Optical Microscopy Exterior Paint Analysis

Ailey Young House
Wake Forest, North Carolina 27587-2932

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www.wakeforestnc.gov/planning/historic-preservation/aileyyoung-house

Purpose:

The goal of this project is to identify the weathered, chalky coatings remaining on the front door frame, the siding, and a window frame of the ca.1875 Ailey Young House. If the original paints survive and can be identified through paint analysis, the colors will be matched with a colorimeter/microscope for documentation and possible replication, and recommendations will be made for preservation of the fragmentary evidence.

Procedures:

Four samples from the door frame, siding and window frame were sent to Susan Buck for analysis. Before casting, the samples were examined at 45X magnification under a binocular microscope to screen them for duplicates. The samples that retained the most complete stratigraphies were cast into polyester resin cubes for permanent mounting. The cubes were ground and polished for cross-section microscopy analysis and photography. The sample preparation methods and analytical procedures are described in the reference section of this report.

The cast samples were analyzed with a Nikon Eclipse 80i epi-fluorescence microscope equipped with an EXFO X-Cite 120 Fluorescence Illumination System fiberoptic halogen light source and a polarizing light base using SPOT Advanced software (v. 5.1) for digital image capture and Adobe Photoshop CS for digital image management. Digital images of the best representative cross-sections are included in this report. Please note that the colors in the digital images are affected by the variability of color capture and rendering, and do not accurately represent the actual colors.

Background:

Michelle Michael provided an overview of the house and its history: "The Town owns the Ailey Young House, a Reconstruction-era, African American house that is being rehabilitated to interpret African American history in Wake Forest. The house suffered a fire sometime in the 1970s which caused a lot of damage. The entire attic was mostly destroyed as was the roof structure and the majority of the west pen interior. We have recently replaced the roof structure, standing seam metal roof, and interior finishes that were deteriorated beyond repair. The exterior is board-and-batten and has remnants of a paint or limewash on the boards that remain. Photos of the building are attached from 2009 when its significance was documented, 2020 with the roof 90 % complete and the front and back of one of the boards."[1] It was hoped that paint analysis could document the surviving evidence and offer recommendations for appropriate treatment. The following photographs were provided for context and reference.

Ailey Young House in 2009

South Elevation Roof in 2020

[1] Michelle Michael, email communication, February 4, 2020.

Board with paint remnants

Back of board with paint remnants

Paint Analysis Results:

When the wood fragments were examined at 45X magnification prior to cross-section microscopy analysis, it was apparent that there are at least two generations of deeply cracked, grimy paints remaining in samples 1 and 2 from the east side door frame and the south elevation siding, respectively. The wood surface of sample 3 from the window frame is deeply worn and weathered, with only tiny whitish spots of paint, and almost no paint can be seen on the surface of sample 4, from the south elevation siding.

Paint Sample Locations
1. East side door frame.
2. South elevation siding.
3. Window frame north elevation.
4. South elevation siding (board removed from house).

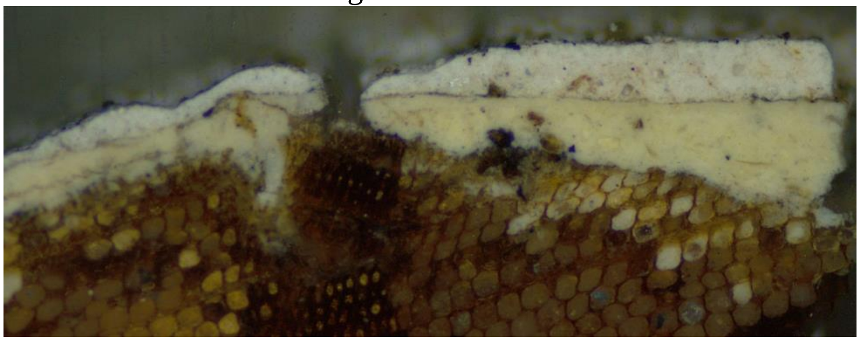
The most intact paint evidence was found in sample 1 from the door frame and sample 2 from the south elevation siding. In cross-section it is apparent that there are gritty accumulations of grime, mold and soot on the surfaces of the wood substrate. This suggests that either these elements were initially left unpainted, or the earliest paints were allowed to completely weather away before repainting. There are two generations of paint on top of the grimy wood substrate. The first generation is an opaque pale yellow paint. This pale yellow paint was allowed to become cracked and grimy before it was painted over with one layer of off-white paint.

