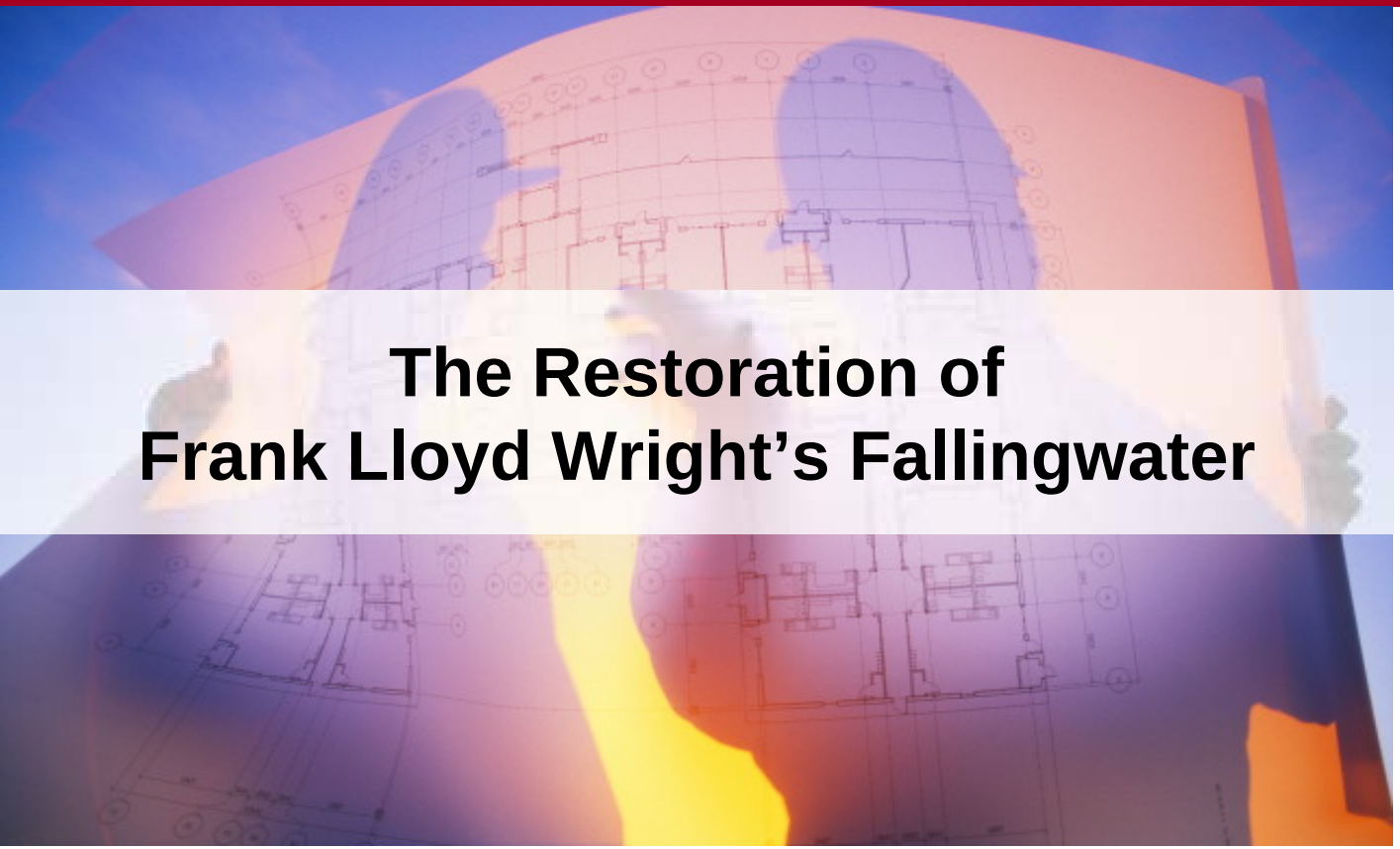

The Restoration of Frank Lloyd Wright's Fallingwater

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The Restoration of Frank Lloyd Wright's Fallingwater

Presented By: Paul R Bertram, Jr. FCSI, CDT, LEED-AP
PRB Connect
1461 Fairway Oaks Dr.
Casselberry, FL 32707

Description: Provides an overview of the restoration of Frank Lloyd Wright's Fallingwater, including details regarding structural issues, moisture intrusion, roof and terrace restoration, and interior and exterior coatings.

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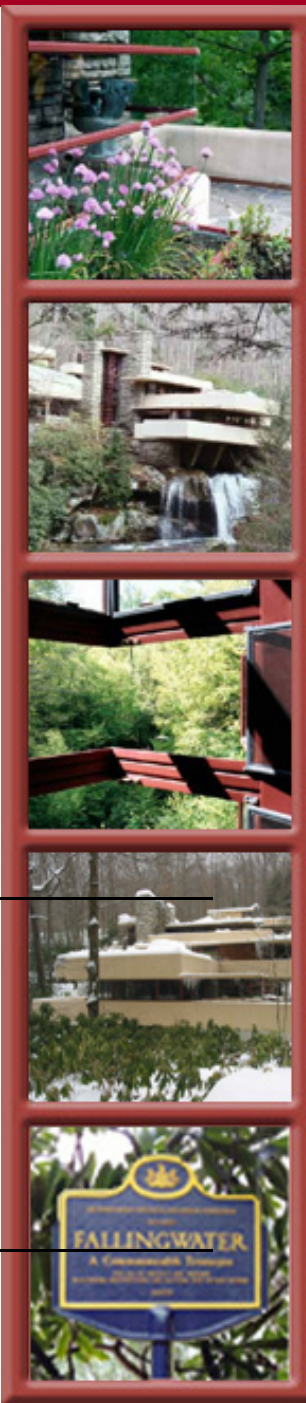

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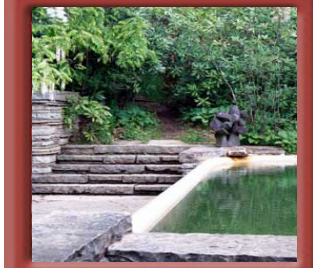
Learning Objectives

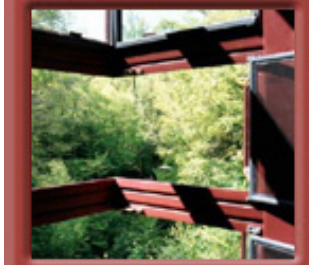
Upon completing this course, you will have a better understanding of:

- The history of Fallingwater and Frank Lloyd Wright's design intent
- The preservation and conservation standards used at Fallingwater
- The structural issues related to Fallingwater's cantilevered terraces
- How the building envelope design resulted in moisture intrusion
- The extensive restoration of Fallingwater's many roofs and terraces
- The restoration of Fallingwater's interior and exterior coatings
- What Fallingwater can teach us about designing buildings today





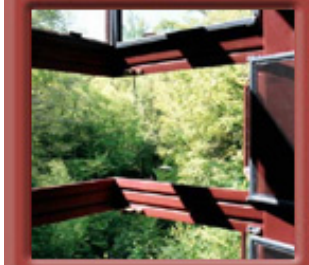
Frank Lloyd Wright & Fallingwater



Frank Lloyd Wright & Fallingwater

Introduction

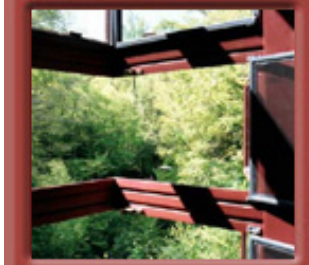
- Frank Lloyd Wright believed buildings should look as if they belong to the ground. He was bold in his thinking and what he believed to be a viable thought process for architecture.
- His integration of structure into the natural, fractured rock land-scape at Fallingwater creates a harmonious order.
- Wright's Fallingwater is like a surreal painting, which today is recognized as one of his most acclaimed works. In 1991, AIA members voted it "the best all-time work of architecture."



Frank Lloyd Wright & Fallingwater

Frank Lloyd Wright

- Frank Lloyd Wright was born in Richland Center, WI on June 8, 1867 and died in Phoenix, AZ on April 9, 1958, at the age of 91.
- Wright believed architecture was a great inclusive agency through which humankind adapted the environment to human needs and reciprocally, attuned human life to its cosmos; architecture could keep human life more natural and nature more humane.
- Wright was 68 years old when commissioned to do Fallingwater, a project that ultimately caused his career to soar to new heights.

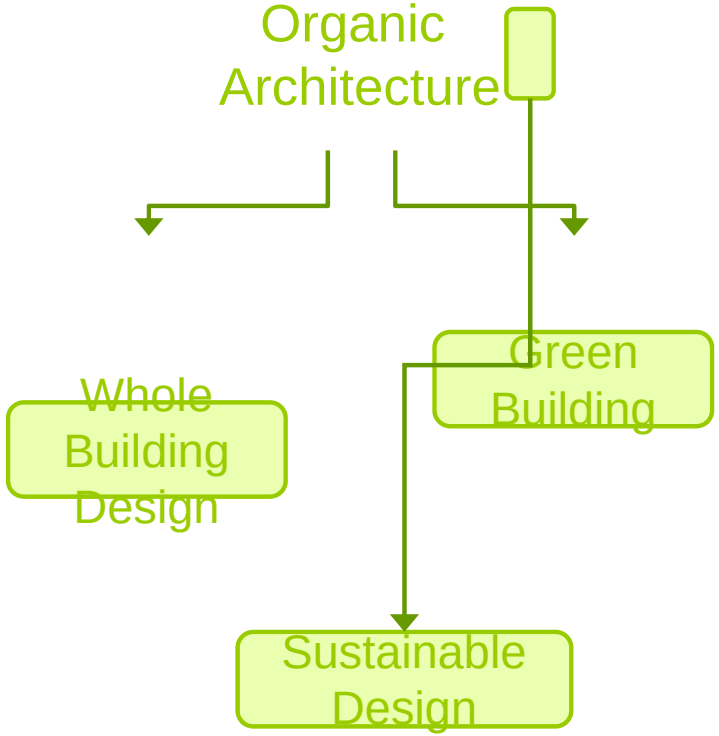


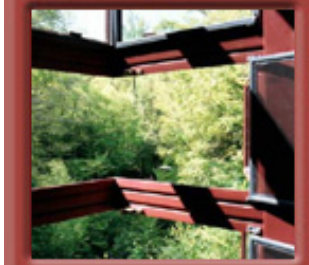
Frank Lloyd Wright & Fallingwater

Organic Architecture

"Organic architecture is an architecture from within outward, in which entity is an ideal...Organic means intrinsic—in the philosophic sense, entity—wherever the whole is to the part as the part is to the whole and where the nature of the materials, the nature of the purpose, the nature of the entire performance, becomes clear as a necessity. Out of that nature comes what character in any particular situation you can give to the building as a creative artist."

Frank Lloyd Wright





Frank Lloyd Wright & Fallingwater

Wright's Thoughts

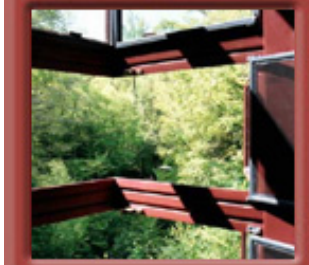
"The thing always happens that you really believe in; and the belief in a thing makes it happen…"

Frank Lloyd Wright

"The scientist has marched in and taken the place of the poet. But one day somebody will find the solution to the problems of the world and remember, it will be a poet, not a scientist."

Frank Lloyd Wright

Photo by Ruschak provided by Fallingwater



Frank Lloyd Wright & Fallingwater

History of Fallingwater

- In 1935, Edgar Kaufmann Sr., president of Pittsburgh's Kaufmann Department stores, commissioned Frank Lloyd Wright to design a weekend retreat for his family.
- Wright and Kaufmann agreed on the division of responsibilities, with construction beginning in 1936 and ending in 1939 with the completion of the guest house.
- Wright selected the contractors to oversee concrete and stonework and sent apprentices from Taliesin to represent him on the job site.

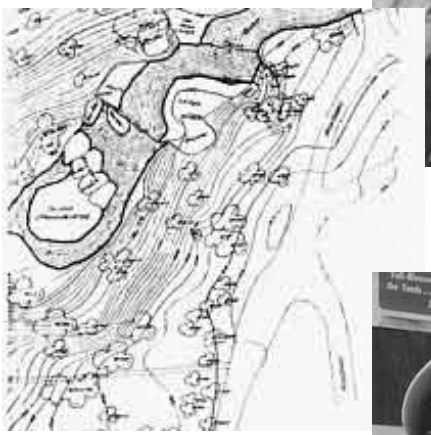
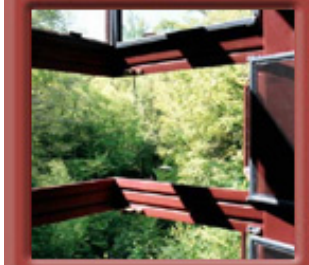


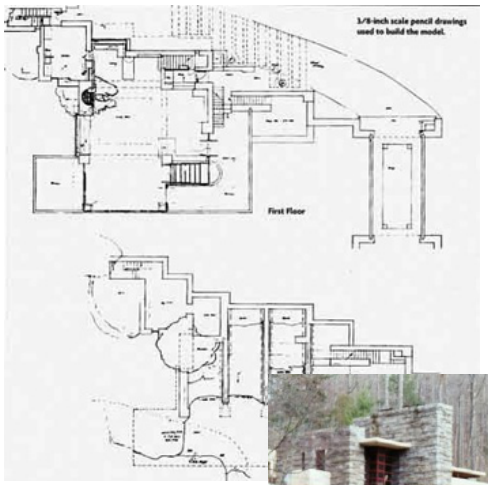
Photo by Ezra Stoller

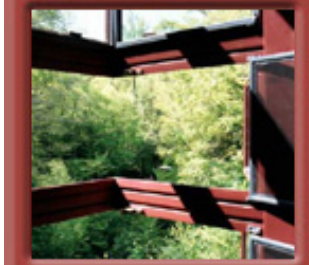


Frank Lloyd Wright & Fallingwater

History of Fallingwater Cont'd…

- The labor force consisted of local tradesmen (thought to be a cost saving decision) who were trained in Wright's individual ways.
- In the summer of 1936, Kaufmann had engineers increase the length of the concrete beams, creating a load of almost twice what Wright had originally specified.
- Engineers redrew the plans and added steel for safety. Although his representatives approved the plans, Wright never approved these potentially hazardous loads.





