

ASBESTOS IS OUT, BUT WHAT ABOUT SUBSTITUTES?

A review of problems with some roof shingle replacements

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KEYWORDS Asbestos, cellulose, cement, roofing shingles, slates.

ABSTRACT This paper explores:

- the transition from asbestos fiber reinforced Portland-cement roofing shingles to cellulose fiber reinforced portland cement roofing shingles, slates, and tiles;
- the sad fate of several of these cellulose-cement shingles, and;
- the lessons learned, through the clear eyes of hindsight, on how to minimize these problems in the future.

SOMMARIO DEL ARGOMENTO

- la transizione da le tegole di cemento Portland rinforzate da la fibra asbestos a le tegole di cemento Portland rinforzate da la fibra cellulosa,
- il triste destino di tante di queste tegole di cemento rinforzato con cellulosa, e;
- le lezione imparate, ci dicono come ridurre al minimo questi problemi in futuro.

ZUSAMMENFASSUNG Dieser Artikel untersucht:

- den Übergang von Faserzement mit Asbestfasern auf Faserzement mit Zellulosefasern für Dachplatten.
- Die trauige Geschichte von einigen Dachplatten aus diesen neuen Faserzementprodukten.

- Was man hinterher von diesen Erfahrungen lernen kann, und wie man diese Probleme in der Zukunft vermeiden kann.

RESUMÉ Cette etude explore:

- la transition des bardeaux de toiture de ciment-portland renforcé de fibre d'amiante en bardeaux, ardoises, et tuiles de toiture de ciment-portland renforcé de fibre de cellulose;
- le destin triste de plusieurs de ces derniers bardeaux de ciment-cellulose et;
- les leçons apprises, par les yeux clairs de la retrospective, sur la façon de reduire au minimum ces problemes à l'avenir.

WRITERS

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INTRODUCTION

Asbestos fiber reinforced portland cement, called "asbestos-cement," was invented and introduced in England in the late

1800s. This modern, strong, fire resisting material was formed into many building materials including pipe, corrugated sheets, residential siding, roofing shingles, artificial slates, and roofing tiles. Many of these products gave blameless performance for a host of years in all parts of the world and are still performing well in many countries. The current ASTM standard for asbestos-cement shingles was issued in 1949, after asbestos-cement products had been produced and performed successfully for over 60 years.

The Transition

During the late 1960s through the late 1980s, asbestos fibers were identified as a health risk. Public perception and government regulation created an environment that all but banned asbestos-containing products in the United States, even though there is no evidence that products such as asbestos-vinyl floor tile or asbestos-cement products (to name just two product lines) are health hazards. The use of asbestos is not banned by any legislation, but it became politically incorrect and perceived by many manufacturers to be economic suicide to make asbestos-containing products.

Manufacturers had many years to research and develop substitutes for asbestos, but this was not enough time to fully test these substitutes in products with expected long-service lives. The substitution was easy to test when the final product had a short service life, but very difficult when the service life extended beyond ten years or more. As a result, some products were produced and sold without adequate testing. The substitution of cellulose fibers for asbestos fibers in portland cement roofing shingles was often an unfortunate substitution. The problem was compounded when the manufacturers offered 40- and 50-year product warranties that might have been appropriate with the asbestos reinforced product, but often represented a warranted life twenty times longer than their actual experience.

Sad to report that some of the products that failed claimed to comply with ASTM C1225 *Standard Specification for Non-Asbestos Fiber-Cement Roofing Shingles, Shakes and Slates* and appropriate building codes. As we show in Table 1, all of the tests we performed on unweathered materials confirm

compliance. Thus our current standards and codes fail to protect us from products that are not suitable for use.

Our Laboratory and Field Findings

Table 1 describes laboratory test results and descriptions, as well as field observations on various types of fiber-cement shingles that we investigated. The products of five separate producers are identified as products "A" through "E." We offer the following comments on these products, all of which were taken from actual use on roofs where they had failed. Our comments present our opinions; the information in Table 1 is factual.