Binding media characterization of the paints in sample 1 shows that both contain strong oil components (with the biological fluorochrome DCF), and there is oil in the wood. This oily material might have been applied separately as a preservative, or it might have soaked into the wood when the first pale yellow oil paint was applied. There are weak carbohydrate components in the off-white paint (with the fluorochrome TTC) which could be a natural gum additive to the paint. Neither paint layer reacted positively for the presence of proteins. Generation 1 may contain zinc white and white lead, and generation 2 may contain titanium white (a pigment available after about 1920) based on their autofluorescence characteristics.

1. East side door frame. Uncast sample with degraded paints on the wood.

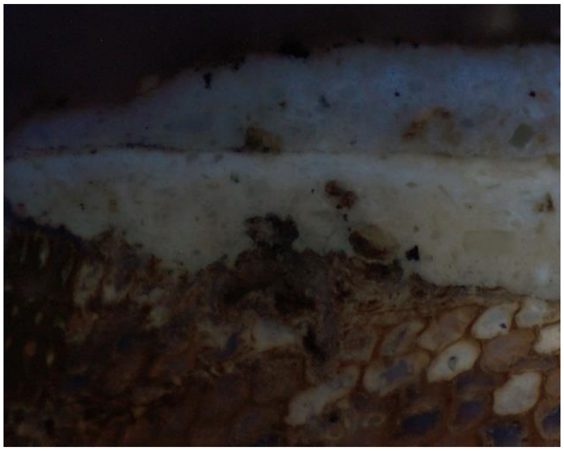
Uncast Sample Photographed at 40X

Cross-section in Visible Light 40X



Cross-section in Visible Light 100X

Ultraviolet Light 100X

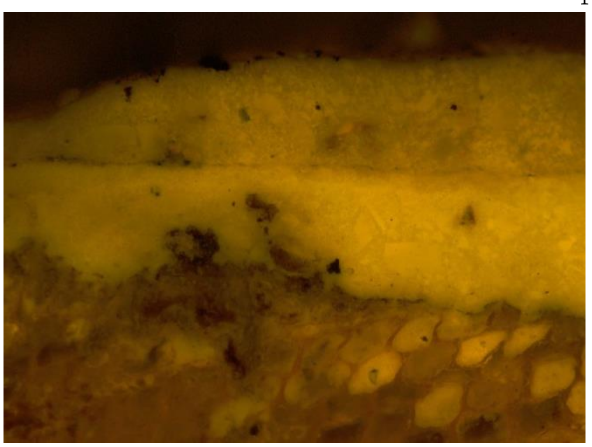


1. East side door frame.

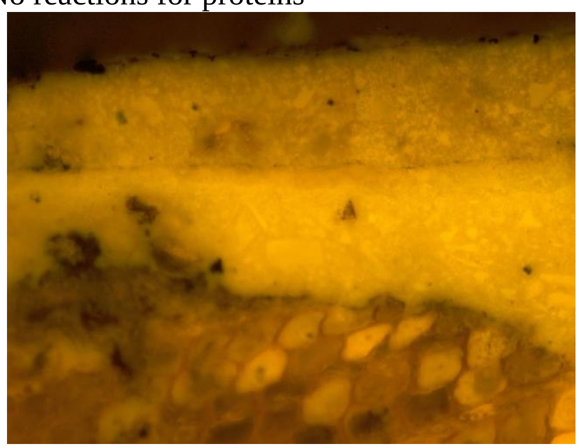
UV Light & TTC for carbohydrates 100X
Weak + reactions for oils in generation 2

