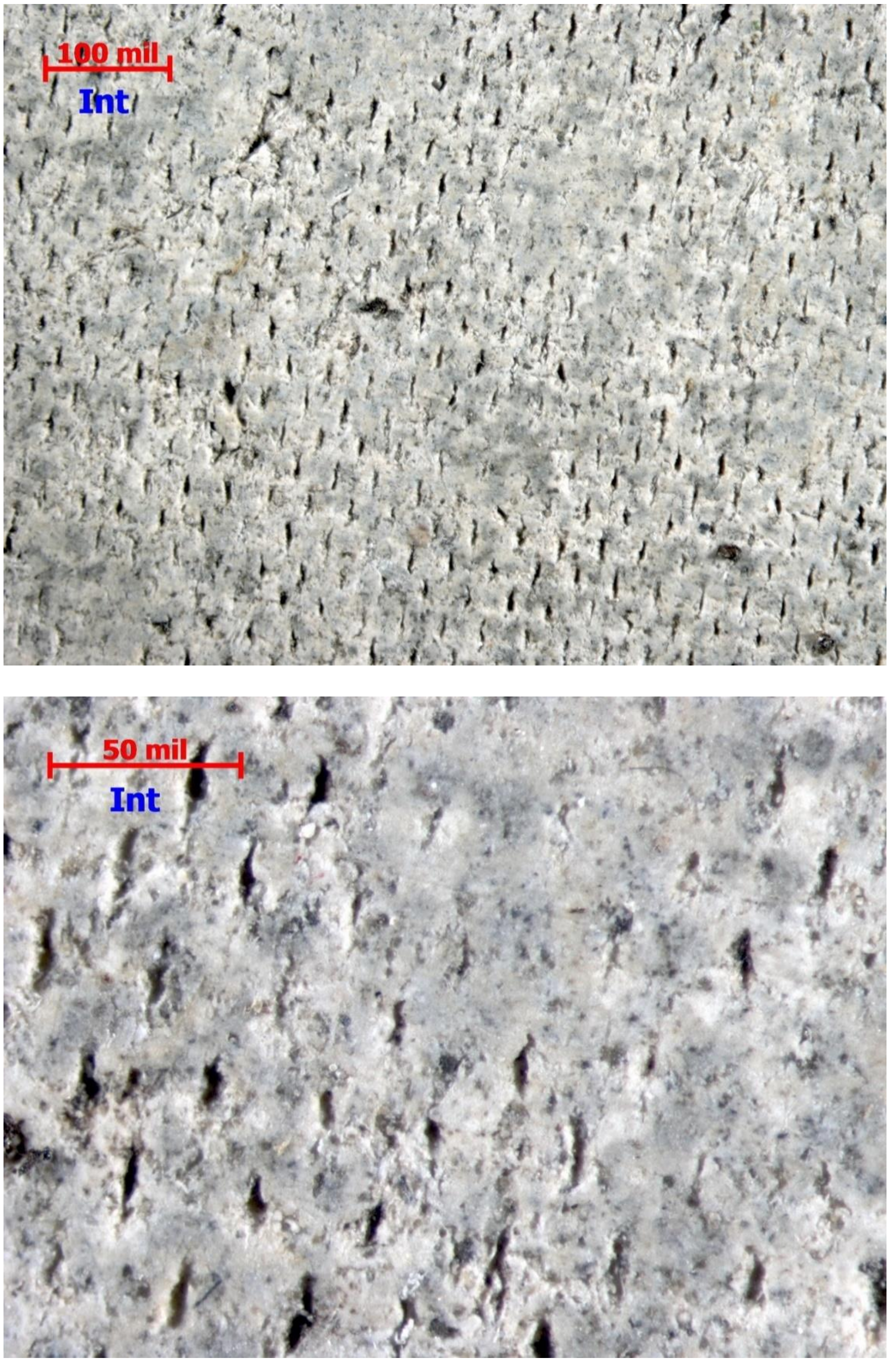


Figure 5. Sample D3. Close-up views of the interior surface, as received.

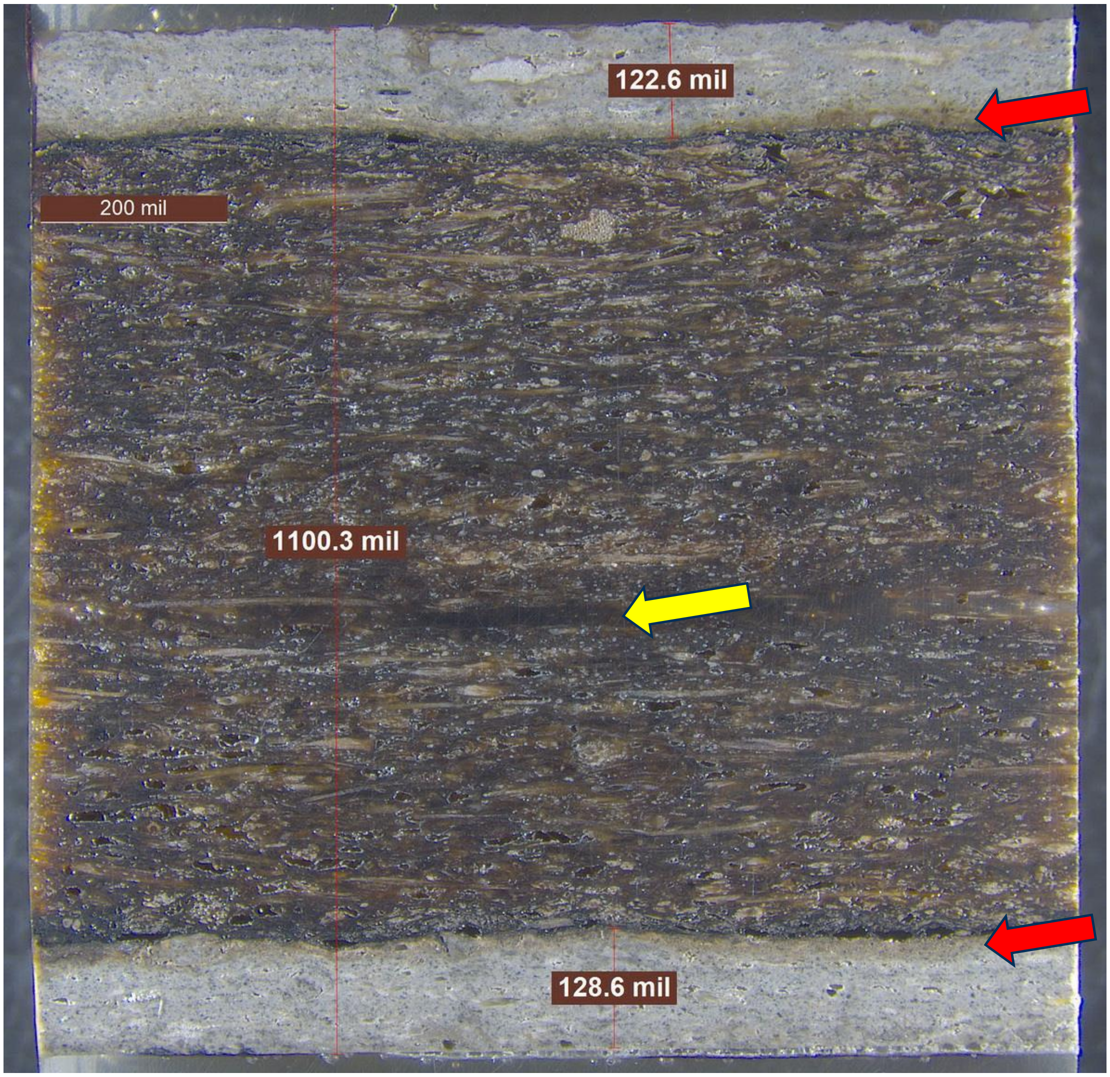


Figure 6. Lapped cross section of the panel embedded in epoxy shows the overall appearance and thicknesses of the asbestos sheets (exterior on the top and interior on the bottom) and the insulation core. Red arrows indicate minor staining of the asbestos sheets by a black asphalt-like binder shown below. Yellow arrow shows mainly epoxy used in sample preparation.

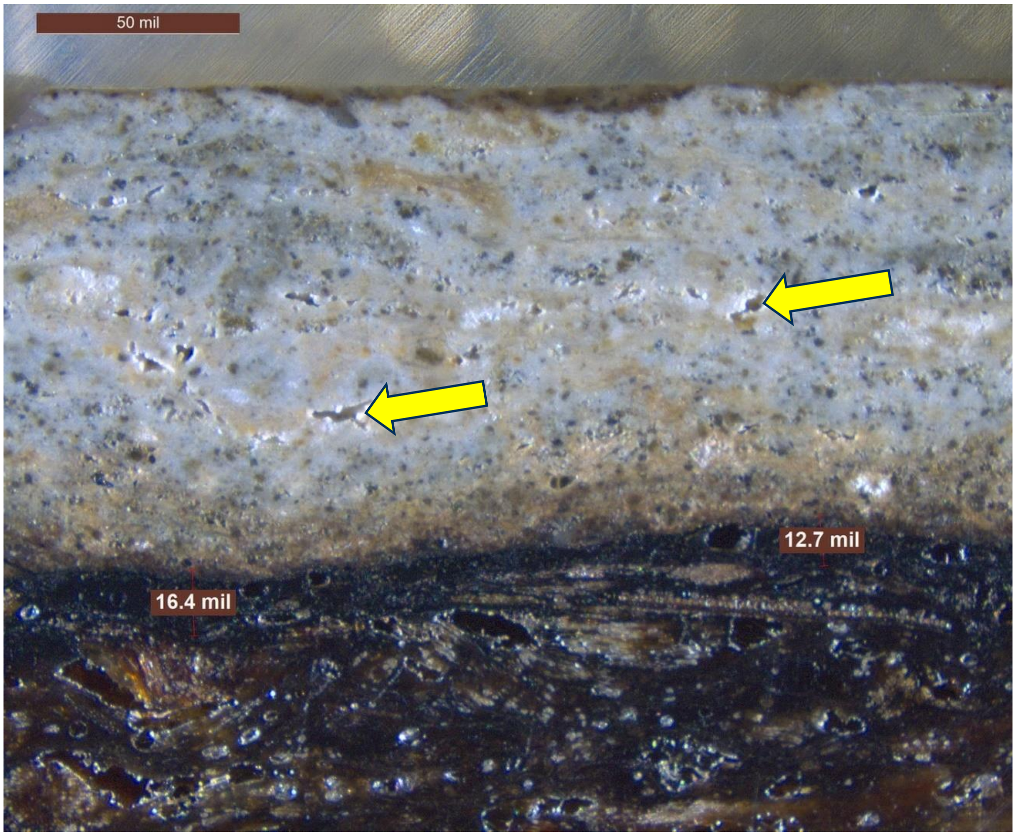


Figure 7. Close-up view of the exterior sheet and a portion of the insulation core. A layer of asphalt-like binder or adhesive was present between the sheet and the insulation core, measuring 10 to 20 mils thick. SEM/EDX analysis revealed the layer consists of mainly carbon and oxygen. Small amounts of the binder are also present in the insulation core. Arrows indicate voids that probably represented concentrations of water at time of manufacture and aligned by pressing/dewatering.