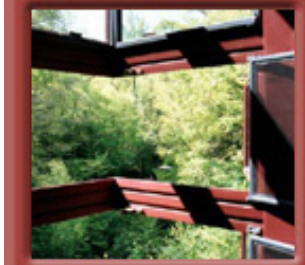
Frank Lloyd Wright & Fallingwater

History of Fallingwater Cont'd…

- The Kaufmann family used Fallingwater until 1963 when Edgar Kaufmann, Jr. entrusted the property to the Western Pennsylvania Conservancy (WPC).
- The architectural community considered this gift a significant contribution to preservation, as several Wright-designed structures had already been lost due to their maintenance requirements.
- The WPC is committed to implementing conservation strategies that connect people to their natural world.

www.wpconline.org





Frank Lloyd Wright & Fallingwater

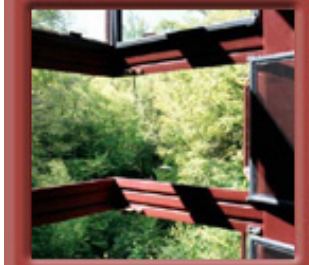
Fallingwater Facts

- Location: Mill Run, PA. About 60 to 70 miles southeast of Pittsburgh and 30 minutes East of Shanksville, PA, the 9/11 crash site of Flight 93.
- Site Size: Originally 1,500 acres, the site has been expanded by 3,500 acres to 5,000 acres by the Western Pennsylvania Conservancy as part of the Bear Run Reserve.
- Project Size: Approximately 7,000 sq. ft., about half of which consists of terraces. Also include a separate two-storey guest house with a carport and servants quarters.

Frank Lloyd Wright & Fallingwater

Fallingwater Facts Cont'd…

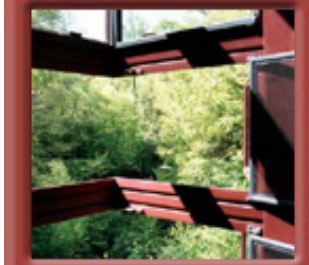
- Cost: Original budgeted to cost between $20,000 and $40,000, the project went more than $100,000 over budget, with a final cost of $155,000 at completion.
- Renovations: Currently undergoing an $11.8 million dollar renovation, being conducted in accordance with the Archeology & Historical Preservation guidelines of the NPS, Department of the Interior.
- Attraction: A National Historic Landmark, Fallingwater attracts in excess of 140,000 visitors annually.



Frank Lloyd Wright & Fallingwater

Views of Fallingwater

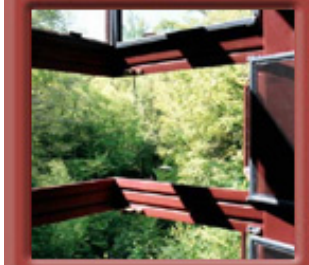
- Walking down the hill toward Fallingwater, one is immediately struck by its picturesque beauty, surrounded by arching formations of rhododendron and a thick and pristine forest setting.
- Reaching the stream, "Bear Run", you discover the intrinsic contrast of the natural rock formations and the cantilevered house.
- The design reflects the natural patterns of the rock ledges, with floors stratified to a height of 30' and suspended over the stream.



Frank Lloyd Wright & Fallingwater

Views of Fallingwater Cont'd…

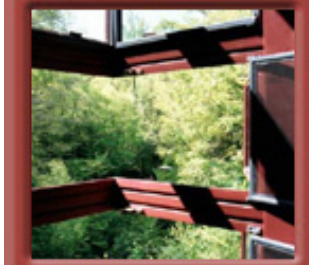
- The Lipchitz statue visible in the lower right foreground is titled "Mother and Child" and was part of the Kaufmann's art collection.
- This is the view from the bridge looking toward the stairs leading down from the great room to the falls. The area behind the statue is the spot where Mrs. Kaufmann went swimming almost everyday.
- The temperature of the water is about 50°F year round. Notice the natural stone that was quarried and cut on Fallingwater property.



Frank Lloyd Wright & Fallingwater

Views of Fallingwater Cont'd…

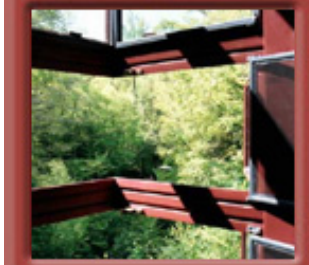
As you walk around the outside of Fallingwater or look from the inside to the outside, you truly can appreciate the successful accomplishment of Frank Lloyd Wright's "organic architecture" design intent. The structure assumes the character of the natural setting from whatever vantage point you experience it.



Frank Lloyd Wright & Fallingwater

Views of Fallingwater Cont'd…

Add to that, the seasonal changes of brightly colored leaves in the fall, to snow-capped, icicled winters, to the budding of spring and the density of full summer and one can clearly understand what Emerson meant when he said "Beauty is the moment of transition."

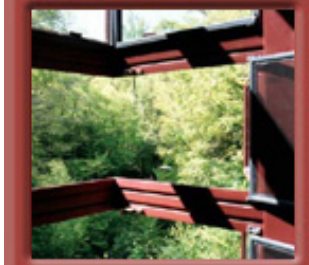


Frank Lloyd Wright & Fallingwater

Thoughts on Fallingwater

"Fallingwater is famous because the house in its setting embodies a powerful ideal—that people can learn to live in harmony with nature …As technology uses more and more natural resources, as the world's population grows even larger, harmony with nature is necessary for the very existence of mankind."

Edgar Kaufmann, Jr.

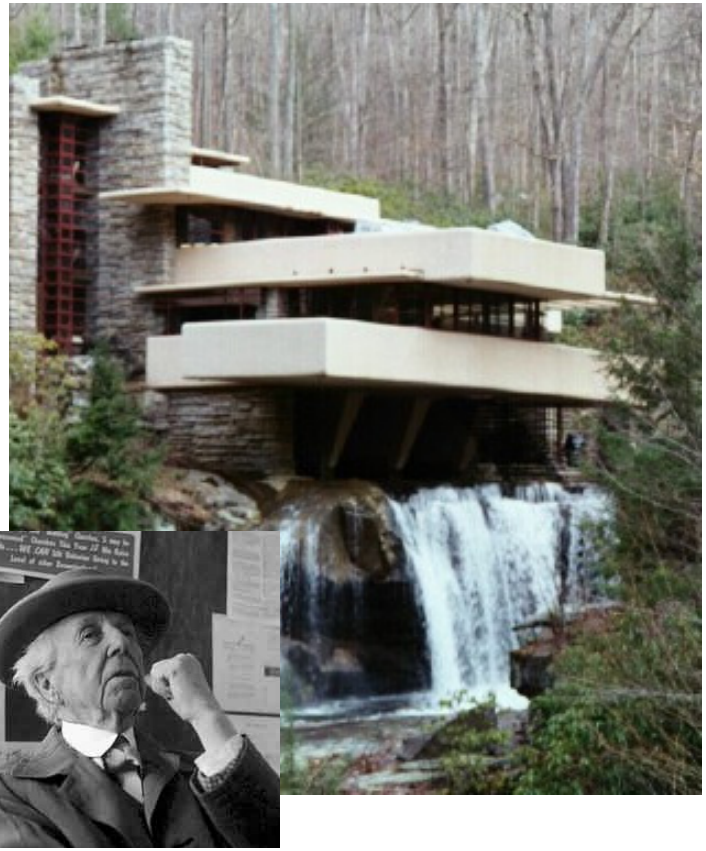


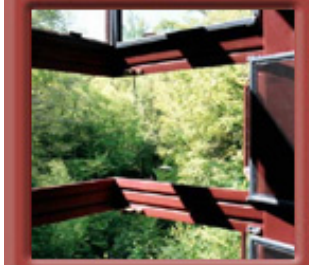
Frank Lloyd Wright & Fallingwater

Thoughts on Fallingwater Cont'd…

"Fallingwater is a great blessing– one of the great blessings to be experienced here on earth. I think nothing yet ever equaled the coordination, sympathetic expression of the great principle of repose where forest and stream and rock and all the elements of structure are combined so quietly that you really listen not to any noise whatsoever although the music of the stream is there. But you listen to Fallingwater the way you listen to the quiet country."

Frank Lloyd Wright





The Deterioration of Fallingwater

The Deterioration of Fallingwater

Aesthetics vs. Functionality

- The aesthetics of the "intended design" of Fallingwater were Frank Lloyd Wright's paramount focus.
- As Wright stated: "This structure may serve to indicate that the sense of shelter–the sense of space where used with sound structural sense–has no limitations as to form except the materials used and the methods by which they are employed for what purpose."
- According to architect Pamela Jerome: "This resulted in a problematic situation–aesthetics over the functionality of a water-tight building".

The Deterioration of Fallingwater

Signs of Deterioration

- Even before the family moved in to Fallingwater, Edgar Kaufmann noticed cracks appearing in the east and west parapets of the terrace for the main bedroom.
- Over the years Kaufmann had his engineers monitor the angle of the cantilevers after it became obvious that they rose and fell in response to seasonal temperature changes.
- This constant movement resulted in cracks, which were treated with an occasional cosmetic patching and repainted without addressing the underlying structural issues.

The Deterioration of Fallingwater

Signs of Deterioration Cont'd…

- Other problematic areas included the discovery of stalactites and carbonate lines in the soffits below the terraces and near drains, and the sodden lumber and insulation beneath roof and terrace flooring.
- The parapet walls were also of concern. Even Wright believed they were not as effective in carrying the load as had been anticipated.
- From the outset, engineers who were independently contracted by Kaufman expressed doubts about the structure and believed it would eventually break apart.

The Deterioration of Fallingwater

Signs of Deterioration Cont'd…

- In the interior of the structure, warped doors, peeling paint, stains and cracks also appeared as a result of structural deficiencies involving the cantilevers.
- "As in any building, maintenance is a constant issue at Fallingwater" says Lynda Waggoner, VP of the Western Pennsylvania Conservancy and Director of Fallingwater.
- The current 11.8 million dollar renovation demonstrates the need for a distinction between routine maintenance and restoration / renovation / preservation efforts.

The Deterioration of Fallingwater

Nonstructural Pathology

- In a paper written for the APT Bulletin, Norman Weiss, Pamela Jerome, and Stephen Gottlieb provided a detailed account of the deterioration of Fallingwater.
- The paper provided details of the 13-year long investigation of the deterioration mechanisms at work and prototype treatments.
- This report was instrumental in leading to a better understanding of the nonstructural pathology of materials deterioration taking place at Fallingwater.

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Cover: View of patient pavilions, kitchen, and dining rooms, connected by enclosed corridors, at Sea View Hospital, Staten Island, N.Y., c. 1920. Courtesy of Sea View Hospital Archives.

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APT BULLETIN

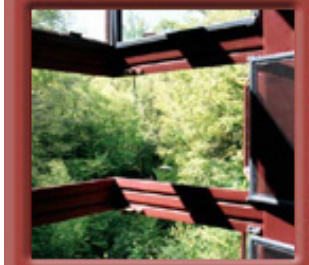
SPECIAL FOCUS ON TERRA COTTA

The Deterioration of Fallingwater

Importance of Building Science

- It is important to recognize that both Kaufmann and Wright understood that Fallingwater was an exploration beyond the limits of conventional practice.
- Low ceilings, unfinished stone inside and out, cantilevered terraces, and a structure built over a stream. Can you imagine submitting this design today?
- Fallingwater reminds us of the importance of research and building science in architecture. They are critical to ensuring that structures perform as intended.

The Preservation of Fallingwater



The Preservation of Fallingwater

Preservation Terminology

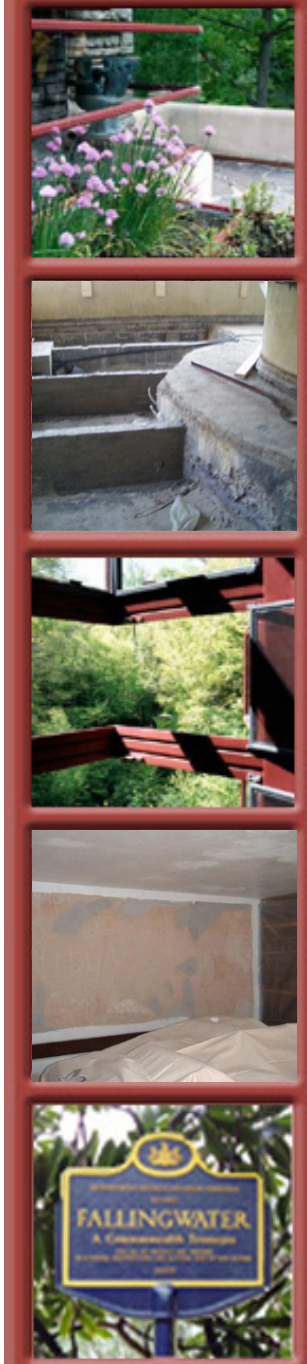
- Preservation: Defined as the act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property.

