Keeping A Lid On It: Asbestos-Cement Building Materials

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While used separately in many prior successful applications, asbestos and cement were first combined in the United States in the early 1900s to form an innovative new building material. Asbestos-cement products were used in a host of applications, which took advantage of its durability, fire resistance, ease in processing, forming, installing, and overall economic benefits. Although often tarnished by the angst associated with asbestos, careful examination of asbestos-cement's history and material characteristics reveal its importance as a twentieth-century building material. In addition, references to applicable regulations and recommendations for proper conservation treatments are addressed.

HISTORY AND MATERIAL CHARACTERISTICS

Asbestos-cement is a composite material that consists of portland cement reinforced with asbestos fibers. Before the combination of asbestos and cement, these constituent materials were utilized independently for commercial use. Asbestos tended to be too coarse and abrasive to be useful by itself, which led to diverse and popular composite mixtures beginning in the 1880s. Many experiments with asbestos fibers resulted in a variety of mixtures; however, the combination of asbestos and cement (typically portland) proved most useful in the building industry. The proportion of cement to asbestos fibers varied over a range of ten to seventy-five percent by weight, depending on the desired characteristic.[1] The portland cement matrix ultimately binds the fibers of asbestos into a hard mass, which is a durable material, mechanically and chemically compatible with the fibers.

Asbestos' popularity in the building industry stemmed from its inexpensive processing and its special chemical and physical properties, which make it virtually indestructible. Asbestos is a fibrous silicate mineral that maintains chemical resistance especially to alkalis, fire resistance, mechanical strength due to the fibers' high length to diameter ratio, flexibility, and good friction and wear characteristics.[2] In addition, good bond to the cement matrix with no evidence of an interfacial transition zone is attributed to the hydrophilic surface of the asbestos fibers.[3] Approximately ninety-five percent of asbestos used in building products was in the form of crysotile (white asbestos), and occasionally amosite (brown asbestos) was used.[4] Other forms of asbestos, namely crocidolite, anthophylite, tremolite, and actinolite, were not used as they were considered more hazardous due to excessively brittle and thin fibers.[5]

Asbestos-cement was first manufactured in the United States in 1905,[6] introduced first in the form of a coating. It was easily installed and assumed to be indestructible when applied as a covering to boilers, steam pipes, hot blast furnaces, and stills. H. W. Johns Manufacturing Company (later Johns-Manville) became one of the leaders in the development of cement products containing asbestos.

The company initially marketed asbestos-cement coating as an agent for repairing roofs, and guaranteed it to stop all leaks when properly applied, making seemingly worthless roofs serviceable for many years. This product was used in joints around chimneys, dormer windows, skylights, scuppers, shingles, and nail holes on roofs (Figure 1). Asbestos-cement was also invaluable for protecting beams, posts, walls, and ceilings, especially in hotel and restaurant kitchens, or places where it was desired to prevent the transmission of heat to adjoining rooms.[7] H. W. Johns along with other early manufacturers, such as Keasbey & Mattison Company, Baltimore Roofing & Asbestos Manufacturing Company, Inc., Philip Carey Manufacturing Company, and Flintkote Company, engaged in producing a wide range of asbestos-cement products throughout much of the first half of the century.