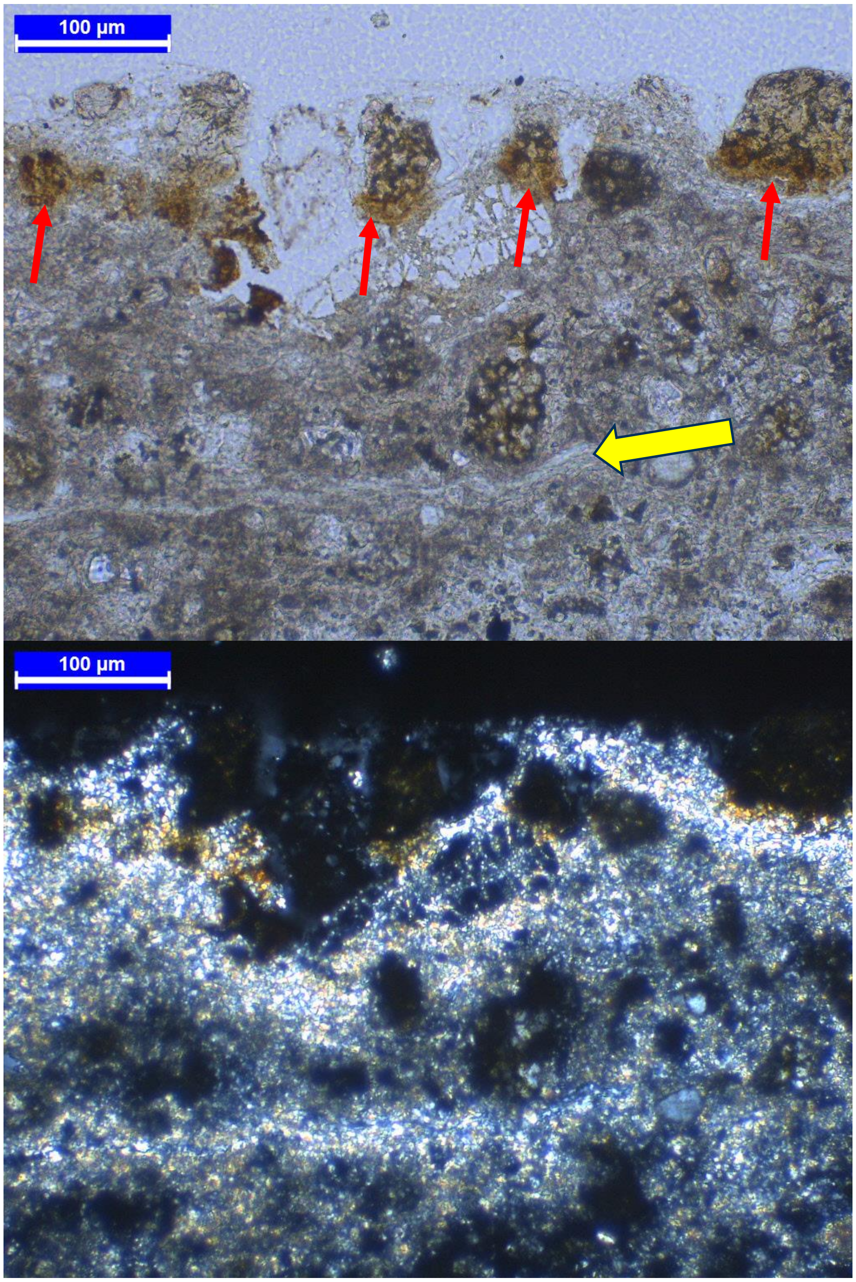


Figure 8. Thin-section photographs show a near-surface region of the exterior sheet where brown staining or discoloration was observed on the planar surface. The discoloration appeared to be caused by hydration or leaching of large near-surface cement particles (red arrows). Paste is partially carbonated and surficial paste appeared to be leached or decalcified. Yellow arrow indicates a thin asbestos strand, along which paste is carbonated as well. Top photo: plane-polarized light. Bottom photo: cross-polarized light.

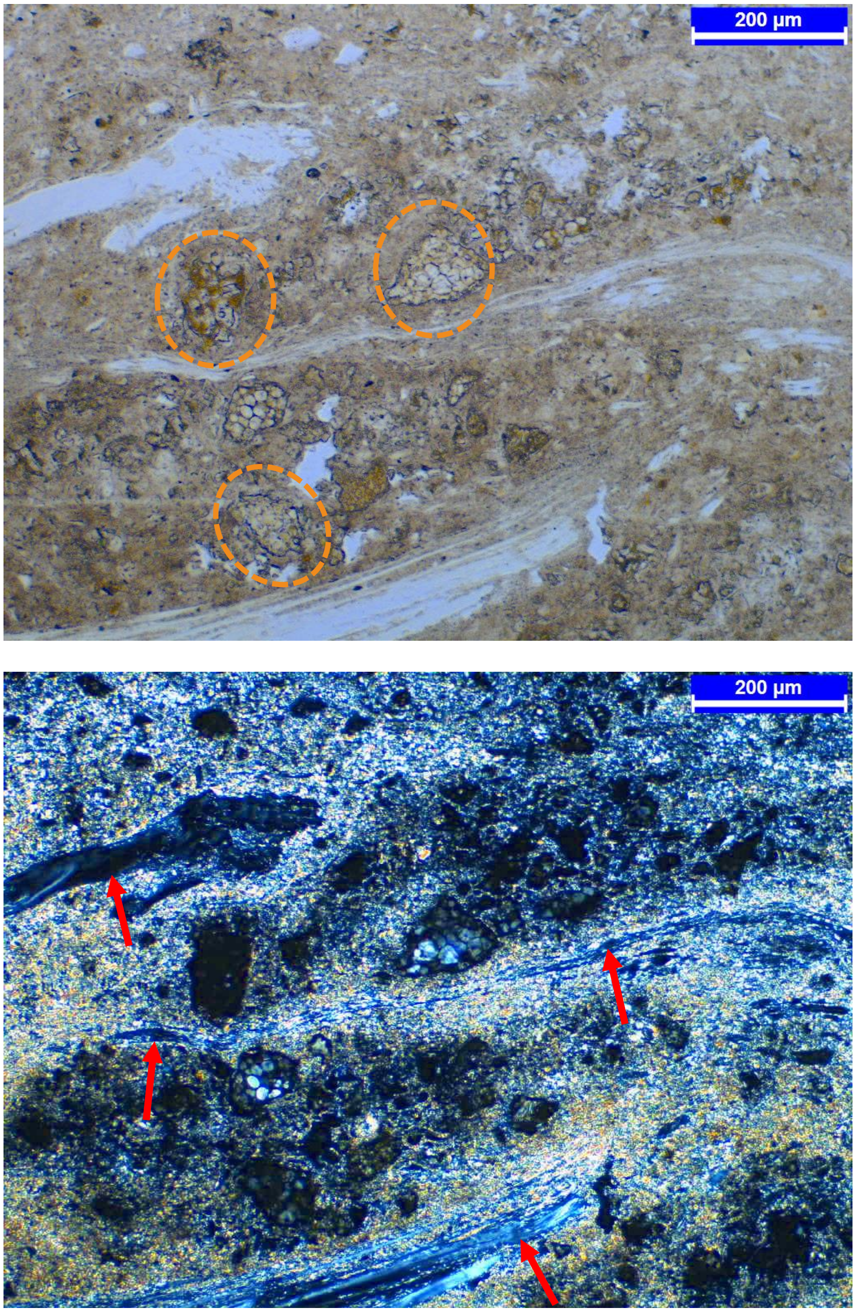


Figure 9. Thin-section photographs of the exterior sheet show large residual portland cement particles (circles) and asbestos strands (arrows). Note the patched or non-uniform carbonation along the fiber strands (golden bright specks in bottom photo). Top photo: plane-polarized light. Bottom photo: cross-polarized light.

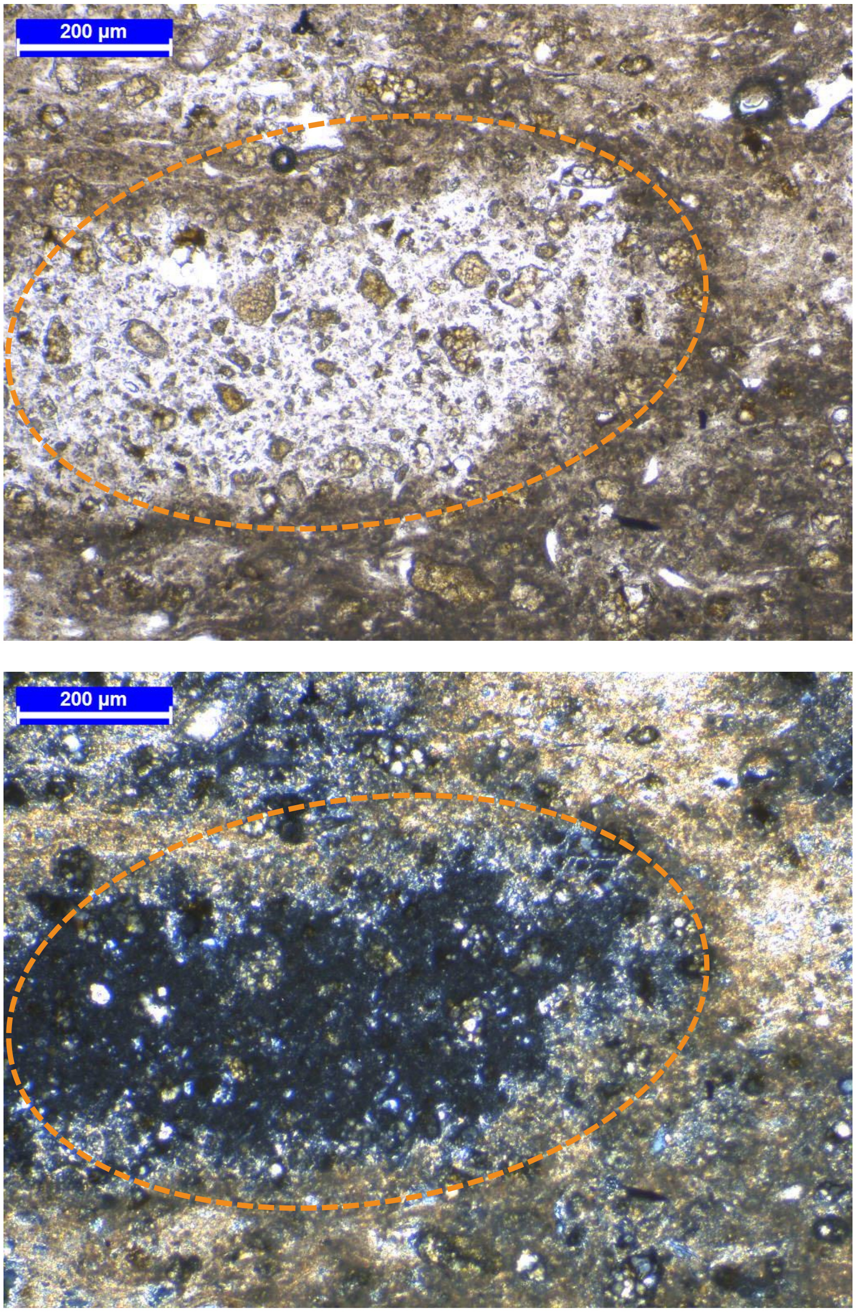


Figure 10. Thin-section photographs of the interior sheet show a portland cement lump (circled). Top photo: plane-polarized light. Bottom photo: cross-polarized light.

