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USMMA Historic District Property Maintenance and Repair Manual

Volume 6 – Roofing Elements

Sunny E. Adams and Adam D. Smith

June 2018

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Cover Photo: Slate tile roof is stained from mildew growth on Quarters A (Neiley house) (ERDC-CERL, 2015).

USMMA Historic District Property Maintenance and Repair Manual

Volume 6 – Roofing Elements

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Abstract

The U.S. Merchant Marine Academy is located in Kings Point, New York. The Academy is listed on the National Register of Historic Places (#14000538). The historic district contains contributing mansions constructed during the Gold Coast Era and the Academy buildings constructed in 1942 to 1969. All buildings require regular planned maintenance and repair. The most notable cause of historic building element failure and/or decay is not because the historic building is old, but rather it is caused by an incorrect or inappropriate repair and/or basic neglect of the historic building fabric. This document is a maintenance manual compiled with as-is conditions of building materials at the Academy. The *Secretary of the Interior's Standards for the Treatment of Historic Properties on Preservation, Rehabilitation, and Repair* are discussed per material. This 8-volume report includes an overview volume plus volumes on each of the following elements: concrete, wood, brick, metal, roofing, stucco, and mechanical systems. All mentioned repair procedures are from the U.S. General Services Administration (GSA): Historic Preservation Technical Procedures and/or the National Park Service's series of Preservation Briefs. This report satisfies Section 110 of the National Historic Preservation Act (NHPA) of 1966, as amended.

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Contents

Abstract.....	ii
Figures and Tables.....	iv
Preface	vi
Foreword	vii
1 Roofing Elements.....	1
1.1 Roofing – general	1
1.1.1 Immediate concerns for roofing.....	1
1.1.2 Guidelines, briefs, bulletins, and sources for roofing	12
1.1.2.1 General inspection and maintenance of gutters and downspouts (GSA 2017a)	13
1.1.2.2 Roofing for historic buildings (Sweetser 1978 – Preservation Brief #4)	16
1.2 Roofing element – terra cotta clay tile	24
1.2.1 Immediate concerns for roofing element – clay tile	24
1.2.2 Guidelines, briefs, bulletins, and sources for roofing – clay tile	27
1.2.2.1 Preservation and repair of historic clay tile (Grimmer and Williams 1992 – Preservation Brief #30)	28
1.2.2.2 Replacing clay roof tile (GSA 2016a).....	39
1.2.2.3 Removing and replacing clay tile (GSA 2016b).....	44
1.3 Roofing element – slate tiles	50
1.3.1 Immediate concerns for roofing –slate tile	50
1.3.2 Guidelines, briefs, bulletins, and sources for roofing – slate tile.....	54
1.3.2.1 Repair, replacement, and maintenance of slate roofs (Levine 1992 – Preservation Brief #29)	55
1.3.2.2 Minor repairs to slate roofs (GSA 2017b).....	65
1.3.2.3 Removing dirt buildup (GSA 2017c)	68
1.3.2.4 Reroofing with slate shingles (GSA 2012).....	70
1.3.2.5 Slate shingle specifications (GSA 2017d)	74
1.4 Roofing element – asphalt shingles.....	78
1.4.1 Immediate concerns for roofing – asphalt shingles	78
1.5 Preservation and rehabilitation guidelines for roofing.....	81
1.6 Maintenance / management for roofing.....	84
1.6.1 General roofing	85
1.6.2 Clay tile	85
1.6.3 Slate tile.....	86
1.6.4 Asphalt shingles.....	87
References.....	88
Report Documentation Page	

Figures and Tables

Figures

Figure 1. Example of an original concrete block parapet wall with failing mortar and inappropriately replaced mortar (ERDC-CERL, 2015).....	2
Figure 2. Example of a reconstructed concrete block parapet wall that uses concrete block that does not match the original material (ERDC-CERL, 2015).	3
Figure 3. Example of a failed historic concrete block parapet wall [and damaged cast stone beneath it] that has been encased in nonhistoric metal (ERDC-CERL, 2015).....	3
Figure 4. Example of a failed concrete block historic parapet wall [and damaged cast stone beneath it] that has been encased in nonhistoric metal (ERDC-CERL, 2015).....	4
Figure 5. Example of nonhistoric metal flashing used to stop water infiltration in cast stone (ERDC-CERL, 2015).....	4
Figure 6. Example of a replacement metal downspout [no specifications for downspout colors could be found] (ERDC-CERL, 2015).	5
Figure 7. Example of a replacement metal downspout that needs to be checked for leakage (ERDC-CERL, 2015).	6
Figure 8. Example of misaligned downspouts with resulting leakage causing mildew and efflorescence issues on historic brick element (ERDC-CERL, 2015).	6
Figure 9. Example of a missing downspout that connects into the subdrain, with resulting water damage on concrete block, concrete slab, and stucco (ERDC-CERL, 2015).	7
Figure 10. Examples of a downspout that does not connect directly into a subdrain [left], and a downspout that releases water directly onto a concrete slab (ERDC-CERL, 2015).	7
Figure 11. Close-up view of the downspouts above and the resulting water damage (ERDC-CERL, 2015).....	8
Figure 12. Examples of replacement downspouts [no specifications for downspout colors could be found]: the downspout on the left releases water directly onto a concrete slab, while the one on the right is not connected to the scupper (ERDC-CERL, 2015).....	8
Figure 13. An example of a scupper that does not have a downspout (ERDC-CERL, 2015).	9
Figure 14. An ad hoc addition of a scupper to a concrete block parapet wall that does not connect to a downspout (ERDC-CERL, 2015).	9
Figure 15. An ad hoc addition of a scupper to a concrete block parapet wall that does not connect to a downspout (ERDC-CERL, 2015).	10
Figure 16. Example of a built-in gutter with original downspout (ERDC-CERL, 2015).....	10
Figure 17. Example of a downspout releasing water directly on historic slate roofing (ERDC-CERL, 2015).....	11

Figure 18. Example of a gutter with leaks that are damaging the historic stucco below (ERDC-CERL, 2015).....	11
Figure 19. Example of a downspout releasing water into the space behind a parapet, with resulting damage to historic brick wall and stone coping (ERDC-CERL, 2015).	12
Figure 20. Red barrel terra cotta clay tile roofing material on Melville Hall (ERDC-CERL, 2013).	25
Figure 21. Green glazed terra cotta clay tile roof on Land Hall (Schenck house) (ERDC-CERL, 2013).	25
Figure 22. Terra cotta clay tiles on the American Merchant Marine Museum [Barstow Mansion] (ERDC-CERL, 2013).	26
Figure 23. Backside of the terra cotta clay tiles on the American Merchant Marine Museum [Barstow Mansion] that were manufactured by the Ludowici Celadon Company (www.ludowici.com), which is still in business (ERDC-CERL, 2015).	26
Figure 24. Flat terra cotta clay tiles on Quarters H (ERDC-CERL, 2015).	27
Figure 25. Inspection of flashing is important in maintaining slate tile roof (ERDC-CERL, 2015).	51
Figure 26. A reminder to not walk on the slate tiles while inspecting the roof or other features such as chimneys and gutters (ERDC-CERL, 2105).	52
Figure 27. Slate tile roof stained from mildew growth on Quarters A (Neiley house) (ERDC-CERL, 2015).	52
Figure 28. During inspections look for missing fasteners, document cracked or broken tiles, flashing, bent snow guards, and substrate/roof deck (ERDC-CERL, 2015).	53
Figure 29. Remove vegetation located near or on a slate tile roof (ERDC-CERL, 2015).	53
Figure 30. Asphalt shingles on Delano Hall (ERDC-CERL 2013).	79
Figure 31. Architectural asphalt shingles on Quarters B [note lack of flashing between dormer siding and shingles] (USMMA, 2015).	80
Figure 32. Green asphalt shingles with “storybook” edges on Quarters C (left) replaced with brown architectural asphalt shingles (right) (ERDC-CERL, 2015).	80
Figure 33. Architectural asphalt shingles on Melville Hall addition (USMMA, 2015).	81

Tables

Table 1. Preservation treatment for roofs (Grimmer 2017, 44–45).	82
Table 2. Rehabilitation treatment for roofs (Grimmer 2017, 98–101).	83

Preface

This study was conducted for the U.S. Department of Transportation Maritime Administration (MARAD) under Project Number 450153, “Historic Preservation Plan for U.S. Merchant Marine Academy.” The technical monitor was Barbara Voulgaris, Federal Preservation Officer, U.S. Department of Transportation, MARAD.

The work was performed by the Land and Heritage Conservation Branch (CNC) of the Installations Division (CN), U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Dr. Michael Hargrave was Chief, CEERD-CNC; and Ms. Michelle Hanson was Chief, CEERD-CN. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti, and the Director was Lance D. Hansen.

COL Bryan S. Green was the Commander of ERDC, and Dr. David W. Pittman was the Director.

Foreword

ERDC-CERL's effort to put together a guide to proper maintenance and repair of the historic elements at the U.S. Merchant Marine Academy has been divided into multiple volumes for ease of use by installation personnel.

This is Volume 6 of 8, and it covers guidance for proper maintenance and repair of historic roofing elements at USMMA.

Please see Volume 1 for an overview of the project and the USMMA's historic context, an explanation of the Secretary of the Interior's Standards and their application, and overviews and lists of immediate concerns for the USMMA's historic exteriors and interiors.

ADAM D. SMITH
Project Manager

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1 Roofing Elements

NOTE: Maintenance manuals such as those produced as part of this report are a general guide for the historic materials used throughout the USMMA. Do not assume that because a particular building or a particular material on a building is not mentioned in these manuals that the material in need of maintenance or repair does not need to follow the Standards.

1.1 Roofing – general

A weather-tight roof is basic in the preservation of a structure, regardless of its age, size, or design. During some periods in the history of architecture, the roof imparts much of the architectural character and defines the style and contributes to the building's aesthetics. However, no matter how decorative the patterning or compelling the form, the roof is a highly vulnerable element of a shelter that will inevitably fail (Sweetser 1978 with 2017 update).

1.1.1 Immediate concerns for roofing

A poor roof will permit the accelerated deterioration of historic buildings materials such as masonry, wood, plaster, and paint, and it will cause general disintegration of the basic structure. There is an urgency involved in repairing a leaky roof since such repair costs quickly will grow costly. Although action is desirable as soon as a failure is discovered, temporary patching methods should be carefully chosen to prevent inadvertent damage to sound or historic roofing materials and related features (Sweetser 1978 with 2017 update).

Before any repair work is performed, the historic value of the materials used on the roof should be understood. Then a complete internal and external inspection of the roof should be planned to determine all the causes of failure and to identify the alternatives for repair or replacement of the roofing material (Sweetser 1978 with 2017 update).

The original flat roofs on the USMMA classroom and dormitory buildings do not have historic materials, and with these flat roofs being hidden by

character-defining parapets, replacement of their materials can be done with whatever material is best for keeping weather out of the buildings; however, many of the parapets have water damage from badly replaced roofing designs and materials in the past (Figure 1–Figure 5). A wholesale study should be performed to determine what material and method is best for use on the USMMA flat roofs. In addition to the roofing materials, the other component of roofing-related issues and maintenance are the gutters, scuppers, and downspouts (Figure 6–Figure 19). Many of these components may be past their expected service life so along with the roofing study, a review of all gutters, scuppers, and downspouts will be needed.

Figure 1. Example of an original concrete block parapet wall with failing mortar and inappropriately replaced mortar (ERDC-CERL, 2015).

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Figure 13. An example of a scupper that does not have a downspout (ERDC-CERL, 2015).

Figure 14. An ad hoc addition of a scupper to a concrete block parapet wall that does not connect to a downspout (ERDC-CERL, 2015).

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Figure 18. Example of a gutter with leaks that are damaging the historic stucco below (ERDC-CERL, 2015).

Figure 19. Example of a downspout releasing water into the space behind a parapet, with resulting damage to historic brick wall and stone coping (ERDC-CERL, 2015).

1.1.2 Guidelines, briefs, bulletins, and sources for roofing

In addition to the information contained in this manual, the authors have compiled the following federal resource publications (reproduced here for

convenience, with links for online access given in References) to inform managers about standards, guidelines, and procedures for understanding architecture, and caring for, preserving, and rehabilitating historic buildings with emphasis on historic roofing materials (see subsections 1.1.2.1 and 1.1.2.2).

1.1.2.1 General inspection and maintenance of gutters and downspouts (GSA 2017a)

General Inspection And Maintenance Of Gutters And Downspouts

Procedure code:

763101S

Source:

Hspg Prepared For Nps - Sero

Division:

Thermal and Moisture Protection

Section:

Gutters & Downspouts

Last Modified:

07/05/2017

PART 1---GENERAL

1.01 SUMMARY

- A. This procedure includes guidance on inspecting and maintaining gutters and downspouts.
- B. Gutters on older structures can cause problems because they are often integrated with the roof structure such as built-in gutters, cornice gutters, hidden gutters and Yankee gutters; and if not properly maintained can result in leaks into roof, cornice, or structure itself. Hung-gutter types are more common on newer structures.
- C. A failed gutter often means that damage has spread; repairs will be extensive, maybe complicated, and probably expensive. A well-restored gutter, however, faithfully inspected and maintained, should require no major repairs for some years.
- D. Downspouts, flashing, conductor heads, leaders, roof drains, and scuppers are all part of the drainage system, and should be included in the work list when maintenance or repairs are being evaluated and scheduled for the gutters.

PART 2---PRODUCTS

2.01 MATERIALS

- A. Liquid bleach:

CAUTION: DO NOT MIX AMMONIA WITH CHLORINE BLEACHES, A POISONOUS GAS WILL RESULT! DO NOT USE BLEACH ON BIRD DROPPINGS.

- B. Clean, potable water

2.02 EQUIPMENT

- A. Safety belt or harness
- B. Ladders and scaffolding
- C. Chicken ladder
- D. Garden hose
- E. Plumbers test plugs to fit the downspout conductor head
- F. Carpenter's level
- G. Mason's level
- H. Chalk line
- I. Shaped wooden or plastic paddle for scraping and sweeping

PART 3---EXECUTION

3.01 EXAMINATION

- A. For steep roofs, inspect hanging gutters from ladders. Do not rest ladders on sheet metal gutters. Establish roof foot traffic regulations for inspection of built-in gutters.
- B. Check for interior deterioration which might point to gutter and/or roof problems.
- C. Inspect for buildup of debris and vegetation such as moss or lichen. Biological material excretes corrosive acids. This is apt to occur with improper gutter sloping.
- D. Check for adequate slope and drainage towards downspouts during cleaning.
- E. Make sure all downspout connections have wire strainers and that they are properly installed. Strainers will block large debris and leaves that can block downspouts and sewer lines.
- F. Inspect for gutters that are split or cracked with loose, broken, out of place, hangers, corners or slopes, or pulling of fasteners, broken joints or seams; excessive staining or punctures of gutter fabric.
- G. Inspect joints frequently; Repair cracks immediately.
- H. Look for corrosion around nails. Roof cement on gutters may hide leaks that have not been corrected.
- I. Check for deterioration of adjacent roof and soffit areas, and behind downspouts. Look for peeling paint or stains, or eroded mortar joints on adjacent surfaces.
- J. Inspect the underside of the roof cornices. Water stains may be evidence of ice dams.
- K. Install soffit ventilators in the cornice. This helps the cornice dry out and wards off rot after the inevitable periodic leaks of water into the woodwork. Ventilators have a drawback, of course, in that by increasing air flow inside the cornice, they also add to heat loss in winter. This can be minimized by proper insulation of attic spaces.
- L. Any gutter liners made of tin, galvanized iron, or terne metal should be kept painted.
- M. In addition to scheduled inspections, inspect after each exposure to unusually severe weather conditions such as strong winds, large snowfall, or long continuous rains.
- N. Examine gutters as a part of the annual roof inspection and repair defects immediately. Have a competent roofer and plumber inspect the fabric and the joints for defects. Small gutter leaks may force water into concealed cornice and roof areas leading to major defects.
- O. Carry out a professional survey every five years.

- P. In the Fall, check gutters and clean as necessary once a week from the time the leaves begin to fall until they have all fallen. Monthly inspections are recommended during winter months to insure nothing impedes the flow of water thereby causing an ice dam in freezing weather.

3.02 ERECTION, INSTALLATION, APPLICATION

- A. Debris removal: Clean gutters of debris at least twice a year especially if surrounded by large trees, in late fall after all leaves have fallen; and in late spring after all seed pods, flowers, etc. have fallen. Clogged leaders can cause water overflow and ice build-up, and any acidic elements at the bottom of a damp trash pile can eat away at the metal liner.

1. Sweep debris from gutters with a wood or plastic tool shaped to fit into radii or corners.
2. Remove and bag debris such as leaves, pine needles, branches, nests and other litter so that the gutter drains freely.
3. Where dirt or leaves lodge or normally collect in the gutters, it is advisable to paint at yearly intervals.
4. If debris is blocking downspout, remove a lower section and flush. Do not allow clog to be forced into sewer or drainfield system. Realign the gutters and downspouts.

- B. Removing Biological Growth:

NOTE: ACTIVE METALS SUCH AS TIN AND COPPER DO NOT SUPPORT BIOLOGICAL GROWTH.

1. When moss, lichen, or fungus is present, wipe or scrape off growth. Use a shaped wooden or plastic paddle so as not to scratch the surface of the sheet metal.
2. Use a 50/50 solution of liquid bleach and water to saturate and disinfect the areas of biological growth. Brush the disinfectant solution on the gutters. Keep the solution from splashing to avoid damage to other building material and nearby vegetation.
3. After disinfectant treatment, scrub and rinse thoroughly.
4. When this type of vegetation persists, contact the Regional Historic Preservation Officer (RHPO) for assistance.

1.1.2.2 Roofing for historic buildings (Sweetser 1978 — Preservation Brief #4)

Technical Preservation Services

National Park Service
U.S. Department of the Interior

[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 4 Roofing

Some of the web versions of the Preservation Briefs differ somewhat from the printed versions. Many illustrations are new and in color; Captions are simplified and some complex charts are omitted. To order hard copies of the Briefs, see [Printed Publications](#)®.

PRESERVATION BRIEFS

4

Roofing for Historic Buildings

Sarah M. Sweetser

- [Significance of the Roof](#)
- [Historic Roofing Materials in America](#)
- [Locating the Problem](#)
- [Repair or Replace](#)
- [Historical Research](#)
- [Replacing the Historic Roofing Material](#)
- [Alternative Materials](#)
- [Temporary Stabilization](#)
- [Precautions](#)
- [Maintenance](#)
- [Summary and References](#)
- [Reading List](#)
- [Download the PDF](#)

Decorative roofing feature. Photo: HABS Collection, NPS.

Significance of the Roof

A weather-tight roof is basic in the preservation of a structure, regardless of its age, size, or design. In the system that allows a building to work as a shelter, the roof sheds the rain, shades from the sun, and buffers the weather.

During some periods in the history of architecture, the roof imparts much of the architectural character. It defines the style and contributes to the building's aesthetics. The hipped roofs of Georgian architecture, the turrets of Queen Anne, the Mansard roofs, and the graceful slopes of the Shingle Style and Bungalow designs are examples of the use of roofing as a major design feature.

But no matter how decorative the patterning or how compelling the form, the roof is a highly vulnerable element of a shelter that will inevitably fail. A poor roof will permit the accelerated deterioration of historic building materials—masonry, wood, plaster, paint—and will cause general disintegration of the basic structure. Furthermore, there is an urgency involved in repairing a leaky roof since such repair costs will quickly become prohibitive. Although such action is desirable as soon as a failure is discovered, temporary patching methods should be carefully chosen to prevent inadvertent damage to sound or historic roofing materials and related features. Before any repair work is performed, the historic value of the materials used on the roof should be understood. Then a complete internal and external inspection of the roof should be planned to determine all the causes of failure and to identify the alternatives for repair or replacement of the roofing.

Historic Roofing Materials in America

Clay Tile: European settlers used clay tile for roofing as early as the mid-17th century; many pantiles (S-curved tiles), as well as flat roofing tiles, were used in Jamestown, Virginia. In some cities such as New York and Boston, clay was popularly used as a precaution against such fires as those that engulfed London in 1666 and scorched Boston in 1679.

Repairs on this pantile roof were made with new tiles held in place with metal hangers. Photo: NPS files.

The plain or flat rectangular tiles most commonly used from the 17th through the beginning of the 19th century measured about 10" by 6" by 1/2," and had two holes at one end for a nail or peg fastener. Sometimes mortar was applied between the courses to secure the tiles in a heavy wind.

In the mid-19th century, tile roofs were often replaced by sheet-metal roofs, which were lighter and easier to install and maintain. However, by the turn of the century, the Romanesque Revival and Mission style buildings created a new demand and popularity for this picturesque roofing material.

Slate: Another practice settlers brought to the New World was slate roofing. Evidence of roofing slates have been found also among the ruins of mid-17th century Jamestown. But because of the cost and the time required to obtain the material, which was mostly imported from Wales, the use of slate was initially limited. Even in Philadelphia (the second largest city in the English-

speaking world at the time of the Revolution) slates were so rare that "The Slate Roof House" distinctly referred to William Penn's home built late in the 1600s. Sources of native slate were known to exist along the eastern seaboard from Maine to Virginia, but difficulties in inland transportation limited its availability to the cities, and contributed to its expense. Welsh slate continued to be imported until the development of canals and railroads in the mid-19th century made American slate more accessible and economical.

Slate was popular for its durability, fireproof qualities, and aesthetic potential. Because slate was available in different colors (red, green, purple, and blue-gray), it was an effective material for decorative patterns on many 19th century roofs (Gothic and Mansard styles). Slate continued to be used well into the 20th century, notably on many Tudor revival style buildings of the 1920s.

Shingles: Wood shingles were popular throughout the country in all periods of building history. The size and shape of the shingles as well as the detailing of the shingle roof differed according to regional craft practices. People within particular regions developed preferences for the local species of wood that most suited their purposes. In New England and the Delaware Valley, white pine was frequently used; in the South, cypress and oak; in the far west, red cedar or redwood. Sometimes a protective coating was applied to increase the durability of the shingle such as a mixture of brick dust and fish oil, or a paint made of red iron oxide and linseed oil.

Commonly in urban areas, wooden roofs were replaced with more fire resistant materials, but in rural areas this was not a major concern. On many Victorian country houses, the practice of wood shingling survived the technological advances of metal roofing in the 19th century, and near the turn of the century enjoyed a full revival in its namesake, the Shingle Style.

Colonial revival and the Bungalow styles in the 20th century assured wood shingles a place as one of the most fashionable, domestic roofing materials.

Metal: Metal roofing in America is principally a 19th-century phenomenon. Before then the only metals commonly used were lead and copper. For example, a lead roof covered "Rosewell," one of the grandest mansions in 18th century Virginia. But more often, lead was used for protective flashing. Lead, as well as copper, covered roof surfaces where wood, tile, or slate shingles were inappropriate because of the roof's pitch or shape.

Copper with standing seams covered some of the more notable early American roofs including that of Christ Church (1727–1744) in Philadelphia. Flat-seamed copper was used on many domes and cupolas. The copper sheets were imported from England until the end of the 18th century when facilities for rolling sheet metal were developed in America.

Sheet iron was first known to have been manufactured here by the Revolutionary War financier, Robert Morris, who had a rolling mill near Trenton, New Jersey. At his mill Morris produced the roof of his own

Replacement of particular historic details is important to the individual historic character of a roof, such as this rounded butt wood shingle roof. In the restoration, the drainage around a dormer was improved by the addition of carefully concealed modern metal flashing. Photo: NPS files.

Galvanized sheet-metal shingles imitating the appearance of pantiles remained popular from the second half of the 19th century into the 20th century. Photo: NPS files.

Philadelphia mansion, which he started in 1794. The architect Benjamin H. Latrobe used sheet iron to replace the roof on Princeton's "Nassau Hall," which had been gutted by fire in 1802.

The method for corrugating iron was originally patented in England in 1829. Corrugating stiffened the sheets, and allowed greater span over a lighter framework, as well as reduced installation time and labor. In 1834 the American architect William Strickland proposed corrugated iron to cover his design for the market place in Philadelphia.

Galvanizing with zinc to protect the base metal from rust was developed in France in 1837. By the 1850s the material was used on post offices and customhouses, as well as on train sheds and factories. In 1857 one of the first metal roofs in the South was installed on the U.S. Mint in New Orleans. The Mint was thereby "fireproofed" with a 20-gauge galvanized, corrugated iron roof on iron trusses.

Tin-plate iron, commonly called "tin roofing," was used extensively in Canada in the 18th century, but it was not as common in the United States until later. Thomas Jefferson was an early advocate of tin roofing, and he installed a standing-seam tin roof on "Monticello" (ca. 1770–1802). The Arch Street Meetinghouse (1804) in Philadelphia had tin shingles laid in a herringbone pattern on a "piazza" roof.

However, once rolling mills were established in this country, the low cost, light weight, and low maintenance of tin plate made it the most common roofing material. Embossed tin shingles, whose surfaces created interesting patterns, were popular throughout the country in the late 19th century. Tin roofs were kept well-painted, usually red; or, as the architect A. J. Davis suggested, in a color to imitate the green patina of copper.