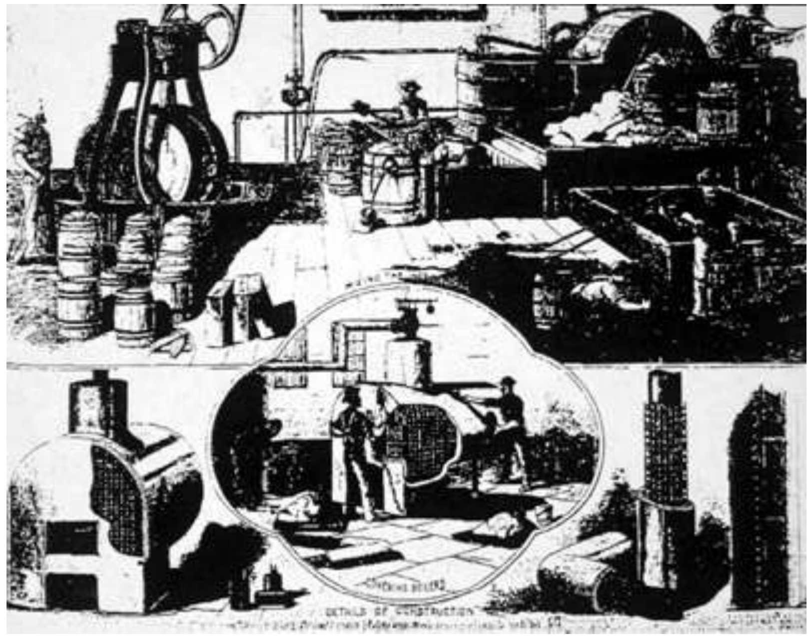

Figure 1. Manufacture of non-conducting asbestos-cement coverings for steam-pipes and boilers (*Scientific America*, 1876).[26]

It was not until 1907 that the invention by an Austrian engineer, Ludwid Hatschek, made possible the manufacture of pre-formed asbestos-cement products.[8] The Hatschek machine, a wet transfer roller, was used to produce the initial asbestos-cement sheets (Figure 2), while two other manufacturing processes included the Mazza process for pipes, and the Magnani semi-dry process for corrugated sheets.[9] After being formed, most products were steam cured to achieve the optimum microstructure for strength and durability. It is these asbestos-cement building products that have many desirable material characteristics, such as being lightweight, impermeable to water, durable, tough, resistant to rot, termites, soiling, corrosion, warping, and fire, and easy to clean and maintain. Asbestos-cement also possesses low thermal conductivity and is therefore a good electrical insulator. These highly desirable material characteristics, apparent in the new found material, sparked growth in manufacture of a plethora of forms and styles to suit different needs.

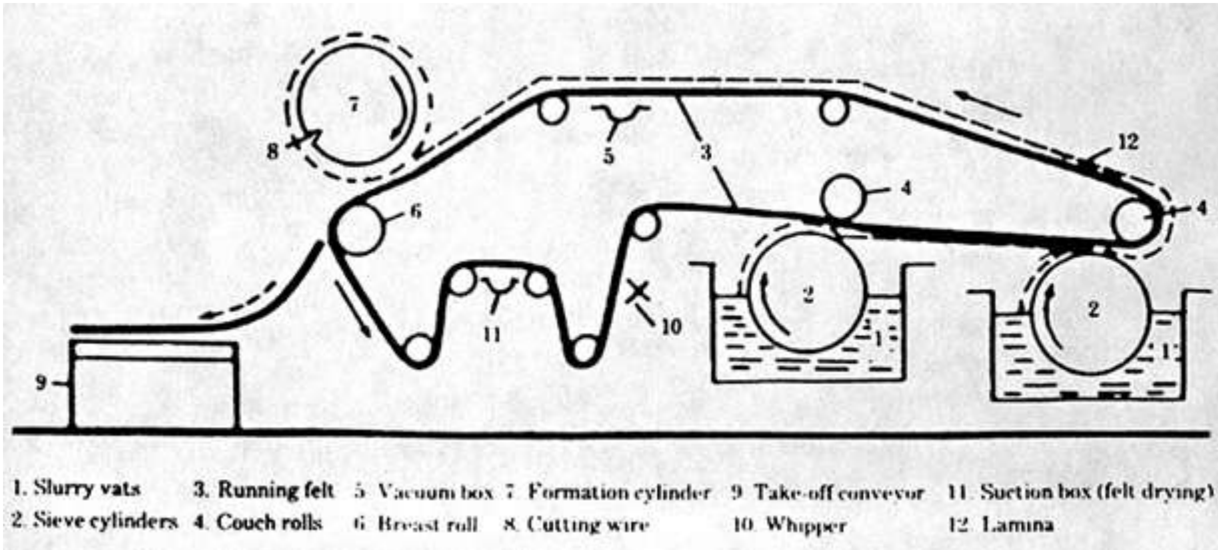

Figure 2. Simplified representation of a Hatschek machine for asbestos-cement production (Wilden, 1986).[27]

With the refinement of the asbestos and cement mixture, as well as the forming and curing procedures, the market soon developed major commercial products of synthetic roof and wall shingles, corrugated wall and roof panels, flat millboard, and decorative wall and ceiling moldings. Additional manufactured products included water pipes, simulated ceramic bathroom tiles, facings of acoustical materials, electrical switchboard panels, laboratory tabletops, electrical conduits, and even smaller diameter pipes were used for purlins and trusses in wartime construction to conserve steel and lumber.[10] The principle manufactured products used in building construction were, in order of their production volume: siding shingles, flat sheets, roofing shingles, and corrugated sheets.[11] These asbestos-cement products lent themselves to rapid construction techniques and, therefore, were particularly useful for lightweight housing and industrial buildings.