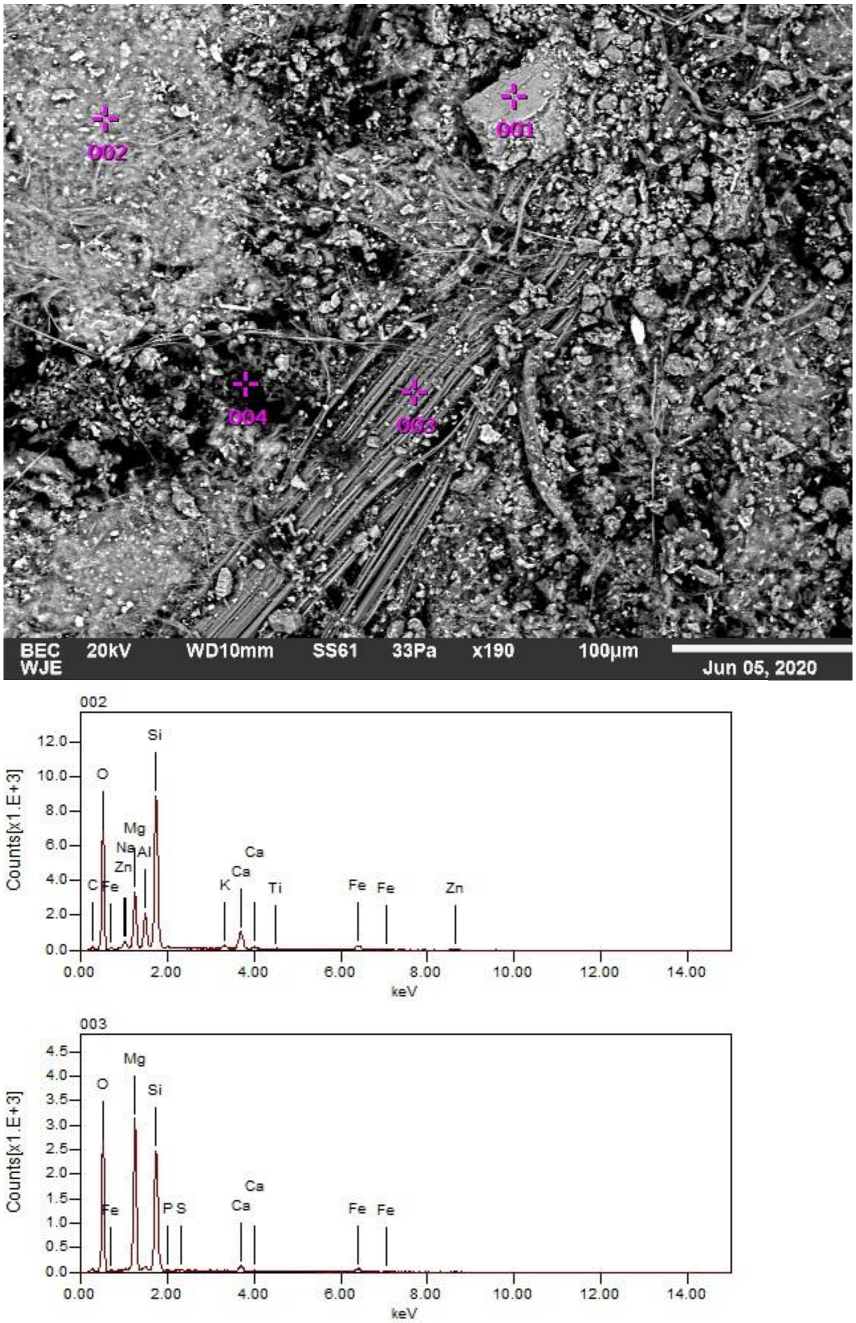


Figure 11. Backscattered electron image (top) of the exposed surface of the exterior sheet and representative EDS spectra for marked Spot 002 (middle, decalcified silicate gel) and for 003 (bottom, asbestos). Spot 001 was a hydrated cement particle. Spot 004 was a void.

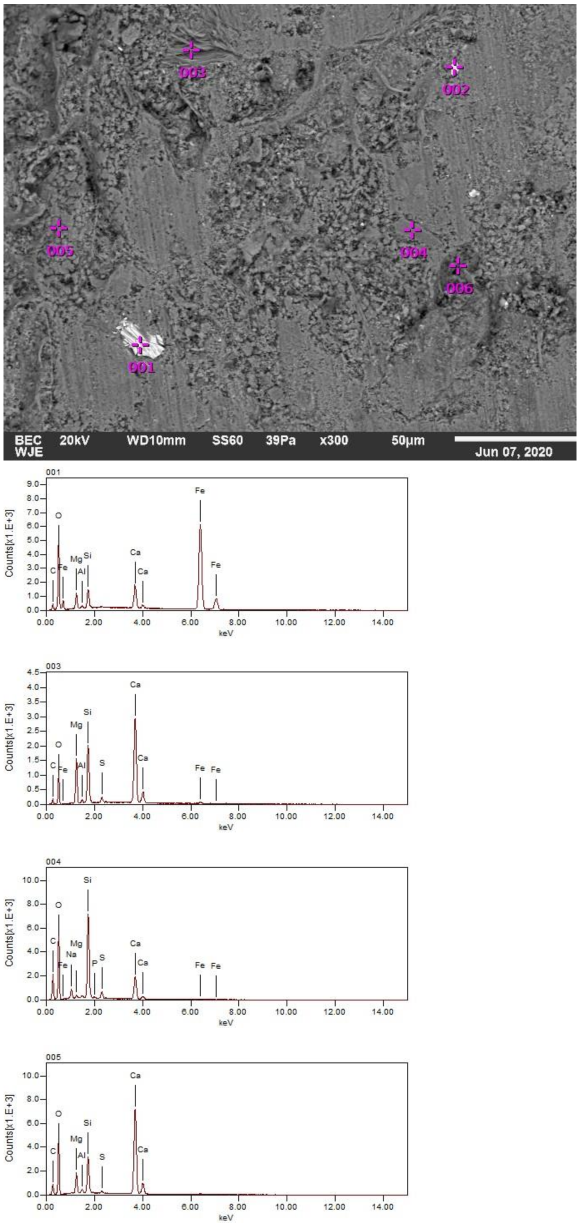


Figure 12. BE micrograph and point EDS spectra of the interior surface. Each EDS spectrum has a number in the upper left that corresponds with the location marked by cross-hairs with the same number in the micrograph. Spots 001 and 002 (spectrum not shown) were iron oxides/hydroxides. Spots 003 and 004 were mainly asbestos with minor calcite. Spot 005 was decalcified gel and Spot 006 was mainly calcite. The interior surface exhibited less amounts of asbestos strands and was in overall better condition than the exterior, consistent with the XRD observations shown below.

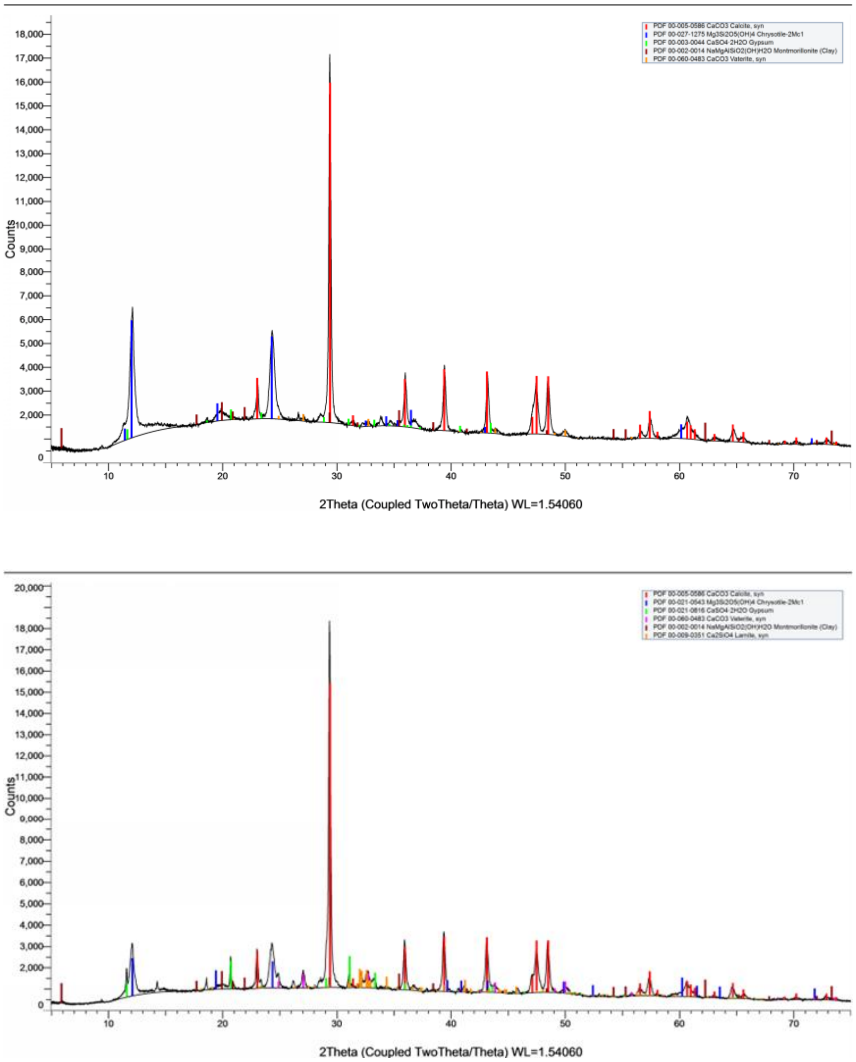


Figure 13. XRD patterns of the exterior surface (top) and the interior surface (bottom) of the panel. The patterns were collected directly on the exposed surfaces. Greater amounts of chrysotile were observed on the exterior surface than the interior surface (relative to calcite), consistent with more leaching and erosion on the exterior sheet. The greater hump with a peak position near 20 degrees two theta may represent the decalcified high-silica gel that is more abundant on the exterior surface than the interior surface. Trace to minor amounts of gypsum were detected, more on the interior surface.