Terne plate differed from tin plate in that the iron was dipped in an alloy of lead and tin, giving it a duller finish. Historic, as well as modern, documentation often confuses the two, so much that it is difficult to determine how often actual "terne" was used.

Zinc came into use in the 1820s, at the same time tin plate was becoming popular. Although a less expensive substitute for lead, its advantages were controversial, and it was never widely used in this country.

Other Materials: Asphalt shingles and roll roofing were used in the 1890s. Many roofs of asbestos, aluminum, stainless steel, galvanized steel, and lead-coated copper may soon have historic values as well. Awareness of these and other traditions of roofing materials and their detailing will contribute to more sensitive preservation treatments.

Tin shingles, commonly embossed to imitate wood or tile, or with a decorative design, were popular as an inexpensive, textured roofing material. Photo: NPS files.

Locating the Problem

Failures of Surface Materials

When trouble occurs, it is important to contact a professional, either an architect, a reputable roofing contractor, or a craftsman familiar with the inherent characteristics of the particular historic roofing system involved. These professionals may be able to advise on immediate patching procedures and help plan more permanent repairs. A thorough examination of the roof should start with an appraisal of the existing condition and quality of the roofing material itself. Particular attention should be given to any southern slope because year-round exposure to direct sun may cause it to break down first.

Wood: Some historic roofing materials have limited life expectancies because of normal organic decay and "wear." For example, the flat surfaces of wood shingles erode from exposure to rain and ultraviolet rays. Some species are more hardy than others, and heartwood, for example, is stronger and more durable than sapwood.

Ideally, shingles are split with the grain perpendicular to the surface. This is because if shingles are sawn across the grain, moisture may enter the grain and cause the wood to deteriorate. Prolonged moisture on or in the wood allows moss or fungi to grow, which will further hold the moisture and cause rot.

Metal: Of the inorganic roofing materials used on historic buildings, the most common are perhaps the sheet metals: lead, copper, zinc, tin plate, terne plate, and galvanized iron. In varying degrees each of these sheet metals are likely to deteriorate from chemical action by pitting or streaking. This can be caused by airborne pollutants; acid rainwater; acids from lichen or moss; alkalis found in lime mortars or portland cement, which might be on adjoining features and washes down on the roof surface; or tannic acids from adjacent wood sheathings or shingles made of red cedar or oak.

Corrosion from "galvanic action" occurs when dissimilar metals, such as copper and iron, are used in direct contact. Corrosion may also occur even though the metals are physically separated; one of the metals will react chemically against the other.

in the presence of an electrolyte such as rainwater. In roofing, this situation might occur when either a copper roof is decorated with iron cresting, or when steel nails are used in copper sheets. In some instances the corrosion can be prevented by inserting a plastic insulator between the dissimilar materials. Ideally, the fasteners should be a metal sympathetic to those involved.

Iron rusts unless it is well-painted or plated. Historically this problem was avoided by use of tin plating or galvanizing. But this method is durable only as long as the coating remains intact. Once the plating is worn or damaged, the exposed iron will rust. Therefore, any iron-based roofing material needs to be undercoated, and its surface needs to be kept well-painted to prevent corrosion.

One cause of sheet metal deterioration is fatigue. Depending upon the size and the gauge of the metal sheets, wear and metal failure can occur at the joints or at any protrusions in the sheathing as a result from the metal's alternating movement to thermal changes. Lead will tear because of "creep," or the gravitational stress that causes the material to move down the roof slope.

Slate: Perhaps the most durable roofing materials are slate and tile. Seemingly indestructible, both vary in quality. Some slates are hard and tough without being brittle. Soft slates are more subject to erosion and to attack by airborne and rainwater chemicals, which cause the slates to wear at nail holes, to delaminate, or to break. In winter, slate is very susceptible to breakage by ice, or ice dams.

Tile: Tiles will weather well, but tend to crack or break if hit, as by tree branches, or if they are walked on improperly. Like slates, tiles cannot support much weight. Low quality tiles that have been insufficiently fired during manufacture, will craze and spall under the effects of freeze and thaw cycles on their porous surfaces.

Failures of Support Systems

Once the condition of the roofing material has been determined, the related features and support systems should be examined on the exterior and on the interior of the roof. The gutters and downspouts need periodic cleaning and maintenance since a variety of debris fill them, causing water to back up and seep under roofing units. Water will eventually cause fasteners, sheathing, and roofing structure to deteriorate. During winter, the daily freeze-thaw cycles can cause ice floes to develop under the roof surface. The pressure from these ice floes will dislodge the roofing material, especially slates, shingles, or tiles. Moreover, the buildup of ice dams above the gutters can trap enough moisture to rot the sheathing or the structural members.

Many large public buildings have built-in gutters set within the perimeter of the roof. The downspouts for these gutters may run within the walls of the building, or drainage may be through the roof surface or through a parapet to exterior downspouts. These systems can be effective if properly maintained; however, if the roof slope is inadequate for good runoff, or if the traps are allowed to clog, rainwater will form pools on the roof surface. Interior downspouts can collect debris and thus back up, perhaps leaking water into the surrounding walls. Exterior downspouts may fill with water, which in cold weather may freeze and crack the pipes. Conduits from the built-in gutter to the exterior downspout may also leak water into the surrounding roof structure or walls.

Failure of the flashing system is usually a major cause of roof deterioration. Flashing should be carefully inspected for failure caused by either poor workmanship, thermal stress, or metal deterioration (both of flashing material itself and of the fasteners). With many roofing materials, the replacement of flashing on an existing roof is a major operation, which may require taking up large sections of the roof surface. Therefore, the installation of top quality flashing material on a new or replaced roof should be a primary consideration. **Remember, some roofing and flashing materials are not compatible.**

Roof fasteners and clips should also be made of a material compatible with all other materials used, or coated to prevent rust. For example, the tannic acid in oak will corrode iron nails. Some roofs such as slate and sheet metals may fail if nailed too rigidly.

If the roof structure appears sound and nothing indicates recent movement, the area to be examined most closely is the roof substrate—the sheathing or the battens. The danger spots would be near the roof plates, under any exterior patches, at the intersections of the roof planes, or at vertical surfaces such as dormers. Water penetration, indicating a breach in the roofing surface or flashing, should be readily apparent, usually as a damp spot or stain. Probing with a small pen knife may reveal any rot which may indicate previously undetected damage to the roofing membrane. Insect infestation evident by small exit

Temporary stabilization or "mothballing" with materials, such as plywood and building paper, can protect the roof of a project until it can be properly repaired or replaced. Photo: NPS files.

holes and frass (a sawdustlike debris) should also be noted. Condensation on the underside of the roofing is undesirable and indicates improper ventilation. Moisture will have an adverse effect on any roofing material; a good roof stays dry inside and out.

Because of the roof's visibility, the slate detailing around the dormers is important to the character of this structure. Photo: NPS files.

Repair or Replace

Understanding potential weaknesses of roofing material also requires knowledge of repair difficulties. Individual slates can be replaced normally without major disruption to the rest of the roof, but replacing flashing on a slate roof can require substantial removal of surrounding slates. If it is the substrate or a support material that has deteriorated, many surface materials such as slate or tile can be reused if handled care fully during the repair. Such problems should be evaluated at the outset of any project to determine if the roof can be effectively patched, or if it should be completely replaced.

Will the repairs be effective? Maintenance costs tend to multiply once trouble starts. As the cost of labor escalates, repeated repairs could soon equal the cost of a new roof.

The more durable the surface is initially, the easier it will be to maintain. Some roofing materials such as slate are expensive to install, but if top quality slate and flashing are used, it will last 40–60 years with minimal maintenance. Although the installation cost of the roof will be high, low maintenance needs will make the lifetime cost of the roof less expensive.

Historical Research

In a restoration project, research of documents and physical investigation of the building usually will establish the roof's history. Documentary research should include any original plans or building specifications, early insurance surveys, newspaper descriptions, or the personal papers and files of people who owned or were involved in the history of the building. Old photographs of the building might provide evidence of missing details.

Along with a thorough understanding of any written history of the building, a physical investigation of the roofing and its structure may reveal information about the roof's construction history. Starting with an overall impression of the structure, are there any changes in the roof slope, its configuration, or roofing materials? Perhaps there are obvious patches or changes in patterning of exterior brickwork where a gable roof was changed to a gambrel, or where a whole upper story was added. Perhaps there are obvious stylistic changes in the roof line, dormers, or ornamentation. These observations could help one understand any important alteration, and could help establish the direction of further investigation.

Because most roofs are physically out of the range of careful scrutiny, the "principle of least effort" has probably limited the extent and quality of previous patching or replacing, and usually considerable evidence of an earlier roof surface remains. Sometimes the older roof will be found as an underlayment of the current exposed roof. Original roofing may still be intact in awkward places under later features on a roof. Often if there is any unfinished attic space, remnants of roofing may have been dropped and left when the roof was being built or repaired. If the configuration of the roof has been changed, some of the original material might still be in place under the existing roof. Sometimes whole sections of the roof and roof framing will have been left intact under the higher roof. The profile and/or flashing of the earlier roof may be apparent on the interior of the walls at the level of the alteration. If the sheathing or lathing appears to have survived changes in the roofing surface, they may contain evidence of the roofing systems. These may appear either as dirt marks, which provide "shadows" of a roofing material, or as nails broken or driven down into the wood, rather than pulled out during previous alterations or repairs. Wooden headers in the roof framing may indicate that earlier chimneys or skylights have been removed. Any metal ornamentation that might have existed may be indicated by anchors or unusual markings along the ridge or at other edges of the roof. This primary evidence is essential for a full understanding of the roof's history.

Caution should be taken in dating early "fabric" on the evidence of a single item, as recycling of materials is not a mid-20th century innovation. Carpenters have been reusing materials, sheathing, and framing members in the interest of economy for centuries. Therefore, any analysis of the materials found, such as nails or sawmarks on the wood, requires an accurate knowledge of the history of local building practices before any final conclusion can be accurately reached. It is helpful to establish a sequence of construction history for the roof and roofing materials; any historic fabric or pertinent evidence in the roof should be photographed, measured, and recorded for future reference.

During the repair work, useful evidence might unexpectedly appear. It is essential that records be kept of any type of work on a historic building, before, during, and after the project. Photographs are generally the easiest and fastest method, and should include overall views and details at the gutters, flashing, dormers, chimneys, valleys, ridges, and eaves. All photographs should be immediately labeled to insure accurate identification at a later date. Any patterning or design on the roofing deserves particular attention. For example, slate roofs are often decorative and have subtle changes in size, color, and texture, such as a gradually decreasing coursing length from the eave to the peak. If not carefully noted before a project begins, there may be problems in replacing the surface. The standard reference for this phase of the work is

Recording Historic Buildings, compiled by Harley J. McKee for the Historic American Buildings Survey, National Park Service, Washington, D.C., 1970.

Replacing the Historic Roofing Material

Professional advice will be needed to assess the various aspects of replacing a historic roof. With some exceptions, most historic roofing materials are available today. If not, an architect or preservation group who has previously worked with the same type material may be able to recommend suppliers. Special roofing materials, such as tile or embossed metal shingles, can be produced by manufacturers of related products that are commonly used elsewhere, either on the exterior or interior of a structure. With some creative thinking and research, the historic materials usually can be found.

Craft Practices: Determining the craft practices used in the installation of a historic roof is another major concern in roof restoration. Early builders took great pride in their work, and experience has shown that the "rustic" or irregular designs commercially labeled "Early American" are a 20th-century invention. For example, historically, wood shingles underwent several distinct operations in their manufacture including splitting by hand, and smoothing the surface with a draw knife. In modern nomenclature, the same item would be a "tapersplit" shingle which has been dressed. Unfortunately, the rustic appearance of today's commercially available "handsplit" and re-sawn shingle bears no resemblance to the handmade roofing materials used on early American buildings.

Good design and quality materials for the roof surface, fastenings, and flashing minimize failures. Photo: NPS files.

Early craftsmen worked with a great deal of common sense; they understood their materials. For example they knew that wood shingles should be relatively narrow; shingles much wider than about 6" would split when walked on, or they may curl or crack from varying temperature and moisture. It is important to understand these aspects of craftsmanship, remembering that people wanted their roofs to be weather-tight and to last a long time. The recent use of "mother goose" shingles on historic structures is a gross underestimation of the early craftsman's skills.

Supervision: Finding a modern craftsman to reproduce historic details may take some effort. It may even involve some special instruction to raise his understanding of certain historic craft practices. At the same time, it may be pointless (and expensive) to follow historic craft practices in any construction that will not be visible on the finished product. But if the roofing details are readily visible, their appearance should be based on architectural evidence or on historic prototypes. For instance, the spacing of the seams on a standing-seam metal roof will affect the building's overall scale and should therefore match the original dimensions of the seams.

Many older roofing practices are no longer performed because of modern improvements. Research and review of specific detailing in the roof with the contractor before beginning the project is highly recommended. For example, one early craft practice was to finish the ridge of a wood shingle roof with a roof "comb"—that is, the top course of one slope of the roof was extended uniformly beyond the peak to shield the ridge, and to provide some weather protection for the raw horizontal edges of the shingles on the other slope. If the "comb" is known to have been the correct detail, it should be used. Though this method leaves the top course vulnerable to the weather, a disguised strip of flashing will strengthen this weak point.

Detail drawings or a sample mockup will help ensure that the contractor or craftsman understands the scope and special requirements of the project. It should never be assumed that the modern carpenter, slater, sheet metal worker, or roofer will know all the historic details. Supervision is as important as any other stage of the process.

Alternative Materials

The use of the historic roofing material on a structure may be restricted by building codes or by the availability of the materials, in which case an appropriate alternative will have to be found.

Some municipal building codes allow variances for roofing materials in historic districts. In other instances, individual variances may be obtained. Most modern heating and cooking is fueled by gas, electricity, or oil—none of which emit the hot embers that historically have been the cause of roof fires. Where wood burning fireplaces or stoves are used, spark arrestor screens at the top of the chimneys help to prevent flaming material from escaping, thus reducing the number of fires that start at the roof. In most states, insurance rates have been equalized to reflect revised considerations for the risks involved with various roofing materials.

In a rehabilitation project, there may be valid reasons for replacing the roof with a material other than the original. The historic roofing may no longer be available, or the cost of obtaining specially fabricated materials may be prohibitive. But the decision to use an alternative material should be weighed carefully against the primary concern to keep the historic character of the building. If the roof is flat and is not visible from any elevation of the building, and if there are advantages

to substituting a modern built-up composition roof for what might have been a flat metal roof, then it may make better economic and construction sense to use a modern roofing method. But if the roof is readily visible, the alternative material should match as closely as possible the scale, texture, and coloration of the historic roofing material.

Asphalt shingles or ceramic tiles are common substitute materials intended to duplicate the appearance of wood shingles, slates, or tiles. Fire-retardant, treated wood shingles are currently available. The treated wood tends, however, to be brittle, and may require extra care (and expense) to install. In some instances, shingles laid with an interlay of fire-retardant building paper may be an acceptable alternative.

Lead-coated copper, terne-coated steel, and aluminum/ zinc-coated steel can successfully replace tin, terne plate, zinc, or lead. Copper-coated steel is a less expensive (and less durable) substitute for sheet copper.

The search for alternative roofing materials is not new. As early as the 18th century, fear of fire caused many wood shingle or board roofs to be replaced by sheet metal or clay tile. Some historic roofs were failures from the start, based on overambitious and naive use of materials as they were first developed. Research on a structure may reveal that an inadequately designed or a highly combustible roof was replaced early in its history, and therefore restoration of a later roof material would have a valid precedent. In some cities, the substitution of sheet metal on early row houses occurred as soon as the rolled material became available.

Cost and ease of maintenance may dictate the substitution of a material wholly different in appearance from the original. The practical problems (wind, weather, and roof pitch) should be weighed against the historical consideration of scale, texture, and color. Sometimes the effect of the alternative material will be minimal. But on roofs with a high degree of visibility and patterning or texture, the substitution may seriously alter the architectural character of the building.

Temporary Stabilization

It may be necessary to carry out an immediate and temporary stabilization to prevent further deterioration until research can determine how the roof should be restored or rehabilitated, or until funding can be provided to do a proper job. A simple covering of exterior plywood or roll roofing might provide adequate protection, but any temporary covering should be applied with caution. One should be careful not to overload the roof structure, or to damage or destroy historic evidence or fabric that might be incorporated into a new roof at a later date. In this sense, repairs with caulking or bituminous patching compounds should be recognized as potentially harmful, since they are difficult to remove, and at their best, are very temporary.

Precautions

The architect or contractor should warn the owner of any precautions to be taken against the specific hazards in installing the roofing material. Soldering of sheet metals, for instance, can be a fire hazard, either from the open flame or from overheating and undetected smoldering of the wooden substrate materials.

Thought should be given to the design and placement of any modern roof appurtenances such as plumbing stacks, air vents, or TV antennas. Consideration should begin with the placement of modern plumbing on the interior of the building, otherwise a series of vent stacks may pierce the roof membrane at various spots creating maintenance problems as well as aesthetic ones. Air handling units placed in the attic space will require vents which, in turn, require sensitive design. Incorporating these in unused chimneys has been very successful in the past.

Whenever gutters and downspouts are needed that were not on the building historically, the additions should be made as unobtrusively as possible, perhaps by painting them out with a color compatible with the nearby wall or trim.

Maintenance

Although a new roof can be an object of beauty, it will not be protective for long without proper maintenance. At least twice a year, the roof should be inspected against a checklist. All changes should be recorded and reported. Guidelines should be established for any foot traffic that may be required for the maintenance of the roof. Many roofing materials should not be walked on at all. For some—slate, asbestos, and clay tile—a self-supporting ladder might be hung over the ridge of the roof, or planks might be spanned across the roof surface. Such items should be specifically designed and kept in a storage space accessible to the roof. If exterior work ever requires hanging scaffolding, use caution to insure that the anchors do not penetrate, break, or wear the roofing surface, gutters, or flashing.

Any roofing system should be recognized as a membrane that is designed to be self-sustaining, but that can be easily damaged by intrusions such as pedestrian traffic or fallen tree branches. Certain items should be checked at specific times. For example, gutters tend to accumulate

leaves and debris during the spring and fall and after heavy rain. Hidden gutter screening both at downspouts and over the full length of the gutter could help keep them clean. The surface material would require checking after a storm as well. Periodic checking of the underside of the roof from the attic after a storm or winter freezing may give early warning of any leaks. Generally, damage from water or ice is less likely on a roof that has good flashing on the outside and is well ventilated and insulated on the inside. Specific instructions for the maintenance of the different roof materials should be available from the architect or contractor.

Special problems inherent in the design of an elaborate historic roof can be controlled through regular maintenance. The shape and detailing are essential elements of the building's historic character, and should not be modified, despite the use of alternative surface materials. Photo: NPS files.

Summary and References

The essential ingredients for replacing and maintaining a historic roof are:

- **Understanding the historic character** of the building and being sympathetic to it.
- **Careful examination and recording** of the existing roof and any evidence of earlier roofs.
- **Consideration of the historic craftsmanship** and detailing and implementing them in the renewal wherever visible.
- **Supervision of the roofers** or maintenance personnel to assure preservation of historic fabric and proper understanding of the scope and detailing of the project.
- **Consideration of alternative materials** where the original cannot be used.
- **Cyclical maintenance** program to assure that the staff understands how to take care of the roof and of the particular trouble spots to safeguard.

With these points in mind, it will be possible to preserve the architectural character and maintain the physical integrity of the roofing on a historic building.

Acknowledgements

This Preservation Brief was written by **Sarah M Sweetser**, Architectural Historian, Technical Preservation Services Division. Much of the technical information was based upon an unpublished report prepared under contract for this office by John G. and Diana S. Waite. Some of the historical information was from Charles E. Peterson, FAIA, "American Notes," Journal of the Society of Architectural Historians. The illustrations for this brief not specifically credited are from the files of the Technical Preservation Services Division.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Technical Preservation Services (TPS), National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

February 1978

Reading List

Boaz, Joseph N., ed. *Architectural Graphic Standards*. New York: John Wiley and Sons, Inc., 1970. (Modern roofing types and detailing)

Briggs, Martin S. *A Short History of the Building Crafts*. London: Oxford University Press, 1925. (Descriptions of historic roofing materials)

The Association for Preservation Technology Bulletin. Vol. 2 (nos. 12) 1970. (Entirely on roofing)

Holstrom, Ingmar; and Sandstrom, Christina. *Maintenance of Old Buildings: Preservation from the Technical and Antiquarian Standpoint*. Stockholm: National Swedish Building Research, 1972. (Contains a section on roof maintenance problems)

Insall, Donald. *The Care of Old Buildings Today*. London: The Architectural Press, 1972. (Excellent guide to some problems and solutions for historic roofs)

Labine, R. A. Clem. "Repairing Slate Roofs." *The Old House Journal* 3 (no. 12, Dec. 1975): 67.

Lefer, Henry. "A Birdseye View." *Progressive Architecture*. (Mar. 1977), pp. 8892. (Article on contemporary sheet metal)

National Slate Association. *Slate Roofs*. Reprint of 1926 edition, now available from the Vermont Structural Slate Co., Inc., Fairhaven, VT 05743. (An excellent reference for the many designs and details of slate roofs)

1.2 Roofing element – terra cotta clay tile

Four of the USMMA historic buildings have barrel-rolled terra cotta clay tile roofs (Figure 20–Figure 23), and one has flat tiles (Figure 24). Because the pattern, detailing, and craftsmanship of terra cotta clay tile roofs are important design elements of historic buildings, they should be repaired rather than be replaced whenever possible.

1.2.1 Immediate concerns for roofing element – clay tile

Overall, terra cotta clay tiles will weather well, but they tend to crack or break if hit by something such as a tree or its branches. The tiles cannot support much weight. Low-quality tiles that have been insufficiently fired during manufacture will craze and spall under the effects of freeze and thaw cycles on their porous surfaces (Sweetzer 1978; Grimmer and Williams 1992).

While clay roofing tiles themselves are most likely to deteriorate because of frost damage, a clay tile roof system most commonly fails due to breakdown of the fastening system. Another area of potential failure of a historic clay tile roof is the support system. Terra cotta clay tiles are heavy, and it is important that the roof structure remain sound. If gutters and downspouts are allowed to fill with debris, water can back up and seep under roofing tiles, causing the eventual deterioration of roofing battens, the sheathing and fastening system, or even the roof's structural members. During freezing weather, ice can build up under tiles and cause breakage during the freeze-thaw cycle (Grimmer and Williams 1992).

Figure 20. Red barrel terra cotta clay tile roofing material on Melville Hall (ERDC-CERL, 2013).

Figure 21. Green glazed terra cotta clay tile roof on Land Hall (Schenck house) (ERDC-CERL, 2013).

Figure 22. Terra cotta clay tiles on the American Merchant Marine Museum [Barstow Mansion] (ERDC-CERL, 2013).

Figure 23. Backside of the terra cotta clay tiles on the American Merchant Marine Museum [Barstow Mansion] that were manufactured by the Ludowici Celadon Company (www.ludowici.com), which is still in business (ERDC-CERL, 2015).

Figure 24. Flat terra cotta clay tiles on Quarters H (ERDC-CERL, 2015).

1.2.2 Guidelines, briefs, bulletins, and sources for roofing – clay tile

In addition to the information contained in this manual, the authors have compiled the following federal resource publications (reproduced here for convenience, with links for online access given in References) to inform managers about standards, guidelines, and procedures for understanding architecture, and caring for, preserving, and rehabilitating historic buildings with emphasis on historic clay tile roofing material (see subsections 1.2.2.1–1.2.2.3).

1.2.2.1 Preservation and repair of historic clay tile (Grimmer and Williams 1992 – Preservation Brief #30)

Technical Preservation Services

National Park Service
U.S. Department of the Interior

[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 30 Clay Tile Roofs

Some of the web versions of the Preservation Briefs differ somewhat from the printed versions. Many illustrations are new and in color; Captions are simplified and some complex charts are omitted. To order hard copies of the Briefs, see [Printed Publications](#)®.

PRESERVATION BRIEFS

30

The Preservation and Repair of Historic Clay Tile Roofs

Anne E. Grimmer and Paul K. Williams

[Historical Background](#)

[Revival Styles Renew Interest](#)

[Early Tiles](#)

[Clay Tile Substitutes](#)

[Traditional Tile Shapes and Colors](#)

[How Tiles are Attached](#)

[Flat Tiles](#)

[Pantiles](#)

[Ridge or Hip Tiles](#)

[Roof Pitch and Weather](#)

[Preservation and Repair](#)

[Summary and References](#)

[Reading List](#)

[Download the PDF](#)

Historic clay tile roof. Photo: NPS files.

Clay tiles are one of the most distinctive and decorative historic roofing materials because of their great variety of shapes, colors, profiles, patterns, and textures. Traditionally, clay tiles were formed by hand, and later by machine extrusion of natural clay, textured or glazed with color, and fired in high-temperature kilns. The unique visual qualities of a clay tile roof often make it a prominent feature in defining the overall character of a historic building. The significance and inherently fragile nature of historic tile roofs dictate that special care and precaution be taken to preserve and repair them.