Figure 3. Keasbey & Mattison Company advertisement showing typical asbestos-cement roofing shingles (Sweet's Catalogue of Building Construction, 1940s).

As early as the 1920s the National Board of Fire Underwriters recommended that home owners incur the additional expenses associated with fire-resistant roof coverings as replacements to avoid the hazards associated with wooden shingles.[12] Among the various approved alternatives were asbestos-cement roofing products (Figure 3). This was a milestone in the public's acceptance of the product that a nationally reputable organization recognized and recommended its use.

Originally, roof shingles were manufactured in three typical colors: natural cement gray, Indian red (tile), and blue-black (slate). Two primary designs produced were Hexagonal (diamond shape) and Dutch lap (similar to wood shingles). Each shingle is held by two nails, with the addition of a storm nail at the apex of the Hexagonal pattern. They are much lighter than tile or slate and weigh only a little more than wooden shingles, allowing for a more economical substructure. Other shapes include: Poilite Straight Cover Slating (square or chamfered corners), Scalloped (three or five scales to a tile), Bell's Pan (ogee shape, or a skewed pan tile), and Endurol (wave pan tile).[13] When asbestos-cement roofing shingles were properly manufactured and installed, the shingles were so durable that the roof would commonly outlast the functional lifespan of the building.

Asbestos-cement siding shingles imitated wood siding shingles in shape and appearance, typically available in sizes of twelve by twenty-four inches. These shingles originally came in nondescript tones like gray-green, gray-pink, and Dover white. Textures such as grooved, wood-grained, or smooth were pressed into the large asbestos-cement sheets, then cut to the profile of the design, such as Tapertex (flat horizontal lines), Thatched, or Waveline. They were usually predrilled for ease of installation with two to three nails on the bottom of each shingle to secure the panels to the sheathing. Installation was executed from the bottom up. As one row of shingles was nailed, the bottom lip would secure the top of the shingle from the row below (Figure 4).[14] This construction technique allowed ease in replacing shingles, unlike wood or slate shingles that were secured at the top of each shingle.

Large flat asbestos-cement sheets were available in sizes of twelve-feet long by four-feet wide and thicknesses ranging from approximately an eighth of an inch to one inch.[15] Asbestos-cement flat sheets were, at one time, manufactured only in the typical gray color of cement and usually only accepted for industrial purposes. Eventually sheets were made with smooth surfaces, waxed or lacquered, with a variety of colors for use as office partition walls, kitchen walls, tabletops, acoustical panels, and building corridors. They were often used where ease of cleaning was important. One popular material for interior lining was an embossed sheet with a figured pattern that could be painted or distempered, thus providing the effect of plaster at a relatively low cost.

Another popular variation consisted of a smooth surface and wood-grain appearance available in a range of colors. Some sheets were glazed, thus presenting a smoother, more resilient finish.

Flat sheets were often incorporated into composite products. 'Transitop' was a typical composition board consisting of an integrally impregnated insulating board core, faced on both sides with asbestos-cement board. Waterproof adhesives were used to laminate the insulating core as well as to bond the noncombustible asbestos-cement faces to the core.[16] This combination of materials provided for structural strength, high insulation values, and maintenance-free interior and exterior finishes in a single fire-resistant panel.