Figure 14. Close-up views of the insulation core. It appeared to contain small amounts of black asphalt-like binder

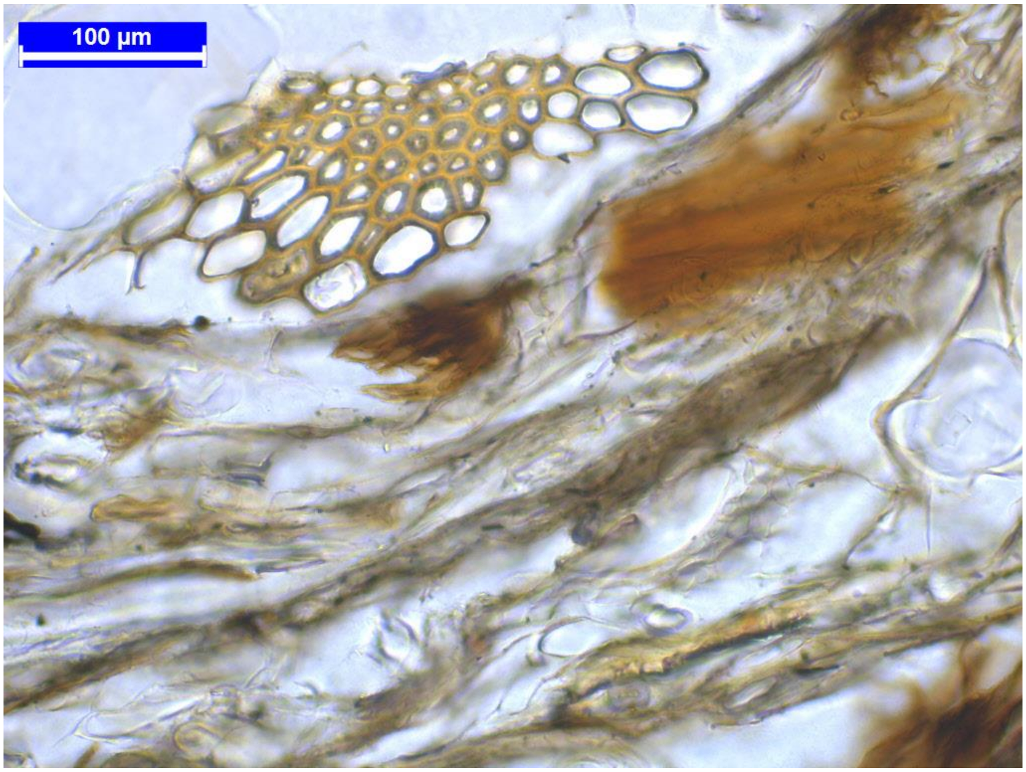


Figure 15. Thin section photo of the insulation core shows cellulose texture of plant. Plane-polarized light.

APPENDIX III

Asbestos-Cement Panels of the Twentieth Century

A.1 Introduction

The Cemesto panels at the Eames House are one of many asbestos-cement composite panels manufactured in the United States during the twentieth century. These products appeared in many contexts and architectural styles and were employed in a wide range of uses that included chalkboards, roof decks, residential sheathing, and curtain walls. While their appearances, manufacturing technologies, and component materials varied, each panel entailed the lamination of asbestos-cement sheets to other materials, resulting in a prefabricated product that benefited from the durability, rigidity, economy, and fire resistance of asbestos cement. Today, as an increasing number of twentieth-century buildings are the subject of preservation efforts, understanding this versatile product type will become ever more relevant for conservation decision-making.

The following description of asbestos-cement composite panels draws from a noncomprehensive survey of Sweet's Architectural Catalog Files (Sweet's Catalog), a master compilation of architectural product catalogs published in the United States annually since 1906, with few exceptions and under several name variations. The survey was supplemented by other trade catalogs, company-distributed brochures, patents, asbestos industry publications, and secondary sources in pursuit of specific lines of inquiry. While the term "asbestos-cement panel" can suggest various types of products, here it refers specifically to factory-assembled building products that incorporate at least one asbestos-cement sheet laminated through integral, adhesive, or mechanical means to an additional layer of any material. This report does not address stand-alone asbestos-cement sheets or boards, or marketing materials published outside the United States.

The resources described above suggest that this product type had been developed conceptually by the late 1920s and was available commercially by the 1930s. Until the 1950s, only three manufacturers advertised asbestos-cement panels in Sweet's Catalog, offering simple compositions of asbestos-cement facings and insulating cores. In the mid- to late 1950s, an increasing number of manufacturers specializing in neither asbestos cement nor insulation but rather various facings and general panel lamination began advertising panels employing asbestos-cement sheets in diverse compositions, mirroring a surge in panel products. By 1965, the number of companies advertising such products had increased to at least thirteen, and the number of distinct product names grew to more than twenty-six, with many new options for product customization. Manufacturer and product numbers in 1975 were similar, if not slightly reduced. Hampered by litigation and the threat of government restrictions, the asbestos industry declined in the United States in the late 1970s and 1980s.

A.2 Early Asbestos-Cement Panels

The first advertisements for asbestos-cement panels date from the early 1930s with the Celotex Company's (later reincorporated as Celotex Corporation) Cemesto Board and the Johns-Manville Corporation's Transite-Encased Insulating Board.[1] Both products comprised a rigid fiberboard insulating core—primarily of bagasse for Cemesto and wood fiber for Transite-Encased Insulating Board—laminated to asbestos-cement facings on one or both sides according to customer preference. Patents for the products suggest that both were laminated integrally, with still-wet asbestos-cement facings bonded under pressure to the insulating cores, and included an additional interlayer binding agent. For Cemesto Board, this binding agent was specified to be asphaltic, whereas that of Transite-Encased Insulating Board was suggested to have "the character of Portland cement" (Beckwith 1932; Munroe and Swenson 1934).

The products' physical appearances were characterized by their light gray asbestos-cement surfaces, described in marketing material as light-reflecting and generally pleasing and sometimes compared to stucco in half-timber construction. Both products eventually came in a standard size of 4 by 8 feet (1.22 by 2.44 meters), but available sizes varied by company and year. For example, Transite-Encased Insulating Board was initially available only in widths up to 42 inches (1.07 meters), and by 1935 Cemesto could be ordered in lengths up to 12 feet (3.66 meters) (Johns-Manville 1932; Sweet's Catalog 1935, 13/17). Product thickness also varied depending on available options and desired performance, ranging from ⅝ inch to 2⅜ inches (1.59 to 6.03 centimeters). Insulating cores ranged from ½ inch to 2 inches (1.27 to 5.08 centimeters) thick, and while both products' standard facing was ⅛ inch (3.2 millimeters), by 1940 Johns-Manville offered 3⁄16-inch (4.76 millimeters) facings for "exceptionally severe conditions" (Sweet's Catalog 1940, 6/30). These dimensions, though variable, remained relatively consistent across the history of both products.

Early advertisements emphasized the advantages of combining asbestos cement with fiberboard to create a single insulating product that was fire-resistant and durable as a finished material. While suggested uses focused primarily on industrial applications, including dryers, air ducts, industrial partitions, roof decks, and ovens, some early advertisements included limited references to the use of asbestos-cement panels in residential construction as well.

By 1937, the Philip Carey Company had joined Johns-Manville and Celotex in advertising asbestos-cement panels, and by 1939 the company was marketing three branded panels differentiated by their insulating cores: Carey Insulated Sheathing, which featured a fiberboard core; Careycel Insulated Sheathing, named after the company's proprietary laminated asbestos-felt insulation; and Aircel Insulated Sheathing, which likely featured a core made from "aircell," a generic term for corrugated asbestos felts. While advertisements mention Carey Insulated Sheathing and Careycel Insulated Sheathing in the context of roof decks and boiler furnaces, respectively, most early references to these products do not address their exact compositions, dimensions, or suggested uses (*Asbestos* 1937; Philip Carey 1939; Sweet's Catalog 1938, 10/54). However, all three clearly feature the same tripartite structure as Cemesto and Transite-Encased Insulating Board.

Over the next two decades, panel branding evolved, possibly corresponding with minor changes in materials or composition. Throughout the 1940s, Transitop gradually replaced Transite-Encased Insulating Board as a product name in otherwise identical marketing, and by 1948 the standard version of that product was faced with Flexboard, a stronger, more flexible asbestos-cement sheet; the original, rigid Transite facings remained available upon request (Johns-Manville 1944, 1948). Similarly, Carey Insulated Sheathing was renamed Thermo-Bord in Philip Carey's advertising in the late 1940s, but it is unclear if this coincided with physical changes in the product (Sweet's Catalog 1949, 8a/3). Around the same time, Careycel Insulated Sheathing and Aircel Insulated Sheathing disappeared from the company's advertisements.

Despite the new product names, advertisements in Sweet's Catalog suggest that the asbestos-cement panel industry underwent few changes over the next two decades. The Johns-Manville Corporation, Philip Carey Company, and Celotex Corporation continued to be the only manufacturers to market such products in the publication, and the sandwich-like structure of their flagship panels remained unchanged. The nature of these companies' marketing, however, evolved. Increasingly, they advertised their asbestos-cement panels in the context of prefabricated building systems, some of which were proprietary and patented. This tendency, part of a larger move toward prefabrication in twentieth-century construction, helps contextualize the further development of this product type and its uses in the late 1950s and 1960s.

A.3 Asbestos-Cement Panels in Systems

Increasing emphasis on asbestos-cement panels as part of larger, frequently pre-engineered and prefabricated systems is evident in marketing beginning around 1937. That year, an early reference to Carey Insulated Sheathing introduced the product in the context of "Carey Insulated Sheathing Roof Deck," a patented roof-deck construction system, and seemed to reference the panel and the system interchangeably (*Asbestos* 1937). This was also reflected in the expanded marketing literature for Cemesto. By 1938, Celotex's advertisements included instructions for the product's application to wood and steel building frames, as well as examples of the product's aesthetic potential in residential architecture. Though absent from the Sweet's Catalogs that were surveyed, the Cemesto house, a pre-engineered structure using Cemesto panels to facilitate mass construction, was also developed around this time (Prudon 2008, 305). However, the use of asbestos-cement panels in curtain walls and interior partition systems was most relevant to the products' evolution and future uses.