Clay tile has one of the longest life expectancies among historic roofing materials—generally about 100 years, and often several hundred. Yet, a regularly scheduled maintenance program is necessary to prolong the life of any roofing system. A complete internal and external inspection of the roof structure and the roof covering is recommended to determine condition, potential causes of failure, or source of leaks, and will help in developing a program for the preservation and repair of the tile roof. Before initiating any repair work on historic clay tile roofs, it is important to identify those qualities important in contributing to the historic significance and character of the building.

Clay tile was a popular roofing material for residential structures during the Romanesque Revival period. Photo: NPS files.

This Brief will review the history of clay roofing tiles and will include a description of the many types and shapes of historic tiles, as well as their different methods of attachment. It will conclude with general guidance for the historic property owner or building manager on how to plan and carry out a project involving the repair and selected replacement of historic clay roofing tiles. Repair of historic clay tile roofs is not a job for amateurs; it should be undertaken only by professional roofers experienced in working with clay tile roofs.

Historical Background

The origin of clay roofing tile can be traced independently to two different parts of the world: China, during the Neolithic Age, beginning around 10,000 B.C.; and the Middle East, a short time later. From these regions, the use of clay tile spread throughout Asia and Europe. Not only the ancient Egyptians and Babylonians, but also the Greeks and Romans roofed their buildings with clay tiles, and adaptations of their practice continue in Europe to the present. European settlers brought this roofing tradition to America where it was established in many places by the 17th century.

Archeologists have recovered specimens of clay roofing tiles from the 1585 settlement of Roanoke Island in North Carolina. Clay

tile was also used in the early English settlements in Jamestown, Virginia, and nearby St. Mary's in Maryland. Clay roofing tiles were also used in the Spanish settlement of St. Augustine in Florida, and by both the French and Spanish in New Orleans.

Dutch settlers on the east coast first imported clay tiles from Holland. By 1650, they had established their own full-scale production of clay tiles in the upper Hudson River Valley, shipping tiles south to New Amsterdam. Several tile manufacturing operations were in business around the time of the American Revolution, offering both colored and glazed tile and unglazed natural terra-cotta tile in the New York City area, and in neighboring New Jersey. A 1774 New York newspaper advertised the availability of locally produced, glazed and unglazed pantiles for sale that were guaranteed to "stand any weather." On the west coast clay tile was first manufactured in wooden molds in 1780 at Mission San Antonio de Padua in California by Indian neophytes under the direction of Spanish missionaries.

By far the most significant factor in popularizing clay roofing tiles during the Colonial period in America was the concern with fire. Devastating fires in London, 1666, and Boston in 1679, prompted the establishment of building and fire codes in New York and Boston. These fire codes, which remained in effect for almost two centuries, encouraged the use of tile for roofs, especially in urban areas, because of its fireproof qualities. Clay roofing tile was also preferred because of its durability, ease of maintenance, and lack of thermal conductivity.

Although more efficient production methods had lowered the cost of clay tile, its use began to decline in much of the northeastern United States during the second quarter of the 19th century. In most areas outside city-designated fire districts, wood shingles were used widely; they were more affordable and much lighter, and required less heavy and less expensive roof framing. In addition, new fire-resistant materials were becoming available that could be used for roofing, including slate, and metals such as copper, iron, tin-plate, zinc, and galvanized iron. Many of the metal roofing materials could be installed at a fraction of the cost and weight of clay tile. Even the appearance of clay tile was no longer fashionable, and by the 1830s clay roofing tiles had slipped temporarily out of popularity in many parts of the country.

Revival Styles Renew Interest in Clay Roofing Tiles

The clay tile roof is important in defining the character of the c. 1917 Mission-style Grove Park Inn, Asheville, North Carolina. Photo: NPS files.

By the mid-19th century, the introduction of the Italianate Villa style of architecture in the United States prompted a new interest in clay tiles for roofing. This had the effect of revitalizing the clay tile manufacturing industry, and by the 1870s, new factories were in business, including large operations in Akron, Ohio, and Baltimore, Maryland.

Clay tiles were promoted by the Centennial Exhibition in Philadelphia in 1876, which featured several prominent buildings with tile roofs, including a pavilion for the state of New Jersey roofed with clay tiles of local manufacture. Tile-making machines were first patented in the 1870s, and although much roofing tile continued to be made by hand, by the 1880s more and more factories were beginning to use machines. The development of the Romanesque Revival style of

Tapered barrel clay roof tiles were custom made for the restoration of the 1820s Indian barracks at Mission Santa Cruz in California. Photo: NPS files.

architecture in the 1890s further strengthened the role of clay roofing tiles as an American building material.

Alternative substitutes for clay tiles were also needed to meet this new demand. By about 1855, sheet metal roofs designed to replicate the patterns of clay tile were being produced. Usually painted a natural terra cotta color to emulate real clay tile, these sheet metal roofs became popular because they were cheaper and lighter, and easier to install than clay tile roofs.

Clay roofing tiles fell out of fashion again for a short time at the end of the 19th century, but once more gained acceptance in the 20th century, due primarily to the popularity of the Romantic Revival architectural styles, including Mission, Spanish, Mediterranean, Georgian and Renaissance Revival in which clay tile roofs featured prominently. With the availability of machines capable of extruding clay in a variety of forms in large quantities, clay tiles became more readily available across the nation. More regional manufacturing plants were established in areas with large natural deposits of clay, including Alfred, New York; New Lexington, Ohio; Lincoln, California; and Atlanta, Georgia; as well as Indiana, Illinois and Kansas.

The popularity of clay tile roofing, and look-alike substitute roofing materials, continues in the 20th century, especially in areas of the South and West—most notably Florida and California—where Mediterranean and Spanish-influenced styles of architecture still predominate.

Clay tiles emphasize the prominence of the peaked roofs of these late 19th century row houses. Photo: NPS files.

Early Tiles

During the 17th and 18th centuries the most common type of clay roofing tiles used in America were flat and rectangular. They measured approximately 10" x 6" x 1/2" (25cm x 15cm x 1.25cm), and had two nail or peg holes at one end through which they were anchored to the roofing laths. Sometimes a strip of mortar was placed between the overlapping rows of tile to prevent the tiles from lifting in high winds. In addition to flat tiles, interlocking S-shaped pantiles were also used in the 18th century. These were formed by molding clay over tapered sections of logs, and were generally quite large. Alternately termed pan, crooked, or Flemish tiles, and measuring approximately 14 1/2" x 9 1/2" (37cm x 24cm), these interlocking tiles were hung on roofing lath by means of a ridge or lug located on the upper part of the underside of each tile. Both plain (flat) tile and pantile (S-shaped or curved) roofs were capped at the ridge with semicircular ridge tiles. Clay roofing tiles on buildings in mid-18th century Moravian settlements in Pennsylvania closely resembled those used in Germany at the time. These tiles were about 14"-15" long x 6"-7" wide (36cm-38cm x 15cm-18cm) with a curved butt, and with vertical grooves to help drainage. They were also designed with a lug or nib on the back so that the tiles could hang on lath without nails or pegs.

The accurate dating of early roofing tiles is difficult and often impossible. Fragments of tile found at archeological sites may indicate the existence of clay tile roofs, but the same type of tile was also sometimes used for other purposes such as paving, and in bake ovens. To further complicate dating, since clay tile frequently outlasted many of the earliest, less permanent structures, it was often reused on later buildings.

Clay Tile Substitutes

In addition to sheet metal "tile" roofs introduced in the middle of the 19th century, concrete roofing tile was developed as another substitute for clay tile in the latter part of the 19th century. It became quite popular by the beginning of the 20th century. Concrete tile is composed of a dense mixture of portland cement blended with aggregates, including sand, and pigment, and extruded from high-pressure machines.

Although it tends to lack the color permanence and the subtle color variations inherent in natural clay tile, concrete tile continues to be a popular roofing material today because it reproduces the general look of clay tile, if not always the exact profile or proportions of historic clay tile, at a somewhat lower cost and weight. Another modern, slightly cheaper and lighter substitute for clay tile more recently developed consists of a mixture of mineral fiber and cement with pigments added to supply color. While these aggregate tiles also replicate the shape and appearance of clay roofing tiles, they have many of the same dissimilarities to clay tiles that are found in concrete tiles. Thus, like concrete tiles, they are seldom appropriate substitutes for clay tiles.

Asphalt shingles are an incompatible replacement substitute for the original Spanish clay tiles. Photo: NPS files.

Traditional Tile Shapes and Colors

There are two types of clay roofing tiles: interlocking and overlapping. Interlocking tiles are designed in pairs so that an extrusion or "lip" on one of the tiles "hooks" over the other tile thereby "locking" or securing the two together; they are also

usually nailed to the roof structure. Overlapping tiles, which can also function in pairs, generally do not have any sort of "lip" and must be nailed in place. There is a wide range of shapes of historic clay roofing tiles, and many, sometimes with slight variations, are still produced today. There are many variations, and the country of origin of some of them may be revealed in their names, but there are essentially only two kinds of shapes: pantiles and flat tiles. Both pantiles and flat tiles may be either interlocking or overlapping.

Pantiles

The shape most commonly associated with historic clay roofing tiles is probably that of convex or rounded tiles, often grouped together generically as "pan tiles" or "pantiles." These include Spanish tiles-sometimes called "S" tiles, or the similarly shaped Mission tiles, also known as Barrel or Barrel Mission tiles, straight or tapered, as well as Roman tiles, and their Greek variation.

Flat Tiles

Flat, shingle tiles are another type of historic clay roofing tiles. Flat tiles can be completely plain and flat, and, like roofing slates, overlap one another, attached with nails to the roof sheathing. Or they may interlock at the top and on one side. Although the "interlock" holds them together, most interlocking shingle tiles also have one or more holes, usually near the top, for nailing to the roof sheathing. Flat tiles are mostly variations of English or Shingle tiles, and include English Shingle, Closed Shingle, Flat, Shingle or Slab Shingle, as well as French tiles which have a slightly higher and more contoured profile.

Any of the standard tile shapes may be known by a different name in another region of the country, or in different parts of the world. For example, what are known as Spanish or "S" tiles in the United States, may be called Single Roman tiles in England. Sometimes Spanish and Mission tiles are equated despite the fact that the former are usually 1-piece interlocking tiles and the latter are single Ω cylinders that overlap. Since missions and the Mission style are associated with the Americas, Mission tiles in the United States are more commonly referred to as Spanish tiles in England and Europe. In a similar vein, Spanish or "S" tiles, or Barrel tiles, might seem to be more typical of some tiles used in France than what are marketed as French tiles by American manufacturers.

Today some tile manufacturers have given their own trademark name to historic tile shapes. Other companies market uniquely shaped "S" tiles that are more in the shape of a true, but rather low profile "s" without the customary flat portion of traditional American "S" tiles.

An eave closure or birdstop to keep out birds is notably absent from the replacement tile in the center of the bottom row. Photo: NPS files.

Field and Specialty Tile

The tiles that cover the majority of the flat surface of the roof are called field tile. Some roof shapes, particularly conical towers or turrets, require tiles of graduated sizes, and some shapes or patterns of field tile also require specially shaped finish tiles to complete the roof covering package. Other uniquely-shaped tiles were made to fit odd-shaped spaces and places including dormers and valleys, roof hips, rakes, ridges and corners. There are also finish tiles that fulfill certain needs, such as eave closures or clay plugs called "birdstops." These are intended to keep out snow and rain, and birds from nesting in the voids under the bottom row of curved tiles. Different patterns and designs can also be created by combining, or mixing and matching flat tiles with dimensional tiles.

Tile Colors

A terra cotta red is the color most commonly associated with historic clay roofing tiles. The reddish color comes from clay with a large percentage of iron oxide, and there are many variations of this natural color to be found in tiles ranging from deep reddish browns to softer and paler oranges and pinks. Lighter buff and beige colors, as well as black, also appear on traditional tile-roofed buildings. Buff-colored tiles were made from nearly pure fire clay, and pouring manganese dissolved in water over the tile before firing resulted in smoke brown or black glazed tiles. Toward the end of the 19th century the popularity of colored glazes for roofing tiles increased, and their use and the range of colors continues to expand today. Most historic glazed roofing tiles are in fairly natural hues that range from reds and browns and buffs, to blacks and purples, blues (often created with smalt, or powdered blue glass), and a wide variety of greens (usually created with copper slag). There could be a considerable range in the colors of tiles that were baked over a wood fire because the temperature within the kiln was so uneven; tiles closest to the fire cooked all the way through and turned a darker red, while tiles farthest from the flames were likely to be smoke-stained, and lighter orange in color.

How Tiles are Attached

The method used to attach clay roofing tiles varies according to the shape, size and style of the particular tile. For the most part, traditional and modern methods of installing clay roofing tiles are very similar, except that modern practice always

includes the use of wood sheathing and roofing felt. But most of the earliest clay roofing tiles were laid without benefit of wood sheathing and hung directly on roofing laths and battens that were nailed to the roof rafters; this practice continued up into the mid-19th century in some regions. While this method of attachment allowed for plenty of ventilation, and made it easy to find leaks and make repairs, it also meant that the overall water-tightness of the roof depended entirely on the tiles themselves.

Gradually, the practice evolved of nailing roofing tiles directly onto continuous wood sheathing, or hanging them from "nibs" on horizontal lath that was attached to roof rafters or sheathing. Some kinds of tile, especially the later Mission or Barrel tiles were laid over vertical strips or battens nailed to the sheathing, or the tiles were fastened to wood purlins with copper wire.

Partly because they do not always fit together very closely, some tile shapes, including Spanish, Barrel or Mission as well as other types of interlocking tiles, are not themselves completely water-repellent when used on very low-pitched roofs. These have always required some form of sub-roofing, or an additional waterproof underlayer, such as felting, a bituminous or a cementitious coating. In some traditional English applications, a treatment called "torching," involved using a simple kind of mortar most commonly consisting of straw, mud, and moss. The tapered Mission tiles of the old Spanish missions in California were also laid in a bed of mud mortar mixed with grass or straw which was their only means of attachment to the very low-pitched reed or twig sheathing (latia) that supported the tiles.

Projections on the underside of these replacement Spanish clay tiles help them adhere to the cement mortar on the roof sheathing. Photo: NPS files.

More recent and contemporary roofing practices require that the tiles be laid on solid 1" (2.5cm) wood sheathing felted with coated base sheets of at least 30 lbs., or built-up membranes or single-ply roof membranes. This substantially increases the water-tightness of the roof by adding a second layer of waterproofing. Horizontal and vertical chalk lines are drawn to serve as a guide in laying the tile and to indicate its patterning. Most tiles are designed with one or two holes so they can be attached by copper nails or hangers, and/or with projecting nibs, to interlock or hang on battens or lath attached to the base sheathing.

Before laying the tiles, the copper or lead gutters, flashings and valleys must be installed, preferably using at least #26 gauge (20-24 ounce) corrosion-resistant metal extending a minimum of 12" (30.5cm) under the tile from the edge, or in accordance with the manufacturer's specifications. The long life and expected durability of clay tiles require that, as with the roofing nails, only the best quality metal be selected for the flashing and guttering.

These tapered barrel clay tiles were accurately reproduced from archeological materials found on site. Photo: NPS files.

"Field tile" is usually ordered by the number of "squares"—that is, a flat section 10' x 10' (25cm x 25cm)—needed to cover a roof section. The tile company or roofing contractor should calculate the number of tiles needed according to the type of roof, and based on architect's drawings to ensure accuracy. This should include specialty ridge and eave tiles, decorative trim, partial "squares" approximately 10-20 per cent allowance for breakage, and extra tiles to store for repairing incidental damage later on. Once at the site, the tile is evenly distributed in piles on the roof, within easy reach for the roofers.

The tiles are laid beginning with the first course at the lower edge of the roof at the eaves. The method by which roofing tiles are laid and attached varies, depending on the type and design of the tiles and roof shape, as well as on regional practice and local weather conditions. A raised fascia, a cant strip, a double or triple layer of tiles, or special "birdstop" tiles for under the eaves, may be used to raise the first row of tiles to the requisite height and angle necessary for the best functioning of

the roof. The tile is positioned to overhang the previously installed gutter system by at least 1-1/2" (4cm) to ensure that rainwater discharges into the central portion of the gutter. Once this first course is carefully fitted and examined from the ground level for straightness and color nuances, and adjusted accordingly, successive courses are lapped over the ones below as the roofer works diagonally up the roof toward the ridge. Positioning and laying tiles in a 10" x 10" (25cm x 25cm) square may take on the average of 16-1/2 man hours.

Flat Tiles

Most flat clay tiles have one or two holes located at the top, or on a "nib" or "lug" that projects vertically either from the face or the underside of the tiles, for nailing the tile to the sheathing, battens, or furring strips beneath. As successive rows of tile are installed these holes will be covered by the next course of tiles above. Traditionally, clay tiles on the oldest tile roofs were hung on roofing laths with oak wooden pegs. As these wood pegs rotted, they were commonly replaced with

nails. Today, copper nails, 1-3/4" (4.5cm) slaters' nails, are preferred for attaching the tiles because they are the longest lasting, although other corrosion-resistant nails can also be used. Less durable nails reduce the longevity of a clay tile roof which depends on the fastening agents and the other roofing components, as much as on the tiles themselves. Clay roofing tiles, like roofing slates, are intended to hang on the nails, and nailheads should always be left to protrude slightly above the surface of the tile. Nails should not be driven too deeply into the furring strips because too much pressure on the tile can cause it to break during freeze/thaw cycles, or when someone walks on the roof.

Plain flat tiles, like roofing slates, are attached to the roof sheathing only with nails. They are laid in a pattern overlapping one another in order to provide the degree of impermeability necessary for the roof covering. Because plain flat tiles overlap in most cases almost as much of one half of the tile, this type of tile roof covering results in a considerably heavier roof than does an interlocking tile roof which does not require that the tiles overlap to such an extent. Interlocking flat tiles form a single layer, and an unbroken roof covering. Although most interlocking tiles on all but the steepest roofs can technically be expected to remain in place because they hang on protruding nibs from the roofing laths or battens, in contemporary roofing practices they are often likely to be nailed for added security. In most cases it is usually a good idea to nail at least every other tile.

Pantiles

With Mission or Barrel tiles, where one half-cylinder overlaps another inverted half-cylinder to form a cover and pan (cap and trough) arrangement, the fastening is more complicated. While the pantiles that rest directly on the sheathing are simply nailed in place, there are two ways of attaching the cover tiles that rest on the pantiles. They can be secured by a copper wire nailed to the sheathing or tied to vertical copper strips running behind the tiles. Another method requires the installation of vertical battens or nailing strips on the roof to which the cover tiles are nailed, or the use of tile nails or hooks, which are hooked to the pantile below and secured with twisted copper wire.

Sometimes cement mortar, or another underlayer such as grass, moss or straw, or hair-reinforced mortar was added under the tiles. Before the use of felting this was a particularly common practice on some of the plain flat tile or Spanish tile roofs with low rises that were themselves not especially waterproof. Mortar also helped to keep driving rain from getting under the pantiles, and it is still customary in contemporary roofing to add a dab of cement mortar to help secure them.

Ridge or Hip Tiles

At the roof ridge or hip, clay tile is usually attached to a raised stringer with nails and a small amount of mortar, elastic cement or mastic. The joint is sealed with a flexible flashing such as copper or lead. Ridge tiles are often somewhat larger and more decorative than the field tile utilized on the broad sections of the roof.

Roof Pitch and Weather Factors in Tile Attachment

The means by which clay tile is attached to the sheathing is also partly determined by the roof pitch. Generally the fastening requirements increase with an increase of roof pitch. For low-pitched rises of 4"-6" (10cm-15cm) in a 12" (30.5cm) run the weight of the tiles is usually sufficient to hold them in place on the lath by the ridge or "lug" on the underside of the tile, with only the perimeter tiles requiring metal clips to secure them to the sheathing. But the tiles on even these low-pitched roofs are usually nailed for added security, and additional fastening measures are necessary on roofs with a higher pitch, or in areas subject to high winds or earthquakes. For steeper pitched roofs, such as towers, 7"-11" (18cm-28cm), or 12"-15" (30.5cm-38cm) in a 12" (30.5cm) run the tiles are nailed and a band of perimeter tiles three to four tiles thick is secured with clips. For roof rises over 16" (41cm) in a 12" (30.5cm) run, and in areas prone to earthquakes or hurricanes, every tile may be secured with both a nail and a copper or noncorrosive metal clip, and often also with a dab of roofing mastic or mortar.

The installation of clay roofing tiles in areas with significant amounts of snowfall-over 24" (61cm) per year-also varies somewhat from the normal guidelines. Larger battens may be necessary, as well as additional clipping or tying of the tile to securely attach it to the sheathing. The roof structure itself may also need added bracing, as well as the insertion of small snow clips or snow birds that protrude above the surface of the tile to prevent snow and ice from sliding off the roof and damaging the tile.

Preservation and Repair

Identifying Common Problems and Failures

While clay roofing tiles themselves are most likely to deteriorate because of frost damage, a clay tile roof system most commonly fails due to the breakdown of the fastening system. As the wooden pegs that fastened the early tiles to hand-riven battens rotted, they were often replaced with iron nails which are themselves easily corroded by tannic acid from oak battens or sheathing. The deterioration of metal flashing, valleys, and gutters can also lead to the failure of a clay tile roof.

Another area of potential failure of a historic clay tile roof is the support system. Clay tiles are heavy and it is important that the roof structure be sound. If gutters and downspouts are allowed to fill with debris, water can back up and seep under roofing tiles, causing the eventual deterioration of roofing battens, the sheathing and fastening system, or even the roof's structural members. During freezing weather, ice can build up under tiles and cause breakage during the freeze/thaw cycle. Thus, as with any type of roof, water and improperly maintained rainwater removal and drainage systems are also chief causes for the failure of historic clay tile roofs.

Clay tiles may be either handcrafted or machine-made; in general, roofs installed before the end of the 19th century consist of hand formed tiles, with machine-made tiles becoming more dominant as technology improved during the 20th century. Clay tile itself, whether made by hand or made by machine, can vary in quality from tile to tile. Efflorescence of soluble salts on the surface may indicate that a tile has excessive porosity which results from under-burning during its manufacture. Poor quality porous tiles are particularly susceptible to breaking and exterior surface spalling during freeze-thaw cycles. By letting in moisture, porous tiles can permit the roof battens and roof structure to rot. The problem may be compounded by waterproof building paper or building felt laid underneath which can, in some instances, prevent adequate ventilation.

Clay roofing tiles can also be damaged by roofers walking carelessly on an unprotected roof while making repairs, or by overhanging tree branches, falling tree limbs, or heavy hail. Broken tiles may no longer provide a continuous waterproof surface, thereby allowing water to penetrate the roofing structure, and may eventually result in its deterioration if the broken tiles are not replaced in a timely manner.

Although modern, machine-made clay tiles are more uniform in appearance than their handmade counterparts, they also have the potential for failure. Occasionally, entire batches of mass-produced tile can be defective.

Regular Inspection and Maintenance

Broken or missing tiles, or leaks on the interior of the building, are obvious clues that a historic clay tile roof needs repair. Even though it may be clear that the roof is leaking, finding the source of the leak may not be so easy. It may require thorough investigation in the attic, as well as going up on the roof and removing tiles selectively in the approximate area of the roof leak. The source of the leak may not actually be located where it appears to be. Water may come in one place and travel along a roofing member some distance from the actual leak before revealing itself by a water stain, plaster damage, or rotted wooden structural members.

Temporary Protection during Repair

In some instances temporary protection and stabilization may be necessary to prevent further damage or deterioration of a historic clay tile roof. Plywood sheets, plastic, roll roofing, or roofing felt can provide short-term protection until repair or replacement materials can be purchased. Another option may be to erect a temporary scaffold that is encased or covered with clear or semitransparent polyethylene sheeting over the entire roof. This will not only protect the exposed roofing members during repair or until repairs can be made, but also lets in enough natural light to enable the reroofing work to take place while sheltering workmen from cold or wet weather.

General Repair Guidance

Once the source and cause of a leak has been identified, appropriate repairs must be made to structural roofing members, wood sheathing, felt or roofing paper if it is part of the roofing membrane, or possibly to vertical roof battens to which the tiles may be attached. If the problem appears limited to gutters and flashing in disrepair, repair or replacement will probably require temporary removal of some of the adjacent tiles to gain access to them. If the roofing tiles are extremely fragile and cannot be walked on even with adequate protection (see below), it may also be necessary to remove several rows or a larger area of tiles and store them for later reinstallation in order to create a "path" to reach the area of repair without damaging existing tiles. Even if most of the tiles themselves appear to be intact but no longer securely attached to the roof substrate due to deterioration of the fastening system or roofing members, all the tiles should be labeled and removed for storage. Regardless of whether the repair project involves removal of only a few damaged tiles, or if all the tiles must be removed and relaid, historic clay roofing tiles are inherently fragile and should be pulled up carefully with the use of a slate ripper. The tiles can be reattached one-by-one with new corrosion-resistant copper nails, copper straps or tabs, "tingles", or another means after the necessary repairs have been made to the roof.