UV & DCF for oils 100X
Strong + reactions for oils in the paints and in the wood

B-2A filter 100X



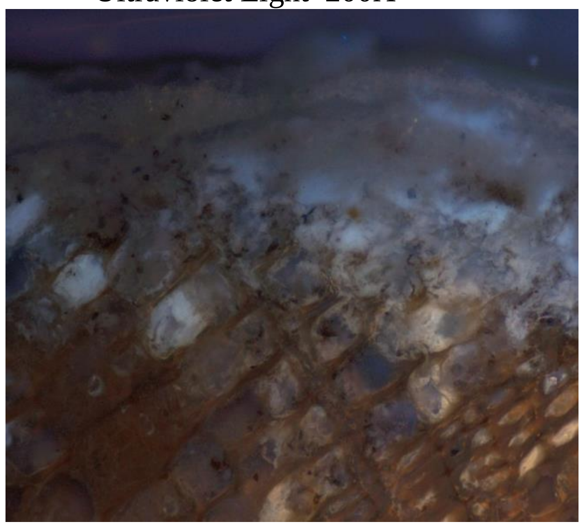
B-2A filter & Alexafluor 488 for proteins 100X
No reactions for proteins



2. South elevation siding. Uncast sample with degraded paints on the wood.
Uncast Sample Photographed at 40X

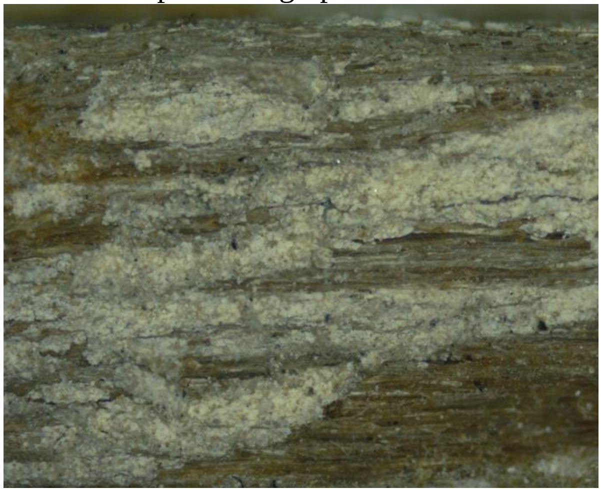
Cross-section in Visible Light 200X

Ultraviolet Light 200X



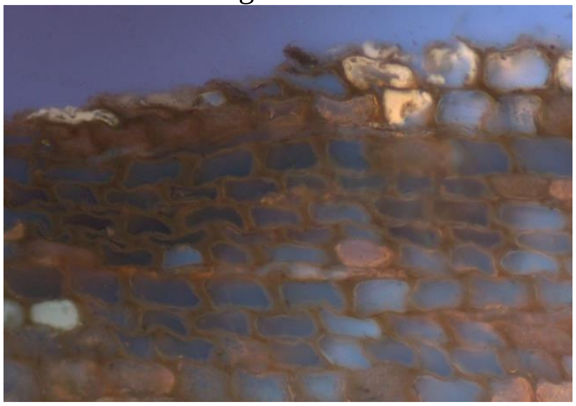
The wood surface of sample 3 is deeply fissured and fibrous, and there are only chalky remnants of off-white paint remaining in the depressions in the wood surface. In cross-section there are small pockets of paint trapped in the wood fibers, but the paints here are particularly fragile and ephemeral.