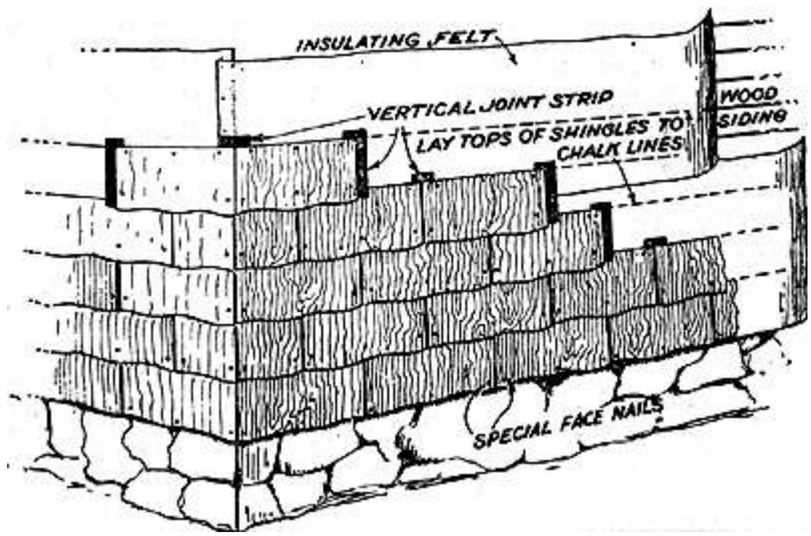

Figure 4. Asbestos-Cement siding installation specifications (McCawley, 1940).

With the advent of asbestos-cement corrugated sheets, the enclosure of factory buildings, warehouses, and train sheds was simple, economical, and effective for either permanent or portable structures.[17] Corrugated asbestos-cement sheets were applied in the same way that corrugated iron was applied, either nailed to wooden strips, bolted to the purlins, or clipped directly to the purlins by clips of hoop-iron or wire. They were available in standard sheets, twenty-seven and a half inches wide and in lengths of four, five, six, seven, eight, and ten feet. Two primary shapes were Trafford (with peaks), and Fibrotile (with waves). A series of special hardware devices was designed for use with corrugated sheets so that buildings could be completely encased in the material. Corrugated asbestos-cement sheeting was also used for decorative purposes in uniquely styled buildings of all descriptions.

During the 1940s construction boom, a wider variety of colors became available, including a spackled look, where the colors were impregnated throughout the sheet so they would not powder or peel off. When color change became desirable after installation, owners were encouraged to paint the asbestos-cement products. It was the "attractive home safeguarded with modern asbestos siding, fireproof, rot proof, termite proof" idea that intrigued many Americans during this era.[18] By 1950, approximately one billion square feet of asbestos-cement products had been produced for use in the building industry.[19]

By the time the Environmental Protection Agency (EPA) was established in 1970, the commercial world of asbestos-cement products had expanded into many markets. Annual use of asbestos-cement in the United States continued to climb for another three years before reaching the peak of its popularity, only to plummet to a quick death in 1973 when the EPA implemented the initial ban on asbestos.[20] Asbestos-cement products are still produced in a few countries outside of the United States and are considered a beneficial resource; however now they carry the label "hazardous material" and not "miracle mineral" as they once did.

ASBESTOS REGULATIONS

Some asbestos fibers, when inhaled, constitute a health hazard leading to asbestosis, a form of lung cancer. These health risks prompted the establishment of strict environmental regulations on working with asbestos. Health risks were shown to be greatest during mining and production processes, but minimal during installation and use of asbestos-cement products.[21] According to the EPA, a material containing asbestos is deemed potentially hazardous only in a friable state, which means when it can be crumbled, pulverized, or reduced to a powder by hand pressure. Asbestos-cement is not considered friable, and therefore not hazardous, because the cement binds the asbestos fibers and prevents their release into the air under normal use conditions. However, asbestos-cement products are classified as friable when severe deterioration disturbs the asbestos or mechanical means are used for chipping, grinding, sawing, or sanding, therefore allowing particles to become airborne.

Maintenance and management guidance for asbestos-containing materials has been formulated by the National Institute for Building Science (NIBS) in their publication "Asbestos Operations and Maintenance Work Practices," and by the EPA in publication 20T-2003, "Managing Asbestos in Place." The two primary institutions that regulate asbestos-containing materials are the EPA and the Occupational Safety and Health Administration (OSHA). Regulations are mandated by the National Emission Standards for Hazardous Air Pollutants (NESHAP), a branch of EPA, under 40 CFR Part 61 Subpart M, and by OSHA under the Federal Register 29 CFR 1926.1101, "Asbestos in Construction Standard." These regulations can change or be superseded by more stringent state and local codes. It is recommended that these procedures be followed to protect the asbestos-cement materials from becoming friable during any restoration project.