Replacing Individual Tiles

The most difficult aspect of replacing a single broken clay roof tile is doing so without breaking neighboring tiles. While flat shingle tiles can generally be walked on by a careful roofer without likelihood of much damage, high profile pantiles are

A special system consisting of brass or copper wires is used to attach these tapered barrel roof tiles. Photo: NPS files.

very fragile and easily broken. By using sheets of plywood, planks, or burlap bags filled with sand to distribute weight, the professional roofer can move about the roof to fix broken tiles or flashing without causing additional damage. Another method involves hooking a ladder on the ridge to support and evenly distribute the weight of the roofer.

A broken tile should be carefully removed with a slate ripper or hacksaw blade inserted under the tile to cut the nail or nails holding it in place. If successive layers of tile are already in place covering the nailholes, it will not be possible to attach the replacement tile with nails through the holes, so an alternative method of attachment will be necessary. By nailing a tab of double thickness copper stripping on the sheathing below the tile, the new replacement tile can be slipped into position and secured in place by bending the copper strip up with a double thickness of the copper over the tile. A slate hook or "tingle" can be used in the same way. This fastening system functions in place of nails.

When replacing hard-to-match historic tile, and if matching clay tile cannot be obtained, it may be possible to relocate some of the original tiles to the more prominent locations on the roof where the tile is damaged, and insert the new replacement tile in secondary or rear locations, or other areas where it will not show, such as behind chimney stacks, parapets, and dormer windows. Even though replacement tile may initially match the original historic tile when first installed, it is likely to weather or age to a somewhat different color or hue which will become more obvious with time. Thus, care should be taken to insert new replacement tile in as inconspicuous a location as possible. New, machine-made clay tile or concrete tiles should generally not be used to patch roofs of old, handmade tile because of obvious differences in appearance.

Sources for Replacement Tiles

When restoring or repairing a clay tile roof it is always recommended that as many of the original tiles be retained and reused as possible. Sometimes, particularly when working with "pan and cover" type tile roofs, while many of the "cover" tiles may be broken and require replacement, it may be possible to reuse all or most of the "pan" tiles which are less susceptible to damage than the "cover" tiles. But, in most cases, unless matching replacements can be obtained, if more than about 30 per cent of the roofing tiles are lost, broken, or irreparably damaged, it may be necessary to replace all of the historic tiles with new matching tiles. When counting the number or percentage of missing or broken tiles that need to be replaced, it is important to order extra tiles to allow for breakage and damage during shipping and on the job site. The size of the tiles must be noted, whether they are all the same size, the same size but laid with different amounts of exposure to compensate for changes in perspective, or of graduated sizes according to horizontal rows-typical, for example, on conical or tower roofs.

Many late-19th and early-20th century tiles are marked on the back with the name of the company that made them, along with the size and the name of that particular tile shape. Some companies that were in business in the United States at the turn of the century are still producing many of the traditional tile shapes, and may be able to supply the necessary replacements. But it is important to be aware that in some cases, although the name of a particular tile pattern may have remained the same, the actual shape, size, thickness and profile may have changed slightly so that the new tile does not match the historic tile closely enough to permit it to serve as a compatible replacement for missing or broken tiles. While such tiles may be acceptable to use on a secondary or less prominent elevation, or to use when an entire tile roof needs replacement, they would not be suitable to use on an area of the roof that is highly visible.

Even if the particular tile is no longer manufactured by a company, the original molds may still exist which can be used to make new tiles to match the historic tiles if the quantity needed is sufficiently large to warrant a custom order. Other companies stock and sell salvaged tile, and keep a variety of old tiles available which can be identified and matched by the number and company imprint on the back of the tiles. Still other companies specialize entirely in custom-made reproduction of historic clay tiles for a specific preservation project.

Modern clay tiles are even more varied than historic tiles. Many shapes and styles are offered in a wide variety of colors and glazes. Several manufacturers produce special color-blended tiles, as well as tiles of different hues that are intended to be carefully mixed when installed. Yet, it is important to remember that many of these modern tiles may not be appropriate for use on historic clay tile roofs. The place of manufacture must also be taken into consideration. For instance, tiles made for use in a hot, dry climate may not be able to withstand wet weather, drastic temperature changes or freeze-thaw cycles. Some of the tile shapes, and many of the colors-especially those that are very bright and highly glazed-are completely contemporary in design, and do not represent traditional American styles, and thus, are not suitable for use on historic buildings.

Repairing a Failed Fastening System

Clay roofing tiles, as noted before, frequently outlast their fastening systems. Wood pegs rot, nails rust, and even copper nails that are not adequately driven in can pull out of the roof's structural members. Although it is unusual that all of the clay tiles on a roof need to be replaced unless matching replacements cannot be obtained, it is not uncommon for old tile roofs to be stripped of all their tiles in order to relay the tiles with new fastenings and battens. When the fastening system has failed, all the roof tiles must be removed and reattached with new corrosion-resistant fasteners. If possible, all the tiles

should be numbered and a diagram should be drawn showing the location of each tile to aid in replicating the original pattern and color variations when the tiles are relaid. Ideally, each tile should be numbered to ensure that it is reinstalled in its original location. But this may not always be feasible or practical, and it may be enough simply to group the tiles as they are removed by type and size or function—such as field tiles, custom tiles for hips, dormers and ridges, and specially cut pieces. This will help facilitate reinstallation of the tiles. If all of the tiles have to be removed, it is probably a good idea to consider installing a layer of modern roofing felt over the wood sheathing. This will add another layer of waterproofing, while providing temporary protection during reroofing.

Even if the tiles were originally attached with wooden pegs, it is generally recommended that they be rehung with corrosion-resistant, preferably heavy copper, or aluminum alloy nails or hooks. Today there are numerous nontraditional fastening systems for clay tile roofs, and many of them are patented. Roofing contractors and architects may have individual preferences, and some systems may be better suited than others to fit a particular roof shape or to meet a specific climatic or seismic requirement. Original battens or other roof members that may have deteriorated should be replaced to match the original using pressure-treated wood. Additional support may be necessary, particularly if the original roof was inadequate or poorly designed.

Replacing Flashing

Deteriorated flashing, gutters and downspouts should generally be replaced in kind to match the historic material. Copper or lead-coated copper, if appropriate to the building, or terne-coated stainless steel, is often preferred for use on historic clay tile roofs because of their durability and long lasting qualities. However, copper staining from downspouts can sometimes be a problem on light-colored masonry walls which should be taken into consideration when planning replacements to rainwater removal systems. Clay tile roofs usually have an open valley system where the tiles are separated by metal flashing at intersections of roof sections with different angles. This makes the insertion of new flashing quite easy, as only a few surrounding tiles must be removed in the process. New copper flashing that is too "bright" can be made to blend in and "mellowed" by brush-coating it with boiled linseed oil or proprietary solutions.

Inappropriate Repairs

The most important repair to avoid is replacing broken or missing roof tiles on a historic building with materials other than matching natural clay tiles. Concrete, metal or plastic tiles are generally not appropriate substitutes for clay roofing tiles. They lack the natural color variations of clay tile, and they do not have the same texture, shape, thickness or surface irregularities.

Although much concrete tile and composition tile is produced to resemble the general shape, if not the exact profile, of clay roofing tiles, concrete tile is generally too thick and also lacks the range of colors inherent in natural clay tile. Concrete tile is not a compatible substitute material to repair or replace individual historic clay tiles.

Patching a historic clay tile roof with roofing tar, caulk, asphalt, pieces of metal, or non-matching clay tiles is also inappropriate. Such treatments are visually incompatible. They also have the potential for causing physical damage. Water can collect behind these patches, thus accelerating deterioration of roof sheathing and fastening systems, and during the expansion and contraction of a freeze-thaw cycle ice buildup at patches can break surrounding tiles.

Summary and References

Clay roofing tile itself, when correctly installed, requires little or no maintenance. Often, it is the fastening system used to secure the tiles to the sheathing that fails and needs to be replaced rather than the tiles themselves. In fact, because clay tiles frequently outlasted the building structure, it was not unusual for them to be reused on another building. When the fastening system has deteriorated, or the roofing support structure has failed, clay tiles can be removed relatively easily, necessary repairs can be made, and the historic tiles can be relaid with new corrosion-resistant nails or hooks. Broken or damaged tiles should be replaced promptly to prevent further damage to neighboring tiles or to the roof structure itself.

As with any kind of historic roofing material, regular maintenance, such as cleaning gutters and downspouts, can add to the life of a tile roof. Additional preventive measures may include placing wire mesh over downspout openings or over the entire gutter to prevent debris from collecting and water from backing up. Periodic inspection of the underside of the roof from the attic after a heavy rain or ice storm for water stains may reveal leaks in their early stages which can be eliminated before they escalate into larger, more serious repair problems.

If replacement tile is required for the project, it should match the original tile as closely as possible, since a historic clay tile roof is likely to be one of the building's most significant features. Natural clay tiles have the inherent color variations, texture and color that is so important in defining the character of a historic tile roof. Thus, only traditionally shaped, clay tiles are appropriate for repairing a historic clay tile roof.

Selected Sources of Clay Roofing Tiles

Boston Valley Terra Cotta

6860 South Abbott Road

Orchard Park, NY 14127

Custom-made architectural terra cotta and clay roofing tiles

C.C.N. Clay Roof Tiles (Canteras Cerro Negro S.A.)

8280 College Parkway, Suite 204

Ft. Myers, FL 33919

Distributors of C.C.N. clay roofing tiles from Argentina

Earth/Forms of Alfred

5704 East Valley Road

Alfred Station, NY 14803

Made-to-order reproduction clay roofing tiles

Gladding, McBean and Co.

P.O. Box 97

Lincoln, CA 95648

Manufacturer since 1875 of terra cotta and clay roofing tiles, and custom reproductions

Hans Sumpf Company, Inc.

40101 Avenue 10

Madera, CA 93638

MADE-TO-ORDER Mission-style clay roofing tiles

International Roofing Products, Inc.

4929 Wilshire Blvd., Suite 750

Los Angeles, CA 90010

New clay roofing tiles, some suitable for historic buildings

London Tile Co.

65 Walnut Street

New London, OH 44851

MADE-TO-ORDER reproduction clay roofing tiles

LudowiciCeladon, Inc.

4757 Tile Plant Road

New Lexington, OH 43764

Manufacturer since 1880s of clay roofing tiles, and custom reproductions

M.C.A. (Maruhachi Ceramics of America, Inc.)

1985 Sampson Avenue

Corona, CA 91719

New clay roofing tiles, some suitable for historic buildings

The Northern Roof Tile Sales Company

P.O. Box 275

Millgrove, Ontario LOR 1V0, Canada

Traditional clay roofing tiles imported from England and South America

Raleigh, Inc.

6506 Business U.S. Route 20

P.O. Box 448

Belvidere, IL 61008-0448

Inventory of new and salvage clay roofing tiles

Supradur Manufacturing Corp.

P.O. Box 908

Rye, NY 10580

Imports Spanish ("S") clay roofing tiles from France

TileSearch

P.O. Box 580

Roanoke, TX 76262

Computerized network for new and salvage clay roofing tiles

United States Tile Company

P.O. Box 1509

909 West Railroad Street

Corona, CA 91718

New clay roofing tiles, some suitable for historic buildings

Note: Measurements in this publication are given in both the U.S. Customary System and International (Metric) System for comparative purposes. Metric conversions are, in some cases, approximate and should not be relied upon for preparing technical specifications.

Acknowledgements

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This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Technical Preservation Services (TPS), National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

September 1992

Reading List

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Labine, Clem, and Judith Siegel Lief. "The Rise of the Ornamental Roof," and "Traditional Building's Source-List of Traditional Roofing & Specialties." *Traditional Building*. Vol. 5, No. 3 (May/June 1992), pp. 3546.

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Vogel, Neal A. *Roofing Houses of Worship: Roofing Guidance for Church and Temple Administrators*. Information Series No. 59. Chicago: National Trust for Historic Preservation and Inspired Partnerships, 1992.

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1.2.2.2 Replacing clay roof tile (GSA 2016a)

U.S. General Services Administration

Replacing Loose, Broken Or Missing Clay Roof Tiles

Procedure code:

732103S

Source:

Hspg Prepared For Nps - Sero

Division:

Thermal and Moisture Protection

Section:

Clay Tiles

Last Modified:

07/19/2016

PART 1---GENERAL

1.01 SUMMARY

- A. This procedure includes guidance on replacing clay roof tiles that are loose, broken, or missing. THIS WORK SHOULD BE DONE BY AN EXPERIENCED ROOFING CONTRACTOR
- B. See 01100-07-S for general project guidelines to be reviewed along with this procedure. These guidelines cover the following sections:
 - 1. Safety Precautions
 - 2. Historic Structures Precautions
 - 3. Submittals
 - 4. Quality Assurance
 - 5. Delivery, Storage and Handling
 - 6. Project/Site Conditions
 - 7. Sequencing and Scheduling
 - 8. General Protection (Surface and Surrounding)These guidelines should be reviewed prior to performing this procedure and should be followed, when applicable, along with recommendations from the Regional Historic Preservation Officer (RHPO).
- C. For guidance on cleaning blackened clay roofing tiles, see 07321-02-R.

1.02 SYSTEM DESCRIPTION

- A. A good roofing tile should be well and evenly burnt throughout, compact, hard yet tough, free from pinholes, lumps, or specks of unslaked lime, cracks or laminations, glazed or vitrified patches on the bed or underside, must not be warped or otherwise distorted, must not have broken edges or corners, and must not have high absorbent qualities. It should also comply with ASTM standards for strength in resistance to compressive and tensile loads.

- B. A dense well-burned tile will show a clean fracture when struck sharply with the edge of a trowel; a soft tile will crumble, and an overburnt tile will splinter or crack.
- C. A clay tile roof in good condition is free of any loose, broken, or missing field tiles. All starter tiles, circular cover starter tiles, eave closure tiles, top fixture pieces, ridge covers and other "special tiles" are also in place. The roof surface is clear of all debris so that rainwater flow is not impeded.

1.03 DELIVERY, STORAGE, AND HANDLING

A. Storage and Protection:

1. Store tile roofing materials in a dry location. When stored outside, place on platforms off the ground covered with waterproof coverings which will not produce any condensation.
2. Field tile is generally shipped in pallets, and fittings in boxes. Upon receipt of the shipment, pallets and boxes should be inspected for transportation damage. Examine the tiles for color by taking 10 field tiles at random from each of the pallets. Spread them out and observe the shade variation. The range of shades is a prime reason why a tile roof is so handsome. Replace the material in its original containers for storage. Pack any existing extra stock in similar manner.
3. Power equipment is needed to deliver the tiles to the roof level. Outside storage is acceptable. Manufacturers supply instructions for stacking tiles on gable and hip roofs so that loads are properly placed and the tiles located for minimum handling by the tile applicator. Proper job organization is important to save unnecessary movement of heavy units.

1.04 PROJECT/SITE CONDITIONS

A. Environmental Requirements:

1. Do not replace or repair tile roofs in wet weather.
2. Do not remove roofing from structures when rain is forecasted or in progress.
3. If roofing is to be removed on a clear day, remove no more than can be replaced or repaired in one day.

1.05 MAINTENANCE

A. Like slate, tile requires little ongoing maintenance:

1. Clay tile requires no painting, no preservative coatings, waterproofing or fireproofing, and almost no cleaning.
2. Its very low porosity makes it extremely weather resistant.
3. Clay tiles can last many years. Thin, flat shingles can last at least 75 years. Barrel tiles have been known to last 350 years.

B. Clay tile roofs are especially susceptible to mechanical damage from walking on tiles or from fallen tree limbs or other objects. Adjacent trees and landscaping should be kept trimmed to avoid breakage, and heavy pads and ridge ladders should be used to equalize a person's weight whenever any work is to be done on the roof.

C. In addition to scheduled inspections, inspect after each exposure to unusually severe weather conditions such as strong winds, hail, or long continuous rains.

PART 2---PRODUCTS

2.01 MANUFACTURERS

A. Boston Valley Terra Cotta

<http://bostonvalley.com/>

6860 South Abbott Rd

Orchard Park, NY 14127

716-649-7490

Manufactures custom-made roof tiles and architectural terra cotta for like replacement. Specialize in restoration projects, will match color, texture, and detail. Free literature.

- B. Gladding, McBean & Co.
<https://www.gladdingmcbean.com/>
601 7th Street,
Lincoln, CA 95648
(800) 776-1133
Clay roofing tiles sold through distributors. Free roofing brochure.
- C. Ludowici Roof Tile Co
<http://www.ludowici.com/>
4757 Tile Plant Rd.
PO Box 69
New Lexington, Ohio 43764
Clay roofing tiles in traditional patterns and imitation wood are sold direct and through distributors. Free product sheets on each style.
- D. Midland Engineering
<http://www.midlandengineering.com/>
52369 S.R. 933 North
South Bend, IN 46637
574-272-0200
A major distributor for roofing products including German clay tiles and Vermont slate, sold through roofers and direct. Free brochures on all products - specify your interest.
- E. Vande Hey Raleigh Mfg., Inc.
<http://www.vrmtile.com/>
1665 Bohm Drive
Little Chute, WI 54140-2529
(920) 766-0156
Manufactures a broad line of extruded concrete roofing tiles, including a simulated slate and a Mission tile. Also has a large stock of recycled slate, concrete, and clay tiles. Free literature.

2.02 MATERIALS

- A. Salvaged or replacement clay tile to match existing (see companies listed above in Section 2.01).
- B. Nails: Use 1-3/4" copper nails, or length and holding power as recommended by the shingle manufacturer. The nails should be long enough to penetrate through the roofing material and at least 3/4 inches into the deck lumber section.
NOTE: Stainless steel tabs with stainless steel nails may be used if no danger of galvanic action exists. Direct contact with, or rainwater run-off from copper, aluminum and aluminum alloys, steel and zinc will cause stainless steel to corrode.
- C. Sealant: Clear Silicone Rubber Sealant or clear silicone sealant of highest quality.
- D. Elastic cement: Use only non-staining, non-corrosive cement as recommended by the manufacturer.

2.03 EQUIPMENT

- A. Rule or Tape
- B. Hammer
- C. Chipping Hammer
- D. Sponge
- E. Fox-tail Broom
- F. Caulking Gun
- G. Slate Ripper
- H. Drill and Glass Drill Bits

PART 3---EXECUTION

3.01 EXAMINATION

- A. Whenever possible, make inspection from ground or from above if possible. Inspect for:
1. Biological growth: Inspect for dirt build-up, biological attack, mold, fungus. Also inspect for buildup of debris and vegetation such as moss or lichen. Heavy coatings of any type form dams and stop natural drainage, resulting in various types of deteriorations. This is more apt to occur on north slopes.
 2. Individual tiles: Inspect tile ridge details and starter courses for missing, loose, broken, or out of place tiles.
 3. Wear: Excessive weathering, spalling or staining indicating weathering and age. Tile movement may be detected by unusually clean areas (lack of stains). Movement is often a sign of failed fastenings.
 4. Leaks: Inspect the underside of the roof deck from the attic to detect leaks. Flashings are the most vulnerable points. Therefore, inspect the underside carefully at all flashing points and along downhill side of any roof penetrations for evidence of leakage such as water stains.

3.02 PREPARATION

- A. Protection:
1. Establish rules for any foot traffic that may be required during repair operations.
 - a. Ideally, clay tile should not be walked on.
 - b. Lay down heavy padding and then hang a self-supporting ladder over the ridge of the roof.
 - c. Ladders to the roof should be secured at the top to prevent any sliding or fall-out from the building. The ladders should be set on an incline whereby the bottom of the ladder is approximately 25% of the height from the base of the building.
 2. Safety on the roof:
 - a. Wear rubber-soled shoes that have non-slip tread (preferably sneakers with a high top for good ankle support). Avoid wearing loose clothing.
 - b. Wear safety-belt or harness and secure to the chimney (if it's in good shape) or to a window on the opposite side of the building. Leave only enough slack so in one area, and adjust the slack as you work on other sections of the roof.
 - c. Be sure the roof is clear of debris and water. Avoid stepping on damaged or crumbling roofing materials.
 3. Steep roofs: On slopes where the roof is steeper than 4 inches rise per foot, special consideration must be given to footing and handling of materials.
 - a. Chicken ladders or cleats shall be used on the roof as required for adequate footing.
 - b. Safety lines, of an approved type should be properly worn and secured with ropes of sufficient strength. Rubber-soled shoes with grip-type bottom should be worn.
 - c. Carrying and transporting of materials should be limited to a safe amount so that balance and footing are not impaired.
 - d. Do not work on roof when wet or snow-covered.
- B. Surface Preparation:
1. Carefully examine, measure, and record existing tile patterns at edges, hips, ridges, and other special conditions. Measure the exposed dimensions and amount of lap of each type piece prior to the removal, as well as length, width, and thickness after removal.
 2. For safety of the personnel, keep the deck clear of waste material as the work proceeds. Sweep the deck clean after all loose or broken pieces have been removed.

3.03 ERECTION, INSTALLATION, APPLICATION

- A. Salvaging a Broken or Loose Tile: If the shingle tile is broken at the nail hole, salvage the tile by carefully drilling a new hole with a carbide-tip drill and nailing the tile in place with a hammer so that the tile "hangs" on the nail.
- B. Replacing Shingle Tiles:

1. Remove loose tile(s).
 - a. If tile is to be salvaged and reused, carefully remove nails using either a slate ripper, or insert a hack saw blade under the cover tile and saw through the nail.
 - b. If the tile is already broken, light blows with a hammer to further break it into pieces will facilitate removal.
2. Select a replacement tile of proper size to match existing, allowing a typical gap on each side.

NOTE: Nothing looks worse than unmatched tiles next to each other in the same course. To blend the new tiles in with the old, don't mix them on the same roof plane. Put the new ones on dormer roofs, on a clipped gable, or in shadows.
3. Slide the replacement tile into position.
4. After aligning it carefully, drill a hole right below the slot of the two covering tiles.

NOTE: Make sure you drill the hole above the double coverage; you want a hole only in the new tile, not the one below it.
5. Hold the new tile in place using a heavy gauge copper wire nail with a large flat head.

NOTE: Its length should be twice the thickness of the tiles plus one inch.
6. Drive the nail between the covering tiles.
7. Cover the nailhead (also known as "making a baby"):
 - a. Bend a strip of copper about 2" wide and 6" long into a slightly concave shape to make a cover for the exposed nailhead.
 - b. After tile is secure, slide copper strip under the tile positioned above the tile just replaced until the bottom of strip is 2" below nailhead.
 - OR-
 - c. Secure with a 1" wide copper tab (20 oz). Nail the copper tab into the deck between the butt joint of the two tiles below.
 - d. Seal the nail hole with a nonstaining, noncorrosive cement as recommended by the manufacturer and suitable for use with copper.
 - e. Lay in the new tile and bend tab up and over the end of the tile to hold it in place. The tab should be doubled at the bent end to provide extra stiffness to the tab.

C. Repair of Barrel Tile:

1. Remove loose or broken tile and select replacement (see Section 3.03 A.1. and 2. above).
2. Nail copper tabs with copper nails to supporting batten or sheathing. For nails through sheathing, seal with a nonstaining, noncorrosive cement as described in Section 3.03 B.7. above.
3. Bend tab as above to hold tile in place (see Section 3.03 B.7.c. above).

1.2.2.3 Removing and replacing clay tile (GSA 2016b)

Removing And Replacing A Clay Tile Roof

Procedure code:

732101S

Source:

Hspg Prepared For Nps - Sero

Division:

Thermal and Moisture Protection

Section:

Clay Tiles

Last Modified:

07/22/2016

PART 1---GENERAL

1.01 SUMMARY

- A. This procedure includes guidance on reroofing a clay tile roof.
- B. Clay tile roofs are extremely weather resistant due to the low porosity of the tiles. The tile itself can last indefinitely.
- C. Premature failure of a clay tile roof usually results from failure of the metal flashing and fasteners (these do not last nearly as long as the tile), poor installation and/or the use of less expensive materials.
 - 1. If nails are driven too far prohibiting the tiles from hanging on the nail, the tiles will crack during thermal movement.
 - 2. If galvanized nails are used to fasten a tile, they will often corrode in 40 years or less.
- D. It is possible to replace just the flashing if the rest of the roof is sound, but if there is widely distributed failure, reroofing may be the best option.
- E. See 01100-07-S for general project guidelines to be reviewed along with this procedure. These guidelines cover the following sections:
 - 1. Safety Precautions
 - 2. Historic Structures Precautions
 - 3. Submittals
 - 4. Quality Assurance
 - 5. Delivery, Storage and Handling
 - 6. Project/Site Conditions
 - 7. Sequencing and Scheduling
 - 8. General Protection (Surface and Surrounding)

These guidelines should be reviewed prior to performing this procedure and should be followed, when applicable, along with recommendations from the Regional Historic Preservation Officer (RHPO).

1.02 DEFINITIONS

- A. Abbey tile--is of the same type as the Spanish, but of a special design. the tiles are tapered and 16" long, the under one a true half-circle in section, the upper one being hog-backed, the combination making a handsome and sound roof. With a 3" lap, 200 tiles are required per square.

