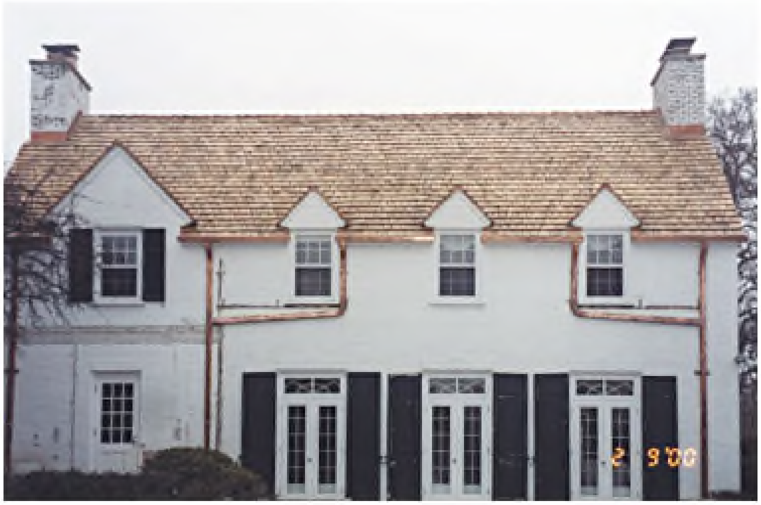


The Edmund Fitzgerald home featured a 70-year-old roof system.

A 70 Year Old Shake Roof

A Case Study by Matt Millen

Durability of wood roofs and shingle exposure have often been lively topics of discussion. George Washington complained about his roofers using double coverage on Mt. Vernon's new roof and wanted it torn off and laid triple coverage because of leaks. Reports from the 19th century suggest that expected service lives from the common sawn shingles were around 15 years. Most of these shingles were white cedar, pine, fir or oak and were 18 to 36 inch long and laid with triple to seven times coverage. Coverage of four times was typical.

The Certigrade Handbook of Red Cedar Shingles claimed that western red cedar shingle roofs could last 75 years. Three or four times coverage were recommended based on roof pitch. The Certi-split Manual of Handsplit Red Cedar Shakes of 1971 recommended triple coverage and interplys on roof pitches of less than 8:12. Today the minimum is double coverage on pitches of 4:12 and greater. Today the average life of wood shake and shingle roofs is 20 to 25 years although some untreated products offer 50 year limited warranties. Tales of having to replace roofs at 15 years are too common. Especially with double and triple coverages over spaced sheathing where No. 15 interlayments are used, where flashings are poorly executed and when substandard shingles are not culled out.Old roofs are our collective experience and contain many lessons for us.

In 1930, Edmond Fitzgerald built a cedar shake roof on his home that lasted 70 years. He also built a great lakes ore carrier that did not last through a November gale as well as his roof did. Good materials and good construction methods are why the roof was durable. After 70 years there were no leaks or water stains on the roof deck except as noted. Twenty-four inch shakes laid at a 7 inch exposure and heavy interlayment were used. The copper flashings were carefully installed. Following is a description of this exceptionally good roof.

ROOF DECK, SLOPES and CLIMATE

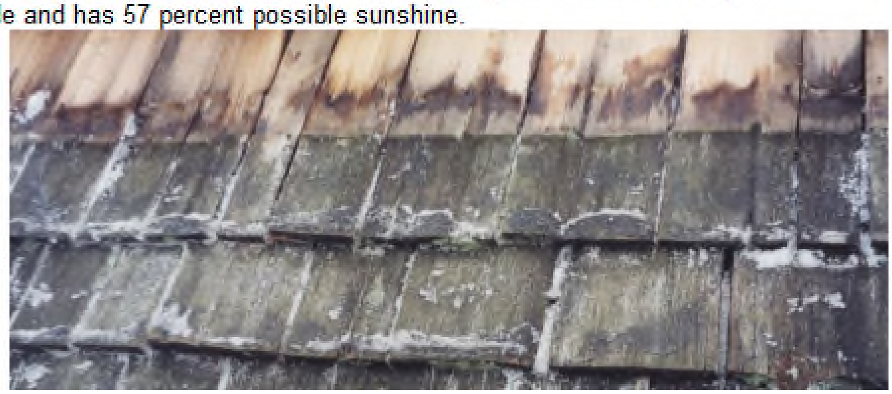
The 7,000 sq. feet house was built at the north end of Olmstead's Lake Park, 3150 E. Kenwood Ave., Milwaukee, WI. It is about 500 feet from a 150 foot bluff on the western shore of Lake Michigan. The architects Judell and Bogner are known for their fine residential buildings. Construction materials and methods throughout the structure are good quality.