3. Window frame north elevation. Uncast sample with degraded paints on the wood.
Uncast Sample Photographed at 40X



Cross-section in Visible Light 200X

Ultraviolet Light 200X

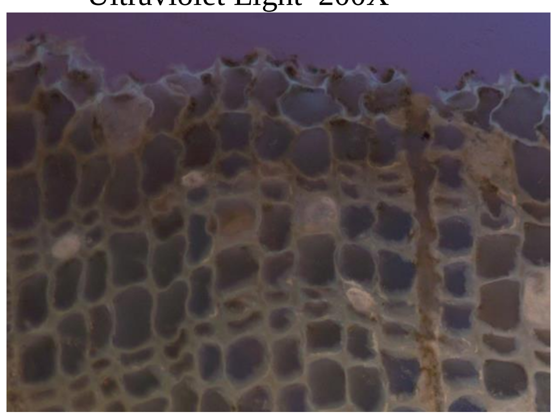


The paints have been almost completely lost in some areas of south elevation siding, based on the evidence in sample 4. The surface of the wood is powdery and fibrous, suggesting decades of exposure with no protective paint covering. In cross-section the wood surface is darkened and oxidized, with soot embedded in the wood fibers.

4. South elevation siding (board removed from house).
Uncast sample with degraded, fibrous wood.
Uncast Sample Photographed at 40X

Cross-section in Visible Light 200X

Ultraviolet Light 200X



Conclusion:

The four paint samples submitted for analysis show the range of conditions of the exterior wood surfaces. The evidence in samples 1 and 2 is compelling as two coherent layers of oil-bound paint survive on top of grimy, gritty wood substrates. It is possible that the exterior was initially left unpainted, or was coated with oil at one point, before the first layer of opaque pale yellow oil paint was applied. This paint was left exposed for many years, and became deeply cracked and grimy, before it was repainted with an off-white oil-bound paint.

There is fragmentary evidence of these paints in sample 3, but the wood is deeply fissured and damaged in this sample from the window frame. There is almost no paint evidence remaining in sample 4 from the south elevation siding, but sample 2 from another area of the siding confirms that the siding was painted in the same manner as the door and window frame.

No evidence of limewash was found in any of the samples. Rather, this modest analysis project confirms that when the building was first painted one layer of a durable oil-bound, pale yellow paint was applied. It was repainted only one more time with a durable oil-bound off-white paint, which now is chalky, discolored and deeply cracked. It is not possible to confidently date the application of either paint layer based on composition and physical characteristics, but the most recent off-white paint must date to after 1920 because of the presence of titanium white.

There are several alternatives for preserving the paint evidence, but none are ideal as consolidated damaged paints on exteriors will continue to be vulnerable to damage from sun, heat, moisture, and mold. Some possible approaches are listed below:

1. Use a conservation-grade, non-yellowing consolidant like 10% Acryloid B-72 in xylene or ethanol applied with an airbrush and/or low-pressure spray gun to consolidate the flaking paints and provide a protective coating. The disadvantage is that this consolidant will slightly saturate and darken the wood and the paint remnants, and leave a sheen on all surfaces.
2. Use a conservation-grade, non-yellowing consolidant like 50:50 Aquazol 50 and Aquazol 500 in ethanol and water applied with an airbrush and/or low-pressure spray gun to consolidate the flaking paints and provide a protective coating. The disadvantage is that this consolidant is not particularly durable for exterior surfaces, but if applied carefully it will not increase the gloss or saturation of the aged surfaces.
3. Spray on a barrier coat of 10% Acryloid B-72 in xylene or ethanol to protect the paint evidence, and then repaint the building with a pale yellow acrylic or oil paint that has been color-matched to the first generation of paint identified in samples 1 and 2.
4. Erect a shed roof over the building to protect the exterior surfaces and leave the exterior untouched.

COLOR MEASUREMENT PROCEDURES

The most intact, representative areas of the earliest pale yellow paint on the siding and door frame were matched using a Minolta Chroma Meter CR-241, a tristimulus color analyzer/microscope with color measurement area of 0.3mm. This instrument has an internal, 360-degree pulsed xenon arc lamp and provides an accurate color measurement in a choice of five different three-coordinate color systems. The color matches were also rechecked at 30X magnification using a color-corrected light source.

