WALL ASSEMBLY DETERIORATION:
ASBESTOS-CEMENT, MODERNISM, AND PANEL CONSTRUCTION

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1.0 INTRODUCTION

In the early twentieth century innovative building materials and assemblies were developed in order to create forms in architecture that reflected a modernizing world. One such building product was asbestos-fiber reinforced cement panelboard. The wide breadth of asbestos applications that can be found in the built environment today arose using a variety of techniques combining asbestos with other materials and resulted in a myriad of forms. Today asbestos is recognized for the health issues that can result from exposure to the material when it is an airborne fiber and no longer exists undisturbed within its stable binder. There is a gap within preservation literature regarding asbestos in general, but more specifically there is a gap regarding the preservation problems that may result from the deterioration of asbestos-containing building products. In response to the lack of literature, this thesis aims to bring light to the deterioration of an otherwise underdiscussed product—asbestos-fiber reinforced cement panelboard, referred to in this thesis as the plural "asbestos-cement panels."

Asbestos-cement panels were a common and cost-effective means of making a building fire-resistant in the early twentieth century. The cementitious product began to be developed towards the end of the eighteenth century with patents for asbestos-cement being filed in the early 1910s and asbestos-cement panels beginning to be patented around 1920.[1] During the manufacturing process, asbestos-cement could be molded into shapes, although this was more common in

[1] Mattison, Method of Manufacturing Fibrous Cement Products.

Europe, and color could be added to the otherwise neutrally colored matrix.[2] Some architects, such as Robert McLaughlin Jr. in the United States, believed that asbestos-cement in all of its forms was underutilized and should have been more pervasive in the building industry. He advocated for the expansion in use of asbestos-cement containing building products during the height of mid-century modern architecture.[3]

The use of asbestos-containing products began to be heavily regulated and banned in many countries beginning in the 1960s.[4] The heyday of asbestos-cement panel construction falls under the purview of preservation and conservation disciplines by virtue of the period of use. While the use of asbestos has never been completely banned within the United States,[5] it is heavily regulated as a toxic substance and therefore it is not realistic to replace deteriorating asbestos-cement panels used in kind, nor is it recommended.[6] In order to prevent the deterioration of asbestos-cement panels, their use and occasional misuse within structural systems and enclosures must be understood and studied.[7] Through an understanding of possible deterioration mechanisms that are likely to occur, the formation of preservation guidelines is possible and preventive conservation can be

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[2] "New Techniques and Developments."
[3] McLaughlin and Jandl, "Asbestos-Cement : A Basic Building Material; An Analysis of Its Use in Modern Architecture."
[4] Environmental Protection Agency, Toxic Substance Control Act Section 6: Asbestos Manufacture, Importation, Processing, and Distribution in Commerce Prohibitions.
[5] Government Publishing Office, "Technical Amendment in Response to Court Decision on Asbestos; Manufacture, Importation, Processing and Distribution Prohibitions."
[6] National Park Service, Grimmer, and Weeks, "The Secretary of the Interior's Standards for the Treatment of Historic Properties."
[7] Tobin, "When the Imitation Becomes Real." Here the author discusses the reasons why asbestos-cement may be understudied.

prescribed and utilized. This thesis serves to outline the potential deterioration mechanisms of three different panel systems and begins to address preservation and intervention options for these deterioration mechanisms.

Due to the potential health and legal implications of deteriorating asbestos-containing products, conservation dilemmas arise when these products are involved. While the asbestos itself is not the deteriorating factor, the binder is susceptible to deterioration and can release the asbestos fibers into the air when compromised. Furthermore, the systems into which the products are installed can lead to deterioration of the asbestos-cement panel if the vulnerabilities of the binder are ignored. Questions regarding the contribution of the asbestos-containing products to the overall material integrity of the building play a role in the decision to retain and conserve these wall assemblies or to abate them. The research question being discussed is "*How can understanding asbestos-cement panelized wall systems inform an understanding of their potential deterioration mechanisms and ultimately treatment options and recommendations?*"

1.1 Scope

Exterior asbestos-cement panel cladding is the focus of this thesis as this category of assembly may have larger architectural or technological significance. This category of asbestos-cement panel is likely to experience a high level of exposure to deterioration mechanisms through weathering. However, it bears mentioning that asbestos-cement panel assemblies are a part of a much wider range of asbestos-containing building products, including roofing shingles, siding, insulation and sound absorption materials, which present similar, yet distinctive, issues regarding conservation. These products will not be covered in the scope of this thesis, however they are a part of the larger problem surrounding the preservation of asbestos-cement products. This thesis will focus on asbestos-cement panels installed in a building as a part of a modular assembly.

1.2 Overview

Asbestos-cement panel systems must be discussed historically in order to form an argument for their architectural and technological importance and conservation. The historical context of panel assemblies will begin with the evolution of modular construction and how it remains pertinent today. Cement panels were originally created without reinforcement but were not ideal as they were not strong enough to fulfil their purpose. Over time the cement component of these panels became more skin than structure due to reinforcing structural materials being incorporated *into* the cement panel product. In order to discuss asbestos-cement panels in the context of the case studies found at the end of this thesis, a discussion of the theory and history of prefabricated housing must be conducted. The history of prefabrication will be discussed within the larger context of housing during the Great Depression through the Second World War.[8] The period played a role in the development of prefabrication as well as within theoretical architectural discourse, which will be interwoven within the history.[9]

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[8] Bergdoll et al., *Home Delivery*.
[9] Gropius, "The Formal and Technical Problems of Modern Architecture and Planning"; Behrendt, *The Victory of the New Building Style*; Gropius, "Architecture in a Scientific World."

The discussion of general modular assemblies will naturally lead to the discussion of the assemblies being developed at the time and how they lent themselves to incorporation within the modern housing solutions, namely asbestos-cement panels. As previously stated, use of asbestos-cement and the regulations surrounding the material have contributed to its sometime tenuous standing within the preservation community. The purpose of this section, in tandem with the following discussion on panel construction, is to synthesize both prefabrication and the product in focus: asbestos-fiber reinforced cement panelboard.

The conservation issues surrounding asbestos-cement panels also need to be directly addressed. While the health and legal implications of asbestos are not explicitly expanded upon within this thesis, they play a large role in the conservation of asbestos-containing materials and products. A few references are provided for this information in order to demonstrate the importance of understanding the deterioration mechanisms involved for asbestos-cement panel containing assemblies. A discussion on preventive conservation regarding asbestos-cement panels will also be included.

The larger umbrella category of asbestos-cement has had cursory overviews for preservation treatments published,[10] however no study has been done on the conservation issues resulting from the system into which the asbestos-cement panels were applied. A discussion of the types of assemblies into which the asbestos-cement panels were installed relates directly to the advice given by

[10] Woods, "Keeping A Lid On It: Asbestos-Cement Building Materials."

manufacturers regarding their products and assembly. Wall sections and other written discourse regarding panelized enclosure assemblies of the time were used to inform this thesis.[11] The modular assemblies are integral to the types of deterioration mechanisms that the panels present.

In order to clearly articulate potential deterioration mechanisms of asbestos-cement panelized systems, three case studies will be presented. The Motohome and the Charles and Ray Eames House (*Case Study House #8*), both of which have interior and exterior asbestos-cement facing panels, will be presented first. The third case study is the John Blair Building located in downtown Chicago, which uses a composite marble and asbestos-cement panel. It serves to juxtapose the previous panels through the addition of the exterior marble element, while also allowing for further deterioration typologies to be explored. The Motohome, designed and constructed between 1934 and 1937, was a prefabricated housing option during the interwar period whereas the Eames House was constructed during the post-Second World War prefabrication boom in 1949. The houses both utilized asbestos-cement panels, but in differing ways. The John Blair high-rise building was built in 1961 and essentially serves as a terminal example in the development of asbestos-cement as a building product. An array of conservation issues can arise depending on which system was utilized, the type of asbestos-cement used, whether the asbestos-cement was used in the proper manner, and the external conditions to which the system is subjected.

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[11] Bemis, *The Evolving House*.

The conclusions drawn from this thesis should serve to prove that, while asbestos-cement panels are a distinct category of building products, the ways in which they are installed and used within a system can lead to an understanding of the deterioration mechanisms of other panel products. The three case studies are important moments within the development of prefabrication and architectural history, but by utilizing an asbestos-cement panelized wall system, their preservation is not as straight forward as that of a traditional wood-framed building. These assemblies are worthy of active preservation discourse and should be treated within the preservation world as important product developments within the built environment and as equal contributors. We are nearing the 100-year mark for the advent of asbestos-cement panels, which were integral to the original architectural designs in which they are found. Therefore, the buildings utilizing the product are beginning to be seen as being worthy of preservation efforts. Future preservation of these buildings requires standards within the preservation world in addition to the pre-existing standards revolving around health and safety.

The deterioration mechanisms of asbestos-cement panels are contingent upon the wall or roof system into which they have been installed as well as the manner in which they were installed. Different systems will present different forms of deterioration as well as those inherent to the product at large. The deterioration found in the Motohome, Charles and Ray Eames House, and John Blair Building are products of their structural systems as well as of their eras. In order to understand this correlation, a firm grasp of prefabrication and asbestos-cement is required.

2.0 MODULAR CONSTRUCTION

A modular assembly is a subset of building prefabrication that combines several materials into a single element of construction. In modular assemblies, defined sections and spaces results in repeatable component assemblies, or modules. The components can create more individualized spaces when brought together, and ultimately a more individual product, however each finished building is visually related to other buildings using that particular system. Regarding this thesis, the asbestos-cement panels being discussed are individual modules that become part of an assembly after they have been placed into their respective framing systems using fasteners and joints.

2.1 The Development of Modular Building Products

The building industry began to standardize materials and products in the early twentieth-century through organizations such as the American Society for Testing and Materials (ASTM). These organizations had two roles: to standardize methods and materials for construction and to set a minimum threshold for safety through the standardization. It is important to keep in mind, however, that early standards were oftentimes driven by the building trades and large companies more so than the welfare of the general populous, especially in standards that were not developed by a third party such as ASTM. The scientific research being developed for the building industry was a response to existing failed forms of construction as well as a response to the necessity for new, cheaper forms of construction.[12]

[12] Yeomans, *Construction since 1900*, 14.

While traditional building materials were still being used, the physical properties of materials such as timber and masonry were seen as "inadequate" when compared with concurrent innovations designed to create specific properties.[13] In order to better the industry, composite building *products* began to be developed more heavily. These products consisted of multiple materials that had been physically or chemically altered through processes ranging from grinding to heating and were then joined together. The intent was to create an economic finished product that was better suited for modern needs.

As a division of prefabrication, the history of modular assemblies follows a similar path of development. Modular assemblies began to be developed as economic solutions to ever-increasing building costs. Building costs stemmed from the cost of labor in addition to the price of materials. One inherent drawback to modularity is that its designs can easily become monotonous if care is not taken to avoid sameness, which may have contributed to its relatively low use-rate in comparison to traditional building styles in the early twentieth century.

2.3 The Rise of Prefabricated and Modular Housing

The use of prefabricated modular components had begun to stand out as its own category within architecture at the beginning of the twentieth century.[14] Before this

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[13] Jester, Tomlan, and Getty Conservation Institute, *Twentieth-Century Building Materials*, 36.

[14] Architects such as F.R.S. Yorke in England were producing treatises discussing modern forms in architecture, including prefabrication, which allowed for more economic building during the economic depression. In Yorke, *The Modern House*. After the Second World War, architects such as Ove Arup are lamenting the issues that have arisen due to over a decade's worth of prefabrication having been erected. In Arup, "Box Frame Construction."

point, prefabricated components, such as precut wooden elements or nails, had been used but the building industry had not yet embraced larger-scale modularity. The word "prefabrication" has a connotation today related to a specific type of building technique involving the fabrication and assembly of component parts offsite in order to have *sections* of the building delivered completed to the site. Originally, prefabrication had a slightly more expansive definition, which allowed for prefabrication to encompass component parts not yet fully assembled, referred to here as "prefabricated components."[15] It is important to keep this subtle shift in connotation in mind when reviewing the early literature and promotional advertising materials.

The economic crash of 1929 led to a relative standstill within the building industry for over a decade. After the sharp decline in the construction and purchasing of houses, a resurgence of residential construction was considered to play an important role in economic stabilization. In an effort to achieve this, the United States government passed legislation to financially aid current homeowners as well as legislation to promote development of new housing through slum clearance.[16] The housing policies of the time resulted in the use of more modern materials within housing because modern materials and prefabrication were

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[15] Bergdoll et al., *Home Delivery*, 13.

[16] This is an extensive topic that began with the Home Owner's Loan Corporation (HOLC), which was formed in 1933 to provide relief to home owners who were at risk of foreclosure due to an inability to pay their mortgages. In Home Owner's Loan Corporation, "Home Owner's Loan Act of 1933 as Amended: And Other Laws Pertaining to the Home Owner's Loan Corporation." Throughout the 1930s the government continued to pass legislation and create organizations in charge of overseeing different aspects of the housing industry, ranging from the building process itself to current owners' mortgages.

opportunities for cost reduction. Manufacturers had a vested interest in experimentation aimed at expanding the uses of their materials in order to have larger profit margins, whereas architects reveled in experimentation because new materials often meant new uses and forms. Asbestos-cement panels, wherein Portland cement blended with asbestos-fiber particles for reinforcement, were one such modern masonry material.[17]

By the 1930s "prefabricated housing" had become almost synonymous with low-cost housing and mass production.[18] Public and professional perception of prefabrication began to shift, most notably through the translation of Le Corbusier's *Towards a New Architecture*, which explicitly praised the automobile for both its design and component parts.[19] Unfortunately, mass consumption and mass production are inherently related to one another. While automobiles could be created on a large scale because the demand was ever increasing, the same could not be said for prefabricated housing stock. Architects dealing in prefabrication, such as Robert McLaughlin, readily admitted that, while their designs were created with mass production in mind, the demand at the time did not allow for that level of prefabrication to be economically viable.[20] In a world where standardization had become the norm for general goods and services, the question of how this could be applied to building materials and products needed to be answered.

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[17] McLaughlin and Jandl, "Asbestos-Cement : A Basic Building Material; An Analysis of Its Use in Modern Architecture."
[18] Bemis, *The Evolving House*, 3:3.
[19] Le Corbusier, *Towards a New Architecture*.
[20] Houses Inc. and Robert W. McLaughlin Jr., "Motohomes," 33.

In 1934 Albert Bemis, a businessman who also had ties to the housing industry, tried to answer this question when he published his argument that housing needed rationalized design. He saw the idea of "rationalization" as consisting of its own component parts, including economic viability, marketing, material, and structure, all of which he demonstrated as being possible through prefabrication.[21] Bemis explained in great depth why "cubical modular design" was both rational and adaptive to the needs of the occupant while still able to respond to the social and political climate of the Great Depression by being an economic solution.

While the new building materials were less expensive than traditional building materials, it is important to keep in mind the social and financial climates of the Great Depression. The government had stepped in to create jobs for Americans through the Works Progress Administration (WPA). Artists, architects, masons, and others were employed to design and construct public buildings. In an economy where people from the building industry were already out of work, it was not likely that this market would advance new building forms that had the potential to reduce employment opportunities.

Despite the efforts of architects, product designers, and the US government, large-scale development within the housing sector did not occur until after the Second World War. Prefabricated housing became viable after the war due to

[21] Bemis's three-volume work *The Evolving House* concludes with dozens of modern forms in building, of which panelized assemblies were their own category. While Bemis discusses the viability of other forms of modern construction, such as board formed concrete, the majority of the construction methods being discussed are to some extent prefabricated off site.

federal subsidies for prefabrication.[22] Again it was seen as "a realization of lower costs, a rationalization of the organization of the construction industry, and a method of production which [would] allow large volume construction of new housing within relatively short periods of time."[23] In contrast to the decade prior, prefabrication was given the opportunity to develop and become more pervasive.

One acknowledged advantage of prefabrication was its inherent cost-saving nature due to the mechanization of tasks normally performed by onsite construction labor. The converse was that these laborers no longer had jobs. However, in the postwar climate where the labor market had been depleted due to war casualties, the mechanization of some jobs filled the labor-gap created by the war in addition to being financially beneficial for the industry.[24] Prefabrication had become less of a threat to the average building industry worker. It was in this postwar era that prefabricated construction, namely panelized exterior wall systems, began to be more readily used, despite having been developed two decades prior.

3.0 ASBESTOS-CEMENT

The complexity of the phrase "asbestos-fiber reinforced cement panelboards" implies that the building product is a composite material. The addition of aggregate and other particles has been two-fold in the history of cement: to reduce the cost by adding an aggregate that is cheaper than the cementitious material and to have comparatively better properties for the resulting product. As such, asbestos-cement

[22] Meikle, *Design in the USA*, 135.
[23] Bloedorn, "Prefabrication," 52.
[24] Ibid, 69.

products evolved from a line of cementitious building products that responded to these two needs, beginning with unreinforced cement. Asbestos-cement continues to have a legacy in the form of the fiber reinforced concrete panels available today. Before explaining the evolution, asbestos-cement should be understood first.

3.1 Asbestos-Cement: The Material

"Asbestos-cement" itself is a composite material that was initially developed in the 1880s.[25] It refers to a cement mixture, usually Portland cement and fine aggregate, with asbestos mineral fibers added into the mixture to reinforce the cement by making it tougher, stronger, and more resistant to cracking.[26] Asbestos-fibers act to increase tensile and bending strength in addition to controlling the rate of the curing process, which lessens cracks in the fabrication process. Asbestos is able to act as a strengthening agent despite how little is present due to the inherent characteristics of the mineral.[27]

Asbestos is a dark green magnesium silicate that has the ability to be split into fibers, which can range in size from 2-900 mm long.[28] The asbestos fibers do not stick to one another because they contain internal positive charges that cause the fibers to repel each other and create dispersion throughout the mixture.[29] These

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[25] Woods, "Keeping A Lid On It: Asbestos-Cement Building Materials," 1.
[26] Brantley and Brantley, *Building Materials Technology*, 79.
[27] The toxicity and negative health effects of asbestos are *also* due to its inherent mineral properties. The small size and geometry of the fibers allows them to get inside the lungs and stay there. There are multiple types of asbestos, Chysotil is the most common, and is known as white asbestos. The other two types are brown and blue asbestos. Hegger and Auch-Schwelk, *Baustoff Atlas*, 268.
[28] Everett, *Mitchell's Building Construction: Materials*, 213.
[29] Dean, *Materials Technology*, 98.

fibers are hydrophilic due to their positive charge, which draws the wet Portland cement mixture to them and creates good adhesion between the fibers and the uncured cementitious matrix.[30] Additionally, the large surface area that results from the long, thin fiber structure allows for a better bond to occur. This effect is magnified if the fibers chosen are angular, as a result of crushing, rather than rounded in shape.[31] Asbestos, however, could not be used by itself in the building industry because the material is too coarse without the addition of cement.[32] Asbestos also performs well in tension, whereas cement performs better in compression, thus making the two complement one another.[33] Combined, they form a building product that has a wide range of properties desirable in the building industry.

The amount of asbestos fibers present in the mixture depends on the end use of the asbestos-cement product. For example, the compressed asbestos containing products, such as the panels discussed within this thesis, perform better in bending strength but are poorer insulators than the asbestos wallboards.[34] Extruded and compressed asbestos-cement products tend to contain higher proportions of cement, whereas wallboards and insulating boards can contain roughly equal

[30] Brantley and Brantley, *Building Materials Technology*, 79.
[31] Dean, *Materials Technology*, 21, 31.
[32] Woods, "Keeping A Lid On It: Asbestos-Cement Building Materials," 1.
[33] Everett, *Mitchell's Building Construction: Materials*, 213.
[34] The bending strength of fully-compressed asbestos-cement had a standardized minimum of 22.06 N/mm^2 whereas the bending strength of asbestos insulating boards could be as low as 5.00 N/mm^2 according to British standards in the 1970s. These same materials had a thermal conductivity of 0.65 W/m°C and 0.115 W/m°C, respectively. Everett, *Mitchell's Building Construction: Materials*, 214.

amounts of asbestos and cement. Other properties of asbestos include its resistance towards acids, its ability to endure high temperatures, and its non-combustibility.

3.2 Cement

Early uses of cement in nineteenth- and twentieth-century housing construction were as simple as cement stucco covering the exterior. This is best illustrated in the Portland Cement Association's 1925 housing catalogue that enumerated the different ways in which the stucco exterior of buildings could be finished.[35] This book was published on the heels of *Concrete Houses*, which illustrated houses built from concrete blocks but finished in cement stucco.[36] Less than a decade later, the Association published books that clearly defined the different types of systems in which cement could be used and expressed as the structural components of the building.[37] While the purpose of these publications was not the same, as the earlier catalogue was a projection for use whereas the latter was a report on existing uses of cement within structures, they show a shift within the association towards cementitious concrete as a more publicly acceptable form of structural building component. Panel construction contributed greatly to the later publication.

However, this is not to say that there were no structural uses of cement before the 1930s, as evidenced by architects such as Henry Mercer's Fonthill Castle, John J. Earley's work, and Thomas Edison's single pour concrete system. Other organizations, such as the American Concrete Institute (ACI), dedicated themselves

[35] Portland Cement Association, *Plans for Concrete Houses*.
[36] Portland Cement Association, *Concrete Houses.*
[37] Portland Cement Association, "Report on Survey of Concrete House Construction Systems."

to researching and testing wider uses of concrete as a building material. The ACI originally formed in 1905 as the National Association of Cement Users, an organization dedicated to the understanding and standardization of cementitious and concrete building materials. Within a decade the organization's name had changed to reflect their dedication to the more structural material, concrete.

3.3 Deterioration

Asbestos-cement is a relatively durable material. The most deterioration-susceptible component of asbestos-cement is the cement sand matrix, which on its own has an expected service life of over 50 years.[38] Concrete is affected by its physical makeup as well as the environment into which it is set. As alluded to previously, literature regarding the preservation of asbestos-cement products is sparse. Of what does exist, Amy Woods created the most comprehensive conservation document for the building material in "Keeping a Lid On It: Asbestos-Cement Building Materials," where she discusses discoloration, biological growth, and cracking as the three main deterioration mechanisms of asbestos-cement.

The cementitious binder present in the cement panel is susceptible to loss when it is exposed to an acidic environment. Acidic deterioration of the cement matrix can lead to disaggregation and exposure of the asbestos fibers, thus creating the health hazard for which asbestos is known. This process has its own reinforcing feedback loop, as more of the surface is exposed, a more porous surface is available

[38] The service life predicted by Dean is between 60-100 years, with the large variation due to the materials used and the environment surrounding the concrete. Dean, *Materials Technology*, 27.

to absorb additional water and acidic solutions. This is not a quick process and can be deterred through encapsulation, which can be as simple as painting or finishing the asbestos-cement surface exposed to the acidic environment. Similarly, freeze-thaw cycling can lead to flaking and spalling of the cement matrix. Moisture enters the porous concrete as a liquid, freezes before it can evaporate, expands within the pores, and creates microcracks, which can lead to separation and loss of the matrix exposing the fibers.

Biological growth can trap moisture at and below the surface, which can lead to further water-related issues in addition to discoloration. Other forms of discoloration may be due to atmospheric or other pollutants and some pollutants have the ability to solubilize and become acids when exposed to moisture. The most concerning part of either discoloration or biological growth stems from their removal rather than their presence. Due to the makeup of composite asbestos-cement products, any type of mechanical cleaning can lead to a loss of surface and the release of asbestos fibers.

3.4 Prevention and Intervention

Despite the few modes of deterioration in asbestos-cement, anything that leads to a loss of material needs to be dealt with swiftly. It is likely for this reason that most literature dances around any conservation tactics—the health and safety risks are too high once the fibers are exposed. Therefore, it is important to identify what can be done for asbestos-cement *before* the material is compromised.

The three ways in which asbestos-cement is treated for the long-term are abatement, encapsulation, and abstention. The former two are recommended by the Secretary of the Interior Standards as the optimal forms of handling an asbestos problem.[39] While the Standards do not list ways in which to determine what would be the better process to address a situation, they do list other types of twentieth century building materials that could potentially serve as siding or roofing replacements. The Standards are therefore vague and contain little direction for asbestos-cement panel assemblies.