The roof deck nominal is 2x6 framing, 16 inches on center covered with nominal 1x6 T & G pine boards. The principal rafter lengths are 14 feet.

The main north – south roof section has slopes on both sides of 12:12 or a 45 degree pitch. There is a lower pitch 8.5:12 or 35 degrees on a swept eave at the bottom 4 feet of the east side of the main roof slope. On the secondary gables the pitch is 14:12 or 50 degrees.

The main ridge is orientated due north. All steep roof slopes face primary directions. Average annual precipitation in Milwaukee is 30 inches, including 46 inches of snow. Relative humidity average is 73 percent. Average temperatures range from 20.9 degrees Fahrenheit in January to 70.7 degrees Fahrenheit in July with an average annual of 46.4 degrees Fahrenheit. Milwaukee is at 43 degrees latitude and has 57 percent possible sunshine.

THE SHINGLES



The shingles are western red cedar, with split faces and resawn backs, 24" x _" (610 x 13 mm) mediums. The _" (10 mm) butt thickness appears very even with an actual range of _ inch to _ inch with an average of 5/8 inch in the samples taken. Most widths used run about 5 inches to 8 inches. In the samples the widest is 8.5 inches and the narrowest is 3 inches.

Grains are primarily edge grain. About 90

Grains are primarily edge grain. About 90 percent have the rings form an angle of more than 75 degrees with the face. Defects such as flat grain and sapwood, are not present. Today the shingles would be classified as a No. 1 Blue Label Premium Select grade. The shingles appear to have been sorted by thickness to give the roof an even appearance. Some culling of substandard shingles probably was done.

Original shingles installed on the roof systems north slope.

Most of the shingles have tight growth rings. In the samples, the counts average from 12 to 19 per .5 inch. When looking at growth rings there is a difference in wood formed early and that formed late in the growing season. This produces the light and dark components of the annual growth ring. The inner portion is called earlywood and is lighter in weight and color, softer, and less dense. The outer portion is called latewood and because of its greater density may be more decay resistant and has better weathering characteristics. In comparison a sample of current production select premium grade western red cedar split and resawn shakes had growth rings averaging from 9 to 14 per .5 inch and the size of the latewood runs about the same. The terms old growth or slow growth are sometimes used to describe a better quality of the wood shingles as compared to new or fast growth. Ring count and latewood portion are an easily observed part of this concept although many other factors are related to the durability of wood shingles.

Original, thinner shingles installed on the roof systems east slope.

The weathering and decay of western red cedar wood shingles and shakes are mainly caused by sunlight, water and fungi. Sunlight, mainly the ultraviolet component, decomposes the lignin in the surface wood cells. Wood is made up of cellulose, which is the main structural element of the wood cell; lignin which cements the cellulose together and is concentrated on the outside of and between the cells; hemicelluloses which are sugars associated with the cellulose; and non structural extraneous materials including the decay resisting extractives in the heartwood.

As the lignin is decomposed by sunlight, the wood cells lose their bonding strength and are eventually washed or blown away. The rate of this erosion is about _ inch to _ inch per 100 years depending on degree of exposure to sun and water, density, grain orientation and temperature. Erosion occurs most rapidly in the thin-walled fibers of earlywood and at a slower rate in dense latewood.

Cycles of wetting and drying cause checking and cracking which leads to more water penetration. Extractives which gives western red cedar its stability, water repellency and natural decay resistance are dissolved and leached from the wood by water.