Curtain-Wall Systems

In 1938, Johns-Manville announced a patented curtain-wall system comprising an interior layer of Encased Insulating Board mechanically attached to an exterior sheathing of Corrugated Transite (fig. A.1) (*Asbestos* 1938). By 1940, ads for this assembly were appearing in Sweet's Catalog. Years later, Philip Carey advertised a nearly identical assembly called Carey "Thermo-Walls," which used Thermo-Bord and Careystone Corrugated Sheathing (Philip Carey 1956). Transitop (formerly Transite-Encased Insulating Board) and Thermo-Bord (formerly Carey Insulated Sheathing) were rarely advertised as stand-alone products between the 1930s and the late 1950s and were marketed almost exclusively in the context of their respective company's roof-deck and curtain-wall systems.

Advertisements for both companies' curtain-wall systems detail numerous advantages of asbestos-cement panels for curtain-wall construction. These advantages generally fell into five broad categories. The first was the systems' rapid, economical construction, which relied on inexpensive materials, minimal labor, and minimal specialized trade skills. Second, they were frequently described as maintenance free, claims that drew on the perception of asbestos cement as durable and permanent. Next was the systems' insulating value and fire resistance, compared favorably to that of heavier masonry walls. The fourth category was the versatility and salvageability of the systems' materials, traits that ostensibly simplified building customization and postconstruction modifications. Finally, marketing frequently referenced the desirable attributes of asbestos-cement surfaces, which, depending on the specific advertisement, could include its permanent, "pleasing" gray-white color, sanitary properties, and overall modern aesthetic (fig. A.2). Despite claims regarding these numerous advantages, the systems were advertised almost exclusively for

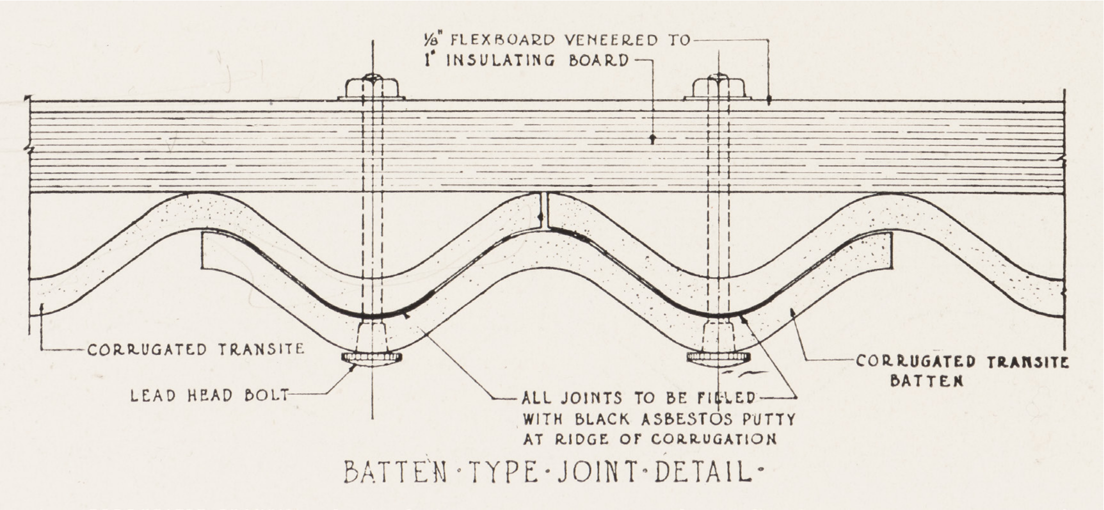
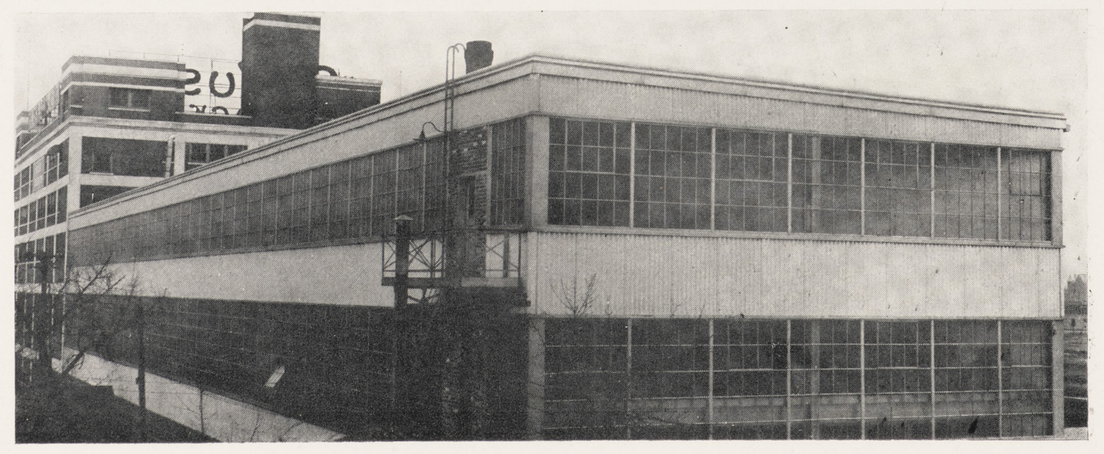


FIGURE A.1 *Joint detail for Johns-Manville's J-M Curtain Wall showing Corrugated Transite applied on-site to Encased Insulating Board (Johns-Manville 1944, 35). Courtesy of Canadian Centre for Architecture.*

industrial buildings such as warehouses, manufacturing facilities, and airplane hangars. Marketing further limited recommended applications of these systems by warning against their use in humid environments.[2]

Toward the close of the 1950s, curtain walls and window walls would become a major application for asbestos-cement panels, driving a surge in new products. For this expansion to occur, however, manufacturers had to overcome the limitations faced by early curtain-wall systems. By 1952, Johns-Manville had addressed the panels' performance in humid environments, advertising a "new, moisture-proof Transitop" that featured an "integrally impregnated core…laminated with a waterproof adhesive" and optional "sealed edges" for additional protection (Johns-Manville 1952, BMM-200). In the late 1950s and into the 1960s, manufacturers further addressed aesthetic limitations and vapor penetration through the introduction of new facing and backing materials, such as alu-



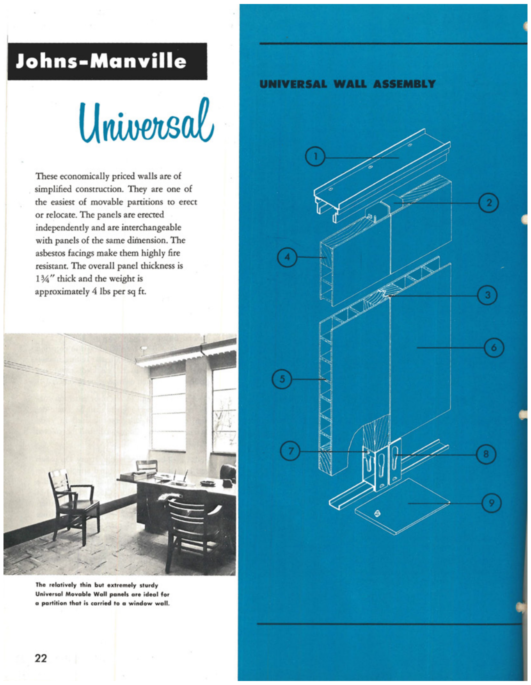
The pleasing gray Transite exterior does not require painting to preserve it. It has unusual durability and fire-resistance

FIGURE A.2 *Promotional image of a J-M Curtain Wall used in an industrial setting. (Johns-Manville 1944, 33). Courtesy of Canadian Centre for Architecture.*

minum and steel, and new finishes, such as polyvinyl chloride (PVC). The dual aesthetic and vapor-resisting qualities of these materials enabled manufacturers to minimize the number of layers while ensuring panels performed adequately as modern exterior cladding. In the absence of protective facings and finishes, manufacturers also increasingly offered foil vapor barriers as either internal layers or backings applied directly to the panel's interior face. These key developments facilitated the growing use of asbestos-cement panels in curtain-wall systems across diverse contexts.

Partition Systems

By the 1940s, Johns-Manville was also marketing interior partition systems that utilized asbestos-cement panels. Unlike the company's curtain-wall system, which offered innovation in the form of a specialized assembly for general-use panels, these partitions featured unique panels designed exclusively for a specific framing system. While the company advertised several types of "Movable Transite Walls," only two incorporated factory-assembled asbestos-cement panels: Universal Wall Assemblies, which appeared as early as 1940, and Class A Wall Assemblies, which would enter the market by 1952 (Johns-Manville 1952, BMT-100; Sweet's Catalog 1940, 20/7).



Johns-Manville

Universal

These economically priced walls are of simplified construction. They are one of the easiest of movable partitions to erect or relocate. The panels are erected independently and are interchangeable with panels of the same dimension. The asbestos facings make them highly fire resistant. The overall panel thickness is 1¾" thick and the weight is approximately 4 lbs per sq ft.

The relatively thin but extremely sturdy Universal Movable Wall panels are ideal for a partition that is carried to a window wall.

22

UNIVERSAL WALL ASSEMBLY

FIGURE A.3 *Catalog page showing Johns-Manville's Universal Wall Assembly (Johns-Manville 1960, 22). Courtesy of Carol J. Dyson, AIA and Building Technology Heritage Library (BTHL).*

These panels differed structurally from previous asbestos-cement panels. While still faced with asbestos-cement sheets, Universal Wall Assemblies featured a hollow core of interlocking Insulating Board strips (fig. A.3) (Sweet's Catalog 1940, 20/7). The core perimeters were framed with hardboard rails and stiles that were molded into S joints to connect individual panels. These stiles extended vertically beyond the tops and bottoms of the panels, where they featured "notches" for receiving assembly hardware, facilitating their installation into floor and ceiling channels. For half-height partitions, a "stiffening" rail stabilized the partition in the absence of a ceiling channel. Class A Wall Assemblies differed from Universal Wall Assemblies in terms of materials, using Marinite rails and stiles, Flexboard for the inner core grid, and mineral wool in the otherwise hollow spaces between grid strips. Price and degree of fire resistance set these products apart. Of the two, Class A Wall Assemblies were more expensive and offered higher fire resistance (Johns-Manville 1960).

Interior partitions were a significant application of asbestos-cement panels throughout their history. Cemesto, Thermo-Bord, Transitop, and later general-use panels were all advertised to varying degrees for this function. Johns-Manville's partitions, however, are significant as early examples of panels with features that facilitated installation for a specific use, disqualifying them from general applications. While general-use panels continued to appear in advertisements, those with incorporated connections and hardware increased throughout the 1960s and 1970s.