- Reconstruction: Defined as the act or process of depicting, by means of new construction, the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location.

- Rehabilitation: Defined as the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values.

- Restoration: Defined as the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period.

Source: http://www.cr.nps.gov/local-law/arch_stnds_10.htm

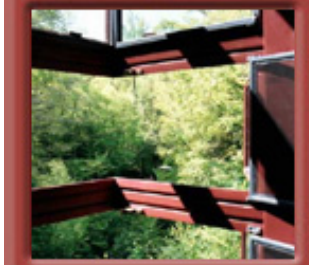


The Preservation of Fallingwater

Preservation Efforts

- Since 1988, all available drawings, published materials, correspondence, consultant's reports, and construction documents, have been archived as part of a research review conducted by a New York architectural firm.
- In 1998, this firm was charged with developing a preservation master plan for Fallingwater. The two-volume master plan, which was submitted for peer review the following year, follows the Archeology & Historical Preservation Standards set out by the U.S. Secretary of Interior.
- The master plan consisted of 177 sheets of measured drawings, photographs and written documentation. Measurements were taken for every surface and then transferred into CAD drawings.
- Notations were added in order to reference any problems visually observed on the structures. The documentation was so detailed that the areas where the flagstone floors and terraces were to be lifted were rendered with stone-by-stone drawings, labeling each stone.

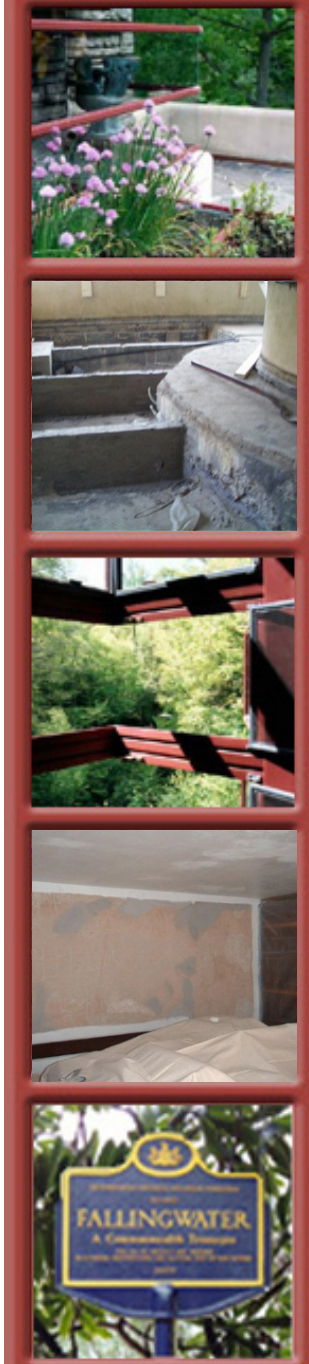




The Preservation of Fallingwater

Preservation Efforts Cont'd…

- In the end, this extensive research and analysis concluded that the main materials-conservation issue facing Fallingwater was deterioration caused by moisture penetration.
- For the restoration, 3-part CSI specifications and construction documents were developed for the bidding process and construction. An engineering firm completed a structural conditions assessment and an architectural firm completed a conditions assessment and preservation master plan.
- The construction documents for the post-tensioning of the main cantilever beams, including the documents for disassembling and reassembling the living room and its terraces, were then peer reviewed at a public forum.
- The seven member panel, which included Edgar Kaufmann Jr., and six other individuals from engineering, architecture, and academia recognized for their outstanding achievements, unanimously endorsed both proposals to stabilize and restore Fallingwater.



The Preservation of Fallingwater

Fallingwater's Preservation & Conservation Philosophy

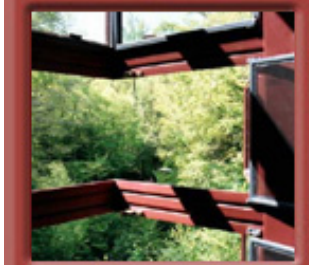
- General Statement: A primary goal of all preservation efforts at Fallingwater is to preserve Frank Lloyd Wright's original artistic intent.

- Building Fabric: It is necessary to understand the nature of the building fabric before any conservation projects are begun. Wright used four primary materials (reinforced concrete, sandstone, steel and glass) to build Fallingwater, creating a sense of harmony and repose both inside and out.

- Conservation Policy: Fallingwater is unique in that it must satisfy two dramatically different programs: that of a work of art to be experienced and that of a modern museum in its operations. The care of Fallingwater is a balance between these two identities.

Each conservation case at Fallingwater must
be considered both individually and as a whole,
taking all factors into account.

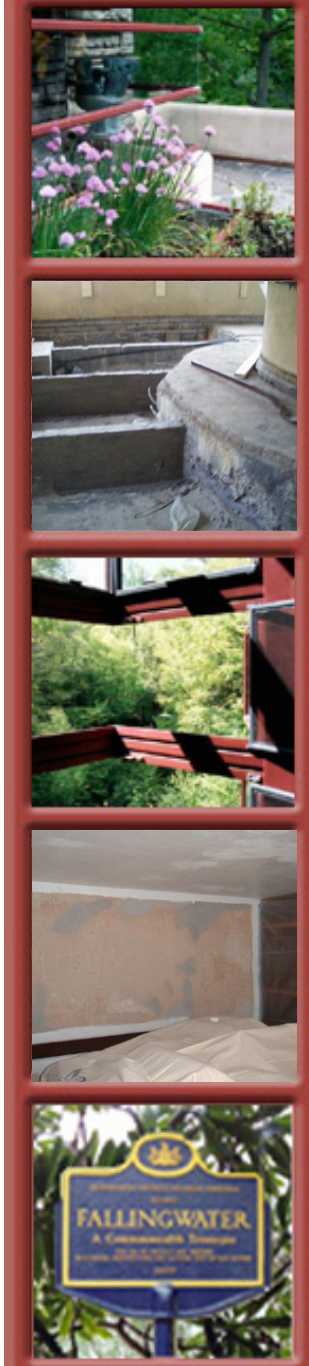




The Preservation of Fallingwater

Fallingwater's Preservation & Conservation Standards

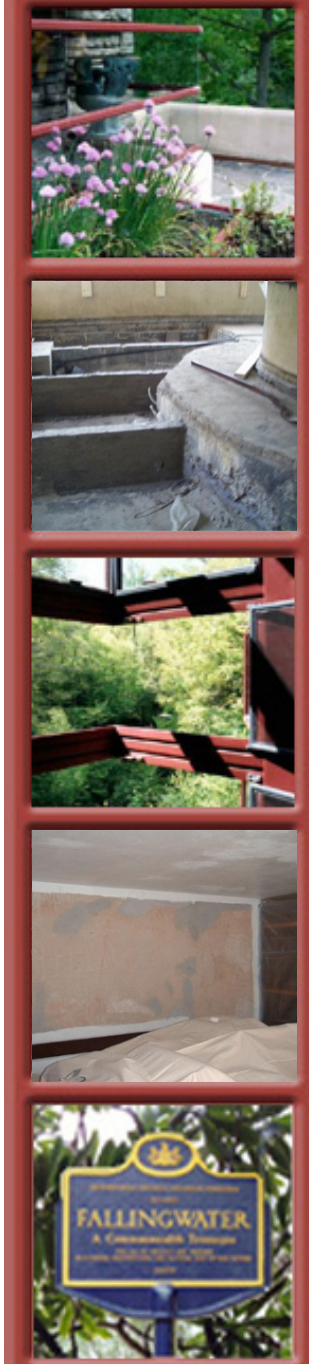
- The condition of the building must be recorded before any intervention.
- Intervention must be governed by the historical aesthetics and physical integrity of Fallingwater.
- All methods and materials used during treatment must be carefully documented.
- Every effort must be made to make all conservation of the building as non-invasive and unobtrusive as possible.
- All interventions must be balanced against their impact on Wright's original vision
- No effort shall be made to revise or improve upon the original design for aesthetic purposes.
- Changes to original building systems can be made if such changes contribute significantly to the long-term preservation of the building.



The Preservation of Fallingwater

The Importance of Reversible Solutions

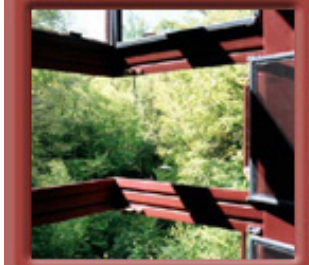
- Preservation and restoration involves unusual corrective challenges, which is why preservationists typically recommend 'reversible' solutions—that is, leaving the ability to undo what has been done.
- Unfortunately, some of Fallingwater's exterior coatings became just the opposite. The application of a cementitious coating between 1978 and 1979 required sandblasting for surface preparation, which damaged the original stucco.
- To complicate the process further, it was revealed during the non-destructive testing of paint stripping methods and materials that paints could only be removed down to the cementitous refinishing layer.
- Removal of this cementitious layer would only further damage the original stucco. This situation emphasizes the fact that, without close visual inspection or non-destructive testing and monitoring, preventative maintenance can actually compound a problem instead of solving it.



The Preservation of Fallingwater

Points to Remember

- It must be recognized, however, that some problems are unique and must to be solved though an educated, well-researched, trial and error basis.
- Interventions almost always involve some loss of authenticity, but are nonetheless justified in order to preserve the structure for the future.
- Conservation involves scales and levels of intensity, determined by physical conditions, causes of deterioration, and anticipated future needs.

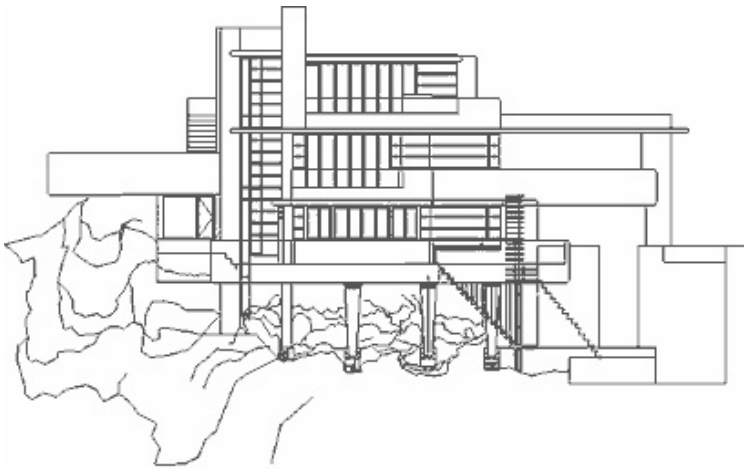


Structural Restoration of Fallingwater

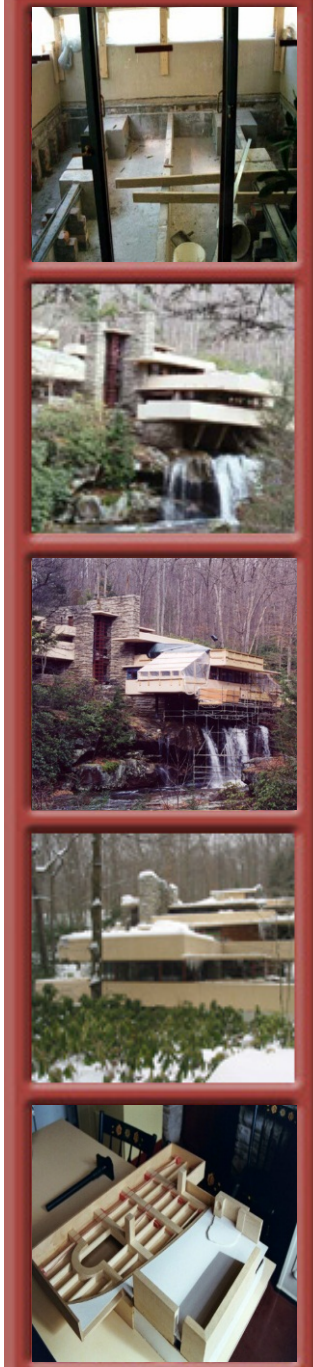
Structural Restoration of Fallingwater

Structural Issues

- Edgar Kaufmann Jr. noted that the cantilevers were never level and that it was an oversight in setting up the concrete forms that was responsible for the angle of the cantilevers.
- During construction, the wood forms should have been sloped upward in order to accommodate any settlement that might occur once the forms were removed.
- Instead, the concrete was poured level and it was the subsequent settlement of the structure, not structural failure, what caused the cantilevers to dip downwards.