Abatement is the most invasive of the options because it requires certified professionals throughout the process. In the United States, the Occupational Safety and Health Administration requires every person on the removal team to undergo extensive training on asbestos hazards and removal processes because abatement can be dangerous if done improperly. The process involves cordoning off the building to create a sealed environment for the removal and the proper disposal of the asbestos-containing material or products. A replacement product must then be chosen and installed in lieu of replacement in kind of the removed asbestos product. The substitution process can raise preservation issues if the replacement product does not visually imitate the original. Alternatively, the high cost of comprehensive abatement may increase the cost of rehabilitation to such a level that the retention of the remaining building is no longer economical, and the building is demolished after abatement in favor of new construction.

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[39] National Park Service, Grimmer, and Weeks, "The Secretary of the Interior's Standards for the Treatment of Historic Properties," 23.

Encapsulation is often chosen as the mode in which to treat asbestos products because it is a broad term that includes most processes that fall between the two extremes of abatement and abstention. The asbestos product can either be coated or surrounded by a new product in order to be considered encapsulated. Coatings can range from clear coatings to painting. There are no straightforward guiding preservation principles for encapsulation outside of the general guidelines of the Secretary of the Interior's Standards. Little is included in addition to the general preservation tenets: avoiding altering the appearance of a building, choosing a material that is not harmful to the building, and choosing a material that will not promote future deterioration.

Abstention is the route often chosen by those that realize asbestos is present but also recognize that disturbing the material may create a larger hazard than currently exists. As Wood's article implied, abstention is typically not chosen for historically important buildings with asbestos-cement façades. Building owners or site managers want their asbestos-cement clad building to look its best, which requires material-sensitive standard maintenance and occasionally even product replacement.

4.0 PANEL CONSTRUCTION

Panel construction refers to the offsite pre-assembly of the wall components of a structure, which are then placed within a frame house as panels. The development of panel wall systems predates the modern movement, but these systems were not ubiquitously popular. Panel wall systems continue to be used today in modular construction.

4.1 History

One of the earliest panel construction houses in the United States was sold by the E. F. Hodgson Company in 1892.[40] These wood panel houses gave rise to poured concrete slab houses in the following decade by Grosvenor Atterbury. The early 1900s also saw wooden panel systems from Sweden being adapted and utilized in Great Britain and Germany, such as the Tektonhaus in Stuttgart.[41]

While not a panel system, Thomas Edison's single-pour concrete houses bear mentioning as their own type of prefabricated assembly being patented and developed contemporary with panelized cement in the 1910s.[42] Edison's process was almost modular in execution. The concrete was placed in four-foot runs that were supported by a balloon frame mold in order to attain their shape.[43]

The 1920s saw the development of the Stadens Company in Sweden, who further developed the wood panel.[44] Other materials, such as porcelain steel building panels, were also being developed and utilized. In Germany, the Frankfurt Slab System, or *Frankfurter Plattenbau*, was being developed. This system utilized small, premade concrete slabs that were assembled in apartment house

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[40] Cherner, *Fabricating Houses from Component Parts*, 11.
[41] Bergdoll et al., *Home Delivery*, 15.
[42] Cherner, *Fabricating Houses from Component Parts*, 11.
[43] Bergdoll et al., *Home Delivery*, 44.
[44] Cherner, *Fabricating Houses from Component Parts*, 11.

construction.[45] The Plattenbau system fell into disuse during the Nazi period, as it was seen as being too sterile, but it experienced a resurgence after the war and was used extensively in East Germany.

Other forms of panel construction were developed by the Bauhaus in Germany in the 1920s. The school, directed by Walter Gropius, had an exhibition entitled "*Die Wohnung*," where they included designs for new styles such as a steel frame house with lightweight prefabricated panels for walls. These developments were terminated by the Nazis in the 1930s, and Gropius immigrated to the United States where he continued to develop his belief in the repetition of component parts in construction.[46]

The 1930s saw the beginnings of stronger regulations within the United States building market through the creation of the Bureau of Standards.[47] The US government was attempting to create better, more sanitary living standards for the population at large. The government offered funding and special loans for those builders who were willing to take on larger scale housing. On the opposite end of the housing spectrum, architects like John J. Earley and Frank Lloyd Wright explored the use of concrete in both poured and precast forms. Earley explored the application of structural precast concrete panel walls in prefabricated housing beginning in 1935 and later patented a panel fastening system.[48] Wright did not delve into sandwich panel construction until the latter part of the 1930s. In his

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[45] Knaack, Chung-Klatte, and Hasselbach, *Prefabricated Systems*, 19.
[46] Bergdoll et al., *Home Delivery*, 17.
[47] Cherner, *Fabricating Houses from Component Parts*, 12.
[48] Cellini, The Development of Precast Exposed Aggregate Concrete Cladding," 67-68.

Jacobs House, the plan was based on a modularized grid filled with sandwich panels and glass.[49] This house served as a stepping stone for the later development of his Usonian houses.

The Second World War brought a slowdown in housing production in many countries, but some governments pushed prefabrication for rapid construction of buildings such as those serving as defense housing. Therefore, prefabrication grew during the war as a portion of the smaller market, but it was not until after the war that panel construction became a widely used form of construction in the general housing market. Part of the reason for the turn towards the composite product assembly was that traditional building materials were in short supply after the war. Panel products had been developed during wartime as a quick means of fireproofing, and the speed of the production process, as well as the surplus wartime materials, were incorporated into general use in the building industry.[50]

In Great Britain panel construction was seen as a quick way to create temporary mass housing in order to address poor housing conditions after the war.[51] The government funded the development and experimentation of housing forms in order to solve their housing problems. During this time, systems of wood frame houses clad with reinforced concrete panels as well as steel framed houses with asbestos sheets were used. By 1948, the British had determined that the cheapest construction method was the large concrete panel.

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[49] Bergdoll et al., *Home Delivery*, 72.
[50] Jester, Tomlan, and Getty Conservation Institute, *Twentieth-Century Building Materials*, 42.
[51] Knaack, Chung-Klatte, and Hasselbach, *Prefabricated Systems*, 26.

In the 1950s the prefabricated house was advertised in America as an easy and viable alternative for vacation houses for professional or middle-income people in most climates.[52] These houses were smaller than the average middle class home and could be constructed in a variety of ways, including panel construction, which was described as the "most conventional type of construction and design adapted to the needs of financing in typical suburban communities."[53]

Panel construction continued to be used throughout the middle of the century but began to slow down in the 1970s. In Great Britain the decline was due to the government no longer funding the housing complexes in which they were frequently used.[54] Traditional styles of building had begun to resurface. In other countries the panel system was simply no longer in style, as the wider-ranging designs allowed by the digital age had begun to eclipse more modular forms of construction by the 1980s.[55]

There has been an even more recent resurgence in the twenty-first century for prefabrication, and the use of panelized systems has again become fairly common. Today there are three main types of cement panel construction: small panel, large panel, and cross wall construction. These categories can further be divided into slab, sandwich, and double wall elements.[56] While cement panels no longer include asbestos in their makeup, an increase in tensile strength of the

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[52] Cherner, *Fabricating Houses from Component Parts*, 14.
[53] Ibid, 24.
[54] Knaack, Chung-Klatte, and Hasselbach, *Prefabricated Systems*, 28.
[55] Bergdoll et al., *Home Delivery*, 24.
[56] Staib, Dörrhöfer, and Rosenthal, *Components and Systems*, 121.

individual panels is still required, and steel wire, steel fiber, or glass fiber reinforcement is used in order to attain adequate levels of tensile strength. Contemporary sandwich panels continue to have three layers as do the panels presented in the case study section of this thesis—load-bearing interior, insulating, and exterior facing—and include reinforcement in the decorative cementitious facing layer in addition to the cementitious load-bearing layer of the system.

4.2 Deterioration

The susceptibility of a cement panel system to deterioration is determined by system type, materials used, construction, age, and climate. Each of these components contributes to the likelihood of a particular deterioration mechanism occurring but does not guarantee its occurrence. Additionally, many deterioration mechanisms rely on multiple factors from the listed components in order to occur. For example, it is likely that a wooden framed panelized system that includes wooden beams set directly on a concrete foundation located along the coast in Florida will encounter moisture driven rot along the wooden sill due to the wetting and drying cycles that stemmed from the location, climate, and materials used. This section will discuss general deterioration.

System Type

The type of framing system chosen when designing a building determines the materials and methods of construction required for fabrication. The system type refers to the design of the framing and the connections between the component parts, therefore the system differs from the materials and construction methods discussed separately. Early panel framing systems were experimental and consequently were erected without the knowledge of what does not continuously function over time. It was through the work of early architects and engineers that today's panel systems were derived. The earlier the system was designed and constructed, and the more experimental it was, contributed to the extent to which inherent flaws occurred within a given system.

In contemporary systems, much attention is given to the joints, as they are integral in weatherproofing a building. Joints will be designed in tandem with the development of the panel system being used in order to ensure adequate defense against the entrance of water or other substances into the system.[57] Historically these joints would be "closed" by being covered with caulk. Without having a means of monitoring or maintenance in place from the beginning, caulk can age and deteriorate through shrinking and cracking, thus leaving the joints vulnerable to weathering elements. Due to the wreathing of caulk, joints for panel systems today are designed to be more inherently weathertight instead of heavily relying on caulk.

Materials

Material properties and material compatibility play large roles in the deterioration of a building. Adjacent materials need to have compatible properties, such as thermal expansion rate or permeability, for the longevity of a system to be

[57] Staib, Dörrhöfer, and Rosenthal, 121.

uniform. A lack of compatibility can lead to individual elements deteriorating before the expected service life of the assembly has ended.

An example of material properties playing a role in deterioration and system evolution over time would be a deterioration mechanism of one of the sandwich panel assemblies discussed here. In Cemesto, discussed in Section 5.2, the exterior surfaces of the panels are asbestos-cement cladding whereas the interior insulation material is a cellulose-based core. The exterior cement surfaces are dense and do not deform in the presence of water. In fact, the low porosity of the cladding means that very little moisture can be absorbed or even adsorbed. The interior bagasse, or cane fiber, core is a plant-derived material and tends to swell in the presence of water. Swelling occurs within the cell structure of the fibers, which served to promote water transportation within the living plant. Two sheets of non-swelling, rigid asbestos-cement board encase the insulation that is not dimensionally stable. The differential movement can lead to separation of the layers and failure of the product.

Construction or Assembly

Here "construction" refers to the human element of the system. Adherence to specifications as well as any in-field alterations may affect the durability of a system. If in-situ alterations occurred and were not recorded, an accurate understanding of known or suspected deterioration is less likely to occur.

Technological Age and Industry Experimentation

The age of the panelized system not only takes into account the known deterioration of materials over time, but also the technology available at the time of construction. The former works in tandem with material properties, while the latter encompasses materials, systems, and construction. The evolution of manufactured materials and systems heavily relies on known and available technology as well as previous experimentation and the dissemination of the experimental conclusions.

Climate

The location and climate of a structure will determine the types of weathering to which the building may be regularly subjected. Moisture, wind, temperature, and ultraviolet radiation are all potential enabling factors of deterioration. Ultimately moisture plays the most common role by either exacerbating existing deterioration through its presence or by preserving the construction materials through its absence. Moisture, when combined with heat, may also create opportunities for biological deterioration. Wind can affect the lateral forces acting on the structure and may require reinforcement or thoughtful site placement before construction begins. Climate often determines the materials used for both framing and insulation, which can determine the type of framing system utilized.

5.0 CASE STUDIES

The case studies are presented in chronological order and serve as general points on the timeline of overall asbestos-cement panel production and development within the United States during the twentieth century. The first, the Motohome, is one example of pre-war panelized house construction, whereas the second, Case Study House #8, belongs within the period of the post-war housing boom. The third and final case study, the John Blair Building, is an example of large-scale panel construction as applied to a high-rise building.

5.1 Motohome

The purpose of this case study is to introduce an early form of asbestos-cement sandwich panel. Motohomes began to be produced in the 1930s as a modern form of housing for the modern consumer. The houses utilized Pyrestos, a loosely-defined paneling product that included an insulating core between two asbestos-cement facing boards (*Image 1*).

Brand History

General Electric (GE, as it is known today) ventured into the housing market in 1934 through their creation of Houses, Inc., although house production was not the aim. Rather than focusing on the design and construction of houses, GE aimed to produce research and products for use within a prefabrication context. Houses, Inc. created products, whereas American Houses, Inc., the company associated with the American Motohome, designed houses using the products. The joint ventures were financially supported by the companies producing the building products being used in the construction of Motohomes.[58]

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[58] Knerr, *Suburban Steel*, 49.

American Houses, Inc. was founded by Holden, McLaughlin and Associates Architects in 1933 as a prefabricated building company and existed as an independent company through 1938. The company sold houses that ranged from about $4,500 to $12,000 depending on the model chosen, as advertised in architectural publications.[59] The lower-end house had fewer amenities while the more expensive house was an air conditioned, multi-story home featuring a full kitchen, garage, and porch.[60] Motohomes followed this pattern but tended to be available for under $10,000.[61]

The Motohome was not a "one size fits all" product. A range of models were available that could be customized beyond the basic model. The design was based on the idea that a singular "Magic Moto-Unit" would serve as the mechanical center of the home and house everything from the air conditioning unit to the plumbing.[62] In 1934, American Houses was touting 140 distinct floor plans based on standardized units that could easily lead to 140 more designs in the future.[63] Of these plans at least sixteen were for Motohomes. The houses could be single story

[59] In order to develop houses for the general public, the company performed a market analysis and determined that roughly half of the houses in the United States were valued between $3,500 and $7,500. Consequently, this research influenced their target price range. Holden, McLaughlin and Associates Architects, "American Houses, Inc.," 277.

[60] "Air conditioned" today has connotations that were not yet fully developed when the Motohome was being produced. In this instance, air conditioning refers to single rooms that could be climate controlled and not central air.

[61] The Motohome could only be purchased for cash, although by the end of 1935 American Houses, Inc. did allow for buyers to purchase the homes using installment plans. Interested buyers had to request the exact prices of Motohome models from American Houses, as prices were rarely advertised. These factors all likely affected the home's marketability, especially when considered in relation to the surrounding economic climate. Houses Inc. and Robert W. McLaughlin Jr., "Motohomes," 33.

[62] R. H. White Co., "American Motohomes."

[63] Holden, McLaughlin and Associates Architects, "American Houses, Inc.," 280.

or two-story homes but were always asymmetrical in plan.[64] McLaughlin wanted to prove that prefabrication did not mean standardization, and he used the Motohome to demonstrate this. In fact, American Houses encouraged outside architects to submit preliminary designs based on the modules involved in the basic makeup of the Motohome.

Furthermore, McLaughlin saw the Motohome as the modern answer to America's housing needs and advertised accordingly. McLaughlin aimed to reshape American familial life and homeownership through his modern design "destined to become the most significant symbol of social progress and of economic security."[65] The relatively cheap cost of materials was seen as an inherent value in the Motohome construction style—one that addressed the housing deficit found in the United States at the time.

Newspaper advertisements would often reference an already-erected Motohome open for public visitation (*Image 2*). These open houses sported modern systems, appliances, and materials in an attempt to draw a crowd and sell the Motohome.[66] Some demonstration Motohomes were in-situ within a neighborhood. However, most were located within department stores such as Wanamaker's in New York City or Strawbridge & Clothier in Philadelphia (*Image 3*).[67] The stores would outfit the home with their furniture in a mutually beneficial sales pitch for both the

[64] Examples of Motohome designs can be found on pages 24-25.
[65] While the Motohome aimed to reshape the American family, the following case study, the Charles and Ray Eames House aimed to respond to the modern American family and the design was created with familial life in mind. R. H. White Co., "American Motohomes."
[66] "Motohome Is Opened."
[67] "'Motohome,' The Latest In Dwellings, On Public View At Strawbridge, Clothier"; "Party at Motohome to Assist a Charity."

store and American Houses, Inc.[68] The demonstration Motohomes occurred primarily in 1935 as a part of a "relaunch" of the Motohome.[69]

The Motohome was featured in transportation journals in the 1930s in addition to architectural journals.[70] The large trucks used in delivering the panel and steel-frame construction units were new for the era and an efficient means of transporting prefabricated products from the factory to the site. The origin locations of prefabricated elements would be different, but warehouses in geographic regions would gather the products necessary for Motohome construction in order to have easy availability of building materials. The Motohome was primarily built in the Mid-Atlantic and Northeast region of the United States, but Motohomes were also built further inland in states such as Wisconsin.[71] Three years into production and planning, forty Motohomes had been erected.

The fabricators found quoting the consumer cost of the Motohome insignificant by 1935 because the home had not yet taken off, and McLaughlin admitted that the Motohome would not be a financially viable option until mass production of the parts and forms had begun to happen.[72] He knew that, in order to reach this stage, mass acceptance of his housing style had to occur, and he anticipated the demonstration houses would warm the general public to the

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[68] McLaughlin saw the high number of visitors inspecting the demonstration houses and concluded that many of these same people would be interested in purchasing a Motohome for themselves. In reality, the Motohome served as more of a spectacle that attracted foot traffic. The thousands of visitors drawn to the demonstration sites were more interested in seeing the furnishings and modern amenities than shopping for their future homes.
[69] Davies, *The Prefabricated Home*, 54.
[70] Gerstin, "New Homes Come Packed in Trucks."
[71] Weisiger, "Ernest and Helen Eggiman House (Motohome) [Madison, Wisconsin]."
[72] Houses Inc. and Robert W. McLaughlin Jr., "Motohomes," 33.

Motohome. Unfortunately, mass acceptance did not occur and the Motohome receded from architectural publications. The buildings ceased production in 1938. The macroeconomic influences surrounding the development and eventual downfall of the Motohome are relevant in understanding the design, materials, and financial availability of the Motohome to the average middle-class family during the Great Depression.

While the widespread success of the Motohome never occurred, McLaughlin's underlying hypothesis that the mass production of building products would lead to a decrease in the cost of both housing and construction continued to be explored for decades. When certain building materials became scarce in the following decade, a more pressing need existed for non-traditional building materials and products to be used in construction. Prefabricated house designs, like the Motohome, became more viable under these circumstances. The Motohome attempted to define modern housing while addressing social and economic constraints. It was not until a decade later that the Motohome became a successful example of living when America had begun to build forms in earnest that descended from the Motohome.

Economic Climate

The housing market was affected by the 1929 stock market crash and Great Depression.[73] After the sharp decline in the construction and purchasing of houses,

[73] The Home Owner's Loan Corporation (HOLC) was formed in 1933 to provide relief to home owners who were at risk of foreclosure due to an inability to pay their mortgages. Through this law, the Federal Housing Authority (FHA) was created in order to ensure that money lenders experienced

a resurgence of residential construction was believed to play an important role in stabilizing the economy.[74] Researchers determined six overarching factors that had contributed to the cyclical stymying of the construction industry: land, materials, labor, financing, maintenance, and taxes. Each of the related industries blamed one another for the high costs.[75] In order to lessen the financial constraints on the building industry, each of the factors would need to be addressed. No growth in residential construction could occur without a reduction of cost in the six areas.[76]

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a lessening of pressure from risk-averse policies regarding home building in the unstable financial climate. Both the construction of new homes and the rehabilitation of existing buildings were encouraged through this act. As a result of the creation of the HOLC and the FHA, the National Housing Act of 1934 was passed and served as a sufficient means of mitigated mortgage default for the average American who had already owned a home. It did not, however, address less economically stable Americans living in slums. To address this gap and further facilitate home construction and purchasing, the federal government passed the Federal Housing Act in February of 1937 for loan management assistance. This new act built upon the 1934 act. Colloquially referred to as the Wagner-Steagall Housing Act of 1937, the act was a part of Franklin D. Roosevelt's New Deal and explicitly addresses slums, farms, and low-income Americans in order to create affordability amongst the underserved population. The law created the United States Housing Authority (USHA), which served in aiding funding for low-cost housing. USHA continued to play a significant role within the house construction industry through World War II. Home Owner's Loan Corporation, "Home Owner's Loan Act of 1933 as Amended: And Other Laws Pertaining to the Home Owner's Loan Corporation." Gotham, "Racialization and the State," 292. U.S. Government, Federal Housing Act of 1937.

[74] New construction was in part hindered due to financial constraints resulting from mortgage rates. Mortgage rates were prohibitively high due to the costs related to construction. There was cyclical reinforcement occurring with little being done to halt the process.

[75] Noyes, "The Future of Home Ownership," 5.

[76] As a direct result of the New Deal housing legislation enacted during the 1930s changes to the availability of mortgages occurred. Lending practices began to be standardized across the United States with the intent of linking the monetary pool to create security for the lender while placing the financial risk on the government. As a result, mortgages with both lower interest rates and down payments became available and their availability allowed more middle- and working-class Americans to become homeowners during this time. Gotham, "Racialization and the State," 300. "Ten or fifteen years ago a man buying a house usually was compelled to pay the equivalent of 9 to 15 per cent interest on the mortgage, including special fees, discounts, and the cost of frequent re-financing. First mortgage loans were ordinarily restricted to from 50 to 60 per cent of the appraised value of the property, which meant either a large down payment or a second mortgage at a usurious rate. Today, under the Federal Housing Administration insured-mortgage plan, a new house can be purchased with a 10 per cent down payment if the total cost is not above $6,000, and the mortgage may run for as long as 25 years at an interest rate of 5 per cent plus 14 of 1 per cent insurance premium on the unpaid balance." Noyes, "The Future of Home Ownership," 3. Government funding was available for construction projects related to slum clearing and for aiding low income Americans through the implementation of affordable rents. Government aid through HOLC, however,

While the initial federal financial resources did not apply directly to the Motohome or the circumstances surrounding the construction of this type of middle-class housing during the Depression, they are tangentially relevant when discussing how the Motohome could be constructed at this time. The availability and affordability of private mortgages relied on the function of governmental aid in other sectors of the housing market. Without federal aid securing current homeowners or federal funding from the Public Works Administration creating housing outlets for working class Americans, the housing market would have likely not stabilized enough to support Motohome construction.[77] Conversely, the nominal number of Motohomes erected can likely be linked to a lack of federal support aimed at middle-class Americans for the construction of new single-family houses.

Concurrently, as a result of the housing legislation being ratified, minimum standards for home construction were created.[78] While building codes existed in cities, they were oftentimes not followed, let alone enforced. Basic standards did not often exist in rural areas and small towns. In New Jersey, the New Jersey Federal Housing Administration was reported as stating higher standards of living and better living conditions were the direct result of the implementation of the FHA

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contributed greatly to the housing market by reducing the monthly number of foreclosures happening across the nation. This form of aid only addresses pre-existing mortgages. HOLC aid even provided retroactive loans to help families who had lost their homes to foreclosure already. The addition of private mortgages supported by, but not directly from, the federal government resulted in better terms for those looking to take out a loan to construct their own home. These loans were given by institutions supported by the Federal Loan Bank. Patch, "Federal Home Loans and Housing," 3. Whiting, "Housing and Home Ownership," 3.

[77] "Interest Cut Boosts Home-Loan Business."

[78] Gotham, "Racialization and the State," 292.

legislation, which required better building.[79] While the Motohome was not designed for the same context (i.e. low-income housing complexes), it was a concurrent design. Thus, any type of new construction standardization would have had some bearing on American Houses' designs.

When considering that Motohomes were constructed using designs meant to accentuate the newness of the products, while at the same time highlighting the uniformity of the prefabricated parts, standardization is an interesting concept. One could argue that American Houses was attempting to create its own type of standard within its various designs. The use of identical products and similar floor plans led to individuality within regularity. Overall, this period within United States architectural history is defined by people both adhering to standards and radically breaking from previous conceptions of design and construction. The Motohome was no different. Yet even after World War II, when prefabrication was an entirely respectable form of house construction, the amount of prefabricated design construction produced paled in comparison to that of conventional construction.[80]

Structural Arrangement

The standard Motohome relied on masonry, metal, and composite building products (*Illustration 3*) and was either a single or dual story structure. Basements or cellars were not typically integrated into the plans of Motohomes, however some sites may have had them added to the design either originally or retroactively as a

[79] "Higher Building Standards Noted in Jersey As Result of FHA Loan Operations."
[80] Huddle, "New Types of Housing," 3.

separate cost.[81] Garages were often included, as were rooftop deck spaces, thanks to the flat roofing system.