Decay-producing fungi will attack western red cedar heartwood under conditions that favor their growth. The fungus in microscopic threadlike strands permeates the wood and uses part of it as food. Some fungi live on the cellulose, other use the lignin as well as the cellulose. Serious decay occurs when the moisture content of wood is above the fiber saturation point (average of 30 percent) and between 50 and 90 degrees Fahrenheit.

The heartwood of western red cedar contain a large amount of soluble extractives which give it a natural decay resistance. The extractives are dissolved and leached from the wood by water. Rating the decay resistance of wood species is difficult because of the difference within a species and the variety of service conditions to which the wood is exposed. The extent of variation in decay resistance of individual trees or wood samples of a species is much greater for the most resistant species like western red cedar than for non resistant species.

The decay resistant heartwood extractives include thujaplieins and other polyphenolics. As they are leached out of the wood, the wood destroying fungi feed and grow causing the wood to become soft and spongy. This occurs first at the butt of the shingle because the cross grain cut allows more water to enter the wood structure.

The general appearance of these shingles at 70 years is well weathered. On the southern exposure the erosion and splitting of the exposed portion of the shingles is severe. Less than .5 percent were eroded to the point of loss which exposed the interlayment and in some instances the second layer of wood below the interlayment. The most extensive cracking was on the south exposure followed by the west exposure which is typical in the area. Part of one slope where all thinner shingles were used was also more deteriorated except under a 1 _ inch copper flashing at a windowsill. On the north and east and some west exposures the appearance was not objectionable. In protected areas along sun shaded walls or below copper flashing there was very little erosion or cracking, the shingles were sound and in very good condition. The principle weathering factor on this roof was ultraviolet deterioration and related erosion and water related cracking and leaching of extractives as well as decay. There appears to be more of a relationship between sun exposure and decay than moisture and decay on this roof. East exposure shingles were more decayed than north exposure shingles even where lichens were growing on the cut butt ends.

The eave construction is unusual and the weakest part of this roof. The roof was not started with three layers of shingles. A 1x6 pine board is laid on the roof boards parallel with the eave as an eave cant. An 18 inch sawn shingle is installed, then an 18 inch interlayment and finally the first course of shakes. There is no ice dam protection membrane. Many of the eave cant boards have water stains and some are deteriorated. The only water stain on a finished interior surface occurred in a 6 inch area at the eave on the lower pitches sweep and eave of 8.5:12 (30 degrees) on the east side sun room.

The seven inch exposure of these shakes gives a triple coverage rather than today's typical double coverage. This triple coverage and a heavy interlayment are some of the principal factors why this roof lasted 70 years.

UNDERLAYMENT, INTERLAYMENTS

Underlayments are used in limited areas, under low sloped, soldered locked seamed galvanized steel roof areas, under saddles of soldered locked seamed lead coated copper and under the wood roof areas immediately adjacent to saddles where accumulated water flows and ice and snow buildups are expected. An example is the spill area below the 3 square metal roof which spilled to a lower 6 sq. foot saddle between two gables.

Type I (No. 15) asphalt saturated felts with organic reinforcing materials are used. They are laid one ply. They are cemented with asphalt roof cement to overlap valley, and saddle metal. Small amounts of roof cement are also used to patch small holes in the underlayment that developed during the construction process.

The underlayments are used for several purposes, as a slip sheet or cushion under the metal roofs and metal saddles, to shed water passing through wood shakes and interlayment layers where large amount of flowing water or ice dammed water is expected, and to provide a temporary roof covering at the spillway below the 3 square flat roof area.

The underlayments directly under the metal roofs are lightly saturated and are brittle. They are not capable of shedding water. But they still separate the wood from the metal and act somewhat like a sponge if necessary. They absorb and later release small amounts of moisture. The underlayments under the layers of wood shakes and interlayment are well saturated and are still pliable and can shed water. They are still tightly adhered to metal flashing edges where laid in asphalt roof cement. The patch of roof cement over small holes in the felt are still effective.