Laws established by federal agencies for non-friable materials are minimal. NESHAP requires no visible emission where-by if a procedure that will disturb the material is being implemented the fibers in the air must be controlled below a visible tolerance. For asbestos-cement, visible emission can easily be controlled by keeping the material adequately wet so that dust does not form. When repairing or replacing, simply spray down the material first, keep the material wet during any abrasive procedures, or use high efficiency particle arresting (HEPA) equipment. Prior to and during demolition use a firehose on the structure. OSHA regulations for disturbing non-friable materials include frequent inspection, operation and maintenance training, respirators (only in emergency settings), awareness training, wet methods, and handling procedures. If the material will not be disturbed, no hazard exists and no precautions are required; however, conducting periodic inspections is still advised.[22]

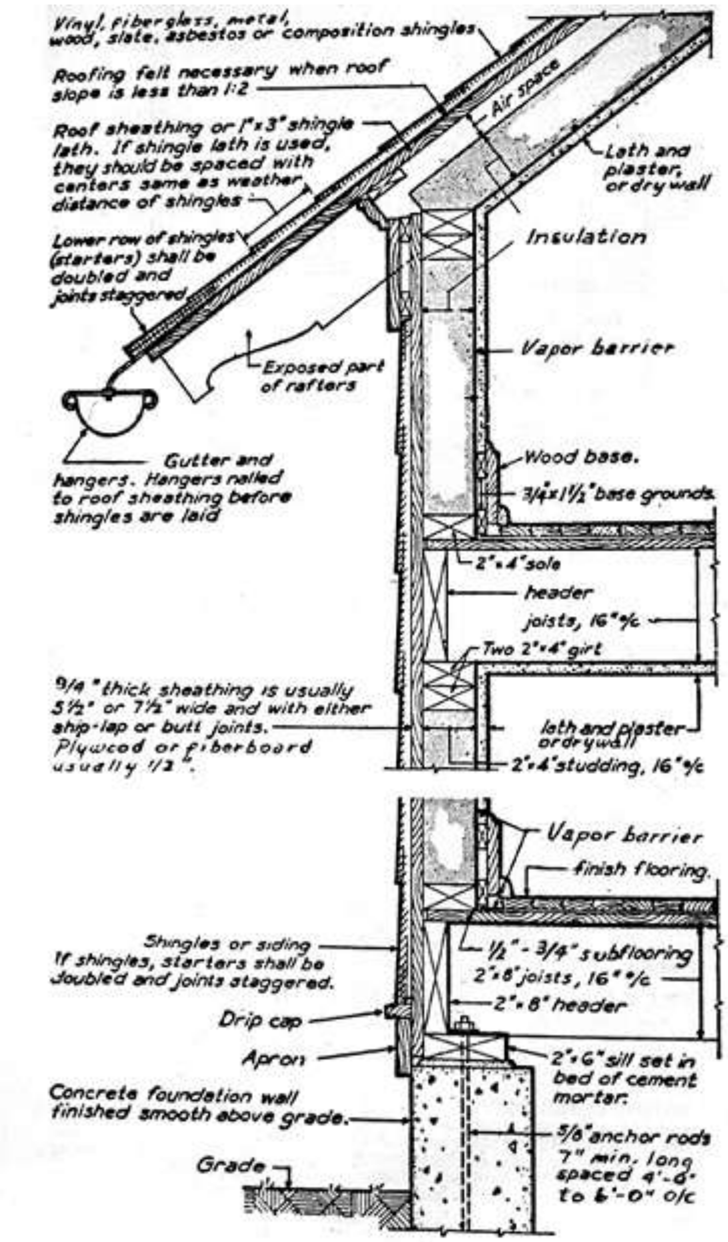

Figure 5. Partial wall section for shingle siding construction; shows a drip cap and apron in place to protect the bottom edge of siding shingles (Graf, 1985).