A.4 Midcentury Developments in Asbestos-Cement Panels

Significant changes in advertised asbestos-cement panels began during the latter half of the 1950s and continued through the mid-1960s. By 1959, the number of manufacturers advertising these products in Sweet's Catalog had increased from the original three to at least eight.[3] By 1965, the number had grown to no fewer than fourteen.[4] These companies included not only asbestos-cement producers but also manufacturers specializing in various types of veneer materials, which sometimes evolved into a general specialization in panel lamination. Collectively, these companies marketed approximately twenty-six distinct branded panel products, yet the number of customization options for any given product resulted in well over a hundred total possible panel compositions. These panels were advertised for many uses, including interior partition systems, chalkboards, roof decks, and interior finishes, but much of this growth stemmed from new panels intended primarily for use as exterior cladding, especially in curtain walls and window walls.

These diverse new types of panels differed from previous asbestos-cement panels in structure as well as in materials and customizability. In general, the products benefited from new adhesives, including rubber- and neoprene-based adhesives, some specified to be thermoplastic. Insulated panels also featured a broad range of new options for insulating cores, including perlite, polystyrene, polyurethane, fiberglass, cellular glass, paper honeycomb insulation, and a variety of asphalt-impregnated fiberboards. Other developments—described in the following sections—varied more significantly across manufacturers and product type, resulting in a plethora of evolving customization options.

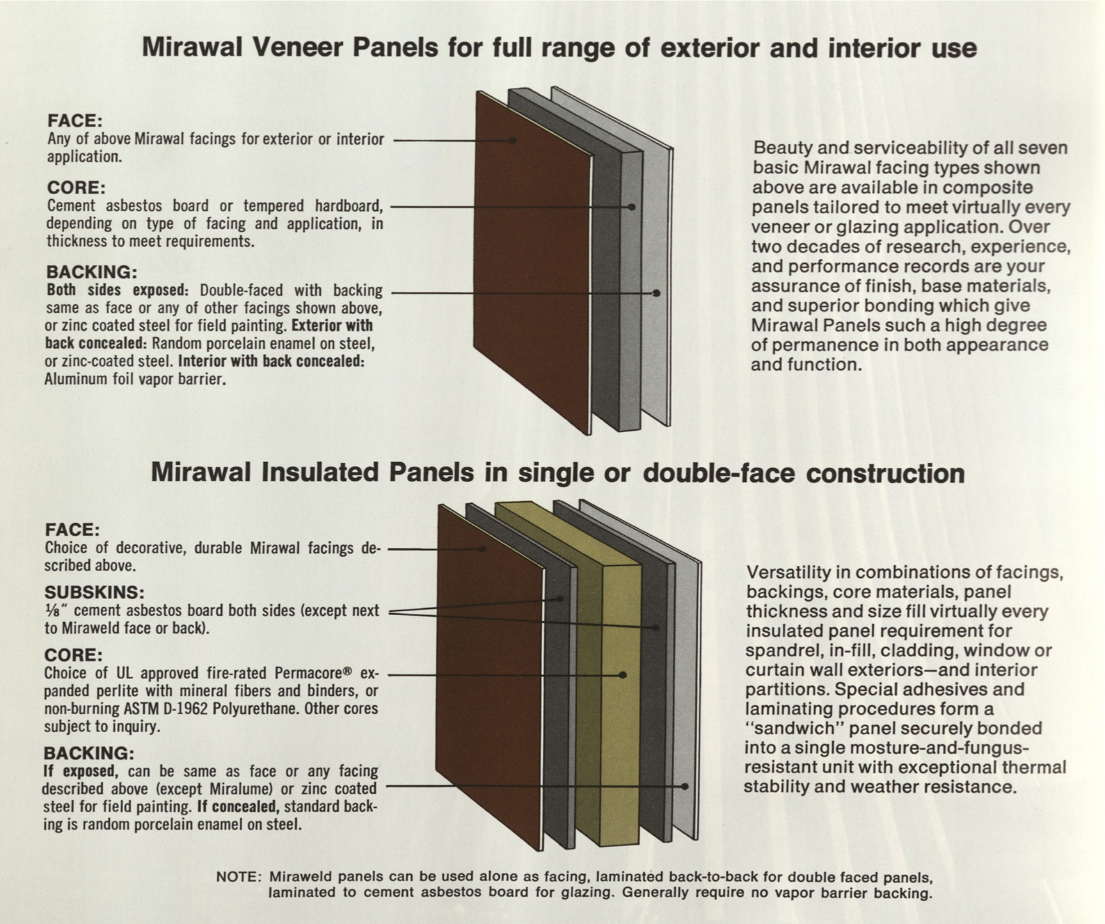
Though advertised primarily for use as curtain walls and window walls, these products were also suggested for nearly any application requiring rigid insulation or cladding, which encompassed a range of uses, as the panels could be tailored to nearly any function, environment, or aesthetic. Advertisements show these panels on hospitals, schools, office buildings, banks, residential architecture, and even high-rises, and with their extreme range in appearance, they are usually difficult to distinguish from any other generic midcentury curtain wall.

Specialty Facings

The rapid increase in asbestos-cement panel products in the mid-twentieth century can be attributed largely to products featuring specialty facings veneered to one or both panel faces. Examples of the new facings and the brands initially associated with them include porcelain-enameled metal (AllianceWall and Mirawal); aluminum (Alcoa); tiles and mosaics (Mosaic Building Products and Ravenswood); aggregates embedded in epoxy resin matrices (Ar-Lite and Artcraft); and decorative cementitious surfacing (Century Brick). Throughout the 1960s, some companies such as Mirawal drastically expanded their facing options, growing to include nearly all the above-mentioned categories. Even Johns-Manville, a major asbestos-cement producer, recognized the growing market for panels with decorative veneers. By 1965, the company had introduced "Micro-Flexboard," an asbestos-cement facing for Transitop designed specifically to receive additional veneering from third-party window-wall manufacturers and laminators. With suggested veneers including "metal skins, ceramic tile, vinyl fabric, wood veneer or similar coverings," the customization options for Transitop beyond Johns-Manville's facilities were virtually endless.

The composition of panels with specialty facings resembled that of traditional asbestos-cement panels, but rather than consisting of three layers—two asbestos-cement sheets and an insulating core—they frequently featured four or five layers including their veneered facings (fig. A.4). While asbestos-cement sheets had been a prominent visual feature of previous panels, here they took on a secondary, internal function. Advertisements for these panels generally portray asbestos-cement sheets in the position of "stabilizing sub-skins," also called "face backings" or "stabilizing core members." These marketing terms suggest that the primary advantage of asbestos cement in such compositions was its rigidity. This provided support to both the insulating core and veneer facings, which, where specified, were frequently less than ¹⁄₃₂ inch (0.79 millimeters) thick. However, some manufacturers also offered the option of using hardboard as an economical alternative to asbestos cement in these panels. Under such circumstances, asbestos cement was usually highlighted as better suited to exterior applications and more fire-resistant.

Depending on the specific product and its intended use, many manufacturers still offered the option of leaving the asbestos cement or hardboard sheets exposed on concealed surfaces; in these instances, they were called interior facings.



Mirawal Veneer Panels for full range of exterior and interior use

FACE:
Any of above Mirawal facings for exterior or interior application.

CORE:
Cement asbestos board or tempered hardboard, depending on type of facing and application, in thickness to meet requirements.

BACKING:
Both sides exposed: Double-faced with backing same as face or any of other facings shown above, or zinc coated steel for field painting. **Exterior with back concealed:** Random porcelain enamel on steel, or zinc-coated steel. **Interior with back concealed:** Aluminum foil vapor barrier.

Beauty and serviceability of all seven basic Mirawal facing types shown above are available in composite panels tailored to meet virtually every veneer or glazing application. Over two decades of research, experience, and performance records are your assurance of finish, base materials, and superior bonding which give Mirawal Panels such a high degree of permanence in both appearance and function.

Mirawal Insulated Panels in single or double-face construction

FACE:
Choice of decorative, durable Mirawal facings described above.

SUBSKINS:
⅛" cement asbestos board both sides (except next to Miraweld face or back).

CORE:
Choice of UL approved fire-rated Permacore® expanded perlite with mineral fibers and binders, or non-burning ASTM D-1962 Polyurethane. Other cores subject to inquiry.

BACKING:
If exposed, can be same as face or any facing described above (except Miralume) or zinc coated steel for field painting. **If concealed,** standard backing is random porcelain enamel on steel.

Versatility in combinations of facings, backings, core materials, panel thickness and size fill virtually every insulated panel requirement for spandrel, in-fill, cladding, window or curtain wall exteriors—and interior partitions. Special adhesives and laminating procedures form a "sandwich" panel securely bonded into a single mosture-and-fungus-resistant unit with exceptional thermal stability and weather resistance.

NOTE: Miraweld panels can be used alone as facing, laminated back-to-back for double faced panels, laminated to cement asbestos board for glazing. Generally require no vapor barrier backing.

FIGURE A.4 *Illustrations of Mirawal Veneer Panels (top) and a Mirawal Insulated Panel showing typical compositions for panels with specialty facings (Sweet's Catalog 1975, 7.5/Mi). Courtesy of Dodge Construction Network and University of Tennessee, Knoxville – Libraries.*

New Asbestos-Cement Varieties and Finishes

The introduction of panels with specialty facings did not result in a decrease in the number of products with asbestos-cement facings. In fact, brands such as Atlas Asbestos, Glasweld, and Gold Bond began advertising products resembling traditional asbestos-cement panels around 1960. However, many companies increasingly offered new varieties of asbestos-cement sheets, including flexible, integrally colored, textured, low density, and other variants, and introducing new aesthetic and functional possibilities in the process. Customization options were compounded by new finishes for asbestos-cement surfaces, including factory-applied primers, colored acrylic surfacing, thermoplastic polymer films, and mineral-enamel coatings (fig. A.5).

While panels with unfinished "utilitarian" asbestos-cement facings continued to be advertised for use as cladding, roof decks, and partitioning in industrial buildings, those with decorative finishes were shown in a variety of contexts, frequently with more emphasis on smaller-scale residential and commercial uses than is observed in advertisements for other products. These panels demonstrate the aesthetic versatility of asbestos cement and its potential to be adapted to almost any style or setting.

Uninsulated Veneer Panels

The aesthetic possibilities introduced in the 1950s and 1960s contributed to the creation of a new type of asbestos-cement panel that served a primarily decorative function. Usually called "veneer panels," these products lacked insulating cores, consisting of a 3⁄16- to 5⁄16-inch (4.76 to 7.94 millime-

FIGURE A.5 *Photo showing the use of Glasweld insulated sandwich panels with a mineral-enamel coating in curtain-wall construction (Sweet's Catalog 1965, 3b/Uni). Reproduced courtesy of Dodge Construction Network and The Ohio State University Libraries.*

ters) asbestos-cement or hardboard core that supported a veneer facing of usually less than 1⁄32 inch (0.79 millimeters). Depending on the intended use, the interior face could be made to match the exterior or feature a utilitarian backing such as galvanized steel (fig. A.6). For certain interior applications, no interior faces were needed, and the asbestos-cement or hardboard core could be left exposed. Occasionally, decorative asbestos-cement sheets, rather than specialty facings, were also used to produce veneer panels. Laminated back-to-back, they formed a two-layer product with two decorative faces.