The interlayment is an asphalt saturated and coated felt with organic reinforcing materials. It is laid 7 inches up from the butt or directly under the exposed portion of the next course of shingles. Today the common practice is to use No. 30 felt and lay it 20 inches up from the butt where a 10 inch exposure is used. The top surface of the interlayment has a heavy mica and vermiculite coating which protects the asphalt and fiber by providing some UV resistance and helps shed water. The interlayment is exposed between the vertical joints of the shingles because of its low location. Because the exposed part of the shingles are about 5/8 inch thick and spaced apart up to _ inch, the exposure to sunlight is limited. At the wider joints the mica surface appears washed. The asphalt is deteriorated at less than 25 percent of the joints. In some cases a _ inch slot is burnt through the interlayment. Where unexposed the interlayment is in good condition. It sheds water and is still pliable. The table shows the results of testing limited samples of this interlayment against current ASTM D 224 and D 226 standards.

Specimen	Net mas of Saturated felt	Mass of saturant (including coating and surfacing)	Mass of desaturated felt	Mass of mineral matter (vermiculite)	Mass of mineral matter passing a No.70 sieve	Total mineral matter
Double-layer samples—Unexposed (bottom layer)						
Sample A	40.8	26.4	5.9	2.5	5.7	8.2
Sample B	42.7	28.1	5.9	2.5	5.9	8.4

Sample B	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Single-layer samples—Unexposed (upper 11 inches [279mm])						
Sample 1	45.7	28.1	6.2	2.7	8.3	11
Sample 2	39.4	26.3	5.7	2.7	4.4	7.1
Single-layer samples—Semiexosed (lower 7 inches [178mm])						
Sample 1	40.2	23.7	5.8	3.3	7	10.3
Sample 2	40.1	27.4	3.4	3.5	5.7	9.2
ASTM D 226						
Type I	11.5	6.2	5.2	not reported	not reported	not reported
Type II	26 (minimum)	15 (minimum)	10 (minimum)	not reported	not reported	not reported
ASTM D 224						
Type I	39.8	25.3	5.2	not reported	not reported	10.8
Type II	54.6 (minimum)	34 (minimum)	10 (minimum)	not reported	not reported	10.8

Figure1: How interlayment specimens from the Fitzgerald home compare with ASTM D 226, "Standard Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing." and ASTM D 224, "Standard Specification for Smooth-Surfaced Asphalt Roll Roofing (Organic Felt)."
Measurements in pounds per 100 square feet.

FASTENERS

The shakes were attached to the roof deck with 2 inch (51 mm) galvanized box nails. The shank diameter is 0.120 inches (3 mm) which is No. 11 stubs gauge. The head is _ inch in diameter. They are a 6d box nail. There is a small amount of rust and corrosion of the steel and galvanizing on the head and top _ inch of the shank of many of the nails. There are approximately 686 fasteners per square based on average shingle widths and exposures. This roof is very difficult to remove and fastener pull out strengths may be excessive for wind loads. Today staples are a common fastener.

Apron flashing installed at a chimney on the roof systems north slope.

FLASHINGS

Open valleys are 16 ounce lead copper. The label on the metal is Revere, Leadtex 15, 16 ounce, C.R. The valleys are formed of 18 inch wide metal, 8 feet long. There is a _ inch W rib through the center and a _ hem at the sides. The sections are lapped 5 to 6 inches to form 17 foot long principal valleys. The hem is removed from the bottom sheet at the lap. The top of each sheet is nailed with four 1 _ inch copper nails. The sides are nailed just inside the hem with both copper nails and 1 _ inch galvanized box nails. Nails occur at one to two foot intervals or where needed to keep the metal flat to the wood deck. The valleys are exposed 3.5 inches on each side of center. The exposure is not tapered. The metal is laid directly on the wood. The shingles are sometimes nailed through the copper not closer than 6.5 inches from the center line. There are no valley leaks or stress areas because of overfastening.