CONSERVATION

Due to the abundance of buildings clad in asbestos-cement products, and the low health risk of the non-friable material, it is necessary to know how to preserve and rejuvenate the material back to a vibrant and usable life. The primary conservation options for asbestos-cement building materials are to maintain and manage in place, repair, replace in part, or abate. The level of deterioration determines the appropriate option to be employed. Abatement, including full removal or encapsulation, should only be used as a final course of action.

Maintain and Manage

Deterioration of asbestos-cement is inevitable, as is eventually the case with most all materials. Maintenance procedures can decelerate deterioration, such as conducting visual inspections to evaluate condition, keeping the material clean, making minor repairs as necessary, and organizing treatment practices that minimize the extent and impact on the material. Also, it is important to maintain the environment that surrounds the structure and protect the asbestos-cement materials. Examples of protective measures include the planting of shrubs or flower beds between the skirt of the wall and lawns to protect from lawnmower damage, adding a bumper material to the bottom row of siding to reduce vulnerability to cracking and chipping (Figure 5), and keeping branches and debris away from the roof and out of gutters.

Repair

When repair is the necessary treatment for a deteriorated asbestos-cement product, the least amount of material should be discarded and the most possible amount of original material should be retained. The type and extent of material deterioration associated with asbestos-cement products depends on the cause of the distress and therefore requires investigation and the tailoring of a solution for each case. When repairing the deteriorated materials the gentlest means possible should be used following applicable asbestos regulations, along with repair techniques sympathetic to the existing fabric.

Asbestos-cement is inherently a brittle material with low impact resistance, so even with the added reinforcing given by the long thin asbestos fibers, the material is susceptible to cracking and chipping as generally induced by low impact forces, repeated cyclical loadings, or deteriorated fasteners. In addition to this primary deterioration tendency, manufactured asbestos-cement products can potentially discolor, erode, spall, flake, form efflorescence, and create an environment for biological growth. Guidance for repairing asbestos-cement products is given here for these several distress manifestations.

Cracking

If a crack forms from either impact or fatigue and mandates repair, several techniques can be used depending on the size of the crack. For hairline cracks, work clear epoxy into cracks with a thin object. Epoxy can be susceptible to UV attack and may need to be restored periodically by removing and replacing. For slightly larger gaps, use a grout of portland cement and water, mixed to a flowing consistency, and tinted to match. For cracks greater than an eighth of an inch, use a thicker grout consistency or add sand to the mix. The crack may need to be widened to rake out the loose material. Soak the crack with water, then trowel patch the grout into it. Keep the repair damp for a week to promote slow and proper curing and reduce shrinkage.[23]

If the fasteners for the asbestos-cement product have become deteriorated or have broken from corrosion, they should be replaced with a more durable metal. Various metals can be considered for the replacement, but should be compatible with the sheathing. Stainless steel is generally recommended because of its superior corrosion resistance. Fasteners such as nails should be long enough to hold the materials securely (self-clinching nails can help with this).

Discoloration

Discoloration of asbestos-cement products stems from a build-up of surface contamination (such as soiling), stains produced by leaching of other material byproducts (such as corrosion run-off), or a direct change in color due to the environment (such as ultra-violet sun bleaching). These discoloration occurrences typically result from normal weathering, but indicate a chemical reaction that may decrease the strength or durability of the material when neglected over time.

Discoloration should be removed from the asbestos-cement products, and cleaning recommendations generally suggest trying several solutions of varying strengths. After evaluating the results of the trials select the alternative that provides the needed results while using the gentlest means possible without causing adverse reactions to the substrate. Mechanical methods for cleaning can promote asbestos fibers to become airborne, therefore should only be used following asbestos regulations.

To clean light stains, such as dirt, the asbestos-cement products should be washed with a detergent solution or a mixture of one half cup of trisodium phosphate dissolved in a gallon of hot water. Rinsing with plenty of clear water helps to remove all trace of the cleaning solution. Start the cleaning at the bottom of the wall, working upward in small sections, rinsing immediately, and keeping the shingles below wet, otherwise, dirty water can drip down over dry surfaces and leave streaks almost impossible to remove later.