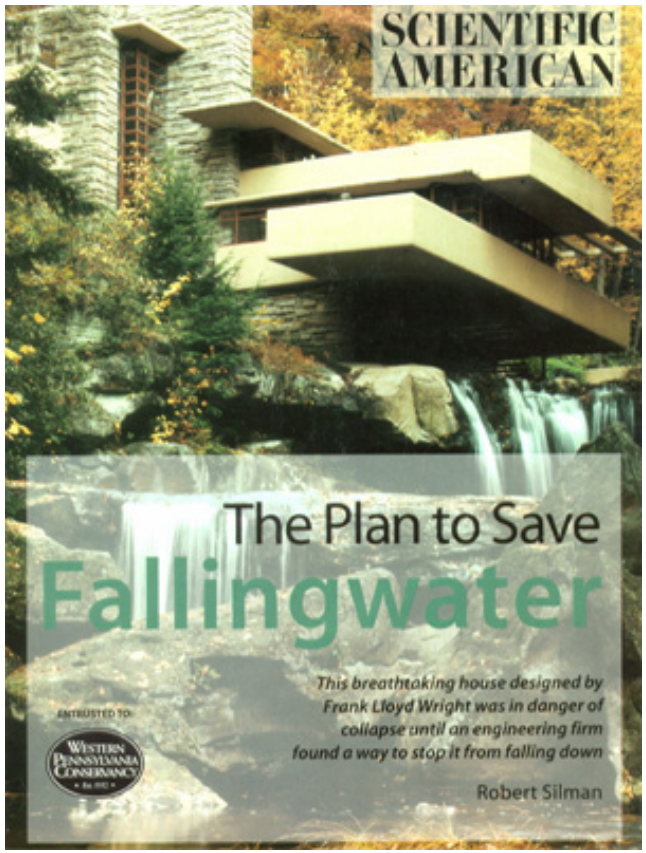
MAIN HOUSE
SOUTH ELEVATION



Structural Restoration of Fallingwater

Structural Solutions

- In 1997 the conservancy approved a plan to temporarily shore up the cantilevers using steel beams and columns.
- The restoration plan incorporated corrective actions that included post-tensioning. A detailed account of the structural analysis and the restoration plan was published in Scientific American.
- The proposed correction was ever so slight as the concern was that, since the cantilevers were never level, trying to do so would cause the structure to break apart.







Structural Restoration of Fallingwater

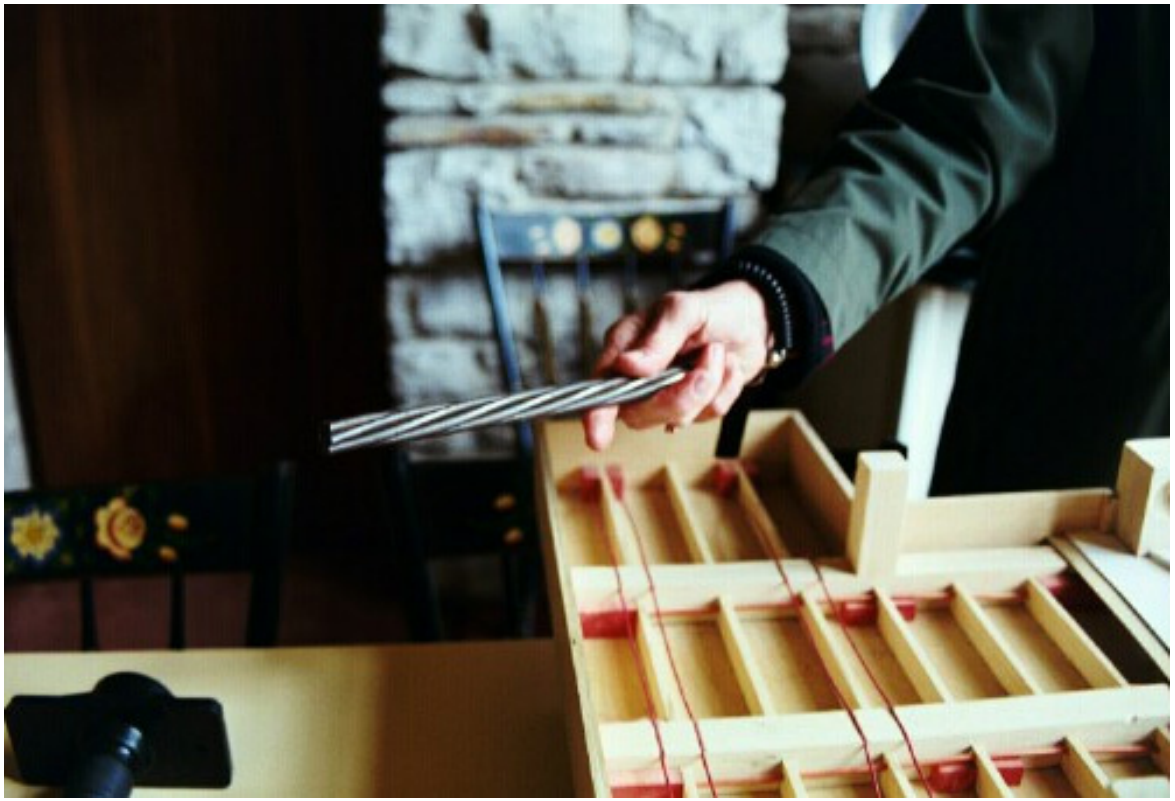
Structural Solutions Cont'd…

This image shows a model of the post-tensioning solution for the cantilevers.

Structural Restoration of Fallingwater

Structural Solutions Cont'd…

This image shows the thirteen-strand steel cable used in the post-tensioning.

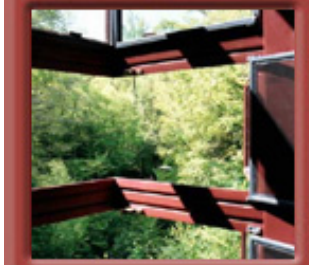


Structural Restoration of Fallingwater

Structural Solutions Cont'd…

This image shows the exposed beams and the addition of post-tension cables.

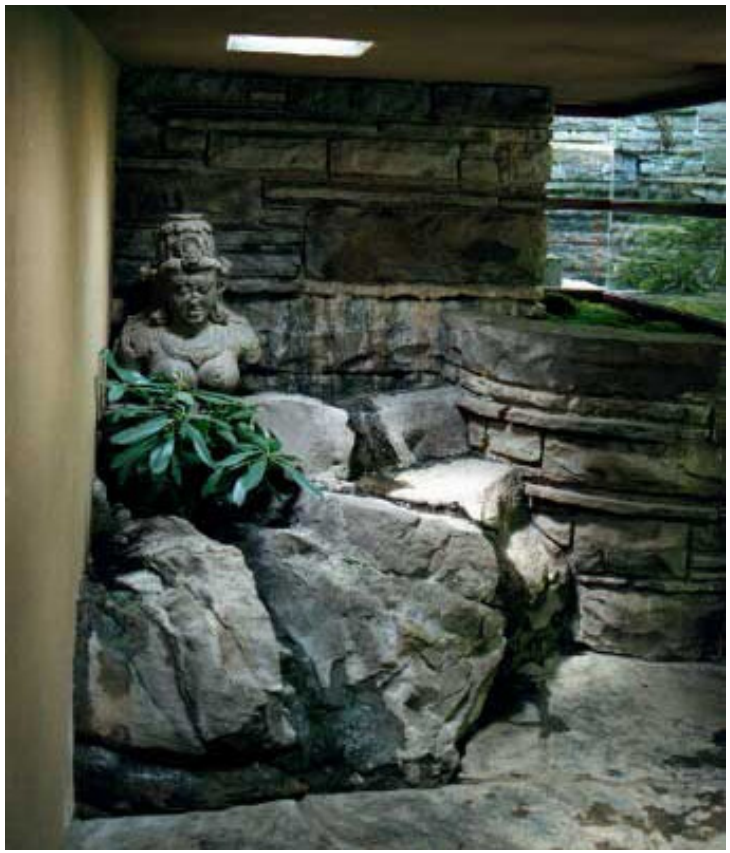
Moisture Intrusion at Fallingwater

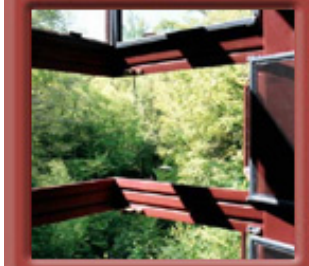


Moisture Intrusion at Fallingwater

Interior Moisture Problems

- Another major issue facing Fallingwater is moisture intrusion. Inside the structure, this on-going problem is responsible for warped doors, peeling paint, stains, and cracks on the walls.
- Water is constantly changing form. Evaporation, condensation, vapor diffusion, capillary action, and flow of moist air occur simultaneously within the building envelope.
- This image provides and example of organic architecture, where Wright allowed rock formations into the structure. You can see water running off this formation. Where does it go?

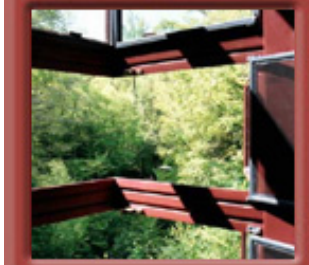




Moisture Intrusion at Fallingwater

Rounded Roof Edges

- In addition to roofs and terraces that incorporated parapet walls, a report cited Fallingwater's rounded roof edges as one area of considerable moisture penetration.
- The rounded roof edges did not provide adequate drainage at the roof roll, causing moisture to migrate from the underside of the concrete roof slab and under the waterproofing membrane.
- It was concluded that the roof and ceiling assembly worked like a sponge: it soaked up moisture, allowed it to collect under the roof membrane and eventually migrate through to the ceiling.

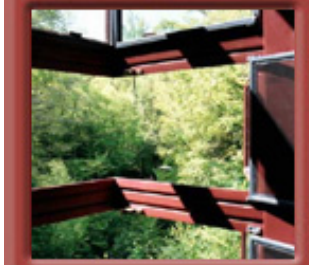


Moisture Intrusion at Fallingwater

Horizontal Exposures

- In the design pathology of Fallingwater, it was also observed that the property's plan resembled a pinwheel with terrace arms that extended outwards.
- These horizontal exposures created a much greater chance of moisture penetration from rain, melting snow, humidity and the general failure of waterproofing and roof system assemblies.
- Fallingwater reminds us that designing the building envelope for watertight integrity requires scientific analysis of the physical properties of materials and the compatibility of assemblies in relation to the forces of nature.

Photo from APT Bulletin, Volume XXXII, Number 4



Moisture Intrusion at Fallingwater

Moisture Intrusion at Roofs & Terraces

- Original System: Originally, Fallingwater's roofs were built up with asphalt-impregnated felts over 1-inch insulation board. Wright wanted the flat roofs to blend with the concrete, so beige-colored gravel was broadcast over the final coat of asphalt.

- Subsequent Systems: During the past 65 years Fallingwater's roof system and terraces have been replaced several times but continued to leak. A 1981 roofing campaign used 4-plies of fiberglass reinforced felts (with hot asphalt in between) laid over ½" thick insulation board. These roofs were replaced from 1987 to 1988 with a single-ply rubberized EPDM membrane.

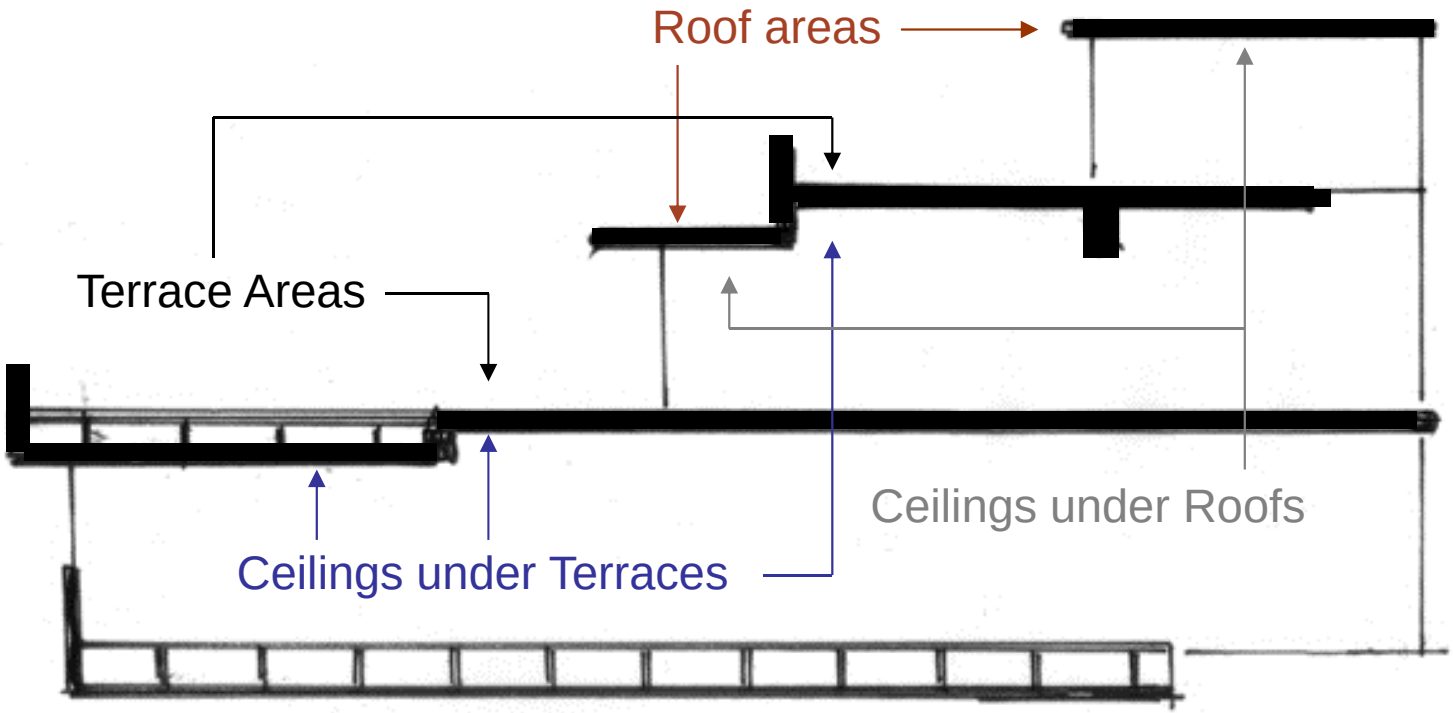
- Problems: Overall, the roofs were in poor condition and most had both patches and pinholes that allowed leaks to continue to occur. Additionally, the fasteners along the roof edges that were meant to secure the membrane were spaced too far apart. This, combined with the unevenness of the concrete, failed gaskets, and failed sealants, also allowed moisture to enter.