At some drip points off the shingle corners, the lead coating is worn away and near the base of the 17 foot valley about _ of the thickness of the copper is worn away in the worst areas. This type of erosion is typical on older lead and copper flashings. Water sheds into the valleys from not all but specific corners of slate, tile and wood shingles. With light rains or heavy condensation the drip water is often acidic from pollution that has been deposited on the roof. This acid solution etches away the protective oxides that develop on copper and lead. The oxides redevelop and are again etched away in a repeating cycle eventually resulting in holes through the metal. This problem is not unique to wood roofs. The extra coating of lead or another layer of copper at the drip points can forestall the problem.

At vertical walls individual flashings are used. They are laid on under the interlayment and under the 7 inch exposed portion of each course. The size is 3x3x10 providing a 3 inch extension up the wall and on the shingle and a 3 inch overlap with the next step flashing. 16 ounce copper is used. The interlayments are laid tight to or to within 1 _ inches of the wall but not up the wall. At gable and dormer sidewalls the wall sheathing paper is laid over the steep flashing as is the wood siding. Where painted shake shingles are used for siding, the wood is then brought to the surface of the roof shingles. The butt edges of the siding are not deteriorated at the roof surface nor are the wood shakes on the roofing. The close proximity of the wood to the copper in these location as well as other location helps preserve the wood. Where a diagonal 1 inch pine wood was used for siding or trim there are some deteriorated wall boards.

At masonry walls and chimneys a 5 inch 16 ounce copper counterflashing is exposed. It covers the step flashing by about 2 inches. The brick was diagonally cut at installation. The 2 to 3 inch top edge of the flashing was installed over the brick and diagonally cut brick were mortared in over the copper edge. There is no water penetration or stains evident. Apron flashings at dormer and chimney head walls are 16 ounce copper. The size is 4 inches over the shingles and 5 inches up the wall. There are some water stains on the roof deck at the chimney apron flashings. At some small dormers there is about 2 inches over the shingles and the remaining, about 4 inches, is set under the wood windowsills or window framing.

On walls covered with cedar shake siding a copper flashing is also used at the side framing of the windows. Two inches extends on to the wall over the wall sheathing paper and 1 _ inches covers the window framing side and 3/8 inch is bent over the face of the frame. Where the sill extends beyond the side frame, this window side flashing is cut and neatly fit to the sill ledge and small inside corners. There is a small 16 ounce copper cricket behind the 4 foot wide chimney.

A 16 ounce copper flashing is used under the wood shake ridge. There are 4 inches of metal on each side of the apex. It is covered with 5 inch wide ridge shingles. They are 24 inches long laid with a 7 inch exposure. The 2 inch galvanized field nails are used. There is no corrosion of the nails at the copper flashing. At the apex, the shingles are saw cut and are butted with an alternate overlap. The ridges have held tight and show no wind damage.

At the cast iron plumbing vent protrusion a 16 ounce copper flashing is used. The flange extends 3.5 inches on all sides. The base of the pipe extension is oversized and the top is formed into the inside of the iron pipe.

At the rake edges and eave edges no perimeter flashing is used, a 1 _ inches by 1 _ inches pine crown molding is fastened to the top of the fascia and the shakes extend about _ inch over the edge of the molding.

At the main eaves 16 ounce lead coated copper gutters are used. The style is 4 inch, half round with a double _ inch bead. Hangers are 1 inch, 11 gauge (.0863 inches) copper bar slock fully clamped over the beads, the tongue is attached to the center of the spreader with copper rivets and brass nuts and bolts. The distance of the gutter from the shingle butt edge runs 2 to 3 inches to create a slight pitch. The pitch is set with the location of a 45 degree bend in the tongue, which then extends about 6 inches onto the roof deck and is fastened with two copper nails.

The downspouts are 16 ounce lead coated copper, 4 inch diameter smooth round. At the intersection of a gutter end and valley, where the roof slope on one side of the valley extends below the other side such as at a raised gable or large dormer, a flashing piece is soldered to the end cap of the gutter and bent to extend up under the lower end of the valley metal. This directs most of the valley water into the gutter and eliminates an excessively wet spillway area on the lower part of the roof along the raised gable or dormer side walls. There is no excessive deterioration of the roof in these areas. Typically the spillway areas are the most deteriorated parts of older roofs.