The foundation of the Motohome is concrete block, which supports the aluminum stile framing.[82] Bemis described this footing as being 4”x8”x12” concrete blocks, which are not a standard size. It is important to keep in mind that the individual specifications stated local labor would be used for the erection of the building despite Motohome components being manufactured, and therefore standardized, offsite.[83] It is possible that local labor used locally sourced foundation materials in deference to their knowledge of the surrounding terrain and community building requirements. Therefore, it is also possible that each Motohome contains a slightly unique foundation. In the case of the Wilmington Motohome, a concrete block basement was added later and includes concrete block partitions.

The basic structure of the Motohome includes asbestos-cement panel walls that are supported in a steel framing system. Batten-like aluminum stiles are bolted to the exterior of the 2.25-inch steel studs and are spaced 4-feet apart in order to accommodate the 4-foot-wide Pyrestos panels. Metal plates are welded to the interior of the studs in order for the edges of the wall panels to rest against them. Both the interior plates and exterior stiles are serving as forms of protection from weathering for the edges of the asbestos-cement panels.

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[81] Gerstin, “New Homes Come Packed in Trucks,” 56.
[82] The standard design of the Motohome foundation also incorporates a 16-inch crawlspace beneath the floor in order to allow for warm air circulate to keep the flooring warm and dry.
[83] Bemis, *The Evolving House*, 3:339; R. H. White Co., “American Motohomes.”

The roof, or second story if applicable, is supported by a 16-inch joist system that relies on a continuous steel angle.[84] The angle is bolted at each stud and caps the top of the wall panel, thus providing similar protection to the top edge of the panel as the vertical stiles and sill plates provide to the other edges. The walls project slightly higher than the roof, thus creating a small parapet along the edges of the flat roof, and a small cornice is attached to the top of the angle for a more polished exterior appearance.[85]

Panel Product

The exact products used in the construction of Motohomes are ambiguous despite the seemingly specific names provided, such as "Pyrestos" for the walls and "Miroflor" for the flooring. These products were never used outside of a Motohome context by the above names. American Houses would create names for products to accommodate improvement and alteration over time.[86] This practice correlates directly with the Motohomes acting as research and testing facilities for General Electric—a product being tested would not yet have a tradename. While this practice is great from a proliferation of architectural design point of view, altering products while continuing to use the same description can lead to confusion. The converse is also true—it can be difficult to discern products trademarked at a later

[84] R. H. White Co., "American Motohomes."
[85] Bemis, *The Evolving House*, 3:341.
[86] "As little as possible is said regarding structural details. Probably this marketing principle has influenced the company in adopting many instances new names for materials already known to the trade…Use of such names also facilitates the future introduction of improved materials as they may become available." Bemis, 3:342.

date from those used in the Motohome because an earlier generation of a product may have been tested in a Motohome.

In relation to this thesis, the generic nomenclature means that the particular asbestos-cement panel system used is unknown. Descriptions of the system exist but are limited, and often the word "Pyrestos" is the only description given. Newspapers for Delaware Motohomes allude to Modern Home Insulation as having been a company supplying insulation for the Wilmington house, but it is unclear as to whether they provided the insulating wall panels or another form of insulation.[87] Adjacent to the advertisements attracting visitors to the demonstration house, landscapers and companies that supplied components to the finished Motohome would advertise as well. Modern Home Insulation ran an advertisement for Eagle rockwool insulation, thus making it possible that the insulation used between the asbestos-cement panel boards is also this product. If that is the case, the insulation is a rockwool, or a molten mineral-based fiber, substance.

Without knowing the exact panel system, it is not possible to discern a high level of detail regarding the fabrication process. Anyone investigating the product must rely on a limited archival analysis and visual inspection. Promotional materials for the Motohome describe Pyrestos as a four-foot-wide panel of insulated and hydraulic pressure-treated asbestos and cement. Each panel is "a story" tall and consists of 2 inches of non-descript insulation.[88] The property highly commented

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[87] "Four 'New American' Homes--Open Today," 11.
[88] Bemis, *The Evolving House*, 3:340–41.

upon for Pyrestos was its color—gray—and any specifications of the product surpassing a cursory visual inspection were mentioned far less frequently.[89]

Site: 1013 Overbrook Road

The Motohome examined in this thesis is located at 1013 Overbrook Road in Wilmington, Delaware. The house is situated within a quiet neighborhood and includes a wooded backyard area, complete with a small stream running through the property. The parcel is 0.63 acres, thus making it larger than many of the neighboring properties.[90] Wilmington's climate is considered "mixed-humid," which means that the environment is moist and experiences a wide range of temperature conditions throughout the year. The largest threat to this Motohome, however, is that it could face demolition in its future due to the desirability of the land and the issues many people associate with the upkeep of an older home.

This Delaware Motohome was used as a demonstration house for the region with over 8,000 visitors having visited the home, inspiring seven more Motohomes to be built in the area.[91] Local newspapers advertised the Wilmington Motohome beginning in October 1936 as one of many "'New American' Homes" to be opening that year, each having been contracted out to different builders, displaying General Electric products. Other houses advertised alongside the Motohome were less radical in design, such as the Early-American Revival style homes built in

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[89] R. H. White Co., "American Motohomes," 5.
[90] Vandemark & Lynch, Inc. *Property of Martin Wagner & Aylene Wagner H/W, Lot 34 – Section E, Westover Hills, Christiana Hundred, New Castle County, Delaware,* March 21, 1986.
[91] "Seven Motohomes to Be Built Here."

Swarthmore and Haverford, Pennsylvania (*Images 4 & 5*), which also included the same modern conveniences on the interior as those found in the Wilmington house.

American Motohomes of Wilmington, Ltd. acted as the local seller of Motohomes in the Delaware Valley area. The property was built between October and November 1936 as a three-bedroom, three-bathroom house with a garage, back porch, and exterior roof sundeck.[92] The original design for the home also contained three large living spaces on the first floor. Over time, the subsequent owners added on a stucco-faced enclosed sunporch to the back of the property, closed in the garage to create a fourth bedroom, moved the front door roughly a foot to the right, removed the rails and sundeck above the living room, replaced the roof, and recently modernized the original moto-unit kitchen.

Previous Repair Campaigns

The only documented repair campaign is the roof replacement in 2017. It came as a response to visible water damage in second-story rooms. It is also clear from visual evidence that all the windows have been replaced from the 1936 original to double-paned casement windows. It is unclear how many window campaigns have occurred over the years. The reason for the most recent window change was likely aesthetic and may have served to unify all windows with those along the façade.

The first-floor windows scheme was altered most dramatically in the living room located on the far left of the façade, or east elevation, and through addition of

[92] "New Motohome Inspected by 3,000 Persons."

windows when the garage doors were removed on the far right of the façade. The corner windows original to the 1936 façade are no longer configured in the same manner (*Image 6*). The façade window has been moved over one bay to be situated in the middle 4-foot panel section rather than in the corner. There are currently windows in each of the three panel bays along the south wall of the living room and the south elevation of windows continues into the added sun porch.

Changes like these to the original window scheme and the slightly altered front door location would have involved altering the asbestos-cement panels. Evidence of localized partial panel replacement is visible in other areas along the front and back elevations as well. While the exact changes and treatments required to perform these alterations are not documented, it can be assumed that the Pyrestos product is no longer present in every bay of the original footprint.

Current Conditions

The extant exterior asbestos-cement panels in 1013 Overbrook Road are in overall good condition. The found deterioration conditions present on these elements appear to be limited to peeling paint and biological growth. The locations of exterior deterioration can be classified as follows: beneath the cornice, underneath windowsills, and where the panels encounter the foundation. Interior deterioration is limited to beneath windowsills and at corner connections (*Image 7*). Other types of water-related deterioration are visible on the ceilings and floors, however these are not the focus of this thesis (*Image 8*).

Deterioration located directly below the angle capping the wall appears to fall into the category of peeling paint (*Image 9*). Paint detachment and loss in this area is likely the result of rainwater runoff with the angle serving as a drip edge. Due to the polarity of water molecules, water has a high surface tension, thus water can travel along a surface before gravitational forces cause the water to drip off the surface (*Illustration 5*). Without the benefit of flashing on the Motohome, rainwater becomes trapped against the panel product. There is a small, but visible gap between the bottom edge of the angle and the panel behind it (*Image 10*). This area likely traps water during precipitation events and stores moisture long after the event due to both the surface tension of water and the minimal number of drying mechanisms available inside the gap between the metal and the relatively non-porous cementitious panel. Prolonged exposure to water can weaken the finish, which can further be exacerbated when water begins to accumulate between the finish layer and the panel product.

Depending on the size of the gap between the angle and the wall surface, water may rise within the space due to capillary action and come in contact with the top edge of the panel. If water enters the asbestos-cement panel product, it must exit through a drying mechanism, such as evaporation to the outside surface. This process may be causing some of the paint blistering and loss due to moisture buildup between the panel and the external paint layer. This process may also be causing damage to the insulation layer if the asbestos-cement dries to the interior. Ultimately, the drying surface is dependent on the availability of open pores.

The hypothesis based on paint loss from retained water is further corroborated when viewing the deterioration occurring directly around windows. The deterioration on the western elevation second story panels between the tops of the windows and the angles best depicts this occurrence (*Image 11*). Deterioration is most prevalent in the corners where the aluminum stiles meet the cornice and again where the stiles meet the tops of the window framing. These areas are providing shelves and extra exposed surface area for water to be transported and trapped, leading to the paint loss. The bottom windowsills are likely experiencing a similar phenomenon, as both lower- and upper-story windows exhibit this triangular pattern of deterioration near the corners where the sills meet the stiles. The bottom sills exhibit more than paint loss, however.

The deterioration seen beneath the first-floor windows (*Image 12*) is a mixture of what was described above as well as the deterioration found in the third area prone to deterioration—where the panel and the foundation meet. The bottom edge of the panel is experiencing both paint loss as well as biological growth due to moisture accumulation (*Image 13*). In addition to the surface tension of water along the surface of the panels, capillarity may be playing a role in the uptake and retention of moisture within the panels themselves. Capillarity is a phenomenon that occurs due to the small size of pores within a material and the surface tension of water. Permeable materials are able to wick water away from the moisture source and further into the material through the collection of water molecules within the pores. The unfinished bottom surface of the panel, where it meets the foundation, is acting as the easiest entry point for moisture. The biological growth found along these areas serves to corroborate the omnipresence of moisture, as these microorganisms require ambient light and moisture to propagate. Shaded areas experience higher levels of biological growth than the areas that have regular sun exposure because the sun acts as a drying mechanism for the wall. Shaded areas experience less drying, and therefore enough water is present for a long enough duration to support biological growth.

The area where water is able to exit the material through drying mechanisms is referred to as the zone of evaporation, and it can be seen as paint loss or paint blistering near the bottom of the wall. On the Motohome panels the zone of evaporation is relatively low and close to the ground. Because this zone is a direct function of permeability and capillary flow of water within the pores, the low level for the zone represents a low porosity, or a dense asbestos-cement product.

While it is not known whether certain panels are the original Pyrestos asbestos-cement panel products or later replacements, a comparison of historical photos with what can be found today is the first step to providing a cursory understanding of where the original panel product still exists. Next, a comparison between the extent of deterioration on each panel can further inform what product is being utilized in each panel bay. The areas in which replacement panels and newer products occur appear to be exhibiting the most extensive deterioration. Areas in which the original Pyrestos is suspected to remain appear to be in overall better condition. This is in part why asbestos-cement panels were considered to be a top choice building product for long-lasting construction.

Opportunities for Deterioration

As alluded by the current conditions, the framing system and panel installation are contributing to the deterioration found on the Motohome in the following ways:

- The panel rests on bare concrete with no form of caulking or mortar to serve as a barrier between the two surfaces. While a concrete cap appears to have been applied in order to cover the gap between the foundation and panels, the cap has experienced loss and is ineffective at preventing water from pooling at the bottom edge of many panels.
- The extruded aluminum stiles serve as superhighways for water collection and retention due to their three-dimensionality and connections to window sashes. The tops of window sashes will be exposed to higher levels of water and pooling.
- The highly angular windowsills provide drip edges with a large surface area where moisture can collect in a protected area.
- The steel angle provides a shaded water storage area. The distance between the angle and the panel is likely small enough to support capillary action and therefore can provide moisture access to the tops of the panels.
- If water can access the tops of the panel product, water can infiltrate and begin to affect the insulation, whether the water deteriorates it or simply saturates the building product.

Conclusion

The Motohome case study holds true to the hypothesis that wall assemblies can contribute to asbestos-cement panel deterioration. While the panels are still intact and will continue to be stable with the additional paint protective layer, if the presence of water remains unchecked and unmonitored, further deterioration requiring more invasive forms of intervention, such as abatement, could be warranted. Areas, such as the bottom of the panel, may require additional protection, however testing would be required to ensure that adding a sill plate or a coating would not inadvertently negatively affect the wall panel, thus leading to more invasive forms of intervention in the future. A chart of preservation responses to each deterioration mechanism described for Pyrestos in the Motohome can be found in Appendix B (*Table 5.1*).

5.2 Eames House (Case Study House #8)

Unlike the other case studies presented in this thesis, much is known about the panel board product utilized at the Eames House in Pacific Palisades, CA. The Eames House was chosen as a case study for this thesis because it utilizes Cemesto, a well-documented asbestos-cement panel board product. While the end use of the structure was a single-family dwelling, just like the Motohome, the Eames House was intended to create a stronger architectural design statement (*Image 14*).

Case Study Program History

Publisher and editor John Entenza sponsored the Case Study House Program through the magazine “Arts & Architecture” from 1945 to 1962 as a way for architectural design to respond to modern living.[93] Entenza was not an architect by trade, but he had a strong belief that architecture should respond to the human scale while also exhibiting the qualities of good design.[94] He commissioned eight architectural offices to design a house that responded to both the lack of housing resulting from the Depression and World Wars and the cultural and stylistic changes that had occurred since the halt in housing construction. Any houses produced through this experimental program had to be able to be duplicated rather than being a single "performance" house.[95] The aim of the program was to play an active role in the development of postwar architecture by creating an ideal living environment for the typical American family.[96]

The Case Study House Program was announced in January 1945, months before the end of the Second World War in July. This meant that the announcement was made amidst nation-wide rationing and repurposing of materials, as manufacturers had turned their production towards the war effort.[97] The end of the war allowed for a turning point in architecture to occur—one that had been in the making for well over a decade, as the Great Depression had originally stalled the building industry before the war had begun. Any products developed during the war were understood to contribute to the war effort in some manner, and building products were developed for defense purposes. After the war, chemists, inventors,

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[93] "Case Study Houses: Program Influenced L.A. Design."
[94] McCoy, *Modern California Houses: Case Study Houses, 1945-1962*, 8–9.
[95] Entenza, "Announcement: The Case Study House Program," 38.
[96] Historic Resources Group, "Eames House/Case Study House #8," 11.
[97] McCoy, *Modern California Houses: Case Study Houses, 1945-1962*, 8.

and architects were able to freely experiment with wartime products such as plastics, resins, and panel products in order to repurpose them for architecture.

The architects chosen to create these new experimental houses included names publicly recognized today, such as Eero Saarinen, Richard Neutra, and Charles Eames. Additional architects announced were J. R. Davidson, Ralph Rapson, Whitney Smith, Sumner Spaulding, and William Wilson Wurster.[98] Similarly to the Motohome, the Case Study Houses were open to the public once completed and attracted a large number of visitors. When visiting a Case Study House, visitors experienced a good living environment not only through the architecture, but also through the purposefully designed furniture and landscape.[99] The entire site was an experience.

The Case Study Program emphasized different aspects of home construction during its twenty-seven-year lifespan. Initially more well-known architects who had established styles were chosen, but over time younger architects were selected to design Case Study Houses. Eames and Saarinen's Case Study House began the middle era, as these years of the program can be classified by a tendency to express the mechanized aspects of society through the incorporation of industrial materials into the house. While most of the program's lifespan concentrated on single houses,

[98] Entenza, "Announcement: The Case Study House Program," 40–41.
[99] In addition to Case Study House #8, Charles Eames was affiliated with the Case Study Program for his furniture design. He produced plywood cabinets and furniture for the other houses as modern, lightweight complementary pieces to the houses. McCoy, "Arts & Architecture Case Study Houses," 56.

larger-scale development and community planning became a focus during its final years.

Ultimately twenty-three houses were constructed as part of the Case Study House Program.[100] The majority of the houses were erected in the immediate vicinity of Los Angeles, California. The Case Study Houses were unable to become inexpensive options for building despite their prefabrication and industrial standardized parts because few small-scale contractors were familiar with the incorporation and use of industrial components in houses. This lack of familiarity and ease of use is in part attributed to the exactness required of steel construction. Wooden construction allows for the discretion of the carpenters and workers to make sure pieces align correctly, whereas the exact dimensions of steel members must be predetermined in order to ensure the framing is joined correctly. A different set of expertise is required.

Structural Arrangement

The Eames House was constructed using industrial parts that could be selected and ordered from catalogues. The steel-frame house sits on a concrete foundation and uses a combination of glass, wood, metal, asbestos, and synthetically derived building materials (*Illustration 6*).[101] The plan of the house is divided into three parts, two enclosures with an open-air court between them (*Image 15*).[102] One portion of the house was to be the living area whereas the other was designed

[100] Giovannini, "Fire Safe," 27.
[101] Historic Resources Group, "Eames House/Case Study House #8," 3.
[102] Entenza and Eames, "Case Study House for 1949," 28.

as the Eameses' studio space. The spaces were divided in a practical manner for the couple because, unlike other Case Study Houses, the Eameses had announced in the house's debut article in "Art & Architecture" that they were going to live in their Case Study House to prove it was in fact comfortably inhabitable.[103]

In order to situate itself amongst the eucalyptus trees that provide shade and to not disturb the meadow on the property, the house relies on an 8-foot tall retaining wall spanning 200-feet to brace the hill into which the house was built.[104] The building is a steel and glass cage structure of H-columns supporting flat trusses in the Warren configuration for both the roof and the second story (*Image 16*). The H-columns are spaced 20-feet apart with stacks of window sashes further dividing special areas of the windows into roughly 3-foot by 1-foot sections (*Image 17*). The exteriors of the framing, flashing, and metal sashes were all originally treated with a rubber-based coating in order to protect against corrosion, thus creating a dark gray colored structure dividing the façade into bays and windows.[105]

The roof and second floors are supported by Truscon open webbed joists running between them that serve to support the Ferrobord and Celotex insulation board ceiling and roof. The walls are a mixture of small and large rectangles with varying degrees of transparency—the transparent and translucent areas being glass and the opaque being Cemesto panels inserted in the sash. Some Cemesto panels have been painted, whereas the majority were left the untreated natural warm

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[103] Ibid, 27.
[104] Ibid, 29.
[105] Ibid, 33.

gray.[106] The Ferrobord can also be found in the courtyard abutting the retaining wall and is described as being painted aluminum.[107]

Panel Product

Many of the original exterior panels used at the Eames House in both fixed and operable sashes are Cemesto—a sandwich panel produced by the Celotex Corporation (*Image 18*). Celotex chemist Treadway B. Munroe applied for a patent for "a material comprising a composite board-like member having portions of differing characteristics" in 1930 and received the patent four years later.[108] The relatively vague nature of the language is typical for patents and allowed the Celotex corporation to have rights to the product without disclosing their trade secrets. Cemesto began to be marketed in 1937.

The sandwich panel product consists of one or two outside layers of asbestos-cement, with a minimum thickness of $^{1}/_{8}$-inch, bonded to an internal insulating layer of bagasse board. Bagasse is a fiber byproduct of sugar cane that had essentially been waste before scientists began to test it as a potential candidate for the creation of a fiber board product.[109] The fibers were not good candidates for mulch material because they are nitrogen and mineral salt deficient, meaning they actually do not decay quickly—a trait frowned upon in the agricultural repurposing business but lauded in the building industry. In addition to this trait, bagasse fibers

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106 Burke et al., "Eames House Conservation Management Plan," 26.
107 Entenza and Eames, "Case Study House for 1949," 30–32.
108 Munroe, The Celotex Company, and Swenson, Structural Material, 1.
109 Lathrop, "The Celotex and Cane-Sugar Industries' Bagasse or Sugar a By-Product?," 449.

are long, strong, and bulky. The negative attributes of the fibers, being high in moisture content and difficult to store, were outweighed by the positive attributes. Celotex began processing bagasse fibers for panel use in 1920.[110]

Bagasse fibers had to be cooked, washed, and refined before they could be formed into panel products. The cooking process removed the organic matter and gums from the fibers while also sterilizing them through the addition of a buffering solution as well as heat. This process prepared the fibers to be shredded before being washed. Washing removed the pith, thus allowing for the resulting fiberboard to be lighter in weight, while adding sizing agents such as rosin and alum to the mixture to waterproof the fibers. The refining process aimed to ensure that there was a mixture of fibers of differing lengths and widths. The wet fibers were then felted together through the excess water removal process and were continually dried until the moisture content was roughly 50%. As time progressed, Celotex began treating the fibers through what they called the "Ferox Process," where alum and sodium arsenate were mixed into the fibers at this board forming stage in order to prevent animal infestation and to prevent against dry rot.[111] The sheets then went through a drying process where the heat was maintained at anywhere from 300-450°F, depending on the machine used. The resulting bagasse insulation board had a moisture content of 8% before equilibrating with the atmosphere and being seasoned with water in order to prevent buckling during the equilibrating

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[110] Ibid, 451.

[111] The Celotex Corporation, "Celotex Manual for Architects," 7; C., "Current Topics: The Ferox Process for Fiber Board," 746.

process.[112] Celotex saw this board having many future end uses, including being used as sound insulation or a sheathing material, years before producing Cemesto.

Celotex called for the adhesive bonding of the bagasse fiberboard and the asbestos-cement boards to be water- and vapor-proof, and the corporation suggested a material such as a bituminous compound. Additionally, the bonding process would occur *before* each of the component parts was finished being manufactured in order to ensure a better bond. The adhesive would also be applied to both the insulation and the asbestos-cement board surfaces for this same reason. As the excess moisture was pressed out during the board-forming process, the asbestos-cement structural layer was simultaneously bonded to the insulation layer. The scientists at Celotex saw this water impermeable barrier as being a vital form of protection for the insulating material.[113]

Cemesto was touted as a rot-, termite-, and fire-resistant panel board product that had both structural and insulative properties. A typical sheet was 4 feet wide by 4, 6, 8, 10, or 12-feet long.[114] The peak of Cemesto production occurred around the Second World War during the post-war housing boom. Cemesto was considered a quick and easy solution to create housing for defense workers both during and after the war. The product was used in multiple Case Study Houses due to its utilitarian look and ability to be placed within an industrial framing system.[115]

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[112] Lathrop, "The Celotex and Cane-Sugar Industries' Bagasse or Sugar a By-Product?," 453–55.
[113] Munroe, The Celotex Company, and Swenson, Structural Material, 1.
[114] The Celotex Corporation, "Application of Celotex Cemesto on Wood Roof Framing," 1.
[115] Richard Neutra's 1945 Case Study House utilized corrugated Cemesto panels installed in a wood frame.

Site: 203 Chautauqua Boulevard

Case Study House #8 was built in its entirety during 1949, from January to December, and was opened to the public for inspection upon completion. The House, located at 203 Chautauqua Boulevard in Pacific Palisades, California, was one of five Case Study Houses designed for and erected on the five-acre parcel of land originally acquired for the program.[116] The Eameses lived in the house after its completion and also used it as studio space for their design careers.

The original design for the house was drafted by both Eero Saarinen and Charles Eames and was visually distinct from what can be seen today (*Image 19*). The built house instead reflects the revised design created by husband and wife Charles and Ray Eames (*Image 20*). Charles Eames did not begin to formulate the new design until after the steel for the Eames/Saarinen design had been delivered. The steel from the previous design was used with minimal additional materials to create what is known today as the Eames House, thus linking the two designs.[117] The house is a 1,500 square foot one-and-a-half-story structure that consists of two bedrooms, two bathrooms, a kitchen and dining area, and a living room. The studio is of the same height but is 1000 square feet, containing a bedroom, bathroom, and studio space. While the divided layout of the Eames House may appear as if it were designed more for the Eameses' particular needs and less for the average American family, it is an example of how many people adapt their houses to their own needs in order to create a home.