Please remember the **exam password** MOISTURE in order to proceed with the online examination.

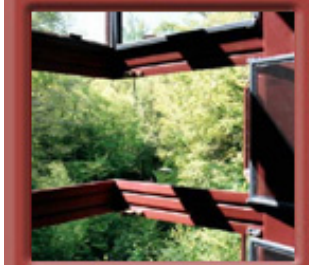
Moisture Intrusion at Fallingwater

Moisture Intrusion at Roofs & Terraces

The design of Fallingwater is such that the concrete roof decks and stone terraces also serve as ceilings in some areas of the structure.





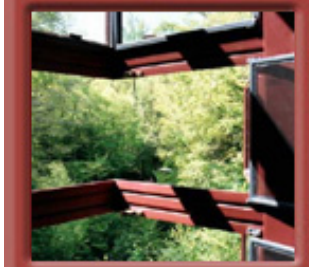


Moisture Intrusion at Fallingwater

Moisture Intrusion at Roofs & Terraces Cont'd…

- In 1999, roof probes indicated moisture penetration due to defective roof seams, perimeters, and the absence of through-wall flashing. A probe on the roof of the servants quarters recorded condensation under the roofing membrane of the terrace.

- The review further stated that a series of mechanical engineering calculations confirmed that there was a relationship between the moisture beneath some of the roof membranes and the lack of a thermal barrier between the exposed concrete roof slabs, which are the undersides of the slabs.



Moisture Intrusion at Fallingwater

Moisture Intrusion at Roofs & Terraces Cont'd…

- Without insulation on the warm side of the slab (finished ceiling), water vapor condenses at the underside of the waterproofing membrane on the top (cold) side. The installation of a vapor barrier, in the form of an impermeable coating applied to the original ceiling substrate, was proposed.

- As illustrated by Fallingwater, understanding the science of combining thermal breaks, vapor barriers, permeable barriers, types of sheathing substrates, airflow (ventilation/HVAC) and roofing membranes is critical to a building envelope's ability to properly handle moisture.

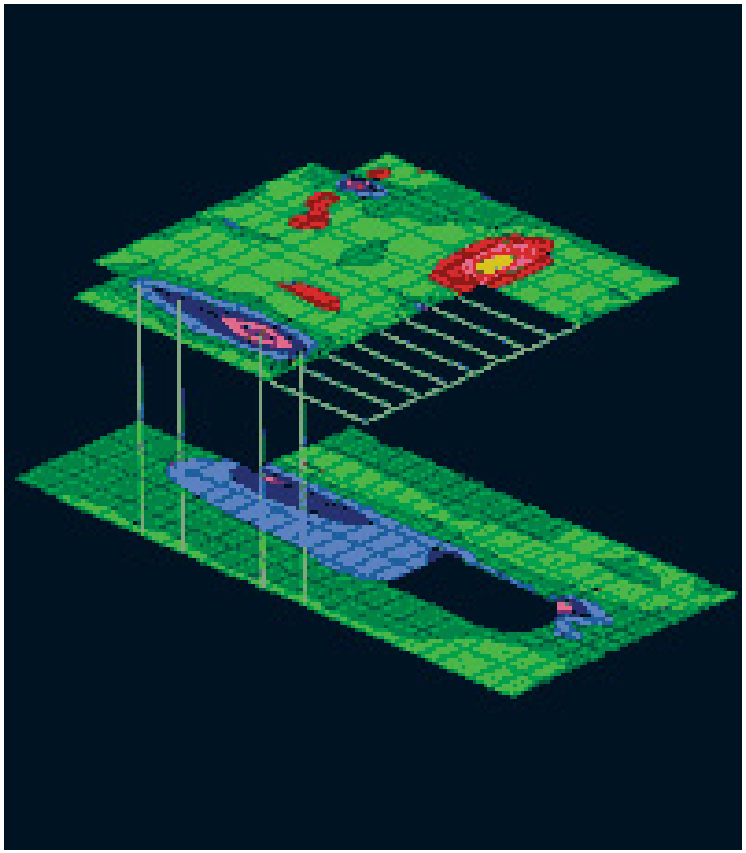
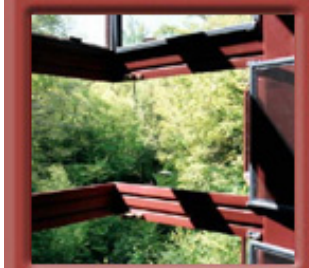


Photo provided by Silman and Associates

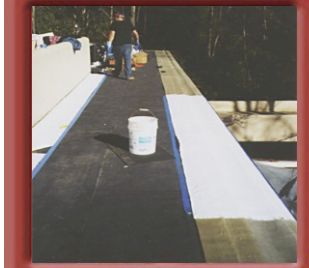


Roof Restoration at Fallingwater

Roof Restoration at Fallingwater

New Roof System

- To help control moisture intrusion and damage, a new roofing system was devised. A Pittsburgh roofing company was brought in to tear off the existing roof and apply the new system.
- While tearing off the existing roof system, contractors made several noteworthy discoveries. For example, some of the lighting fixtures had been installed directly under the roofing membrane.
- Roofing contractors also found that no flashings or interior drains had been incorporated into the roof design. Virtually all of the roof materials removed were wet.

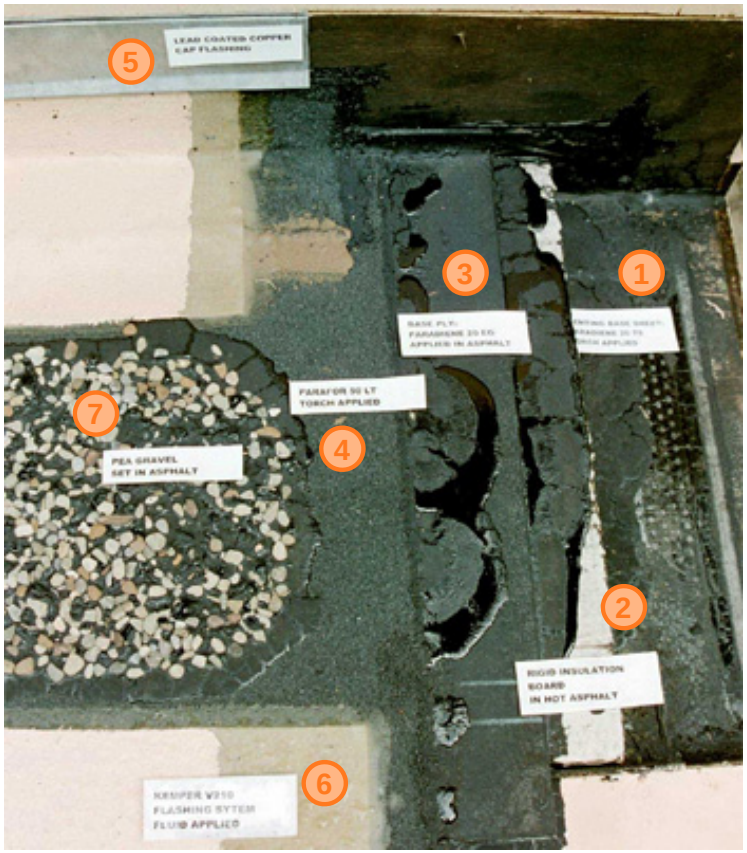


Roof Restoration at Fallingwater

New Roof System Components

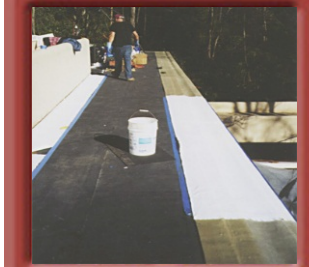
The new roofing system is a layered system that incorporates multiple levels of defense against moisture intrusion.

1. Torch-applied venting base sheet
2. Rigid fiberglass insulation board
3. Base ply applied in asphalt
4. Torch-applied single ply membrane
5. Lead coated copper cap flashing
6. Fluid-applied base flashing for rolled edges
7. Pea gravel beyond rolled edges







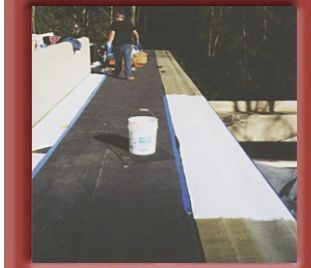


Roof Restoration at Fallingwater

New Roof System Installation

1. A venting base sheet is torch applied over the primed concrete slab. This base sheet is a modified bitumen ply with a series of modified asphalt stripes, which bond to the concrete slab and provide venting channels to disperse any vapor pressure.

2. Rigid fiberglass insulation boards are then laid in asphalt and placed over the venting base sheet. The original specification called for an organic insulation but the contractor firmly believed the moisture concerns of Fallingwater would be better served with fiberglass rigid board insulation.

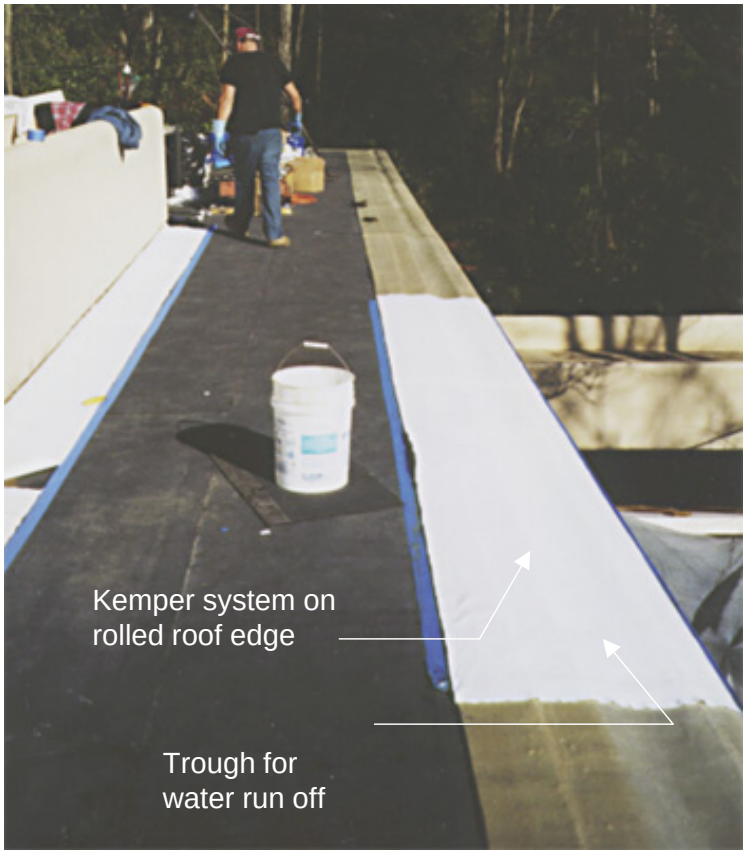


Roof Restoration at Fallingwater

New Roof System Installation

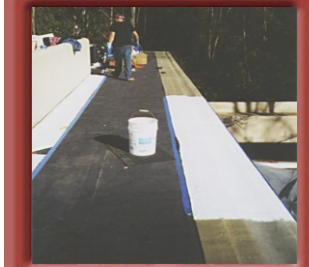
3. A base ply is then applied in asphalt and a single ply membrane is torch applied on top of that. Both roofing membranes consist of high quality modified Sequenced Butadiene Styrene (SBS) asphalt reinforced with a fiberglass mat.

4. Lead coated copper cap flashing is then installed at the walls and a fluid-applied base flashing is used to terminate the roofing at the rolled edges. As in the original system, pea gravel is laid in the asphalt to protect the membrane from exposure to UV radiation that would cause the asphalt in the membrane to oxidize over time.