The measurements were first generated in the Munsell color system (a color standard used in the architectural preservation field), and after the measurements were taken the closest Munsell color swatches from a standard Munsell Book of Color (gloss paint standards) were compared under 30X magnification to the actual samples. The measurements were also generated in the CIE L*a*b* color space system, which is currently one of the most widely accepted industry color space measuring systems. The most appropriate commercial match is included for reference.

Ailey Young House – Earliest Yellow Paint

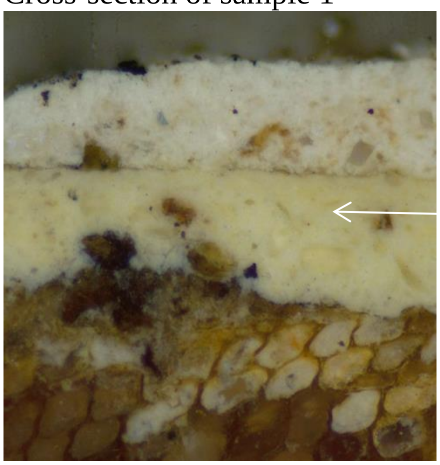
Color Match – April 20, 2020[2]

Samples 1 and 2

Benjamin Moore #2151-60 "Linen sand"

Color System*		Coordinates	
Munsell	Hue	Value	Chroma
	0.7GY	9.0	2.9
CIE L*a*b*	Black to White	Green to Red	Blue to Yellow
	L90.83	a-6.44	b+20.81

Cross-section of sample 1



The Benjamin Moore match #2151-60 is an excellent visual match to the best preserved areas of the earliest pale yellow oil-bound paint when examined in full spectrum light both at 30X magnification and unmagnified. The evidence suggests that that this layer was somewhat glossy and could be replicated in an eggshell or satin gloss level.

[2] Color matching conducted after cross-section microscopy analysis by Susan L. Buck, Ph.D., Conservator and Paint Analyst, with a Minolta Colorimeter CR-241.

* Chroma Meter CR-241 offers five different color systems for measuring absolute chromaticity: CIE Yxy (1931), L*a*b* (1976), and L*C*H* (1976) colorimetric densities DxDyDz; Munsell notation and four systems for measuring color differences.

For two colors to match, three quantities defining color must be identical. These three quantities are called tristimulus values X, Y, and Z as determined by CIE (Commission Internationale de l'Eclairage) in 1931.

Color as perceived has three dimensions: hue, chroma and lightness. Chromaticity includes hue and chroma (saturation), specified by two chromaticity coordinates. Since these two coordinates cannot describe a color completely, a lightness factor must also be included to identify a specimen color precisely.

Munsell Color System: The Munsell color system consists of a series of color charts which are intended to be used for visual comparison with the specimen. Colors are defined in terms of the Munsell Hues (H; indicates hue), Munsell Value (V; indicates lightness), and Munsell Chroma (C; indicates saturation) and written as H V/C.

CIE Yxy (CIE 1931): In the Yxy (CIE 1931) color system, Y is a lightness factor expressed as a percentage based on a perfect reflectance of 100%, x and y are the chromaticity coordinates of the CIE x, y Chromaticity Diagram.

CIE L*a*b*: Equal distances in the CIE x,y Chromaticity Diagram do not represent equal differences in color as perceived. The CIE L*a*b* color system, however, more closely represents human sensitivity to color … Equal distances in this system approximately equal perceived color differences. L* is the lightness variable; a* and b* are the chromaticity coordinates.