1. Most fiber-cement products have a porous texture, facilitating water entry. Four of the five products were "punky" (i.e., soft), after removal from the roof.
2. Some products have a layered structure and are delaminated. In the forty-eight-hour water test, many of the unexposed (covered) artificial shakes showed delamination. Three of four expose shakes delaminated in the water bath specified in ASTM C1225.
3. We found the reinforcing fibers to derive from paper and/or wood.
4. Four of five products have coatings, which we found to be flaking off.
5. Products B through E, for exposed samples, do not meet the minimum modulus of rupture specified by ASTM C1225. Product A does meet that standard, but the petrification of its fibers resulted in a product that was so brittle that it experienced extensive cracking of the product when used for roofing.
6. Natural slate, ASTM Standard C406, has a significantly higher modulus of rupture requirement than ASTM C1225 (62 v. 5.5 MPa). ASTM Standard for Asbestos Cement (ASTM C222) also has a higher standard (9.0 v. 5.5MPa). We see no rational reason for the reduction in the modulus of rupture in ASTM C1225; the weight of an installing mechanic does not decrease if an asbestos-cement slate is replaced by a fiber-cement material.

TABLE 1 – SUMMARY OF LABORATORY AND FIELD OBSERVATIONS

LABORATORY OBSERVATIONS	Product A		Product B		Product C		Product D		Product E		Natural Slate		Asbestos Cement	
	fine grained with tight matrix	non-uniform	microgranular to granular with porous matrix	more fibers in bottom than in top	porous	porous	porous	porous	porous	porous	porous	porous	porous	none
Fiber distribution	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	none
Product is soft (punky) throughout	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	none
Fiber orientation	longitudinal	no	longitudinal	longitudinal	random	random	random	random	random	random	random	random	random	random
Layering/delamination	no	no	severe	no	no	no	no	no	no	no	no	no	no	no
Deflection at break, mm/0.001 inch, (milis)	0.64/25	1.8/70	2.2/87	2.4/96	2.2/87	2.4/96	2.2/87	2.4/96	2.2/87	2.2/87	2.2/87	2.2/87	2.2/87	—
Reinforcing fibers	paper	paper	wood	wood	wood	wood	wood	wood	wood	wood	wood	wood	wood	—
Pettification of fiber	yes	?	?	?	?	?	?	?	?	?	?	?	?	?
Top coating flaking off	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	?
Properties	ASTM C 1225	Exposure (Averages)	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi	MPa	psi
Modulus of Rupture	§ 6.1.1, Table 1	Unused	11.72	1,700	13.57	1,969	11.72	1,700	13.57	1,969	11.72	1,700	13.57	1,969
(flexural)	5.5 MPa/798 psi	Exposed	11.17	1,620	12.53	1,818	11.17	1,620	12.53	1,818	11.17	1,620	12.53	1,818
			16.20	2,350	3.53	512.5-46	792.3	16,458	1.43	208	792.3	16,458	1.43	208
			Nm/m	ft-lb/ft	Nm/m	ft-lb/ft	Nm/m	ft-lb/ft	Nm/m	ft-lb/ft	Nm/m	ft-lb/ft	Nm/m	ft-lb/ft
Breaking Moment	§ 6.1.1, Table 1	Unused	57	13.8	76	18.5	57	13.8	76	18.5	57	13.8	76	18.5
	5.6 ft lbs/ft	Unexposed	59	14.7	122	27.4	59	14.7	122	27.4	59	14.7	122	27.4
	25 Nm/m	Exposed	117	27.3	24.5.5	106	24	76	17	150	34	76	17	150
			Nm/m	ft-lb/ft	Nm/m	ft-lb/ft	Nm/m	ft-lb/ft	Nm/m	ft-lb/ft	Nm/m	ft-lb/ft	Nm/m	ft-lb/ft
Water Absorption	§ 6.2.2: % (No requirement)		< 6		25**		25		24		47*		24	
Warm Water Resistance	§ 11.4: No visible cracks	passed			N/T		N/T		N/T		N/T		N/T	
FIELD OBSERVATIONS														
Cracking in service %	close to 100		10		none		±35		±50		±50		±50	
Surface softness			extensive where exposed		extensive where exposed		extensive where exposed		extensive where exposed		extensive where exposed		extensive where exposed	
Exfoliation at edges	minor		extensive		extensive		extensive		extensive		extensive		extensive	
Slate curling/cupping	limited		10%		10%		10%		10%		10%		10%	
Organic growth on surface	no		±10%		±10%		±10%		±10%		±10%		±10%	
Surface erosion	no		yes		yes		yes		yes		yes		yes	
Surface discoloration	yes		yes		yes		yes		yes		yes		yes	
Loss of coating	yes		N/A		N/A		yes		yes		yes		yes	
N/T – Not Taken														
*50% after 131 hours														
** extensive delamination before test or in water bath														