- B. English tile--a plain, flat tile that interlocks at the head and on one side.
- C. French tile--is a large interlocking shingle tile with deep grooves that give strong shadow lines and channel water.
- D. Greek pan--a tile system consisting of flat pans that are capped by a gable-shaped top piece
- E. Italian pan--a tile system consisting of a flat pan with short splayed-outward sections that act as a pan or when flipped over act as the cover between two pans.
- F. Mission tile--same thing as barrel tile. They do not interlock, but are lapped in courses. The convex pieces are laid on battens and cover the vertical joints between rows of concave tiles.
- G. Shingle tile--also called flat tiles, are individual pieces that are lapped and nailed like slate.
- H. Spanish tile--also known as S tile or Pantile, is an interlocking tile that provides a moderately undulating roof surface.
- I. Roman tile--is a tile system consisting of flat pans that are capped by barrel-shaped top pieces. Also called a pantile.

1.03 DELIVERY, STORAGE AND HANDLING

- A. Packing and Shipping:
 - 1. Field tile is generally shipped in pallets, and fittings in boxes.
- B. Acceptance at Site:
 - 1. Upon receipt of the shipment, pallets and boxes should be inspected for transportation damage.
 - 2. Examine the tiles for color by taking 10 field tiles at random from each of the pallets.
 - 3. Spread them out and observe the shade variation. The range of shades is a prime reason why a tile roof is so handsome.
 - 4. Replace the material in its original containers for storage. Pack any existing extra stock in similar manner.
- C. Storage and Protection:
 - 1. Store tile roofing materials in a dry location. When stored outside, place on platforms off the ground covered with waterproof coverings which will not produce any condensation.
 - 2. Power equipment is needed to deliver the tiles to the roof level. Outside storage is acceptable.
 - 3. Manufacturers should supply instructions for stacking tiles on gable and hip roofs so that loads are properly placed and the tiles located for minimum handling by the tile applicator. Proper job organization is important to save unnecessary movement of heavy units.
 - 4. DO NOT stack or store the roofing materials on the roof structure. Improper roof loads may cause the structure to fail.

1.04 PROJECT/SITE CONDITIONS

- A. Environmental Requirements:
 - 1. Do not apply new or repaired tile roofs in wet weather.
 - 2. Do not remove roofing from structures when rain is forecasted or in progress.
 - 3. If roofing is to be removed on a clear day, remove no more than can be replaced or repaired in one day.

1.05 MAINTENANCE

- A. Like slate, tile requires little ongoing maintenance: no painting, no preservative coatings, waterproofing or fireproofing, and almost no cleaning.
- B. Tile's very low porosity makes it extremely weather resistant. The tile itself can last many years; 75 years is claimed for a thin flat shingle, and 350 years is not unreasonable for a barrel tile.
- C. Clay tile roofs are especially susceptible to mechanical damage from walking on tiles or from fallen tree limbs or other objects. Adjacent trees and landscaping should be kept trimmed and away from roof to avoid breakage. Heavy pads and ridge ladders should be used to equalize a person's weight whenever any work is done on the roof.

PART 2---PRODUCTS

2.01 MANUFACTURERS

- A. Boston Valley Terra Cotta
www.bostonvalley.com
6860 South Abbott Rd
Orchard Park, NY 14127
716-649-7490
Manufactures custom-made roof tiles and architectural terra cotta for like replacement. Specialize in restoration projects, will match color, texture, and detail. Free literature.
- B. Gladding, McBean & Co.
www.gladdingmcbear.com
Lincoln, CA 95648
(800) 776-1133
Clay roofing tiles and terra cotta pieces sold through distributors. Free roofing brochure.
- C. Ludowici Roof Tile Co.
www.ludowici.com
4757 Tile Plant Rd.
P.O. Box 69
New Lexington, Ohio 43764
info@ludowici.com
(800) 945.8453
Terra cotta pieces and clay roofing tiles in traditional patterns and imitation wood are sold direct and through distributors. Free product sheets on each style.
- D. Midland Engineering
www.midlandengineering.com
South Bend, IN 46637
(574) 272-0200
A major distributor for roofing products including German clay tiles and Vermont slate, sold through roofers and direct. Free brochures on all products - specify your interest.
- E. Vande Hey Raleigh Mfg., Inc.
www.vrmtile.com
Little Chute, WI 54140
(920) 766-0156
Manufactures a broad line of extruded concrete roofing tiles, including a simulated slate and a Mission tile. Also has a large stock of recycled slate, concrete, and clay tiles. Free literature.
- F. Hendricks Tile Manufacturing Co., Inc.
www.hendrickstile.com
Concrete Tiles.
- G. Monier Co.
www.monier.com
Concrete tiles designed to imitate wood and terra cotta are sold through distributors. Free literature.

2.02 MATERIALS

- A. Sheathing: Must be sound with no embedded metal or nails, no rotted areas, splits, cracks, or unevenness that would cause difficulty in laying tile or create potential for breakage of the brittle tile.
- B. Flashing: Use 20-oz. copper or lead-coated copper. Use 24 oz. material if bending is not complex. Line all valleys at least 20" wide for short valleys, 24" wide for long valleys, with 1/4" edge turned over and fastened with cleats. Lap joints a minimum of 4", do not solder.

C. Nails:

1. Nails for tiles and cleat (to fasten valley metal) shall be copper of sufficient length and holding power as recommended by the tile manufacturer. Roofing nails should have barbed or deformed shanks. They should be 11- or 12-gauge and have large heads of 3/8 to 7/16 inch diameter. The nails should be long enough to hold the tile and penetrate at least 3/4 inches into the deck lumber section.

NOTE: NAILS SHOULD NOT BE DRIVEN TIGHT AGAINST THE TILE TO PREVENT DAMAGED AND ALLOW FOR MOVEMENT.

2. Plywood deck - use ring shank nail, length for slight penetration through underside of deck.
3. Board plank deck - use smooth shank nail at least 1 (one) inch length but nail must NOT penetrate underside of deck.
4. Gypsum plank and nailable concrete decks use stainless steel or silicon bronze screw shank nail of length to penetrate 1/2 to 3/4 distance of deck. Never penetrate underside of deck. (Deck material should be fresh when tiles applied as old decking may be difficult.) If deck material is excessively hard use smooth shank nail.
5. Sealant: Dow Corning Clear Silicone Rubber Sealant, or clear silicone sealant as manufactured by General Electric, or approved equal.
6. Elastic Cement: Use only non-staining, non-corrosive cement as recommended by the manufacturer.

2.03 EQUIPMENT

- A. Rule or tape
- B. Chalk line and chalk
- C. Hammer
- D. Chipping hammer
- E. Felt knife
- F. Roof jacks
- G. Mason's trowel and bucket
- H. Sponge
- I. Fox-tail broom
- J. Caulking gun
- K. Sheet metal shears
- L. Slate ripper
- M. Drill and glass drill bits
- N. Diamond blade masonry saw (water-cooled)
- O. Tile-setters blade saw with tub

PART 3---EXECUTION

3.01 EXAMINATION

- A. Whenever possible, make inspection from ground or from above if possible.
- B. Inspect for dirt build-up, biological attack, mold, fungus. Also inspect for buildup of debris and vegetation such as moss or lichen. Heavy coatings of any type form dams and stop natural drainage, resulting in various types of deteriorations.
- C. Inspect tile ridge details and starter courses for missing, loose, broken, or out of place tiles. Inspect for rust around nails (this will tell you if galvanized rather than copper nails were used), or nail pulling, excessive weathering or exposure, erosion, or staining indicating overall deterioration.
- D. Tile movement may be detected by unusually clean areas (lack of stains). Movement is often a sign of failed fastenings.
- E. Inspect the underside of the roof deck from the attic to detect leaks. Flashings are the most vulnerable points. Therefore, inspect the underside carefully at all flashing points for evidence of leakage such as water stains.
- F. In addition to scheduled inspections, inspect after each exposure to unusually severe weather conditions such as strong winds, hail, or long continuous rains.

3.02 PREPARATION

A. Protection:

1. Establish rules for any foot traffic that may be required for the maintenance of the roof. Clay tile should be walked on as little as possible.
 2. Lay down heavy padding and then hang a self-supporting ladder over the ridge of the roof.
 3. Ladders to the roof should be secured at the top to prevent any sliding or fall-out from the building. The ladders should be set on an incline whereby the bottom of the ladder is approximately 25% of the height from the base of the building.
 4. Safety on the roof:
 - a. Wear rubber-soled shoes that have non-slip tread (preferably sneakers with a high top for good ankle support). Avoid wearing loose clothing.
 - b. Wear safety-belt or harness and secure to the chimney (if it's in good shape) or to a window on the opposite side of the building. Leave only enough slack so you can work comfortably in one area, and adjust the slack as you work on other sections of the roof.
 - c. Be sure the roof is clear of debris and water. Avoid stepping on damaged or crumbling roofing materials.
- B. Steep roofs: On slopes where the roof is steeper than 4 inches rise per foot, special consideration must be given to footing and handling of materials.
- a. Chicken ladders or cleats shall be used on the roof as required for adequate footing.
 - b. Safety lines, of an approved type should be properly worn and secured with ropes of sufficient strength. Rubber-soled shoes with grip-type bottom should be worn.
 - c. Carrying and transporting of materials should be limited to a safe amount so that balance and footing are not impaired.
 - d. Do not work on roof when wet or snow-covered.
 - b. Remove only a quantity of old tiles which may be replaced on that same day. At the end of the day, use 15 pound roofing felt or polyethylene sheeting and insert under old tiles or lap junctions of new tile areas with existing and secure to make the roof watertight and windproof.

C. Surface Preparation:

1. Carefully examine, measure, and record existing tile patterns at edges, hips, ridges, and other special conditions. Measure the exposed dimensions and amount of lap of each type piece prior to removal, as well as length, width, and thickness after removal.
2. When removing existing roofing, strip tiles down to the roof deck.
3. If necessary, point up chimney joints and replace worn flashings. Clean, rebuild or replace gutters. After repairing of problem areas, clean debris from the roof surface.
4. Be careful not to damage old metal wall and vent flashings that may be used templates for cutting replacements. If metal cap flashings at the chimney and other vertical masonry wall intersections have not deteriorated, bend them up out of the way so that they may be used again. Carefully remove tiles in these areas to avoid damaging reusable base flashing.
5. For safety of the personnel, keep the deck clear of waste material as the work proceeds. Sweep the deck clean after old roofing has been removed.
6. At this point, inspect the deck to determine whether it is sound. Make whatever repairs are necessary to the existing roof framing to strengthen, level and true the deck. Replace rotted, damaged, or warped sheathing or delaminated material plywood.
7. Cover all large cracks, knot holes, loose knots and resinous areas of the deck with sheet metal patches nailed to the sheathing.
8. Remove loose or protruding nails or hammer them down.
9. Do not apply new materials over wet sheathing.

3.03 ERECTION, INSTALLATION, APPLICATION

A. Replacing Flashing only:

1. Remove tiles surrounding the valley flashing.
 - a. If tile is to be salvaged and reused, carefully remove nails using either a slate ripper, or insert a hack saw blade under the cover tile and saw through the nail.
 - b. If the tile is already broken, lightly strike the broken tile with a hammer to further break it into pieces for removal. Exert extreme care to avoid damage to any lightning protection system.
2. Replace underlayment as required. Use minimum 40 lb. asphalt impregnated roofing felt.
3. Cut and install new copper flashing and counter flashing as required. See (b)(2) below.
4. Replace tiles matching original lap and general appearance.

B. Reroofing with Clay Tile Shingles:

1. Installing Underlayment:
 - a. Cover all pitched roofs under tile with best quality asphalt impregnated roofing felt weighing not less than 40 pounds per square, 60 pounds on low slopes.
 - b. Lay parallel to ground level, lap 2" horizontally and 6" vertically.
 - c. Carry felt 6" up all vertical surfaces and 4" over gutter and valley metal.
 - d. Double layer shall be applied at eaves.
 - e. Fasten all edges with large headed galvanized nails on 6" centers.
2. Install Flashing:
 - a. Open Valleys: Line all valleys with 16 oz. copper, usually 20" in width for short valleys, 24" for long valleys (wider where necessary), with 1/4" edge turned over and fastened with cleats. Lap joints 4" (more where required), but do not solder.
 - b. Closed Valleys: Flash between each course of tiles with 16" strips of same length as tiles.
 - c. Rounded Valleys: Flash between each course of tiles with curved strips of same length as tiles. Extend strips 8" beyond tiles, 4" under tiles and at least 6" up wall.
 - d. Underlay all valley metal with full width 40 lb. felt. Where gutter metal extends upon roof, it must be brought up to a point above gutter level.
 - e. Extend flashing at dormers, chimneys and other side walls up the vertical surfaces not less than 6" and thoroughly counterflashed. Extend such flashing under tile not less than 4".
 - f. Wood saddles and returns must be lined with 16 oz. copper extending upon sloping roofs not less than 12" (more where necessary) and up vertical walls not less than 6", thoroughly counterflashed.
 - g. All counterflashing is to be plugged, pointed and made secure.
 1. Where tile and metal roofs intersect, extend metal up tile roof 12" or more.
 2. Extend gutter metal up roof to a point higher than outer edge of gutter.
3. Wood Strips:
 - a. Apply on hips and ridges 1" wood stringers of proper height to carry hip rolls and ridge. Also as required by the particular style of tile, cart strip at eaves, gable rakes and end bands, and for covers of mission tiles. See manufacturers instructions.
 - b. If roof deck is poured concrete, embed from ridge 1" x 2" beveled wood strips, extending from eave to ridge, spaced 20" on centers.
 1. Concrete must be smooth and flush with strips.
 2. Use felt weighing 50 pounds per square and fasten with lath nailed over embedded strips.
 3. Across lath apply horizontally 1" x 2" wood strips spaced to accommodate tile, and proceed as directed for a sheathed roof.

NOTE: All strips to be supplied by general contractor and applied by his crew under direction of roofer.
4. Application of Tile:
 - a. Minimum roof pitch is determined by the type of tile used. Follow the manufacturer's instructions.

- b. Roof deck shall be clean, smooth and dry when roof tiles are applied.
- c. On vertical applications or extremely steep pitches where wind currents may cause lift, set the butt of each tile in a bead of plastic cement or sealant or install copper "hurricane clips" at intervals indicated by manufacturer. Use plastic cement or sealant carefully to avoid smearing exposed tile surface.
- d. Lay tiles in straight lines parallel to ground level, lapped according to manufacturer's instructions.
- e. Fasten each tile with 1, 2 or 3 nails as required in each tile or fitting. Fasten tiles overlapping sheet metal valleys with copper wire nailed into deck beyond flashing-- do not nail through metal.
- f. For open valleys the exposure of metal at th top shall be at least 6" and shall increase at the rate of 1" for every eight feet of flow down the valley.
- g. Cement gable rakes to field tiles and fasten with nails.
- h. Cement ridges in laps and where they rest on roof tiles. Fasten with 2" copper nails.
- i. Cement hip rolls in laps and fasten with 2" copper nails.
- j. Where tiles join hip stringers, make thoroughly waterproof with plastic cement.
- k. When hip starter and closed ridge end fittings have not been specified, the voids at ends of hips and ridges shall be filled with mortar colored to nearest match of tile color.
- l. When ridge angles and hip/ridge terminals have not been specified they shall be mitered of job, nailed or wired, and set in elastic cement.

1.3 Roofing element – slate tiles

Slate is one of the most durable of all roofing materials. Installed properly, slate roofs require relatively little maintenance and will last up to 125 years or longer. Because the pattern, detailing, and craftsmanship of slate roofs are important design elements of historic buildings, they should be repaired rather than be replaced whenever possible.

The Mariners' Chapel and Quarters A (Neiley house) are the only USMMA buildings that have slate tile.

1.3.1 Immediate concerns for roofing –slate tile

The durability of a slate roof depends primarily on four factors: the physical and mineralogical properties of the slate; the way in which it is fabricated; installation techniques employed; and, regular and timely maintenance (Levine 1992).

Adequate drainage is critical component of a properly functioning slate roof system (Figure 25). For this reason, slate roofs typically have a high slope, so that water runs off as quickly as possible. Walking on a slate tile roof during inspections of the roof or other features such as chimneys or gutters or selecting the wrong type of fasteners for replacement slates could lead to cracked stone pieces tumbling off the roof. Do NOT walk on a slate roof (Figure 26).

Look for loose and missing fasteners, and flashing that exhibits deformation, wearing, corrosion, or pin holes (Figure 28). Open seams and missing flashing members are common sources of water entry. Areas to investigate include: ridge, hip, valley, roof-to-wall, drip edge, and step flashing.

Limit cleaning to removing organic debris and delaminated slate flakes from valleys, snow guards, gutters, and the area behind chimneys. Debris and moss buildup hold moisture in the slates that can split them during winter freezes (Figure 27 and Figure 29).

Figure 25. Inspection of flashing is important in maintaining slate tile roof (ERDC-CERL, 2015).

Figure 26. A reminder to not walk on the slate tiles while inspecting the roof or other features such as chimneys and gutters (ERDC-CERL, 2105).

Figure 27. Slate tile roof stained from mildew growth on Quarters A (Neiley house) (ERDC-CERL, 2015).

Figure 28. During inspections look for missing fasteners, document cracked or broken tiles, flashing, bent snow guards, and substrate/roof deck (ERDC-CERL, 2015).

Figure 29. Remove vegetation located near or on a slate tile roof (ERDC-CERL, 2015).

1.3.2 Guidelines, briefs, bulletins, and sources for roofing – slate tile

In addition to the information contained in this manual, the authors have compiled the following federal resource publications (reproduced here for convenience, with links for online access given in References) to inform managers about standards, guidelines, and procedures for understanding architecture, and caring for, preserving, and rehabilitating historic buildings with emphasis on historic slate tile roofing material (see subsections 1.3.2.1–1.3.2.5).

1.3.2.1 Repair, replacement, and maintenance of slate roofs (Levine 1992 – Preservation Brief #29)

Technical Preservation Services

National Park Service
U.S. Department of the Interior

[Home](#) > [How to Preserve](#) > [Preservation Briefs](#) > 29 Slate Roofs

Some of the web versions of the Preservation Briefs differ somewhat from the printed versions. Many illustrations are new and in color; Captions are simplified and some complex charts are omitted. To order hard copies of the Briefs, see [Printed Publications](#)®.

PRESERVATION BRIEFS

29

The Repair, Replacement and Maintenance of Historic Slate Roofs

Jeffrey S. Levine

- [History of Slate Use](#)
- [Character and Detailing](#)
- [Where Does Slate Come From?](#)
- [Deterioration of Slate and Slate Roofs](#)
- [Repairing Slate Roofs](#)
- [The Replacement of Deteriorated Roofs](#)
- [Maintenance](#)
- [Summary and References](#)
- [Reading List](#)
- [Download the PDF](#)®

Slate roof repair. Photo: Jeffrey S. Levine.

Slate is one of the most aesthetically pleasing and durable of all roofing materials. It is indicative at once of the awesome powers of nature which have formed it and the expertise and skill of the craftsman in handshaping and laying it on the roof. Installed properly, slate roofs require relatively little maintenance and will last 60 to 125 years or longer depending on the type of slate employed, roof configuration, and the geographical location of the property. Some slates have been known to last over 200 years. Found on virtually every class of structure, slate roofs are perhaps most often associated with institutional, ecclesiastical, and government buildings, where longevity is an especially important consideration in material choices. In the slate quarrying regions of the country, where supply is abundant, slate was often used on farm and agricultural buildings as well.

Because the pattern, detailing, and craftsmanship of slate roofs are important design elements of historic buildings, they should be repaired rather than replaced whenever possible. The purpose of this Preservation Brief is to assist property owners, architects, preservationists, and building managers in understanding the causes of slate roof failures and undertaking the repair and replacement of slate roofs. Details contributing to the character of historic slate roofs are described and guidance is offered on maintenance and the degree of intervention required at various levels of deterioration.

The relatively large percentage of historic buildings roofed with slate during the late nineteenth and early twentieth centuries means that many slate roofs, and the 60 to 125 year life span of the slates most commonly used, may be nearing the end of their serviceable lives at the end of the twentieth century. Too often,

Although slate replacement roofs are expensive, the superiority of materials and craftsmanship will give years of continued service. If amortized over the life

these roofs are being improperly repaired or replaced with alternative roofing materials, to the detriment of the historic integrity and appearance of the structure. Increased knowledge of the characteristics of slate and its detailing and installation on the roof can lead to more sensitive interventions in which original material is preserved and the building's historic character maintained. Every effort should be made to replace deteriorated slate roofs with new slate and to develop an effective maintenance and repair program for slate roofs that can be retained.

of the roof, the replacement cost can be very reasonable. Photo: NPS files.

History of Slate Use in the United States

Although slate quarrying was not common in the United States until the latter half of the nineteenth century, slate roofing is known to have been used prior to the Revolution. Archeological excavations at Jamestown, Virginia, have unearthed roofing slate in strata dating from 1625-1650 and 1640-1670. Slate roofs were introduced in Boston as early as 1654 and Philadelphia in 1699. Seventeenth century building ordinances of New York and Boston recommended the use of slate or tile roofs to ensure fireproof construction.

In the early years of the Colonies, nearly all roofing slate was imported from North Wales. It was not until 1785 that the first commercial slate quarry was opened in the United States, by William Docher in Peach Bottom Township, Pennsylvania. Production was limited to that which could be consumed in local markets until the middle of the nineteenth century. Knowledge of the nation's abundant stone resources was given commercial impetus at this time by several forces, including a rapidly growing population that demanded housing, advances in quarrying technology, and extension of the railroad system to previously inaccessible markets. Two additional factors helped push the slate industry to maturity: the immigration of Welsh slate workers to the United States and the introduction of architectural pattern and style books. Slate production increased dramatically in the years following the Civil War as quarries were opened in Vermont, New York, Virginia, and Lehigh and Northampton Counties, Pennsylvania. By 1876, roofing slate imports had all but dried up and the United States became a net exporter of the commodity.

The U.S. roofing slate industry reached its highest point in both quantity and value of output in the period from 1897 to 1914. In 1899, there were over 200 slate quarries operating in 13 states, Pennsylvania historically being the largest producer of all. The decline of the U.S. roofing slate industry began c.1915 and resulted from several factors, including a decline in skilled labor for both the fabrication and installation of slate and competition from substitute materials, such as asphalt shingles, which could be mass produced, transported and installed at a lower cost than slate. Only recently, with the increasing popularity of historic preservation and the recognition of the superiority of slate over other roofing materials, has slate usage begun to increase.

Architectural pattern books of the mid-19th century awakened Americans to the availability and quality of slate for roofing purposes. Drawing: Design XX, "A French Roof House," in A.J. Downing's *Victorian Cottage Residences*.

Character and Detailing of Historic Slate Roofs

During some periods of architectural history, roof design has gone far beyond the merely functional and contributed much to the character of buildings. Roofs, by their compelling forms, have defined styles and, by their decorative patterns and colors, have imparted both dignity and beauty to buildings. The architectural styles prevalent during the latter half of the nineteenth and early twentieth centuries placed strong emphasis on prominent roof lines and greatly influenced the demand for slate. Slate, laid in multicolored decorative patterns, was particularly well suited to the Mansard roofs of the Second Empire style, the steeply pitch roofs of the Gothic Revival and High Victorian Gothic styles, and the many prominent roof planes and turrets associated with the Queen Anne style. The Tudor style imitated the quaint appearance of some English slates which, because of their granular cleavage, are thick and irregular. These slates were often laid in a graduated pattern, with the largest slates at the eaves and the courses diminishing in size up the roof slope, or a textural pattern. Collegiate Gothic style buildings, found on many university campuses, were often roofed with slate laid in a graduated pattern.

The configuration, massing, and style of historic slate roofs are important design elements that should be preserved. In addition, several types of historic detailing were often employed to add visual interest to the roof essentially elevating the roof to the level of an ornamental architectural element. When repairing or replacing a slate roof, original details affecting its visual character should be retained.

Before repairing or replacing an existing slate roof, it is important to document the existing conditions and detailing of the roof using written,

visual, and physical evidence so that original features can be identified and preserved. Documentation should continue through the repair or replacement process as significant details, long obscured, are often rediscovered while carrying out these activities. Local histories, building records, old receipts and ledgers, historic photographs, sketches, and paintings, shadow lines and nail hole patterns on the roof deck, and bits of historic material left over from previous interventions (often found in eave cavities) are all useful sources of information which can be of help in piecing together the original appearance of the roof. Size, shape, color, texture, exposure, and coursing are among the most important characteristics of the original slates which should be documented and matched when repairing or replacing an historic slate roof.

This graduated slate roof is composed of large, thick slates at the eave which are reduced in size and thickness as the slating progresses to the ridge. Photo: Jeffrey S. Levine.

Historically, three types of slate roofing—**standard, textural, and graduated**—were available according to the architectural effect desired. Standard grade slate roofs were most common. These are characterized by their uniform appearance, being composed of slates approximately 3/16" (0.5cm) thick, of consistent length and width, and having a smooth cleavage surface. Thirty different standard sizes were available, ranging from 10" (25cm) x 6" to 24" x 14" (15cm x 61cm x 35cm). The slates were laid to break joints and typically had square ends and uniform color and exposure. Patterned and polychromatic roofs were created by laying standard slates of different colors and shapes on the roof in such a way as to create sunbursts, flowers, sawtooth and geometric designs, and even initials and dates. On utilitarian structures, such as barns and sheds, large gaps were sometimes left between each slate within a given course to reduce material and installation costs and provide added ventilation for the interior.