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[116] McCoy, "Arts & Architecture Case Study Houses," 54.
[117] McCoy, *Modern California Houses: Case Study Houses, 1945-1962*, 57.

The Eames House was nominated as a National Historic Landmark in 2005 on the thematic grounds that the Case Study House Program expressed the cultural values of its period through art, architecture, and invention.[118] The nomination recognizes that the Eames House is the most well-known of the Case Study Houses. In fact, the Eames House retains its Eames-era integrity today, whereas many of the other houses have been adapted to changing styles and technologies over time.[119]

Previous Repair Campaigns

The Eames house has been the subject of preservation studies within the last decade in order to better prepare for the future conservation of the house. In 2011 and 2012 the Getty Conservation Institute (GCI) investigated the environmental and physical conditions of the site in order to create a comprehensive conservation management plan for the Eames House. Firstly, they intended to address any changes that may have occurred to the site due to the salty environment and the natural wear and tear that had occurred since the Eames House was constructed over sixty years ago.[120] The GCI's ultimate goal is to protect the intended interior living space and the collection of personal items that the Eameses had within their house.

During the 2012 investigation, the interior floor tiles were determined to be at the end of their lifespan and in need of replacement. The tiles were found to contain asbestos and abatement was performed during their removal. The GCI and

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[118] Historic Resources Group, "Eames House/Case Study House #8," 8.
[119] McCoy, "Arts & Architecture Case Study Houses," 62.
[120] Normandin, "Charles and Ray Eames: Modern Living in a Postwar Era," 26.

Eames Foundation were able to replace the original tiles with new vinyl tiles that were aesthetically identical to the originals.[121] The example of the tiles, while not the focus of this thesis, shows that the Eames Foundation is committed to replacement with visually identical materials when health and safety concerns arise. The project team met again in 2017 in order to develop an environmental improvement plan to better conserve the house and its collection.[122]

The official Conservation Management Plan for the site became publicly available in 2019. Within the document, the GCI documented the original locations of the Cemesto panels, as well as the extent of replacement that has occurred since their installation. Deteriorating Cemesto panels were replaced with Transitop panels, another asbestos-cement panel product, in the 1970s and 1980s, and more recent replacements have utilized plywood.[123] The report acknowledges that the use of Cemesto is a vulnerability of the site due to the health implications of its deterioration and the inability to replace the panels in kind.

Opportunities for Deterioration

Cemesto may deteriorate because of its fabrication, its method of shaping, or its method of installation.[124] The fabrication of the panel, as described above, provides opportunities for deterioration in each layer of the board. Cemesto was not installed in the manufactured 4-foot sheets at the Eames House but rather was

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[121] Normandin, "The Eames House: Conserving a California Icon."
[122] "GCI News: Eames House Environmental Investigation," 26.
[123] Burke et al., "Eames House Conservation Management Plan," 124, 181.
[124] Cemesto was utilized in construction in a variety of climates and structural systems. For this reason, the potential deterioration mechanisms explained below are not a comprehensive list for Cemesto, but rather a list of potential mechanisms for the Eames House.

shaped by field cutting in order to adequately fit into the design. Finally, the insulation methods and materials used in the panel production may have created vulnerable points in the panel's enclosure.

The interstitial asphaltic adhesive layer between the asbestos-cement and bagasse layers of the panels is important and any weakening of this layer due to age could lead to further deterioration of the panel at large. While its full deterioration is unlikely, asphaltic materials can become less water-tight as they age and as the binder deteriorates, thus allowing for water and vapor to pass between layers of the panel. While this is not problematic in its own right, provided the cementitious and treated bagasse layers remain intact and the bolts holding the panel into the framing system remain intact, any source of moisture would meet very little resistance in moving between layers without the asphaltic layer acting as a water barrier. If the bolts were to also have experienced deterioration over time, the layers of the panel may become detached from one another due to the bagasse fibers absorption of water and the resulting expansion in size of this layer. The dimensional changes bagasse experiences upon exposure to water are the result of the cellular structure of the cane fibers. The fibers acted as moisture storage and transportation routes for the living sugarcane plant and retained these abilities after becoming a processed bagasse product. Panel layer separation from water-related bagasse expansion could result in cavities within the panel and potential areas for water to gather. Any long-term presence of water will contribute to deterioration.

While Celotex was known for the Ferox treatment and claimed it to be "non-volatile, odorless, [and] permanent" the long-term deterioration of the chemicals was not likely studied.[125] In early developments of the process scientists knew that when the alum and sodium arsenite slurry dried, it created "an insoluble complex, [that was] difficult to leach out," but not impossible.[126] Published articles about the material do not mention initial chemical reactions or any compounds resulting from this reaction, nor oxidation products resulting over time. Sodium arsenite decomposes over time when exposed to the air and also reacts with acids. A resultant chemical from the decomposition of the initial alum and sodium arsenite components may result in unknown deterioration. In 1934, Celotex patented a new sizing technique for fibrous products that replaced alum with a ferrous salt in order to precipitate rosin onto the bagasse fibers to repel water.[127]

The ways in which the Cemesto panels were cut and installed into the H-frame and beam system would determine the exposure of the Ferox treated bagasse to weathering mechanisms. As Eames mentioned rabbeting being necessary to set the Cemesto panels into their frames during construction, the bagasse is likely more exposed to moisture than it was designed to be.[128] The exposed bagasse panel may have initially been protected and secured into the window frame using a material similar to glazing putty or caulk. These materials are prone to embrittlement leading to loss over time and their deterioration may allow for water infiltration of the bagasse layer.

[125] The Celotex Corporation, "Celotex Manual for Architects," 7.
[126] C., "Current Topics: The Ferox Process for Fiber Board," 746.
[127] Lathrop, Irvine, and The Celotex Company, Water Repellent Size for Fiber Products, 1.
[128] Burke et al., "Eames House Conservation Management Plan," 25.

The window frame, as seen in Image 17, may be contributing to water entering the bagasse layer. The Truscon frame uses a lip that may be trapping water to hold the Cemesto panel in place. The interior portion of the frame would also be susceptible to corrosion from the trapped water, as it has likely not been treated against corrosion to the extent the exterior the framing has been treated. Any resulting corrosion jacking would create a uneven frame surrounding the edges of the panel that may further contribute to trapping water against the panel.

If the Ferox process was not evenly applied to the bagasse fibers, untreated areas could experience heightened susceptibility to insect damage or dry rot if the edges of the panels are not sealed or if the Cemesto board had been compromised in some manner. This type of deterioration would hinge on potential entrance points for moisture, which would attract biological activity, as well as a failure of Celotex's waterproofing process.[129] The field cutting of the Cemesto board may have exposed the edges of the panels to the elements in a way that they had not been designed to sustain, as Celotex sealed the edges of the precut board products.

Additionally, Celotex suggested that Cemesto panels be bolted to the framing system during proper installation. In the technical drawings for Cemesto application in steel framed structures, the panel board is depicted with bolts going through the board itself near the edges in order to secure it to girts and jambs (*Image 21*). This area was further depicted as being caulked over in order to seal itself.[130] The deterioration and failure of caulking is another potential mode for

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[129] The Celotex Corporation, "Celotex Manual for Architects," 7.
[130] The Celotex Corporation, "Industrial Application of Cemesto To Steel Framed Structures."

deterioration as any perforation to this weather seal could allow for water to infiltrate the interior of the panel.

Conclusion

As with the other case studies, the largest threat to the Cemesto panels is the infiltration of water. Due to the breadth of literature available for the production and processing of Cemesto, the potential deterioration mechanisms of these asbestos-cement panel boards are more tailored than the other two case studies presented in this thesis. The Eames House is an example of a building that has undergone studies regarding its preservation, which include the asbestos-cement fiber-reinforced panelboard. The wall panels are integral to the layout and design of this Case Study House and are therefore historically significant. The Cemesto panels already lost to deterioration have created an opportunity for the installation of a visually similar substitution product. A chart of preservation responses to each deterioration mechanism described for Cemesto at the Eames House can be found in Appendix B (*Table 5.2*).

5.3 John Blair Building

The purpose of this case study is to contrast the scale and materials of the asbestos-cement panel product against the previous two single family homes. The John Blair Building was built as a multi-story high rise rentable office building in downtown Chicago in 1961, making it the latest of the three case studies. The Vermarco brand asbestos-cement panel product used in cladding the building served as a curtain wall with an exterior-facing marble surface, thus leading to different pathologies for deterioration (*Image 22*).

Architectural History

John Blair & Company was founded in 1935 and, by the time the John Blair Building was built in Chicago, had offices in cities across the United States.[131] C.F. Murphy Associates[132] designed the John Blair Building as office and retail spaces for Blair company stockholders, including those from John Blair & Company, Blair-TV, and Blair Television Associates.[133] The completion of the building was advertised in broadcasting magazines due to the Blair companies' large role in selling advertisement time slots for both radio and television. After this building became operational, the company continued to expand their advertisement business both on the air and in print.

When the building was completed in 1961, it was a part of a much larger wave of construction occurring along Michigan Avenue. That same year, two large hotel additions occurred in the neighborhood, adding 900 rooms for visitors.[134] As the bottom stories of the building acted as a small retail hub, the John Blair Building's location near hotels was advantageous because the hotels were able to supply visitors and therefore revenue. The scale of the buildings erected

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131 Waggoner, "John P. Blair, Founder of Company with Varied Interests, Dies at 83."

132 C.F. Murphy Associates had previously been known as Shaw, Naess & Murphy, and in 1981 was renamed Murphy/Jahn. The architectural firm designed many buildings in the Chicago area, including the Prudential Building in 1955, which began a subsequent boom in downtown Chicago architecture. Heise, "Charles F. Murphy, Chicago Architect."

133 "Cornerstone: Salesmanship," 14.

134 "Michigan Av. Has New Eye-Catching Finery, Too, for the Easter Occasion."

concurrently with the John Blair Building were similar to those that are found today, meaning that the Blair Building's eleven-stories have always been surrounded by buildings greater than twenty-stories tall.

Structural Arrangement

The John Blair Building is an eleven-story reinforced concrete office building. The building is divided into evenly spaced bays that are further divided by I-beams that appear to have been applied to the exterior surface (*Image 23*). Horizontally the building is divided by alternating rows of windows and green-tinted black marble panels with white veining. The windows and panels are situated between metal sash elements that protrude from the surface of the building and appear to be further secured using a black sealant (*Illustration 9*).[135] On the corner of Michigan Avenue and Erie Street, a portion of the bottom row marble panels, those at the bottom of the third floor, appear to have been removed in a recent remodel (*Image 24).* An alteration such as this may have been performed in order to create visual continuity for the retail stores that occupy both the first and second floor, while additionally creating floor-to-ceiling windows for GREC Architects on the third floor (*Images 25 & 26*). The exterior panel walls, while not acting as structural members, do encounter significant wind loads due to the nature of high-rise building enclosures. The surface area of the panel exposed to the wind is much greater than the area of structure or the framing system holding the panels in place.

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[135] This information was extrapolated using GoogleMaps. While this is an imperfect survey technique, the building manager and engineer will not be available until April 3, 2019 due to the managerial offices currently undergoing relocation within the building.

Panel Product

In 1959 Vermarco, a subsidiary company of Vermont Marble Company, began to advertise Vermarco Panel-Walls, which were described in the *AIA Journal* as "a layer of half-inch thick marble, bonded to a core of insulation, with interior face of asbestos-cement board" (*Image 27*).[136] The advertisements were aimed at practicing architects in the hopes that their product would be incorporated into new buildings. No specific building using the system was mentioned, however a basic installation description was included for their flush-mounted panel system. A tongue and groove system connected the panels and a vinyl expansion seal acted as a weatherstop. The panels supposedly sealed themselves against weather and moisture through the nature of the system. The smaller marble panels could be combined with each other to create a larger panel that could be installed into a variety of curtain wall systems. It is important to draw attention to the wording regarding the use of Vermarco. The company recognized that these panels should only be used in a curtain wall capacity and explicitly stated such in their AIA advertisements.

The year following the appearance of the *AIA Journal* advertisement, the John Blair Building was completed. Advertisements as late as 1963 utilized images of the building to advertise the Vermarco Panel Wall, however this iteration of the panel description was slightly different. Instead of the insulation being described as bonded to both a marble slab and one of asbestos-cement, now the insulation is

[136] "Vermarco Marble Panel-Walls."

between a sandwich of asbestos-cement sheets and the marble panel is bonded to one of the asbestos-cement sheets. The panels are singular units that have been installed into an aluminum frame using a similar, if not identical, vinyl expansion seal.

Site: 645 N. Michigan Avenue

The John Blair Building is located on the southeast corner of Michigan Avenue and Erie Street along the "Magnificent Mile" in downtown Chicago, Illinois. It is only four blocks west of Lake Michigan and stands among many high-rise buildings in the downtown area. Many different companies have occupied space in the building over the years. 645 N Michigan LLC and Nakash 645 N Michigan LLC have owned the building since 2003 and operate it as a mixed retail and office space. Currently there are conference room spaces available to rent, operational retail spaces, and offices located in the building. TGI Fridays and other chains such as clothing retailer Salvatore Ferragamo occupy space on the first and second floors, while floors three through eleven serve as office and conference spaces.

Current Condition

The marble panels outwardly appear to be in overall good condition with no explicit signs of deterioration. The durability of marble exteriors was likely the reason the Vermarco panels were chosen as the panel cladding for belt courses on the John Blair Building. Interior access to the panels is likely minimal, as these areas are covered with the ventilation system in the interior conference room spaces, thus making the panels difficult to access. This may have been a form of encapsulation to minimize dispersion in the event the panels began to deteriorate. The GREC Architects studio took another approach to solving potential future problems by abatement through the removal of the panels. While this is less-ideal from a preservation standpoint, the John Blair Building is likely not widely considered to be historic due to only being fifty-eight years-old.

The city of Chicago requires all buildings to undergo a façade inspection performed by engineers every eight years. These inspections are supplemented by annual visual inspections that serve to monitor any cracks found during the façade inspections. New cracks and expansion of existing cracks are flagged, and the building owners are required to address these issues. Due to Vermarco panels no longer being available, the Blair Building has opted to substitute the deteriorated marble panels with glass encasing an image of marble.[137] The extent and patterns of replacement are unknown.

Opportunities for Deterioration

Many aspects of this system are also unknown, such as the insulation material, the adhesion material, or instances of replacement for the vinyl expansion seal securing the panels. Knowledge of the exact elements of the product and its history would allow for determining material-specific concerns for future deterioration mechanisms and conservation efforts. However, despite the

[137] Interview with the building engineer's office, April 18, 2019.

unknowns, it is possible to hypothesize deterioration pathologies for the Vermarco asbestos-cement panel.

The first line of defense the panel system has against exterior weathering is the expansion seal that doubles as a weathering strip. The vinyl seal is highly likely to deteriorate because vinyl materials have known patterns of deterioration when exposed to ultraviolet light and/or moisture. Over time, exposure leads to yellowing, hardening, cracking, and loss of substrate. The extent and rate of each is determined by the type of vinyl material used as well as the intensity of light and level of moisture exposure.[138] If the seal has been replaced, past deteriorated vinyl seals may have allowed for a breach to reach behind the marble slab face of the panel and into the adhesive, asbestos-cement sheets, or insulation layer.

The adhesive is likely not water soluble, as marble has a permeability that allows for water molecules to travel through the substrate, albeit very slowly. Additionally, inventors were aware of the importance of water-resistant adhesives decades before the John Blair Building was constructed.[139] It is likely that the bond between the asbestos-cement and marble is acting as both an adhesive and an impermeable layer in the event that water does travel through to this interstitial surface. There is also the possibility that the insulation material is bonded to the asbestos-cement boards using the same adhesive, thus not only creating more impermeable layers that prevent water from entering but also prevent any incidental water from easily escaping. The insulation is the most protected

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[138] Andrady et al., "Effects of Increased Solar Ultraviolet Radiation on Materials," 99.
[139] Beckwith, Laminated Sheet Material.

component of this building system and the deterioration mechanisms of this component are dependent on the material used.

The asbestos-cement board surrounding the insulation was likely formulated as a high density, low porosity product, meaning water would not easily travel through the board. Over time, prolonged exposure to water sources in conjunction with freeze-thaw cycles, of which Chicago experiences over 50 annually, can lead to spalling and cracking of the asbestos-cement.[140] This process involves the expansion of the water molecule during the freezing process and the resulting hydrostatic pressure created within the pores due to the expansion. The pressure can cause microcracks that expand over time, eventually resulting in a spall, or loss of material. If this were to occur in the asbestos-cement material, it would need to be contained and remediated for health safety reasons. Since no asbestos-cement is exposed to exterior conditions this is significantly less likely to occur.

Any damage or deterioration to the panel framing system can lead to the exacerbation of the above decay mechanisms by creating a new avenue for water to infiltrate the system. Open joints or missing components are the worst-case scenario and can lead to exponentially increasing deterioration if left untreated. Conversely, a small-scale failure of the framing system can occur where it intersects with the vinyl sealing. If installation of the sealant was not done properly or the sealant has dimensionally altered with age, a small gap could begin to form and go undetected.

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[140] Portions of the building are extremely likely to undergo additional freeze-thaw cycles due to solar radiation heating exposed surfaces. National Climate Data Center, "Chicago, O'Hare, Il."

Conclusion

The Vermarco panels used in the John Blair Building have an added layer of protection not seen in the previous case studies—the external marble panel. While the framing system is not visibly contributing to the active deterioration of the panel, it is important to keep in mind that aspects of the framing system are more susceptible to damage, and these components should undergo regular maintenance and monitoring. Any problems should be addressed as they arise. A chart of preservation responses to each deterioration mechanism described for Vermarco in the John Blair Building can be found in Appendix B (*Table 5.3*).

6.0 CONCLUSION

Prefabricated and panelized modern construction were inherently experimental in both theory and design. The availability of new laboratory-produced materials and new composite building products began to inspire and fuel architectural design beginning in the 1920s. Architects were designing new forms for a modern society. While production halted during the Depression and wartime, ideas were not stymied. In fact, many products were developed for the war effort that could be adapted and utilized for civilian life. The ending of the Second World War brought about more opportunity for investment in both product development and housing construction. Materials and products continue to be modified today in order to enhance performance and durability while maintaining a level of cost-effectiveness.

Asbestos-cement board was one stop on a longer-living trajectory, as fiber-reinforced cement board panels continue to be developed today. As an early twentieth-century form of cement reinforcement, asbestos played an important role in the development of panelized construction. It provided a lightweight, fireproof building enclosure that could be utilized in many different climates across the United States. When asbestos-cement boards were combined with insulating material in order to form a sandwich panel product, the material showed its adaptability and ability to protect the material it encapsulated.

As a developing product, certain aspects of asbestos-cement panels were not fully understood, however. The obvious example being the adverse health effects garnered from the releasing of the asbestos fibers when the integrity of the material is compromised. Another example being the perforation of the panel surface for construction purposes, as seen in manufacturer's manual for Cemesto.

6.1 Application

The conclusion of each case study ended with references to the tables found in Appendix B, which utilize a shaded color system of recommendations for preservation intervention options for the deterioration mechanisms discussed in this thesis. The tables use the definitions of abstention, mitigation, reconstitution, circumvention, substitution, and acceleration as defined by Samuel Harris in his book *Building Pathology.*[141]

Abstention refers to a situation in which no intervention alters the deterioration mechanism that is occurring. In the tables attached, monitoring of the

[141] Harris, *Building Pathology*, 39–44.

condition without intervention is considered to fall into this category. Monitoring can refer to either quantitative or qualitative data accumulation, meaning data logger technology may be employed for exact measurements but periodic visual inspections may also suffice in monitoring types of deterioration changes. That is not to say, however, that abstention through monitoring may not lead to a form of intervention in the future.

Mitigation occurs when interventions alter the environment that supports the deterioration mechanism rather than the substrate itself. An example of mitigation in this thesis is the biological growth that has grown along the bottom portions of the Pyrestos panels of the Motohome. A basic or pH neutral biocidal cleaning agent could be applied to the surface without additional agitation in order to kill the lichen and algae already growing on the surface while creating an inhospitable environment for future growth. Mitigation can also include removing trees or building elements that are creating shady, damp areas harboring biological growth.

Reconstitution interventions alter the substrate that is deteriorating and are those that have historically been thought of as common preservation interventions. In terms of this thesis, reconstitution encompasses refreshing the paint on encapsulation layers or reapplying an asphaltic adhesive layer between the asbestos-cement sheet and insulation layer within the panel structure. These interventions fall under the category of "replacement in kind," but are not the only forms of reconstitution. Composite repairs to any cracked marble slabs on the John Blair Building would also constitute reconstitution.

Circumvention alters the *system* to which the deterioration is occurring rather than a single substrate experiencing the deterioration. The Motohome has the most opportunity for circumvention, as elements such as the window framing elements do not appear to be original and the cornice appears to have been removed, yet both are causing water retention issues. Adding flashing to soffits or the cornice area has the ability to redirect water from the areas where it is currently being retained. Additionally, the Pyrestos to concrete foundation connection could be modified to leave the asbestos-cement product less susceptible to water absorption. Encapsulation, a traditional way of treating products containing asbestos by surrounding the product in its entirety, is an additional form of circumvention.

Substitution is the direct replacement of the substrate with another replacement material. For the three case studies presented in this thesis, substitution is recommended for other aspects of the panel system, such as the caulking or the adhesive layer. These modern petroleum products may not have identical products available to replace them as they age, or the products available may have more desirable properties than the original material. This is a first-level consideration for these elements because they are not the primary historic material and are not likely to have readily available exact replacements. They contribute to the system, however they have much shorter service lives and must be renewed in order to prevent unnecessary deterioration from occurring to the asbestos-cement product.

Acceleration is the least common of the interventions in the preservation world, however it is necessary in some situations. In these interventions, demolition or removal of the substrate occurs without replacement. For asbestos-cement products acceleration is an unlikely course due to the toxicity that results from any form of deterioration, let alone advanced deterioration. It is only a second-level consideration for removing Ferox byproducts in a controlled manner if it is determined that any byproducts are already leeching from the insulation layer. No substitution could occur until the previous issue had been stymied. Acceleration could also be considered where paint is blistering from the exterior surface of the Pyrestos panels if the natural asbestos-cement surface is desired again as a finish.

Ultimately these tables aim to show that there are steps that can be taken throughout individual deterioration mechanisms that allow for small-scale interventions to halt or slow down deterioration. Once a mechanism begins, it does not have to continue until the deterioration is so advanced that one must resort to asbestos abatement—it can be halted earlier. While any disaggregation of asbestos-cement substrate should be professionally investigated, it is likely that, for this to be occurring, an advanced stage of deterioration has begun and abatement should be considered as a means of treatment for the building element.

6.2 Larger Implications

The largest implication of this thesis is that framing systems can lead to the deterioration of other elements within the enclosure system. Additionally, alterations that occur over time must take into account both the beneficial as well as detrimental repercussions of their installation. While asbestos-cement board is an extreme example due to the repercussions of its deterioration, it forces us to recognize the different stages of deterioration in order to protect ourselves and our environment. If the deteriorating material being studied were to have a benign deterioration product, its stages of deterioration may not be monitored or studied as closely.

6.3 Further Research

Further avenues of research not encountered within this thesis include the following categories: case studies, intervention costs, circumvention interventions, methods for consciously waterproofing asbestos-cement exterior surfaces, sensitive forms of encapsulation, and appropriate uses of monitoring techniques in order to determine sources of deterioration.

Additional case studies are useful as there have been countless combinations of framing systems and enclosure material combinations available since panel construction began last century. Panel systems have been utilized in a wide variety of climates in many countries, and the ways in which their deterioration is recognized and treated also likely varies considerably. The costs of any interventions should be weighed against their benefits, and it may be determined in some cases that many small interventions are not as financially feasible as a singular but more invasive treatment such as abatement. Cost analyses will be on a more case-by-case basis, as no two buildings will be entirely identical. Ultimately methods of intervention will be determined by cost and resource availability for a given treatment.