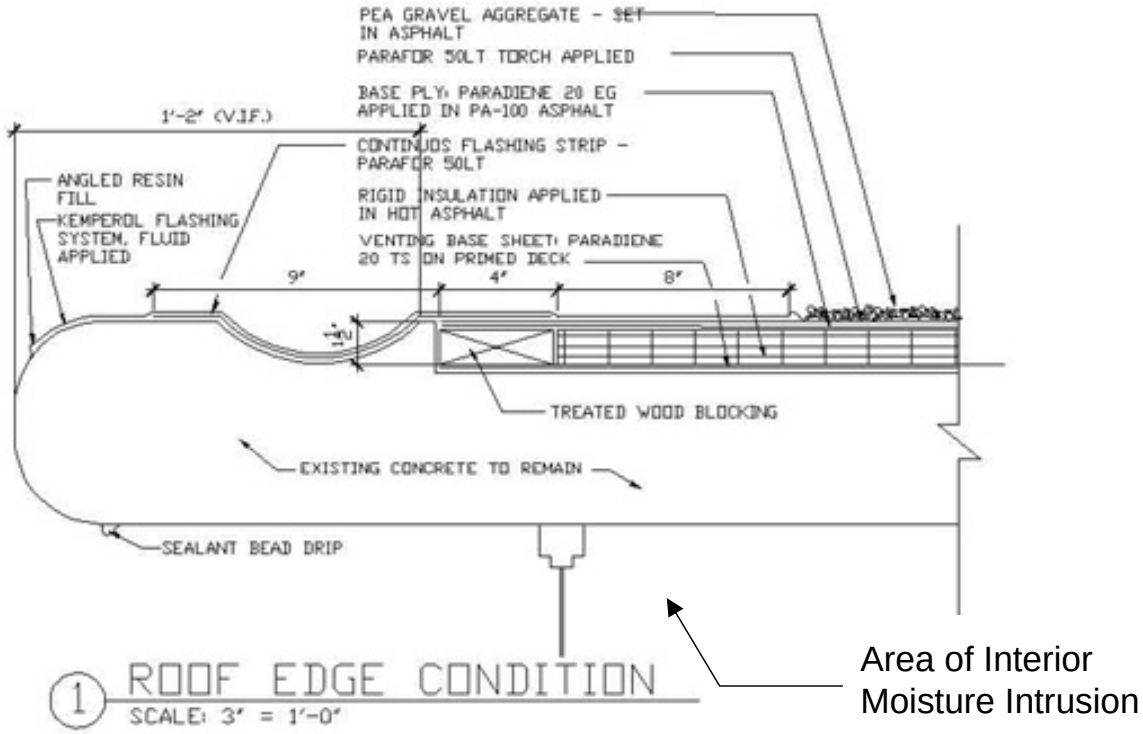




Roof Restoration at Fallingwater

New Roof System Details

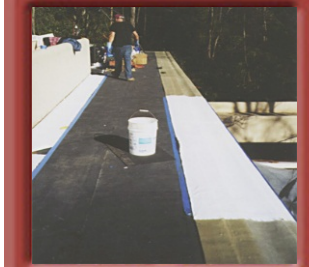
This detail shows the recommended reconstruction of the roof decks and also illustrates how moisture migrated from the underside of the concrete roof slab (interior side) to the top side (under the waterproofing membrane).



Detail reprinted with the permission of WASA LLP and the Western Pennsylvania Conservancy.



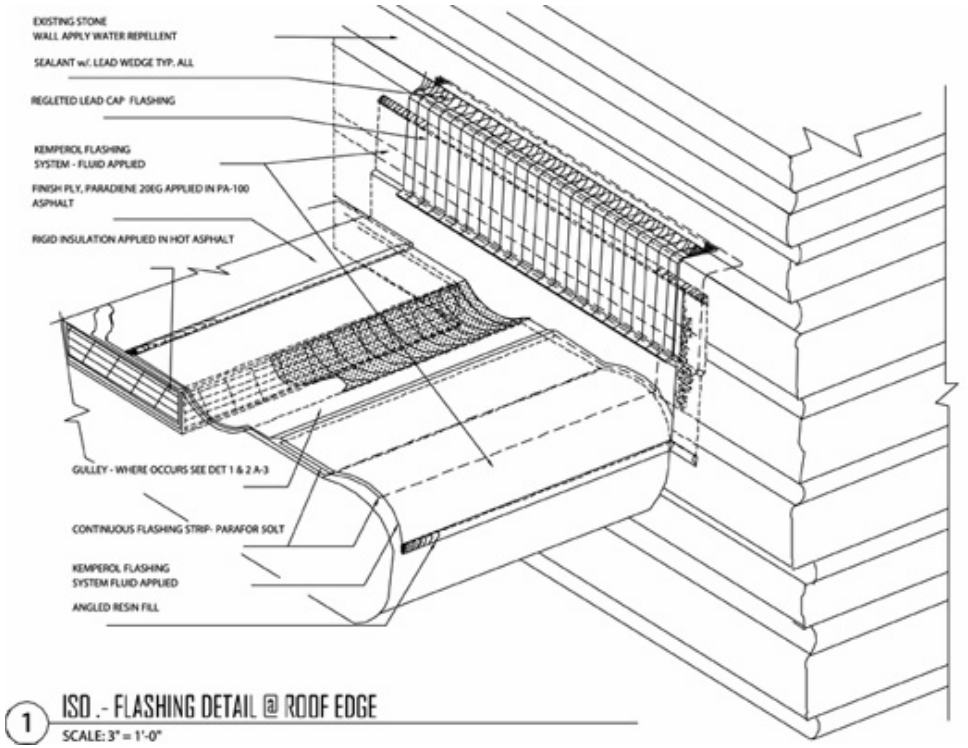




Roof Restoration at Fallingwater

New Roof System Details Cont'd…

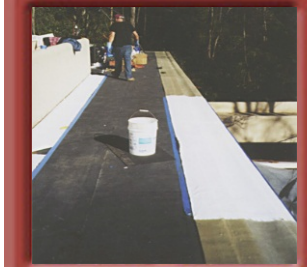
This detail shows one of the flashing areas that has been problematic over the years. This area consists of a complex assembly of flashings and sealants that has many potential failure points for water intrusion.



Detail reprinted with the permission of WASA LLP and the Western Pennsylvania Conservancy.







Terrace Restoration at Fallingwater

Terrace Restoration at Fallingwater

Terrace Construction

- Terrace slabs were originally constructed either as exterior floors or as ceilings with other interior living spaces below.
- The terraces that functioned as floors consisted of concrete decks with parapet walls for additional support. The parapets also added rigidity to the horizontal planes.
- The terraces that functioned as ceilings consisted of wood decks and flagstone raised above the floor slab by deep ribbed concrete support beams. The air space between the slab and the wood decking acted as insulation.

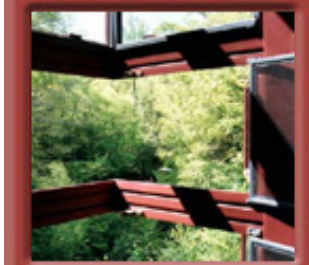
Terrace Restoration at Fallingwater

Terrace Waterproofing

- Original System: Terraces were (and still are) surfaced with large, irregularly shaped stones quarried on the site that vary in thickness from ½" to 1 ½". The original terrace substrate was ¾" redwood decking. A 3-ply built up roof of hot asphalt and building felts was laid over the wood or, on terraces that are not cantilevered such as the Herb Terrace, directly onto the concrete slab.

- Subsequent Systems: The Servants' Quarters Terrace was rebuilt in the late 1950s. The East Living Room Terrace, West Living Room Terrace, and Master Bedroom Terrace were lifted and reassembled in 1987. Edgar Kaufmann Sr.'s Terrace was redone in 1988.

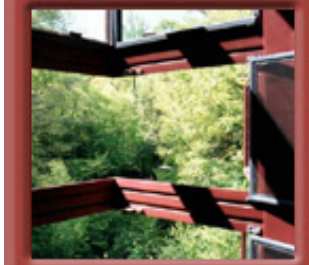
- Problems: Wherever waterproofing or repairs were performed over the last 15 years, a membrane extends up the wall approximately 6" where terraces meet parapet walls. This membrane is covered by lead counter flashing that terminates in a reglet remedially cut into the concrete. The lead flashing is malleable and is easily knocked out by the feet of thousands of visitors. This, coupled with sealant failure and the negative pitch of the flashing within the reglet, directed water under the membrane and allowed moisture entry into the building and the cracking of mortar joints during the freeze-thaw cycle.



Terrace Restoration at Fallingwater

Terrace Waterproofing Cont'd…

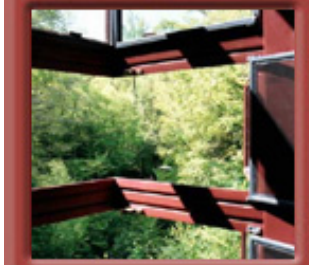
- In 2001, a new waterproofing system was installed at the Herb Terrace, however its design created a number of problems.
- Because the filter fabric around the drain was too fine and the drains were not set lower than the deck, water was able to get under the drainage mat, causing the entire overburden to float.
- Also, the needle punched fabric of the drainage mat allowed for flexing, resulting in a sort of trampoline effect. This, combined with the sand bed, lead to the rocking of the flagstones and the cracking of the grout joints.



Terrace Restoration at Fallingwater

Preparation of Terrace Surfaces

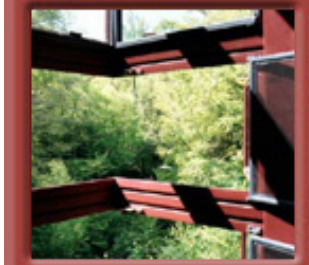
Terrace restoration began with removal of the flagstone. Stone masons photographed, mapped, and numbered each stone for removal.



Terrace Restoration at Fallingwater

Preparation of Terrace Surfaces Cont'd…

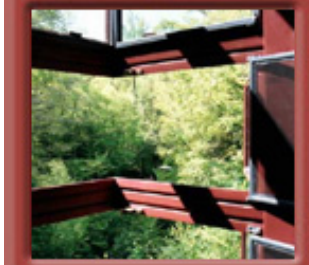
They carefully chipped away the grout and pried up each stone, which was then removed and vertically stored on pallets.



Terrace Restoration at Fallingwater

Preparation of Terrace Surfaces Cont'd…

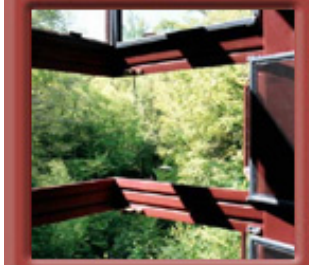
Some of the concrete decks required patching before the new terrace water proofing system could be applied.



Terrace Restoration at Fallingwater

Preparation of Terrace Surfaces Cont'd…

During the winter months the terrace areas were tented to protect the exposed concrete decks from the weather.

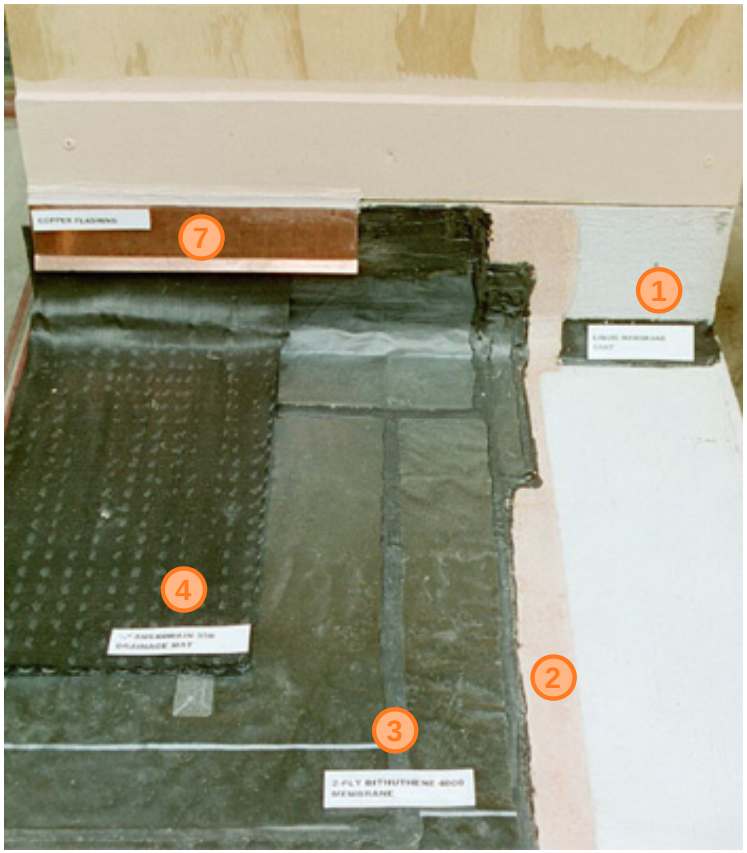


Terrace Restoration at Fallingwater

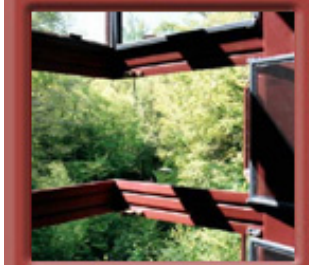
New Terrace Waterproofing System Components

The new terrace waterproofing system incorporates multiple layers of defense against moisture intrusion.