Textural slate roofs incorporate slates of different thicknesses, uneven tails, and a rougher texture than standard slates. Textural slate roofs are perhaps most often associated with Tudor style buildings where slates of different colors are used to enhance the effect.

Graduated slate roofs were frequently installed on large institutional and ecclesiastical structures. The slates were graduated according to thickness, size, and exposure, the thickest and largest slates being laid at the eaves and the thinnest and smallest at the ridge. Pleasing architectural effects were achieved by blending sizes and colors.

Detailing at the hips, ridges and valleys provided added opportunity to ornament a slate roof. Hips and ridges can be fashioned out of slate according to various traditional schemes whereby the slates are cut and overlapped to produce a watertight joint of the desired artistic effect. Traditional slate ridge details are the saddle ridge, strip saddle ridge and comb ridge, and for hips, the saddle hip, mitered hip Boston hip, and fantail hip. A more linear effect was achieved by covering the ridges and hips with flashing called "cresting" or "ridge roll" formed out of sheet metal, terra cotta, or even slate. Snow guards, snow boards, and various types of gutter and rake treatments also contributed to the character of historic slate roofs.

Valleys are formed at the internal angle of two roofing slopes. Flashing is often placed under the slate to increase moisture protection at this vulnerable joint. Photo: Jeffrey S. Levine.

Two types of valleys were traditionally employed, the **open valley** and the **closed valley**. The open valley is lined with metal over which slates lap only at the sides. Closed valleys are covered with slate and have either a continuous metal lining or metal flashing built in with each course. Open valleys are easier to install and maintain, and are generally more watertight than closed valleys. Round valleys are a type of closed valley with a concave rather than Vshaped section. Given the broader sweep of the round valley, it was not uncommon for roofers to interweave asphalt saturated felts rather than copper sheet in the coursing in order to cut costs.

Although principally associated with graduated and textural slate roofs, round valleys were infrequently employed due to the difficulty and expense of their installation.

Common types of sheathing used include **wood boards, wood battens**, and, for fireproof construction on institutional and government buildings, **concrete or steel**. Solid wood sheathing was typically constructed of tongue and groove, square edged, or shiplapped pine boards of 1" (2.5 cm) or 1-1/4" (3 cm) nominal thickness. Boards from 6" (15 cm) to 8" (20 cm) wide and tongue and groove boards were generally preferred as they were less likely to warp and curl.

Wood battens, or open wood sheathing, consisted of wood strips, measuring from 2" (5 cm) to 3" (7.5 cm) in width, nailed to the roof rafters. Spacing of the battens depended on the length of the slate and equaled the exposure. Slates were nailed to the batten that transected its midsection. The upper end of the slate rested at least 1/2" (1.25 cm) on the batten next above. Open wood sheathing was employed primarily on utilitarian, farm, and agricultural structures in the North and on residential buildings in the South where the insulating value of solid wood sheathing was not a strict requirement. To help keep out dust and wind driven rain on residential buildings, mortar was often placed along the top and bottom edge of each batten, a practice sometimes referred to as torching.

Steel angles substituted for the wood battens in fireproof construction. The slates were secured using wire wrapped around the steel angle, where it was twisted off tight. Alternately, any of a variety of special fasteners patented over the years could have been used to attach the slate to the steel angle. On roofs with concrete decks, slates were typically nailed to wood nailing strips embedded in the concrete.

Beginning in the late nineteenth century, asphalt saturated roofing felt was installed atop solid wood sheathing. The felt provided a temporary, watertight roof until the slate could be installed atop it. Felt also served to cushion the slates, exclude wind driven rain and dust, and ease slight unevenness between the sheathing boards.

Slate was typically laid in horizontal courses starting at the eaves with a standard headlap of 3" (7.5 cm) (Figure 10). Headlap was generally reduced to 2" (5 cm) on Mansard roofs and on particularly steep slopes with more than 20" (50 cm) of rise per 12" (30 cm) of run. Conversely, headlap was increased to 4" (10 cm) or more on low pitched roofs with a rise of 8" (20 cm) or less per 12" (30 cm) of horizontal run. The minimum roof slope necessary for a slate roof was 4" (10 cm) of rise per 12" (30 cm) of run.

Eave details include snow guards, snow boards, and gutter treatments. Snow guards are generally used in areas where the ice and snow accumulate to avoid dangerous slides from the roof. Photo: Jeffrey S. Levine.

Where Does Slate Come From?

Slate is a fine grained, crystalline rock derived from sediments of clay and fine silt which were deposited on ancient sea bottoms. Superimposed materials gradually consolidated the sedimentary particles into bedded deposits of shale. Mountain building forces subsequently folded, crumpled, and compressed the shale. At the same time, intense heat and pressure changed the original clays into new minerals such as mica, chlorite, and quartz. By such mechanical and chemical processes bedded clays were transformed, or metamorphosed, into slate, whole geologic ages being consumed in the process. Slates vary in composition, structure, and durability because the degree to which their determinant minerals have been altered is neither uniform nor consistent.

The adaptation of slate for roofing purposes is inextricably linked to its genesis. The manufacturing processes of nature have endowed slate with certain commercially amenable properties which have had a profound influence on the methods by which slate is quarried and fabricated, as well as its suitability for use as a roofing tile.

Slate roofing tiles are still manufactured by hand using traditional methods in a five step process: **cutting, sculping, splitting, trimming, and hole punching**. In the manufacturing process, large, irregular blocks taken from the quarry are first cut with a saw across the grain in sections slightly longer than the length of the finished roofing slate. The blocks are next sculped, or split along the grain of the slate, to widths slightly larger than the widths of finished slates. Sculping is generally accomplished with a mallet and a broad faced chisel, although some types of slate must be cut along their grain. In the splitting area, the slightly oversized blocks are split along their cleavage planes to the desired shingle thickness. The splitter's tools consist of a wooden mallet and two splitting chisels used for prying the block into halves and repeating this process until the desired thinness is reached. The last two steps involve trimming the tile to the desired size and then punching two nail holes toward the top of the slate using a formula based on the size and exposure of the slate.

These traditional slater's tools are used to cut and trim, hammer, measure, and rip out nails. Photo: Jeffrey S. Levine.

Minerals, the building blocks of rocks, through their characteristic crystalline structures define the physical properties of the rocks which they compose. Slate consists of minerals that are stable and resistant to weathering and is, therefore, generally of high strength, low porosity, and low absorption. The low porosity and low absorption of slate mitigate the deleterious action of frost on the stone and make it well adapted for roofing purposes. The two most important structural properties of slate are cleavage and grain.

The metamorphic processes of geologic change necessary to produce slate are dependent upon movements in the earth's crust and the heat and pressure generated thereby. For this reason, slate is found only in certain mountainous regions. The most economically important slate deposits in this country lie in the Mid-Atlantic and Northeastern states transversed by or bordering on the Appalachian Mountain chain. Variations in local chemistry and conditions under which the slate was formed have produced a wide range of colors and qualities and ultimately determine the character of the slate found in these areas.

Slate is available in a variety of colors. The most common are **grey, blue-grey, black, various shades of green, deep purple, brick red, and mottled varieties**. The presence of carbonaceous matter, derived from the decay of marine

organisms on ancient sea floors, gives rise to the black colored slates. Compounds of iron generate the red, purple, and green colored slates.

Generally, the slates of Maine, Virginia, and the Peach Bottom district of York County, Pennsylvania are deep blue-black in color. Those of Virginia have a distinctive lustrous appearance as well due to their high mica content. The slates of Lehigh and Northampton Counties, Pennsylvania, are grayish-black in color. Green, red, purple, and mottled slates derive from the New York-Vermont district. The slate producing region of New York, which centers around Granville and Middle Granville, is particularly important because it contains one of the few commercial deposits of red slate in the world.

Slates are also classified as fading or unfading according to their color stability. Fading slates change to new shades or may streak within a short time after exposure to the atmosphere due to the presence of finegrained disseminated pyrite. For example, the "weathering green" or "seagreen" slates of New York and Vermont are grayish green when freshly quarried. Upon exposure, from 20% to 60% of the slates typically weather to soft tones of orange-brown, buff, and gray while the others retain their original shade. Slates designated as unfading maintain their original colors for many years.

Color permanence generally provides no indication of the durability of slate. Rather, time has shown that the Vermont and New York slates will last about 125 years; Buckingham Virginia slates 175 years or more; and Pennsylvania SoftVein slates in excess of 60 years; Pennsylvania HardVein slates and Peach Bottom slates, neither of which is still quarried, had life spans of roughly 100 and at least 200 years respectively. The life spans provided should be used only as a general guide in determining whether or not an existing slate roof is nearing the end of its serviceable life.

Ribbons are visible as bands on the cleavage face of slate and represent geologic periods during which greater amounts of carbonaceous matter, calcite, or coarse quartz particles were present in the sediment from which the slate was formed. Ribbons typically weather more and were most common in Pennsylvania slate quarries. As they were not as durable as clear slates, ribbon slate is no longer manufactured for roofing purposes. Mottled grey slates from Vermont are the closest match for Pennsylvania ribbon slate available today.

In recent years, slates from China, Africa, Spain and other countries have begun to be imported into the United States, primarily for distribution on the West Coast. The use of imported slates should probably be limited to new construction since their colors and textures often do not match those of U.S. slate.

Deterioration of Slate and Slate Roofs

The white blotches on these Pennsylvania Soft-Vein slates indicate areas where gypsum is leaching out onto the surfaces of the slates. Photo: Jeffrey S. Levine.

The durability of a slate roof depends primarily on four factors: the physical and mineralogical properties of the slate; the way in which it is fabricated; installation techniques employed; and, regular and timely maintenance. The first three of these factors are examined below. The maintenance and repair of slate roofs are discussed in later sections of this Brief.

The natural weathering of roofing slate manifests itself as a slow process of chipping and scaling along the cleavage planes. Paper thin laminations flake off the surface of the slate and the slate becomes soft and spongy as the inner layers begin to come apart, or delaminate. The nature of the sound given off by a slate when tapped with one's knuckles or slating hammer is a fair indication of its condition. Highgrade slate, when poised upon the fingertips and struck, will emit a clear, solid sound. Severely weathered slates are much less sonorous, and give off a dull thud when tapped.

The weathering of slate is chiefly due to mineral impurities (primarily calcite and iron sulfides) in the slate which, in concert with alternating wet/dry and hot/cold cycles, react to form gypsum. Because gypsum molecules take up about twice as much volume as calcite molecules, internal stresses result from the reaction, causing the slate to delaminate. This type of deterioration is as prominent on the underside of the roof as on the exposed surface due to the leaching and subsequent concentration of gypsum in this area. Consequently, deteriorated roofing slates typically cannot be flipped over and reused.

The chemical and physical changes which accompany slate weathering cause an increase in absorption and a decrease in both strength and toughness. The tendency of old, weathered slates to absorb and hold moisture can lead to rot in underlying areas of wood sheathing. Such rot can go undetected for long periods of time since, often, there is no accompanying leak. Due to their loss of strength, weathered slates are more prone to breakage, loss of corners, and cracking.

Slates with low calcite content tend to weather slowly. Dense slates, with low porosity, likewise decay slower than slates with equal calcite, but with a greater

Paper thin lamination can be seen flaking off this weathered, 120 year piece of Pennsylvania Hard-Vein slate. Photo: Jeffrey S. Levine.

porosity. The pitch of a roof can also affect its longevity. The steeper the pitch, the longer the slate can be expected to last as water will run off faster and will be less likely to be drawn under the slates by capillary action or driven under by wind forces. Spires and the steep slopes of Mansard roofs often retain their original slate long after other portions of the roof have been replaced. Areas of a roof subject to concentrated water flows and ice damming, such as along eaves and valleys, also tend to deteriorate more rapidly than other areas of the roof.

Mechanical agents, such as thermal expansion and contraction and the action of frost, are subordinate in the weathering of slate, coming into play only after the slate has been materially altered from its original state by the chemical

transformation of calcite to gypsum. The more rapid deterioration of slates found on roof slopes with the most severe exposure to the sun, wind, and rain (typically, but not always, a southern exposure) may be attributable to the combined result of the deleterious effects of impurities in the slate and mechanical agents. Atmospheric acids produce only negligible deterioration in roofing slate.

It is difficult to assess the procedures by which a piece of slate has been fabricated without visiting the quarry and observing the process first hand. The location and size of nail holes, grain orientation, the condition of corners, and the number of broken pieces are all things which may be observed in a shipment of slate to judge the quality of its fabrication. Nail holes should be clean and with a shallow countersink on the face of the slate for the nail head; grain oriented along the length of the slate; and, corners left whole. An allowance for 10% breakage in shipment is typically provided for by the quarry.

Installation problems often involve the improper nailing and lapping of slates. The nailing of slates differs from that of other roofing materials. Slate nails should not be driven tight as is the case with asphalt and wood shingles. Rather, they should be set such that the slate is permitted to hang freely on the nail shank. Nails driven too far will crack the slate and those left projecting will puncture the overlying slate. Nail heads left exposed accelerate roof deterioration by providing a point for water entry. Non-ferrous slater's nails, such as solid copper or stainless steel, should always be used since plain steel and galvanized nails will usually rust out long before the slate itself begins to deteriorate. The rusting of nineteenth century cut nails is a common cause of slate loss on historic roofs.

When joints are improperly broken (i.e., when slates lap the joints in the course below by less than 3" [7.5 cm]), it is possible for water to pass between the joints, through the nail holes and ultimately to the underlying felt, where it will cause deterioration and leaks to develop. Insufficient headlap can also result in leaks as water entering the joints between slates may have a greater tendency to be wind blown beyond the heads of the slates in the course below.

Occasionally, individual slates are damaged. This may be caused by falling tree limbs, ice dams in gutters, valleys, and chimney crickets, the weight of a workman walking on the roof, or a naturally occurring fault in the slate unit. Whatever the form of damage, if it is caught soon enough, the roof can usually be repaired or selectively replaced and deterioration mitigated.

The ability to lay slate properly so as to produce a watertight and aesthetically pleasing roof requires training, much practice, and the right tools. The installation and repair of slate roofs should be entrusted only to experienced slaters.

Repairing Slate Roofs

Broken, cracked, and missing slates should be repaired promptly by an experienced slater in order to prevent water damage to interior finishes, accelerated deterioration of the roof and roof sheathing, and possible structural degradation to framing members.

The damaged slate is first removed by cutting or pulling out its nails with a ripper. If steel cut nails, rather than copper nails, were used in laying the roof, adjacent slates may be inadvertently damaged or displaced in the ripping process, and these, too, will have to be repaired. If the slate does not slide out by itself, the pointed end of the slate hammer can be punched into the slate and the slate dragged out. A new slate, or salvaged slate, which should match the size, shape, texture, and weathered color of the old slate, is then slid into place and held in position by one nail inserted through the vertical joint between the slates in the course above and approximately one inch below the tail of the slate two courses above.

To prevent water penetration through the newly created nail hole, a piece of copper with a friction fit, measuring roughly 3" (7.5 cm) in width and 8" (20 cm)

View of these slates laid on open sheathing shows that delamination and flaking are just as bad or worse on the underside of slates as on the exposed surface. This is why most slates cannot be flipped over for reuse. Photo: Jeffrey S. Levine.

After removing the deteriorated slate and sliding the new slate into place, it is secured with a copper nail. A copper bib (shown here) is formed to protect the newly created nail hole. Finally, a slate hammer is used to push the bib in place over the nail head. Photo: Jeffrey S. Levine.

in length, is slid lengthwise under the joint between the two slates located directly above the new slate and over the nail. Alternate methods for securing the replacement slate include the use of metal hooks, clips, and straps that are bent over the tail end of the slate. The application of roofing mastic or sealants to damaged slates should not be considered a viable repair alternative because these materials, though effective at first, will eventually harden and crack, thereby allowing water to enter. Mastic also makes future repairs more difficult to execute, is unsightly, and, when applied to metal flashings, accelerates their corrosion.

When two or more broken slates lie adjacent to each other in the same course, or when replacing leaky valley flashings, it is best to form pyramids (i.e., to remove a diminishing number of slates from higher courses) to keep the number of bibs required to a minimum. When reinstalling the slates, only the top slate in each pyramid will need a bib. Slates along the sides of the pyramid will receive two nails, one above the other, along the upper part of its exposed edge.

When many slates must be removed to effect a repair, the sheathing should be checked for rotted areas and projecting nails. Plywood is generally not a good replacement material for deteriorated wood sheathing due to the relative difficulty of driving a nail through it (the bounce produced can loosen adjacent slates). Instead, new wood boards of similar width and thickness to those being replaced should be used. Because the nominal thickness of today's dimension lumber is slightly thinner than that produced in the past, it may be necessary to shim the new wood boards so that they lie flush with the top surface of adjacent existing sheathing boards. Pressure treated lumber is not recommended due to its tendency to shrink. This can cause the slates to crack and become displaced.

To permit proper re-laying of the slate, the new roof sheathing must be of smooth and solid construction. At least two nails should be placed through the new boards at every rafter and joints between the ends of the boards should occur over rafters. Insufficient nailing will cause the boards to be springy, making nailing of the slates difficult and causing adjacent slates to loosen in the process. Unevenness in the sheathing will show in the finished roof surface and may cause premature cracking of the slate. Roof sheathing in valleys and along hips, ridges, and eaves may be covered with waterproof membrane underlayment rather than roofing felt for added protection against leakage.

In emergency situations, such as when severe hurricanes or tornadoes blow numerous slates off the roof, a temporary roof covering should be installed immediately after the storm to prevent further water damage to the interior of the building and to permit the drying out process to begin. Heavy gauge plastic and vinyl tarpaulins are often used for this purpose, though they are difficult to secure in place and can be blown off in high winds. Roll roofing, carefully stitched in to areas of the remaining roof, is a somewhat more functional solution that will allow sufficient time to document the existing roof conditions, plan repairs, and order materials.

Slate roof repair is viable for localized problems and damaged roofs with reasonably long serviceable lives remaining. If 20% or more of the slates on a roof or roof slope are broken, cracked, missing, or sliding out of position, it is usually less expensive to replace the roof than to execute individual repairs. This is especially true of older roofs nearing the end of their serviceable lives because even the most experienced slater will likely damage additional slates while attempting repairs. Depending on the age of the slate, its expected serviceable life, and the cause(s) of deterioration, it may or may not be cost effective to salvage slates. Where deteriorated nails or flashings are the cause of the roof failure, salvage of at least some slates should be possible for use in repairs. When salvaging slates, each must be sounded to discover cracks and faults and the degree to which it has weathered. It is usually wise to salvage slates when only a portion of the roof is to be replaced. In this way, the salvaged slates may be used for future repairs to the remaining sections of the roof.

After a hurricane or other natural disaster, it may be necessary to stabilize a roof temporarily until materials can be obtained and a qualified roofing contractor hired. Significant slate roofs should not be stripped off and replaced with asphalt shingles. Photo: NPS files.

The Replacement of Deteriorated Roofs

Historic slate roofs should be repaired rather than replaced whenever possible. Before replacing a slate roof, check for isolated damage, corroded and worn flashings, leaky gutters, poor ventilation in the attic, and other possible sources of moisture. All too often slate roofs are mistakenly replaced when, in fact, they could have been effectively repaired. Deciding whether an historic slate roof should be repaired or replaced can be difficult and each roof must be judged separately.

If repair is not possible and a new slate roof must be installed, it is important to remember that more than just the replacement of the slate is involved. The old slate should be removed to prevent overloading of the roof timbers. Stripping should be done in sections, with felt installed, to avoid exposing the entire subroof to the weather. In the process, rotted wood sheathing should be replaced and the roof timbers checked for signs of stress including deflection, cracking, and twisting. If such conditions are found, a structural engineer experienced in working with older buildings should be consulted. Other repairs, such as chimney repointing, which may require access to the roof should be completed before the new roof is put on.

Drawings and specifications for a new slate roof should be prepared by a restoration architect, especially if the project is going to be competitively bid or if the roof is particularly complex. Standard specifications, like those published in 1926 by the National Slate Association may be used as a basis for developing specifications appropriate for a particular project. The specifications and drawings should contain all the information necessary to replicate the original appearance of the roof as closely as possible. Certain changes may have to be accepted, however, since several types of slate once prominent in this country, such as ribbon slate, are no longer quarried. It is wise to anticipate the replacement of older roofs so that proper planning can be undertaken and financial resources set aside, thereby, reducing the likelihood of rash last minute decisions.

Prior to a replacing a roof, historical documentation is gathered (such as photo documentation) to determine the roof configuration. Photo: NPS files.

Roofing slate is sold by the square in the United States. One square is enough to cover 100 square feet (13.3 square meters) of plain roof surface when laid with a standard headlap of 3" (7.5cm). When ordering slate, considerable lead time should be allowed as delivery may take anywhere from 4 to 12 weeks and even as long as 1 year for special orders. Orders for random widths of a particular slate can generally be filled more quickly than orders for fixed widths. Once on site, slates should be stored on edge, under cover on pallets.

A roof and its associated flashings, gutters, and downspouts function as a system to shed water. Material choices should be made with this in mind. For example, use a single type of metal for all flashings and the rainwater conductor system to avoid galvanic action. Choose materials with life spans comparable to that of the slate, such as nonferrous nails. Use heavier gauge flashings or sacrificial flashings in areas that are difficult to access or subject to concentrated water flows.

Flashings are the weakest point in any roof. Given the permanence of slate, it is poor economy to use anything but the most durable of metals and the best workmanship for installing flashings. Copper is one of the best flashing materials, and along with terne, is most often associated with historic slate roofs. Copper is extremely durable, easily worked and soldered, and requires little maintenance. Sixteen ounce copper sheet is the minimum weight recommended for flashings. Lighter weights will not endure the erosive action of dust and grit carried over the roof by rain water. Heavier weight, 20 oz. (565 grams) or 24 oz. (680 grams), copper should be used in gutters, valleys, and areas with limited accessibility. Lead coated copper has properties similar to copper and is even more durable due to its additional lead coating. Lead coated copper is often used in restoration work.

Terne is a less desirable flashing material since it must be painted periodically. Terne coated stainless steel (TCS) is a modernday substitute for terne. Although more difficult to work than terne, TCS will not corrode if left unpainted; a great advantage, especially in areas that are difficult to access.

Once a metal is chosen, it is important to use it throughout for all flashings, gutters, downspouts, and metal roofs. Mixing of dissimilar metals can lead to rapid corrosion of the more electronegative metal by galvanic action. Where flashings turn up a vertical surface, they should be covered with a cap flashing. Slates which overlap metal flashings should be nailed in such a manner as to avoid puncturing the metal. This may be accomplished by punching a second hole about 2" (5cm) above the existing hole on the side of the slate not overlapping the metal flashing. It is important that holes be punched from the back side of the slate. In this way, a shallow countersink is created on the face of the slate in which the head of the nail may sit.

The use of artificial, mineral fiber slate is not recommended for restoration work since its rigid appearance is that of a manmade material and not one of nature. Artificial slates may also have a tendency to fade over time. And, although artificial slate costs less than natural slate, the total initial cost of an artificial slate roof is only marginally less than a natural slate roof. This is because all the other costs associated with replacing a slate roof, such as the cost of labor, flashings, and tearing off the old roof, are equal in both cases. Over the long term, natural slate tends to be a better investment because several artificial slate roofs will have to be installed during the life span of one natural slate roof.

Clear roof expanses can be covered by an experienced slater and one helper at the rate of about two to three squares per day. More complex roofs and the presence of chimneys, dormers, and valleys can bring this rate down to below

one square per day. One square per day is a good average rate to use in figuring how long a job will take to complete. This takes into account the installation of flashings and gutters and the setup and breakdown of scaffolding. Tear-off of the existing roof will require additional time.

Repair/Replacement Guideline

The following guideline is provided to assist in the repair/replace decision making process:

1. Consider the age and condition of the roof versus its expected serviceable life given the type of slate employed.
2. Calculate the number of damaged and missing slates. Is the number less than about 20%? Is the roof generally in good condition? If so, the roof should be evaluated for repair rather than replacement. Also, keep in mind that the older a roof becomes, the more maintenance it will likely require.
3. Determine if there are active leaks and what their source may be. Do not assume the slates are leaking. Gutters, valleys and flashings are more likely candidates. "False leaks" can be caused by moisture condensation in the attic due to improper ventilation.
4. Check the roof rafters and sheathing for moisture stains. Poke an awl into the wood to determine if it is rotted. Remember that very old, delaminating slates will hold moisture and cause adjacent wood members to deteriorate even if there are no apparent leaks.
5. Are many slates sliding out of position? If so, it may be that ferrous metal fasteners were used and that these are corroding, while the slates are still in good condition. Salvage the slates and relay them on the roof. If the slates have worn around the nails holes, it may be necessary to punch new holes before relaying them.
6. Consider the condition of the roof's flashings. Because slate is so durable, metal flashings often wear out before the slate does. Examine the flashings carefully. Even the smallest pinhole can permit large quantities of water to enter the building. Is the deterioration of the slate uniform? Often this is not the case. It may be that only one slope needs replacement and the other slopes can be repaired. In this way, the cost of replacement can be spread over many years.
7. Press down hard on the slates with your hand. Sound slates will be unaffected by the pressure. Deteriorated slates will feel brittle and will crack. Tap on slates that have fallen out or been removed. A full, deep sound indicates a slate in good condition, while a dull thud suggests a slate in poor condition.
8. Are new slates readily available? Even if replacement is determined to be necessary, the existing roof may have to be repaired to allow time for documentation and the ordering of appropriate replacement slates.