Recommendations for stains such as rust, are to dissolve one part of sodium citrate in six parts of commercial glycerin. Mix part of this with inert dry clay, such as diatomaceous earth, to form a poultice and apply as a thick layer. When the paste is dry, replace with fresh paste or moisten with the remaining liquid. Complete removal of the stains may require a week or longer. A ten percent oxalic acid solution has also been found to successfully remove rust from cementitious products. If the substrate, metal fixtures, or other adjacent objects are causing staining they should be cleaned and coated or replaced.

If the stain cannot be removed, another option is painting the asbestos-cement products. Painting is an especially good solution if the material was originally painted, but adds a maintenance factor. Oil based paints and varnishes are not chemically compatible with cementitious materials. High quality alkali-resistant and weather resistant exterior paint (i.e., 100% acrylic coating) should be used on exterior asbestos-cement materials, or use pigmented shingle stain. Before being painted, asbestos-cement surfaces should be cleaned, then primed with an alkali-resistant primer.

Eroding, Spalling, or Flaking

Erosion removes cement particles and can result in the release of asbestos fibers, leaving the material with less reinforcement. Due to the high density, low permeability, and low porosity of the material, this tendency is virtually unnoticeable. However, erosion can become a more serious problem under regular and extremely harsh weather conditions. If intense erosion occurs, the durability of the material can be compromised.

Although rare, spalling or flaking occurs when elements permeate beneath the surface of the asbestos-cement material and then expand, causing a portion of the material to be released due to the resulting stress. As the moisture content increases, more severe deterioration can occur. This deterioration is more likely to occur in products that were cured at lower temperatures and therefore are more vulnerable to water penetration.

To control eroding, spalling, or flaking, chemical consolidants and/or breathable sealers (most commonly silane) can be applied to strengthen the material while adding water protection. Testing is critical since consolidants and sealers can promote spalling if water is getting in through the backside of the material.

A grout or latex-patch may also be considered, but must be compatible with, and typically softer than, the asbestos-cement material to form a good bond and not promote increased spalling. This repair procedure can be tricky and may lead to constant patching, and may be unsightly if not done with extreme care. For these types of deterioration tendencies, the material may be better off left alone or partially replaced.

Efflorescence

Efflorescence appears on many portland cement products that are exposed to weathering. This form of crystalline growth indicates that water is passing through the material, which can promote deterioration of the asbestos-cement, in addition to making it unsightly. Generally this is seen at the beginning of the material’s life, where rain and weathering tend to remove it over time.

To clean efflorescence deposits, the surface should first be dry brushed with soft bristles, not scratching the surface. If efflorescence still remains, test to see if it is water soluble or acid soluble. If water soluble, the wall should be wiped with a wet sponge or brush (a light detergent can also be added). A hose can be used, but spray the water in a downward direction as perpendicular force will drive the efflorescence back into the material. If acid soluble, clear ‘white’ vinegar, acetic acid, phosphoric acid, or similar proprietary products diluted in water should be used. It is recommended to wet the surface with solution, then apply solution more liberally on the asbestos-cement. After two or three minutes, scrub using a fiber brush with more solution, then rinse extremely well with clear water. Safety precautions provided on the product labels should be followed, and again tested before commencing extensive application as adverse effects or discoloration may occur. Pitting from chemicals will increase dirt buildup and water permeability, decreasing the durability of the material.

Biological Growth

Biological growth on the exterior of asbestos-cement can be a problem in sheltered environments or on northern exposures. Shade trees located close to a building can shield sunlight and result in prolonged dampness of the asbestos-cement building product and promote biological formations, such as moss and algae. Not only are the growths unsightly, but they can stimulate surface disintegration, dissolution, and staining.

The presence of moss and other fungi growth signals that the moisture content of the material is high and therefore an attack by a more damaging biological species could occur.[24] It is not only important to remove the growth from the asbestos-cement material, but also to remove the environment that is causing the growth. To eliminate biological growth, a strong mixture of weed killer and water could be tested. If unsuccessful, a solution of four parts bleach, one part trisodium phosphate, and twelve parts warm water is recommended. After a week or so when the moss has turned brown and dry, it should be brushed off. In the case of ivy this technique is sometimes not helpful in removing the thousands of tiny roots left after the ivy has been pulled off; a stronger product may be needed (i.e., copper sulfate). It is important to remember that biological growths differ widely and so do the processes for their removal. Testing various products and selecting appropriately is highly encouraged.