1. Liquid membrane cant strip
2. Liquid-applied, self-curing, rubber-based membrane
3. Two-ply, self-adhering waterproofing membrane
4. ¼" drainage mat
5. Portland cement and sand setting bed (not shown)
6. Paving stones (not shown)
7. Copper flashing



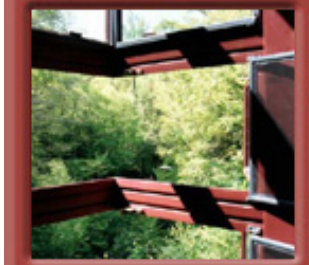




Terrace Restoration at Fallingwater

New Terrace Waterproofing System Installation

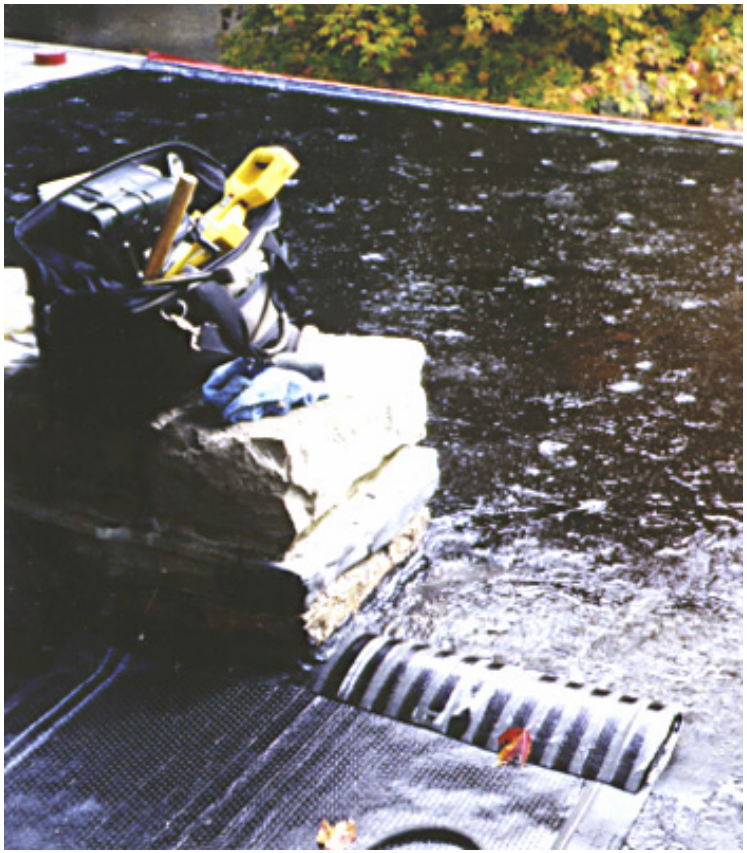
1. A two-part, self-curing liquid membrane is applied where the terrace deck meets the wall to form an angled cant. This cant helps to relieve stress between the horizontal and vertical joints and creates a thermal break.
2. A two-part, self-curing, rubber- based material is then fluid applied over the deck to create a protective membrane.
3. Once this membrane has set, two plies of self-adhering, modified-asphalt membrane are laid shingle fashion. Two plies are also installed at the flashing and the top edge is sealed with two plies of liquid membrane.

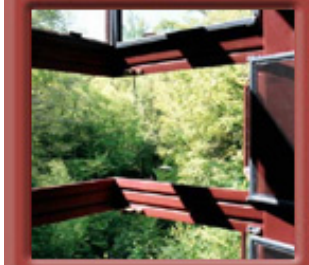


Terrace Restoration at Fallingwater

New Terrace Waterproofing System Installation Cont'd…

4. A ¼" drainage mat is then laid on top of the membrane. This drainage mat protects the membranes below and directs water to the drains. This mat is thinner than the drainage mat initially used on the Herb Terrace and is covered with an open monofilament woven filter fabric. This fabric has a greater tensile strength than the filter fabric on the original drainage mat (250 lbs vs. 90 lbs) and will not give under pressure, eliminating the trampoline effect. Its permeability is 100 gallons/sq. ft./min., which is twice that of the setting bed and well above what any downpour could dump on the terraces.





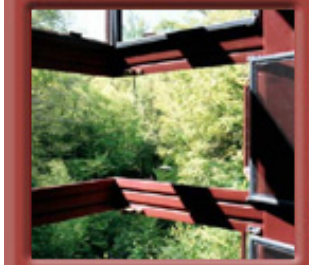
Terrace Restoration at Fallingwater

New Terrace Waterproofing System Installation Cont'd…

5. The next layer is the setting bed (1 part Portland cement to 10 parts sand). The first good rain dampens the cement and solidifies the sand so that the bed does not shift. The amount of cement used does not significantly alter the permeability of the sand bed, and is not enough to "glue" down the flagstones.

6. The paving stones are then laid in the setting bed over top of the waterproofing system. The joints are mortared with a mix of 1 part cement to 3 parts sand.

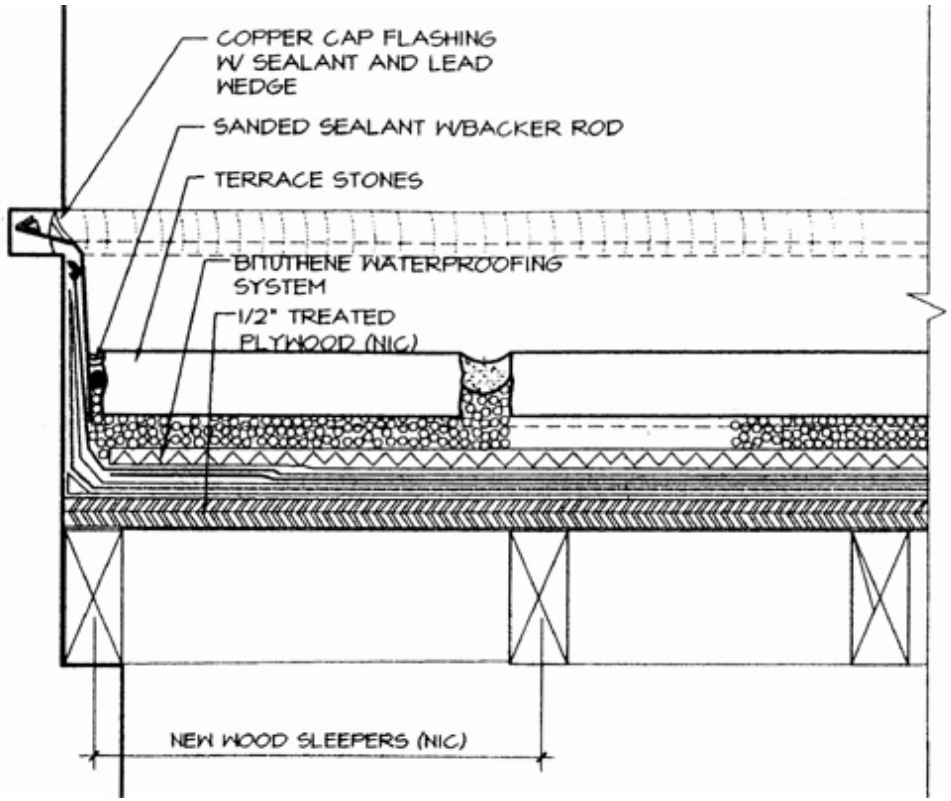
7. Finally, copper flashing is positioned between the vertical walls and the paving stones.



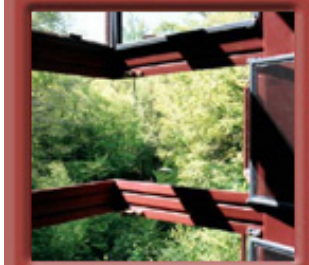
Terrace Restoration at Fallingwater

New Terrace Waterproofing System Detail

This detail shows the recommended reconstruction of the terraces. New wood sleepers were used to raise the ½"plywood deck above the concrete.



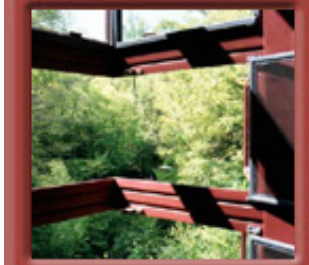




Terrace Restoration at Fallingwater

The Finished Terrace

This image shows one of the finished reconstructed terraces, with new drains, copper flashing, and grouted flagstone.

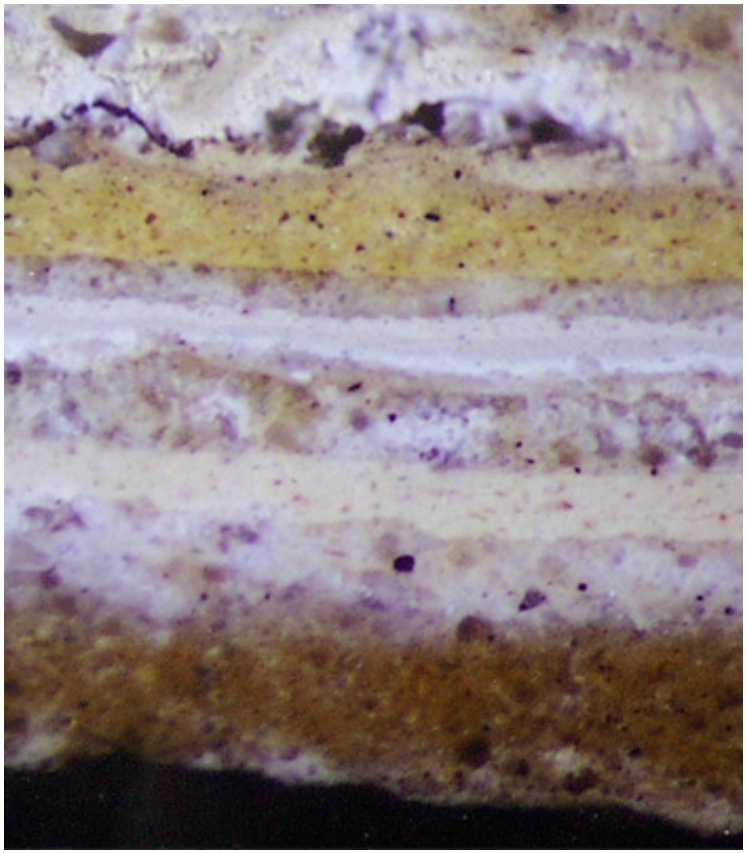


Restoration of Interior & Exterior Coatings

Restoration of Interior & Exterior Coatings

Interior Paint Issues

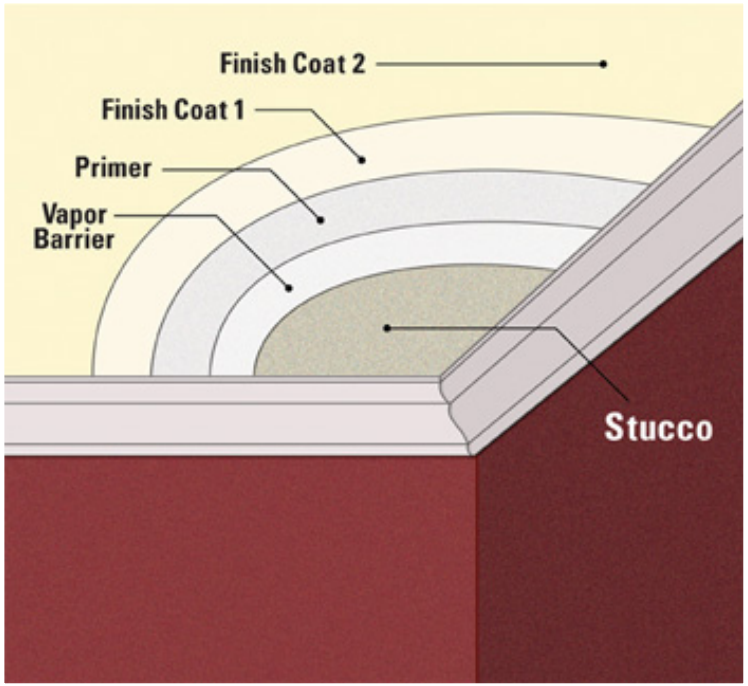
- In 2001, a review was conducted of Fallingwater's interior paint. Samples were taken from several areas of the main house where paint failure had been observed.
- A conservation firm examined the photomicrographs, which showed that delamination was occurring as a result of there being too many layers of paint. It was determined that paint removal was necessary.
- Paint removal was challenging and, complicated by the sensitivity of the built-in furnishings, required the use of a small-needle scaler modified with a vacuum attachment.



Restoration of Interior & Exterior Coatings

Interior Paint Solutions

- Fallingwater required an interior paint system that could provide a vapor barrier coating, a primer and a finish paint, while still maintaining Wright's originally specified paint texture and colors.
- The collected data was used to set the parameters for monitoring adhesion, system compatibility, lifecycle, maintenance, weather and environmental sensitivities.
- This illustration shows the basic paint system that was developed by the building team, including Fallingwater staff, consulting architects, and paint company representatives.







Restoration of Interior & Exterior Coatings

Interior Paint Solutions Cont'd…

- The concrete construction further complicated matters, because the added moisture affects adhesion. Another aspect to be considered was durability: Fallingwater hosts over 140,000 visitors annually.
- The building team experimented with paint and coating products to determine the most effective way of achieving building envelope durability and breathability along with interior presentation.
- Once a system was selected, field and lab tests were conducted to verify performance. Micrographs were used to study the existing paint and system compatibility.

Restoration of Interior & Exterior Coatings

Interior Paint Solutions Cont'd…

A full account of this interior paint system was published in The Construction Specifier (Dec 2002), which is available online at www.csinet.org.