7. Our tests show that slates, tested after a few years of service on a roof, generally do not meet even the low modulus of rupture requirement of ASTM C1225, except in Product A, which self-destructs in service because of petrification of reinforcing fibers.
8. Water absorption is very high in most products. Reinforcing fibers are moisture sensitive, subject to decay, and are dimensionally unstable in the presence of water.
9. All of the shingles show cracking in service.
10. We have observed cupping of shingles in service in most of the fiber-cement products.
11. Exfoliation of shingles at edges is extensive.
12. Organic growth and surface erosion occurs in many of the slates observed.
13. We saw discoloration in all of the products we investigated.
14. We found that all coatings erode after a few years of service.
15. Deflection at break, measured during the modulus of rupture tests, are low. This means that the products will break rather than bend when they curl in service or are installed with gaps between the shingles caused by a protruding nail heads.

In Summary, We Find:

- All of the materials we have encountered are inherently defective. Most do not even conform to the requirements of the applicable ASTM standard after a few years of service.
- The ASTM standard does not necessarily set values to assure that the fiber-cement slates are fit for use as roofing.
- The strength requirements set by ASTM C1225 may not be sufficient to support the weight of a mechanic installing the product.
- The ASTM standard C1225 does not establish flexibility requirements that would ensure the product will survive expected service conditions.

We conclude that many fiber-cement products are insufficient to serve for their intended purpose and that compliance with ASTM

Standard C1225 is not enough to provide assurance that the products will work when used for roofing.

We strongly recommend improvement of ASTM C1225, not only in strength, but also to account for the time-conditional reduction in strength, flexibility, and durability.

The Sad Fate

Of the eight manufacturers marketing fiber-cement tiles, slates, shingles, or shakes a few years ago, at least four have ceased production and a few more are expected to fade out of the market. The usual reason given is "lack of market." One of the departed has gone into bankruptcy "because the value of the outstanding complaints were greater than their assets." Several other manufacturers are facing class action lawsuits. For those of you unfamiliar with class action suits, these enable many small-injured parties to be combined into a single class to seek redress for their losses. The average homeowner's loss is too small to permit an individual legal action, but the value of the group loss permits funding of the legal action. Class actions benefit the manufacturers because they only have the legal fees for one case instead of the fees associated with settling many cases.

The common denominator for the failures of all of these products is the very high water absorption they exhibit (Figure 1). One product absorbs almost half its dry mass in water after a three-day water soak. Wood fibers can absorb 25% water depending on the species selected. The wood fibers swell as the moisture content increases and contract as they dry out.

Most of the expansion is perpendicular to the length of the fiber. Wood fibers also swell in the presence of alkali; soaking wood in as little as 2% sodium hydroxide in water for 32 days results in a 50% loss in bending strength. The top surface of many of these tile-shaped shingles cracks (Figure 2), the shingle warps upward (Figure 3), the cracks admit more water, the wood fiber rots (sometimes acting as a fertilizer to grow grass and brush on the roof – Figure 4), and water leaks into the building.