Note: measurements in this publication are given in both U.S. Customary System and International (Metric) System for comparative purposes. Metric conversions are in some cases approximate and should not be relied upon in preparing technical specifications.

Maintenance

Given the relatively high initial cost of installing a new slate roof, it pays to inspect its overall condition annually and after several storms. For safety reasons, it is recommended that building owners and maintenance personnel carry out roof surveys from the ground using binoculars or from a cherry picker. Cracked, broken, misaligned, and missing slates and the degree to which delamination has occurred should be noted, along with failed flashings (pin holes, open seams, loose and misaligned elements, etc.) and broken or clogged downspouts. A roof plan or sketch and a camera can aid in recording problems and discussing them with contractors. In the attic, wood rafters and sheathing should be checked for water stains and rot. Critical areas are typically near the roof plate and at the intersection of roof planes, such as at valleys and hips. Regular maintenance should include cleaning gutters at least twice during the fall and once in early spring, and replacing damaged slates promptly. Every five to seven years inspections should be conducted by professionals experienced in working with slate and steep slopes. Good record keeping, in the form of a log book and the systematic filing of all bills and samples, can help in piecing together a roof's repair history and is an important part of maintenance.

As part of regular maintenance, an attempt should be made to keep foot traffic off the roof. If maintenance personnel, chimney sweeps, painters, or others must walk on the roof, it is recommended that ladders be hooked over the ridge and

Roofing felt is being installed over the decking; a rubberized membrane is used selectively at the eaves and under some flashing. Photo: NPS files.

that the workmen walk on the ladders to better distribute their weight. If slates are to be walked on, it is best to wear soft soled shoes and to step on the lowermiddle of the exposed portion of the slate unit.

Summary and References

Slate roofs are a critical design feature of many historic buildings that cannot be duplicated using substitute materials. Slate roofs can, and should be, maintained and repaired to effectively extend their serviceable lives. When replacement is necessary, details contributing to the appearance of the roof should be retained. High quality slate is still available from reputable quarries and, while a significant investment, can be a cost effective solution over the long term.

Acknowledgements

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This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Technical Preservation Services (TPS), National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments to a broad public.

September 1992

Reading List

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1.3.2.2 Minor repairs to slate roofs (GSA 2017b)

Minor Repairs To Slate Roofs

Procedure code:

731501S

Source:

Hsr - Federal Bldg/P.O., Wash, Dc - Bldg Conservation Tech

Division:

Thermal and Moisture Protection

Section:

Slate Shingles

Last Modified:

07/03/2017

PART I---GENERAL

1.01 SUMMARY

- A. This procedure includes guidance on replacing individual cracked or broken slate shingles, and re-hanging loose shingles.
NOTE: THIS WORK SHOULD BE PERFORMED BY AN EXPERIENCED ROOFING CONTRACTOR WITH EXPERTISE IN WORKING WITH SLATE.
- B. If 20% of roof requires repair, complete replacement should be considered.
- C. See also procedure 07315-02-S for general information concerning slate. See 07315-04-S for supplemental guidelines for repairing and replacing slate roofs.
- D. See 01100-07-S for general project guidelines to be reviewed along with this procedure. These guidelines cover the following sections:
 - 1. Safety Precautions
 - 2. Historic Structures Precautions
 - 3. Submittals
 - 4. Quality Assurance
 - 5. Delivery, Storage and Handling
 - 6. Project/Site Conditions
 - 7. Sequencing and Scheduling
 - 8. General Protection (Surface and Surrounding)

These guidelines should be reviewed prior to performing this procedure and should be followed, when applicable, along with recommendations from the Regional Historic Preservation Officer (RHPO).

1.02 REFERENCES

- A. American Society for Testing and Materials (ASTM) www.astm.org

1.03 SUBMITTALS

- A. Samples:
 - 1. Submit nails proposed for use to the RHPO for approval.
 - 2. Submit slate shingles proposed for use to the RHPO for approval.

1.04 PROJECT/SITE CONDITIONS

- A. Environmental Requirements:
 - 1. Maintain the weathertightness of the roof during repair operations.
 - 2. Protect adjacent shingles from damage during examination and repair of shingles. DO NOT walk on slate shingles.

PART 2---PRODUCTS

2.01 MATERIALS

- A. Slate Shingles:
 - 1. Provide new slate shingles hand-cleft from sound stone, meeting Federal Specification, 55-5-451, Grade A, maximum water absorption (ASTM C121) of .1%. Color and appearance shall match existing as closely as possible.
 - 2. Thickness: 3/16 inch nominal thickness, or to match existing; thickness to be within the tolerances of minus 0 inches and plus 1/8 inch.
 - 3. Shingle Size: To match existing.
- B. Nails: Provide large head hard copper wire nails
 - 1. Wood deck: (Length of nail equals twice the thickness of the slate plus 1".) 3d nails for standard slates up to 18 inches long; 4d nails for extra long slates; 6d nails for ridge and hip slates.
 - 2. Concrete Deck: 1-1/2 inch length, 10 gauge suitable for driving into nailing concrete.
- C. Roofer's Cement: ASTM D-282. Non-staining and non-corrosive.
- D. Copper Sheetting: Provide 16 ounce soft, rolled copper to match existing flashing (i.e. lead-coated copper, stainless steel, etc.)

2.02 EQUIPMENT

- A. Slate cutter
- B. Slate ripper
- C. Slate hammer

PART 3---EXECUTION

3.01 EXAMINATION

- A. Inspect the conditions under which the work is to be carried out. Inspect the condition of the roof deck to which the slate shingles will be applied. Report any unsatisfactory conditions to the RHPO. DO NOT walk on slates during examination.

3.02 ERECTION, INSTALLATION, APPLICATION

- A. Removal of Existing Loose or Damaged Shingles:
1. Using a slate ripper, carefully remove any loose, cracked and broken slate shingles from the roof, taking care not to break those that are only loose. Remove any remaining small pieces of slate.
 2. Store removed full slate shingles for reuse, to the extent desired by the Contracting Officer on the job site where directed.
- B. Acceptance of Roof Deck: Inspect roof deck for flaws which could prevent the proper installation of the new slates. Report any defects to the Contracting Officer in writing.
- C. Replacement of Slate Roofing (method one):
1. Slide in new slates to replace broken, missing or cracked slates. Reuse existing full slates wherever possible.
 2. Line up slate in its course making sure any pre-punched holes are covered by the slates above.
 3. Neatly fit the slate around all pipes, vents and other penetrations.
 4. Mark location of new nail hole through the vertical joint of slates in the overlying course, approximately 5 inches from the head of the overlaying slate or 2 inches below the tail of the second course of slate above.
 5. Punch or drill new hole and nail slate into position using copper nails as specified. Cut nail head as required to fit between slates in overlaying courses. Nail shall not be driven so far as to put strain on the slates; slate should hang from the nail.
 6. Slates overlapping sheet metal shall have the nails so placed as to avoid puncturing the sheet metal.
 7. Cut a piece of copper approximately 3 inches wide by 8 inches long. Cut edge slightly to help with friction fit. Bend piece slightly lengthwise to make it concave or convex which will insure its remaining tightly in place. Insert the piece of copper lengthwise over the slating nail and under the course above so that it extends a approximately two inches under the succeeding course and completely covers the new nail hole.
- D. Alternative method: THIS METHOD SHOULD NOT BE USED IN NORTHERN CLIMATES WHERE SNOW AND ICE COULD CAUSE TAB TO UNBEND.
1. Remove damaged slate as directed above.
 2. Cut a copper tab approximately 1 inch wide by 8 inches long. Double over bottom 4 inches and bend up to form an "L" shape.
 3. Nail top of tab to roof deck using a copper nail. Daub nail head with non-corrosive, non-staining elastic roofing cement.
 4. Slide replacement slate into place so that bottom of slate rests on copper tab. Bend doubled portion of tab up and over the bottom of the slate to hold it in place. Approximately 1 inch of the tab should be visible.

3.03 ADJUSTING/CLEANING

- A. Clean work areas of all debris as roofing work progresses. At conclusion of job, clean up loose slates, containers and nails and leave job site neat and clean.

1.3.2.3 Removing dirt buildup (GSA 2017c)

Removing Dirt Build-Up From Slate Shingles

Procedure code:

731502S

Source:

Unknown

Division:

Thermal and Moisture Protection

Section:

Slate Shingles

Last Modified:

02/02/2017

PART 1---GENERAL

1.01 SUMMARY

A. This procedure includes guidance on removing surface dirt from slate shingles.

B. See 01100-07-S for general project guidelines to be reviewed along with this procedure. These guidelines cover the following sections:

1. Safety Precautions
2. Historic Structures Precautions
3. Submittals
4. Quality Assurance
5. Delivery, Storage and Handling
6. Project/Site Conditions
7. Sequencing and Scheduling
8. General Protection (Surface and Surrounding) These guidelines should be reviewed prior to performing this procedure and should be followed, when applicable, along with recommendations from the Regional Historic Preservation Officer (RHPO).

PART 2---PRODUCTS

2.01 MATERIALS

NOTE: Chemical products are sometimes sold under a common name. This usually means that the substance is not as pure as the same chemical sold under its chemical name. The grade of purity of common name substances, however, is usually adequate for stain removal work, and these products should be purchased when available, as they tend to be less expensive. Common names are indicated below by an asterisk (*).

A. For Light Dirt:

1. Murphy's oil soap

B. For Heavy Dirt Build-up and Staining:

1. Oxalic Acid (COOH)₂ or (H₂C₂O₄):
 - A poisonous strong acid that occurs in various plants as oxalates and is used especially as a bleaching or cleaning agent and in making dyes.
 - Other chemical or common names include Ethanedioic acid.
 - Potential Hazards: TOXIC; CORROSIVE TO CONCRETE, STEEL, WOOD OR GLASS.
 - Available from chemical supply house, dry cleaning supply distributor, drugstore or pharmaceutical supply distributor, hardware store, or photographic supply distributor (not camera shop). (Often sold under a manufacturer's brand name; the chemical name may appear on the label.)

-OR-

Muriatic Acid (generally available in 18 degree and 20 degree Baume solutions):

- a. A strong corrosive irritating acid.
- Other chemical or common names include Chlorhydric acid; Hydrochloric acid (30-35%); Hydrogen chloride; Marine acid*; Spirit of salt*; Spirit of sea salt*.
- Potential Hazards: TOXIC, CORROSIVE TO FLESH; CORROSIVE TO CONCRETE, STEEL, WOOD OR GLASS, FLAMMABLE.
- Available from chemical supply house, drugstore or pharmaceutical supply distributor, or hardware store.

C. Clean, potable water

2.02 EQUIPMENT

A. Clean, soft cloths

B. Stiff bristle brush

PART 3---EXECUTION

3.01 ERECTION, INSTALLATION, APPLICATION

A. For Light Dirt:

1. Apply Murphy's oil soap to the slate and rub with a clean, soft cloth.
2. Thoroughly rinse the slate with clean, clear water and allow to dry.

B. For Heavy Dirt Build-up and Staining:

1.3.2.4 Reroofing with slate shingles (GSA 2012)

Reroofing Using Slate Shingles

Procedure code:

731503S

Source:

Hspg Prepared For Nps - Sero

Division:

Concrete

Section:

Slate Shingles

Last Modified:

02/24/2012

PART 1---GENERAL

1.01 SUMMARY

- A. This procedure includes guidance on reroofing a slate shingle roof.
- B. See also Procedure 07315-02-S for general information concerning slate. See 07315-04-S for supplemental guidelines in repairing and replacing slate roofs.
- C. Safety Precautions:
 - 1. Wear rubber-soled shoes that have non-slip tread (preferably sneakers with a high top for good ankle support). Avoid wearing loose clothing.
 - 2. Wear a safety belt or harness and secure it to a substantial chimney or other substantial object secured to the building. Leave only enough slack to work comfortably in one area. Move and adjust as required to work on other sections of the roof.
 - 3. As the work proceeds, keep roof clear of debris and water. Avoid stepping on damaged or crumbling roofing materials.
 - 4. On slopes where the roof is steeper than 4 inches rise per foot, special consideration must be given to footing and handling of materials. Chicken ladders or cleats should be used on the roof as required for adequate footing.
 - 5. Do not work on shingled roofs when wet or snow-covered.
 - 6. Carrying and transporting of materials should be limited to a safe amount so that balance and footing are not impaired.
- D. See 01100-07-S for general project guidelines to be reviewed along with this procedure. These guidelines cover the following sections:
 - 1. Safety Precautions
 - 2. Historic Structures Precautions

3. Submittals
4. Quality Assurance
5. Delivery, Storage and Handling
6. Project/Site Conditions
7. Sequencing and Scheduling
8. General Protection (Surface and Surrounding)

These guidelines should be reviewed prior to performing this procedure and should be followed, when applicable, along with recommendations from the Regional Historic Preservation Officer (RHPO).

1.02 DELIVERY, STORAGE AND HANDLING

- A. Acceptance at Site: Keep roof materials dry during delivery, storage, and handling.
- B. Storage and Protection:
 1. Store materials in stacks with provisions for air circulation within stacks. Protect bottom of stacks against contact with damp surfaces. Protect materials against weather.
 2. When the slates are stored in an open yard, cover the piles with overlapping boards or use tar paper weighted down. Adequate protection prevents the slates from being frozen together. While slates are of ample strength when used in their proper place, reasonable care should be used in the handling of the material.
 3. Slates up to and including 20" X 11" may be safely piled up to 6 tiers high. Slates of a larger size should never be piled more than 4 tiers high. Closely piled, 100 commercial slates average 20" to 24".

1.03 PROJECT/SITE CONDITIONS

- A. Environmental Requirements:
 1. Do not apply new or repaired shingle roofs in wet weather.
 2. Do not remove roofing from structures when rain is forecasted or in progress.
 3. If roofing is to be removed on a clear day, remove no more than can be replaced or repaired in one day.

1.04 MAINTENANCE

- A. Whenever possible, make inspection from ground or from above if possible.
- B. Inspect roof for broken or missing slates, delamination or flaking of surfaces, slate particles collecting in valley flashing, staining, or other manifestations of slate failure.
- C. Look for indications that nails are corroding or pulling loose. Loose and missing slates, or metallic stains are an indication of this.
- D. Inspect the underside of the roof deck from the attic to detect leaks. Inspect at all flashing points carefully for evidence of leakage such as water stains.
- E. In addition to scheduled inspections, inspect after each exposure to unusually severe weather conditions such as strong winds, hail, or long continuous rains.

PART 2---PRODUCTS

2.01 MANUFACTURERS

- A. Slating tools: John Stortz & Sons 210 Vine Street Philadelphia, PA 19106 215/627-3855

2.02 MATERIALS

- A. Slate/substitute material: roofing units used for replacement should match existing slate in thickness, color and texture. Individual slates should be pre-punched for nailing. See Procedure 07315-02-S for complete list of manufacturers of natural slate and substitute materials.
- B. Large flat-head hard copper wire nails not less than 7/8" long. Length should be twice the thickness of an individual slate plus 1 inch.
- C. Flashing material - match appearance and material of existing.
1. Copper - 16-oz. soft copper; occasionally 20-oz. required, consult manufacturer. All edges to be soldered shall be tinned 1-1/2" on both sides.
 2. Lead - 2-1/2# to 3#.
 3. Terne - 20# or 40# depending on type of flashing, i.e cap and base flashing, 20# or vertical and horizontal surfaces, 40#. Consult manufacturer.
 4. Galvanized - 24 ga. to 26 ga. depending on type of flashing, consult manufacturer.
- D. 15-lbs asphalt-saturated rag felt underlayment with Commercial Standard Slate; with graduated roofs use 30-lb for 1/4" slate, and 45-lb, 55-lb, or 65-lb prepared roll roofing for heavier slate.
- E. Solder shall be 50% lead and 50% block tin, with rosin flux.
- F. Elastic cement or exterior grade caulk such as "Gutter-Seal" (Dow), "Roof Sealant" (Alcoa), or approved equal.

2.03 EQUIPMENT

- A. 25' steel tape
- B. Hacksaw(s)
- C. Slate ripper
- D. Machine punch and hand (or mawl) punch
- E. Slate cutter
- F. Hammer
- G. Slater's Stake
- H. Nail pouch

PART 3---EXECUTION

3.01 EXAMINATION

- A. Inspect the deck to determine whether it is sound. Make whatever repairs are necessary to the existing roof framing to strengthen it and to level and true the deck. Replace rotted, damaged, or warped sheathing or plywood.

3.02 PREPARATION

- A. Surface Preparation:
1. Carefully examine, measure, and record existing slate shingle patterns at edges, hips, ridges, and other special conditions.
 2. Remove existing roofing down to the roof deck. Salvage original slates for reuse where possible.

3. Use a slate ripper to remove the nails of slates in good condition which can be reused. Use care in the removal and stacking of slates to avoid damage.
4. Be careful not to damage old metal wall and vent flashings that may be used as a pattern for cutting templates. If metal cap flashings at the chimney and other vertical masonry wall intersections have not deteriorated, bend them up out of the way so that they may be used again. Carefully remove slate shingles in these areas to avoid damaging reusable base flashing.
5. Remove loose or protruding nails or hammer them down.

3.03 ERECTION, INSTALLATION, APPLICATION

- A. Lay felt over entire deck.
 1. Lay felt in horizontal layers with joints lapped toward eaves and at ends at least 2". Secure edges with flat head copper nails.
 2. Lap felt over all hips and ridges a minimum of 12", and 2" over the metal of any valleys and gutters.
 3. Omit felt at valleys, using instead, rosin paper to allow for thermal movement of the sheet metal.
- B. Determine exposure of slate: subtract 3" (standard head lap between alternating courses) from over all length of slates being used. Divide this number in half to determine final exposure.
- C. If required by slope of roof, nail cant strip at bottom eaves, even with edge of sheathing, to slightly raise first courses of slate. Thickness of cant strip allows second course of slate to be laid correctly. A 1/4" taper is usually sufficient.
- D. Lay under-eave starter slate. Butt of slate shall project 2" beyond cant strip or bottom edge of sheathing, and 1" beyond the edge of the sheathing at gable ends. Under-eave slate is shorter than other slates. Determine length of under-eave slates by adding 3" to the exposure as determined in B. above. Secure each slate with two nails.
 1. Drive the nails into the punched holes until heads just clear surface of slate. The slates should "hang" on the nails, not be driven in so far as to produce a strain on the slate.
 2. Use 3d nails for standard-thickness slates up to 18 in. long. Use 4d nails for extra-long slates, and 6d nails on hips and ridges.
- E. Lay full first course with bottom of slate even with bottom of under-eave slate. Position joints between slates so that there is a minimum 3" off-set between the vertical joints of the under-eave slates below.
- F. Lay second full course of slate using the exposure as determined in B. above. Off-set vertical joints a minimum of 3" from the vertical joints in the course below. Continue to lay main field of slates in this manner.
- G. Lay hip slates and ridge slates (or install ridge and hip cap flashing) as originally designed. Consult with slate manufacturer for construction details.
 1. Ridge types (slate): saddle ridge, strip saddle ridge, comb ridge, cox-comb ridge.
 2. Hip types (slate): saddle hip, mitred hip, boston hip, fantail hip.
- H. Build in and place all flashing pieces furnished by the sheet metal contractor. Valley design shall match original construction. Valleys may be open, closed, or round. Consult with slate and/or sheet metal manufacturer for construction details.
- I. Slates overlapping sheet metal work should have the nails so placed as to avoid puncturing the sheet metal. Exposed nails should be permissible only in top courses where unavoidable.
- J. Fit slate neatly around any pipes, ventilators, or other roof penetrations.

1.3.2.5 Slate shingle specifications (GSA 2017d)

Specifications for Slate Shingles

Procedure code:

731502S

Source:

NPS Southeast Regional Office

Division:

Thermal And Moisture Protection

Section:

Slate Shingles

Last Modified:

12/26/2017

PREFACE: This procedure should be used in conjunction with "Re-Roofing Using Slate Shingles"

PART 1---GENERAL

1.01 CHARACTERISTICS OF SLATE

- A. Slate is a natural stone and can produce a wide range of effects based on its appearance, color, thickness, surface texture, and roof texture.
 - 1. A permanent material that is waterproof, fireproof, resistant to climatic changes, and requires no preservative coatings or paint, and no cleaning, resulting in lower insurance premiums, higher property values, little or no maintenance costs, and a high salvage value.
 - 2. Some slates have a greater porosity than others and will eventually begin to spall due to freeze-thaw cycles.
 - 3. The quality and characteristics of various slate types vary greatly among the various quarry sources. Slate types that are rated as ASTM S-1 are considered the best quality.

Reference: National Slate Association

1.02 CAUSES FOR ROOF FAILURE

- A. Failure of a slate roof is generally due to poor installation methods.
 - 1. Nails that are driven too far may cause tension in the tightly held slate resulting in cracking of individual units.
 - 2. Nails not driven quite far enough may cause the slate in the course above to rest unevenly on the protruding nail head. This makes the slates more susceptible to breaking if stepped upon.
 - 3. The use of inappropriate nails can lead to failure such as rusting. If some slates are letting go because their nails have rusted through, all the slates may eventually have to be re-laid with the proper copper nails.
 - 4. If shingle nails rather than large, flat-head wire nails are used, individual slates can easily slip off of the nails.
- B. Leaks in slate roofs can also be caused by deteriorated flashings. Flashings gradually erode due to scouring of rain water running down valleys. Atmospheric conditions can also cause flashings to corrode.

- C. To a lesser extent, slate roofs can fail due to the deterioration of the slates themselves. If the majority of the slates are delaminating or crumbling due to atmospheric conditions reacting with the mineral content of the slates, it is impossible to save the roof.

1.03 DEFINITIONS

- A. Butt - the exposed end of a roofing slate.
- B. Clear - in regions where slate contains bands of rock compositionally different from the main body of slate "clear" denotes slates which have been trimmed of all such ribbons.
- C. Commercial Standard Slate - most common and available roofing slate. Exact definition varies by region, but generally this slate is 3/16" thick with varying widths (8" to 14") and a length between 18" and 24". Each slate has a bevelled edge and pre-punched nail holes. Quality is fairly consistent.
- D. Comb Ridge - ridge finishing treatment in which the combing slates on the north or east side are laid extending 116" to 1" over the other side. The grain of the combing slates may be either vertical or horizontal.
- E. Cox Comb Ridge - the combing slates (those projecting at the top) alternately projecting on either side of the ridge.
- F. Curb - the line formed by the junction of two different slopes on one side of a roof--especially on Mansard and Gambrel roofs.
- G. Exposure - the length of each slate exposed to the weather, i.e., not covered by the next above course. Exposure is expressed in inches. A simple formula is used to compute the exposure: Deduct 3" (standard lap) from length of slate and divide by two. For a 24" slate, usual exposure is $24 - 3 = 21$, $21 \div 2 = 10\frac{1}{2}$ ".
- H. Freaks - slates having an unusual combination or variation of color, bought for special effects on special order. They are thicker than usual--never split under 1/4" and up to 2" or more.
- I. Graduated roof - variation on the Standard slate roof described below. Slates are arranged so that the thickest and longest are at the eaves, diminishing in size and thickness to the ridges. Usually this is combined with other generally more labor-intensive treatments such as closed valleys.
- J. Lap (headlap) - that part of a slate overlaying the slate two courses below. The standard lap is 3". Roofs with less slope (flatter) often take a 4" lap; those very steep need only a 2" lap.
- K. Ribbon Stock - slate which contains bands of rock differing in composition and color from the main body of stone. It is always labelled as such. Usually from Pennsylvania quarries.
- L. Saddle Ridge - finish in which the regular roofing slate are extended to the ridge line so that slates on both sides of roof are butted flush. Then another course of slates is laid with its grain horizontal (combing slates) and lapped horizontally to cover the previous combing slate's nail holes. They are butted flush on either side of the ridge.
- M. Standard Roof - one composed of Commercial Standard Slate n (approx. 3/16 in. thick) of more-or-less uniform standard width and length, with butts laid to a line, in standard slate colors. (No color patterns, no freaks.) Encompasses those slates with butts (exposed ends) trimmed to have an hexagonal, diamond, or Gothic pattern.
- N. Square - number of slates needed to cover 100 square feet of plain roof surface, when laid with the customary lap of 3". (Roofs with a flatter slope require only a 4" lap, so more slates are need to cover 100 sq. ft.; very steep roofs take a 2" lap, so fewer slates are needed per square.) Commercial Standard Slate weighs 650-750 lbs. per normal square.
- O. Textural Roof - in between a Standard roof and a Graduated roof. Generally, such a roof has more visual interest than the Standard, with use of rough slates instead of smooth, or with unevenly laid butts, or variations in the thickness, size, and color of slates. (Not usually over 3/8" thick.)
- P. Unfading - a color designation given to those slates that do not "weather" appreciably or change color over the years. (As Unfading Red.)
- Q. Weathering - the exposed surface of a shingle, or a modifying word describing the color characteristic of a slate. Weathering slates react chemically with the atmosphere to gradually change hue over the years; does not affect longevity or hardness of the slate. See Unfading.