Restoration of Interior & Exterior Coatings

Exterior Paint Finishes

- In 1936, after Edgar Kaufmann Sr. rejected plans for a gold leaf exterior, the structure was painted with light ocher-colored paint made with lime pigment, powdered clay, and milk/casein.
- Between 1937 and 1950, the exterior was painted twice more with milk paint, which soiled quickly. Experimentation with latex paint was conducted in the late 1940s.
- In 1951, the exterior was painted with oil-based paint and in 1971, other paints were considered to replace paint that was not adhering properly to the exterior substrate.

Restoration of Interior & Exterior Coatings

Exterior Horizontal Surfaces

- The unique design of Fallingwater incorporates a number of exterior horizontal surfaces and canopies, which also required restoration.
- These surfaces are covered with a stucco-like concrete, or plaster coat, painted with an Ocher color common to much of Fallingwater. In contrast to the stone work, these surfaces have a plasticity that is both warm and soft.
- The paint on these horizontal surfaces was not adhering well, due to the effects of long-term exposure to weather, standing water, ice, snow, dirt, and organic debris from decaying leaves.

Restoration of Interior & Exterior Coatings

Exterior Horizontal Surfaces Cont'd…

The area where the overhead canopy meets the roof deck of the main house is showing signs of delamination, efflorescence, and microbial growth.

Restoration of Interior & Exterior Coatings

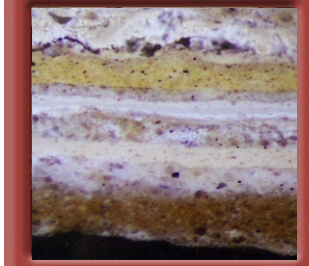
Exterior Horizontal Surface Restoration

- Testing was conducted on the guest house canopy, facing south, and included parapets and other horizontal surfaces.
- Surfaces were pressure washed and two coats of silicate-based paint were applied. Both coats were diluted with approximately 15% water and the second coat was applied about two hours after the first.
- Silicate-based paint consists of a combination of silicone resin and a special water-soluble alkali silicate. The silicate acts as a binding agent, providing a breathable, yet water repellant coating.

Restoration of Interior & Exterior Coatings

Exterior Vertical Surfaces

Exterior vertical surfaces, such as walls and parapets, also required restoration. Various paint test samples were exposed to the effects of all four seasons.



Restoration of Interior & Exterior Coatings

Exterior Stone Work

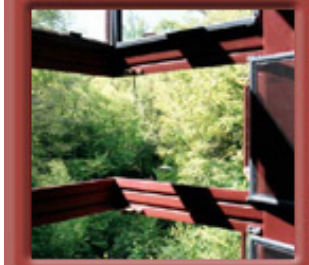
In addition to the exterior plaster surfaces, the exterior stone work also required repointing in some areas and application of a water repellant coating.

Window Restoration at Fallingwater

Window Restoration at Fallingwater

Existing Steel Windows

Another area in the research review revealed extensive restoration needs concerning the steel windows and doors of Fallingwater.



Window Restoration at Fallingwater

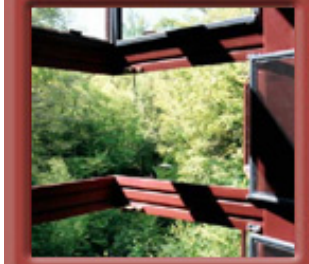
Window Restoration

In 1988, the original glass in Fallingwater was replaced with a special UV-filtered glass to block out harmful UV rays and help preserve interior materials.

Window Restoration at Fallingwater

Window Restoration Cont'd…

A local window contractor was hired to adjust and service each operable window sash and door for proper operation.



Window Restoration at Fallingwater

Window Restoration Cont'd…

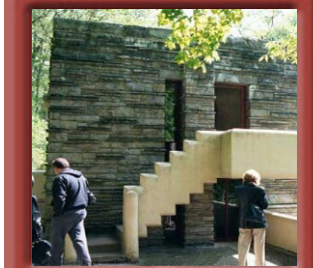
This involved stripping 60 years worth of accumulated paint and caulk followed by recaulking and painting with Fallingwater's signature Cherokee Red.

Window Restoration at Fallingwater

Skylight Restoration

Skylights represented another source of moisture penetration, which required extensive repair and restoration.

Parting Views of Fallingwater



Parting Views of Fallingwater

What Can We Learn?

- Fallingwater is similar to a ship, in that it requires continuous maintenance due to moisture and environment conditions. Many of the problems found at Fallingwater are similar to those found in today's buildings.

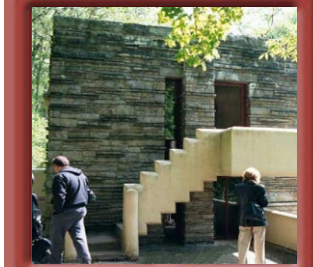
- For instance, the failure of building envelopes, not incorporating adequate scientific research into the design phase, and specifications and details that are insufficient to allow facility managers to make intelligent maintenance decisions. Together, these issues lead to the use of incompatible products, the failure of assemblies, and greater building operating costs.

- Architects often believe that they are not compensated enough to provide detailed specifications or scientific data to support the performance of assemblies, and that owners will not pay the additional fees required to provide detailed specifications and supporting documentation.

- However, it is interesting to note that additional funds are often made available for Commissioning Agents, litigation expenses, and increased building operation and maintenance costs when necessary.







Parting Views of Fallingwater

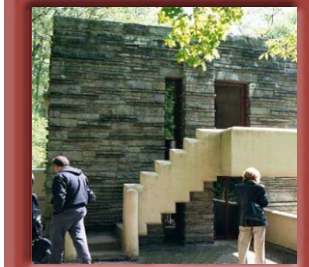
Frank Lloyd Wright Building Conservancy

- During his long and prolific career, Frank Lloyd Wright designed over 1,000 buildings. Over 500 designs were built, however one in five has been lost due to disaster, neglect or encroaching development.
- After the tragic demolition of the Larkin Administration Building, the Imperial Hotel, the Francis W. Little House II, and many others, Wright building administrators nationwide decided to fight this trend.
- Since the founding of the Frank Lloyd Wright Building Conservancy, not one Wright building has been destroyed! In 2001 alone, they saved four important buildings.

The Conservancy was recently able to save the Duncan House (1957, Lisle, IL) and the Glasner House (1905, Glencoe, IL). Read more about it at www.savewright.org







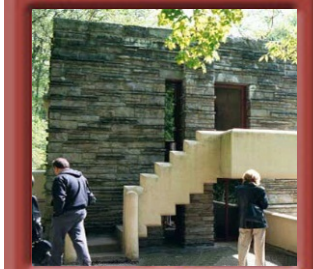
Parting Views of Fallingwater

Sources & Image Credits

Bertram, P.R., A Unique Painting of Fallingwater, *The Construction Specifier*, Dec 2002. Copies are available online at www.csinet.org.

Silman, R., The Plan to Save Fallingwater, *Scientific American*, Sept 2000. Reprints are available from the Western Pennsylvania Conservancy. Visit them online at www.wpconline.org.

Weiss, N., Jerome, P. & Gottlieb, S., Fallingwater Part 1: Materials-Conservation Efforts at Frank Lloyd Wright's Masterpiece, *APT Bulletin,* Volume XXXII, No. 4, 2001. For more information, visit www.apti.org.



Parting Views of Fallingwater

Sources & Image Credits Cont'd…

Photos of Edgar Kaufmann Sr. and Edgar Kaufmann Jr. from *Fallingwater: A Frank Lloyd Wright Country House*. Published by Abbeville Press, 1996.

Photos of roof and terrace restoration from J.L. Robinson, Inc, Pittsburgh, PA.

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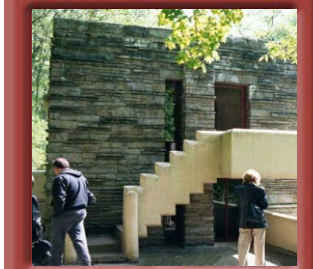

Parting Views of Fallingwater

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RSA's consulting engineers were instrumental in the structural analysis and rehabilitation of Fallingwater. Robert Silman Associates are located at 88 University Place, NY, NY 10003. For more information, visit www.rsapc.com.

WASA's preservation team has been involved since 1988 in the rehabilitation and preservation of Fallingwater. Wank Adams Slavin Associates LLP are located at 740 Broadway, NY, NY 10003. For more information, visit www.go2wasa.com.

Green Seal is a non-profit organization that strives to achieve a healthier and cleaner environment by identifying and promoting environmentally friendly products and services. For additional information, visit www.greenseal.org.

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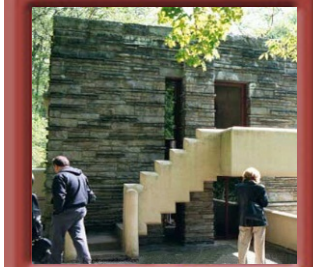

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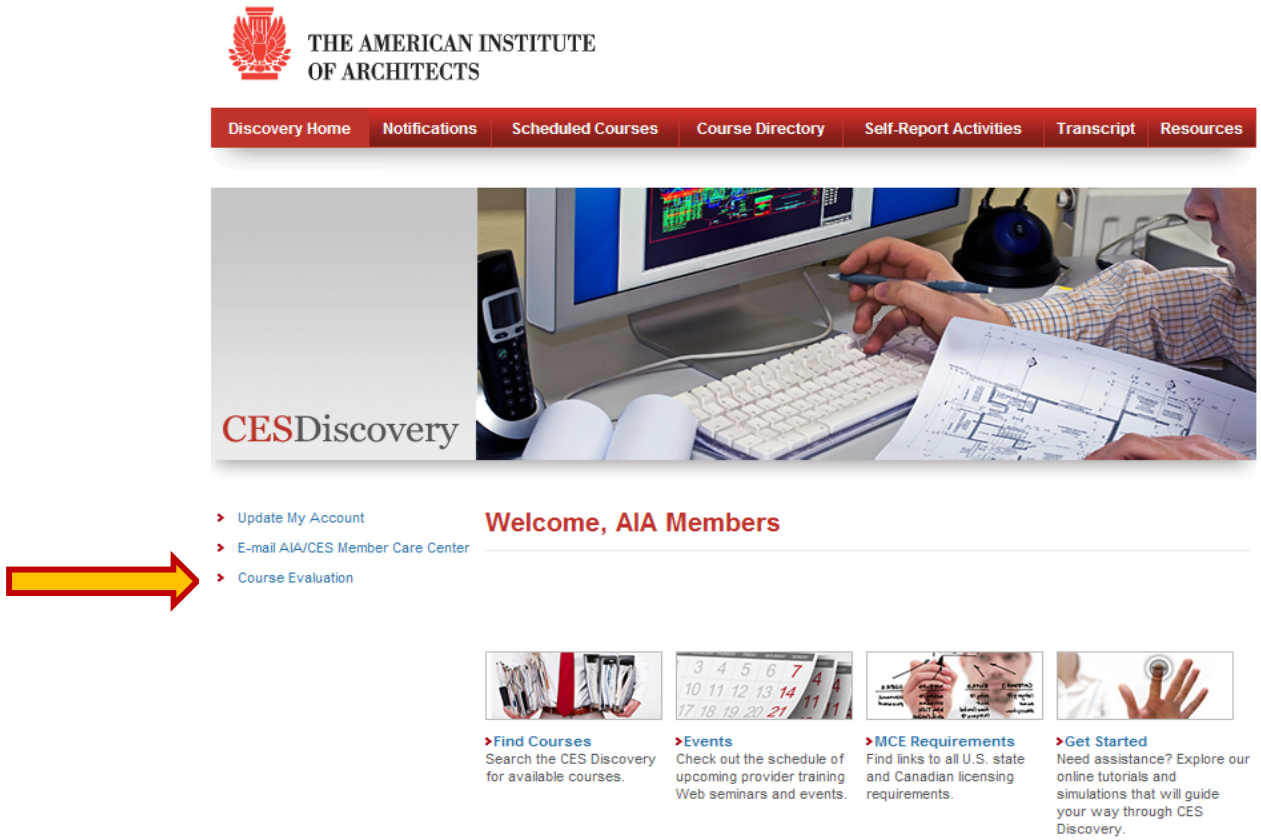

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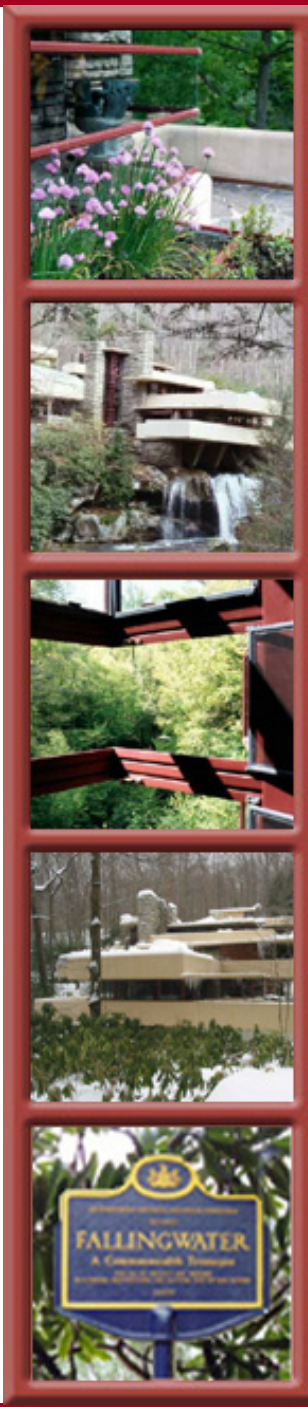

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