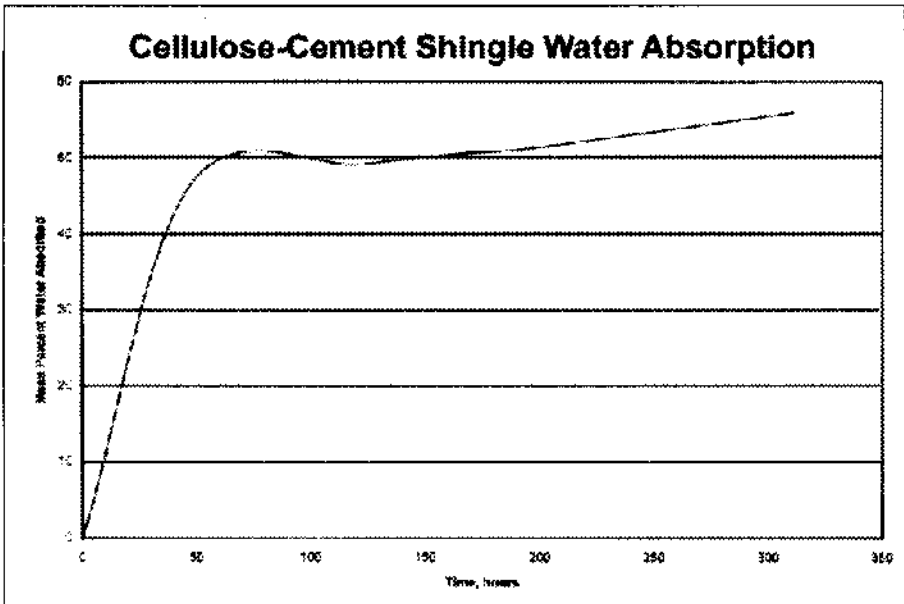


Figure 1

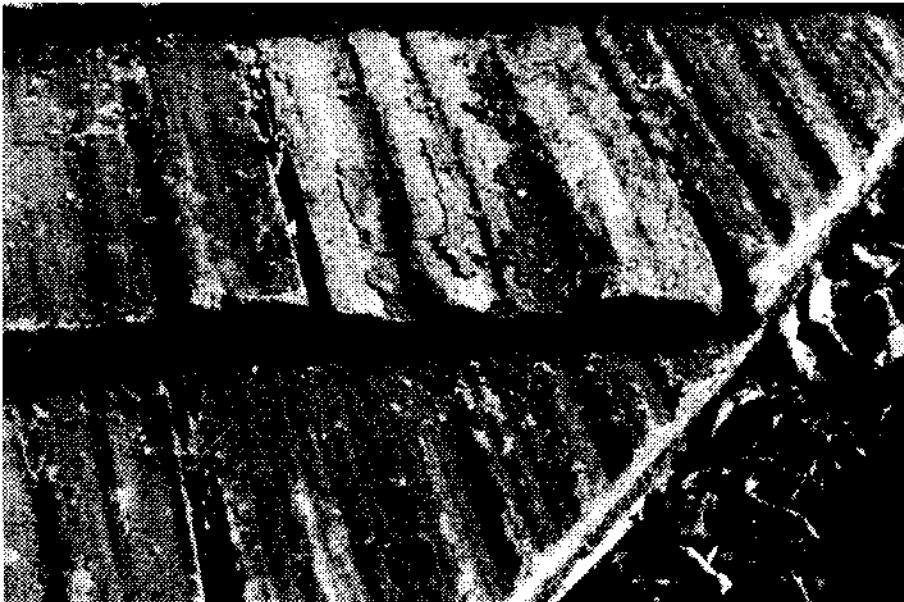


Figure 2

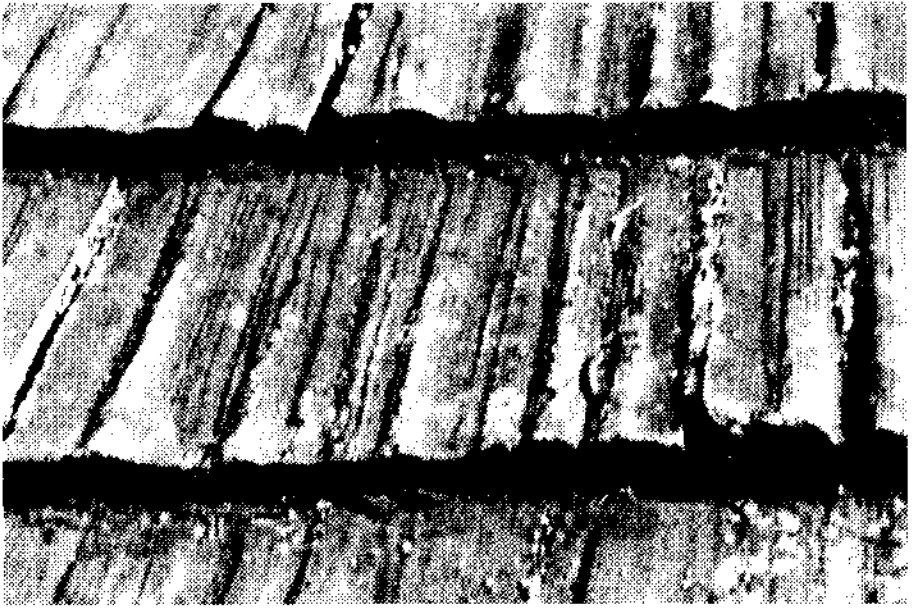


Figure 3

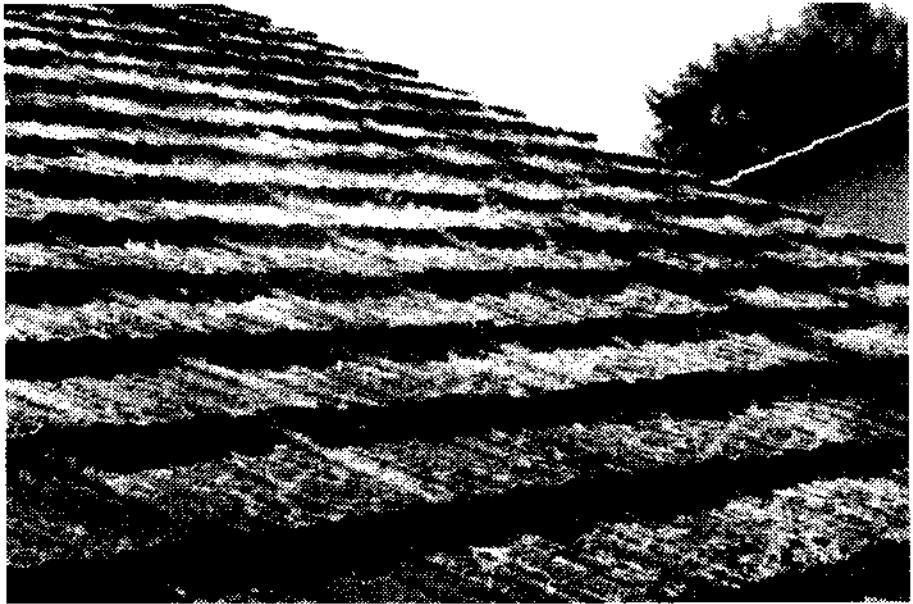


Figure 4

The water dissolves the free calcium hydroxide from the cement and carries it into the hollow tubular cells of the cellulose, where it combines with carbon dioxide from the air to form the insoluble calcium carbonate (similar to stalagmites, stalactites, limestone, and marble). This petrifies the fibers (as one piece of a manufacturer's literature states). The outcome is increased brittleness. Thus, a product that is acceptable when it is installed may become too fragile and brittle in service.

We found micro-cracks in one slate-like product that had never been installed on a roof. The cracking took place during the manufacturing process, because we found coating sprayed on the product within the cracks. Upon weathering, these cracks grow in width and length (Figure 5) until a piece of the shingle drops off (Figure 6).

Some of these faux-slates are intended to be hung or installed loosely with nailheads not touching the upper slate surface. When these slates are tested in bending, the deflection at maximum load is less than the thickness of a nailhead, and a crack is not visible at failure. The sample comes apart at the slightest subsequent touch. This illustrates that the slates cannot be installed without cracking them; the cracks may not be visible when they occur, and the broken pieces just fall off later.

We have seen or heard of some of these products being less than ideally installed, but the quality of the workmanship is very seldom the proximate cause of failure. Failure would have taken place even if angels had installed the shingles.