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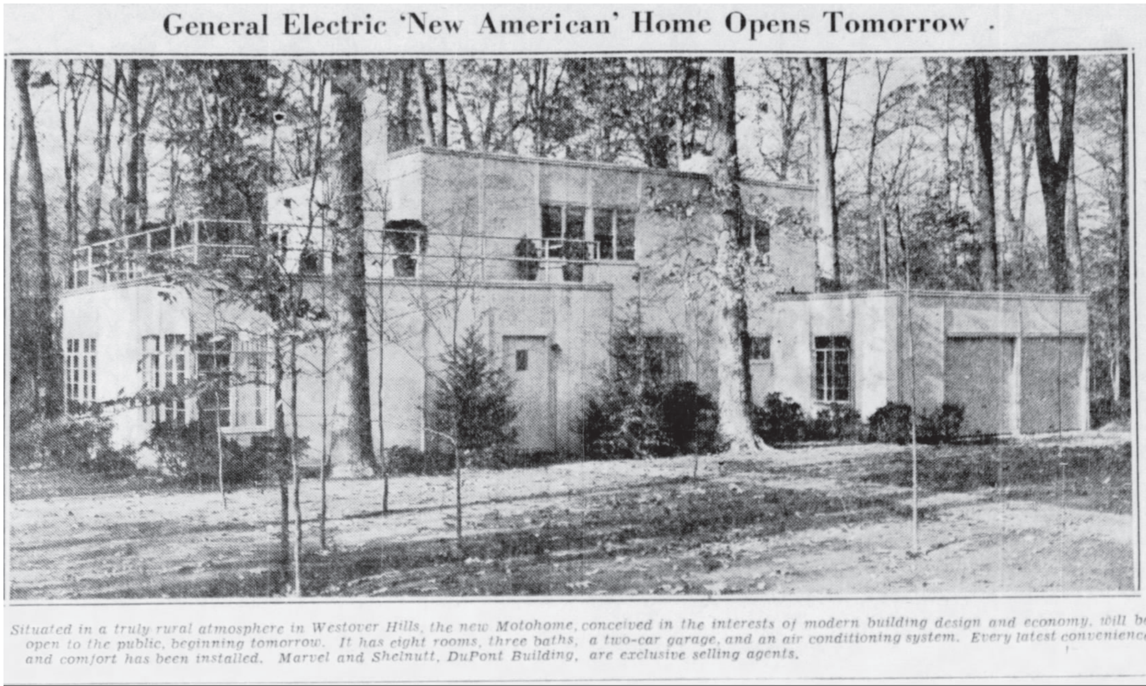
APPENDIX A: IMAGES

This appendix contains the images referenced throughout the text. All images produced by author unless otherwise noted.

Image 1: 1013 Overbrook Road as it appears today



General Electric 'New American' Home Opens Tomorrow .

Situated in a truly rural atmosphere in Westover Hills, the new Motohome, conceived in the interests of modern building design and economy, will be open to the public, beginning tomorrow. It has eight rooms, three baths, a two-car garage, and an air conditioning system. Every latest convenience and comfort has been installed. Marvel and Shelnutt, DuPont Building, are exclusive selling agents.

Image 2: 1013 Overbrook Road as it appeared in 1936
(*The News Journal*, Wilmington, DE, November 21, 1936, p. 9).

TWELVE WILMINGTON MORNING NEWS, WILMINGTON, DELAWARE, WEDNESDAY, JUNE 5, 1935

STRAWBRIDGE & CLOTHIER

Market and Filbert at Eighth Street
PHILADELPHIA

Philadelphia Store Open Till 9 P. M. Wednesday

So doing will not change the schedule of working hours operative under former Code rules

This Will Permit All to Share in the

Great ANNIVERSARY SALE

. . . and to View the

MOTOHOME

Nothing that Philadelphia has ever seen in the way of homes has aroused so much interest and attention as the MOTOHOME which was opened yesterday with special services and dedicated by the First Lady of Pennsylvania. It is so entirely new, so practical, so fundamental in its concept of what the house of the future will be that everybody will want to see it.

A Marvelous Kitchen

The kitchen will elicit admiration from every woman. Arranged compactly in one continuous straight line are the electric refrigerator, sink, laundry tub and range. It is a fascinatingly attractive unit, with no place for dirt and grease to accumulate. The faucets are chromium plated; there is ample cupboard space for all the kitchen equipment. An exhaust removes all the cooking odors. There is an electric clock set in flush with the cabinet and there are convenient outlets for electric appliances.

Easily and Quickly Erected

The house can be built in a few weeks and is all ready for you to move into with three days' food supply. On a concrete foundation, a sturdy steel frame is anchored. The exterior walls come in large panels which are fastened to the steel frame. The roof is designed to be used as a sun deck. The floor is made of steel reinforced mineral compound. The windows are of the patented steel casement type, operated by a small crank and lock automatically. The house can be easily moved and more rooms can be added by "unbuttoning" the walls.

The bathroom is a marvel in itself and includes many details which you have never seen before. It would take many newspaper pages to tell all of the features of this wonderful new home. You will want to come and see it and get one of the circulars which give a complete description.

Several Styles and Sizes

MOTOHOMES come in several styles and sizes. The model shown here has a living room, two bedrooms, kitchen, bathroom and storage room. It is priced at $5,500 complete. Strawbridge & Clothier do not sell the MOTOHOME. It can be purchased only through American Houses, Inc. A representative will be in attendance at all times to answer any questions you may care to ask.

The house has been furnished by Strawbridge & Clothier and duplicates of any of the furnishings are on sale here.

Financing the MOTOHOME

Representatives of the Federal Housing Administration will be here to explain to you how the Government will help you to buy and build one of these homes, if you so desire.

The MOTOHOME Will Be Open Today From 9 A. M. to 9 P. M.

—and each day thereafter during regular business hours. AMERICAN MOTOHOMES are dedicated to the women of America because they are planned, designed and engineered entirely from the woman's point of view and they make possible a rebirth of the ideals of family life and home ownership attuned to a modern age in which the marvels of science remove drudgery from the home and lengthen the hours for leisure and culture.

Why This New Type of Home

One of the greatest problems that has grown out of the depression has been the need of reducing the cost of building to a price that is not out of balance with the other necessities of life. It is obvious that by manufacturing houses on a mass-production principle, as exemplified in the automobile industry, the cost can be brought down to a point where everybody can afford to own their home and give their children a better chance in life.

Developed Through Long Research

AMERICAN *MOTOHOMES* are the first and only prefabricated, mass-produced houses that come to you "complete with food in the kitchen." They have been developed through long research. Architects, engineers and technicians have planned and replanned, tested and re-tested before any final conclusions were made. As a result, these houses are lightning-proof, termite-proof and have been tested to withstand a high wind velocity. The whole house is air-conditioned. It gets its name, "MOTOHOME," from the magic moto-unit—"the thing that makes the house go." This moto-unit is the mechanical nerve centre of the MOTOHOME. All the plumbing, air-conditioning, all the electrical and mechanical devices come complete in a large metal cabinet around which the house is built. It has no attic and no cellar—none is necessary.

The MOTOHOME is located in the Exhibition Salon on the Eighth Floor —continuous elevator service.

A Real Innovation

Introduced by Strawbridge & Clothier for the Benefit of All Customers

The Shoppers Bonus

There is something new in the mercantile world! There have been certain inequalities in stores throughout the country, hitherto regarded as unavoidable, in the advantages conferred upon the several classes of cash and charge customers. It remained for Strawbridge & Clothier to originate an EQUALIZATION PLAN, FAIR TO ALL CUSTOMERS, with specific benefits to each, in accordance with the preference and convenience of each as to the method of payment for the merchandise purchased. It is so simple and so equitable in its application that we ourselves wonder that we have hesitated until now in making completely effective the plan we have had in mind.

Two Per Cent. Off for Cash

On cash purchases, 2 per cent. of the price of any merchandise (except the few articles on which price is regulated by manufacturer's requirement) is redeemable in either money or merchandise. You may accumulate your cash sales checks and take them to a Service Desk to be exchanged for Shoppers' Bonus Coupons, which you may shop with or cash immediately.

One Per Cent. Off Monthly Accounts

Charge Accounts paid in full by the 15th of the month following that in which purchases were made will entitle you to receive on the next quarterly bonus date a Bonus Coupon equal to 1 per cent. of your purchases. (First Bonus Coupon to be mailed October 1, on bills paid in accordance with this plan for prompt monthly payment, and quarterly thereafter.)

The Two-Month Payment Plan

Charge customers may defer payment until the 15th of the second month following the month in which purchases were made. Accounts so paid will not be entitled to the bonus. This gives you an extension of one month, as compared with our former terms. All bills will be mailed monthly as usual.

More Time on Deferred-Payments

Details of this plan may be had from our Credit Department. The most significant change, however, is that carrying charges start on the second month following the month in which purchases were made.

Where to Look for What You Want in the Great Anniversary Sale From 9 Till 9 TODAY!

Dinner will be served in the Restaurant from 5:30 to 7:30—an unusually fine meal for 85c or order a la carte, if you prefer. There will be a special 45c Anniversary dinner in the Basement Tea Room, and Fountain Lunch, in addition to the regular menu.

(Our Suburban Stores will not be open in the evening.)

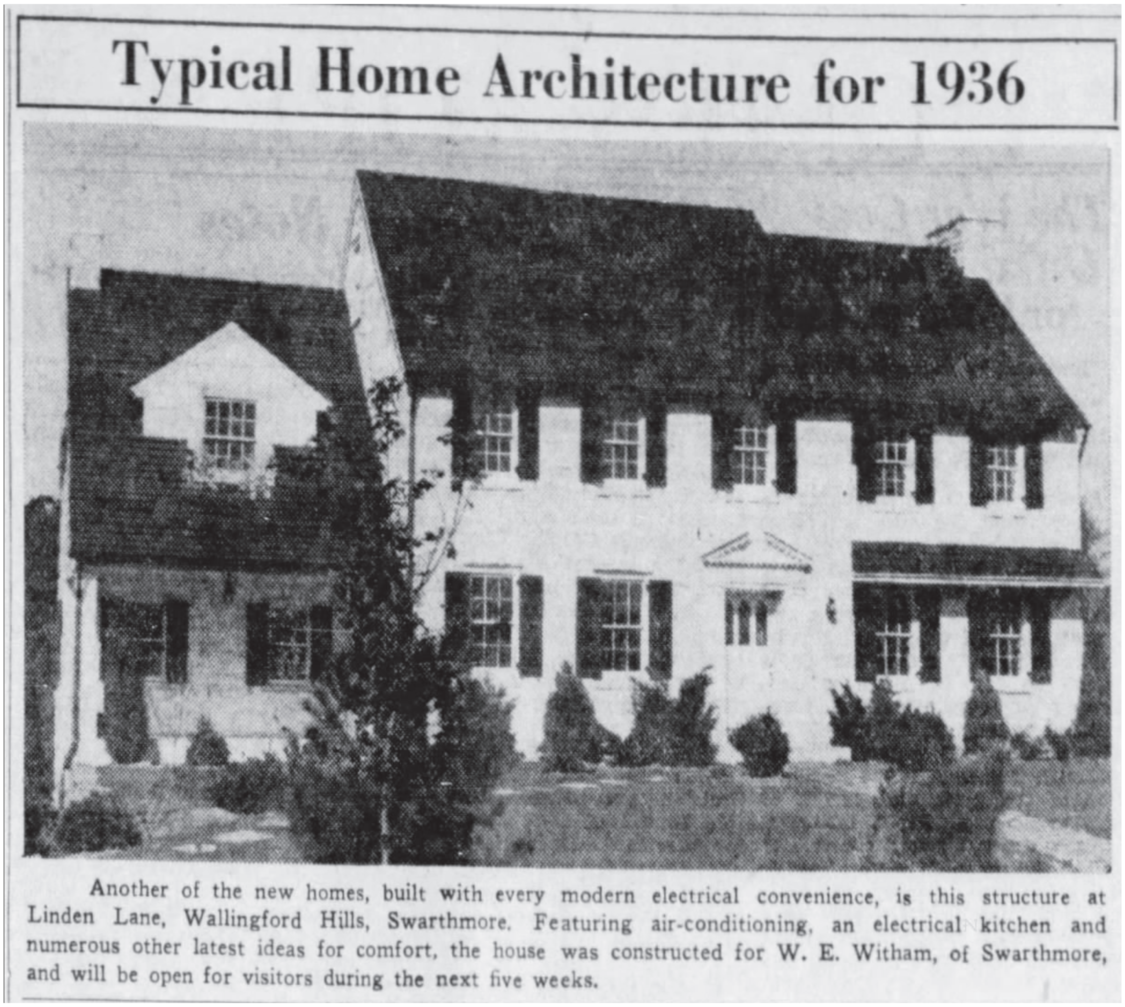
. . . . *a Great Sale*

—because many *great* interesting new things are being done.

—because many extraordinary values on most desirable merchandise have been achieved.

—because a great many experts have surveyed a great many markets and have secured a vast quantity of opportunities to present to the truly great market of Philadelphia—3,000,000 home-loving citizens.

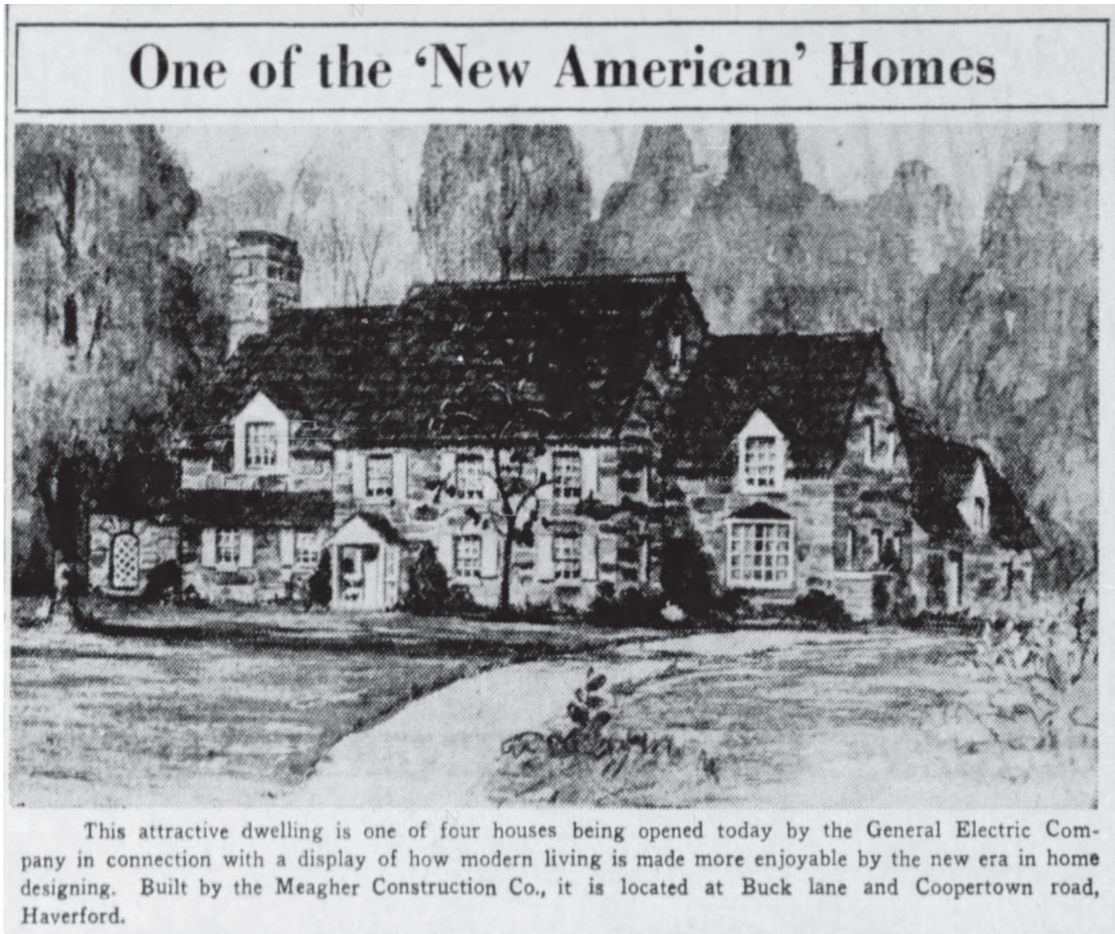
Image 3: Advertisement to view a Motohome at Strawbridge & Clothier in Philadelphia (*Wilmington Morning News*, June 5, 1935, p. 12).



Typical Home Architecture for 1936

Another of the new homes, built with every modern electrical convenience, is this structure at Linden Lane, Wallingford Hills, Swarthmore. Featuring air-conditioning, an electrical kitchen and numerous other latest ideas for comfort, the house was constructed for W. E. Witham, of Swarthmore, and will be open for visitors during the next five weeks.

Image 4: Contemporaneous General Electric house in Swarthmore, Pennsylvania (*The Philadelphia Inquirer*, October 31, 1936, p. 11).



One of the 'New American' Homes

This attractive dwelling is one of four houses being opened today by the General Electric Company in connection with a display of how modern living is made more enjoyable by the new era in home designing. Built by the Meagher Construction Co., it is located at Buck lane and Coopertown road, Haverford.

Image 5: Contemporaneous General Electric house in Haverford, Pennsylvania (*The Philadelphia Inquirer*, October 31, 1936, p. 10).

Image 6: Altered window arrangement on the front elevation, as it appears today

Image 7: Interior corner panel connection beneath window sills

Image 8: Residual water staining from previous leaky roof

Image 9: Paint peeling below steel angle

Image 10: Slight gap visible between the angle and wall panel

Image 11: Paint loss and blistering concentrated in the corners where the stiles and window sashes meet

Image 12: Southern elevation experiencing paint loss where the panel meets the foundation

Image 13: Biological growth and paint loss on northern elevation

Image 14: Charles and Ray Eames House (Case Study House #8)
(Elizabeth Trumbull, 2019)

Image 15: Open air court between the house and studio spaces
(Elizabeth Trumbull, 2019)

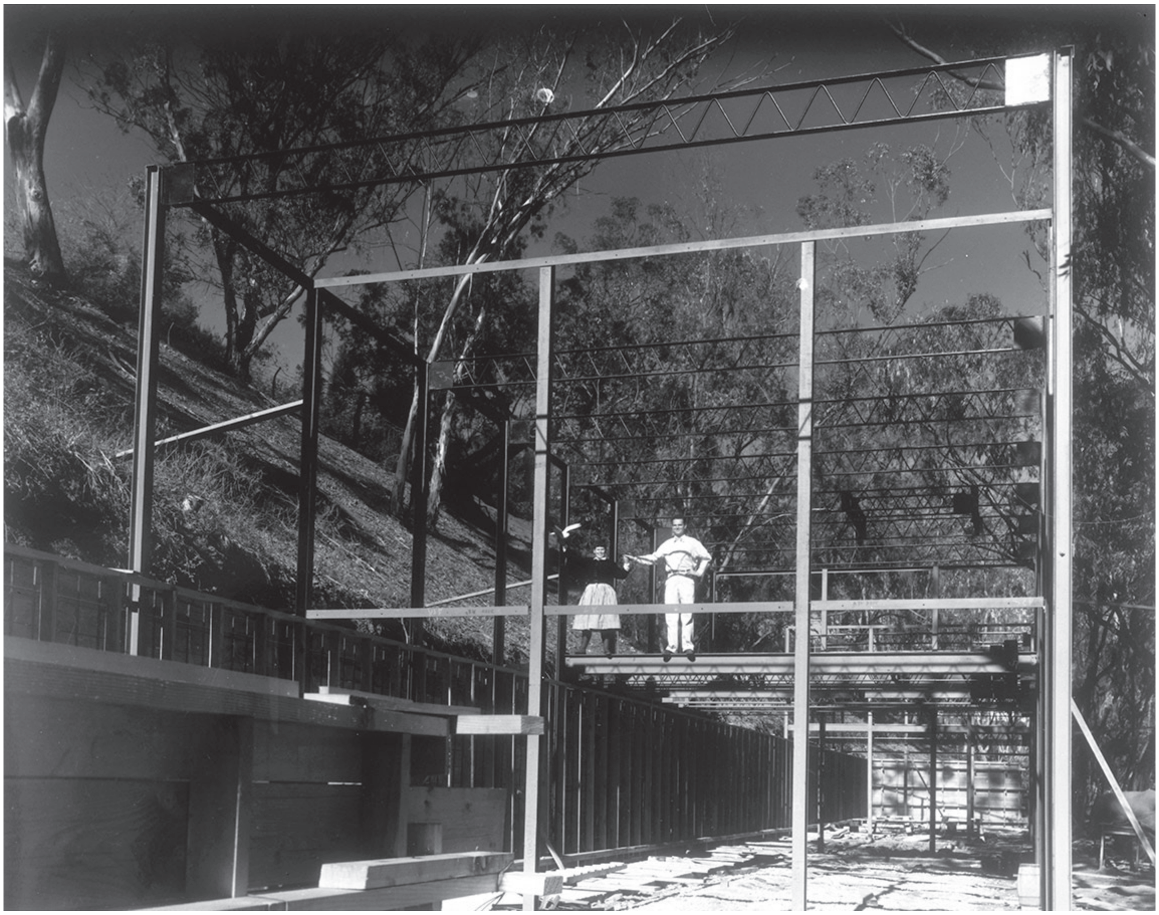


Image 16: Roof configuration with flat Warren trusses with Charles and Ray (1949, © Eames Office LLC (eamesoffice.com)).

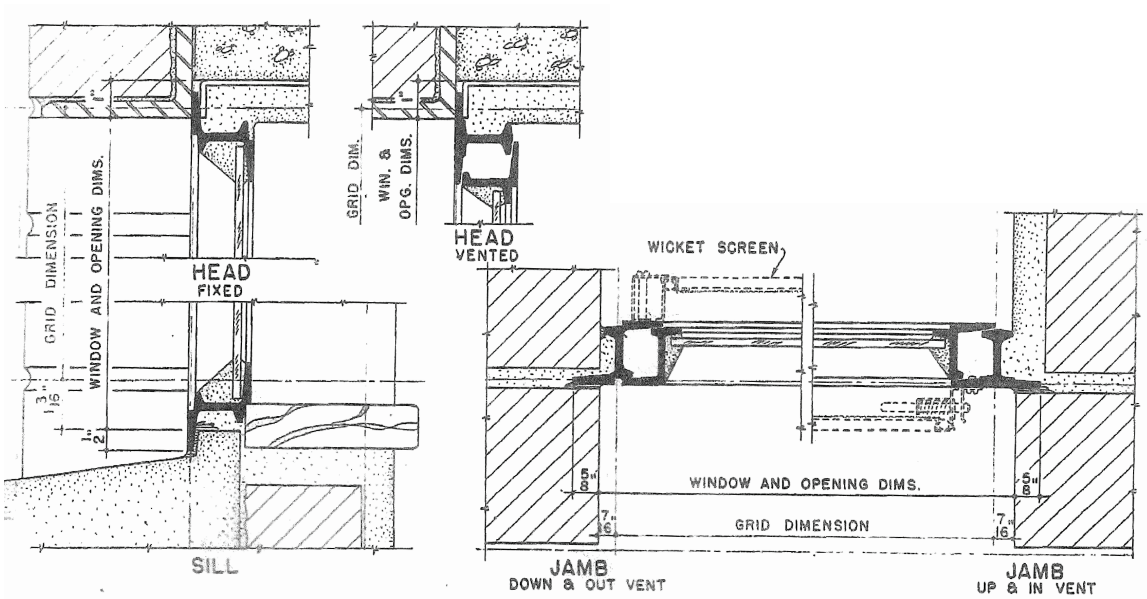


Image 17: Truscon window sash construction details (*Truscon Steel Windows and Industrial Doors,* catalogue, 1948 Edition, p. 39)

Image 18: Cemesto advertisement
(Celotex Corporation, "Arts & Architecture," April 1948, p. 47).