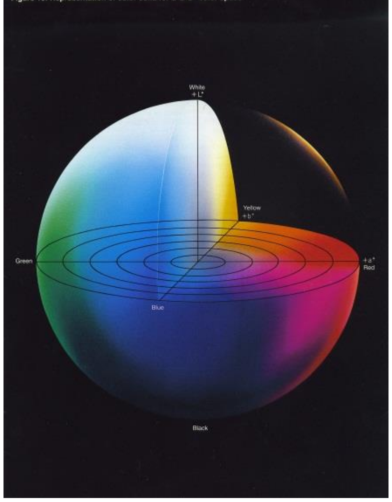


Figure 10: Representation of color solid for L*a*b* color space

ΔE (Delta E) is the industry measure used to determine how closely two colors match in the CIE L*a*b*. The symbol Δ means "the change in". It is based on calculating the sum of the differences between each measure. The calculation is: $\Delta E = \sqrt{(L^*)^2 + (a^*)^2 + (b^*)^2}$, or, the color difference equals the square root of the squared sums of the differences between each of the three L* a* b* tristimulus values. Industry color standards indicate a ΔE of 1 is barely perceptible to the human eye, and ΔE of 6 to 7 is acceptable for color matches in the printing industry.

REFERENCES

Cross-section Preparation Procedures:

The samples were cast into mini-cubes of polyester resin (Excel Technologies, Inc., Enfield, CT). The resin was allowed to cure for 24 hours at room temperature and under ambient light. The cubes were then ground to expose the cross-sections, and dry polished with 400 and 600 grit wet-dry papers and Micro-Mesh polishing cloths, with grits from 1500 to 12,000.

Cross-section microscopy analysis was conducted with a Nikon Eclipse 80i epi-fluorescence microscope equipped with an EXFO X-Cite 120 Fluorescence Illumination System fiberoptic halogen light source and a polarizing light base using SPOT Advanced software (v. 4.6) for digital image capture and Adobe Photoshop CS for digital image management. Photographs and digital images of the best representative cross-sections are included in this report. UV photographs were taken with the UV-2A filter in place (330-380 nanometers excitation with a 400 nm dichroic mirror and a 420 nm. barrier filter). Please note that the colors in the printed photomicrographs may not accurately reflect the actual color of the samples because the colors in the digital images are affected by the variability of color printing.

The following fluorescent stains were used for examination of the samples:

> Triphenyl tetrazolium chloride (TTC) 4.0% in ethanol to identify the presence of carbohydrates (starches, gums, sugars). Positive reaction color is dark red or brown.
>
> Fluorescein isothiocyanate (FITC) 0.2% in anhydrous acetone to identify the presence of proteins. A yellow or yellowish-green colors indicates a positive reaction.
>
> 2, 7 Dichlorofluorescein (DCF) 0.2% in ethanol to identify the presence of saturated and unsaturated lipids (oils). Positive reaction for saturated lipids is pink and unsaturated lipids is yellow.

The best cross-section photographs for each area were mounted and labeled and are included with this report. Photographs were taken at 100X, 200X and 400X magnifications.

Information Provided by Ultraviolet Light Microscopy:

When viewed under visible light, cross-sections which contain ground, paint and varnish may often be difficult to interpret, particularly because clear finish layers look uniformly brown or tan. It may be impossible using only visible light to distinguish between multiple varnish layers. Illumination with ultraviolet light provides considerably more information about the layers present in a sample because different organic, and some inorganic, materials autofluoresce (or glow) with characteristic colors.

There are certain fluorescence colors which indicate the presence of specific types of materials. For example: shellac fluoresces orange (or yellow-orange) when exposed to ultraviolet light, while plant resin varnishes (typically amber, copal, sandarac and mastic) fluoresce bright white. Wax does not usually fluoresce; in fact, in the ultraviolet it tends to appear almost the same color as the polyester casting resin. In visible light wax appears as a somewhat translucent white layer. Paints and glaze layers which contain resins as part of the binding medium will also fluoresce under ultraviolet light at high magnifications. Other materials such as lead white, titanium white and hide glue also have a whitish autofluorescence.

There are other indicators which show that a surface has aged, such as cracks which extend through finish layers, accumulations of dirt between layers, and sometimes diminished fluorescence intensity, especially along the top edge of a surface which has been exposed to light and air for a long period of time.