Advertisements for veneer panels emphasized slightly different applications than for their insulated counterparts, although uses for both overlapped considerably. Generally, marketing for these panels focused on their use as interior partitions, wainscoting, bulkheads, transoms, storefronts, spandrels, and interior and exterior wall finishes (fig. A.7).

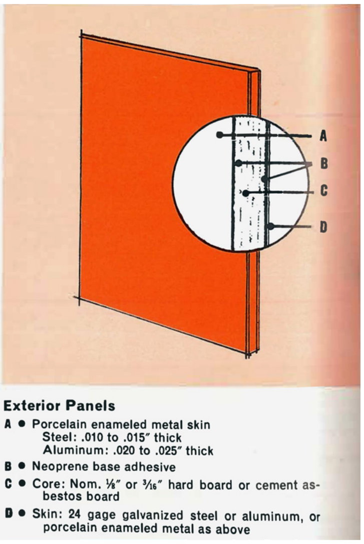


FIGURE A.6 *Illustration showing the composition of an AllianceWall veneer panel (Sweet's Catalog 1960, 6d/Al). Courtesy of Carol J. Dyson, AIA and BTHL.*

New Levels of Prefabrication: Panels as Curtain-Wall Systems

Asbestos-cement panels had been used in curtain walls since at least 1938, but by the 1960s new types of panels constituting curtain-wall systems in and of themselves had emerged. Described in one 1970s advertisement as an "instant exterior wall," such panels incorporated elements—usually metal frames, pans, or connections—that facilitated their direct installation onto structural frames with minimal on-site labor (Sweet's Catalog 1975, 7.5/Ce). While some panels could be custom engineered for specific structural systems, others were advertised as being compatible with most standard framing systems. In either case, similar to Johns-Manville's partition assemblies, these panels differed from conventional sandwich-style panels insofar as

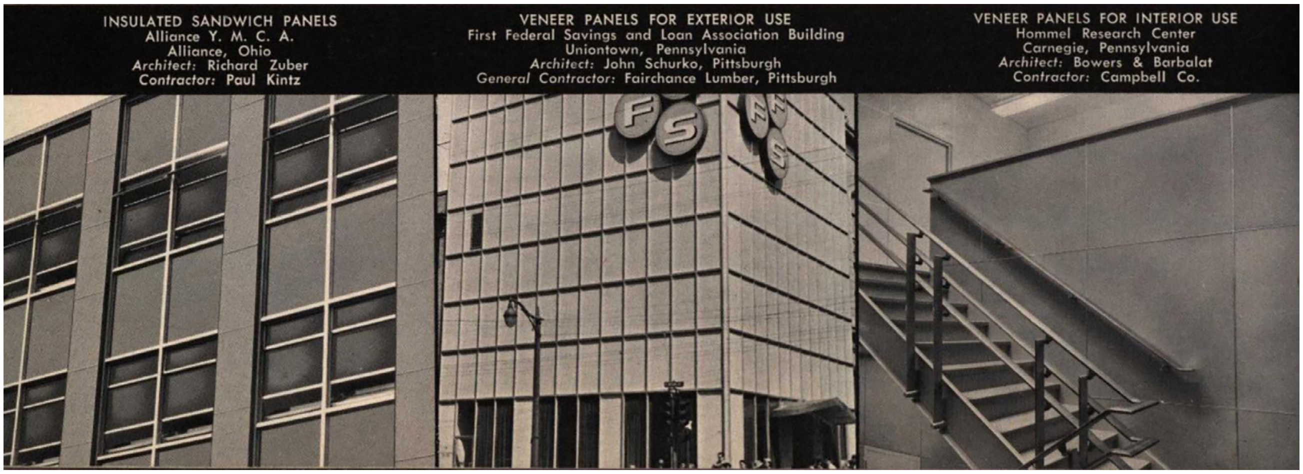
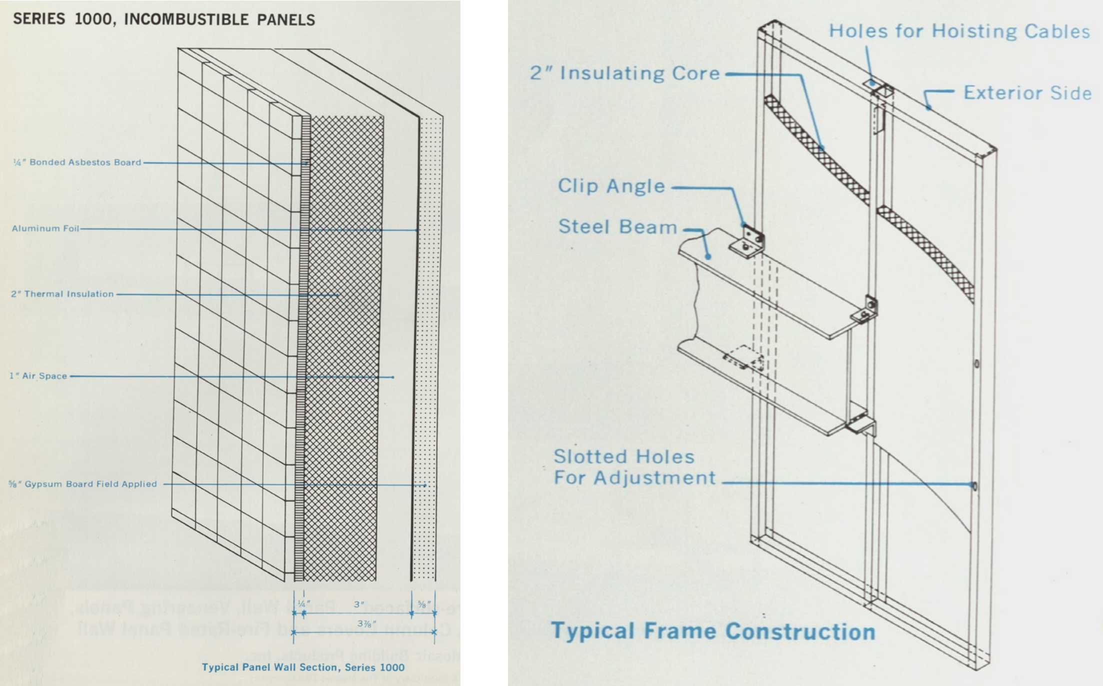


FIGURE A.7 *Photos showing applications of AllianceWall's insulated sandwich panels and veneer panels on the exteriors and interior of three buildings (Sweet's Catalog 1960, 6d/Al). Courtesy of Carol J. Dyson, AIA and BTHL.*



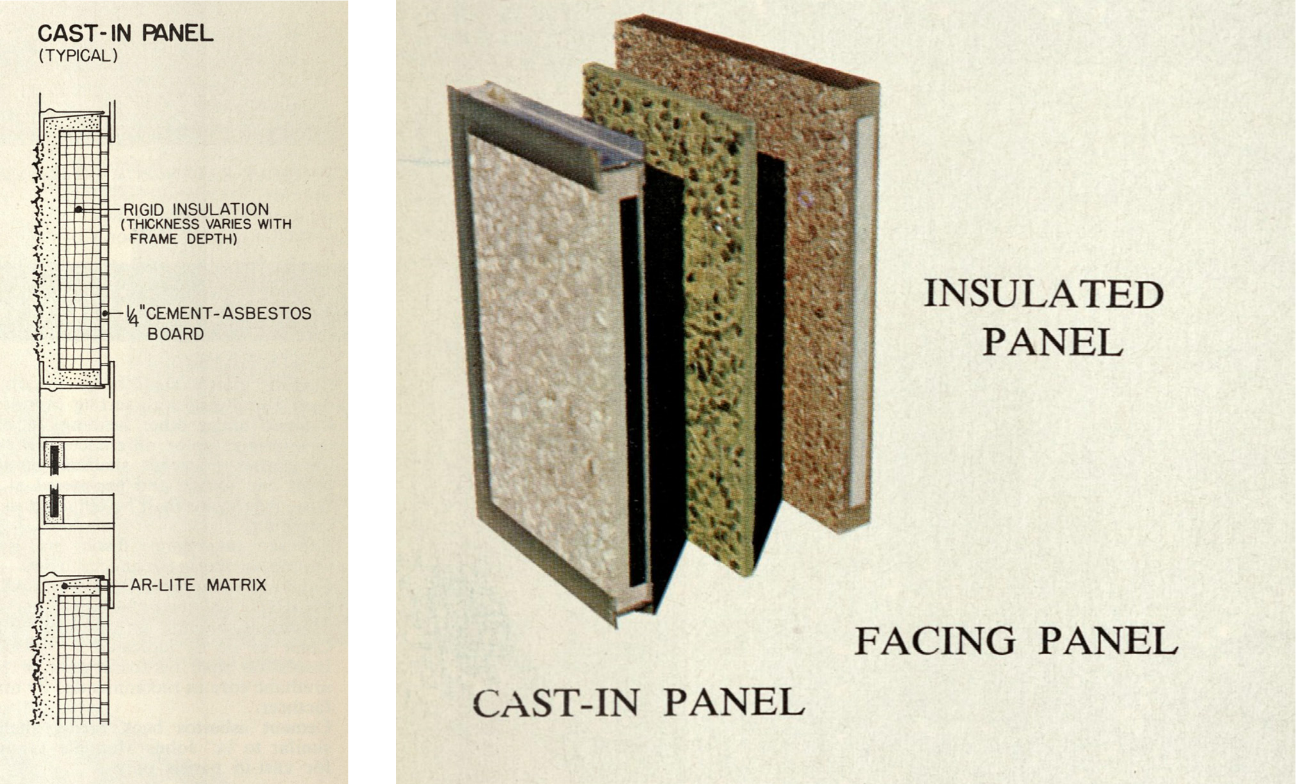
(A) **(B)**

FIGURE A.8A, A.8B *Diagrams of a prefabricated curtain-wall system from Mosaic Building Products Inc. The panel (a) is factory-applied to the steel frame (b), which provides additional rigidity and facilitates installation (Sweet's Catalog 1965, 3b/Mo). Reproduced courtesy of Dodge Construction Network and The Ohio State University Libraries.*

they were not prefabricated building materials for general use, but rather prefabricated systems designed for a specific function.