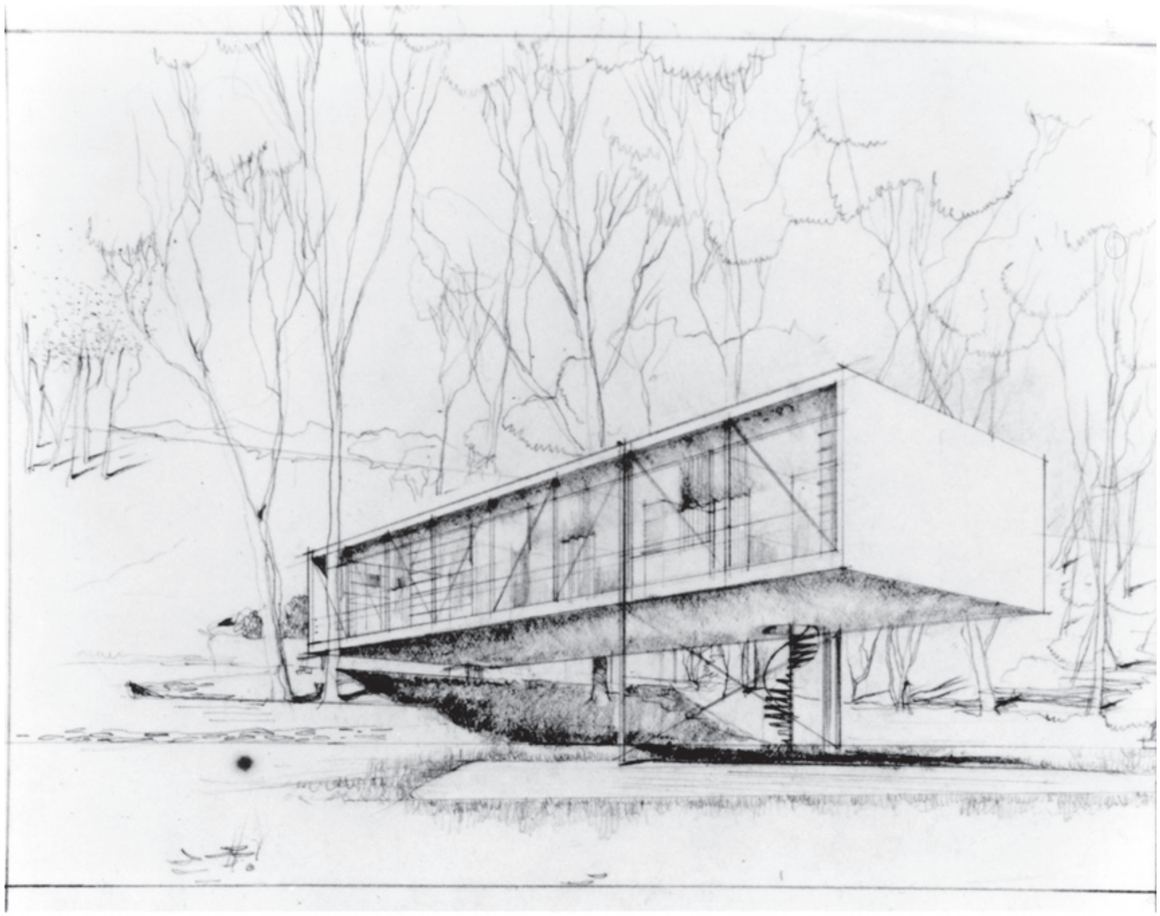


Image 19: Eero Saarinen and Charles Eames design for Case Study House #8 (Eero Saarinen and Charles Eames, *Case Study House #8*, 1948, © Eames Office LLC (eamesoffice.com)).

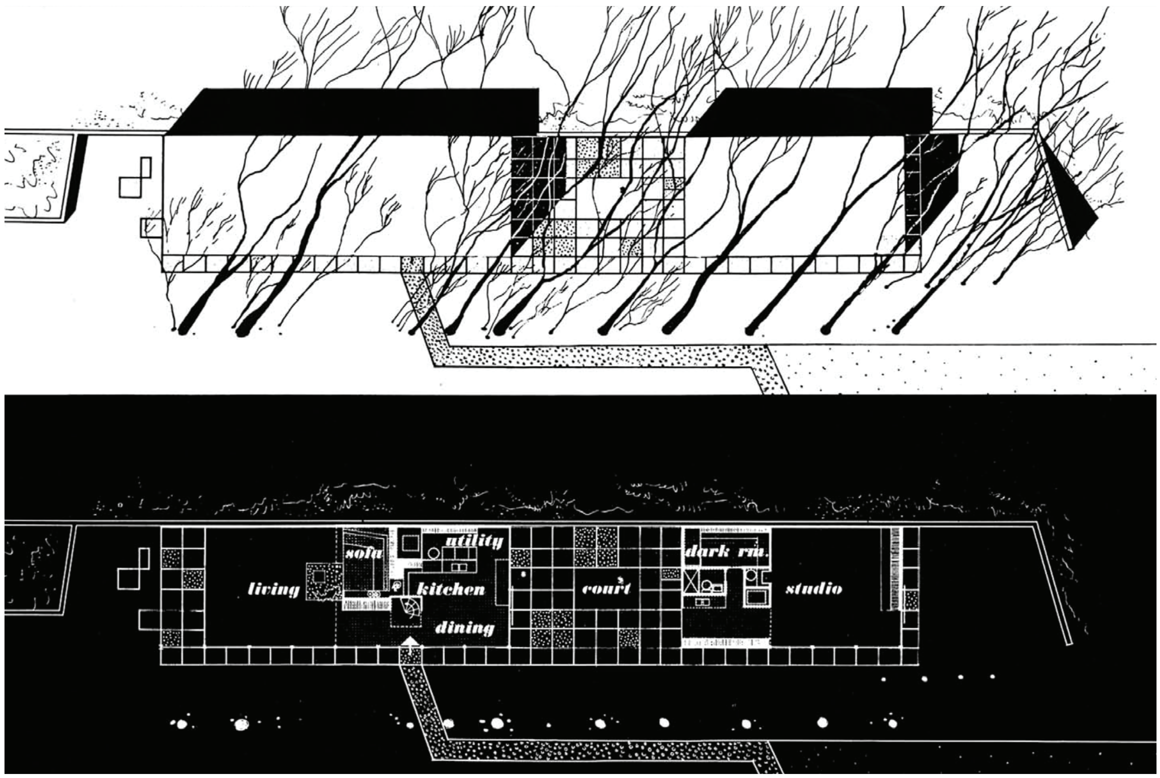


Image 20: Charles and Ray Eames design for Case Study House #8
(Charles Eames and Ray Eames, "Arts & Architecture," *Case Study House #8*,
December 1949, p. 28).

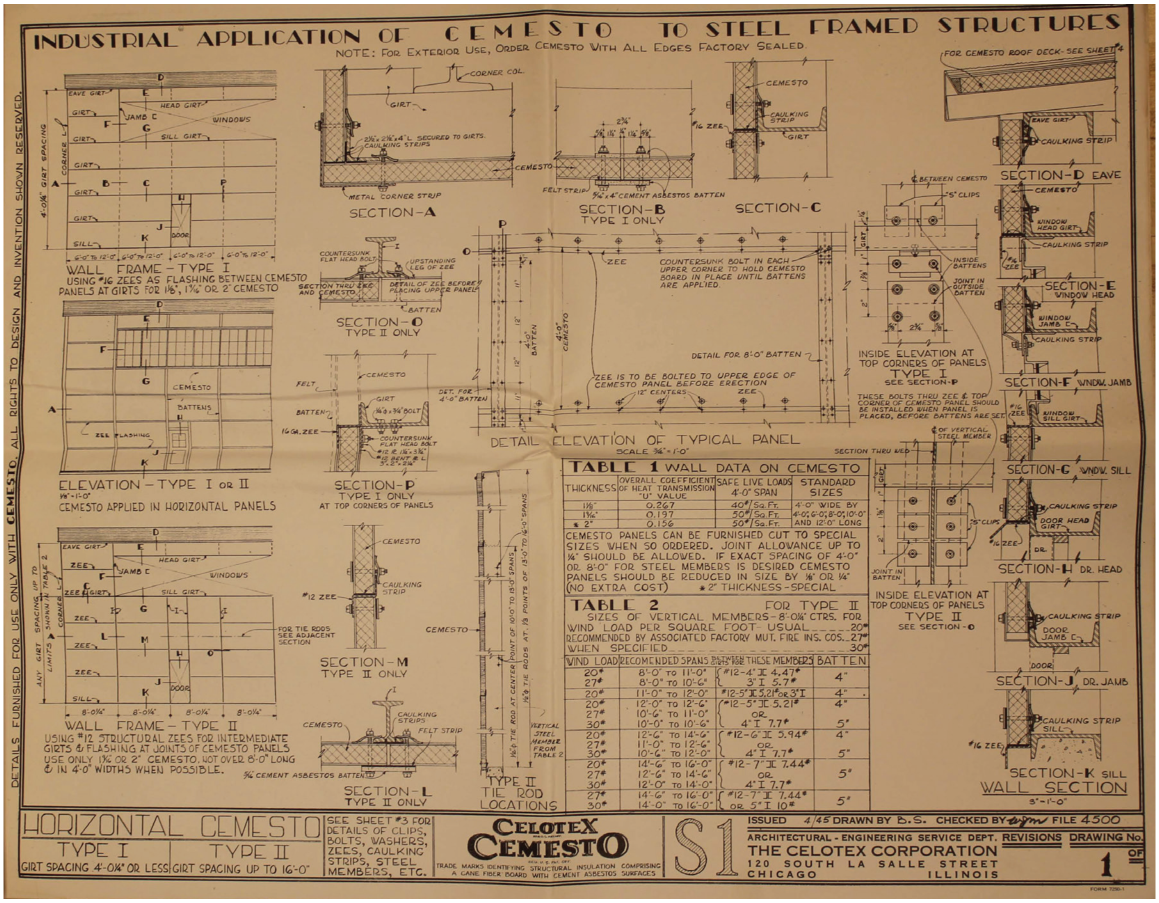


Image 21: Cemesto Manual depiction of panel connections (Celotex Corporation, n.d., courtesy of Michael C. Henry).

Image 22: John Blair Building
(Google, September 2017, accessed April 22, 2019)

Image 23: I-beams divide the windows and Vermarco panels on the building (Google, October 2018, accessed April 22, 2019)

Image 24: Exterior view of the Blair Building along Michigan Avenue in 2011 (Google, June 2011, accessed April 22, 2019)

Image 25: Exterior view of the Blair Building along Michigan Avenue today (Google, August 2015, accessed April 22, 2019)

Image 26: GREC Architects' 2015 remodel
(Mark Ballogg, "Architect Magazie," October 30, 2015, accessed April 22, 2019).

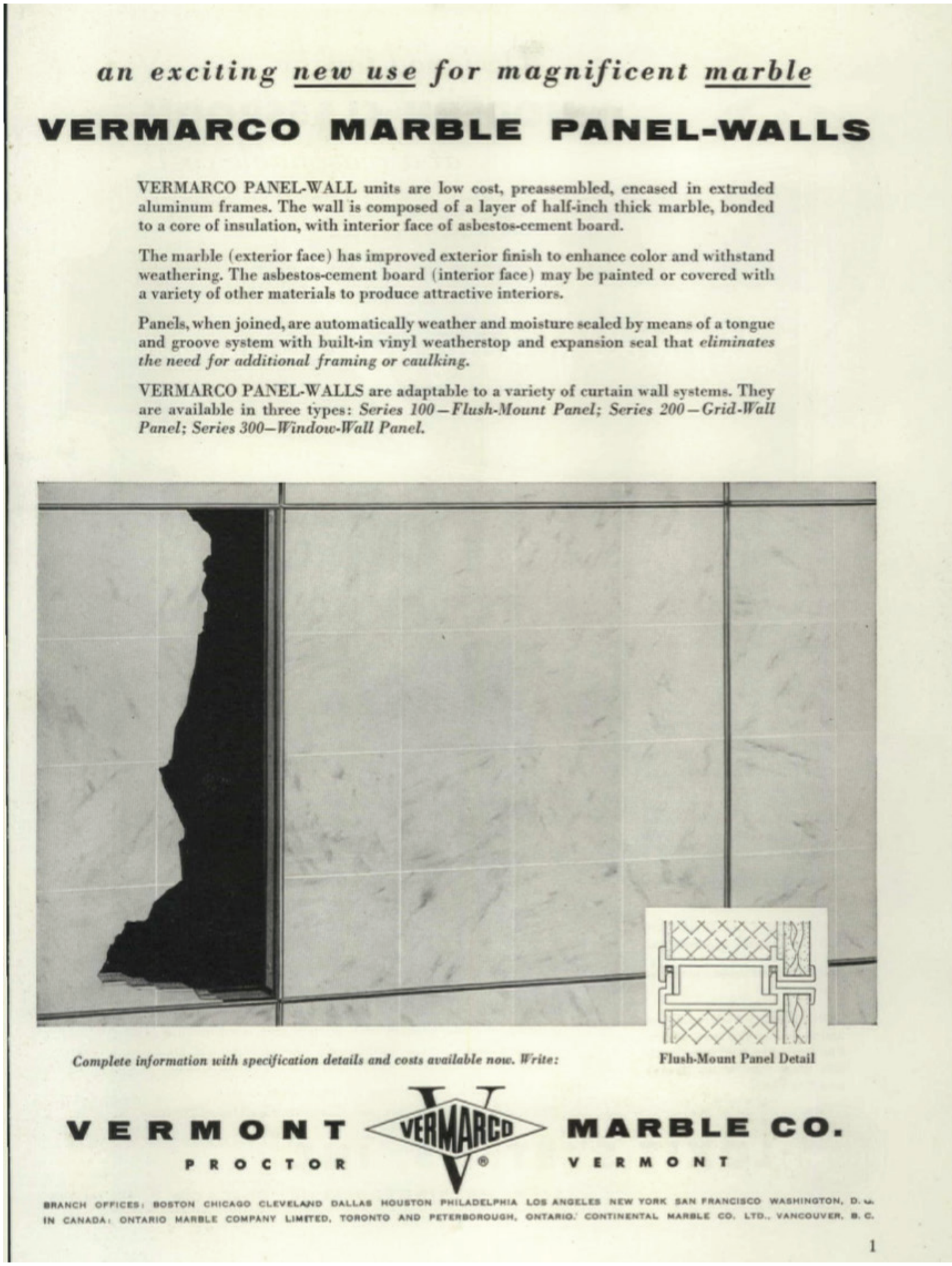


Image 27: Vermarco advertisement
(Vermont Marble Company, *AIA Journal*, August 1959, p. 1).

APPENDIX B: TABLES

This appendix contains tables providing general recommendation suggestions for each type of potential pathology referenced in this thesis.

Table 5.1

Motohome Deterioration Mechanism Potential Responses

Deterioration	*Abstention*	*Mitigation*	*Reconstitution*	*Circumvention*	*Substitution*	*Acceleration*
Pyrestos resting on bare concrete	Recommended	Consideration	Consideration	Recommended	Consideration	Not Recommended
Water pooling along tops of windows	Consideration	Not Recommended	Not Recommended	Recommended	Recommended	Not Recommended
Water trapped beneath cornice	Not Recommended	Consideration	Consideration	Recommended	Recommended	Not Recommended
Water pooling underneath windowsills	Consideration	Not Recommended	Consideration	Recommended	Not Recommended	Not Recommended
Exterior paint blistering	Recommended	Consideration	Recommended	Not Recommended	Not Recommended	Consideration
Biological growth	Recommended	Recommended	Consideration	Not Recommended	Not Recommended	Not Recommended
Freeze-thaw cycling	Recommended	Not Recommended	Not Recommended	Consideration	Recommended	Not Recommended

Key: **Recommended** **Consideration** **Not Recommended**

Table 5.2						
Eames House Deterioration Mechanism Potential Responses						
Deterioration	*Abstention*	*Mitigation*	*Reconstitution*	*Circumvention*	*Substitution*	*Acceleration*
Asphaltic adhesive failure						
Loss of Ferox/ Inadequate application of Ferox						
Leeching of Ferox byproducts over time						
Bolting through boards						
Caulk deterioration						
Field cutting						
Ultraviolet solar radiation damage						

Key:		
Recommended	Consideration	Not Recommended

Table 5.3

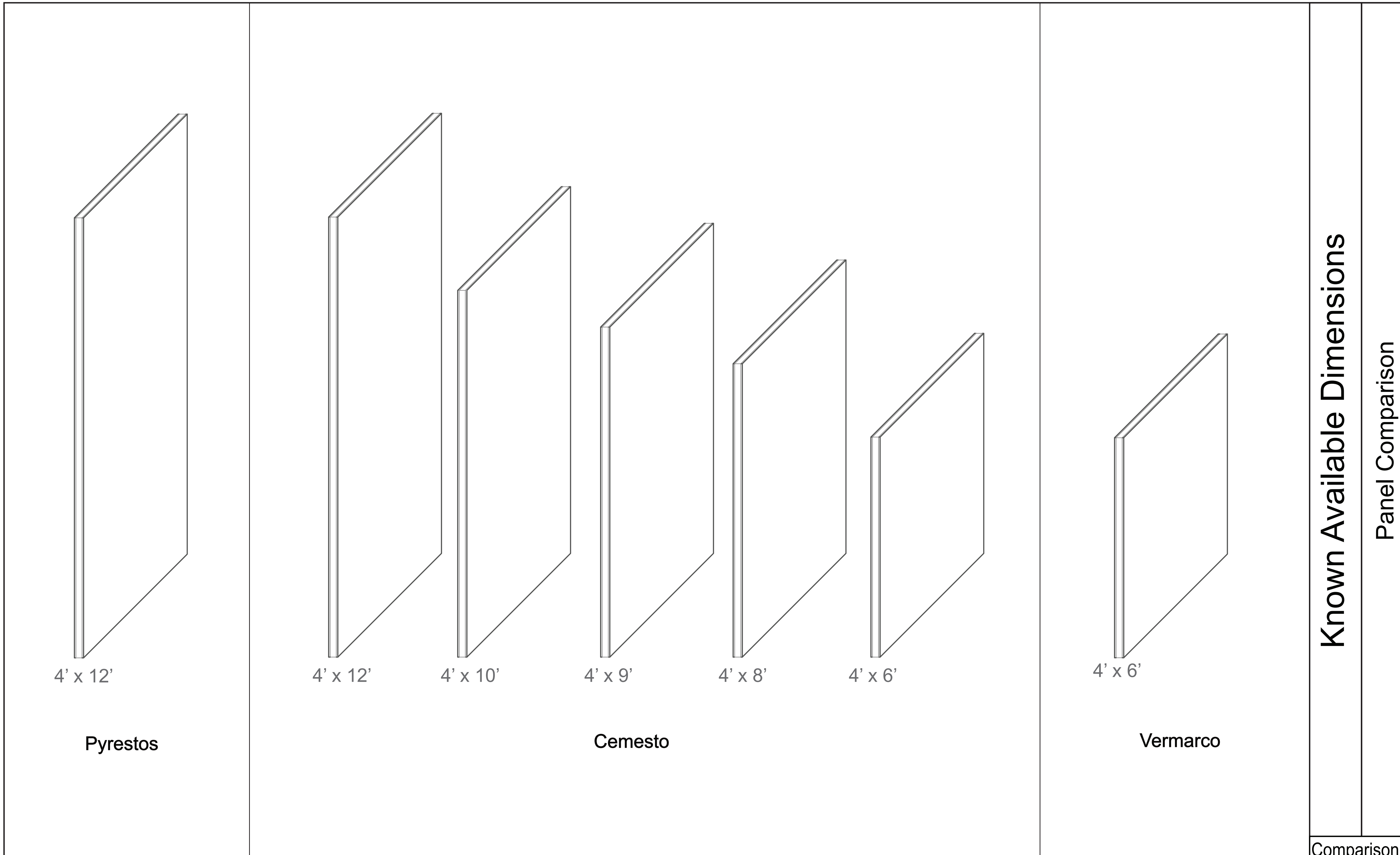
John Blair Building Deterioration Mechanism Potential Responses

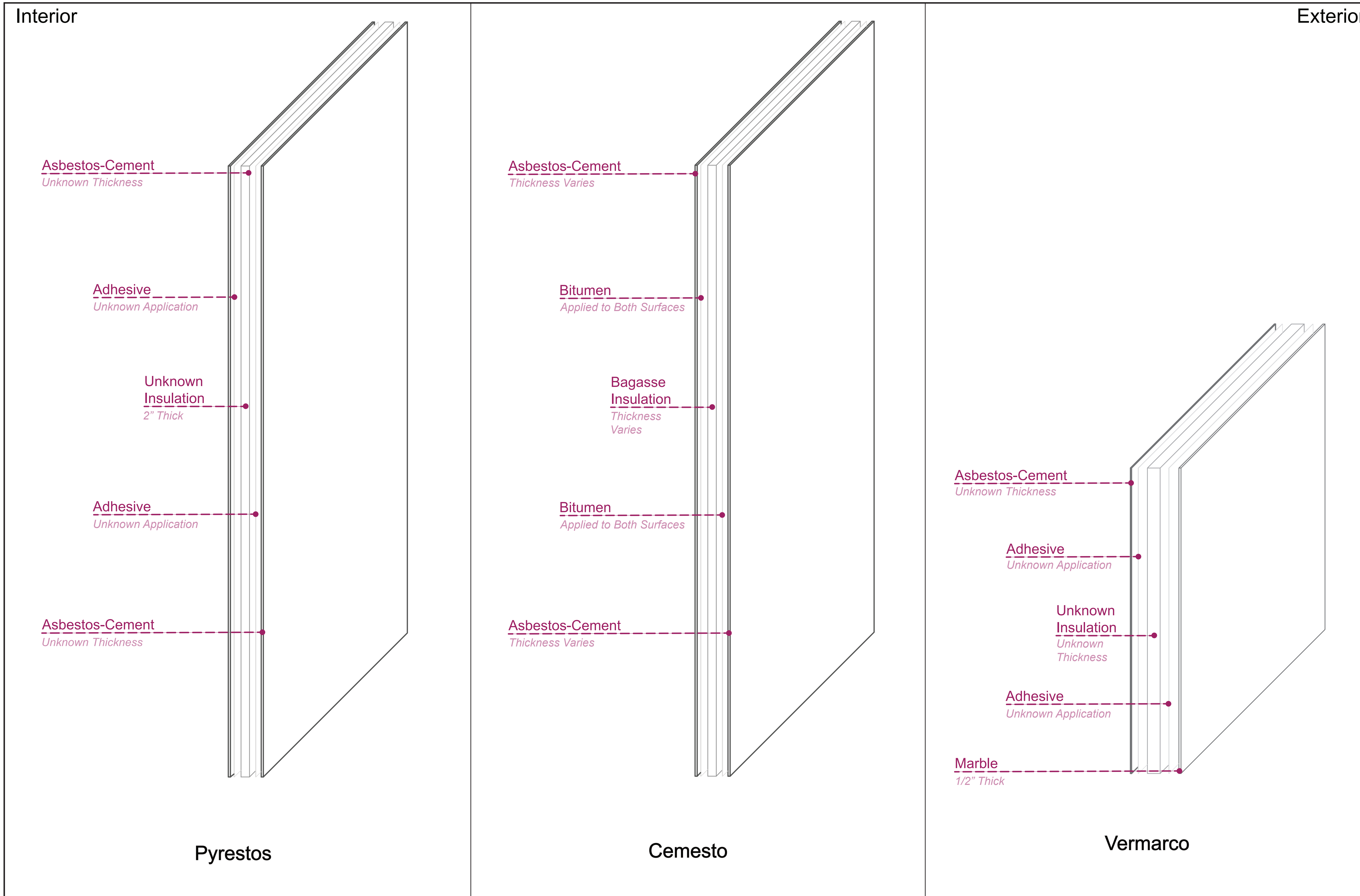
Deterioration	*Abstention*	*Mitigation*	*Reconstitution*	*Circumvention*	*Substitution*	*Acceleration*
Weathering of the vinyl expansion seal						
Deterioration of adhesive layer						
Freeze-thaw cycling						
Crack in exterior marble slab						

Key:		**Recommended**		**Consideration**		**Not Recommended**

APPENDIX C: ILLUSTRATIONS

This appendix contains 11x17 illustrations produced to aid a comparison between the asbestos-cement products discussed in the case study section of this thesis.