The gutter system is functional even though it may be undersized for some of the main roof areas. There seems to have been no harm to the windows, walls and foundation. In some areas the gutter was pushed in, possibly from ladders. Ice loads probably caused some sags between a few of the over spaced hangers. Some downspouts had split seams or damaged elbows due to ice expansion.

Ventilation of the attic was done through two attic dormer windows placed just below the ridge at opposite ends of the T shaped attic space. The 14 x 38 inch windows when manually opened have a net free venting area of about 500 square inches.

The attic floor area is about 3,000 sq. feet and volume is about 15,000 cubic feet. There is no soffit, ridge or other venting. All sheathing is tongue and groove and gable end walls are face brick over frame construction or sheathing covered with a tarred and reinforced building paper and painted cedar shakes. If one window is acting as an intake and one as an exhaust the venting ratio is 864 to 1. This is substantially less than the 150 to 1 ratio first suggested by in 19 . There are no signs of moisture build up on the underside of the roof deck or within the wood shake and interlayment assembly. There is no evidence of molds in the attic or frost stains around nails that penetrate the underside roof deck. There is no indication that the shingles and interlayments suffered from heat buildups, moisture accumulation or lack of drying from the underside. No vapor air barrier is used at the second floor ceiling. The attics of many older buildings with board roof decks appear to adequately breathe. The original attic floor insulation is a few inches of vermiculite. Later blown cellulose was added to fill the 7.35 inch ceiling to attic floor cavity. This is, in effect, a warm attic.

For the record, this roof was removed and replaced in early 2000 with a similar roof as part of a larger remodeling project.

There are many good ways to build a roof. Industry standards and government codes often describe limited ways and minimums. The practicalities of having to cover a wide variety of climates, building uses and styles, and traditions of construction practice necessarily limits the variety of what is included. Codes and standards are also created in a political environment which tries to balance the interest of public safety as well as manufacturing and construction efficiency and value. This roof in some ways exceeds and in other ways is less than the specification in today's codes and standards, and the roof works very well.

In the art of roofing, the craftsmen use the knowledge of local environments and the micro climates and conditions created by roof geometry and the surrounding area. They understand the deteriorating forces the roof and related components are subject to including all the ways water moves. They know the limits of the materials they have to work with. They appreciate the complex relationships between budgets, economic value, and appearance versus function and owner expectations. This roof offers some general lessons and other more specific to the climate, slope and materials uses. It also raises questions. The degree of roof slope and orientation are important factors for material durability. The number of layers and quality of cover material and interlayment are critical for longevity of the system. The skill and thoughtfulness at flashing details is equally important.

Will an owner accept or appreciate the appearance of an old weathered roof. The taste for moss or lichen on stone and tile roofs often changes when it comes to wood roofs. The pride and satisfaction with the look of new wood is similar to that for newly painted surfaces.

With triple coverage versus double coverage is the 50 percent additional material cost and less than 50 percent additional labor cost worth the extended service life. Life cycle costs analysts will debate the theory and appropriateness of including other factors. Long term market and industry trends have been toward less expensive systems and shorter service lives and hopefully more value.

Are there other ways to extend the service lives of wood roofs such as using thicker shingles, better and more underlayments, better grades of wood or more culling and using steeper roof pitches.

Do we put too much emphasis on the need for breathing to reduce the moisture component of the fungus decay system which typically starts at the butt end on the top of the assembly. There seems to be some confusion between breathing and ventilation for interior condensation control.

Can ultraviolet resistant interlayments be more effectively used if located directly under the exposed portion of the shingle. They would shed more water and directly protect the rest of the shingle than the typical higher placed interlayments.

Should more emphasis be placed on post construction protective coatings for wood shakes and shingles. Coatings can provide a UV barrier, they can repel water to reduce the cracking and splitting and they can carry fungicides.

The way we build roofs continues to evolve as technologies develop and markets adjust. It is with our understanding of how our old roofs perform that new advances can be most successfully applied to build better roofs.

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