Owners are not the only people harmed by poor performance. General contractors, specialty roofing contractors, distributors, and designers have all been stained by these failures. Some designers relied on the past performance of the asbestos-cement products and failed to check on the performance of the new material. The materialmen and contractors relied on the manufacturers' representations, and several of the owners had agreed to spend a little more – so they would not have to replace the roof in their lifetime. All parties were disappointed.



Figure 5



Figure 6

The Lessons Learned

The critical lessons learned include some that are old but bear repeating.

- Most experiments fail. Look upon all new materials and systems with a jaundiced eye.
- Changing one component of a material or system makes it a new material or system.
- There is no single or battery of laboratory tests that can predict the performance of a material.
- Accelerated testing routines may only be valid when they are verified by prolonged outdoor exposures, but don't count on it.
- Rely only on outdoor exposures, outdoor performance history, and your own observations on similar jobs.
- As a rule, you can estimate the effective performance of a material or system to be no more than twice the effective performance it has demonstrated in the same climate.
- Be careful of all manufacturers' literature; it's written by the marketing departments.
- The warranty period has no relationship to the service life of the product.

Many of us continue to try and develop accelerated test programs together with the results of outdoor weathering tests in different climates. You are urged to work with those of us that are doing the research to improve our performance prediction and upgrading our standards for material and systems.

It is important for us all to work closely with standard- and code-setting agencies to contribute to the development of standards that protect us all from products that are unsuitable for the purpose and that represent economic loss for society. Consensus standards can frequently result in criteria determined by the lowest common denominator. We must avoid this trap by setting criteria based on the performance required or expected from the product.

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