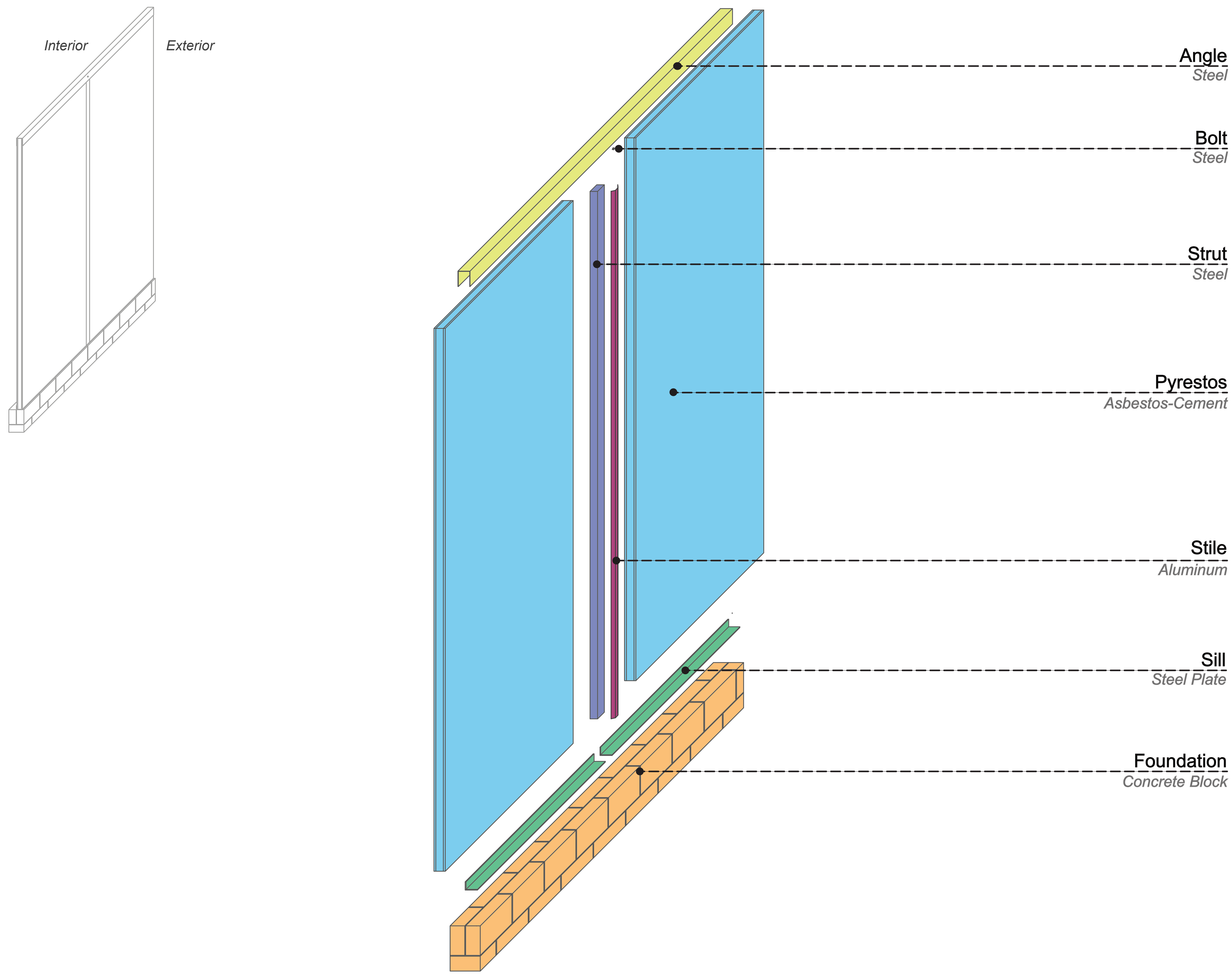

4’ x 12’
Pyrestos
4’ x 12’
4’ x 10’
4’ x 9’
4’ x 8’
4’ x 6’
Cemesto
4’ x 6’
Vermarco
Known Available Dimensions
Panel Comparison
Comparison 1



Understanding the Layers

Panel Comparison

Comparison 2



Motohome

Framing System Utilizing Pyrestos Panel Boards

Pyrestos 1

Example 1: Paint loss at the interface between angle and panel. The gap between the two surfaces is also visible.

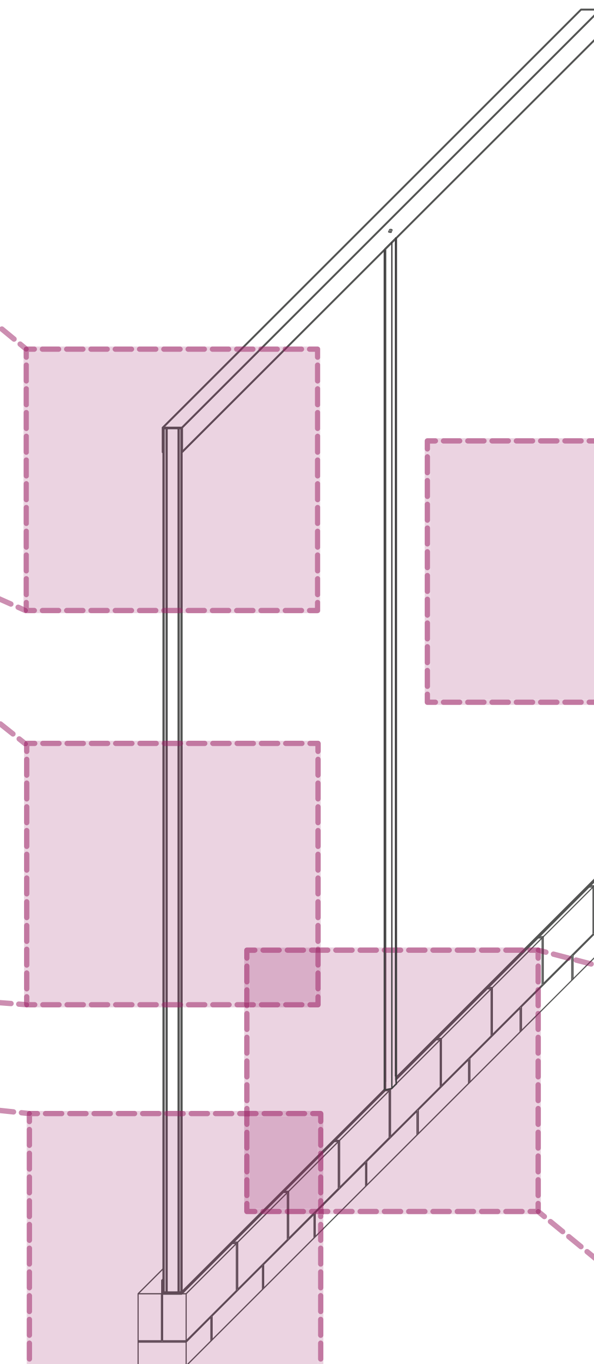
See Mechanism 1 on next page

Example 2: Paint loss and blistering above window sashes, below the steel angle, and around the vertical stiles.

See Mechanisms 1, 3, and 4 on next page

Example 3: Water infiltration where concrete cap has been lost between foundation and wall panel may cause rust jacking.

See Mechanism 2 on next page



Example 4: Paint loss and blistering below window sills, especially near the vertical stile connections.

See Mechanism 3 on next page

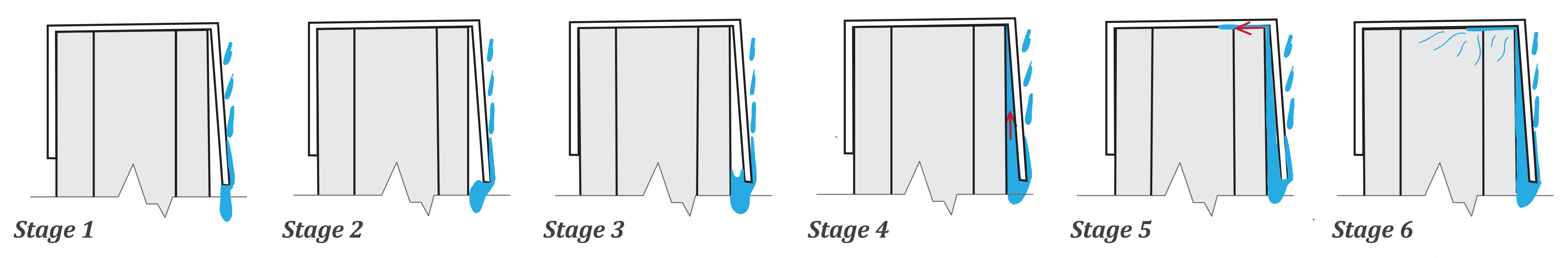
Example 4: Paint loss, water infiltration, and biological growth where the foundation meets wall panel.

See Mechanism 4 on next page

Motohome

Potential Deterioration Mechanisms

Mechanism 1



Stage 1: *Moisture exposure & formation of a drip edge*

Stage 2: *Drip rate increases and brings moisture in contact with panel*

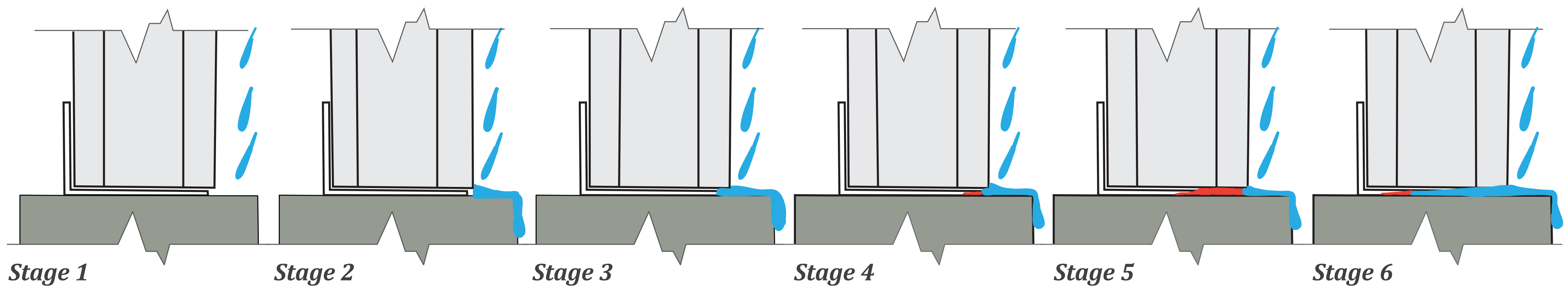
Stage 3: *Capillary bridging occurs between angle and panel wall*

Stage 4: *Capillary rise draws moisture into gap between angle and panel*

Stage 5: *Moisture reaches top of panel*

Stage 6: *Moisture travels into the panel*

Mechanism 2



Stage 1: *Moisture exposure*

Stage 2: *Pooling begins to occur at base of panel wall*

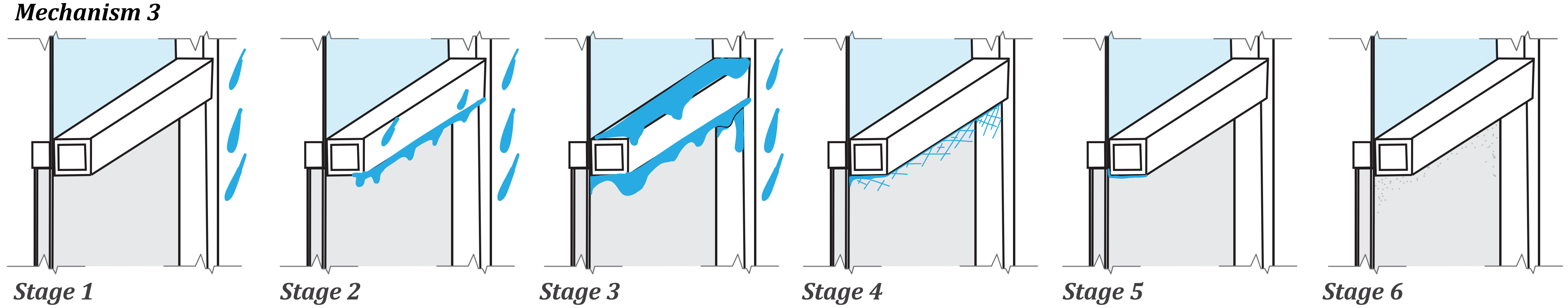
Stage 3: *Moisture travels into small gap beneath panel*

Stage 4: *Repeated exposure to moisture corrodes metal sill plate*

Stage 5: *Over time corrosion spreads and jacking occurs*

Stage 6: *Corrosion jacking creates a larger gap between panel and foundation susceptible to water*

Mechanism 3



Stage 1: *Moisture exposure*

Stage 2: *Drip edge forms*

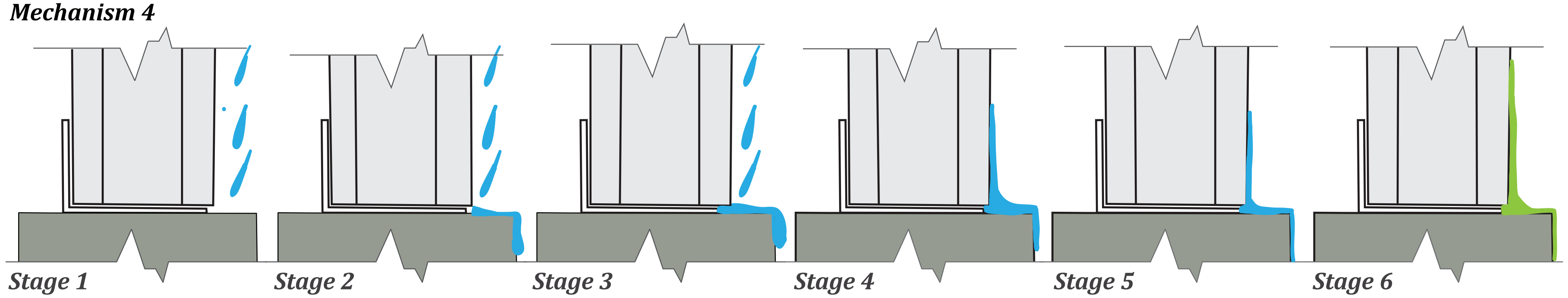
Stage 3: *Pooling occurs on top of window sill, intensifying drip edge, and moisture runs down vertical stile*

Stage 4: *Moisture is protected by sill and does not dry quickly*

Stage 5: *Moisture infiltrates area between sill and panel*

Stage 6: *Moisture interferes with efficacy of finish layer*

Mechanism 4



Stage 1: *Moisture exposure*

Stage 2: *Pooling begins to occur at base of panel wall*

Stage 3: *Moisture travels into small gap beneath panel*

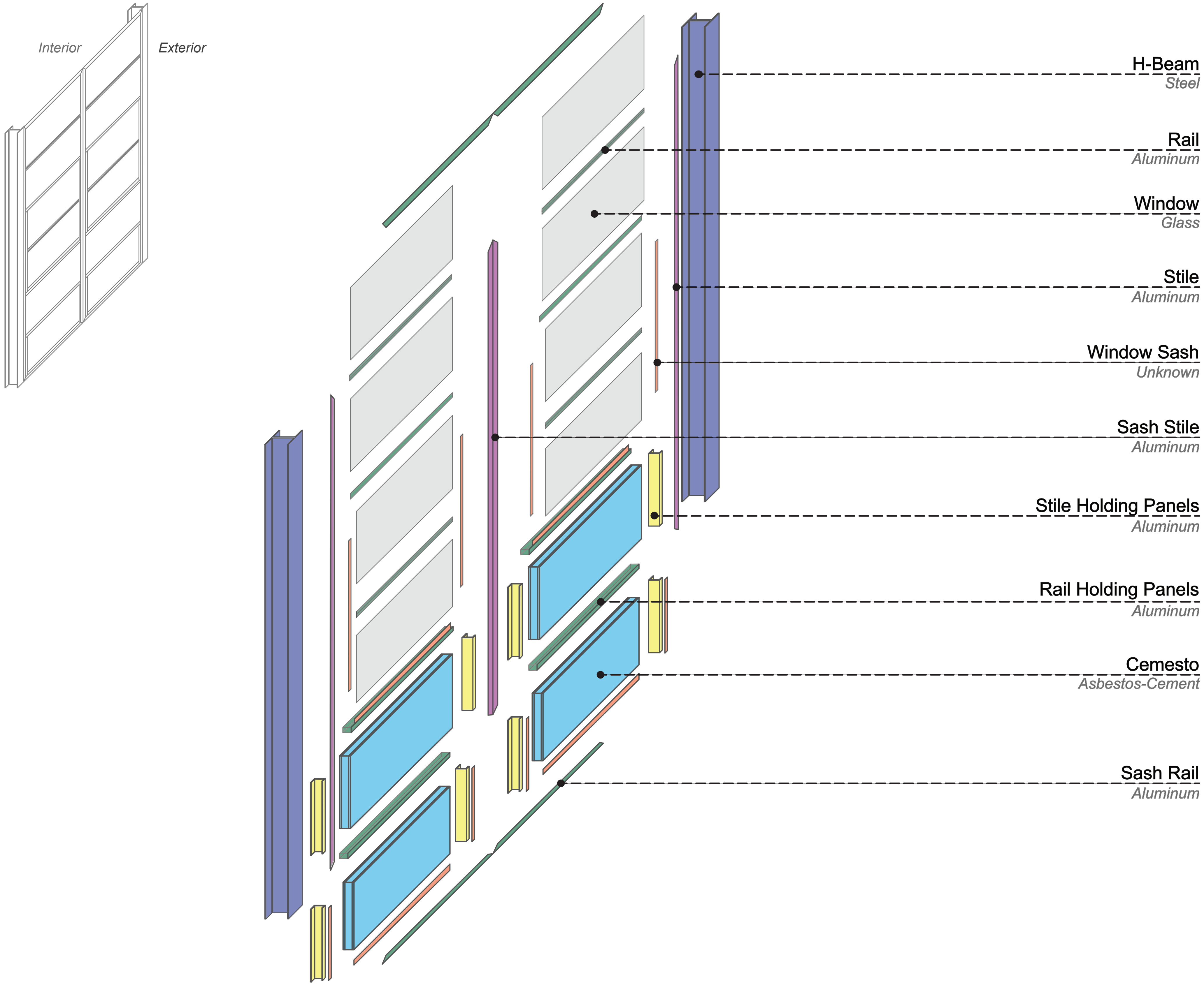
Stage 4: *North-facing panels and shaded panels experience little drying*

Stage 5: *Moisture remains on and below panel wall*

Stage 6: *Biological Growth forms and propagates*

Panel Product	Concrete Foundation	Metal Feature	Window	Moisture	Corrosion Product	Biological Growth

Pyrestos 3



Eames House (Case Study House #8)

Framing System Utilizing Cemesto Panel Boards

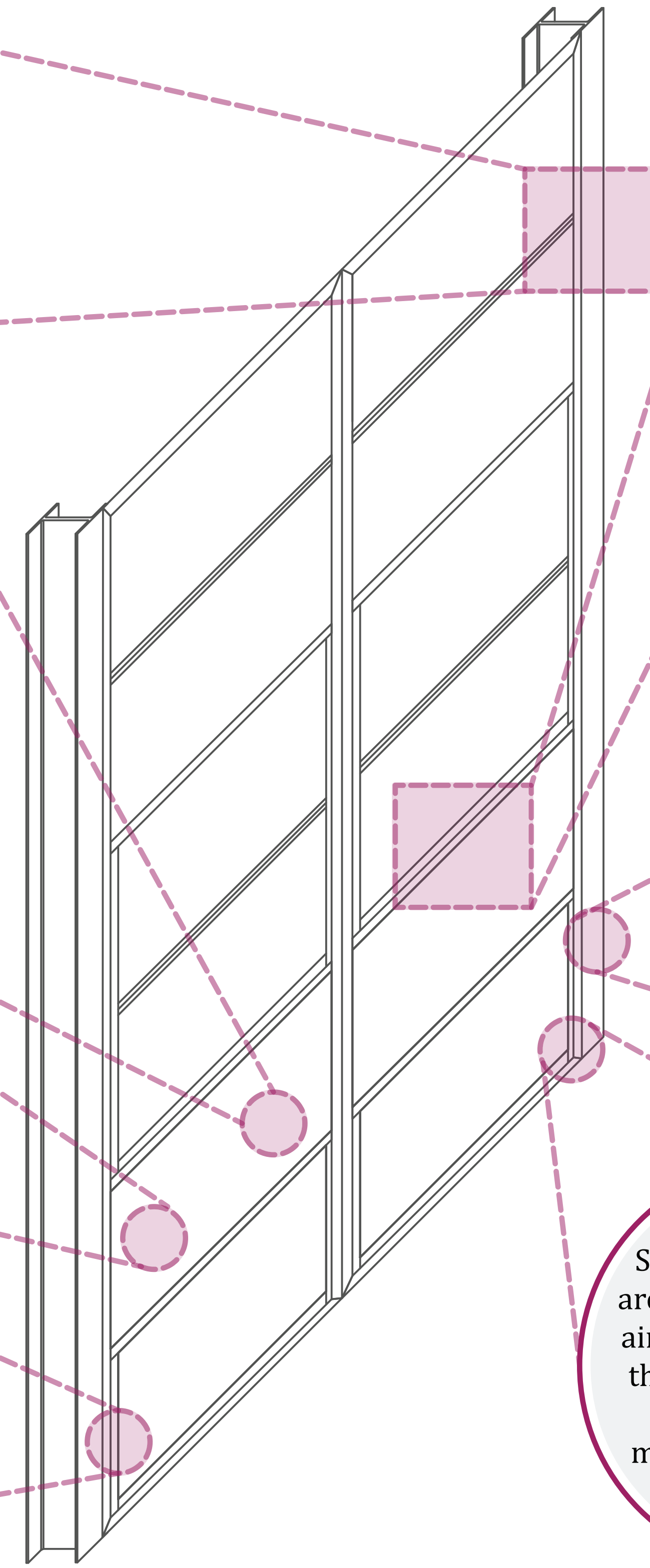
Cemesto 1

Photo by Elizabeth Trumbull

Prevention:
The Eames House metal framing system has utilized finishes as protective coatings to prevent a corrosion product from forming.

Photo by Elizabeth Trumbull

Deterioration:
Some Cemesto panels that have lost substrate have been encapsulated to prevent further loss and ensure asbestos fibers are contained.



Example 1:
The Ferox treatment may not have been evenly distributed in the manufacturing slurry bath, leading to potential rot and insect activity within the panel.

See Mechanism 1 on next page

Example 2:
The asphaltic adhesive layer may have deteriorated over time, allowing moisture to pass between the different layers of the panel.

See Mechanism 2 on next page

Example 3:
Field cutting of the Cemesto panels may have left edges susceptible to water infiltration.

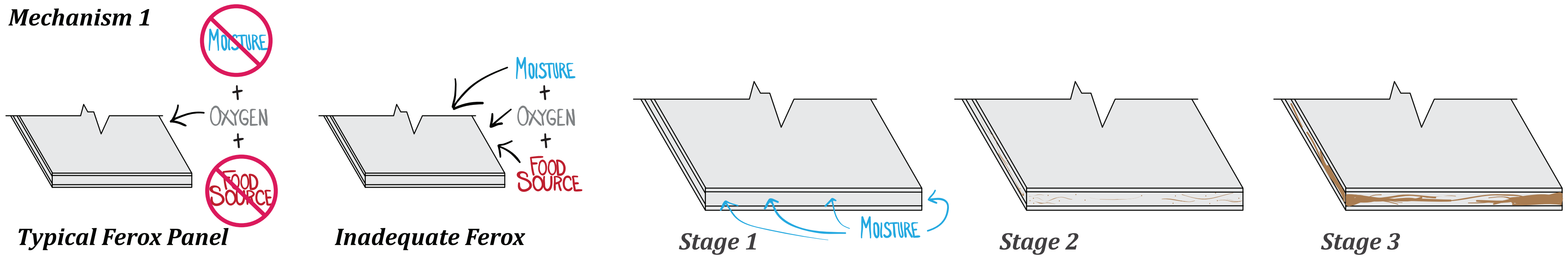
See Mechanism 3 on next page

Example 4:
Installation guidelines require the surface of the Cemesto panel to be perforated by hardware to secure the panel into a steel frame. The caulking over these bolts may have deteriorated over time.