Replacement

Since asbestos-cement products were manufactured in standard sizes, shapes, colors, and textures, partial replacement is well suited for implementation. This process is acceptable when part of, or pieces of, the existing asbestos-cement building material have deteriorated to such a degree that it is much more feasible to replace than repair (Figure 6). Since the United States no longer produces asbestos-cement products, an alternative material should be selected to match the original. Some materials that have been manufactured to replicate asbestos-cement building components are non-asbestos reinforced cement, fiberboard with asphalt, fiberglass, metal, and vinyl. For the purposes of preservation, one of the non-asbestos reinforced cement products is most appropriate.

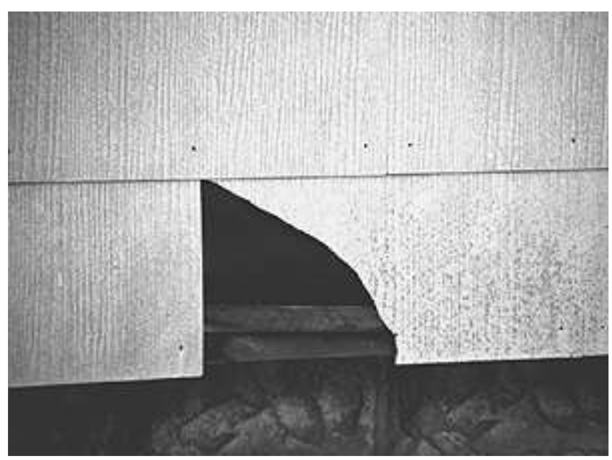

Figure 6. Asbestos-cement products most commonly deteriorate by cracking and chipping. These kinds of deterioration are not typically feasible to repair, and therefore it is recommended that a non-asbestos fiber cement piece by used as a replacement (photo by author).

Figure 7. Replacement non-asbestos fiber-cement shingles in place, before being painted and after (photo by author).

Many varieties of non-asbestos reinforced cement or fiber-cement are currently available. Fibers that have been introduced with cement include: steel, glass, polypropylene, wood (these four being the most common), acrylic, akwara, alumina, carbon, cellulose, coconut, kevlar, nylon, perlon, polyethylene, rock wool, and sisal.[25] Combinations of fibers are currently undergoing research in order to get properties closely matching those of asbestos. Several companies manufacture products that replicate asbestos-cement roofing and siding shingles, flat sheets, and corrugated sheets. Some of these manufacturers include: Supradur Manufacturing Company, Cement Board Fabricators, U.S. Architectural Products, Inc., Re-Con Building Products, and GAF Materials Corp. The fiber-cement products replicate the size, shape, thickness, and structure, along with texture and color of many of the asbestos-cement products previously available. Where color matching is not found, an alternative is to replace in size and shape then paint over the entire structure for a uniform appearance (Figure 7). In addition, the hardware and the installation procedures for these products are similar to those for asbestos-cement products due to their similar characteristics and proportions.

CONCLUSION

Asbestos-cement products were developed in an era of ingenuity for creating easy to install and economic building materials. Although asbestos-cement has acquired a poor reputation by association of its title, it has not gained that reputation through a lack of durability or utility. In order to preserve this twentieth-century material, understanding what makes, or does not make, asbestos a hazard is truly important. In this case, no hazard is created when asbestos-cement building materials are sound and left in place, or when treatments incorporate non-abrasive means.

END NOTES

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[3] Arnon Bentur and Sidney Mindess, *Fibre Reinforced Cementitious Composites* (London: Elsevier Applied Science, 1990), 288-304. This text reviewed long-term performances of asbestos-cement and concluded that "in natural weathering the composite is excellent." More detailed quantitative material properties are also given in this text.

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[19] Rosato, 63.
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[21] Bentur and Mindness, 304.
[22] Guidance given here only makes recommendations based on national agency laws and regulations; all applicable federal, state, and local laws and regulations must be followed for any asbestos-containing material project.
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–Link no longer works, 10/12/2012, L. Drummond