1.04 SYSTEM DESCRIPTION

- A. Slate quarried for roofing stock is of dense, sound, rock, exceedingly tough and durable. \

1. Slate, like any other stone, becomes harder and tougher upon exposure than when first quarried, and is practically non-absorbent.
 2. Many slates split to a smooth, practically even and uniform surface, while others are somewhat rough and uneven.
- B. The color of slate is determined by its chemical and mineralogical composition and may be obtained in a variety of colors and shades.
1. Grey, Blue Grey, Purple, Mottled Purple and Green, Green, and Red.
 2. These color designations should be preceded by the word "unfading" or "weathering," according to the ultimate color effect that may be desired.
- C. There are several grades and types of slate, but the most commonly specified is the Commercial Standard slate, which has the following properties:
1. Surface: Reasonably smooth straight cleavage full length of slate both front and back. The maximum bend should not exceed 1/4" in lengths up to 16", not exceed 3/8" in lengths from 16" to 24".
 2. Texture: Should be free from knots or knurls that in any way interfere with the safe conveyance or the laying of the slate on the roof.
 3. Corners: Reasonably full corners on exposed ends. No broken corners on covered ends that would sacrifice nailing strength, or the laying of a water tight slate roof.
 4. Weight: 600 to 750 lbs. per square, depending on type, color, and quarry. Allow 8 lbs. per square foot dead load for combined weight of slates, nails, and felt.
 5. Thickness: Approximately 3/16".

ART 2---PRODUCTS

2.01 MANUFACTURERS

A. Slate shingles:

1. Buckingham-Slate Corporation
(Blue-black. High quality Virginia slate sold through distributors. Free literature)
2. Evergreen Slate Co.
(Gray-green, purple, green mottled green-purple, gray black, unfading red, Vermont black. Vermont & New York slate sold direct. Also slater's tools. Free brochure)
3. Hilltop Slate Co.
(Gray-green, purple, green, mottled green-purple, gray-black, gray, Vermont black. New York and Vermont Slate sold direct and through distributors. Free brochure)
4. Midland Engineering Co.
(A major distributor for roofing products including German clay tiles and Vermont slate, sold through roofers and direct. Free brochures on all products - specify your interest)
5. Vermont Slate Company Mr. Slate
6. Penn Big Bed Slate Co.
(Gray black)
7. Monson Maine Slate Co.
(Unfading black slate, only on special order)
8. Rising and Nelson Slate Co.
(Green, gray, Vermont black, and gray-black, purple, mottled green-purple, red. Vermont slate is not sold direct. Free brochure)
9. Shelton Slate Products Co.
(All typical New York-Vermont colors)
10. Structural Slate Co.
(Pennsylvania slate sold through distributors. Free brochure)

11. Vermont Structural Slate Co.

(Green, gray Vermont black, gray-black, purple, mottled green-purple, red. Vermont roofing slate sold direct and through distributors. Free brochure)

B. Slate roofing substitutes

1. Monier Group

(Concrete tiles designed to imitate terra cotta, wood, and slate tiles are sold through distributors. Free literature)

2. Vande Hey Raleigh

(Manufactures a broad line of extruded concrete roofing tiles, including a simulated slate and a Mission tile. Also has a large stock of recycled ms slate, concrete, and clay tiles)

C. Slating tools:

1. Stortz & Son

2.02 MATERIAL PERFORMANCE REQUIREMENTS

A. Slate: Natural slate roofing units used for replacement should duplicate existing slate installed on the roof and match for thickness, color and texture, as well as type, size and existing, and should be punched for nailing. It should be noted that slate is always sold by the "square", or 100 sq. ft. of roof laid with a 3" head lap NOTE: THE FOLLOWING INFORMATION SHOULD BE SUPPLIED TO THE ROOFING CONTRACTOR WHEN DETERMINING QUANTITIES AND COSTS.

1. Kind and color of slate.
2. Size of slate desired, stating length and "all one width" or random width.
3. Thickness, as "commercial standard," 1/4", 3/8", etc.
4. Type of roof, as standard, textural, graduated or flat.
5. Kind of nails, as zinc clad, zinc, "yellow metal", copper clad, or copper.
6. Kind of valleys and flashings.
7. If hip or gable roof.
8. Kind of snow guards, as galvanized, yellow metal or copper.
9. If snow rails, size of pipe and number of rows of pipe.
10. Location of job; if in city or vicinity, or out of city.
11. When job is to be finished.

B. Nails:

1. All nails, rivets, and similar fastenings, if any, used throughout the work should be of best grade hard copper.
2. Nails should be large flat-head copper wire nails. DO NOT USE COPPER ROOFING NAILS OR ORDINARY COPPER WIRE NAILS.
3. Nail length should be twice the thickness of the slates plus 1". Minimum length is 7/8". Sizes: 3d for commercial standard slates up to 18" in length; 4d for slates over 18"; 6d for ridge and hip slates.

C. Flashings:

1. All intersections of roofs with vertical surfaces of every kind and all openings in roof surfaces, should be properly flashed.
2. Match appearance of original materials. If any existing flashings are to be reused, new material must be the same as the original material to prevent galvanic corrosion.
 - a. Copper - 16-oz. soft copper; occasionally 20-oz. required, consult manufacturer.
 - b. Lead - 2-1/2# to 3#.
 - c. Terne - 20# or 40# depending on type of flashing, i.e cap and base flashing, 20# or vertical and horizontal surfaces, 40#. Consult manufacturer.
 - d. Galvanized - 24 ga. to 26 ga. depending on type of flashing, consult manufacturer.

D. Base flashings:

1. Should be at least 4" high.
2. Should project at least 4" out onto the roof.
3. Should be a full 96" in length. On sloping roofs they should lap longitudinally at least 3".

E. Reglets:

1. Flashings should finish in reglets in the masonry.
2. The flashing should be turned into the reglet the full depth and should be turned back to form a hook. After the flashing is in place the reglet should be filled caulked, using molten lead on flat surfaces, and lead wool on vertical surfaces. After caulking the reglet should be made smooth by filling with elastic cement.

F. Step flashings:

1. Step flashings should be used where vertical surfaces occur in connection with slopes.
2. They should be formed of separate pieces built into the masonry as specified for cap flashings in masonry.
3. Steps should generally be 3", but should in no case be less than 2", and should not be soldered. Lap joints should be vertical.

G. Vent flashings:

1. All pipes passing through roofs should be flashed and counterflashed.
2. Base flashings should extend out on the roof not less than 6". They should be of sufficient length to cover the slate course next below the pipe and to extend up under the slate course above as far as possible without puncture by nails.

H. Open valley flashings:

1. Open valleys should be not less than 4" wide.
NOTE: To determine the proper width for flashing, start at the top with a width of 4", increase the width one inch for every 8 feet of length of the valley. Flashing pieces should be full length sheets and of sufficient width to cover the open portion of the valley and extend up under the slate not less than 4" on each side.
2. Where two valleys of unequal size come together, or where the areas drained by the valley are unequal, there should be placed in the valley a "crimp" angle or tee not less than 1" high. This "crimp" may be formed in the valley sheet before placing, or it may be made of a separate piece soldered to the valley sheet.

I. Closed valley flashings:

1. Flashing pieces, for closed valley should be of sufficient length to extend 2" above the top of slate roofing piece and lap the flashing piece below 3", and of width sufficient to extend up the sides of the valley far enough to make the valley inches deep.
2. They should be placed with the slate so that all pieces are separated by a course of slate. Pieces should be set so as to lap at least 3" and to be entirely concealed by the slates. They should be fastened by the nails at the top edge only.

J. Elastic cement or exterior grade caulk such as "Gutter-Seal" (Dow), "Roof Sealant" (Alcoa), or approved equal.

1. A sticky, waterproof compound used to secure hip and ridge slates.
2. It has a high melting point and low freezing point.

1.4 Roofing element – asphalt shingles

Asphalt shingles have three major components: asphalt, felts and colored mineral or ceramic granules. Asphalt is a byproduct of petroleum distillation and also occurs in natural deposits. This dense mixture of hydrocarbons provides the waterproofing for the shingle. The felt fibers reinforce and stabilize the asphalt, while granule aggregates protect the assembly from sun, wind, rain, and other minor foot traffic.

1.4.1 Immediate concerns for roofing – asphalt shingles

The most significant building with asphalt shingles is Delano Hall (Figure 30). Asphalt shingles have also replaced historic roof materials on several buildings such as Quarters J (Neiley garage) and Quarters B (Figure 31) or have been placed on additions to historic buildings such as Melville Hall (Figure 33).

Asphalt roofing has a relatively short life of 10 to 30 years. Cycles of dampness and dryness will break down the asphalt, which can lead to warping, buckling, blistering, and loss of granules. Asphalt shingles also deteriorate with oxidation and exposure to heat, ultraviolet rays, corrosive chemicals, and biological growth. Damage is usually most evident at roof valleys and changes in roof pitch. Foot traffic and falling branches can also harm the roofing, particularly when the shingles' granules fall off and expose the base (Wilson and Snodgrass 2008).

Some of the immediate concerns regarding asphalt shingles on the USMMA buildings involve black stains or “roof mold” (Figure 32, left). Usually these stains appear on the north side of roofs because that side does not get as much sun and thus, it remains damp for longer amount of time.

Figure 30. Asphalt shingles on Delano Hall (ERDC-CERL 2013).

Figure 31. Architectural asphalt shingles on Quarters B [note lack of flashing between dormer siding and shingles] (USMMA, 2015).

Figure 32. Green asphalt shingles with “storybook” edges on Quarters C (left) replaced with brown architectural asphalt shingles (right) (ERDC-CERL, 2015).

Figure 33. Architectural asphalt shingles on Melville Hall addition (USMMA, 2015).

1.5 Preservation and rehabilitation guidelines for roofing

According to *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings*, the proper procedure for preservation and rehabilitation is to respect the significance of the original materials and features, repair and retain them wherever possible, and replace them only when absolutely necessary (Grimmer 2017).

The following recommendations for care of historic roofing elements are to be thoroughly read and understood before a treatment is specified. Table 1 (preservation) and Table 2 (rehabilitation) contain information excerpted from Grimmer 2017. Any related NPS or GSA guidelines should also be consulted to determine the appropriateness of any treatment.

Table 1. Preservation treatment for roofs (Grimmer 2017, 44–45).

Preservation Treatment for Roofing	
RECOMMENDED	NOT RECOMMENDED
Identifying, retaining, and preserving roofs and their functional and decorative features that are important in defining the overall historic character of the building. The form of the roof (gable, hipped, gambrel, flat, or mansard) is significant, as are its decorative and functional features (such as cupolas, cresting, parapets, monitors, chimneys, weather vanes, dormers, ridge tiles, and snow guards), roofing material (such as slate, wood, clay tile, metal, roll roofing, or asphalt shingles), and size, color, and patterning.	Altering the roof and roofing materials which are important in defining the overall historic character of the building so that, as a result, the character is diminished. Replacing historic roofing material instead of repairing or replacing only the deteriorated material. Changing the type or color of roofing materials.
Stabilizing deteriorated or damaged roofs as a preliminary measure, when necessary, prior to undertaking preservation work.	Failing to stabilize a deteriorated or damaged roof until additional work is undertaken, thereby allowing further damage to occur to the historic building
Protecting and maintaining a roof by cleaning gutters and downspouts and replacing deteriorated flashing. Roof sheathing should also be checked for indications of moisture due to leaks or condensation.	Failing to clean and maintain gutters and downspouts properly so that water and debris collect and cause damage to roof fasteners, sheathing, and the underlying structure
Providing adequate anchorage for roofing material to guard against wind damage and moisture penetration.	Allowing flashing, caps, and exposed roof fasteners to corrode, which accelerates deterioration of the roof.
Protecting a leaking roof with a temporary waterproof membrane with a synthetic underlayment, roll roofing, plywood, or a tarpaulin until it can be repaired.	Leaving a leaking roof unprotected so that accelerated deterioration of historic building materials (such as masonry, wood, plaster, paint, and structural members) occurs.
Repainting a roofing material that requires a protective coating and was painted historically (such as a terneplate metal roof or gutters) as part of regularly-scheduled maintenance.	Failing to repaint a roofing material that requires a protective coating and was painted historically as part of regularly-scheduled maintenance.
Protecting a roof covering when working on other roof features.	Failing to protect roof coverings when working on other roof features.
Evaluating the overall condition of the roof to determine whether more than protection and maintenance, such as repairs to roof features, will be necessary.	Failing to undertake adequate measures to ensure the protection of roof features.
Repairing a roof by ensuring that the existing historic roof or compatible non-historic roof covering is sound and waterproof.	Removing historic materials that could be repaired or using improper repair techniques. Failing to reuse intact slate or tile when only the roofing substrate or fasteners need replacement.
Using corrosion-resistant roof fasteners (e.g., nails and clips) to repair a roof to help extend its longevity.	
<i>The following work is highlighted to indicate that it represents the greatest degree of intervention generally recommended within the treatment Preservation, and should only be considered after protection, stabilization, and repair concerns have been addressed.</i>	
Limited Replacement in Kind	
Replacing in kind extensively deteriorated or missing components of roof features when there are surviving prototypes, such as ridge tiles, roof cresting, or dormer trim, slates, or tiles, or when the replacement can be based on documentary or physical evidence. The new work should match the old in material, design, scale, color, and finish.	Replacing an entire roof feature, such as a chimney or dormer, when limited replacement of deteriorated or missing components is appropriate. Using replacement material that does not match the historic roof feature.

Table 2. Rehabilitation treatment for roofs (Grimmer 2017, 98–101).

Rehabilitation Treatment for Roofing	
RECOMMENDED	NOT RECOMMENDED
<p>Identifying, retaining, and preserving roofs and their functional and decorative features that are important in defining the overall historic character of the building. The form of the roof (gable, hipped, gambrel, flat, or mansard) is significant, as are its decorative and functional features (such as cupolas, cresting, parapets, monitors, chimneys, weather vanes, dormers, ridge tiles, and snow guards), roofing material (such as slate, wood, clay tile, metal, roll roofing, or asphalt shingles), and size, color, and patterning.</p>	<p>Removing or substantially changing roofs which are important in defining the overall historic character of the building so that, as a result, the character is diminished.</p> <p>Removing a major portion of the historic roof or roofing material that is repairable, then rebuilding it with new material to achieve a more uniform or “improved” appearance.</p> <p>Changing the configuration or shape of a roof by adding highly visible new features (such as dormer windows, vents, skylights, or a penthouse).</p> <p>Stripping the roof of sound historic material, such as slate, clay tile, wood, or metal.</p>
<p>Protecting and maintaining a roof by cleaning gutters and downspouts and replacing deteriorated flashing. Roof sheathing should also be checked for indications of moisture due to leaks or condensation.</p>	<p>Failing to clean and maintain gutters and downspouts properly so that water and debris collect and cause damage to roof features, sheathing, and the underlying roof structure.</p>
<p>Providing adequate anchorage for roofing material to guard against wind damage and moisture penetration.</p>	<p>Allowing flashing, caps, and exposed fasteners to corrode, which accelerates deterioration of the roof.</p>
<p>Protecting a leaking roof with a temporary waterproof membrane with a synthetic underlayment, roll roofing, plywood, or a tarpaulin until it can be repaired.</p>	<p>Leaving a leaking roof unprotected so that accelerated deterioration of historic building materials (such as masonry, wood, plaster, paint, and structural members) occurs.</p>
<p>Repainting a roofing material that requires a protective coating and was painted historically (such as a terneplate metal roof or gutters) as part of regularly-scheduled maintenance.</p>	<p>Failing to repaint a roofing material that requires a protective coating and was painted historically as part of regularly-scheduled maintenance.</p>
<p>Applying compatible paint coating systems to historically-painted roofing materials following proper surface preparation.</p>	<p>Applying paint or other coatings to roofing material if they were not coated historically.</p>
<p>Protecting a roof covering when working on other roof features.</p>	<p>Failing to protect roof coverings when working on other roof features.</p>
<p>Evaluating the overall condition of the roof and roof features to determine whether more than protection and maintenance, such as repairs to roof features, will be necessary.</p>	<p>Failing to undertake adequate measures to ensure the protection of roof features.</p>
<p>Repairing a roof by ensuring that the existing historic or compatible non-historic roof covering is sound and waterproof. Repair may include the limited replacement in kind or with a compatible substitute material of missing materials (such as wood shingles, slates, or tiles) on a main roof, as well as those extensively deteriorated or missing components of features when there are surviving prototypes, such as ridge tiles, dormer roofing, or roof monitors.</p> <p>Using corrosion-resistant roof fasteners (e.g., nails and clips) to repair a roof to help extend its longevity.</p>	<p>Replacing an entire roof feature when repair of the historic roofing materials and limited replacement of deteriorated or missing components are feasible.</p>

(Table continues on next page.)

RECOMMENDED	NOT RECOMMENDED
Replacing in kind an entire roof covering or feature that is too deteriorated to repair (if the overall form and detailing are still evident) using the physical evidence as a model to reproduce the feature or when the replacement can be based on historic documentation. Examples of such a feature could include a large section of roofing, a dormer, or a chimney. If using the same kind of material is not feasible, then a compatible substitute material may be considered.	Removing a feature of the roof that is unrepairable and not replacing it, or replacing it with a new roof feature that does not match.
Replacing only missing or damaged roofing tiles or slates rather than replacing the entire roof covering.	Using a substitute material for the replacement that does not convey the same appearance of the roof covering or the surviving components of the roof feature or that is physically or chemically incompatible.
Replacing an incompatible roof covering or any deteriorated non-historic roof covering with historically-accurate roofing material, if known, or another material that is compatible with the historic character of the building.	Failing to reuse intact slate or tile in good condition when only the roofing substrate or fasteners need replacement.
<i>The following work is highlighted to indicate that it is specific to Rehabilitation projects and should only be considered after the preservation concerns have been addressed.</i>	
Designing the Replacement for Missing Historic Features	
Designing and installing a new roof covering for a missing roof or a new feature, such as a dormer or a monitor, when the historic feature is completely missing. It may be an accurate restoration based on documentary and physical evidence, but only when the historic feature to be replaced coexisted with the features currently on the building. Or, it may be a new design that is compatible with the size, scale, material, and color of the historic building.	Creating an inaccurate appearance because the replacement for the missing roof feature is based upon insufficient physical or historic documentation, is not a compatible design, or because the feature to be replaced did not coexist with the features currently on the building.
	Introducing a new roof feature that is incompatible in size, scale, material, or color.
Alterations and Additions for a New Use	
Installing mechanical and service equipment on the roof (such as heating and air-conditioning units, elevator housing, or solar panels) when required for a new use so that they are inconspicuous on the site and from the public right-of-way and do not damage or obscure character-defining historic features.	Installing roof-top mechanical or service equipment so that it damages or obscures character-defining roof features or is conspicuous on the site or from the public right-of-way.
Designing rooftop additions, elevator or stair towers, decks or terraces, dormers, or skylights when required by a new or continuing use so that they are inconspicuous and minimally visible on the site and from the public right-of-way and do not damage or obscure character-defining historic features.	Changing a character-defining roof form, or damaging or destroying character-defining roofing material as a result of an incompatible rooftop addition or improperly-installed or highly-visible mechanical equipment.
Installing a green roof or other roof landscaping, railings, or furnishings that are not visible on the site or from the public right-of-way and do not damage the roof structure.	Installing a green roof or other roof landscaping, railings, or furnishings that are visible on the site and from the public right-of-way.

1.6 Maintenance / management for roofing

All building materials deteriorate with age and exposure to the weather. Through routine inspection and cyclical maintenance, the useful life span of a building and its historic fabric will be greatly increased. Preventive maintenance involves regular inspection of those parts of the building that are most likely to develop problems. Having a checklist for each USMMA building is advised to help the USMMA CRM and maintenance department identify and keep an accurate record or inventory of the building's problems, to facilitate systematic repair and maintenance. Begin early in project planning to ensure that design scopes, qualifications, and budgets address preservation compliance requirements.

Repair, renovation, and replacement of character-defining features to the contributing features to the USMMA historic district, such as historic roofing elements, **MUST** be coordinated with the NY SHPO. If a character-defining feature has been previously removed or replaced on the contributing building, prior to this report, and as future renovations occur, these need to be replaced with elements that replicate the original character-defining features of that building. Historic photographs found in *Character-Defining Features of Contributing Buildings and Structures in the United States Merchant Marine Academy Historic District* report (Smith, Enscore, and Adams 2014) will help guide this process in coordination with the NY SHPO.

General roofing

- A regularly scheduled maintenance program is necessary to prolong the life of any roofing system. A complete internal and external inspection of the roof structure and the roof covering is recommended to determine the condition, potential causes of failure, or source of leaks, and the inspection will help in developing a program for the preservation and repair of the roofing materials.
- Regular maintenance such as cleaning gutters and downspouts can add to the life of a roof.
- Periodic inspection for water stains of the underside of the roof from the attic after a heavy rain or ice storm may reveal leaks in their early stages which can be eliminated before the escalate into larger, more serious repair problems.
- Water and improperly maintained rainwater removal and drainage systems are also chief causes for failure in historic roofing materials.

Clay tile

Clay roofing tile itself, when correctly installed, requires little or no maintenance. Often, it is the fastening system used to secure the tiles to the sheathing that fails and needs to be replaced rather than the tiles themselves. When the fastening system has deteriorated, or the roofing support structure has failed, clay tiles can be removed relatively easily, necessary repairs can be made and historic tiles can be re-laid with new

corrosion-resistant nails or hooks. Broken or damaged tiles should be replaced properly to prevent further damage to neighboring tiles or to the roof structure itself (Grimmer and Williams 1992).

Slate tile

- Broken, cracked, and missing slate tiles should be repaired promptly by an experienced slater in order to prevent water damage to interior finishes, accelerated deterioration of the roof and roof sheathing, and possible structural degradation to framing members.
- Cracked, broken, misaligned, and missing slates and the degree to which delamination has occurred should be noted, along with failed flashings (pin holes, open seams, loose and misaligned elements, etc.) and broken or clogged downspouts. A roof plan or sketch and a camera can aid in recording problems and discussing them with contractors.
- Regular maintenance should include cleaning gutters at least twice during the fall and once in early spring, and replacing damaged slates promptly.
- Good record keeping, in the form of a logbook and the systematic filing of all bills and samples, can help in piecing together a roof's repair history and keeping such details is an important part of maintenance (Levin 1992).
- As part of regular maintenance, an attempt should be made to keep foot traffic off the roof (Levine 1992).
 - If maintenance personnel, chimney sweeps, painters, or others must walk on the roof, it is recommended that ladders be hooked over the ridge and that the workmen walk on the ladders to better distribute their weight.
 - If slates are to be walked on, it is best to wear soft-soled shoes and to step on the lower-middle of the exposed portion of the slate unit.
- Every 5 to 7 years, a more thorough inspection of the slate roofs should be done by a qualified roofing professional.

- Limit cleaning of slate tiles.
 - If there is moss, mold, or rust spots that are reachable, gently scrub them with a medium-stiff brush and a solution of ¼ cup general household soap to one gallon of water. Wash away soap residue and remaining bits with a gentle spray from a garden hose.
 - Do not use pressure washers or even a strong blast from the garden hose, because the pressure can break apart slates and drive water up and under slates, causing leaks.

Asphalt shingles

- Extend the life of asphalt roofing with regular and preventive maintenance measures (Wilson and Snodgrass 2008).
 - Clean gutters and downspouts.
 - Trim overhanging branches so they do not scrape or fall onto the roof, and remove organic debris such as leaves. Make sure there is adequate attic ventilation to minimize heat and moisture buildup.
 - Maintain the roof's flashing to prevent the roof from leaking.
- Install a zinc strip near or at the roof ridge to minimize growth of moss or fungus.
- Use roofing cement to patch small holes and cracks and to secure loose or curling shingles. Do not apply too much cement or the shingles will not lie flat and will be more vulnerable to wind damage.
- Clean the black stain “roof mold” off the asphalt shingles by using gentle rinsing method.
 - Do NOT use a pressure washer. Pressure washing roofs can blow off the granules that are there to protect the asphalt shingle from the ultraviolet rays of the sun.

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14. ABSTRACT The U.S. Merchant Marine Academy is located in Kings Point, New York. The Academy is listed on the National Register of Historic Places (#14000538). The historic district contains contributing mansions constructed during the Gold Coast Era and the Academy buildings constructed in 1942 to 1969. All buildings require regular planned maintenance and repair. The most notable cause of historic building element failure and/or decay is not because the historic building is old, but rather it is caused by an incorrect or inappropriate repair and/or basic neglect of the historic building fabric. This document is a maintenance manual compiled with as-is conditions of building materials at the Academy. The <i>Secretary of the Interior's Standards for the Treatment of Historic Properties on Preservation, Rehabilitation, and Repair</i> are discussed per material. This 8-volume report includes an overview volume plus volumes on each of the following elements: concrete, wood, brick, metal, roofing, stucco, and mechanical systems. All mentioned repair procedures are from the U.S. General Services Administration (GSA): Historic Preservation Technical Procedures and/or the National Park Service's series of Preservation Briefs. This report satisfies Section 110 of the National Historic Preservation Act (NHPA) of 1966, as amended.					
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