These panels took on various forms. A common one consisted of an asbestos-cement sheet laminated to a rigid frame of welded steel studs with the sheet serving as the substrate for decorative finishes such as exposed aggregates; ceramic, glass, and stone tiles; and stone veneers. Other elements of panel composition varied by manufacturer and could include rigid or nonrigid insulation, vapor barriers, and even air voids (figs. A.8a and A.8b). A second form, referred to in marketing as "cast-in" panels, employed asbestos-cement sheets not as a substrate but as a backing. Laminated on one side to rigid insulation, the sheet was inserted into a metal curtain-wall frame such that the unlaminated asbestos-cement surface served as the panel's interior face. An epoxy resin matrix was poured into the frame, covering the rigid insulation and contained by the asbestos-cement backing. The panels were finished with an aggregate facing, forming a "monolithic unit" that served as a lightweight alternative to precast concrete (figs. A.9a and A.9b).

Some manufacturers adhered more closely to the typical sandwich-style asbestos-cement panel while incorporating metal framing and connecting elements. In some cases, this took the form of laminating an insulated sandwich panel to a metal pan that covered the panel's perimeter and interior face, and at least one company achieved a similar end by finishing its panels with a metal



(A) **(B)**

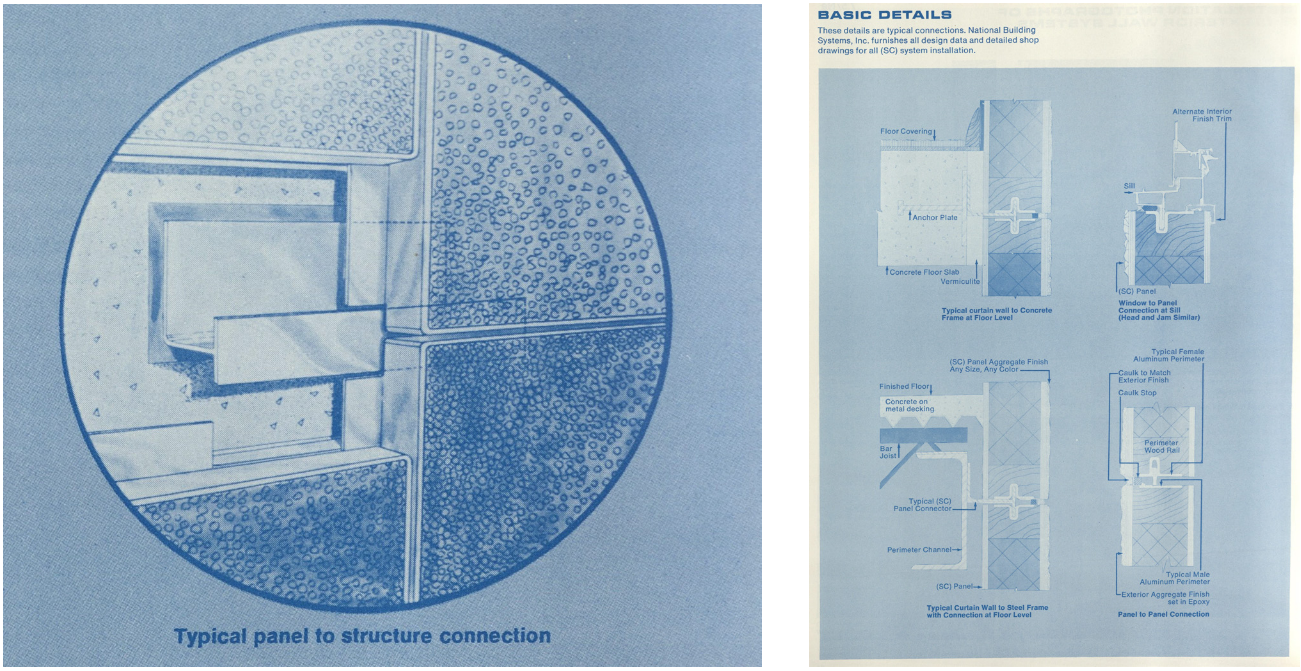
FIGURE A.9A, A.9B *Diagram (a) and illustration (b) of an Ar-Lite Cast-In Panel. Note that the company's Insulated Panel and Facing Panel do not utilize asbestos-cement sheets (Sweet's Catalog 1965, 3b/Ar). Reproduced courtesy of Dodge Construction Network and The Ohio State University Libraries.*

perimeter set within wood perimeter rails. Such panels were frequently shown with aggregate facings (figs. A.10a and A.10b).

Mosaic Building Products Inc., which advertised several varieties of curtain-wall systems, also marketed various asbestos-cement veneer panels with integral steel mounting systems. These panels were advertised for both interior and exterior applications as well as for use as cladding for structural columns (Sweet's Catalog 1965, 3b/Mo). Other companies may also have marketed such panels in company-issued publications or produced similar items as custom-engineered panels, a service mentioned in many advertisements.

A.5 Decline of Asbestos-Cement Usage

Many of the developments observed in the 1960s continued through the 1970s. In 1975, at least eleven manufacturers advertised approximately twenty-two asbestos-cement products in Sweet's Catalog with customization options again resulting in many more possible compositions.[5] While



These details are typical connections. National Building Systems, Inc. furnishes all design data and detailed shop drawings for all (SC) system installation.

(A)

(B)

FIGURE A.10A, A.10B *Isometric illustration (a) and section (b) showing typical connections for National Building Systems' S-C Curtain Wall System. While both panel faces are asbestos cement, the exterior face is surfaced with an aggregate finish (b). Courtesy of Dodge Construction Network and University of Tennessee, Knoxville – Libraries.*

the overall numbers are not markedly different from those of 1965, the types of manufacturers advertising these panels in 1975 suggest that the market share associated with asbestos-cement producers had decreased. An increase in the number of companies associated more generally with panel production—those for which asbestos cement was not necessarily an essential panel component, though they continued to use the material—contributed to the stability in the overall number of companies advertising asbestos-cement panels. Notably, Thermo-Bord, Cemesto, and panels made by the Atlas Asbestos Company were absent, and the customization options for asbestos-cement panels advertised by Johns-Manville and Gold Bond were more limited.

Furthermore, by 1975 the relatively innocuous term *mineral fiber* had largely replaced *asbestos* in both advertisements and the Sweet's Catalog index, reflecting the growing public concern over the toxic material. Analyses show that US asbestos consumption peaked in 1973 before rapidly declining amid increasing litigation and regulation (Castleman 2005, 730–31). In 1982, Johns-Manville filed for bankruptcy and by 1985 had sold off its asbestos-using factories (Bureau of Mines 1985, 62). Celotex, which merged with Philip Carey in 1972 under the Jim Walter Corporation, also filed for bankruptcy in 1990 (*New York Times* 1972; *Wall Street Journal* 1990). Today, asbestos-cement sheets are no longer produced in the United States, and, according to regulations introduced by the Environmental Protection Agency in 2019, their reintroduction onto the US market through manufacture or import would require review (Environmental Protection Agency 2019). However, panels featuring other types of fiber cement may resemble those containing asbestos, an issue requiring consideration when identifying and characterizing materials.

A.6 Conclusion

Advertisements spanning the mid-twentieth century show that asbestos-cement panels were a versatile product type that could be used wherever sheathing, partitioning, or rigid insulation was required. Early advertisements describe a standardized product type easily recognized by its asbestos-cement surfaces and suggested for use in relatively limited contexts, usually industrial or residential. By the 1960s, however, advertisements depicted the use of asbestos-cement sheets in a greater variety of panels that exhibited diverse compositions and appearances. They were advertised for a large number of contexts and applications, though they were frequently intended for use in curtain and window walls.

While the results of this survey of marketing literature may assist in the identification of potential asbestos-cement panels and in anticipating contexts in which they may appear, individuals such as Charles and Ray Eames—who deviated from advertised uses and aesthetics in favor of adapting products to suit their own unique needs and tastes—must be taken into consideration. Ultimately, the legacy of asbestos-cement panels, the extent of their actual applications as opposed to those advertised, and their implications for conservation practice must be explored through further research.

Endnotes

1 The name Transite-Encased Insulating Board, frequently shortened simply to Encased-Insulating Board, references two previously existing Johns-Manville products: Transite, the company's flagship asbestos-cement material, and (J-M) Insulating Board, a wood-based fiberboard.

2 See, for example, Johns-Manville 1944; Sweet's Catalog 1945, 8c/6; *Asbestos* 1958; and Sweet's Catalog 1965, 8b/Car.

3 See Sweet's Catalog 1959, specifically AllianceWall (6d/Al, 3c/Al); Aluminum Company of America, or Alcoa (6a/Alu); Celotex Corporation (10a/Ce); Glasweld Department, United States Plywood Corporation (5b/Un); Gold Bond Division, National Gypsum Company (8b/Na); Johns-Manville Corporation (8b/Jo); Mirawal Company (3c/Mi, 6d/Mi); and Philip Carey Manufacturing Company (8b/Ca).

4 See Sweet's Catalog 1965, specifically AllianceWall (3b/Al); Aluminum Company of America (3b/Alu); Ar-Lite Panel Division, Architectural Research Corporation (3b/Ar); Atlas Asbestos Company (8b/At); Ceco Steel Products Corporation (3a/Ce); Century Brick Corporation of America (3b/Ce); Glasweld Department, United States Plywood Corporation (3b/Uni); Gold Bond Division, National Gypsum Company (3b/Na, 8b/Na); Johns-Manville Corporation (8b/Jo, 22a/Jo, 22a/Joh); Mirawal Company (3b/Mi, 21/Mi); Modern Partitions Inc. (22a/Mo); Mosaic Building Products Inc. (3b/Mo); Philip Carey Manufacturing Company (8b/Car); and Ravenswood Panel Corporation (3b/Uni).

5 See Sweet's Catalog 1975, specifically Aluminum Company of America (7.3/Alu, 8.14/Alu); AllianceWall (7.5/All); Artcraft Industries, Inc. (7.5/Art); Ar-Lite Panel Division, Architectural Research Corporation (7.5/Ar); Granostruct Division, Cement Enamel International Corporation (7.5/Ce); Glasweld Division, PPG Industries (7.5/Pg); Johns-Manville Corporation (7.4/Joh, 8.14/Jo); Mirawal Company (7.5/Mi); Gold Bond Division, National Gypsum Company (8.14/Go); National Building Systems, Inc. (7.5/Na); and William Bortolotti & Sons Pretest Co., Inc. (7.5/Bor).

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APPENDIX IV

Cemesto and Conserving Asbestos Content Materials: A Bibliography

The selected bibliographic references below are organized into the following sections:

- History and Background includes resources that provide general information on the history, fabrication, advertising, and use of Cemesto, its components (asbestos-cement sheet and fiberboard), and similar construction materials readily available throughout the twentieth century.
- Conserving Asbestos Content Materials (ACM) contains references on issues specific to the conservation and monitoring of ACM, including remediation in the event of airborne asbestos release within a context involving culturally significant collections.
- Scientific Research comprises journal articles and reports addressing scientific investigations of ACM, including methodologies and findings.

The references listed herein are part of an ongoing process of completion, update, and revision during the development of the Cemesto study.

A.1 History and Background

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