See Mechanism 4 on next page

Example 5:
Some Cemesto panels are louvered to promote air circulation, however these panels may be in contact with more moisture sources than stationary panels.

Mechanism 1



Typical Ferox Protection: *Even application does not allow the bagasse to act as a food source.*

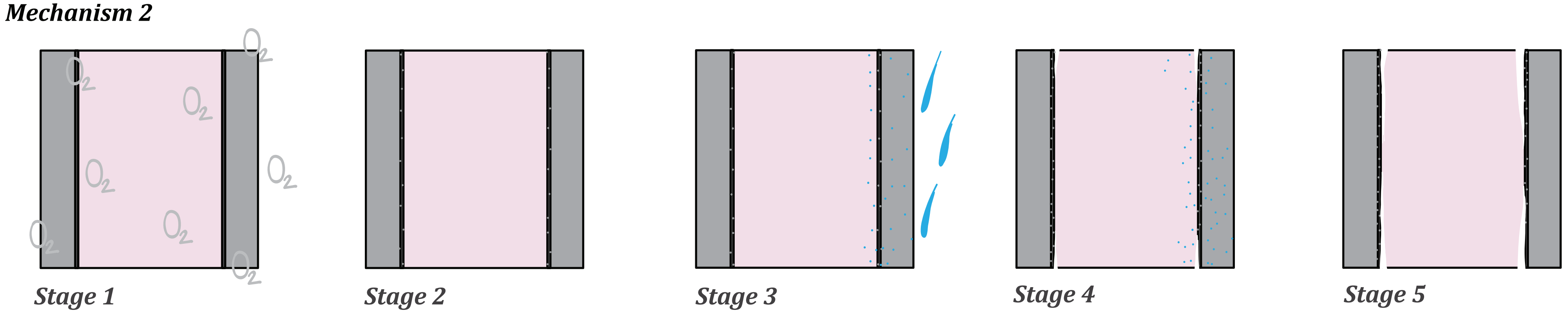
Inadequate Ferox Protection: *All necessary and suf icient factors for biological activity can exist.*

Stage 1: *Water enters the bagasse.*

Stage 2: *Unprotected bagasse serves as a food source.*

Stage 3: *Rot or insects habituate between the asbestos-cement layers.*

Mechanism 2



Stage 1: *The asphaltic adhesive layers are exposed to oxygen.*

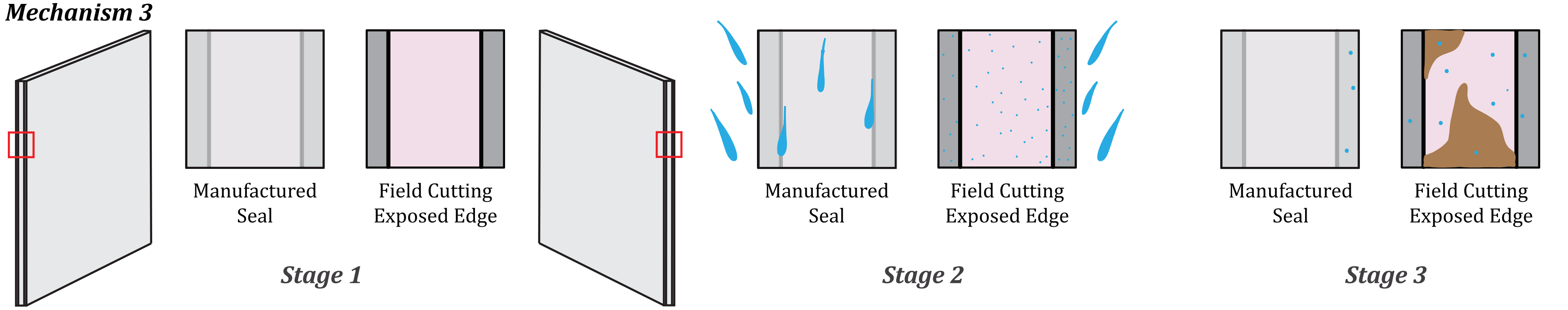
Stage 2: *Over time the adhesive deteriorates.*

Stage 3: *Areas now exist where water can penetrate into the bagasse layer, but may not be able to easily dry.*

Stage 4: *Repeated exposure to moisture further deteriorates the adhesive and layers begin to separate.*

Stage 5: *Separation between layers worsens over time.*

Mechanism 3



Stage 1: *Edge type*

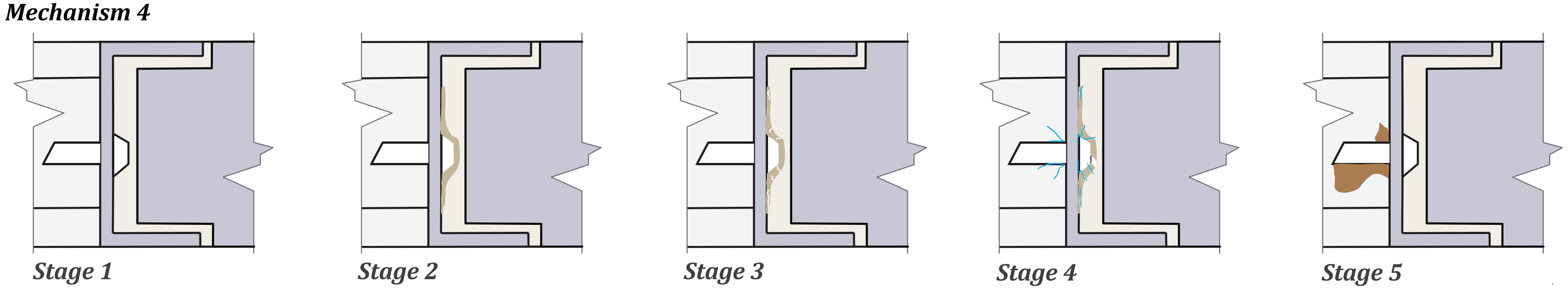
Manufactured Seal: *Edges are protected against moisture.*

Field-Cut Exposed Edge: *No protection against moisture exists.*

Stage 2: *Moisture cannot enter panel with the manufactured seal, but has no barrier to enter the ield-cut panel.*

Stage 3: *The manufactured seal panel is protected against deterioration for a longer period of time. See* ***Mechanisms 1 & 2*** *for further deterioration.*

Mechanism 4



Stage 1: *Rabbeting requires bolts to install the panel.*

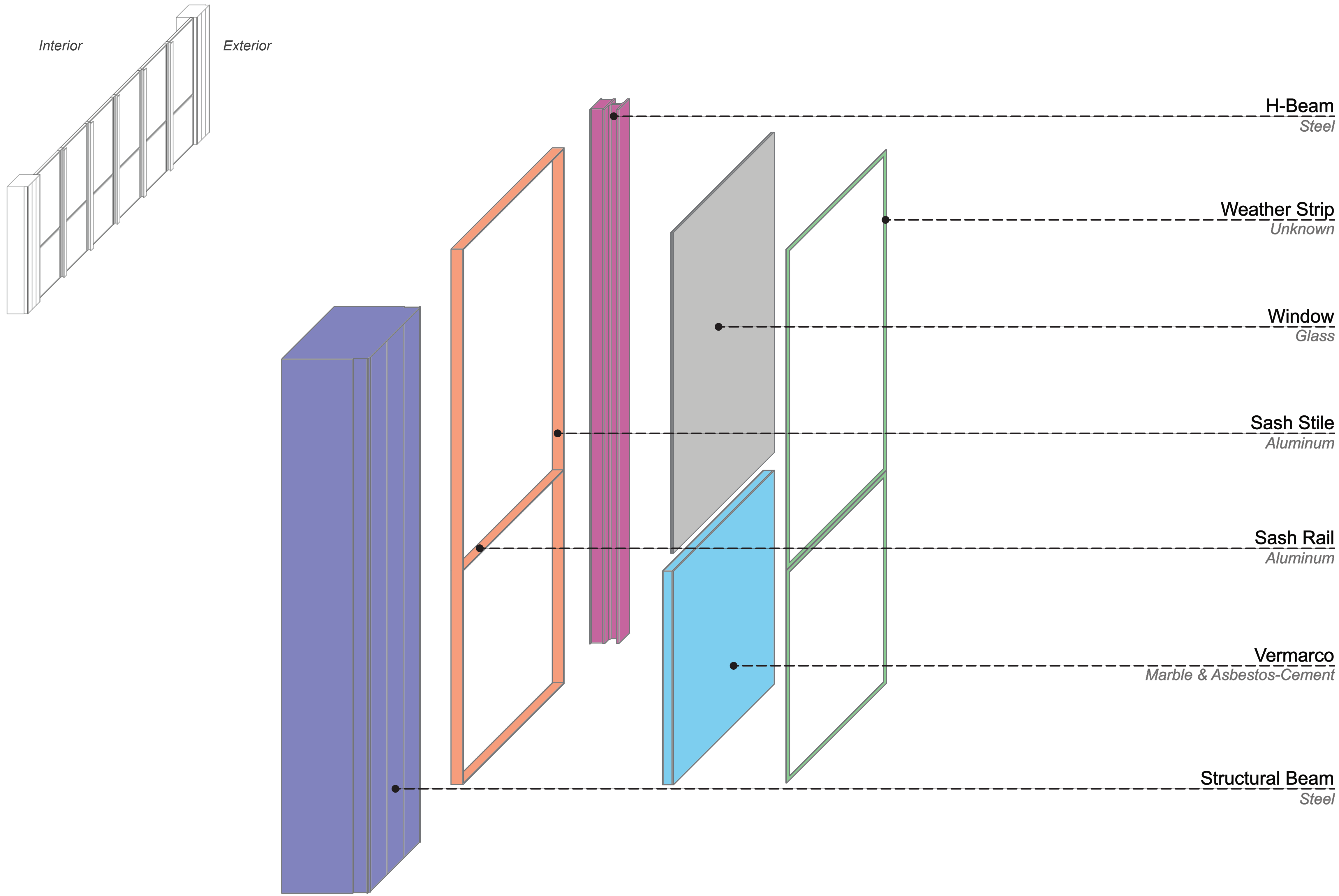
Stage 2: *Bolts must be sealed with caulk to minimize moisture in iltration.*

Stage 3: *Caulk can weaken over time due to yellowing and embrittlement.*

Stage 4: *Moisture can enter the cracks and areas of caulk loss caused by embrittlement.*

Stage 5: *Moisture in iltration can lead to* ***Mechanisms 1 & 2****.*

Panel Product | Asbestos-Cement | Insulation | Adhesive | Caulk | Hardware | Framing | Moisture | Rot/Insect Activity



John Blair Building

Framing System Utilizing Vermarco Panel Boards

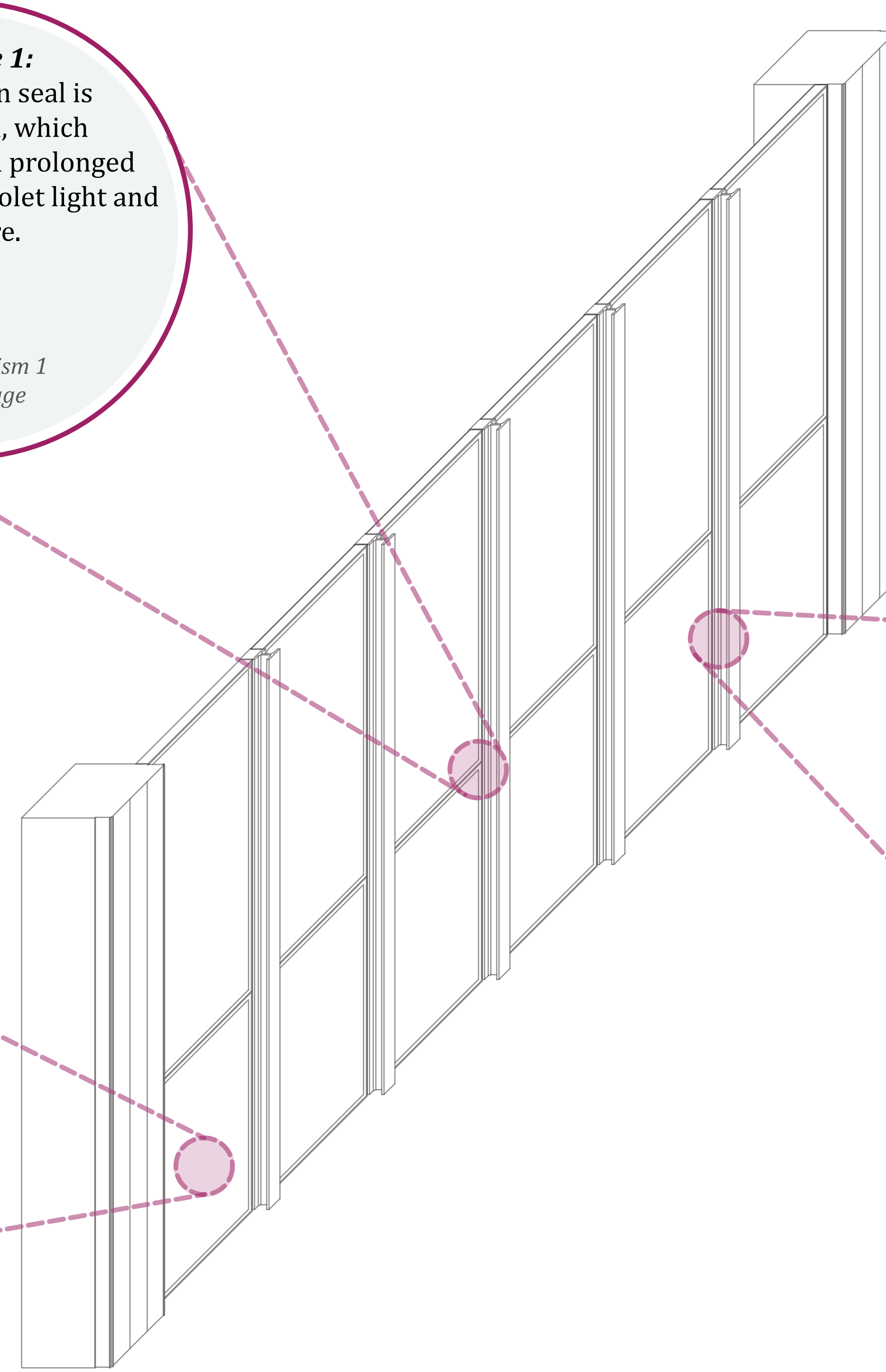
Vermarco 1

Example 1:
The expansion seal is made of vinyl, which deteriorates with prolonged exposure to ultraviolet light and moisture.

See Mechanism 1 on next page

Example 2:
The adhesive chosen to bond the marble, insulation, and asbestos-cement layers together can trap moisture inside of the panel if it deteriorates.

See Mechanism 2 on next page



Example 3:
Asbestos-cement is not typically porous, but prolonged exposure to water combined with Chicago's climate may lead to spalling or cracking.

See Mechanism 3 on next page

John Blair Building

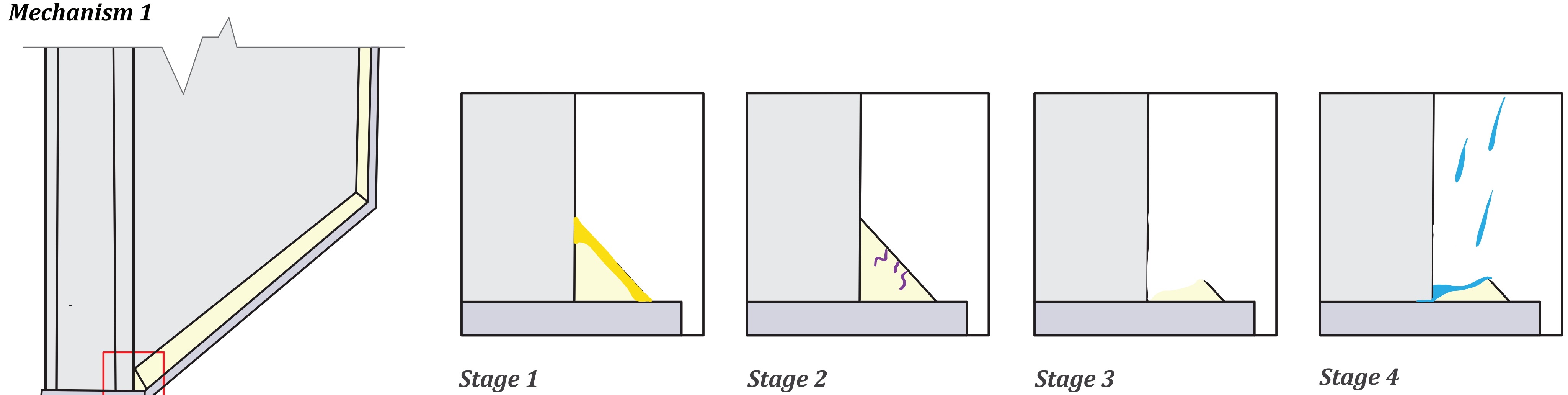
Potential Sites for Deterioration

Vermarco 2

John Blair Building

Potential Deterioration Mechanisms

Mechanism 1



Weather Seal Deterioration:
Due to exposure to moisture, and ultraviolet light, the vinyl weather seal will deteriorate.

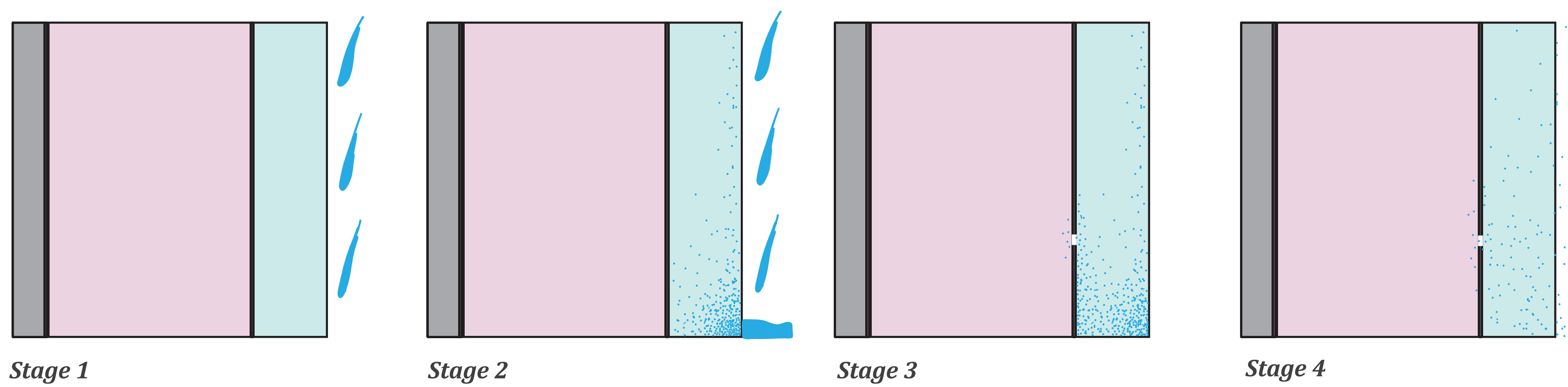
Stage 1: *Yellowing, while considered aesthetically unpleasing, is not equivalent to loss or deterioration of vinyl substances.*

Stage 2: *Vinyl will become embrittled over time with continued UV and moisture and cracks may begin to form.*

Stage 3: *Cracks worsen over time and lead to loss in the vinyl weather seal.*

Stage 4: *Moisture can now enter into the framing system and panel with little hindrance.*

Mechanism 2



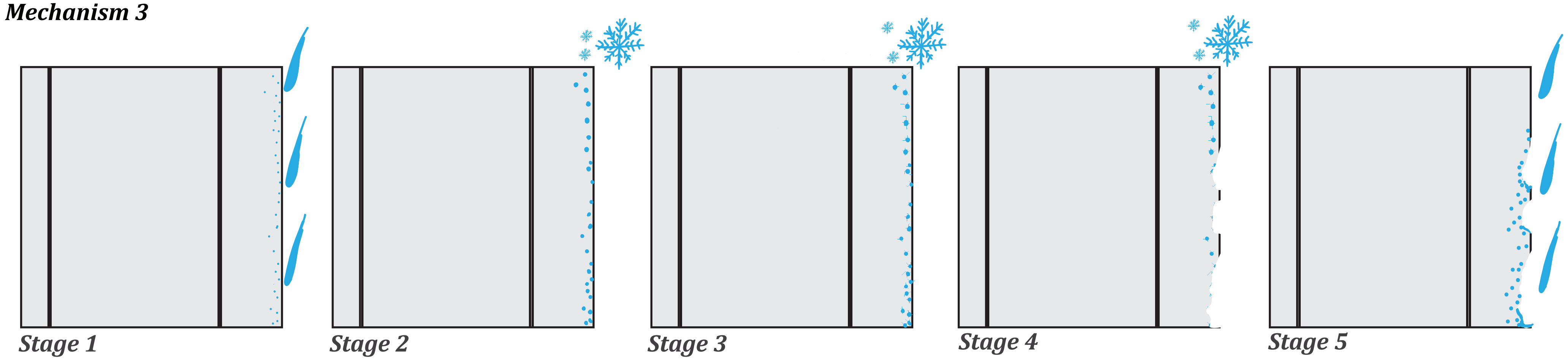
Stage 1: *Moisture exposure*

Stage 2: *Prolonged contact with moisture may saturate the marble*

Stage 3: *Water sits at the non-porous marble surface against the adhesive. Any perforation to the adhesive will allow water to pass.*

Stage 4: *Water passing into the insulation layer cannot be easily evaporated or transported out of the insulative layer.*

Mechanism 3



Stage 1: *Moisture exposure*

Stage 2: *Moisture inside marble pores freezes and expands.*

Stage 3: *Moisture expansion causes micro-cracks that worsen during every freeze-thaw cycle, as they ill with water that freezes and expands, and eventually connect with each other.*

Stage 4: *As the cracks connect, marble substrate loss can occur.*

Stage 5: *The newly exposed marble has a greater surface area at a greater depth for water to enter in the future, thus making this process cyclic.*

Panel Product | Metal Framing | Vinyl | Asbestos-Cement | Marble | Insulation | Adhesive | Water | Cracking | Yellowing

Vermarco 3

APPENDIX D: DEFINITIONS

A

Acceleration – demolition or removal of the substrate without replacement

Abstention – no intervention to the deterioration mechanism

Asbestos-Cement – a Portland cement mixture that utilizes asbestos fibers as a form of aggregate in the mixture

Asbestos-Cement Board – a flat, dimensioned sheet of asbestos-cement

Asbestos-Cement Panel – a flat, dimensioned building product containing at least one layer of asbestos-cement board

Asbestos-Cement Panel System – a wall system that utilizes asbestos-cement panels in either a structural or curtain wall capacity

Asbestos-Fiber – a small, thin fiber derived from asbestos; fibers range in thickness from 5-5,000 um and are toxic due to the small particle size

Asbestos-Fiber Reinforced Cement Panelboard – see *Asbestos-Cement Panel*

Assembly – an aspect of a structure that requires component parts utilized and installed correctly to function

C

Cemesto – asbestos-cement building panels designed and produced by the Celotex Corporation

Circumvention – altering the system to which the deterioration is occurring

Component Assemblies – see *Module*

M

Material – a category of building component that does not require assembly after formation (i.e. brick, steel, oak)

Mitigation – interventions alter the environment supporting the deterioration mechanism

Modern – an ambiguous term here referring to post-industrial architecture that also embodied mechanization and utilized new technologies

Modular Assembly – a structural system that relies on pre-dimensioned and pre-assembled components

Module – a singular assembled component of a modular assembly

P

Panel Board Product – a dimensioned building product containing multiple layers

prefabricated components – small-scale individual building elements, such as nails or plywood

Prefabrication – a type of architecture that utilized mechanization and standardization in order to increase productivity while decreasing cost

Product – a composite building component made of more than one building material

Panel Construction – a conventionally framed house with pre-assembled wall panels

Pyrestos – asbestos-cement panels used in Motohomes

R

Reconstitution – interventions alter the substrate deteriorating

S

Substitution – direct replacement of the substrate with another material

V

Vermarco– subsidiary brand of Vermont Marble Company selling marble-based building products; panels used in the John Blair Building containing a layer of asbestos-cement

INDEX